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Bank-Netherlands Water Partnership

Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia

Final Report

Annex 6

Cyprus

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DHV Water BV, the Netherlands

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To increase the water resources of Government embarked in an ambitious program of tapping the surface water, which was lost to the sea. To further increase the water resources and especially to relieve the domestic water supply from the vagaries of the weather, the Government signed contracts for the construction and operation of two desalination plants of the reverse osmosis type built in Dhekelia and Larnaca.

Recycled wastewater is an additional source of water that is applied in Cyprus.

Energy. Cyprus has no indigenous energy resources and is therefore completely dependent on imported energy, particularly oil

There is some scope to develop hydroelectric power and other renewable energy sources such as solar-powered heating, which is already well established in the domestic sector.

Institutions. The Water Development Department was established in 1896 as a Section of the Public Works Department, with responsibility for domestic water supply and irrigation.

As regards the provision of potable water the WDD is responsible for the collection and storage of water in reservoirs, the treatment of the water and its conveyance to the cities and villages in Cyprus. It is also responsible for obtaining the water from the two desalination plants. The WDD makes sure that the water is delivered at the agreed quantities and that the water quality is in order.

The water is supplied to the people by the Water Boards, the Municipal Boards and the Village Boards. There are four water boards in Cyprus: at Nicosia, Limasol Larnaca and Famagusta (this board is currently inactive).

Current Status of Desalination. Since 1970 some 37 desalination units, on 18 different sites, have been installed in Cyprus. Desalination of seawater was first introduced in Cyprus on a large-scale in 1997 with the operation of the 20,000 m^3/day RO Dhekelia plant. The plant was soon expanded to 40,000 m^3/day. The Dhekelia plant uses a seawater intake. A second seawater desalination plant of 40,000 m^3/day was opened in 1999 in Larnaca.

The two large plants in Cyprus are of particular interest and importance in that they are the only large desalination plants operating on a purely commercial basis in a non-oil rich economy. They are therefore excellent case studies.

The desalinated water is sold to the Government at source and in bulk at US$ 1.00 at the time of concluding the contract in 1997 for Dhekelia and US$ 0.74 at the time of contracting for Larnaca. At present, these unit prices are raised by more than 25 percent due to an increase in the price of oil.

Private Sector Participation. The two plants in Dhekelia and Larnaca are run under a BOOT type of contact. The contracts run for 10 years. Once the contracts expire, it is very likely that the government will float management contracts for the operation of the plants. The initial operators (of the BOT contract) may be retained to carry out those management contracts.

Environmental Impact.

In Cyprus most of the harmonisation with the environmental acquis has taken place. This harmonisation would mean that at least on paper, environmental legislation should exist up to approximately the level of the EU Directives. Enforcement of the legislation is often another issue. EIA is certainly carried out on a regular basis. It appears as if this legislation is being properly

enforced, though the Consultant has seen only a small example of an EIA report.

Future Plans for Desalination. The Government of Cyprus is currently considering building two further desalination plants, one at Limassol and another at Pafos. Each plant will produce 20,000 m3/day.

1 Country Profile

Cyprus is the third largest island in the Mediterranean, after Sicily and Sardinia, with an area of 9,251 sq.kms. It is situated at the north-eastern corner of the Mediterranean. Cyprus lies at a latitude of 348°33' North and longitude 32°16'-34°37' East.

Cyprus is irregular in shape; in the extreme north-east the island narrows abruptly to form the Karpasia Peninsula, which extends east towards the Syrian coast. The island has two mountain ranges which define the climate and geography: the Pentadaktylos range which runs along the entire northern coast, and the Troödos massif in the central and south-western parts of the island. The coastal line is indented and rocky in the north, with long sandy beaches in numerous coves in the south. The north coastal plain, covered with olive and carob trees, is backed by the steep and narrow Kyrenia mountain range of limestone, rising to a height of 1,042m. In the south, the extensive massif of Troödos, covered with pine, dwarf oak, cypress and cedar, culminates in the peak of Mount Olympus, which is 1,953m above sea-level. Between the two ranges lies the fertile plain of Messaoria.

Cyprus enjoys a Mediterranean climate with its typical seasonal rhythm strongly marked in respect of temperature, rainfall and weather generally. Hot, dry and cloudless summers from June to September and changeable winters from November to March are separated by short autumn and spring seasons of rapid change in weather patterns in October, April and May. The mean annual temperature is 20.6°C. The average rainfall is 500 mm which falls unevenly around the island, the fall from December to February contributing nearly two-thirds of the annual total. Cyprus has no permanent rivers although a number of watercourses bring the overflow from the winter rains down to the Messaoria plain in spring but are dry for most of the year. There are a few freshwater lakes and two large saltwater lakes.

The present population of Cyprus is 770,000 of whom 620,000 (84.5%) are Greek Cypriots, 92,000 (12.5%) Turkish Cypriots and 22,000 (8.3%) foreigners residing in Cyprus. There is also a Turkish military force of some 30,000 strong in the north of the island according to United Nations' estimates. The balance of the community is made up of Armenians and other ethnic groups. Both the Greek and Turkish communities retain the way of life, customs and to a great extent, the national identity of their co-religionists on the mainland. Members of the Greek community adhere to the Church of Cyprus, which is in agreement with the Eastern Orthodox Church, but is independent and has no allegiance to any patriarch. The Turkish community are predominantly Sunni Muslim; other religions make up about 4% of the population. Mass dislocation due to the Turkish invasion in 1974 have effected a virtually complete geographical separation of Greeks and Turks. The overall population density is about 77 persons per km^2. The principal city is Nicosia with an estimated population of 190,000 for the Greek part and an estimated population of 45,000 in the Turkish part. Limasol (129,700), Larnaca (59,600) and Famagusta (20,516) are the chief ports.

About 17% of the land area is under cultivation and most of the rural holdings are small and are worked using traditional methods. Principal crops include potatoes, grapes, citrus fruit, vegetables, barley, wheat, carobs and olives. The output of cereals is insufficient to meet domestic demand. Livestock breeding, mainly of sheep and goats, is important, although pigs, cattle (including draft oxen), mules and horses are also raised. Dairy products are mainly cheese and yogurt made from sheep and goat milk.

The chief forest products are lumber and firewood. Sponge fisheries in the coastal waters are valuable; otherwise fishing is not a significant source of wealth.
The chief mineral is copper, which was named after Cyprus because it was the main source of copper for the ancient world. Other minerals include asbestos, iron pyrites, gypsum and chromite.

It can be safely said that there is no major environmental problem in Cyprus. Given the specific geographic, climatic and economic conditions, some issues are of more particular importance than others; for instance ensuring the sustainable development of industrial, tourist and agricultural activities; protection of the scarce water resources; preservation of the quality of the marine environment and of the natural assets of Cyprus, and management of waste.

Table 1.1 Statistical profile

Topic	
Geographical area	Middle East
Area (km2)	9,250 km2
Climate	temperate, Mediterranean with hot, dry summers and cool winters
Natural resources	copper, pyrites, asbestos, timber, salt, marble
Land use: arable land	10.6 %
permanent crops	4.7 %
other	84.7 %
Irrigated lands	400 km2
Environment - current issues	water pollution from sewage and industrial waste, seawater intrusion, coastal degradation,
Population	770,000 (2003)
Population growth	0.56 % (2003)
Languages spoken	Greek, Turkish, English
Capital city	Nicosia
Inhabitants	
Other cities, inhabitants	Larnaca, Limasol, Paphos, Kyrenia
Economy	tourism,
GDP	USD 9.4 billion (Greek area) USD 0.78 billion (Turkish area)
GDP per capita	USD 15,000 (Greek area) USD 6,000 (Turkish area)
GDP composition	agriculture 4.6 % (Greek area) industry 19.9 % services - 75.5 %
Industries	food, beverages, tourism, chemicals, metal products
Agriculture	potatoes, citrus, vegetables, grapes, olives
Administrative divisions	6 districts on Greek side

Source: CIA - The World Factbook 2002 and 2003

2 Water Resources

Cyprus has a Mediterranean climate with hot dry summers from mid-May to mid-September and rainy rather changeable winters from mid-November to mid-March separated by short spring and autumn seasons. The mean annual precipitation is 500 mm with substantial variation from 300 mm in the plains to over 1000 mm on the upper parts of Troodos. The precipitation records of the last 100 years indicate a 15% decrease of the mean annual precipitation, but the interannual variation in the mean precipitation is considerable with common periods of three consecutive years with rainfall below average affecting considerably the annual water resources of the island.

For the last fifty years the water demand in Cyprus was mostly satisfied by groundwater. The total storage of groundwater in 1969 was 3174 MCM and the annual extraction was 45 MCM beyond the safe yield. This resulted to saline intrusion and quality deterioration of all coastal aquifers and spoiling valuable underground water storage. Overpumping caused depletion of inland aquifers and variable increase of their boron content. Intensive irrigated agriculture and over-fertilization increase nitrate content, particularly in the coastal areas.

To increase the water resources of Cyprus government embarked in an ambitious program of tapping the surface water which was lost in to the sea. The storage capacity reached 304 MCM from 6 MCM in 1960 and conveyors over 100 km long transfer water from the water rich areas in the west to water poor areas in the east and supply domestic water for all the major cities and tourist areas. The yield of the reservoirs was estimated at 130 to 150 MCM per year but because of the decline of the annual rainfall, particularly in the last 30 years, reduced their average annual yield to 80 MCM. To the reduction of the stream flow contributed also human interventions such as construction of ponds, overexploitation of the Troodos aquifers and extensive terracing for reforestation and agricultural land.

To increase further the water resources and especially to relieve the domestic water supply from the vagaries of the weather the Cyprus government signed contracts for the construction and operation of two desalination plants of the reverse osmosis type with a combined annual capacity 33 MCM on a BOOT basis. An additional source of water is recycled waste water. The first sewage treatment plant in operation produces 5 MCM of tertiary treated water and the new plants under construction and planning will produce 13 MCM by the year 2005 and 30 MCM by the year 2012.

The total annual water demand and use in the greek area is estimated to be 266 MCM with agriculture being the main user (78%) followed by domestic supply (20%) tourism (1.5%) and industry (0.5%).

Out of a total cultivated area of 141,000 ha 36,000 ha are under irrigation. Irrigation contributes 70% of the value of the annual agricultural product which is CYP 360 million, it contributes 6% of the GDP and offers work to 8.3% of the employed population of the island. Agriculture accounts for 20% of the merchandise exports of the island and a further 11% of processed agricultural products. Improved irrigation methods are widely used with drip irrigation being the predominant method. The demand for domestic water supply for the year 2000 was estimated at 67.5 MCM of which 53.4 MCM are for inhabitants and 14.1 MCM for tourism. The latter contributes more than 50% of the GDP.

To bring about a balance between supply and demand it will be necessary to curtail the irrigation area, reduce losses in the conveyance systems and field applications especially in the mountainous areas, change cropping patterns in favor of less water intensive crops grown preferably during winter months, increase water tariffs to cover considerable part of the cost of the water.

In the domestic supply it is essential to reduce the losses by uncounted for water, and to rehabilitate the distribution systems to minimize losses. It is also essential to vigorously campaign on people's awareness of the scarcity of water and its importance for sustainable development.

For the implementation of any policy for better management of the water resources it is necessary to consolidate and update the existing legislation and allocate all the responsibility of water management to one Ministry and the establishment of a water entity.

3 Water Resources Management

Water constitutes the most significant factor in all fields of development in Cyprus. Until very recently, the country has had to rely solely on rainfall for all its water needs and the island has always suffered from droughts often lasting up to several years. Because of the vital importance of water, successive governments have attempted to develop, exploit and safeguard the potential water resources of the country. During the course of the 1989-93 Five-Year Development Plan, some CYP 126 million is estimated to have been allocated to water development. The Water Development Department of the Ministry of Agriculture and Natural Resources is responsible for the overall policy on water resources, planning, design and construction of water projects. With the help of the United Nations and individual countries, it has embarked on an ambitious programme of execution of multi-basin and island-wide projects to solve the acute water problem and render Cyprus capable of satisfying the ever-increasing demand for water for agriculture, domestic, industrial and tourist uses. With the implementation of these projects, water storage capacity in reservoirs has increased to 304 MCM compared to 6 MCM at the outset of the Republic. House to house water supply is now available throughout Cyprus, a great improvement compared to the inadequate and poor supply network at independence in 1960. However, despite the intensive development of water supply sources and distribution, serious attention is given to desalination of sea water by the Water Development Department to meet the future needs of the island as it continues to develop.

Within the ministry there are four departments that are directly related to water. These are the Water Development Department, the Agriculture Department, the Geological Survey Department and the Agriculture Research Institute.
The Water Development Department was established in 1896 as a Section of the Public Works Department, with responsibility for domestic water supply and irrigation. In 1939 it was set up as an independent Government department called the "Water Supply and Irrigation Department" and in 1954 the name of the Department was changed to its present name of "Water Development Department". With the establishment of the Cyprus Republic in 1960 the department came under the Ministry of Agriculture, Natural Resources and Environment and it was restructured in several divisions with responsibility for implementing the water policy of the newly established Republic.

The Water Development Department is responsible for implementing the water policy of the Ministry. The main objective of this policy is the rational development and management of the water resources of Cyprus. In this context, the responsibilities of the department cover a wide and diverse spectrum, which includes:

- the collection, processing and classification of hydrological, hydro geological, geotechnical and other data necessary for the study, maintenance and safety of the water development works,
- the study, design, construction, operation and maintenance of works, such as dams, ponds, irrigation, domestic water supply and sewerage schemes, water treatment works, sewage treatment and desalination plants, and
- the protection of the water resources from pollution.

The main tasks of the Water Development Department are:

- Water Resources,
- Hydrology,
- Planning,
- Design,
- Rural Projects Planning and Design,
- Sewage and Reuse,
- Construction,
- Management,

- Operation and Maintenance of Government Water Supply Systems,
- Operation and Maintenance of Irrigation Systems,
- Telemetry,
- Mechanical-Electrical Services.

3.1 Domestic water supply

As regards the provision of potable water the WDD is responsible for the collection and storage of water in reservoirs, the treatment of the water and its conveyance to the cities and villages in Cyprus. It is also responsible for obtaining the water from the two desalination plants that are in operation in Dhekelia and Larnaca. The WDD makes sure that the water is delivered at the agreed quantities and that the water quality is in order.

The water is supplied to the population by the Water Boards, the Municipal Boards and the Village Boards. There are four water boards in Cyprus: at Nicosia, Limasol Larnaca and Famagusta. The Water Board of Famagusta is inactive because Famagusta is under Turkish Occupation
In all other towns, municipalities and villages there are local water communities that are part of the municipal works organisation.

The objectives of the Water Boards are :

- maintenance of the water distribution network,
- the determination of water rates in order to finance the operating expenses and development projects of the Board, while remaining a non-profit making organisation.
- planning and execution of development projects,

3.2 Water Board of Nicosia

The Water Board of Nicosia is treated here with some more detail. The other water boards are organised in a similar manner.
The Water Board of Nicosia (WBN), is a semi-governmental agency, as are the other water boards. It belongs to the local authority. It has no dealings with sewerage, and is only involved in water supply. The Water Boards basically runs without any subsidy. However, it should be noted that the bulk water that is bought from the Government is subsidized.
The total volume of water distributed in Nicosia is around 15 MCM/year. 13.8 MCM is for domestic use, 0.5 MCM is for hotels, offices, etc. and 0.7 MCM is for industry in Nicosia. This shows that since there is not much industry or tourism in Nicosia, the lion's share of water supply is domestic water supply.

WBN was established in 1953. It serves six municipalities, with 200,000 people, who are linked to some 80,000 connections. The network is divided into 21 districts which all have bulk meters in place. They are connected to a central SCADA monitoring system.
WBN buys water in bulk from the Water Development Department and is only responsible for the distribution thereof. The only adjustment to the water is slight chlorination in the WBN reservoirs. The reservoirs have a total capacity of 70,000 m3, the equivalent of two days' water supply. The entire water supply system is under gravity.

WBN has 35 employees, who carry out repairs, maintenance, meter reading, etc. Only large works are outsourced to WDD. Otherwise the only outsourcing that takes place is the billing process.

In order to reduce the un-accounted for water (UfW) there are ongoing leak reduction programmes. Two permanent staff and two part-time staff are working on this. The total UfW is around 20%, including administrative losses, the target is to arrive at between 12 and 15% UfW.

When there were serious water shortages this was not only very disturbing for the customers and employees of WBN (who were harassed) , but is also seriously harmed the distribution system, due to pressure being off and on, which lead to an increased number of leaks. The problem of water rationing, which troubled consumers for decades, was finally resolved in 2001 thanks to the implementation of desalination programmes and other measures adopted by the Government of Cyprus.

All water consumption is metered; all meters are in accordance with the relevant EU regulations. Over 90 % of all meters are class C meters. Meters are replaced each 7-8 years. They cost are around CYL 10. Typical meters that are used are Kent meters, Soger, Schlumberger, and Arad (Israeli).

The tariff system that is in place is a progressive block tariff.

4 Desalination

4.1 Introduction

Cyprus has always had difficulties in terms of water availability; overexploitation of groundwater resources, with seawater intrusion, has occurred for more than 30 years. Realistically speaking, groundwater can no longer be regarded as a good source of drinking water. Since the sixties surface water has been used as a source of drinking water. Use thereof has since been optimised; many dams have been constructed. (Cyprus has the highest number of dams per capita in the world). The average consumption is some 150 to 170 litres per capita per day, which is low. An interviewee was of the opinion that desalination became a part of the water management policy in Cyprus only when it turned out to be one of the very few options left for Cyprus. Desalination was not considered when WDD was preparing and implementing the construction of dams to optimise use of surface water.

In the early nineties Cyprus arrived at a point where the ambitions of the water master plan had been realized and all major sources were being used at their maximum capacity. Due to the water shortages, caused to a great extent by overpumping, the Government developed a major water development programme (after 1974), including the development of many dams with a total capacity of slightly over 300 MCM. Most of these dams were built after 1980, and they usually serve a dual purpose of providing water for domestic consumption and agricultural purposes.

Supply was thus maximized, and since the sixties various programmes have been attempting to limit demand, e.g. by the promotion of drip irrigation, and general efficiency promotion in irrigation. Awareness programmes aimed at domestic water supply have been in place since long and are considered to be quite successful. An interviewee is of the opinion that the biggest challenge lies in lowering the water use in the agricultural sector, since large gains can be made there.

To summarise, there is not much scope left for the construction of new dams. Therefore the Government of Cyprus decided to make water independent of the weather, also in the light of the requirements of the tourism industry. Hence desalination was developed as an alternative source for domestic water supply and for water supply for tourism.

Desalination of seawater was first introduced in Cyprus on a large-scale basis, on 1 April 1997, with the operation of the 20,000 m^3/day RO Dhekelia plant. Due to the drought prevailing at the time, the plant was soon expanded to 40,000 m^3/day. The Dhekelia plant uses a seawater intake that is 550 m off the coast, with a 1.2 m diameter. Chlorination takes place once a week (shock chlorination).

A second RO desalination plant was opened in Larnaca in 2001. This plant is thought (by an interviewee) to be the most optimised desalination plant in the world. The plant is uses a five-stage process that may be monitored by internet:

1. A seawater intake (1 km long into the sea)
2. Pre-treatment (coagulation and filtration , < 5 micron particles coming through)
3. RO Units (60-75 bar)
4. Post treatment (limestone reactor, and chlorination)

Besides desalination there is a second source of non-conventional water, namely re-used wastewater. In Limasol, wastewater is treated to a tertiary level and then used for irrigation. There is however some resistance against using this water, since people are not eager to use treated wastewater for irrigation. The argument that people do not like effluent re-use was countered by an interviewee, who stated that during drought, the demand was high for such water. An interviewee confirmed that it is very likely that the Limasol seawater desalination plant will indeed be tendered and built. Environmental Impact Assessments are currently underway. He stated that environmental issues are very important to the Government, particularly where desalination is concerned.

4.2 Existing Desalination plants

Since 1970 some 37 desalination units, on 18 different sites, have been installed in Cyprus. A detailed breakdown of these is given in Wangnick's Desalination Plant Inventory 2002 and this is included in Appendix A . A summary of this is shown in Table 4.1.

Table 4.1 Cyprus Desalination Plant Summary

Process	Sites	Units	Capacity (M3/Day)
MSF	6	8	5155
VC	3	4	2310
RO	7	25	94867
Total	**16**	**37**	**102332**

As can be seen from this table, the Multi Stage Flash (MSF) and Vapour compression (VC) plants were all small units and were mainly associated with power generation or were for industrial use. They make up only 7.3% of the installed capacity.

In 1996 the first large-scale desalination plant was commissioned at Dhekelia to supplement the municipal water supply. This was for 20,000 m3/day of potable water from seawater using reverse osmosis. The following year a second plant of the same size was commissioned on the same site to give a total output of 40,000 m3/day. The plant was built on a BOT basis by a local contractor who has a contract to run the plant for 10 years at which point the plant reverts to the Government.

A second large scale RO plant was brought into operation at Larnaca in 2001. This plant has a capacity of 52,000 m3/day. This was built by IDE on a BOT contract and the company also has a 10 year operating contract.

Both plants sell their output to the Water Development Department who operate a Southern Conveyor which runs along the south coast of the island distributing water to Water Boards, Municipalities and Villages.

The two plants in Cyprus, at Dhekelia and at Larnaca, are of particular interest and importance in that they are the only large desalination plants operating on a purely commercial basis in a non-oil rich economy. They are therefore excellent case studies. Cyprus has no indigenous energy sources. Consequently energy is expensive.

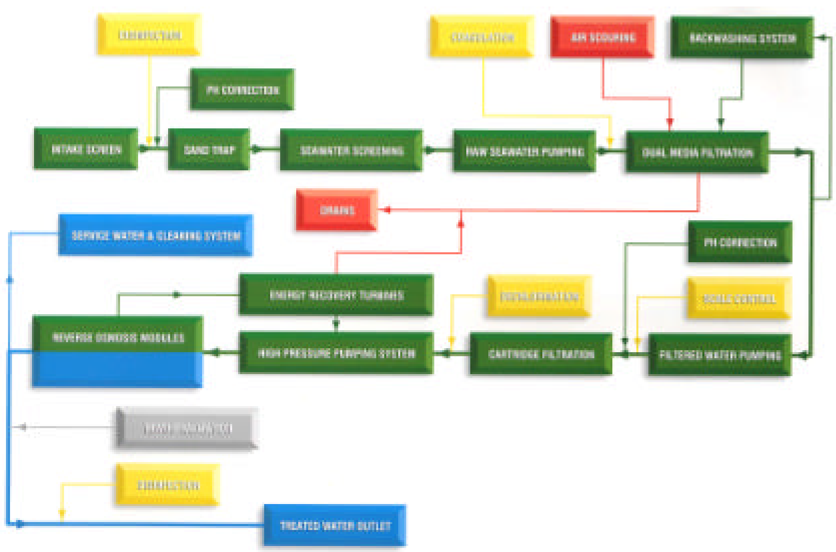
4.3 Dhekelia Desalination plant

The initial specification for the Dhekelia Desalination plant was for an output of 20,000 m3/day. Following competitive tender a contract was awarded in 1996 to a local company, now Caramondani Desalination Plants, to build and operate the unit on a BOT basis for 10 years. Because of the critical water shortage at the time, a second unit was ordered in 1997 and it came into service in 1998. The combined cost was USD 29 million. The water price was initially fixed at CYP 0.53 subject to adjustment on an agreed basis.

The design was based on the Dupont B10 and is a single pass design with energy recovery using reverse running pumps (See Fig 4.1). There are 8 identical trains. A schematic diagram of the process is shown in Fig 4.2.

Figure 4.1 HP pumps and energy recovery system

Figure 4.2 Process Block Diagram. Dhekelia

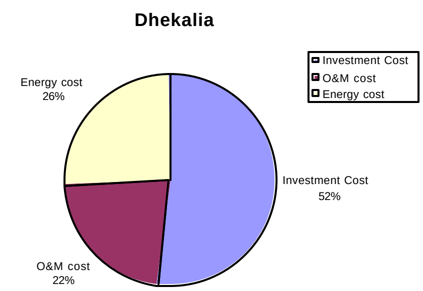


The seawater intake is sited 550 metres offshore and uses a 1.2 m diameter pipe. Because of the importance of tourism to Cyprus, the local planning authority insisted on that the desalination plant be built 500 metres from the coast. Only the seawater pump-house was allowed to be sited adjacent to the beach.

Pre-treatment is conventional and involves the addition of a flocculating agent together with an anti-scalent followed by dual media filtration which in turn is followed by a 1 micron cartridge filtration. Both chlorination and chemical addition have been the subject of considerable research both on the plant and on an associated pilot plant. It was concluded that continuous chlorination was causing more problems that it solved and was reduced to twice a month for four hour periods. This had the added benefit of reducing sodium bisulphite consumption. Ferric chloride and poly-electrolyte are dosed at 2.5 and 0.3 ppm respectively.

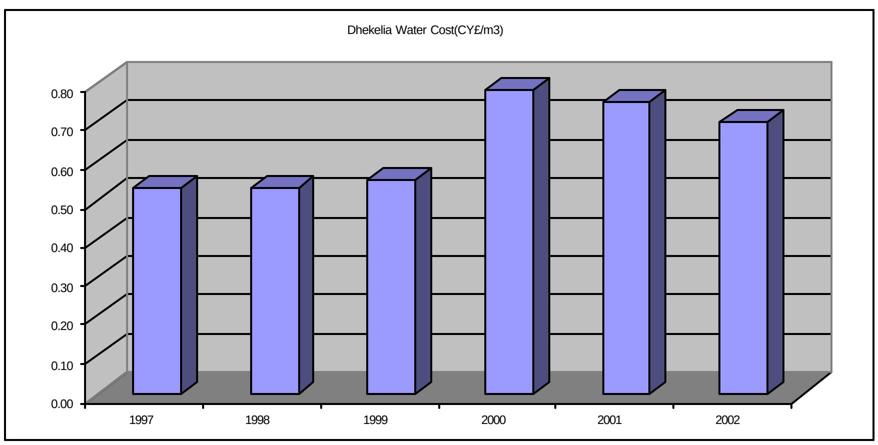
Following commissioning it was found that the number of permeators had to be increased from 130 to 176. This was due to the fact that the actual seawater salinity was higher at 41,500 than specified at 39,500 and the temperature range as 17-32 ^{O}C rather than 18-24 ^{O}C in the original specification.

Figure 4.3 Dhekelia Water Costs



Average water costs paid to the company in 2002 were CYP 0.73 per m3 (Fig. 4.4). The split of this is as shown above (Fig. 4.3). The relatively short length of the contract, 10years, results in the very high proportion of the cost being investment cost. Clearly a longer contract would reduce this element. Energy costs are also a significant factor. Fig. 4.4 shows the actual average water costs paid by the Cyprus government to the company operating the Dhekelia plant. This includes the profit to that company.

Figure 4.4 Average Water Costs at Dhekelia



The operators of the plant have endeavoured to optimise plant performance and to reduce energy and chemical consumption. To this end they have installed frequency controllers on the HP pumps to reduce energy consumption further. Pelton wheels have been looked at and the owners are currently experimenting with pressure exchangers. Design energy consumption of 5.3 kWh/m3 has been achieved. The management is continuously looking at means to improve the performance of the plant and to increase the profitability. The plant has a total of 25 staff on the payroll. Water produced by the plant is pumped to a government storage tank sited next to the plant.

4.4 Larnaca Desalination plant

Following competitive tender, a contract awarded in 1999, to a consortium led by IDE, to construct a 52,000 m3/day seawater reverse osmosis plant on a BOT basis for 10 years. The plant came into operation in 2001. The value of the contract was $32 million.

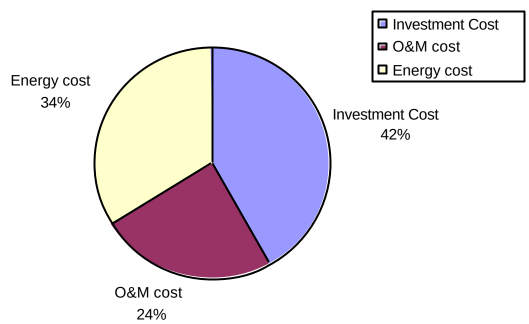
The design of the Larnaca Desalination plant is broadly similar to the Dhekelia plant but differs in some important aspects, as shown in Fig. 4.5. The process can be broken into 5 stages.

Figure 4.5 Larnaca. Process Block diagram

Intake pipe Screen Intake pumps	Chemical Dosing: Coagulation / Flocculation Dual media Filtration Booster Pumps Micron Filtration	High Pressure Pumps R.O. trains: Pressure vessels Membranes Energy Recovery system	Limestone reactors: Calcium, Hardness and pH correction Chemical Dosing: additional pH correction & disinfect ion	Product Tank Delivery Pumps Quality & quantity monitoring

The seawater intake is located 1 km offshore. Only the seawater pump-house is located on the shoreline. The desalination plant is located 500 metres inland. Pre-treatment consists of chemical additions prior to dual media filtration followed by 5micron cartridge filters. To date, no chlorination of the feed-water has taken place, but the situation is closely monitored for marine activity. The RO system comprises 6 identical trains of 9000 m^3/day each operating at 60 – 75 Bar. Each train is a single stage using spiral would membranes supplied by Hydranautics. The energy recovery system is a Pelton wheel system. To meet the Boron specification, a portion of the plant output is passed through a second stage which is then mixed with the product from the first stage to give a blended product that is within the target specification of 1ppm. Post-treatment consists of a limestone reactor to harden the water and chlorination.

Figure 4.6 Larnaca Water Costs



The average cost of water paid by the Cyprus Government to the company operating the Larnaca plant was USD 0.74/m3 in 2002. Water produced by the plant is pumped 12 km to a government storage tank at an elevation of 90 metres. Reasons for Larnaca cost being lower than Dhekelia are economies of scale, better loan conditions, lower equipment cost and lower energy consumption at 4.5kWh/m3 (includes transmission). The plant management are continuing to optimise operating conditions to reduce running cost. An improved energy recovery using the DWEER or pressure exchanger is under consideration.

5 Energy

5.1 Conventional Energy

Cyprus has no indigenous energy resources and is therefore completely dependent on imported energy, particularly oil, with 50% of export earnings being spent on petroleum products. Total final energy consumption in Cyprus is 1.2 million toe (1990) compared to 723 million toe in the European Community. Energy intensity in Cyprus (gross inland consumption/GDP) in 1990 was 610, more than double the EC figure of 286. Electricity power generation (690MW - 1995) is oil-based and uses about a third of oil imports. Electricity generation and supply is the sole responsibility of the Electricity Authority of Cyprus, which supplies the whole island, for which there is an integrated grid network, an important link between the two parts of the island. A major problem for the Authority is the unbilled consumption of electricity supplied to the Turkish community.

5.2 Renewable Energy

There is some scope to develop hydroelectric power and other renewables such as solar-powered heating, which is already well established in the domestic sector. Cyprus is taking steps to encourage energy efficiency and conservation to reduce the growth in energy demand. This is undertaken mainly by the private sector with supportive measures and fiscal legislation by the government.

6 Capacity Building

Whereas professional water management is one of the fortes of Cyprus, the organisational set-up of the water sector does not really facilitate an optimum functioning of it. The development, planning and management of water use is extremely fragmented, down to a level where water departments of very small municipalities have an active stakeholder role to play. A typical example is that the activities of the water authorities or departments and the wastewater authorities or departments do not work together. This is now initiated for the first time in Nicosia. There is a need for an umbrella law that will encompass all aspects and stages of water management. The unit for water management should be the water basin/watershed. Moreover, a single authority/institution should be responsible for all facets (quantitative and qualitative) of water resources planning, development and use. (George Socratous, M.B.A., Ph.D, 2003).

Water legislation is generally old, dating from before 1960, and as fragmented as the water sector itself. There are some 28 laws that relate directly or indirectly to water supply. Socratous calls for an all encompassing law, that naturally should comply with the provisions of the European Water Framework Directive.

As good as the implementation of Cypriot water management and demand management activities have worked out (see chapter on WRM) desalination has become a part of the water management policy in Cyprus only when it turned out to be one of the very few options left for Cyprus. Desalination was not considered when the Water Development Department was preparing and implementing the construction of dams to optimize use of surface water. In retrospect this has been the good order to address things, but reality is that the way things turned out is not the way things were planned with regard to long-term water resources development.

Desalination of sea water was first introduced in Cyprus, on a large scale basis, on the 1st of April 1997 with the operation of the Dhekelia plant. Today there are two desalination plants in operation, the one at Dhekelia of 40,000 m3 per day capacity and the other at Larnaca of 52,000 m3 per day capacity. The contract for the contract in Larnaca became effective on 1 April 2001.

6.1 Private Sector Participation

Both the Dhekelia and the Larnaca plant are reverse osmosis plants, built on a Built, Own, Operate and Transfer (BOOT) basis. The desalinated water is sold to the Government at source and in bulk at US$ 1.00 at the time of concluding the contract in 1997 for Dhekelia and US$ 0.74 at the time of contracting for Larnaca. At present, these unit prices are by more than 25 percent higher due to an increase in the price of oil.
The unit cost-price for the Larnaca plant is lower due to the fact that better loan conditions were available and due to higher efficiency of the rapidly evolving technology.

6.2 Dhekelia plant

The Dhekelia plant, using RO, is the first desalination plant that became operational in Cyprus in 1997. The guaranteed price for 1m3 produced is US$ 1.00 when the contract was signed. This amount can be split up into 52 cents for capital investment cost, 22 cents operational costs and 26 cents for energy. This amount is subject to adjustments e.g. for power consumption when water is not taken-off, or correction for inflation.

The Spanish contractor Cadagua has only been involved in construction of the plant, Caramondani fully owns and operates the plant. agreement between the public and the private parties. The parties entered a 10 year BOT contract. One of the foundations of the contract is the take-or-pay agreement.

6.3 Larnaca plant

The Larnaca plant is the second plant, also using RO, also realized under a BOT arrangement. The plant was built and is now operated by IDE of Israel. The USD 0.74 price per m3 can be split up as follows: 31 cents capital cost, 18 cents operational cost and 25 cents for energy.

Whether the plant makes a profit or not depends largely on the power consumption, that is why power recovery devices are being used. The plant is realized under a BOT scheme, and is in its 3rd year of operation.
The contractual arrangements are very similar to the Dhekelia plant: BOT guaranteed by a take-or-pay agreement, for the duration of 10 years.

Once the Dhekelia and Larnaca contracts expire, it is very likely that the government will float management contracts for the operation of the plants. The initial operators (of the BOT contract) may be retained to carry out those management contracts.

There is a guaranteed price for the water that is bought off the plants by the Government. The price is determined by a formula taking into account capital cost, energy cost, O&M cost (and a profit margin). The price is flexible to a limited extent, depending on the development of the above mentioned cost and e.g. the quantity the actual water provided to the government, who are bound to take off water under a take-or-pay arrangement.

7 Environmental Issues

7.1 Environmental Impacts

The below impacts are described in general in Chapter 8 of the Main Report; these impacts are also valid for the situation in Cyprus. More specific impacts for the situation in Cyprus are presented in the following sections.

7.1.1 Construction Stage

New plants that are planned, such as the Limasol plant, will undergo the issues described in this section. Plants that are to be refurbished, or receive new membrane systems, may undergo a few of the below-described problems. Construction that will take place on the desalination plant planned for Limasol will occur in the coastal zone. Construction may impact habitats and populations of various plants and animals: it is unclear which organisms have or should have protected status in Cyprus, but areas supporting endangered species must not be disturbed); as well as disturbance to archaeological or paleontological sites (a danger that also affects the tourism sector, of great importance in Cyprus). As Cyprus is to accede to the EU, construction will have to conform to the Birds and Habitat Directives. The pipe intake at Larnaca is fairly long and its environmental impacts should be used an example to provide an indication of the impact of the new pipeline (see RZEE, circa 2000). Impacts on tourism and the landscape from a visual perspective should be examined carefully before proceeding.

7.1.2 Operational Stage

Energy Use and Air Quality
Extra emissions from power plants interfere with any commitments Cyprus might have made to the Kyoto Protocol (ratified in 1999, but not yet signed (UNFCCC, 2003)); in the case of the Larnaca plant, for example, it was expected that its operations would contribute 2.2% more toward the national emissions of greenhouse gases from Cyprus.

Marine Environment
At this time, there is considerable uncertainty about how well desalination plant discharges, either alone or combined with other discharges, such as nearby wastewater treatment plants (as nearby the Larnaca plant) will be diluted in seawater.

Accidental spillage of chemicals such as sulphuric acid, hydrochloric acid, sodium hypochlorite and sodium hydroxide is also a risk (RZEE, ca. 2000). Contamination of seawater (or other surface water, groundwater or soil) could result. Eventually, health effects on any surrounding population could arise.

Increased Development
Desalination plants built in rural areas could lead to growth in these areas rather than within existing urban boundaries; desalination plants built in urban areas may also change the character of these areas. However, it is notable in Cyprus that desalination was undertaken at least in part to mitigate the water demand by the tourism sector, a sector which is expected to grow.

Water Balance Issues
In Cyprus, the interested parties appear to be well-informed about all water issues, and are likely to keep these possibilities well in mind.

7.2 Recommendations for Mitigation

7.2.1 Institutional and Management Mitigation

Proper enforcement of any existing environmental or water laws or regulations

In Cyprus most of the harmonisation with the environmental acquis has taken place. This harmonisation would mean that at least on paper, environmental legislation should exist up to approximately the level of the EU Directives. Enforcement of the legislation is often another issue. EIA is certainly carried out on a regular basis. It appears as if this legislation is being properly enforced, though the Consultant has seen only a small example of an EIA report.

Effective water resources management planning with environmental aspects; development of unconventional water resources

Water resources management appears to be well implemented in Cyprus, with the exception of good cooperation between the two parts of Cyprus. Non-conventional water resources are also being developed. A non-conventional water source that is being developed is the re-use of effluent. Wastewater re-use is a large potential resource, since by 2012, in line with the EU Directives, all villages of more than 2000 inhabitants are must have central sewer systems. This will generate a new stream of water that can be used e.g. for irrigation or aquifer recharge.

In making the supply meet the demand the Government policy has encouraged and adopted such management measures as water rationing, increase of public awareness for water conservation measures and water pricing for improvements in the water use efficiencies. Water rationing has been extensively applied in an attempt to curtail the demand in periods of drought. This has allowed the authorities in the last year (1997) to reduce the water by 20% of the normal demand for domestic purposes and by 67% for irrigation purposes. Water conservation measures include subsidies for use of inferior quality groundwater or the treatment of the grey water from households for the flashing of toilets and irrigation of house gardens in the cities. Furthermore the campaign for raising the "water awareness" of the public towards water conservation proved to be successful. Now, water pricing is an integral part of the Government policy on water. Water for municipal including industrial, commercial and tourist purposes is sold at full cost, while irrigation water is heavily subsidized by as much as 77 percent.

Properly developed environmental institutions; ensuring that environmental responsibilities are not divided over too many institutions; clear mission statements regarding environment for involved institutions

A bottleneck in the development of the water sector in Cyprus is that it is very fragmented. There are many stakeholders, but many of these are very small, actually being water departments of small municipalities. In addition, sewerage and water services are provided by different Boards. An interviewee applauded the initiative in Nicosia where the Sewerage Board and the Water Board are working together rather closely, and might even merge in the future. There have been talks of an overall water authority for the country since long, but this has never resulted in any real measures or action. Steps in this direction may improve institutional relations and water conservation yet further.

Further awareness-raising for water conservation

Awareness-raising activities have already been well undertaken and quite successful (see above); however, various interviewees have raised the issue of the need for further awareness-raising, especially among farmers, whose generous subsidies have given them little reason to save water, and indeed have led to water wastage (see above the subsidy of 77%).

7.3 Physical Mitigation

For the purpose of water conservation

Avoidance of problems associated with saltwater intrusion
Saltwater intrusion is a pervasive problem in all Mediterranean countries. However, these measures have largely been taken to the extent possible in Cyprus, where this issue has been on the agenda for decades. It can only be re-emphasised that overpumping is detrimental to ground/freshwater resources.

Use of drip irrigation and less conventional methods for agriculture
In the above mitigation section, it has already been seen that the agricultural sector in Cyprus tends to waste water. In Cyprus there are also examples of development of less conventional agricultural methods, for example hydro-culture. In this process, soil is replaced by a synthetic product, which at the bottom has a water collection system. The water is enriched with fertilizers, but is captured time after time and recycled many times, since the crops are raised in a closed environment. In doing so only a tenth of the water is used, since nothing leaks away into the soil, evaporates or runs off. An interviewee adheres to the school of thought that supports water as being an economic good: farmers should be made aware of the value of water and be charged for the use of water accordingly. This action should go together with their being motivated through economic incentives or otherwise to change their business into growing higher value cash crops that are less water intensive.

Improved wastewater treatment for the existing situation
The first large sewage treatment plant in the Government controlled areas started operation in Limasol in summer of 1995. Sewage treatment plants are now under design or construction in all the major cities and sensitive mountain villages of Cyprus. All municipal sewage treatment plants have provisions for tertiary treatment. Projections estimate that the volume of reclaimed sewage effluent will increase from 5 MCM of today to 13 MCM by the year 2005 rising to 25 MCM by the year 2020 (website). As seen above, re-use water is in demand under drought conditions but not under normal conditions. Wastewater treatment capacity is therefore already good.

For the purpose of desalination plant mitigation

Operational

Energy Use and Air Quality
Energy recovery systems are already in place at the plant in Larnaca (use of the Pelton wheel). Renewable power is applied to a limited extent in Cyprus; there is no hydro power, nor real potential for wind energy. However, there is an initiative to develop a 6MW wind power project by the government, and a private initiative to develop a 8MW wind power project. In Nicosia, the entire water supply system is gravity based, so no energy is used for supply. Whether the Larnaca plant makes a profit or not depends largely on the power consumption, that is why power recovery devices are being used. This is a useful way in which to assure that energy consumption is optimised. Tying plant profits into the energy consumed is an effective method to reduce the use of energy to the extent possible.

Mixing of waste streams
Difficulties in enforcement of wastewater quality regulations may arise if desalination wastes are mixed with other waste streams, as may be the case in Lacuna. Monitoring is therefore of importance in order to ensure that regulations are being enforced properly.

Other
Regarding health issues, the system should not be out of use for long, and leaks should be fixed immediately.

8 Future Developments

The Government of Cyprus is currently considering to build two further desalination plants, one at Limassol and another at Pafos. Each plant will produce 20,000 m3/day .

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Appendix A List of Desalination plants

List of Desalination plants

Cyprus											
Location	**Total Capacity m3/d**	**Units**	**Process**	**Equipment**	**Feature**	**Customer**	**Water Qual**	**User**	**Con.Year**	**Plant Supplier**	**Membrane Supplier**
Moni	197	1	MSF	FLASH	*Unknown	Electric. Board	SEA	POWER	1970	CLARK GB	*Unknown
	197	1	MSF	FLASH	*Unknown	Electr. Author.	SEA	POWER	1972	CLARK GB	*Unknown
Dhekelia	1800	2	MSF	FLASH	*Unknown	Electricity Aut	SEA	POWER	1980	OSMOTEC DE	*Unknown
Dhekelia	1440	2	MSF	FLASH	HST	Electricity Co.	SEA	POWER	1980	VATECH WABAG AT	*Unknown
Dhekelia	681	1	MSF	FLASH	*Unknown	Environment	SEA	MIL	1982	CLARK GB	*Unknown
Dhekelia	840	1	MSF	FLASH	HST	Municipality	SEA	POWER	1990	VATECH WABAG AT	*Unknown
Total	5155	8									
Larnaca	150	1	VC	HTE	*Unknown	CYPRUS REFINERY	SEA	INDU	1981	SASAKURA JP	*Unknown
	360	1	VC	HTE	MVC	CYPRUS ELECTRIC	SEA	POWER	1992	IDE IL	*Unknown
Vasilikos	1800	2	VC	HTE	TVC	EAC	SEA	POWER	1997	VATECH WABAG AT	*Unknown
Total	2310	4									
	120	1	RO	SWM	HST	AMBROSIA OIL	BRACK	INDU	1973	BIWAT ER GB	*Unknown
Nicosia	151	1	RO	HFM	*Unknown	CARLSBERG	BRACK	INDU	1972	USFILTER US	DUPONT US
	1896	8	RO	MTU	*Unknown	HELLENIC CHEMIS	BRACK	INDU	1978	USFILTER US	*Unknown
Dhekelia I	20000	4	RO	HFM	ER/PRE	WDD	SEA	MUNI	1996	CADAGUA ES	DUPONT US
Dhekelia II	20000	4	RO	HFM	ER	Government	SEA	MUNI	1997	CADAGUA ES	DUPONT US
Larnaca	54000	6	RO	SWM	ER/PEL	WDD	SEA	MUNI	1999	IDE IL	HYDRANAUTICS US
	700	1	RO	SWM	ER		SEA	TOUR	2001	UNIHA AT	*Unknown
Vasilikos	40000	8	RO	SWM	ER	Power Station	SEA	MUNI	2002	PROJECT	*Unknown
Limassol	20000	4	RO	PROJECT	*Unknown	Electricity Aut	SEA	MUNI	2002	PROJECT	*Unknown
Total	156867	37									

Source: 2002 IDA Worldwide Desalting Plants Inventory No. 17, Wangnick Consulting GMBH and IDA