Project

Development and implementation of an innovative, self-sufficient, brackish water treatment pilot plant for the production of drinking water in communities of Jordan

Partners:

National Technical University of Athens (NTUA)

Jordan University of Sciences and Technology (JUST)

Deliverable 1.1 for:

ACTIONS 1 & 2

Report on

the existing situation on water resources sector,

the quantity & characteristics of brackish water

& the existing situation about its management in Jordan

2011

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BACKGROUND

Jordan is a relatively small country with limited natural resources. The average population is about 6 million. The recent average population growth rate stands at about (2.8%). However, about (78%) of the population are located in urban areas concentrated in four governorates: Amman, Irbid, Zarqa and Balqa (Department of Statistics of Jordan, 2005).

The climate in Jordan is arid and semi arid with minimal rainfall and high percentage of evaporation. The climate is a mix of Mediterranean and dry desert climate. Jordan is divided into the following nine bioclimatic Mediterranean zones:

1. Dry sub-humid Mediterranean, warm and cool: restricted to a very small area in Ajloun and Ras Muneef.

2. Semi-arid Mediterranean, warm: includes Irbid, Amman, Taybeh andBaka'a.

3. Semi-arid Mediterranean, cool: restricted to Shoubak in the south west.

4. Arid Mediterranean, cool: areas of Mafraq, Jiza, and Wadi-Dhuleil.

5. Arid Mediterranean, warm: includes the cities of Zarqa and Ramtha.

6. Arid Mediterranean, very warm: Deir-Alla, Shuneh North and Wadi Yabis.

7. Saharan Mediterranean, cool: very arid areas of Al-Jafr, Ma'an, Safawi, Rwayshid and Azraq.

8. Saharan Mediterranean, warm: very arid strip or belt of land with an average depth of 20 km where annual rainfall ranges between 100 and 150 mm.

9. Saharan Mediterranean, very warm: includes the areas of the southern Ghors (south of Dead Sea), Wadi Araba, Aqaba and Disi area.

The expanding population and the climatic and topographical conditions of the country have exerted enormous pressure on the limited water resources and created a severe water supply-demand imbalance where the renewable water resources are among the lowest in the world, and is declining with time. Jordan is considered one of the poorest four countries in the world in water resources and falls below the water poverty line (1,000 m^3/capita/year). In the year 2008 the renewable freshwater resources available per capita in Jordan were about 140 m^3 /capita/year. By the year of 2025, the available per capita per year will be 90 m^3 putting Jordan in the category of an absolute water shortage. (MoE, 2007); El-Naser, 2009). The per capita of water supply in Syria reaches 1,028 m^3 and in Iraq reaches 2,172 m^3. This shows the extent of water poverty in Jordan (ESCWA Report, 2006). The supply-demand imbalance has influenced the quality of water resources where over abstraction from groundwater aquifers exploited the aquifers at more than double their sustainable yield in the average. Due to population growth and increasing living standards in urban areas, it is expected that the total water demand will rise to 1647 MCM/year in 2020, compared to 1321 MCM/year in 2005. The Ministry of Water and Irrigation plans to partly satisfy the rising demand through increased wastewater reuse (Heinrich, 2004). In 2006, the major consumer of freshwater was the agricultural sector, using about 64%. The municipal share was 30% and the share of tourism and industries was 4% and 2%, respectively (WAJ, 2009). Since the main priority in Jordan is domestic water use, the share used for agricultural purposes is expected to decrease in the next decades (Heinrich, 2004).

The lack of water and meeting water demand will be one of the most serious challenges to Jordan’s future economic growth and managing water resources is, therefore, imperative and very important. Such situation will be worsened in the future by the fact that the population is expected to double by 2029 and the already low availability will be halved. There is an increasing and an urgent need for Jordan to conserve and protect water resources (Mohammad et al., 2003; Udluft and El-Naser, 1992; El-Naser, 2009).

WATER DEMANDS AND USES IN JORDAN

Jordanian rural communities suffer largely from lack of water. Securing clean water and sanitation for households, farms and small businesses present a daily challenge for them (Faruqi, 2004). The majority of Jordan population (95%) is connected by the sewer network. However, households in Jordan receive water once a week and in many occasions citizens are forced to buy water from tankers. Moreover, municipal water in Jordan is used by the domestic and commercial sectors, public institutions, as well as by small industries that are connected to the public water system. The municipal water requirements are determined by population growth, industrial development, urban concentration and income increase" (Jordan Environmental Watch 2007). Most citizens of the capital Amman receive water only once a week and average daily per capita use does not exceed 140 liters (WAJ Report, 2006).

The annual growth in demand for water in Jordan is estimated at 25 mm^3/year (MWI, 2009). Water is mainly used for agriculture (63%). Water use in Jordan by user sector reflects that municipal water uses accounts for 290 MCM, industrial accounts for 38.5 MCM, irrigation accounts for 588 MCM, while livestock accounts for 8 MCM (AbdelKahleq, 2008).

The gab between supply and demand was unfortunately solved by the unsustainable practice of overdrawing highland aquifers, resulting in lowered water tables and declining water quality (Hadadin et al., 2009). The water deficit in Jordan is usually addressed by reducing and rationalizing the water use by the domestic and the agricultural sectors. In the most parts in Jordan the potable water supply is delivered to the residential area once a week at the best. (MoE, 2007). The demands and uses of water are far exceeding renewable supply. The deficit gab tends to expand as a result of continuous increase in population, increase in economical (agricultural, industrial and other sectors) growth and tourist. (MoE, 2007). Moreover, the amount of water from the renewable resources are continuously declining as a results of the over pumping of groundwater resulting in lowered water table in many basins and declining water quality as well (MoE, 2007).

The reallocation of water between competing sectors helps to reduce the consequences of water shortages for important sectors especially during dry seasons. In general, priority criterion for water allocation has to be based on economic, social and environmental considerations. It is recommended that the first priority of allocation of available resources is to users with purposes that are deemed to have high returns in economic and social terms such as for municipal, tourist and industrial sectors. Agricultural use has less priority and water is given to agriculture mainly to sustaining existing irrigated projects. In particular, trees irrigated from groundwater should continue to receive an amount sufficient for their sustainability with the use of advanced irrigation methods, for example drip irrigation. Also priority should be given to agricultural projects irrigated by reservoirs of water whose quality does not qualify for use in municipal and industrial purposes.

Given this difficult situation for water sector in Jordan, it is crucial therefore to development new water resources and to find ways of increasing water supply. Earlier studies have suggested ways to increase water supply in Jordan. These include desalination of seawater and brackish water, importation of water from neighboring countries, intensive water harvesting of the rainwater, and other alternatives from non conventional water resources. It should be noted however, that these ways are costly and some have geopolitical constraints (Haddadin and Tarawneh, 2007).

Parallel to these recommended programs it is essential to conduct public awareness programs at a national level to overcome the lack of understanding and to raise community understanding and support for water allocation among competing water use sectors. In addition, Jordan should consider the adoption of water tariffs should to attract private investment in water projects.

The MWI projected the future water demand and water supply in Jordan until 2022. Total supplies are estimated to increase from 933 MCM in 2010 to 1163 MCM in 2020 with out the Red-Dead Conveyance and 1663 with the Red-Dead Conveyance. The total water demand is estimated to increase from 1,496 MCM in 2010 to 1,673 MCM in 2020. The demand will increase mainly due to increased domestic and industrial demand. Significant features will be: the large increase in utilization of surface water from the Yarmouk River, the reductions that will be essential in the rate of groundwater extraction, the development of brackish and fossil groundwater resources, and the increasing significance of reclaimed wastewater.

The projections of the water balance for the next coming 10 years or so illustrate that:

1. The demand for water will continue to increase over time (as a result of population growth, socio-economical development in the country)

2. The available resource on the other hand will increase in by about the same magnitude thus, keeping the gab and deficit wide

3. If the Red-Dead Sea conveyance project will start to function and operate in 2022, the deficit will decrease from about 500 to only 11 MCM. This project

includes a desalination stations for desalination of sea water providing about 500 MCM.

Main water consumers, 2010

Users

Agriculture	64
Domestic	30
Industrial	5
Tourism	1

Table 1: Projection the water balance for the next ten years

Year	Resources	Demand	Deficit
2010	933	1496	-563
2015	1085	1569	-484
2020	1143	1645	-502
2022	1163	1673	(w/o Red-Dead conveyance) -511
2022	1663	1673	(with Red-Dead conveyance) -11

Comparative Water Resources Availability in the Region

By the year 2025, if current trends continue, per capita water supply will fall to only 91 cubic meters, putting Jordan in the category of having an absolute water shortage. A comparison between Jordan's past and projected per capita supply with other countries in the region is shown in Table 2.

Table 2: Projected Per capita water supply for different countries

Year	1960	1990	2000	2025
Egypt	2251	1112	886	645
Israel	1024	467	400	311
Syria	1196	439	321	161
Jordan	529	224	170	91

WATER RESOURCES JORDAN

The limited water resource in Jordan is one of the major problems facing the economic development, particularly the Agricultural Sector which is consuming the largest quantity of water. The total available water utilized in Jordan is provided from renewable groundwater and from surface water. Additional water resources include the water from the peace treaty water, treated wastewater, water from desalinization of brackish and seawater and groundwater from non renewable aquifers (Al-Jayyousi and Shatnawi, 1995; Haddadin and Tarawneh, 2007). The amount of water derived from surface and groundwater sources are used for agriculture sector (64.6%), for industrial purposes (4.6%) and for domestic purposes 30.8% (Bashaar, 2007).

Jordan's renewable available water resources are estimated at 780 MCM/year, of which 505 MCM/year is surface water, and 275 MCM/year are groundwater resources (from the following basins: Yarmouk, Amman-Zarqa, Side Wadis, Jordan Valley, Dead Sea, Azraq, Hamad, Wadi Araba North, Wadi Araba South, and Wadi Sirhan) **(**Malkawi, 2003). Jordan's groundwater non-renewable water resources are located in the Jafr and Disi basins, and have an estimated safe yield of 140 MCM per annum. The volume of effluent from the different wastewater treatment plants was estimated to be about 100 MCM in the year of 2010 (MoE, 2007).

Water resources in Jordan are divided into two main categories: These are:

- Conventional water resources &
- Non-conventional water resources.

1. Conventional water resources

1.1. Surface Water Resources

Surface water resources, which constitute two-thirds of Jordan's potential usable water resources, are at present used exclusively for agriculture, except for spring water, which is sometimes collected for municipal use. Most of the municipal water supply systems and industries in Jordan at present depend on groundwater and springs. Although surface water resources exist on the northern border such as in the Yarmouk River, in the Jordan valley, and in some of the wadis flowing into the Jordan River, exploitation of surface water for municipal and industrial water supply has not so far occurred to any great extent because of sporadic flow patterns, priority use for irrigation, relatively low elevation, and the long distances to population centers.

Surface water

Jordan has three major rivers, the Jordan, the Zarqa and the Yarmouk. The Jordan River is saline therefore, can not be used directly for drinking but can be used for irrigation based on the national standards. The River Zarqa is also saline and receives large amount of municipal effluent rendering it unsuitable for domestic but can be used for irrigation uses according to the national standards. Only during flood periods does the water quality improve. The Yarmouk River is less stressed and is also a sink for municipal wastewater (Abu_Taleb and Maher, 1994). Moreover, two of the major sources of Jordan's surface water are the Jordan River and the Yarmouk River, both of which have been depleted by upstream diversion and over-pumping in Syria and Israel that affected the quantity and quality of the Jordan’s water share (Wardam 2004). The Jordan-Israel Peace Treaty, which was signed in 1994, guaranteed Jordan an equitable share of water from the Yarmouk and Jordan Rivers, (Office of King Hussein I 2009).

The total flow of the Yarmouk River has dropped drastically due to urbanization, upstream uses and climatic changes. On the other hand, the heavy utilization of groundwater in Amman-Zarqa basin has resulted also in significant reduce (1/5) in the base flow of Zarqa River. Actually, the flow of the Zarqa river is currently the treated wastewater from the Al-Samra Plant (Wardan, 2007; MWI annual report, 2003).

Other surface waters affected by pollution are wadis, creeks, rivers and dams lying downstream from wastewater treatment plants, trans-boundary movement of pollutants and solid waste disposal sites (Gideon, 1990; Tal Alon, 2007). Other sources of water for Jordan include aquifers of limited potential, such as the now nearly depleted Azraq Oasis that supplies Amman (Hof, 1995).

Surface water resources in Jordan are distributed among 15 major basins. The annual amount of surface internal water resources is about 680 MCM (0.68 km^3/year) (EarthTrends 2006). The three major surface water resources are the Jordan River, Zarqa River and Yarmouk Rivers. The later which is at the border with Syria is the largest source of external surface water and it accounts for 40% of the surface water resources of Jordan, including water contributed from the Syrian part of the Yarmouk basin. It is also the main source of water for the King Abdullah Canal which is ther main source for irrigation in the Jordan Valley (FAO Aquastat 2008).

The flow in River Jordan has dropped drastically. The water of most of the rivers and wadis draining water towards the Dead Sea basin are being utilized or stored by some nine reservoirs with a total capacity of 221 MCM. The major reservoirs are King Talal Reservoir (KTR), Wadi el-Arab and Tanour dams, the Unity Dam and others.

Eighteen small dams with capacity of about 30 MCM are located in the desert and the stored water is mainly used for animal uses and artificial groundwater recharge. In addition, many water harvesting projects storing the rainfall in large and small reservoirs.

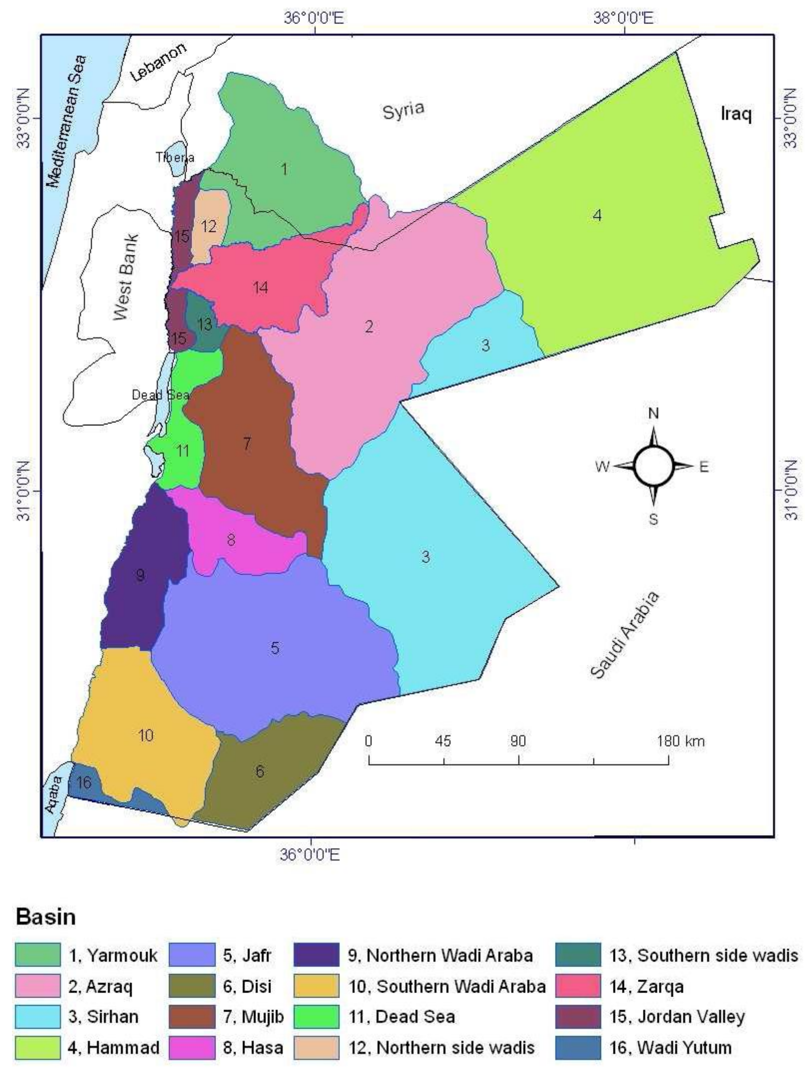

Figure 1: Surface water basins (NAP 2006)

1.2 Groundwater Resources

Groundwater in Jordan is distributed among 12 major basins, concentrated mainly in the Yarmouk, Amman-Zarqa and Dead Sea basins. The total internally produced renewable groundwater resources are estimated at 500 million m³/year and 220 million m³ of them constitute the base flow of the rivers (FAO Aquastat 2008). Groundwater aquifers are considered the main sources of water for domestic supply. However, these aquifers are under severe pressure from the agricultural sector, which consumes about 70% of resources (Wardam 2004). According to the FAO statistics, the safe yield of renewable groundwater resources in Jordan is estimated at 275 million m³/year. Most of it is currently exploited at maximum capacity and, in several cases, beyond the safe yield. Six of the 12 groundwater basins are practically over-extracted, four are balanced with respect to abstraction and two are under-exploited.

The main non-renewable aquifer presently exploited is the Disi aquifer (sandstone fossil), in southern Jordan with a safe yield estimated at 125 million m³/year for 50 years. Over-extraction of groundwater resources has degraded water quality and reduced exploitable quantities, resulting in the abandonment of many municipal and irrigation water well fields" (FAO Aquastat 2008).

Groundwater contributes approximately 54% to total water supply. The unsustainable abstraction of groundwater largely due to the increasing demand of the increasing population growth and due to agriculture expansion is making the water status in Jordan very crucial. This will not only increase the gab between the supply and demand. but also deteriorate the water quality and consume the groundwater reserve soon creating a water crisis for Jordan in the near future. This has been exacerbated by the lack of enforcement of regulations on private sector well drilling, and the near absence of controls on licensed abstraction rates. Overpumping of the groundwater lead to lowering the water table and increase the water salinity. There are several brackish springs have been identified in various parts of the country. The stored volumes of brackish groundwater for the major aquifers suggest immense resources; however, not all of these quantities will be feasible for utilization.

The ground water aquifers in Jordan are classified into three main complexes, the deep, middle and shallow aquifer complexes. The deep aquifer complex is formed from sandstone and it is found as one unit in the south and two units in the north separated by thick limestone and marl layers. The middle complex (the upper and middle cretaceous complex) consists of limestone, dolomite, marl stone and chert beds. The shallow aquifer complex, which is the mostly exploited, consists of two main systems: the basalt aquifer system and the sedimentary rocks and alluvial deposits of Tertiary and Quaternary ages system. Twelve groundwater basins are identified having a total renewable annual supply "safe yield" of about 275 MCM. Groundwater development was rapid in the 1980s and early 1990s, as successive Governments freely awarded licenses for tube-wells. As a result, by the mid-1980s, a pattern of systematic overdrawing of groundwater had been established. Over-abstraction is evident in six of the basins where the safe yields have been exceeded by more than 100 percent in some cases space (Wardan, 2007).

The total groundwater abstraction from eleven basins in 2003 was about 506 MCM representing an over-draft of about 226 MCM. Water levels in the main aquifers are declining due to this over-exploitation with some aquifers showing considerable deterioration of their water quality due to salinity. There is, in addition, an annual abstraction of about 70 MCM of fossil water mostly from the Disi basin (in the south of Jordan) which is being exploited for irrigation supplies (55 MCM) and domestic supply to Aqaba (15 MCM). Many studies indicate that an annual abstraction of 125 MCM can be supported over a 50-year period with a drawdown not exceeding 250 meters. The other non-renewable groundwater source is that of the Jafr basin with annual yield of 18 MCM, estimated to be sustainable over a 40-year period.

Some details about the most affected aquifers that suffer from overexploitation are provided below:

1- Amman-Zarqa Basin,

With its safe yield of 88 MCM per annum, Amman-Zarqa Basin is the critical renewable ground water basin in Jordan. This basin is situated in the most urbanized part of the Jordan where Amman and Zarqa cities are located and is hosting 54% of the total population. One of the first agricultural expansions in Jordan started in this basin in the area of Dhuleil and Hallabat, and resulted in over-pumping that reached 157% of the safe yield. The intensive urbanization where sewage infiltration from septic tanks and broken sewer networks were combined with over pumping and resulted in the fast depletion in water quantity and quality in the aquifer contributing to rapid desertification in this part of the country. On the other hand, the basin host about 70% of the small to medium size scales industries.

2- Yarmouk Basin,

Yarmouk basin is the next in size where it is recharged in the mountain areas north of Jordan and south of Syria with relatively high rainfall intensities. The Yarmouk Basin safe yield is estimated at about 40 MCM per annum. The pumping level reaches 59 MCM per annum. With the fluctuation in rainfall volumes, the over-pumping in the Yarmouk Basin raises the concern of depletion. The water quantity and quality is An Environmental Profile of Jordan 2006

17 NCSA Project- March 2006 categorized as being at the higher end of the scale of ground water resources in Jordan.

3- Azraq Basin,

One of the major groundwater basins in Jordan is the Azraq Basin which supplies most of the water to Amman Municipality. During the 1970s and later, agriculture activities started to bloom in the Azraq area using excessive amounts of the available ground water, abstracting twice the amount of safe yield of the basin, which is estimated to be 24 MCM per annum. The over-pumping from the shallow aquifer resulted in a substantial depression on the groundwater level that exceeded 20 meters. The large water level depression resulted in the deterioration of the groundwater quality and the ecological habitats at the Azraq oasis located at the centre of the Basin where the groundwater level was above the ground surface and formed a desert oasis. The water quality deterioration is due to the intrusion of saline groundwater from the middle aquifer into the upper aquifer. The main two oases in the basin have almost dried up and thus affecting the entire ecological system in the area. Organic soils which were formed around the wetland have been completely degraded.

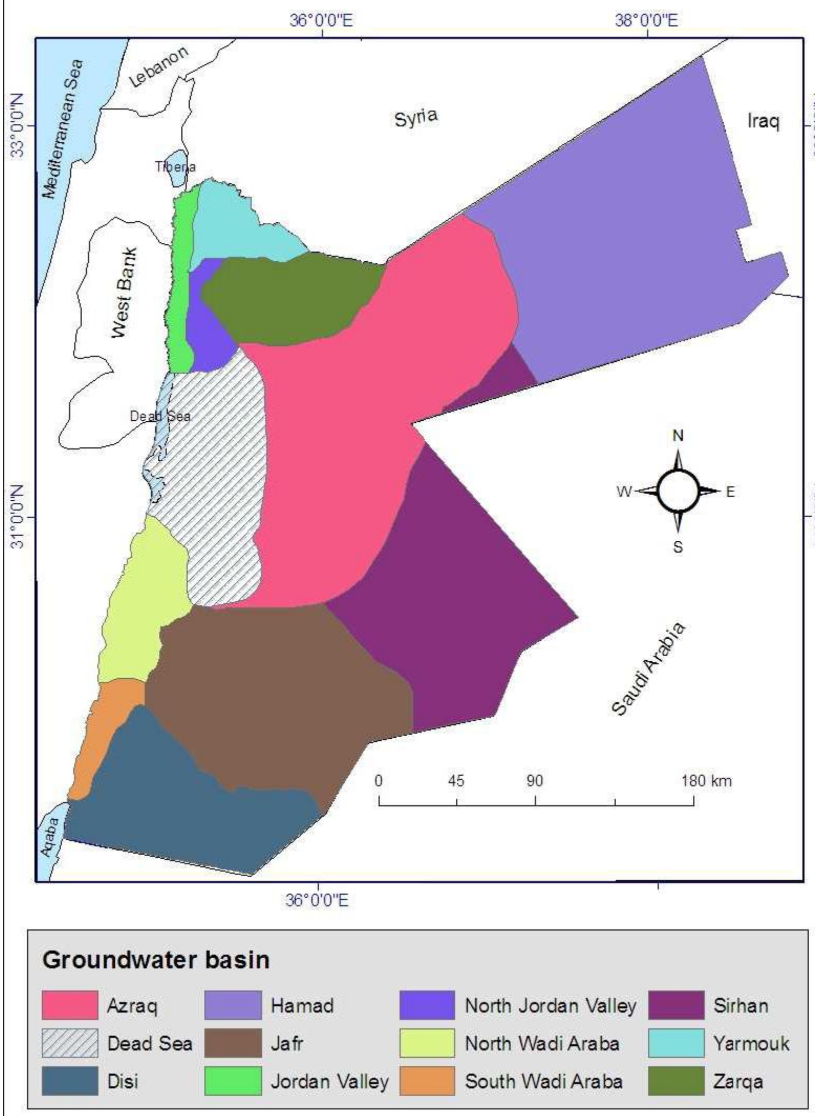

Figure 2: Groundwater basins in Jordan (NAP 2006)

1.3. Rainfall

The rainfall is very variable in time and place where the rainfall is mainly occurring usually between October and May. The annual precipitation in Jordan ranges from 50 mm in the desert to 600 mm in the northwest highlands. However, about 80% of the country is receiving less than 200 mm and, therefore, is considered (FAO Aquastat 2008). The total rain fall in Jordan is estimated at 8.5 billion cubic meters of which about 92.2% is lost by evaporation with the remainder flowing into wadis and partially infiltrating into deep aquifer (MWI, 1996). While most of rainfall evaporates, limited amounts (15%) flow into rivers and wadis as flood flows and recharges groundwater (Wardam 2004). It is estimated that about 5.4% recharges the groundwater and the rest (2.4%) goes to the surface water.

2. Non-conventional Water Resources in Jordan

2.1. Treated wastewater

2.2. Treated greywater

2.3. Water harvesting

2.4. Brackish groundwater

2.5. Seawater

2.1. Treated wastewater.

The Water strategy of Jordan called for considering the treated wastewater as a valuable source of water that should be reused efficiently in unrestricted agriculture and other non-domestic purposes, including groundwater recharge (MWI 2009). Treated wastewater generated at 19 wastewater treatment plants is an important component of Jordan's water resources (MWI 2009). Almost all of the wastewater generated in the capital city Amman is treated for reuse in the Jordan Valley. In Jordan only 40% of the wastewater is collected and treated and the plan is to increase collection and to improve the treatment by establishing more treatment plants in different places in Jordan. Ministry of Water and Irrigation estimated that an about 89 MCM of wastewater per year is treated in the current 19 treatment plants (MWI 2009). Among the 19 wastewater treatment existing in Jordan, the As-Samra Plant is the most important and considered one of the biggest in the world, serving about half the population of the country (USAID 2001). Actually, Jordan is in the process of rehabilitating and expanding its wastewater treatment plants, and exploring options for smaller communities" (Faruqi et al. 2004). By the year of 2025 when the population is projected to reach about 10 million and the percentage of the population with sewerage services will have increased about 280 MCM per annum of wastewater is expected to be generated.

2.2. Treated greywater:

Reusing household greywater is one option to increase access to good nutritious food, preserve valuable fresh water for drinking, and generate income for poor communities. A series of projects on greywater treatment and reuse have been implemented. The projects explored water management techniques, simple technological innovations and creative agricultural practices for greywater reuse at the household level. “Households used the recycled water to irrigate crops. Officials monitored the quality of the greywater used for irrigation over time and concluded that the system met WHO’s standard for restricted irrigation. As a result, the Ministry of Planning supported the construction of a further 700 systems in 90 communities across the country” (Stanley 2006).

2.3. Water Harvesting

Water in the desert represents a significant part of the water budget in Jordan. This water is dispersed over a wide area and, if properly collected, could provide a significant addition to the water reserves of the country (Hiniker, 1999).

Many researches and studies related to the water harvesting have been conducted and the results of some studies indicated the possibility of increasing the water budget directly. For example the analysis of the geo-hydrology of the upper Wadi Madoneh area, that is about 9 km south of Zarqa city and 15 km east of Amman, determined the infiltration capacities, Dams locations, amount of water added, and the influence of the recharged water on the aquifer in terms of forecasting the effects on groundwater levels, as well as on water quality (Al-Qaisi, 2008). On the other hand, other studies focused on water harvesting as indirect measure to improve the water supply by reducing the demand, for example, the analysis of rainfall harvesting in rain-fed agricultural areas, where rainfall can be stored directly in the soil for crop production using terraces, rippers, contour ridges, and other types of water collection methods. However, the efficiency of these methods is limited by the infiltration characteristics of soil and climatic conditions (Abu-Zreig et al., 2000).

Water harvesting in Jordan is quite popular across the country. Several techniques are adapted for water harvesting. Water harvesting consists of constructing small, typically micro-scale dams and trenches to gather and make optimal use of rainfall and storm run-off. Such technique was first used by earlier civilizations -such as the Nabateans- as a mean to establish livelihoods in the desert. The collected rainfall over a relatively large area can be used to irrigate soil, for animals and for domestic purposes. It has been estimated that if consistently applied, this source could add 30–50 MCM per year or around 5% to the water supply of Jordan" (Mohsen 2006).

2.4. Brackish groundwater

Brackish groundwater is generally stored in deep aquifers except in the southwest, where the Disi formation or Precambrian complex outcrops. The quality of the brackish groundwater ranges from 1,000 - 2,000 mg of TDS per litre to 5,000-10,000 mg/l, which is not good for neither domestic use nor irrigation.

Indicative examples of the composition of brackish water in Jordan are provided in the next two tables.

Table 3: Brackish water composition based on previous sampling and analysis

Source	Sampling Date	Treatment Stage	Cadmium	Al	Ammonium	Bicarbonate	Calcium	Carbonate	Chroride	Chromium	Copper	Conductivity	Fluride	Hardness	Magnesium	Manganese	Nickel	Nitrate
Salheyat Al Naeem Well / After 96 Hours	19/03/2003	Post Chlorination	<0.003	<0.01	2.49	286.09	226.25	0	394.76	<0.01	<0.01	2680	1.60	899	81.35	0.01	<0.01	
Salheyat Al Naeem Well / After 96 Hours	19/03/2003	Post Chlorination			<0.05													
Salheyat Al Naeem Well / After 72 Hours	18/03/2003	Post Chlorination	<0.003	<0.01		265.35	218.04	0	432.04	<0.01	<0.01	2680	2.35	975	104.7		<0.01	0.9
Salheyat Al Naeem Well / After 56 Hours	17/03/2003	Post Chlorination	<0.003	<0.01	2.49	275.72	217.63	0	430.26	<0.01	<0.01	2680	1.75	1030	118.44	0.01	<0.01	0.8

Source	Sampling Date	Treatment Stage	Other Phosphorus	P	Sodium	Sulfate	Sulfer Bacteria	Sulfur	Total Coliform	Turbidity	Zinc	pH	Lead	Arsenic
Salheyat Al Naeem Well / After 96 Hours	19/03/2003	Post Chlorination	0.04	23.46	243.8	624.48			<2	30	0.01	6.90	<0.01	
Salheyat Al Naeem Well / After 96 Hours	19/03/2003	Post Chlorination						15.07	<2					
Salheyat	19/03/2003	Post					50	14.84	<2					

Al Naeem Well / After 96 Hours		Chlorination												
Salheyat Al Naeem Well / After 72 Hours	18/03/2003	Post Chlorination		25.81	232.76	700.32			<2			6.80		<0.01
Salheyat Al Naeem Well / After 72 Hours	18/03/2003	Post Chlorination						14.26	<2					
Salheyat Al Naeem Well / After 72 Hours	18/03/2003	Post Chlorination					50	14.14	<2					
Salheyat Al Naeem Well / After 56 Hours	17/03/2003	Post Chlorination	0.04	24.63	232.76	700.8			<2	30.0		6.80		<0.01
Salheyat Al Naeem Well / After 56 Hours	17/03/2003	Post Chlorination						15.28	<2					
Salheyat Al Naeem Well / After 56 Hours	17/03/2003	Post Chlorination						15.18	<2					

Table 4: Results of the latest sampling and analysis of the brackish water under examination

Date		**pH**	**EC**	**TDS**	**Hard**	**Ca**	**Mg**	**Na**	**K**	**Cl**	**SO_4^{2-}**	**CO_3^{2-}**	**HCO_3^-**	**NO_3^-**	**Turb**	**SiO_2**	**NH_4^+**	**PO_4^{3-}**	**Mo**	**Sb**
		unit	**uS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Sample 1	18/12/2010	7,23	2730	1775	882	162	108,42	229,8	11,8	300	459,4	0	392	0,6	41,5	19,04	2,6	0,15	<0.01	
Sample 2	18/12/2010																			
Sample 1	19/12/2010	7,23	2720	1768	907	182	109,51	208,4	10,9	295	457,9	0	384	<0.20	45,7		2,5		<0.01	
Sample 2	19/12/2010																			
Sample 1	20/12/2010	7,21	2710	1762	972	198	115,68	223,8	12,7	300	477,1	0	383	0,47	44,6		1,9		<0.01	
Sample 2	20/12/2010																			

Source	Date	**Fe**	**Mn**	**Cu**	**Pb**	**Cr**	**Cd**	**Zn**	**Ni**	**S**	**F**	**Odor**	**ABS**	**Ag**	**Al**	**Se**	**As**	**CN**	**Ba**	**TotalColi**
		mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**TON**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**MPN/ 100ml**
Sample 1	18/12/2010	1,15	0,05	<0.01	<0.01	<0.01	<0.003	<0.06	<0.01	16,4	<0.20		<0.02	<0.01	<0.01	0,006	<0.005	<0.05	0,08	<1.8
Sample 2	18/12/2010																			<1.8
Sample 1	19/12/2010	1,1	0,05	<0.01	<0.01	<0.01	<0.003	<0.06	<0.01	15,8	<0.20		<0.02		<0.01	0,007	<0.005			<1.8
Sample 2	19/12/2010																			<1.8
Sample 1	20/12/2010	2,96	0,06	<0.01	<0.01	<0.01	<0.003	<0.06	<0.01		<0.20		<0.02							<1.8
Sample 2	20/12/2010																			<1.8

Brackish groundwater with salinity of less than 2,000-3,000 mg/l, can be used directly for some crop irrigation, depending on pervious or sandy soil conditions. Another potential use for brackish groundwater is for specific purposes in the mining industry such as for washing water. In general, brackish groundwater can be safely used after desalination or mixing with very fresh water.

Brackish groundwater has been found in some places in the Jordan valley, and has been accidentally detected in some deep sandstone aquifers, such as the Kurnub formation on the uplands during either exploratory or exploitation Grillings, but no systematic study or investigation of brackish-water potential has been undertaken. However, a large storage potential for brackish groundwater is conceivable in the rather shallow aquifers of the eastern desert of Jordan, including the areas of Azraq, Sirhan, and Hamad. In these areas, the target aquifers will be the Amman-Wadi Sir (B2/A7) formation, which is underlain by the shallow aquifer unit of Rijam (B4). These brackish aquifers may exist at depths of 200-300 m and 500-700 m with l DS of 2,000-5,000 mg/l. From the scanty piezometric data, the depth to the water table from ground level is expected to be only 100-200 m in wadi depressions including the Azraq and Sirhan. This brackish groundwater potential is situated only 100-150 km east of Amman, which suggests a potential source of water supply for the Amman municipalities if cost effective desalination is performed. The most important cost factor in such desalination is the energy cost, which can be controlled by introducing off-peak power operation, taking into account the dominant steam-power generation with high peak demand in Jordan. Recent innovative research in the high-molecular membrane industry could provide the necessary energy saving through the use of low-pressure reverse-osmosis modules for brackish water demineralization.

Desalination of brackish water in Jordan can be more convenient and more realistic in the short term than desalination of Seawater. Jordan has considerable brackish water resources, thus, desalination of brackish water can be a valuable source of water for domestic uses. Jordan, has a relatively larger sources of brackish water. To date, the desalination of either seawater or brackish water in Jordan has been very limited. In the Jordan Valley, there is small-scale brackish water desalination. About twenty stations deliver water largely for irrigation and commercial/industrial use. These stations are located north of the Dead Sea and are privately owned (Mohsen 2007).

There are currently several large-scale projects under development by the Government for brackish water desalination, such as the large RO plant at Abu Zighan and the Hisban project. There is a groundwater desalination plant at Zarqa. The Ministry of Water and Irrigation (MWI) and Water Authority of Jordan (WAJ) have signed an agreement in 2003 for the construction of the Wadi Ma'in, Zara and Mujib desalination plant and conveyance project (MWI 2009).

Since Jordan has few fossil fuel sources of its own, it seems to be more feasible to combine brackish water desalination with renewable energy sources. Such a concept is especially promising in cases of smaller capacities. However, there is a lack of experience with small-scale, decentralized desalination plants powered by renewable energies.

The development of a reverse osmosis (RO) desalination system driven by photovoltaic power system in Jordan has a potential for developing new fresh water sources (Mohsen. 2007). An investigation of the technical feasibility and a cost benefit analysis of a brackish water small-scale desalination plant in a rural area has been carried out and it was revealed and discovered as being the best socio-economic performance for a reverse osmosis directly coupled with a photovoltaic-system (Hani Abu-Qudais. 2002).

2.5. Saline and Seawater

Although, desalination of brackish water is considered a more convenient and realistic option for Jordan in the short term, seawater desalination can be a viable option for tourist and industrial enterprises that will be established as a result of the new Law of Aqaba Free Zone (Aqaba is the only city and the only sea port at he Red Sea in Jordan). The Red Sea is the only sea in Jordan. There are plans for a significant expansion of investment in seawater desalination in the future for tourism and commercial activities in Aqaba. The Red Sea-Dead Sea canal project which plans to convey seawater from the Red Sea to the Dead Sea is an attempt to address Jordan's water and energy challenges. It is primarily foreseen to generate hydropower-taking advantage of the different in elevations- and to augment the water losses of the Dead Sea to the Jordan and Yarmouk Rivers. Part of the electricity generated by this big project can be used to operate seawater desalination plants (El-Naser, 2009 2007).

Currently, feasibility study and environmental assessment are being undertaken for this project by French and British companies. The project is expected to provide Jordan with 500 MCM of water annually. It should be mentioned that the Red-Dead canal project is part of international efforts to save the Dead Sea, which has been shrinking at the rate of one meter per year, largely due to the diversion of water from the Jordan River for agricultural and industrial use. If implemented, it would involve the construction of a pipeline that would pump around two billion cubic meters of water from the Red Sea to a desalination unit near the Dead Sea. Half the amount will be desalinated, supplying the main urban centers of Jordan and the West Bank, while the rest would be directed to the Dead Sea (EMWIS 2009).

It is clear that Jordan has to consider the desalination option more seriously and to start building a national capacity in the field of water desalination. It was emphasized that desalination is not a substitute to traditional water resources; it is rather a supplementary source that can contribute in bridging the water gap of the country (Mousa and Jamal, 2001)

Desalination of brackish or sea water has also become an optional source. Currently, Jordan produces about 50 Million Cubic Meters by desalination from over 10 desalination plants. 40 MCM are being used for domestic purposes and 10 MCM for irrigation (MoE, 2007).

Water available for desalination

Water desalination for domestic use in Jordan is practically non-existent except for some small household units or factories for bottling water for drinking purposes. Several factories use plants for their own industrial needs with a total capacity of nearly 9,000 m^3 per day. These plants are located at Hussein Thermal Power Station, Oil Refinery, Pepsi Cola Co., Potash Co. and other small factories, all established since 1980.

There are two major sources for desalination: The first being the brackish water available throughout the country and the second is seawater at the Gulf of Aqaba. Brackish water in the South of Ghore between Dier Alla town and the Dead Sea with salinity of about 5,000–7,500 ppm and a yield of about 60 Mm^3/yr is one source in Jordan. Other sources are the saline springs east and west of the Jordan Valley with a capacity of about 10 Mm^3/yr and the brackish water that is distributed all over the country estimated at hundreds of millions of cubic meters. 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. 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.

The saline water from the Gulf of Aqaba represents an unlimited resource of water. It can be developed to cover the needs in Aqaba district 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 1,000 (1,400) m of static head.

Desalinated Water:

Desalination water could be considered as a future source of supply to overcome the scarcity problem. According to the National Water Master plan, an estimated amount of 12,000 MCM of saline fossil groundwater are stored in the deep aquifers of Jordan which can be considered as a potential source. Some of the saline springs and deep wells in the Jordan River valley (JRV) and its side tributaries were expected to produce a total of 75 MCM of desalinized fresh water, made available in the near future (MWI, 2003).

At present, an amount of 40 MCM of desalinated water are produced to augment the domestic supply for Amman area and other cities a further 9 MCM are used for Agriculture. The largest two projects are in Abu az-Zeigan with a capacity of 2,500 m^3/hr and al-Lajoun wells of 1,200 m^3/hr. There are other 6 additional projects that supply remote villages and towns. The main environmental concern for all desalination projects is the disposal of the brine. Sea water desalination is viewed in conjunction with the execution of the Red Sea-Dead Sea canal project. If this project could be implemented, an amount of 500 MCM of desalinized sea water would be available for Jordan. The available energy to produce this amount is through utilization of about 400 m head difference between the Red Sea and the Dead Sea and flowing 40-60 m^3/s of sea water in order to restore the Dead Sea to its original elevation of 395 m below the sea level.

Brackish water resources in Jordan:

The following table summarizes the sources of brackish water in Jordan:

Table 5: Sources of brackish water which can be utilized from different groundwater basins (MWI, 2008).

Ground water Basin	Aquifer	Storage amount of nonrenewable (billion m^3)	Assumed safe yield of renewable (MCM/a)	Salinity range (TDS) (mg/1)
Azraq	A7/B(North to central)	46		1.000 to 2.500
	A7/B2 (south)		10 to 12	1.000 to 1.700
	Kurnub	42		1.350 to 3.000
Jordan valley	A11		6	1.350 to 2.500
Dead sea	A7/B2		9 to 12	1.000 to 1.700
Wadi Araba (North a South)	A1		8	1.000 to 7.000
Jafr	A7/B2	1.7		1.000 to 4.000
	Kurnub	12		1.400 to 3.000
	Khreim	88		1.200 to> 10.000
Sirhan	B4		5	1.000 to 2.500
	A2/B2	32		4.500 to 7.000
Hammad	B4/B5		7	1.000 to 3.000
	A7/B2	16		1.500 to 3.200
Total		237.7	55 to 60	

A) Renewable groundwater brackish water.

It was estimated that the amount of renewable brackish water to be 50 MCM/year. Most of this amount is located in the JV where part of it is used for irrigation where the salinity levels range for 2,000 to 5,000 mg/l.

B) Non renewable brackish groundwater.

This is located in the following water layers: AL-Khreem, Al-Zarqa and Sandy Al-Kurnub in different areas in Jordan as well as in the layers of (B2/A7) in the Al-Azraq basin, AL-Hammad basin, Al-Sirhan basin and Al-Jafr basin. Also, it is located in layers (B4/B5) in some location in AL-Azraq, AL-Hammad and AL-Sirhan.

The non renewable brackish water amount was estimated (at all levels, including the whole depth / thickness to be 240 billions cubic meter. Only 10% of that can be used which equate to about 24 billions m^3.

C) Inflow water:

This water is located in the area which extent from the north of Dead sea-Husban, Al-Kafreen till Deir Alla within Al-Zarqa layer/ level: In addition to the western part of Amman_ Al-Zarqa basin through layers of Al-karanak and Al-Zarqa. The amount is estimated to be 365 - 300 MCM/year which can be used. Given the fact that this layer includes the northern and southern Dead Sea, the salinity levels range from 5,000 to 9,000 mg/l.

Disposal of brine water.

The disposal of brine water is considered real problem that need to be solved. Brine water should not remain in the location to avoid leakage to groundwater. It is estimated that about 25% of the water desalinated is brine water. The following options are considered for getting red of the brine water:

1) For aquaculture and establishing a fish farm.

2) For production of salt given the evaporation ponds meet the standards to protect the groundwater.

3) When desalination units are located in places near by the Dead Sea, then the brine water can be disposal to the Dead Sea with no problem.

4) If the desalination units are in the desert areas, the brine water can be used for fish farm, salt production or even can be injected to the aquifers but deep enough which will not be pumped in the future.

Ongoing or planned projects on brackish water use in Jordan.

1) Brackish water in the Jordan Valley (JV): That is located in the shallow alluvial layers. It is used for irrigation especially in the middle JV.

2) Abu- Zighan – Dair Alla.

The amount currently used in this areas is about 10 – 15 MCM/year. This amount is currently meets the needs due to.

A) Decline in the productivity at Abu-Zighan has which utilized from layers at (Zarqa, group).
B) Decline in level of groundwater level (Equipotential Head) of the inflow water layers.
C) Most work have developed a monitory network for groundwater
D) The isotopes studied indicated that the brackish groundwater in these layer are non renewable.

3) Desalination of Karamah Dam to produce drinkable water. The MWI started to desalinate part at this source to produce about one MCM/year at the first phase. It is expandable to desalinate 4 MCM/year .The production started in 2010. It is planned to pump water at capacity of 8 MCM/year from Jordan River into the Dam.

4) AL-Hammad and AL-Sirhan water.

This source include how brackish and non saline water. It is already used through many wells scattered in the areas. About 0.75 MCMof groundwater was used in Hammad and 1.25 MCM in AL-Serhan in 2006. Moreover, about 7.25 MCM/year can also be utilized from AL-Hammad and 3 MCM/year can also be utilized from AL-Sirhan. The amount of desalinated brackish water in the area from the different wells is about 0.4 MCM/year.

Seawater desalination:

The salinity level in the seawater of the Red Sea is about 43,000 ppm TDS (Mohsen, 2007). 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. However, to meet the demand for the expansion of tourism and commercial activities in Aqaba, an investment on seawater desalination is considered in the future

A huge project for transferring the seawater from the Red Sea to the Dead Sea to restore the Dead Sea will include a large scale desalination plant with a capacity of 850 MCM of potable water. 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 1,000 m of static head. The brackish water in the JV can be desalinated with a less cost than that from the Red Sea, but it needs to be transported 45 km and pumped from – 400 to 1000 (1400) m of static head Mohsen, 2007).

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. The following table (Table 6) lists some of these plants.

Table 6: Summary of desalination units in Jordan

Location	Total capacity (m^3.d)	Unit	Process	Water quality	Construction Year
Amman	360	1	RO	Brackish	1979
Amman	3028	4	RO	Sea	1981
Amman	1200	1	RO	Brackish	1981
Amman	409	1	RO	Brackish	1981
	719	1	ED	Brackish	1982
Irbid	545	2	RO	Sea	1982
	1584	2	RO	Brackish	1983
Azraq	600	1	RO	River	1987
Aqaba	1100	1	VC	Sea	1997
	818	1	ED	Brackish	1998

	800	2	RO	Sea	2001
Aqaba	1	1	THE	Sea	1987
Hisban	4	1	RO	River	2001
TOTAL	11168	19	-	-	-

Various studies have shown that Jordan has a considerable brackish water resource. Currently there is a large RO plant at Abu Zighan. The project deliver some 40,000 m^3/d by 2006 (eventually 18 MCM at maximum capacity) to Amman.

The TDS of the feed water for this project is around 7,000 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 7,000–8,000 ppm, but on average it is about 3,000 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. Another plant for desalination of brackish water is the Wadi Ma'in, Zara and Mujib desalination plant. The desalination is carried using the reverse osmosis techniques. The plant includes desalination of 55 MCM per year of water with a salinity of 1,500–2,000 mg/l. It shall provide Amman with 38 MCM per year with a TDS of 250 mg/l.
Brackish water in the South of JV between Dier Alla and the Dead Sea with salinity of about 5,000–7,500 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 (Mohsen, 2007).

The main problems associated with desalination of these brackish water resources are the difficult topography, 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 finding the environmental sound way of brine water disposal.

The JICA carried out a study to evaluate the brackish groundwater resources potential in Hisban, Kafrain, Karameh, and AbuZieghan areas. The study came up with a brackish groundwater resource development strategy for the northern part of Jordan including the Jordan Valley and Amman City. According to this study, about 60 MCM/y of desalinated brackish water can be produced in the study area.

RECOMMENDATIONS FOR INCREASING WATER SUPPLY IN JORDAN:

Many methods have been suggested to increase the water supply, including:

1. Intensive capturing of rainwater through harvesting, the use of micro- and macro-dams, assessing the existing water harvesting structures by hydrological studies, analytical tests and determining the sediments amount in these structures. This research shows that the harvest of surface runoff for groundwater recharge is a viable approach to partially resolve the water shortage problem in Jordan and rehabilitating the ecosystems damaged by groundwater mining. It is suggested to construct micro-dams along the major waterways, in order to store floodwater during winter seasons, to use it again in the summer farming seasons, as complementary irrigation water, instead of the flowing aimlessly through abandoned, uncultivated areas. This way is considered efficient water harvesting of rainwater; this action will benefit the farmers, and raise the national food sufficiency.

2. Desalination of seawater and wastewater.

3. Employing proper treatment technologies to treat industrial wastewater containing heavy metals. The country should also upgrade the existing wastewater treatment plants for better and efficient utilization of the reclaimed water.

4. Treated wastewater should be the main source for irrigating the plants. If no measures are taken a severe water shortage will occur within few years, this will mean need to reduce the agriculture activity plans.

5. Implementing proper maintenance to water distribution network to reduce the losses of drinkable water through leakage.

6. Importation of water from neighboring countries.

7. Severe water shortages required to impose a rationing program in distributing water to endusers.

8. Jordan also needs to increase its water supply to meet its growing needs by decreasing the consumption. Naturally, developing new water sources offer

fewer and more costly options than conservation. For example, desalination could raise the cost of fresh water production. The involvement of the private sector in running water resources is one option to assist in developing Jordan's water infrastructure and hence reducing water losses. Improvements should be carried out for schemes of water and wastewater projects, water meters, domestic appliances, leak detection equipment, pipes, pumps and wastewater treatment plants.

9. Jordan should maximize the full potential of surface water and ground water 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. In addition, Jordan should conduct periodic assessments for its available and future water resources.
1. However, all these are subject to cost-benefit analyses and geopolitical constraints. Water conflicts in Jordan may not remain open much longer. Responsible individuals, organizations, and nations should act now.

INFRASTRUCTURE OF WATER SUPPLY IN JORDAN

Jordan’s water resources are located far away from its population centers, in particular the Greater Amman area where about half the country’s population lives and which lies at about 1,000 meter above the sea level. To address this challenge, Jordan has developed an extensive bulk water supply infrastructure to provide water for both irrigation and municipal uses.

Existing infrastructure

The key elements of Jordan’s water infrastructure are the

1. Wihdeh (Unity) Dam on the Yarmouk River;

2. King Abdullah Canal (KAC) in the Jordan Valley which is fed primarily by the Yarmouk River,

3. Mukhaibah springs near the Yarmouk River and number of wadis draining into the Jordan Valley;

4. Deir Allah-Amman system that treats and pumps water from the KAC to Amman;

5. Samra treatment plant that treats most of Greater Amman's wastewater and discharges it to the Zarqa River; and

6. King Talal Dam on the Zarqa River from where the water returns to the KAC downstream of Deir Allah for irrigation in the Lower Jordan Valley.

The Al Wihdeh Dam on the Yarmouk River. The 96-metre-high dam can hold up to 110 MCM of water. Al Wihdeh Dam was completed and became operational in January 2007. It has been funded by the Arab Fund for Economic and Social Development (80%), the Abu Dhabi Development Fund (10%) and the Government of Jordan (10%). In February 2007, the water storage behind the dam had reached only 7.5 MCM, which means that only 6.8% of the capacity was used. The dam has been operational since January 2008. If the Yarmouk River continues at this low flow rate, it will take several years for the reservoir to fill up (Al-Dustour, 2007).

The main source of water for Amman is the Deir Alla-Amman carrier, which pumps water almost 1,200m up to Amman. It has a capacity of 90 MCM/year and treats the water along the way in the Zai treatment plant Jordan Times, 1998).

The second water source of the capital is the Main-Mujib pipeline with a capacity of 38 MCM/year, followed by a pipeline from a wellfield near the Azraq oasis to the East, local wells and a small wellfield South of Amman.

Infrastructure that is planned or under construction

Disi-Amman Carrier

In August 2008 Jordan launched this 990-million-dollar project to extract 100 million cubic meters of water a year from the fossil Disi aquifer in the Mudawwara area, 325 kilometers south of Amman.

Work on the project is expected to take around four years. The Disi aquifer is non-renewable. It is expected to provide 125 MCM/year for 50 years, when it will be used up. This missing sustainability causes major criticism. The aquifer lies under

Jordanian and Saudi Arabian territory, which might cause a conflict between the two states (Denny et al., 2009; Heinrich, 2004).

Red Sea-Dead Sea Canal

The proposed Two Seas Canal is a multi-billion dollar plan to build a canal from the Red Sea to the slowly evaporating Dead Sea. The project also incorporates the construction of a desalination plant. It is expected to provide Jordan with 500 MCM of water annually.

INSTITUTIONAL STRUCTURE AND LEGISLATION IN JORDAN

MWI is the official body responsible for the overall monitoring and management of the water sector, water supply, and wastewater system. It include the two most important entities dealing with water in Jordan; The Water Authority of Jordan (WAJ), in charge of water & sewerage systems, and The Jordan Valley Authority (JVA), responsible for the socio-economic development of the Jordan Rift Valley, including water development and distribution of irrigation.

WAJ was established as an autonomous corporate body, with financial and administrative independence linked with Minster of Water and Irrigation. WAJ is responsible for planning, implementing and operating water and wastewater projects and all water supply and wastewater facilities in Jordan. WAJ explores existing water resources and maintains and operates water and wastewater networks throughout the Kingdom (WAJ 2009). WAJ's Project Management Unit (PMU) regulates water and wastewater utilities under private management (MWI 2009).

JVA is charged with the integrated social and economic development of the Jordan Rift Valley from the Yarmouk River in the north to Aqaba in the south, it plays a pivotal role in developing and managing the Valley's water resources. JVA creates partnerships with the private sector where appropriate, and also implement projects stemming from regional agreements on water and development on behalf of the Jordanian government (JVA 2009).

The MWI has established also a Water Demand Management Unit WDMU) to provide knowledge and increase awareness on reducing water consumption and better demand management issues. The WDMU is also responsible for monitoring misuse of water and recommending regulatory measures. The WDMU have accomplished achievements such as introducing and promoting the concept of water demand management, promoting water saving technology and water saving devices, participating in introducing new water laws and regulations, studying of the possibility of greywater reuse in areas with no sewer systems and promoting and supporting studies on rainwater harvesting.

The Ministry of Health (MoH) is taking care of monitoring water quality and monitoring the standards of drinking water provided by WAJ. The ministry also monitors public and private wastewater facilities to assure its compliance with standards and regulations. Regulations are issued in coordination between the MOH and the MWI to regulate the use of treated wastewater flows for irrigation.

The Ministry of Agriculture (MoA) is authorized by Law to exploit surface water resources through construction and operation of small dams and other facilities for agricultural production and livestock. Ultimately, MOA policies have a profound effect on the water resources of the country since they affect water policies as well as the planning and management of water resources. Affiliated with the MoA is the National Center for Agricultural Research and Extensions (NCARE).

The Ministry of Environment (MOE) is responsible for protecting natural resources in Jordan. The MOE is responsibility is to coordinate with the proper agencies in order to draft instructions for EIA. MWI has been involved in conducting EIAs for projects under its jurisdiction.

Responsibility for water supply and sanitation

Policy and regulation

The Ministry of Water and Irrigation (MWI) is the official apex body responsible for the formulation of national water strategies, policies and planning, subject to approval by the Council of Ministers. The MWI has been established in 1988 through a bylaw. The establishment of the MWI was in response to Jordan's recognition for the need of a more integrated approach to national water management. Since its establishment, MWI has been supported by several donor organizations that have assisted in the development of water policy and water master planning as well as restructuring the water sector. Two key agencies in the water sector are under the authority of the Ministry: The Jordan Valley Authority (JVA) in charge of irrigation in the Jordan Valley and the Water Authority of Jordan (WAJ) in charge of water and sanitation service provision. However, WAJ is also responsible, together with the Ministry, for water resources planning and monitoring. WAJ has a Project Management Unit (PMU) that carried out major investment projects such as the water loss reduction program in Amman. From 1999 to 2006 it also regulated the private operator in Amman. The PMU was supposed to be an embryonic unit for a future semi-autonomous water regulatory agency for the entire country, to be established by law outside of the Ministry of Water and Irrigation. As a step in that direction, a Water Sector Audit Unit (WSAU) was established in the PMU in May 2008. The unit has set up a benchmarking system using performance indicators that have initially been applied to the Aqaba Water Company and Miyahuna (Al Meeyah News, 2009). In the absence of a regulatory agency, tariff setting is the responsibility of the Cabinet, after proposal from the Ministry of Water and Irrigation (Rebhieh Suleiman, 2008). WAJ also regulates water abstraction by all users, including itself, by issuing licenses. It, thus, combines both regulatory and service provision functions.

In early 2008 King Abdullah II created a Royal Water Committee to develop policies and programs in light of the kingdom's scarce water resources, chaired by Prince Faisal bin Al Hussein. The Committee produced the new Water Strategy in 2009.

Service providers

Water Authority of Jordan (WAJ) is responsible for planning, construction, operating and maintaining the public water supply and sewer services. It is linked with the Minister of Water and Irrigation.

The first WAJ's subsidiary is the Aqaba Water Company (AWC), a public company established in August 2004 as Jordan's first semi-autonomous water utility. It is owned by WAJ (85%) and the Aqaba Special Economic Zone (ASEZA) which owns 15%. The establishment of ASEZA had triggered the establishment of AWC.

The second public water company, Miyahuna, was set up in 2006 for the Governorate of Amman. The company, which was created to take over service responsibility from a private operator, is a 100% subsidiary of WAJ.

The third public company, the Northern Governorates Water Administration (NGWA), is expected to be set up in 2010, also as a 100% subsidiary of WAJ. NGWA, which currently is a department of WAJ with some limited autonomy, serves the Governorates of Irbid, Jerash, Ajloun and Mafraq.

Public, users and private sector participation in water management

The government of Jordan considers the participation of the private sector in managing the water sector as a major step to be achieved. The government, although it has begun, needs to increase private sector participation through transferring infrastructure and services from the public to the private sector in order to improve the performance and ensure the delivery of services to the population. Legislation related to private sector investments in the water sector need to be updated and continually assessed in relation to the benefits and satisfaction of end users. The role of water tariffs should be considered as a tool to attract private investment in water projects targeting the recovery of the capital costs and costs of operation and maintenance. The role of the private sector in agricultural projects should also be encouraged and expanded with emphasis be placed on the social benefits in conjunction with private investments.

In 1999, a public-private partnership (PPP) went underway with the signing of a Management Contract between WAJ and the private joint venture Lyonnaise des Eaux - Montgomery Watson - Arabtech Jardaneh (LEMA). According to the contract, LEMA was responsible for operating and managing water and wastewater services in the Greater Amman area on behalf of WAJ. The original five-year contract which began in August 1999 was extended until December 2006. The contract was intended to strengthen the technical structure and management capability as well as to develop the skills and knowledge of the staff. To do this, a small team of experienced ex-patriates worked with, and trained, around 1,250 local staff. LEMA treated water received from a number of WAJ sources and delivered it to the population of Amman; it also collected wastewater from its customers and transported this to treatment works. The company was able to comply with 12 out of 15 performance targets. In the service area, access to supply increased from 90% in 2000 to universal access in 2005. At the same time, sewer connections increased from 69% to 80%. In 2007 the Jordan Water Company Miyahuna replaced LEMA after its contract had been extended one final time for an extra six months (Word Bank, 2007).

The wastewater treatment plant As-Samra, the largest such plant in Greater Amman, is being operated by a consortium led by SUEZ under a 25-year Build-Operate-Transfer (BOT) contract with WAJ. Another PPP was a management consultancy by Severn Trent International to strengthen the Northern Governorate Water Administration (NGWA). The contract, which was signed in 2006, expired in 2009 without being renewed.

In the Madaba Governorate a different model of private sector participation, called Micro PSP has been carried out starting in 2006. The Micro PSP involved outsourcing customer service operations to Engicon, a local operator hired on a three-year performance-based contract. Aims of the project were to improve water and wastewater revenue, to increase the billing rate and to develop the customer management organization thereby improving efficiency. To achieve this, Engicon trained staff, surveyed and mapped all subscribers and regulated routes to meter readers (to eliminate reader monopoly). As a result, the Madaba Water Administration could start issuing its own bills instead of having to rely on WAJ structures. The accuracy of meter reading improved and net billed water increased by 75%. Net collections increased from 0.9 million in 2005 to 1.9 million in 2008. The levels of non-revenue water (NRW) initially dropped from an average of 45% to 34%, but in 2009 they were back at 40% due to an increase in water pumping pressure. Advantages of the Micro-PSP model include the fact that WAJ maintained asset ownership and that all revenue collected went to WAJ, so that investment costs could be fully recovered within 13 months of operation. The performance-based contract set strong incentives for the private operator to deliver concrete results (The Madaba Micro PSP Water Project 2010).

In addition, there are more than 15 non-governmental organizations (NGOs) work directly or indirectly on water issues in Jordan, including the Jordan Environment Society (JES, 2009) and the Royal Society for the Conservation of Nature. Several water management projects have been implemented by NGOs, with support of international organizations and donors, especially in water harvesting, water reuse and sustainable agriculture issues (Wardam 2004). NGOs carry out awareness projects and provide support to community projects together with national and international partners. NGOs are particularly engaged in water harvesting, water reuse and sustainable agriculture (Heinrich, 2004) The Royal Scientific Society, through its Environmental Research Center, undertakes applied research including water quality assessments and wastewater management (Royal Scientific Society, 2009).

In 1997, the Government of Jordan embarked on a privatization program under the national goal of placing Jordan's economy more towards private sector participation and best present Jordan towards the international financial community (MWI 2009). A community-based water management is always promoted and part of the Jordanian water policies. In fact, there are several initiatives and programs promoting optimal water use at community level are advancing all over the country.

On another issue, it should be emphasized that Women’s involvement in water management in Jordan is very noticeable. In Jordanian rural communities and according to the local culture, women are bearing the responsibility of household management, with a basic reliance on water gathering and utilization. This makes the women role very crucial which has been considered in water management in Jordan.

Tariffs, Pricing and Cost Recovery in Jordan

Historically, water was viewed as a free good but this view has been changing. Currently, the Water Strategy of the Ministry of Water and Irrigation (MWI) calls for covering the operation and maintenance costs of supplying, treating, and distributing water. Thus, water now has a recognized economic value" (Surani 2006). Water valuation is used by the Ministry of Water and Irrigation as an economic tool for better efficiency in water allocation. The Jordan's Water Utility Policy (MWI 1997) seeks to move towards full cost recovery and to use a water tariffs mechanism to promote cost recovery considering water quality, end users as well as economic impacts on the various economic sectors. Cost recovery is a matter of pricing. The Ministry also states that the marginal cost of water is high based on world standards, and also the investments for water and wastewater projects are high and are increasing. Also, old water networks need rehabilitation which is financially challenging.

"It has been argued that domestic piped water prices are affordable for the Jordanian poor. But the supply is not continuous, and the water prices for bottled water and tanked water are 8-10 times that of piped water. Water supply is still subsidized by the government, and the price paid by the consumer does not reflect the full cost of its demand management. At the same time, it has been argues that privatization of the water supply network and utilities had a minor impact on the affordability of water for consumers, but with increasing population growth and decreasing resources a bigger impact could be expected in the future" (Wardam 2004).

The Irrigation Water Policy sets some principles for the pricing of irrigation water. It states that "irrigation water shall be managed as an economic commodity with an immense social value. Like other water resources, irrigation water is a national commodity owned by society at large without prejudice to existing water rights. The water price shall at least cover the cost of operation and maintenance, and, subject to some other economic constraints, it should also recover part of capital cost of the irrigation water project. The ultimate objective shall be full cost recovery subject to economic, social and political constraints. Due consideration shall be made of any water rights as established by law. Moreover, differential prices can be applied to irrigation water to account for quality".

In the municipal water sector, tariffs have been developed and executed to cover operation and maintenance costs as well as to reduce water consumption and wastage. However, these tariffs are not based on a valuation of municipal water through assessing the willingness and affordability of the consumers to pay for water. For social and political reasons, comprehensive water valuation, as demanded by economists, has not yet been implemented in Jordan. Some areas in the desert, such as in Aqaba governorate, Mafraq governorate, etc, are still supplied with municipal water free of charge (MWI 2007). Increasing agricultural water tariffs leave family farmers uncompetitive in contrast with modern industrialized farmers. Stringent bylaws to monitor water abstraction from water wells for agricultural purposes cause unrest in farming communities, provoking strong political and social resistance (Wardam 2004).

The tariff system is an increasing-block system, under which users pay a higher tariff per cubic meter if they consume more water. The tariff is generally affordable for the poor. The tariff system distinguishes between Amman, where tariffs are higher, and the rest of the governorates (Rebhhieh Suleiman et al., 2008). The new tariff system differentiates between domestic and other uses (Rebhhieh Suleiman et al., 2008). The MWI plans to set municipal water and wastewater tariffs at a level which recovers at least operation and maintenance (O&M) costs and to establish different prices according to water quality and end use MWI, 2008). However, in September 2009, King Abdullah stated that water tariffs would not be increased (Jordan Times, 2009). The intermittent supply leads many to rely on bottled or tanked water, which is about 8 to 10 times higher than piped water, so that total household expenditures are often much higher than the utility bill.

Public Awareness:

Public awareness is primarily the process of informing and educating water users about the current and future situation of the water sector. Effective public awareness programs greatly help service providers to manage water demand through educating end users to consume water rationally and to encourage them to conserve water.

Moreover, public awareness programs directly educate end users to confront the problem of resources' depletion and to understand its implications through seeing themselves as caretakers of resource sustainability. In general, public awareness programs could be a conceivable replacement for other demand management methods, including raising water prices and introducing water-saving devices which may be less acceptable to the general public. In Jordan it is essential to conduct public awareness programs at the national level since there is a general lack of understanding and concern about the value and scarcity of water resources. Awareness programs need to be implemented through the media and schools to raise community understanding and support for water allocation among competing water use sectors and to improve public participation in developing and accepting new policies related to water management. These programs should also target the modification of public behavior to assist in reducing illegal water connections and the general misuse and damage of water measurement devices. Workshops and seminars to inform the private sector, mainly well owners and farmers need to be organized to promote groundwater conservation and raise the efficiency of groundwater use and reuse.

Water Laws

- The Water Authority Law (no. 18 for 1988): This law created the Water Authority in Jordan (WAJ) in 1988, and is still the most comprehensive legislation dealing with water issues.
- The Jordan Valley Authority Law (no. 30 for 2001): This law controls the use of water resources in the Jordan Valley and sets guidelines on land ownership and farming activities in the Valley.
- The Ministry of Water and Irrigation bylaw (no. 54 for 1992): This bylaw provides the Ministry with full responsibility for water and public sewage in the Kingdom.
- Drinking Water Standards (No. 286:2001) are based on the WHO drinking water standards (Table 7).

Table 7: Drinking water quality standards – WHO

Parameters		**WHO**
Ammonium	NH_4^+	
Potassium	K^+	
Sodium	Na^+	
Magnesium	Mg^{+2}	30-150
Calcium	Ca^{+2}	75-100
Strontium	Sr	
Barium	Ba	
Carbonate	CO_3^{2-}	
(bicarbonate) Total Alkalinity as	HCO_3^-	
Nitrate	NO_3^-	<50-100
Chloride	Cl^-	200-600
Fluoride	F^-	0.7-1.7
Sulfate	SO_4^{2-}	200-400
Silica	SiO_2	
Boron	B	
Total Dissolved Solids	**TDS**	**500-1500**
pH	pH	7.0-8.5min 6.5-9.2 max
Iron	Fe^{+2}	0.1-1.0
Copper	Cu	0.05-1.5
Sodium Chloride	NaCl	250

The National Water Strategy

The Jordan water strategy addresses water resource development, resource management, legislation and institutional set-up, shared water resources, public awareness, performance, health standards, private sector participation, financing, and research and development. The Strategy stresses that the full potential of surface water and groundwater shall be tapped to the extent permissible by economic feasibility, and by social and environmental impacts and that the use of ground and surface water with different qualities shall be considered. The strategy also considers that wastewater should not be managed as waste; wastewater is to be collected and treated for reuse in unrestricted agriculture and other non-domestic purposes, including groundwater recharge. Similarly, also brackish water and desalinated sea water shall support irrigated agriculture and to produce additional water for municipal, industrial and commercial uses. "Priority criterion for project implementation, and for additional water allocation, shall be based on economic, social and environmental considerations (MWI 2009).

The first water strategy was introduced in 1997. Due to increased water demand, the Ministry of Water and Irrigation (MWI) adopted a Water Strategy in 1997 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.

NEW JORDAN NATIONAL WATER STRATEGY (JNWS) (2008-2022)

In 2009 King Abdullah gave the go-ahead for a National Water Strategy until 2022. The strategy includes investments of Jordanian Dinar 5.86 billion (USD 8.24 billion) over a period of 15 years, corresponding to more than 160% of Jordan's GDP. It also foresees a decreasing reliance on groundwater from the current 32% to 17%, increased use of treated wastewater in agriculture from 10% to 13% and increased use of desalination from 1% to 31%.

The strategy defines the long term goals that the government of Jordan seeks to achieve in the water sector, mainly it focuses on the development of resources, management of resources, legislation and institutional set-up, share water resources, performance, health standards, private sector participation, financing, research and development. An investment plan for the sector of water was issued and a water sector review report is being published with this the road to the development of Jordan's water resources becomes clear and negotiable and the cumulative achievement can be significant with time.

According to Jordan's water strategy, the government has identified three priorities for using limited fresh water resources: the first priority given to the basic human needs (domestic), followed by tourism and industrial needs. The water required for agricultural irrigation has the lowest priority and has to rely increasingly on the reuse of treated wastewater. Therefore, the reuse of treated wastewater exposes an important non-conventional water resource suitable for agricultural irrigation in Jordan (Taha and Haddadin, 2005). Wastewater (WW) reuse in agriculture is considered the economically feasible, environmentally sound use of municipal wastewater for irrigation and aquaculture. Reuse of WW for irrigation will provide additional sources of water, nutrients, and organic matter for soil conditioning, improve the environment by eliminating or reducing discharge to surface waters, conserve freshwater sources and improve the economic efficiency of investments in wastewater disposal and irrigation, mainly near cities and towns where sewerage systems exist.

According to the Minister of Water, Raed Abou Saud, even when the Disi conveyor is completed, the water deficit in 2022 will still be about 500 million cubic meters, highlighting the need for desalination under the Red Sea-Dead Sea canal. The Plan also envisages institutional reforms such as enacting a new water law, separating operational from administrative functions, as well as production from distribution operations, creating a Water Council with advisory functions and establishing a Water Regulatory Commission (Jordan National Water Strategy, 2008).

Water Policies

According to the Jordan national Water Strategy & Policies four policies has been formulated. The first policy is the Water Utility Policy. Securing reliable supply of water, adequate in quantity and quality, is one of the most challenging issues facing Jordan today, planning and policy formulation for the supply and utilization of water sources will be based on comprehensive and reliable data, including data on water quantity, quality and utilization. The supplies of surface water groundwater and treated wastewater and their utilization will be carefully monitored. The importance of shared surface water supplies and groundwater aquifers demand careful and consistent assessment and monitoring of these resources, other non - conventional water resources, particularly brackish water are assessed as desalination becomes more economically feasible (Denny et al., 2009).

The second policy is the Irrigation Water Policy. The production of food in semi-arid countries like Jordan is hardly possible without irrigation. The irrigated areas are located in the Jordan Valley (some 3,300 hectars) and in the high land (some 4,410 hectars) (some 400,000 hectars) are fit for dry land farming , but it is practiced on half of its potential because of the insecurity associated with erratic rainfall and other reasons. The following policy statements detail the long term objectives outlined in the water strategy. It is to be noted that this policy addresses the irrigation water and doesn't extend to the issues of irrigated agriculture. It addresses in more detail water related issues of resources development, agricultural use, resources management, the imperative of technology transfer, water quality, irrigation efficiency, cost recovery, role and sustainability of irrigated agriculture, on farm management regulation and controls, legislation and institutional arrangement, shared water resources, research and development and public awareness (WAJ, 2009).

The third policy is the groundwater policy. The objective of this policy is to outline in more detail the statements contained in the document entitled "Jordan's Water Strategy". The policy statements set out the governmental policy and intentions concerning groundwater management aiming at development of the resources, its protection management and measures needed to bring the annual abstraction from the various renewable aquifers to the sustainable rate of each.

The forth policy is the wastewater management policy. The following policy statement detail the long term objectives outlined in the water strategy which says "Wastewater shall not be managed as (waste), it shall be collected and treated to standards that allow its reuse in unrestricted agriculture and other non-domestic purposes, including groundwater recharge". Treated wastewater is a perennial water resource and shall form an integral part of renewable water resources and the national water budget, and it will be used for different non-domestic uses to substitute the fresh water and to save it for drinking purposes.

Future Challenges

The JNWS foresees the future challenges faces water sector in Jordan. The demand for water will continue to increase and will be by far exceeding the supply and therefore, the deficit will be increasing as well. Despite the proposed or planned projects to increase water availability and search for additional water resources, the demand will still exceed supply through 2022.

The main challenge facing water sector in Jordan in the future is that the traditional water resources will not meet water demand but contrary will decline in quantity and quality. Although, additional resources can be developed such as the reuse of treated wastewater, desalination of brackish water and seawater and others, the demand for water will remain higher than the supply. Therefore, other majors should be taken to improve the efficiency of utilization of the available water resources in Jordan. Improving management of water supply, water demand management, optimizing water demand behavior, and optimizing water allocations are the cornerstones towards reducing the water deficit.

Groundwater quality has deteriorated not only as a result of over pumping but also due to other factors. These factors include agricultural and industrial unplanned development, which were accompanied with polluting the groundwater with industrial pollutants and agrochemicals, the drainage water, the overloading of wastewater treatment plants, the seepage from landfill sites and septic tanks, and improper disposal of dangerous chemicals.

Approach to Achieve the Goals for Water Supply by 2022

The following approached has been identified by the JNWS to meet the goals for water supply by 2022:

Surface Water

Jordan will continue to study opportunities for further investment in surface water facilities. Jordan will schedule a plan to enhance the storage of dams by removing sediments that accumulated over the years. In addition, Jordan will implement a comprehensive monitoring and assessment program for surface water quantity, quality, uses and protection as well as establish an integrated development and conservation program to increase the potential of surface water development in Jordan that will promote:

- surface water systems in the Jordan Valley.

- conversion of open canal systems to pressurized pipe system.

- giving priority to modernizing and upgrading systems.

- water projects which make significant contributions to meeting rising municipal &industrial demands.

Groundwater

For improving the groundwater supply, the following measures and approaches will be taken:

- support the enactment by-law 85/2008 and will implement a program that sets out legal and financial measures aimed at controlling and gradually reducing groundwater withdrawals with the final objective of maintaining the safe yield of aquifers. Measures will also continue to be taken to protect the groundwater resources from all sources of pollution. Bylaw 85/2002 on groundwater abstraction shall be strictly followed and enforced.

- upgrade an integrated program to assess the availability and exploitability of all resources at rates that can be sustained over time. The mining of renewable groundwater aquifers will be reduced to sustainable extraction rates.

- continue to pursue planned and controlled groundwater mining from promising, extensive fossil aquifers as an option to secure incremental supplies for municipal and industrial uses. Groundwater use will take place conjunctively with surface water in places where such joint use has the potential for increasing the available supply.

- improve and centralize groundwater data collection, analysis, and monitoring.

- continuously monitor the quality status of surface and groundwater and the impact of potentially polluting activities on water resources. We will initiate corrective measures to reduce the risk of pollution to a minimum including establishing protection zones for both surface and groundwater. We will make recommendations on what should be done to minimize pollution risks and implement them in coordination with other Ministries.

- Jordan will actively participate in the process of land-use licensing in coordination with other Ministries in order to minimize negative impact on the groundwater and surface water resources from potentially polluting land-use activities.

- Jordan will provide standards, guidelines for design and best management practices for potentially polluting activities, taking into consideration the need for water resources protection.

- Jordan will rehabilitate springs and wells as well as the existing water supply infrastructure in order to better protect water sources from pollution.

- Jordan will further encourage the application of applied research activities, including artificial recharge to increase groundwater supplies, and new technologies that will optimize the operation and development of groundwater systems and promote more efficient and feasible use.

With regards to the Wastewater, the following will be implemented:

- Continue to expand the safe use of treated wastewater by building new wastewater treatment plants and exploring productive uses in agriculture, industry, and urban landscapes.

- Explore the potential for using treated wastewater for aquifer recharge as is done in other parts of the world.

With regards to the Brackish Water

- Assess the potential of brackish water resources in terms of sound technical, economic and environmental feasibility in all groundwater basins within the Kingdom, and then conduct research and studies on desalination and on optimization of brackish water use in agriculture and industry. Brackish water resources will be allocated, either desalinated or in their natural condition, to their best uses in order to provide additional water supply. When desalinated they can produce additional water for municipal, industrial and commercial consumption.

- Continue to encourage international cooperation for the promotion of research, development, information exchange, and training in the field of desalination and other non-conventional sources. Therefore, technology transfer and advanced research in desalination engineering shall be introduced.

With regards to the Resource Management

- Ensure that the guiding principle of water resource management focuses on economic, environmental and social sustainability.

- Review previously developed resources including resources mobilized for irrigated agriculture in the Jordan Valley and other established uses for confirmation of water allocation according to the sustainability principle. Special care shall be given to the protection against pollution, quality degradation and depletion.

- Continually aim at achieving the highest efficiency in water conveyance, distribution, and application and to minimize operation and maintenance costs. Adequate balance shall be sought between demand management and supply management. The cost of production of future industrial, commercial, tourism and agricultural projects shall be measured also in terms of their requirements of units of water flow. Advanced technology shall be adopted to enhance resource management capabilities. The National Water Master Plan shall remain the basis for managing Jordan's water resource.

- Maximize the use of alternative water sources including the use of greywater and rainwater harvesting. Industries and buildings should have structures and incentives in place to significantly increase the use of and better manage this resource.

Institutional Reform

Current Status

The present structure of the water sector has resulted in a number of weaknesses which require institutional reform. In addition, the structure impedes efficient management to effectively address many of the sector's challenges. These weaknesses and challenges include:

- Water demand far exceeds supply and water allocation is unbalanced with 64% going to irrigation, 30% for municipal, 5% for industry and 1% for tourism.

- Non-revenue water is over 50% in much of the country.

- Tariffs do not cover total costs. Accounting systems are weak.

- The Ministry of Water and Irrigation (MWI) is created by a "Bylaw" while the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) are created by "Laws".

- Communication among the three entities (MWI, WAJ and JVA) is limited with each functioning in near isolation from the other.

- There is a lack of cohesiveness, integration of efforts and team work.

- A top-down approach is applied and stakeholders are normally not involved in the decision making process.

- Jordanian capability is not fully tapped to manage the country's water resources.

- The sector requires additional significant investment and new business models with private sector participation.

- There exists overstaffing of MWI, WAJ and JVA and an exodus of talent to the private sector.

- Conflicts of interest in the present set-up of the water sector among MWI, WAJ and JVA.

- There exists an overlap of responsibilities with other Ministries.

However, there are success stories as well to build upon. Enhancing the ability of water and wastewater operators to manage on a commercial business will reap benefits. With the Khirbet As-Samra Wastewater Treatment Plant, MWI have successfully introduced private sector participation into the bulk water treatment market. Miyahuna and the Aqaba Water Company are bringing commercial business practices to the retail distribution and collection and treatment of wastewater market segments. In Aqaba, service has improved, losses reduced and the company is making profit, which is used in order to improve service and infrastructure further. Lessons learned need to be incorporated to expand commercial business practices in water resources management.

The increase in water demand, the limited water resources and the increase in fuel and operating costs make necessary to have a streamlined efficient operation through the implementation of a good plan for the institutional reform. The challenges cited in other chapters all support the need for greater efficiency within the institutional structure. This is arguably the most important area for reform and will set the foundation for many of the other goals articulated in this strategy.

Institutional Reform By 2022

The Ministry of water has planned to take the following measures to enhance the institutional reform by 2022:

- enforce water law

- develop a strong policy for water resource planning strategies

- operate a Water Council and allow for broad stakeholder input into water management.

- establish a Water Regulatory Commission

- train the staff and eliminate the conflicts of interests

- prepare a new Water Law that will define the structure and function of the institutions governing and managing the water sector and clarify the responsibilities of the different ministries involved in the water sector. The new law shall also define legal issues related to water

- revise Groundwater by-law 85/2002 to introduce stringent controls on the use of groundwater including the abolition of the free abstraction and limiting the abstraction quantity based on the aquifer safe yield. Enforcement measures against illegal use, abuse and deteriorating groundwater conditions shall be introduced.

- establish water resources protection legislation to legally implement water resources protection zones for drinking water resources

- study traditional water rights in Jordan in order to develop legislation that balances traditional rights with State rights while moving towards market-based allocation mechanisms. Development of appropriate legislation will require regular and systematic consultation with a diversity of stakeholders and water users

- enact institutional reform to restructure the water sector over the next two five years based on functional roles to cover governance, regulation, supply, transmission, distribution and advisory services. Each of these roles is described briefly below and no existing entity is specifically mentioned. This is purposeful to avoid presupposing that any one entity will exist in its present structure after the reform. The reform will structure opportunities for greater private sector engagement through various business models. The specific roles and responsibilities of these functional roles will be defined through legislation. The action plan that will follow adoption of this strategy will articulate the timing and sequencing for development of these new functional roles.

- the Ministry will collect and analyze data, monitor sector performance, project and plan for future growth in water demand, put in place policy and draft laws to guide the sector, and ensure compliance with environmental and other cross-sector policy, law and regulations. These activities shall be shifted to the Regulator once it is established. The Ministry body will ensure that the National Water Master Plan (NWMP) remains a dynamic document. The NWMP shall include the identification and selection of capital projects and should link between water sector planning and national development planning. The Information Technology (IT) and Geographic Information Systems (GIS) functions, including the maintenance of Geodata Inventories and relevant data handled via GIS, shall remain within the Ministry. Likewise, the Ministry will be responsible for maintaining a Water Information System (WIS)-function that will provide the required information products in support of business processes.

- The Water Regulatory Commission needs to be established. This should be an independent body because it must be separated from political pressure and influence. If it is not separated from the government there is danger, and world experience shows this is very real, that the private sector components cannot function efficiently. Customers could suffer degraded service and ultimate failure of service through infrastructure neglect and deterioration.

- The management of bulk supply to retail users will be monitored by the Ministry and the Water Council to ensure equity, quantity, and quality is maintained.

- The transmission will be the role of WAJ – a merger of all bulk water movement -- comprised of components of the current systems. Examples include: collection of water from the Yarmouk River and transmission via the King Abdullah Canal and Deir Alla – Zai pipeline to the Miyahuna operated Zai Water Treatment Plant, collection of water from Wadis Mujib, Zara, and Ma'in and conveyance to the Zara Ma'in Water Treatment Plant, pumping water from the Mafraq well fields with delivery to Amman, and delivery of bulk irrigation water to water user associations at head units.

- Distribution will continue the reform already implemented among the privatizing water utilities. Jordan should be split into at least three distribution segments (North, Middle, and South) each managed by a distribution utility. Retail distribution of agriculture water would be with Water User Associations

(WUAs). To make this work efficiently and prevent conflicts of interest, all government stock in the three water utility companies should be sold to the private sector.

- An advisory body, which could be known as a Water Council, would be an excellent way to ensure that water resource management includes views from different stakeholders so that governance can be inclusive and strategic. The Water Council will provide a forum for input from the various sectors (industry, domestic and agriculture) and also from other government institutions and ministries (environment, health, tourism). It will also provide a forum for input from the public. The Water Council will analyze and endorse policies and regulations for the water sector and the Ministry will monitor and inform the Water Council on the implementation of these policies. Though the idea can be contentious, a Water Council can serve a useful function if established and focused correctly. Functions could include resolving complaints from other sectors and advising the Ministry and Parliament on policy, planning, and legal issues. The Council Information Systems (GIS) functions, including the maintenance of Geodata Inventories and relevant data handled via GIS, shall remain with the Ministry.

With Regards to Private Sector Participation

*. MWI will expand the role of the private sector. Management contracts, concessions and other forms of private sector participation in water utilities shall be considered and adopted as appropriate. Micro-PSPs, as in the example of Madaba, will be used for performance-based outsourcing of operational tasks to achieve rapid improvements.

*. MWI will encourage and expand the private sector's role in the distribution of retail water, wastewater, treated effluent and irrigated water. Emphasis shall be placed on the social benefits in conjunction with the private investments.

Irrigation Water Pricing and Cost Recovery

*. MWI will review the water tariff in order to facilitate behavior change related to crop selection, cropping pattern, irrigation practices, and water conservation. High volume water users should pay a higher fee more closely in line with actual costs of

providing that water. Market forces should drive choices that farm families make in terms of crop selection and irrigation practices.

*. Concurrently, Jordan will work to reduce and remove tariffs and customs duties that make imported agricultural commodities less competitive in Jordan's markets. This will also help influence choices farm families are making regarding competitive crops and agricultural practices.

*. The water price shall partially cover the supply costs (cost of operation and maintenance, interest and depreciation). MWI will establish the real cost of operation and maintenance and charge for irrigation water accordingly. Depreciation of assets on a yearly basis shall be added in calculating the irrigation water tariff. This additional cost is either added on each invoice using a factor or through the application of a one-time charge against irrigation rights. This would be applied as a rate per unit area of each farm with access to irrigation water.

*. In view of the increasing marginal cost of supplying water in Jordan, the growing demand for water, the low rate of cost recovery and in line with the policy towards private sector participation and privatization, we will set municipal water and wastewater charges at a level that will cover the cost of operation and maintenance. MWI will also achieve the recovery of all or part of the capital costs of water infrastructure within five years. Until the cost recovery is full, and the national savings reach levels capable of domestic financing of development projects, project financing will depend on concessionary loans, private borrowing and BOT arrangements.

*. The water tariffs mechanism shall be considered as a tool to promote cost recovery of water projects. However, profitable undertakings in industry, tourism, commerce and agriculture shall be made to pay the full costs incurred to supply water to them. We will set differential prices for water based on water quality, the end users, and the social and economic impact of prices on the various economic sectors and regions of the country. We will also attempt to regularly review and adjust water tariffs based on the costs of supply, operations, and the comprehensive analysis of economic data.

*. Furthermore, Jordan will structure water tariffs as a tool to drive water consumption behavior change that should lead to more efficient use of water

*. MWI will establish appropriate criteria in order to apply the "polluter pays" principle.

*. MWI will structure different fees for different geographical areas. This shall be assessed for each geographical area as a function of the cost to deliver water to the area, end uses and effluent quality and will be subject to economic and social considerations.

*. MWI will sell treated effluent at a price covering at least the operation and maintenance costs of delivery.

Water Demand and Supply

JNWS called for the needs to explore new alternative water resources which will support Jordan’s development. In this context, alternative water resources may be defined as water resources that are not readily available and suitable for direct use and will include the reuse of treated wastewater, use of greywater and desalination of brackish water and saline seawater.

The challenges facing the option of desalination include the fact that it is an energy intensive and, hence, a high cost option, possible negative environmental impacts of large desalination projects will need to be mitigated, the limitation of brackish water resources and, finally, the lack of expertise in Jordan in the field of desalination. The alternative energy source to keep the cost of desalination as low as possible could be the use of wind and solar energy.

The national water strategy identified the approaches to make use of the desalination as effective as possible. The strategy called for establishing a program to desalinate brackish and sea waters on a short, medium and long-term basis. The short term sources include waters from Hisban, Kafrein, Faisal Greenery, Karamah, Abu Zighan, Deir Alla, Karamah Dam Water, Znia (Mafraq). The long term sources to include Wihda Dam, Red Sea Water, Red Sea-Dead Sea Conveyance Project. In addition, the strategy called for the need for adequate capacity building for staff to operate and maintain infrastructure resources.

According to the JNWS to meet the future water demands, the Ministry of Water has put the plan to meet the water demand by 2022. The following measures will be taken:

- irrigated agriculture in the highlands will need to be capped and regulated and the by-laws will need to be reinforced.

- introduce appropriate water tariffs and incentives in order to promote water efficiency in irrigation and higher economic returns for irrigated agricultural products

- modify policy and regulation to facilitate water allocation among users in Jordan by considering return per cubic meter used while ensuring satisfaction of basic domestic water need.

- create awareness among the Jordanian public and decision makers as it is the first step towards behaviour change and lays the foundation for policy change.

- target audiences to include public and private sectors and the general public.

- prepare and disseminate messages at multiple levels once audiences are identified and current levels of knowledge ascertained.

- work with the Ministry of Education to introduce Water Awareness programs in the form of events and curricula at all school grades.

- invite the private sector to participate with the government in setting and implementing protection zones of surface and groundwater.

- establish and implement Groundwater Management Plans in order to begin to slow this dramatic decline in groundwater.

- revise by-law 85/2002 on groundwater to conserve and protect groundwater from illegal use and over extraction

- implement regulations (incentive structures) to encourage rainwater harvesting.

- facilitate adoption of new innovative and proven technology to produce, distribute, and use and reuse water more efficiently and to increase economic productivity without increasing water use or waste.

- remove tariffs on imported crops to promote transition to crops with higher economic returns per unit of water used.

According to the JNWS to manage and improve the water supply, the Ministry of Water has put the plan to be implemented by 2022. The following measures will be taken:

- make use of desalination of brackish water and seawater

- protect the drinking water resources from pollution.

- efficiently store and utilize the surface water

- efficiently use the treated wastewater

- ensure safe and rational groundwater management

- encourage the use of greywater and rainwater is fully embedded in the codes and requirements of buildings.

- protect the shared water rights

- make a national effort to improve existing systems, expand them to cover areas not being served, and to improve technical and managerial capabilities. Policy issues related to water distribution should focus primarily on questions of efficiency and recouping investment. The general objective of any water distribution system is to distribute water to consumers in adequate quantity and quality and at the required time to meet the demand in the most efficient manner.

- make improvements in water distribution systems including the removal of inadequacies in the various components of the existing systems, such as operational problems, metering problems, supply interruptions, undersized pipes, high water losses in the tertiary networks, lack of automated pressure management approaches leading to high operation pressures, and absence of pressure zones. (Jordan National Water strategy, 2008)

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