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Water strategies and potential of desalination in Jordan

Mousa S. Mohsen
Department of Mechanical Engineering, Hashemite University, Zarqa 13115 Jordan
Tel. +962 (5) 390-3333; Fax +962 (5) 382-6348; email: msmohsen@hu.edu.jo

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Abstract

Jordan is considered one of the countries in the world with the scarcest of water resources. This has led to deterioration of the groundwater quality and an increase in the salinity levels. The dominant environmental challenge facing Jordan is the scarcity of the Kingdom's water resources in an arid land with unpredictable rainfall and an expanding population. Rainfall is confined largely to the winter season and ranges from around 660 mm in the north-west of the country to less than 130 mm in the extreme east. Major surface water resources are the Yarmouk and Zarqa rivers, and the associated side wadis, all flowing westward into the River Jordan and the Dead Sea. Whilst high evaporation rates result in relatively low annual stream flows, the high infiltration rates common in Jordan result in high rates of groundwater recharge. Water conservation is being pursued through increased water recycling, improved irrigation techniques and reducing water loss in distribution; whilst on the supply side is examining the potential for increased desalination, including schemes to transport seawater from Aqaba to the Dead Sea to restore its level and generate potable water, and further investment in dams and domestic reservoirs to collect and hold rainwater. This paper reviews the basic water plans in Jordan, including water resources available, analysis of supply and demand, impacts of water scarcity, water management options, and current situation and future need of desalination, as the only realistic hope.

Keywords: Demand and supply analysis; Water scarcity impacts; Water management; Desalination; Jordan

1. Introduction

Without a doubt, water scarcity is the single most important natural constraint to Jordan's economic growth and development. Rapid increases in population, agriculture and industrial development have placed heavy demands on water resources. Jordan's population reached 5.3 million

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in 2003 and is growing at a very high annual rate of 3.6%.

Due to the variable topographic features of Jordan, the distribution of rainfall varies considerably with location. Rainfall intensities vary from 600 mm in the north-west to less than 130 mm in the eastern and southern deserts, which form about 91% of the surface area.

The average total quantity of rainfall on Jordan is approximately 7200 MCM/y, varying between 6000 and 11500 MCM/y. Approximately 85% of the rainfall evaporates into the atmosphere, the rest going into rivers and wadis as flood flows, and recharging groundwater [1].

Groundwater recharge amounts to approximately 4% of the total rainfall volume, whilst surface water amounts to approximately 11% of total rainfall volume.

The water scarcity issue is not only due to nature and poor resources, but is largely a man-made problem caused by politics in the region. The gravest environmental challenge that Jordan faces today is the scarcity of water. Indeed, water is the decisive factor in the population/resources equation. Whereas water resources in Jordan have fluctuated around a stationary average, the country's population has continued to rise. A high rate of natural population growth, combined with periodic massive influxes of refugees, has transformed a comfortable balance between population and water. The situation has been exacerbated by the fact that Jordan shares most of its surface water resources with neighboring countries, whose control has partially deprived Jordan of its fair share of water. Current use already exceeds renewable supply. The deficit is covered by the unsustainable practice of overdrawing highland aquifers, resulting in lowered water tables and declining water quality.

On a per capita basis, Jordan has one of the lowest levels of water resources in the world. Most experts consider countries with a per capita water production below 1,000 m^3/y to be water-poor countries. In 1997, Jordanians consumed a total of 882 million cubic meters (MCM). In 1996, per capita share of water was less than 175 for all uses. This placed Jordan at only 20% of the water poverty level. The extent of the crisis is further demonstrated by the fact that, from the 1997 total of 882 MCM, around 225 MCM was pumped from groundwater over and above the level of sustainable yield. Likewise, about 70 MCM was pumped from non-renewable fossil water in the south-east of the country [2].

With Jordan's population expected to continue to rise, the gap between water supply and demand threatens to widen significantly. By the year 2025, if current trends continue, per capita water supply will fall from the current 200 m^3 per person to only 91 m^3, putting Jordan in the category of having an absolute water shortage.

Responding to the challenge, the government has adopted a multi-faceted approach designed to both reduce demand as well as increase supply. The peace treaty signed in 1994 by Jordan and Israel guaranteed Jordan its right to an additional 215 MCM of water annually through new dams, diversion structures, pipelines and a desalination/purification plant. Of this 215 MCM, Jordan is already receiving between 55 and 60 MCM of water from across the border with Israel through a newly-built pipeline. Jordan is also entitled to build a series of dams on the Jordan and Yarmouk rivers to impound its share of flood waters. To this end, the Karama Dam in the Jordan Valley has been built to store 55 MCM of water, mainly from the Yarmouk, and its yield will be used to help irrigate some 6000 hectares in the southern Jordan Valley [3].

2. Water resources

The potential for water resources in Jordan ranges from 1,000 to 1,200 MCM, including recycled treated wastewater. Water resources consist primarily of surface and groundwater, with treated wastewater being used on an increasing scale for irrigation, mostly in the Jordan Valley. Renewable water resources are estimated at about 750 MCM/y, including groundwater at 277 MCM/y and surface water at 692 MCM/y, of which only 70% is economically usable. An additional 143 MCM/y is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored, but at least 50 MCM/y is expected to be accessible for urban use after desalination.

2.1. Groundwater resources

Domestic supply of water to Jordanian population depends mainly on groundwater aquifers. Those aquifers, however, are under severe pressure from the agricultural sector, which consumes about 70% of resources, and the rest is used for municipal and industrial consumption. It is noteworthy that the contribution of agriculture to the Jordanian GDP is only 6%.

Groundwater is considered to be the major source of water in Jordan, and the only source of water in some areas of the country. Twelve groundwater basins have been identified in Jordan. Most basins are comprised of several groundwater aquifer systems. The long-term safe yield of renewable groundwater resources has been estimated at 275 MCM/y. Some of the renewable groundwater resources are presently exploited to their maximum capacity, and in some cases beyond safe yield. Overexploitation of groundwater aquifers, beyond the annual potential replenishable quantities, has and will contribute significantly to the degradation of groundwater quality in the exploited aquifers, and endangers the sustainability of these resources for future use.

The main nonrenewable groundwater resource in Jordan exists in the Disi aquifer in the South, with a safe yield of 125 MCM/y for 50 years. Other nonrenewable groundwater resources are estimated at an annual safe yield of 18 MCM.

2.2. Surface water resources

The three major surface water systems in Jordan are the Jordan, Zarqa and Yarmouk, but all have become highly undependable. For the Jordan and Yarmouk Rivers, this is due to upstream diversion and over-pumping by Syria and Israel, leaving Jordan with the rest. The Zarqa River system has been severely affected with water pollution from industries in the Amman–Zarqa area, which includes 70% of Jordanian small-medium sized industries.

Until the peace treaty, Jordan had not been able to tap these sources fully, because the three riparian states did not have a water-sharing agreement, due to the technical state of war that existed between Jordan and Israel.

The King Talal Dam is Jordan’s largest aboveground reservoir, but it faces two problems. Erratic surface water levels often reduce trapped levels to below the total capacity of 86 MCM. Also, pollution from factories that dump untreated waste into tributaries leading to the dam is raising salinity, chemical, and metal levels.

2.3. Wastewater resources

Treated wastewater, generated at sixteen existing wastewater treatment plants, is an important component of Jordan’s water resources. Due to the topography and the concentration of urban population above the Jordan Valley escarpment, the majority of treated wastewater is discharged into various watercourses, and flows downstream to the Jordan Valley, where it is used for irrigation. Currently around 55 MCM of treated wastewater is used for restricted irrigation purposes in the country. The Ministry of Water and Irrigation MWI forecasts state that the amount of wastewater used for irrigation should reach 232 MCM by 2020, especially in the Jordan Valley.

The existing wastewater treatment plants are over-used beyond their design capacity due to increased inflow of wastewater. This has reduced the quality of treated wastewater, and this “resource” has not been effectively used to gradually replace freshwater resources in agricultural uses.

2.4. Water quality

Water quality in Jordan has deteriorated due to various sources of pollution, and over-abstraction resulting in salination. The Water Authority, Ministry of Environment and Royal Scientific Society in Jordan implemented a joint program of water quality monitoring in the country. Reports indicate that [4–6]:

- About 70% of spring water has biological contamination
- Surface water shows high fecal coliform counts from non-point pollution sources, including wastewater treatment plants operating over capacity
- Water resources have a significant level of toxicity
- Industrial discharges are improperly treated or untreated.
- Over-abstraction of groundwater for irrigation has reduced the water table by 5 m in some aquifers and tripled salinity.
- Unregulated fertilizer and pesticide application has increased nitrates and phosphorus in water supplies.

3. Analysis of demand and supply of water

Sustainable water supply in Jordan is limited, whereas demand is rising rapidly. The demand in the year 2002 was around 1,000 MCM, of which 450 MCM was derived from surface water while the rest came from renewable and non-renewable groundwater. To meet the deficit between supply and demand, the groundwater aquifers are mined at a rate of 200 MCM annually. This corresponds to about 160% of the aquifers' sustainable yield [7].

A model of water demand developed by the MWI and the World Bank in 2001 indicated that water requirements will continue to increase as a result of increasing population, including the cumulative impact of past refugees, rising living standards, industrial development and an increase in scale and intensity of cropping activities in the Jordan Valley.

The present annual water demand amounts to 10% of the annual total rainfall on the country. Almost all the economically viable surface water resources in Jordan have been harnessed, mainly for irrigation purposes. The few remaining sources will be relatively expensive to develop. The groundwater resources of the country are over-exploited; some basins have been completely depleted and the rest, if present trends persist, will run dry within a few years. The depletion of groundwater resources is increasing the salinity of the remaining available water, and so action must be urgently taken to prevent this over-pumping.

Currently, it is estimated that sustainable annual water supply per capita in Jordan is less than 200 m^3. Increasing water demand for domestic and industrial purposes is expected as a result of the high population growth rate, and improvements in living standards and the anticipated developments in the tourism and industrial sectors. The amounts of water used for irrigation may have to be reduced in order to satisfy such needs. Increased effectiveness in irrigation, and reallocation from irrigation to other uses, could provide sufficient renewable water to meet the growing domestic demand, at least for the next decade.

The predictable water deficits are high and increasing. Because some potential renewable resources are so expensive to harness, the volume of economically available water is far lower than what could be harnessed annually. Jordan is likely to suffer severe water-rationing early this decade.

The main reason for this high use of water in agriculture is related to the low quantity of surface water available for agriculture, and the fact that the small percentage of land which receives more than 300 mm of rainfall is almost entirely covered by urban development, leaving only dry land to be cultivated. This is exacerbated by the low soil quality and high evaporation rates.

The industrial sector uses around 60 MCM annually and is still growing. The main industrial base in Jordan is the mining and extractive industry, especially for phosphates, cement and potash. All these industries are highly water demanding. Other small-medium scale industries have been suffering from shortages in water supply and increase in their costs. They have opted for more water-conservation efforts in industrial processes by recycling their wastewater streams wherever feasible. The water shortage has also been a limiting factor in the establishment of new industries, as well as expansion of some high-potential energy industries like oil shale.

Jordan is pursuing an economic liberalization system that has resulted in the establishment of many qualified industrial zones (QIZ), and the emergence of new industries following the signing of a free trade agreement with the United States in 2000. This thirst for more investments in the industrial sector is expected to increase the industrial demand for water.

Water losses from the supply network, which suffers from both corrosion and damage, are significant. The unaccounted-for water associated with the municipal and industrial network exceeds 50%, and is most likely to be due to leakages and overflows from reservoirs, unreliable meters and meter reading problems. The overall water losses in the agricultural sector are estimated to be 45%. These losses are unacceptably high in view of the existing water shortages. Thus, the government must act quickly to reduce such losses. This will save not only water, but also the energy required to pump it up from deep wells. It is very clear that Jordanians are using the minimum amount of water needed to sustain life, not only because they are extremely concerned about water use, but more importantly due to water shortage itself.

3.1. Water management and demand projections

Total supply of water is expected to increase from 363 MCM in 2005 to 1287 in 2020, based on the assumption that all projects included in the water investment program 2000–2010 are implemented without delay. The relative share of municipal and industrial supply would increase from 35% of total water use in 2005 to 52% in 2020.

In the same period, the MWI model forecasts an increase in the recycling of wastewater from 67 MCM in 1998 to 232 MCM in 2020, with a parallel reduction in groundwater abstraction by 122 MCM/y, which is necessary to reduce/eliminate the current overexploitation and protect aquifers from salination. However, even if all the projects and measures included in the investment program were to be implemented, the net increase of available supplies by 385 MCM/y would not keep pace with the increase in water requirements by 442 MCM/y, as shown in Table 1 [6].

Table 2 shows that total water requirements are expected to increase from 1205 MCM in 1998 to 1647 MCM in 2020. The demand will increase mainly due to increased municipal and industrial demand from 342 MCM to 757 MCM. This increase will be triggered by population growth and

Table 1
Summary of water supply (MCM/y)

Year	Municipal and industrial	Agricultural	Total supply
1998	275	623	898
2005	363	679	1042
2010	486	764	1250
2015	589	693	1283
2020	660	627	1287

Table 2
Water requirements (MCM/y) 1998–2020

Year	Municipal and industrial requirements	Agricultural requirements	Total requirements
1998	342	863	1205
2005	463	858	1321
2010	533	904	1436
2015	639	897	1536
2020	757	890	1647

Table 3
Water demand and supply projections

Year	Total demand	Total supply	Deficit
1998	1205	898	–307
2005	1321	1042	–279
2010	1436	1250	–186
2015	1536	1283	–254
2020	1647	1287	–360

higher municipal water requirements per capita due to higher living standards. In agriculture, overall demand is expected to increase slightly from 863 MCM in 1998 to 890 MCM in 2020 [6]. This is mainly due to planned higher cropping intensity in the Jordan River Valley.

As shown in Table 3, the difference between supply and demand is likely to decrease in the coming 10 years, provided that all projects were implemented. This is of course unrealistic, and the actual situation may witness another increase in deficit in the second decade of the century due to population growth and the exhaustion of most available resources. Drinking water needs will face shortfalls, but since such needs are given top priority in the government's policy, water availability for agriculture will decline in the coming decades.

4. Impacts of water scarcity

For pure survival a human being needs between 2 and 5 L of fresh water a day. Bedouin tribes afford to live with 20–30 L including cooking and washing. For settled populations, 100 L per person and day for domestic use are said to be the minimum requirement for safe hygienic conditions and a reasonable standard of life. Households in industrialized countries typically consume 250–350 L per person in Europe and over 500 L in North America. But fresh water is much more than just a substance important to biological survival, hygiene, and individual well-being. It is also an indispensable raw material for nearly all economic activities. Worldwide, 92% of water resources are utilized outside private households, primarily in agriculture [8]. To grow an adequate diet for a human being requires about 300 metric tons of water yearly — nearly a ton a day [9]. Where this water does not fall naturally from the sky it must be provided to the fields by irrigation. Hence, 69% of global water consumption goes into irrigated agriculture. Great amounts of water are also needed in industry for washing, diluting, cooling, and preparing steam. Thus, the highly industrialized countries of the West typically utilize most of their water resources for industrial purposes. Water courses are furthermore a source of hydroelectric power and a means of transport. Through their fishery potential in some regions they are even an important direct deliverer of food. Last but not least, water bodies have a high recreational value. They are an important factor of quality of life and become economically significant for tourism. As a rule of thumb, hydrologists designate those countries with annual supplies of 1,000–2,000 m^3 per person as water-stressed. 1,000 m^3 is typically considered the minimum per capita requirement of a moderately developed society. Countries with less than 500 m^3 per capita suffer from absolute scarcity [10]. This does not mean that these countries may literally have to suffer thirst. The amount of 500 m^3 still means about 1,500 L of water per person a day. But lack of water then requires application of expensive technologies and becomes a constraint on food production, social and economic development, and protection of natural systems.

4.1. Environmental impacts

The continuous need for water resources to meet rising demands has had a great impact on the Jordanian environment. The use of groundwater aquifers has dried up a big percentage of aquatic ecosystems in the country. The Azraq Oasis, a wetland of international importance, dried up in 1985 due to the high exploitation of its water resources for domestic and agricultural uses. A series of international rehabilitation projects invested in the restoration of wetland ecological features, but it never regained its natural state.

Most of the cities and towns in Jordan are located on or near wadis that used to have perennial water flow emerging from springs. The human settlements depended on the streams and springs for their water supply, and with population growth the springs' capacity was exceeded and the springs almost dried up.

To look for alternatives, wells were dug to exploit renewable and non-renewable groundwater, which resulted in both decrease of the water table and increased salinity of aquifers. Wastewater flows from treatment plants and wastewater collection systems damaged groundwater resources to a large extent. Most of the current wastewater treatment plants are working beyond capacity, and their resulting effluent is polluting the environment.

4.2. Social impact

Table 2 shows that the greatest water consumer in the Jordan Basin region is agriculture. Nevertheless, the most direct consequences of the lack of water on human life and well-being will be those affecting domestic use. Although demand of private households will by nature be the last sector to be curtailed in a scarcity situation, the water crisis in the Jordan Basin region has had a marked impact on the living conditions of people in their homes.

According to Salameh and Bannayan [11], water supplied for domestic uses was 180 MCM in 1992, serving a population of 4.3 million people. This results in a per capita consumption of about 115 L/d. But the same authors argue that Jordan's inhabitants consume an average of only 85 L/d in the households, the difference being explained by the high losses in the conduits and by other municipal uses. This means Jordan is the country with the lowest domestic water consumption in the Arab world. Syria, Iraq, and Egypt typically have a domestic consumption around 130 L per capita. Lebanon lies around 150 L. In Jordan, municipal demand has surpassed the available supply since the mid-1980s and rationing had to be introduced systematically in most provinces in 1988 [12]. Especially during summer, 85% of the Jordanians live at the hygienic brink. Even in the capital, Amman, running water is only available then for a few hours of the week.

Unlike the oil-producing countries of the Middle East, which have high revenues from their exports and therefore strong trading positions, the parties to the Jordan Basin watershed belong to the second of these two categories. Their trade balance is chronically negative and, with the exception of Israel, they have very limited resources to improve water management systems and/or diversify their economies. This situation has been described as being subject to 'food politics', food supplies being an important leverage mechanism to the US — as the main cereal supplier worldwide — to advance a pro-American attitude among countries of the region [13,14].

4.3. Constraints to industrial development

Industrial production also is dependent on an abundant supply of fresh water. Although industrial water consumption varies considerably, depending on the applied processing technologies, one may state as a rule of thumb that up to three liters of water are needed to produce a tin of vegetables, 100 L for 1 kg of paper, 4,500 L to produce 1 ton of cement, 50,000 L to manufacture a ton of leather, and up to 280, 000 L to manufacture 1 ton of steel [15].

Energy production, which is at the base of all industrial development, is a good example of the dilemmas which industry faces in a situation of acute water scarcity. All thermal power-generating facilities, whether they use fossil or nuclear fuels or geothermal sources of heat, need a cooling system which in its turn requires water to process. The cheapest and most common method is once-through cooling, where large volumes of water are withdrawn from a water body, circulated through the system, and discharged back to the watershed at a higher temperature. If properly managed, most of this water is not lost and can be reused for other purposes, e.g. irrigation. But where great amounts of water are lacking, the possibility of reusing the water does not help.

Similar problems concern all kinds of industrial plants. A study by the German Development Institute [16] on 35 major industrial companies from all sectors in Jordan highlights the constraints posed to the industrial sector. 11 out of the17 companies that depend mainly on the public network declared that they had faced water shortages in the past, primarily during summer. A common solution is the construction of reservoirs, though their size is often insufficient when prolonged shortages occur. Thus, some companies had to rely on water delivered by tankers at highly over-prized costs of up to two Jordanian Dinars (about three US$) per m^3. Eight of the 18 companies using private wells stated that the groundwater table had fallen during recent years. They had to drill deeper wells, and were thus faced with additional investment costs. The general ban on drilling new wells forced companies to locate production sites within areas with existing wells. Understandably, the price for such plots of land is far higher than for usual building ground. Another problem is related to water quality. Several companies reported deteriorating water quality, characterized by increasing salinity. Thus 25 out of 35 companies had to treat their fresh water prior to use. The costs of pre-treatment often substantially surpassed the costs of pumping and/or charges by the water authority. Since available water resources are already fully exploited, it seems inevitable that further industrial development, in Jordan as in the other areas of the region, will need a shift in the sectoral allocation of water. In the present situation this can only mean at the expense of agricultural use. Economically, this would make sense, since the product value of 1 m^3 of water consumed in industrial production is very much higher than for the same amount consumed for irrigating wheat fields or orchards. In Jordan, for example, productivity per unit of consumed water is 40 times higher in industry than in agriculture, and employment effect is 13 times higher [16].

5. Water management options

5.1. Fully developing existing resources

Unfortunately, no unused river or groundwater body remains in the Jordan Basin region. But increased catchments of winter flood water anywhere along an already partially used system can also add resources to the water budget.

5.2. Water harvesting

Related to the technique just mentioned is the practice of “water harvesting”, which consists in constructing small, typically micro-scale dams and trenches to gather and make optimal use of rainfall and storm run-off. The technique was applied by ancient people like the Nabateans to establish rich civilizations in the desert two thousand years ago. Now these practices are being rediscovered and adapted to modern requirements. The basic principle is to collect rainfall over a relatively large area and use it to irrigate just a small portion. However, the technique is only applicable on a large scale in selected places, depending on soil structure and composition. Moreover, the additional water provided will be widely distributed and therefore only available for local use. According to Salameh and Bannayan [11], if consistently applied, this source will add 30–50 MCM/y or around 5% to the water supply of Jordan.

5.3. Wastewater recycling

This resource constitutes an important nonconventional source in the country. To complement the existing wastewater treatment plants in Amman, Zarqa and other cities, plans are underway to construct more treatment plants to serve an additional 34 cities and villages in Jordan. These plants will have a combined capacity of 110 MCM in the year 2010 [17].

5.4. Water imports

Preliminary studies have been conducted to assess the possibilities of importing water to Jordan. A study was completed in 1983 to import 160 MCM/y from River Euphrates in Iraq to supply the northern part of the country. Another major water importing project is the Turkish Peace pipeline. This project is intended to divert the water of Rivers Ceyhan and Seyhan in south Turkey to supply Jordan and other countries with the water [2]. The major concern with regard to importing water is political uncertainty encountered in such multi-national projects.

5.5. Canals from the oceans to the Dead Sea

A combination of water imports from other basins and seawater desalination is represented by the project to convey seawater from the Mediterranean or the Red Sea to the Dead Sea via a tunnel and/or canal system. Originally, these plans were conceived as a means of generating hydropower by taking advantage of the 400 m difference in elevation between the oceans and the Dead Sea. A further goal was to replace the water losses in the Dead Sea due to diversions along the Jordan and Yarmouk rivers. Those plans have now been reconceived so that part of the electricity generated would be devoted to desalinating seawater and thus gaining new fresh-water supplies [18–20]. The option which seems more likely at the moment is the realization of the Red Sea–Dead Sea Canal which could become a focal point of Israeli-Jordanian cooperation after the Peace Treaty of October 1994 However, the Red–Med Canal is a US$ 3-billion mega-project of uncertain economic viability and possibly adverse environmental effects. Estimates of product water costs range from US$ 1 to 2 per m^3 according to Wolf [21]. Another study by Murakami and Musiake [19] cites costs of US$ 0.68 per m^3 of water (at price level of 1990) for a plant producing 100 MCM annually, not counting distribution expenses. This gives the same reasons for skepticism as in the case of simple seawater desalination plants. These prices may only be affordable if the water is primarily used to supply tourism facilities on the shores of the Dead Sea and eventually for some very sophisticated agro-industrial complexes, but not for conventional agriculture.

As regards environmental effects, the main problem is that the balance between water inflows into the Dead Sea and evaporation from its surface is a very complex matter. Among other things, it depends on the salinity of the water, and on possible macro- and microclimatic changes, possibly even induced by the artificial input of seawater. Such a balance is therefore not easy to achieve and much less to foresee. Miscalculations and unexpected effects might result in flooding a greater area than originally planned or require decreasing seawater input, inevitably jeopardizing the project's economical viability. Moreover, studies prepared by Jordanian hydrologists in the 1980s warned that even stabilization of the Dead Sea water table at the planned level of –390 m below sea level would increase salinity in the nearby fresh water aquifers, submerge several inhabited centers, roads as well as tourist establishments, and affect the potash extraction works in the southern part of the lake. Increased pressure on the Dead Sea bottom by the greater volume of the lake might also increase the likelihood of earthquakes and volcanic eruptions in this area very prone to tectonic activities [22].

5.6. Demand-side water management options

Demand management can take many forms, from precautions to diminish losses, to technical measures to improve the efficiency of water use at the system level or at the user end, to measures to control and/or reallocate water consumption among sectors of utilization. In terms of policies, measures can be direct, aimed at prescribing and/or rationing water allotments by administrative orders; or indirect, to influence voluntary behavior through market mechanisms, financial incentives, or public awareness programs. Demand-side management also encompasses the institutional arrangements supervising the water sector, which often have a considerable influence on allocations and consumption patterns [23].

Supply- and demand-oriented instruments, however, should not be played off against each other. Within both sets of measures we find some more and some less economically and environmentally sound instruments. Realistically, a water management plan for the Jordan Basin region will have to rely on both supply- and demand-oriented measures.

5.7. Water re-allocation among uses and sectors

The greatest potential for reducing water demand is probably given by reallocation of water among uses and sectors of consumption. While water conservation concentrates its efforts on optimizing efficiency without questioning the uses themselves, reallocation means shifting water allotment from those uses and sectors which show a low value added per unit of water consumed to those of primary social need or with higher water productivity. In other words, this approach calls for restructuring economy away from heavily irrigated agriculture towards other sectors, in particular domestic consumption (because of population growth), as well as industry and commercial uses. Within the agricultural sector, irrigation should be shifted away from particularly water intensive crops (e.g. cotton, bananas, and wheat), and kept up for those plantations with greater product and value output per water, i.e. vegetables and certain kinds of fruits. Where possible, irrigated cultivation might be converted back into rain-fed farming. The inevitable decrease of agricultural output and the disappearance of some crops from domestic production should be replaced by imports. If one takes into account the real weight of agriculture for the overall economy, resizing this sector in at least some of the countries concerned, appears less unthinkable than at first assumed.

Jordan is no longer an agrarian society, as one might possibly assume. In fact, the country has a high level of urbanization (70%), and the agriculture's contribution to the GNP is only 7%. Somewhat higher is the agriculture's share of total labor force and exports. 25% of the labor force is unemployed, and public resources to finance economic restructuration are limited. Nevertheless, some long-term adjustments aimed at gradually reducing irrigated agriculture and promoting water-saving industrial and commercial activities seem inevitable [16].

5.8. Seawater and brackish water desalination

The prospect of desalinating seawater and thus gaining an almost inexhaustible source of fresh water has been intriguing experts for a long time. Desalination is already an important source of supply in Saudi Arabia, the Gulf States, and Malta. Many experts, especially from Israel, have been proposing large-scale use of desalination technology in the Jordan Basin region, too [24]. The greatest constraint to widespread use of seawater desalination is its cost. In fact, the technology remains very expensive, making it currently impracticable for most applications. A survey submitted by the Commission of the European Communities at the multilateral talks on water shows typical product costs between US$ 1 to US$ 1.7/m^3, depending on process techniques and scale of application. Some Israeli companies active in the business have been offering plants on the drawing board which are supposed to desalinate seawater at product water costs of US$ 0.65–0.70/m^3 [25]. However, product costs of the plant do not include expenses for water storage and transport from plant to consumer. Thus, even if these relatively low figures are accepted as realistic, total water cost for the consumer would probably amount to at least around US$ 1. These costs must be put in relation to the product output per m^3 of water used in agriculture, which is the greatest consumer in the Middle East. According to Fishelson [26], the volume of water consumed per US$ of agricultural output in Israel is about 0.75 m^3. Conversely, this means that the average value output per m^3 of used water is about US$ 1.3. Consequently, should desa-inated seawater be used for irrigation, the value of the yields would just about cover the cost of the water. All remaining labor, investment, and operation costs, including the cost of irrigation facilities, would have to be subsidized. These estimates are confirmed by Kally as quoted in Assaf et al. [27] who states that "the maximum water cost that can be borne by agriculture is about US$ 0.25/m^3 which is the maximum product value for water for most irrigated crops grown under normal modern agricultural techniques".

In this context, one has to consider that the Israeli agricultural sector is one of the most highly developed and water-efficient in the world. In the neighboring Arab countries and in the Occupied Palestinian Territories the account in using desalinated seawater would turn out even much worse [28]. In Jordan, moreover, large-scale seawater desalination has no practicable path, since the only shoreline of the country is at Aqaba on the Dead Sea, far away from the population and production centers. Judging from these facts, seawater desalination is currently a practicable option only in very exceptional cases, e.g. for domestic or industrial consumption in areas with no other freshwater sources available, or for economic activities like tourism with inelastic water demand in relation to price.

More convenient and thus more realistic in the short term is desalination of brackish water. This is water with an amount of total solved solids between 1,000 and 5,000 mg/L, more than affordable for drinking and irrigating, but much less than the 35,000 mg contained in seawater. Such water is relatively widespread in the region, either for natural reasons or because of increasing salinization of fresh supplies.

6. Desalination

Most of the current global desalination capacity is already installed in the Middle East: Saudi Arabia has 26.8%, Kuwait 10.5%, and the United Arab Emirates 10% (by comparison, the United States has 12%). Israel desalinates 4 MCM/y in 33 desalination units at 23 sites, which supply a mere 0.2% of its total water consumption.

The cost of a major desalination plant with a capacity of one quarter of a billion m^3 per year is about $1 billion ($600–700 million for basic overhead and about $250 million for required operating expenses for fifteen years). At the beginning of 1990 there were 70,000 desalination plants worldwide, purifying 13 MCM/d or more than 4 billion m^3/y. Desalination today is a viable option for regular domestic use, and not only for island-resort or oil-rich states. Advanced technologies are applied today in desalination of both brackish water and seawater, making the process more and more economical and commercially feasible. Desalination of brackish water may be accomplished through the use of relatively inexpensive solar energy ponds. Despite the potential cost reductions involved in the use of large desalination plants, however, it is not reasonable to expect that desalination can solve the problem of water supply for agriculture in the near future. For the time being, desalination will serve mainly domestic and some industrial water supply requirements.

To date, the desalination of either seawater or brackish water in Jordan has been very limited. In the case of seawater, Jordan has a very short shoreline on the Gulf of Aqaba and this is very distant from the main centers of population. This is further aggravated by the fact that these centers of population are at high elevations (Amman 1000 m above mean sea level) and would therefore involve high pumping costs. Jordan does have reserves of brackish water and a small number of brackish water desalination plants have been built. Wangnick's survey of 2002 [29] lists 19 plants on

Table 4
List of existing desalination plants

Location	Total capacity (m^3/d)	Units	Process	Equipment	Feature	Customer	Water quality	User	Con. year	Plant supplier	Membrane supplier
Amman	360	1	RO	MTU	Unknown	Brewery	Brackish	Indu	1979	NL	
Akman	3028	4	RO	HFM	Unknown	Jordan Petrol	Sea	Indu	1981		
Amman	1200	1	RO	HFM	Unknown		Brackish	Indu	1981		
Amman	409	1	RO	MTU	Unknown	Armorrebuild	Brackish	Mil	1981		
	719	1	ED	FM	EDR		Brackish	Indu	1982		
Irbid	545	2	RO	HFM	Unknown	University	Sea	Muni	1982		
	1584	2	RO	HFM	Unknown		Brackish	Power	1983		
Azraq	600	1	RO	SWM	Unknown	SOM DATT	River	Indu	1987	AT	S
Aqaba	1100	1	VC	THE	TVC	Sadelmi	Sea	Power	1997		
	818	1	ED	FM	EDR		Brackish	Unknown	1998		
	800	2	RO	SWM	Unknown	Water Ministry	Sea	Muni	2001		C
Aqaba	1	1	THE		Solar	RSS	Sea	Demo	1987	Unknown	
Hisban	4	1	RO	Unknown	Jordan Water		River	Muni	2001	Unknown	
Total	11168	19									

13 sites with a total capacity of 11000 m^3/d (Table 4). There are more plants than this survey indicates as the situation is changing rapidly with new plants coming on stream.

6.1. Seawater desalination

Jordan's only access to the sea is at Aqaba, where it has a short shore line. The seawater at Aqaba has a TDS of 43,000 ppm. Currently Aqaba gets its water from the Disi aquifer and itself has no immediate need for seawater desalination. The per capita consumption of water in Aqaba is around 200 L/capita/d. Several studies have been carried out in the past on the possibilities for desalination at Aqaba. None of these have been shown to be attractive. There are a few small desalination plants for industrial use and in connection with the power station. The construction of a conveyor taking seawater from the Gulf of Aqaba to the Dead Sea to restore the Dead Sea to its natural level will provide the opportunity for very large scale seawater desalination. Such a plant could have a capacity to produce 850 MCM of potable water. There are plans for a significant expansion of tourism and commercial activities in Aqaba which may also require investment in seawater desalination in the future

The saline water from the Gulf of Aqaba represents an unlimited resource of water. It can be developed to cover the needs in Aqaba for tourism and industry, and to supply desalted water for other areas in Jordan. In addition to the desalting process for this source of water, it has to be transported 350 km to Amman and even further to other areas. It will also have to be pumped from zero to about 1000 m of static head. The brackish water in Ghore is less costly than that from Aqaba, but it needs to be transported 45 km and pumped from –400 to 1000 (1400) m of static head.

6.2. Brackish water desalination

Jordan's experience in brackish water desalination has been fairly limited. All of the plants built to date have been small and built for commercial/industrial use or for agriculture. Most have been RO plants but there are at least two EDR plants. Table 5 lists some of these plants.

Table 5
Private sector desalination plants

Project	Raw water TDS	Capacity (m^3/h)
Baptism Site	7000	32
Omari Wells	3000	22.5
Safawi Wells	3700	50
Ruweished Wells	1500	50
Al Reesheh Wells	1100	50
Abu Zighan	7000	1875

Various studies have shown that Jordan has a considerable brackish water resource. There is therefore considerable scope for both RO and EDR plants in the future. In particular there may be scope for EDR for small remote locations. This technology is more robust than RO and the feed water requires significantly less pre-treatment. It may be powered by PV. Currently under development is a large RO plant at Abu Zighan. The project will deliver some 40,000 m^3/d by 2006 (eventually 18 MCM at maximum capacity). The first phase of the project will be operational in a few months, which provides water to Amman. It is very unlikely that this water will be used for purposes other than domestic use. The first phase of the Abu Zighan project is now in its test phase. The TDS of the feed water for this project is around 7000 ppm. The design was made by the Ministry and construction is being carried out by local contractors. The membranes for the plant are from the US. The product water will be around 130 ppm TDS. Seven wells will be drilled. Water will be pumped to Amman. In the Jordan Valley there is small-scale brackish water desalination. Twenty-one stations deliver water destined largely for irrigation use. These stations are located north of the Dead Sea and are privately owned. Studies indicate that there is a maximum of 80 million m^3

of water that can be used in the Jordan Valley. Salinity in the valley is maximum 7000–8000 ppm, but on average it is some 3000 ppm. The Hisban project could be implemented by 2015. This project should deliver some 9–15 MCM/y. There is a groundwater desalination plant at Zarqa, operating at 600 m^3/h. MWI and WAJ have signed an agreement in September 2003 [30]for the construction of the Wadi Ma'in, Zara and Mujib desalination plant and conveyance project. The desalination is carried using the reverse osmosis techniques. This is a Design-Build-Operate contract. The plant will be operated for 2 years before being handed over to the Government. The plant includes desalination of 55 MCM per year of water with a salinity of 1500–2000 mg/l. It shall provide Amman with 38 MCM per year with a TDS of 250 mg/l. As part of the current expansion of the Aqaba wastewater treatment plant a conveyer pipeline is constructed to supply filtered effluent wastewater for certain uses, such as watering of municipal green. In this way more drinking water can be supplied to major water consumers.

Unlike many of its Arab neighbors, Jordan has virtually no indigenous energy sources. Jordan is not a rich country. Consequently any desalination project will be very carefully examined with regards to capital and operating costs. It is therefore almost certain that RO will be selected as the optimum process for large scale desalination. ED & EDR may have useful small scale applications.

Brackish water is the South of Ghore between Dier Alla town and the Dead Sea with salinity of about 5000–7500 ppm and a yield of about 60 MCM/y as drinking water is one of the sources of brackish water in Jordan. Other resources are the saline springs east and west of the Jordan Valley with capacity of about 10 MCM/y. The third source is brackish water distributed all over the country estimated at hundreds of millions m^3. However, it is very difficult to exploit these resources due to the topography of the country, the distance between these scattered resources, the need for special treatment to remove some sorts of chemicals such as manganese, sulfates and iron, as well as gases such as hydrogen sulfide and, finally the main problem is the disposal of the brine which can cause environmental problems. These scattered resources, however, can supply desalted water for small communities by using solar energy or/and wind power.

Studies and projects were carried out to evaluate the feasibility of water desalination in Jordan. Some of the proposed actions focused on utilizing the water in the Gulf of Aqaba for water supply and desalination for major industries. Technologies used and proposed were multistage flash (MSF) or reverse osmosis (RO) and electrodialysis (ED). Currently, there are few, very small desalination plants which are used for industrial purposes. Technologies used in these plants are RO and ED, i.e., Hussein thermal station, oil refinery, Electricity Authority, and medical industries. Moreover, the JICA [4] carried out a study on the evaluation of brackish groundwater resources potential and brackish groundwater Hisban, Kafrain, Karameh, and AbuZieghan areas. The study formulated a brackish groundwater resource development strategy for the northern part of Jordan including the Jordan Valley and Amman City. The study concluded that there is a potential for producing 60 MCM/y of desalinated brackish water in the study area. A pilot plant producing 5 MCM/y of desalinated water was proposed in the Kafrain/Hisban area, and recently studies were carried out to desalinate 30 MCM from Kafrain/Hisban for the urgent need in Amman, as well as 10 MCM from seawater at Aqaba, mainly for industrial purposes, in addition to some small desalination units in the desert area.

The question of funding, however, looms large over the possible construction of desalination plants. The cost of desalination is beyond the purchase capability of Jordan. The sponsorship of desalination plants, however, is an ideal venue for international involvement. Recognizing that desalination could pave the road to peace between Israel, Jordan and the Palestinians, nations as well as international institutions such as the United Nations and the World Bank would most likely be willing to provide the capital for these plants.

7. Discussion and recommendations

Due to the increased water demand, the Ministry of Water and Irrigation (MWI) adopted a Water Strategy in 1997 [31] and supplemented it with different water policies in four water sectors, aiming to balance water demand and supply, with an emphasis on giving a major role to the private sector. The four policies are related to: groundwater management [32], irrigation water [33], water utilities [34] and wastewater management [35]. The Government of Jordan also embarked upon a privatization program. The goal was to increase the efficiency of management, and attract private investment into the economy.

The groundwater management policy addressed the management of groundwater resources, covering development, protection, and reducing abstraction from each renewable aquifer to sustainable rates. The irrigation water policy addressed irrigation water including agricultural use, resource management, technology transfer, water quality and efficiency. It stated that irrigation water should be managed as an economic commodity that water price has to cover at least operation, maintenance, and, as far as possible, capital costs, and that different prices should be applied to different water quality. The strategy specified also preferential rates for small-scale farmers in the Jordan Valley where the income is lower than other regions in the country.

The utility water policy stated that the MWI will continue as a governmental organization and will be responsible for policy formulation, decision making, national water planning, water resources monitoring and studies, and integrating water information systems. According to this strategy, the Water Authority of Jordan (WAJ) will begin separating its bulk water supply and retail delivery functions, and move these functions and services into the private sector via commercial enterprises. With respect to private sector participation, the policy states that the government of Jordan intends to transfer infrastructure and services from the public to the private sector in order to improve the performance and efficiency of the water sector. The use of management contracts and other private sector participation in water utilities was introduced through this policy. Recovery of capital costs, and BOT systems, became part of all water management policies. The MWI then introduced different prices for different qualities and uses of water. Profitable markets (tourism, industry) pay the full water cost. The water policy states that existing water distribution systems should be rehabilitated and enhanced.

In order to meet the growing water demand the Government has drawn up a number of major water development plans.

- The exploitation of fossil non-renewable groundwater in the Disi aquifer.
- The construction of the Al Wahda dam on the Yarmouk River in the north of the country.
- Use of treated waste water will increase.
- Desalination of seawater and brackish water; this remains the only solution to solve the water shortage problems in the long run.

It is recommended that a comprehensive assessment of the socio-economic dimensions of the right to water should be conducted in Jordan, and a portfolio of suggested interventions should be developed to monitor and support the integration of the water rights concepts. This is necessary due to the complexity of political, social, economic and environmental aspects of water resource management in the country.

While significant, the Kingdom's water gains from the peace treaty are barely enough to maintain the status quo. Recognizing a mutual problem, Jordan and Israel declared in Article 6, Paragraph 3 of the treaty: "The parties recognize that their water resources are not sufficient to meet their needs. More water should be supplied for their use through various methods, including projects of regional and international cooperation".

In addition to securing its bilateral rights from Israel in its 1994 peace treaty, Jordan is actively involved in promoting regional cooperation through the Water Resources Working Group of the Multilateral Peace Talks. Likewise, Jordan is currently involved in discussions with Syria pertaining to issues on the upper catchments of the Yarmouk River in an attempt to reach an understanding over stable water sharing and flood storage between the two countries. Jordan has long been a strong advocate of transforming the zero-sum game in water sharing, where there are winners and losers, into a positive-sum game where all the concerned parties will be winners. Hopefully, in the context of future peace, there will be real cooperation among the countries of the region toward achieving the provision of safe and reliable water for future generations.

On the home front, Jordan is striving to balance the water deficit by utilizing new sources as well as by decreasing consumption. The Ministry of Water recently unveiled a package of 58 projects, accounting for approximately US$ 5 billion. The projects will be implemented in stages, addressing the most urgent needs first, until the program is completed in 2010. Upon completion, the package should yield an additional 500 MCM/y.

As the exploitation of new water resources is costly, Jordan will invest heavily in the development and maintenance of water infrastructure. Among the projects requiring immediate attention are storage dams, wastewater treatment and reuse, rehabilitation of distribution systems, and augmenting urban water supplies. Conserving water, reducing leakage and waste, and utilizing a greater proportion of surface water through damming are comparatively economical ways of stretching Jordan's meager water supply further

Jordan also needs to expand its water supply to meet its growing needs by exploiting new sources. Naturally, these offer fewer and more costly options than conservation. Desalination, for example, could raise the cost of fresh water production by as much as two- or three-fold, at a time when budgetary constraints are forcing a broad range of traditional subsidies, including that for water, to be reduced. Other issues and trends also point to a steeply rising demand for funds for the investment, operation and maintenance of water systems in the future. Private sector participation is one way to help develop Jordan's water infrastructure without increasing Jordan's debt burden. Some of the components that can be directly provided by the private sector include BOT/BOO (Build, Operate, Transfer/Build, Operate, Own) schemes for water and wastewater projects, water meters, domestic appliances, and leak detection equipment, pipes, pumps and wastewater treatment package plants.

To squeeze the most from its limited resources, the Kingdom will have to maintain comprehensive and reliable data, including data on water quantity, quality and utilization. The supplies and utilization of surface water, ground water and treated wastewater will be carefully monitored. Likewise, the importance of shared surface water supplies and groundwater aquifers demands careful and consistent assessment and monitoring of these resources. Other non-conventional water resources, particularly brackish water, will be assessed as desalination becomes more economically feasible.

Jordan will maximize the full potential of surface water and groundwater based on economic feasibility, while taking into consideration the relevant social and environmental impacts. Investigative works into deep aquifers have been and are being conducted to support development planning and the interactive use of ground and surface water with different qualities is being studied. Moreover, the Kingdom will conduct periodic assessments of its available and potential water resources.

In order to carefully plan for the future, Jordan has adopted a National Water Strategy. The strategy is a comprehensive set of guidelines employing a dual approach of demand management and supply management. It places particular emphasis on the need for improved resource management, stressing the sustainability of present and future uses. Special care will be given to protecting the water supply against pollution, quality degradation and the depletion of resources. Furthermore, resource management will be improved by increasing the efficiency of conveyance and distribution systems, while the applications and uses of water will be more selectively determined. Multiple resources will be used interactively to maximize both the usable flow as well as the net benefit acquired from a unit of water.

In conjunction with this, the strategy outlines the need to evaluate future industrial, commercial, tourism and agricultural projects in terms of their water requirements. Performance efficiency of water and wastewater systems will be monitored and rated, and improvements in performance will be introduced with due consideration given to resource economics. The strategy also aims to keep operations and maintenance costs to a minimum.

The National Water Strategy ensures that the rightful shares of the Kingdom's shared water resources shall be defended and protected through bilateral and multilateral contacts, negotiations, and agreements. Peace water and wastewater projects, including the scheme for the development of the Jordan Rift Valley, shall be accorded special attention for construction, operation and maintenance. Due respect will be given to the provisions of international law as applicable to water sharing, protection and conservation, as well as to those laws applicable to territorial waters. Jordan shall continue to pursue bilateral and multilateral cooperation with neighboring states, and the Kingdom will continue to advocate regional cooperation.

Jordan is one of the ten most water-deprived countries in the world. Available per capita freshwater lags far behind most other countries. Daily water consumption is also quite low, and the cost of supplying water continues to rise. This extreme scarcity and the increasing cost of supply of water are very serious constraints to Jordan's economic development. Historically, USAID has emphasized water as a central concern because failure to effectively manage scarce water resources would undermine all other aspects of development in Jordan. Already, existing aquifers are being depleted at a rapid rate and water rationing is a fact of life for most Jordanians.

Jordan has developed a 14-year; $5 billion plan to guide water investments in the coming years. The plan hinges on two main approaches to narrowing the gap between water supply and water demand. First, it entails improved water supply management. Second, it involves increased water use efficiency. Both approaches aim at ensuring that scarce water supplies are stretched further. Both approaches also figure prominently in USAID's own water sector program. In addition, through its involvement in improving wastewater management, USAID is helping abate serious environmental degradation while augmenting water supplies from a source that would otherwise be wasted.

Through 1998, USAID's activities to strengthen water institutions focused on improving data collection and analysis, and installing new information management systems for the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) and developing key water policies. During 1999, USAID designed and began a new water policy implementation program focused on reducing groundwater depletion and optimizing the reuse of treated wastewater. USAID also initiated a new program to encourage private sector participation in the water sector and an activity to strengthen the government's capability to develop, contract and manage major infrastructure projects. With USAID assistance, the MWI has a major Build-Own-Transfer (BOT) wastewater project and supports the operation of the first decentralized, public water company for Jordan; the Aqaba Water Company.

To improve the efficiency of water use in the agriculture sector, USAID is providing a variety of technical assistance focused on restructuring irrigation tariffs, increasing cost recovery, and stimulating internal competitiveness for JVA. In coordination with other donors, USAID is also engaged in policy dialogue with the Government of Jordan (GOJ) on the need for significant structural reforms in the irrigated agriculture sector.

Improving the quality of wastewater is also a USAID priority. Four major projects are currently in the design or construction phase. Construction of a new wastewater treatment plant near Petra is now complete. The plant provides modern wastewater facilities for four communities and helps to reduce environmental degradation around the Petra National Park, a World Heritage Site. Construction is underway on wastewater conveyance and treatment facilities for expansion of the wastewater facility in Aqaba. USAID is also supporting the construction of a new wastewater treatment plant to replace the currently overloaded plant at As-Samra. When complete in 2006, this private sector operated, BOT plant will serve over 2 million residents of Greater Amman and Zarqa. Both these projects will help Jordan meet its commitments under the 1994 Peace Treaty with Israel to reduce pollution in the Gulf of Aqaba and the Jordan River. Lastly, contracting is underway on a construction contract for a wastewater treatment plant for Mafraq in northern Jordan.

In January 1992 Israel proposed at the multilateral talks on water of the Arab-Israeli peace conference in Moscow that desalination was the only long-term remedy for water-poor areas such as the Middle East. It is cheaper to invest in desalination of brackish water, seawater, or recycled sewage water than to try to settle by force disputes over available water resources, most of them already overused. Indeed, the cost of a desalination project for 10,000 people equals the cost of one tank, and a project for 100,000 people costs about the same as a jet-fighter aircraft. Similarly, diversion of water from one place to another is much more expensive than the development of new technology for cheaper desalination.

Diversion of rivers, or the reduction of agriculture and the consequent dependence on foreign food sources are unfeasible as well. The recycling of water can yield only marginal quantities. Hence, in a region where nearly all-available water resources are being utilized, the only remaining option is desalination. According to analysis conducted by academic researchers in Jordan [36,37], it was concluded that desalination is the most appropriate option for Jordan to alleviate water scarcity and overcome water budget deficit. Yet even this is not commercially viable for Middle Eastern agriculture at present. Perhaps a generation from now we will possess economical technology for mass desalination of water.

An essential prerequisite for a well-established desalination industry is the presence of the qualified manpower. In Jordan it is at times difficult for water companies to recruit qualified staff, since water supply services are generally provided by the public sector, which has a quite restrictive salary system. Particularly with regard to desalination, absence of well-qualified and experienced personnel in the field of water desalination science and technology is experienced. It is recommend starting programs for capacity building, which can be achieved through cooperation between the academic and research communities with the MWI. This capacity building program can be initiated with the development of an academic focal point on desalination issues and technologies that can be in the form of a center hosted by the Hashemite University. This center could act as a resource body on all aspects of desalination including capacity building, training, research, curriculum development, and public awareness.

In the meantime, conservation measures are necessary such as the reduction of waste in irrigation, the introduction of more economical drip-irrigation methods, the phasing-out of water-intensive crops, recycling, and price increases of formerly subsidized water toward its real value. These conservation measures will sustain the water needs of the steadily growing Jordan population by better utilizing the existing resources. However, critical water shortages are still expected within ten to fifteen years. Therefore, we need to choose our options and plan now to increase the overall water supply in the region.

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