Non-Conventional Water Resources and Opportunities as Water Augmentation to Achieve Sustainable Water Supply and Sanitation in the Middle East: Palestine as a Case Study

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Abstract

Given that availability of renewable water resources in the Middle East is limited, conflicted, and decreasing, non conventional water resources including desalination of brackish and sea water, use or reuse of marginal water quality sources, rainfall-runoff water harvesting, virtual and physical water transfer and others are gaining an increasing importance, attention, and dependence in alleviating water scarcity in the region. To include non-conventional water sources in a sustainable manner, many efforts need to be made to achieve on one side more efficient and sustainable water supply and on the other side food security, public health, economic and social development, and water environment protection. The implementation of such solutions requires vision, political will and facilitation of successful policy and reform implementation as well as technical, technological, economic, environmental and social considerations

This paper is to discuss and analyzes the cumulative influence of non conventional water resources and opportunities in Palestine through reform policies and technologies to reduce water use, to enhance water conservation and management and to preserve the environment sustainable.

Keywords: Middle East, Palestine, Water Resources development, non-conventional water resources.

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1. Introduction

The Middle East (ME) countries are facing severe water shortages which are increasing in the incoming future. The ME is a large geographic area with over a hundred million of population (Wikipedia 2010) which encompasses considerable number of countries from Turkey and Egypt, to Iran and Saudi Arabia (see Figure 1). The increasing demand for water in the ME and the limited amounts of available renewable fresh water supply coinciding with a severe drought has stimulated interest in minimizing water shortages by developing non-conventional water resources options.

The region is already experiencing moderate to high water stress and it is expected that by 2040 the whole population would be under high water stress conditions. Accordingly, water is the most important and binding constraint for any future development in this region including plans and activities to ensure sustainable agriculture (Haddad and Lindner 2001, Haddad 2004, and Haddad 2010).

In the incoming decades water demand is expected to rise and the situation will become more and more critical considering the quantity and quality of water needed for economic and social development. Various water supply and demand scenarios show that, despite an optimal development of conventional water resources, the size of the regional net water gap will greatly depend on future utilization patterns.(GTZ 1998 and ESCWA 2003).

It has been concluded that the size of the future net water gap and, thus, the total amount of additional water needed depends on future water sector policies and the use of pattern in the region include the implementation of bilateral agreements, stringent management demand, a recovery rate of treated wastewater, proportion of fresh water substitution in agriculture, an amount of inter-sector and intra-regional fresh water that is reallocated to higher value uses and future water quality management (Haddad 2009).

Water development options for increasing water supply in the ME (conventional and non-conventional) include (1) water demand management practices including water conservation, improvement of water use efficiency, pricing as well as technical, financial, economic, institutional, legal, and educational measures and (2) augmentation of supply by treated wastewater, (3) increase of supply by various water harvesting technologies and methods including runoff regulation and weather modification, (4) water imports by sea or land from outside the region, (5) exploiting non-renewable groundwater resources, (6) comprehensive regional exchange of agricultural goods and products, (7) use of solar energy in water resources development such as pumping, desalination, etc, and (8) integration of conventional and non- conventional development alternatives

The decision about what option is to be chosen is not an easy nor a clear-cut action since it depends on many factors such as the size, cost, environmental impacts and others. However, experience has proved that a long-term integration of various conventional and non-conventional water management options must be considered (Haddad and Mizyed 2004).

During the process of decision making about a non-conventional water development project and differences in terms of different economic growth's levels and development amongst Middle East countries of the ME, several conditions and policy questions need to be addressed including (1) Would the water developed be used for domestic purposes only, or would it be used for specific benefiting economic sectors or for all sectors? (2) What project size is the most appropriate and feasible, are large systems better for their starting up or is it better to have a series of small ones? (3) Should the cost of development be paid directly by consumers or by governments which share and subsidize water or decide for new special taxes; (4) Who will control and/or own the system and how this will be managed and administered? (5) Are environmental, ecological and social impacts as well as effects of project on all the geographic zones,

if not, what kind of compensations are used to cover differences and irreversible effects; (6) What planning horizon, technologies level and economic sacrifices should the project and parties strive and are committed for?
The careful implementation of non-conventional options will have positive environmental effects such as improving the hydrologic cycle, enhancing water reserves and improving the green cover as well as the climate in the region.

Non-conventional water resources development could be made on the local as well as the regional level. Local level options mainly include wastewater reuse and desalination of brackish and sea water. For higher economic feasibility large scale projects are important. Large scale projects are better implemented on the regional level where regional cooperation and international funding play an important role.

Haddad and Mizyed 2004 indicated that there are huge quantities of fresh water available in Europe, Turkey, Pakistan and Iran as average annual rainfall intensities in these countries are much higher than others in the region (see Figure 2). The closest country to ME's water deficit countries is Turkey where available water supply is about 193,000 MCM and demand of about 34,000 MCM. Thus, Turkey has huge excess quantities of fresh water.

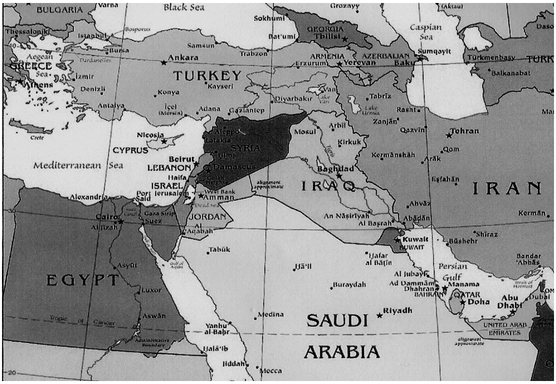

Figure 1 General Location Map of the Middle East
Map Source: U-Texas Library

The discussions in this paper will not cover conventional water development options. This paper attempts to evaluate and assess non-conventional water development options to bridge water shortages in the ME in general and in Palestine in particular and in details. The analysis incorporates technical, socio-economic political, hydrological, legal, institutional and environmental aspects and considerations of these options as well as a section on comparing and integrating conventional and non-conventional options.

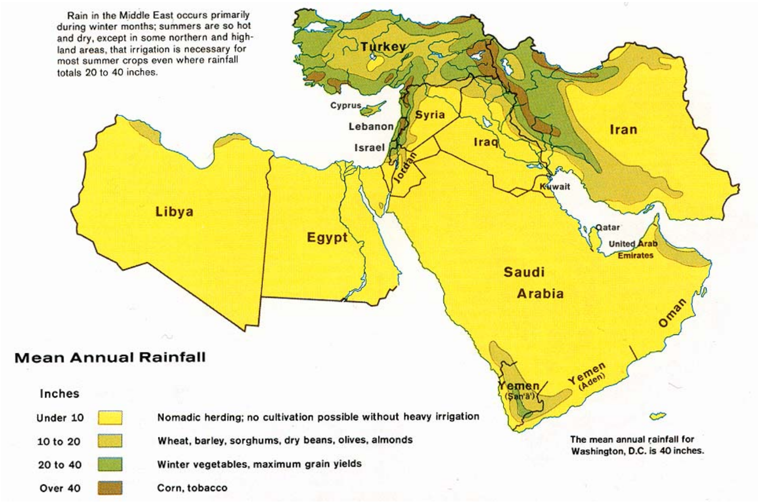

Figure 2 Mean Annual Rainfall in the Middle East
Map Source: U-Texas Library

2. Water Supply and Demand

2.1 Middle East

Yearly water availability pro capita in Southern Mediterranean regions including ME countries decreased from approximately 3,400 m^3 in 1960 to an average of 1,200 m^3 in 2003 (WRI, 1996 and WWF 2003). The majority of ME countries have annual average rainfall ranging between a minimum of 250 to a maximum of 500mm. Such a rainfall intensity is not suitable for any cultivation nor suitable for limited crops so that heavy supplementary irrigation is needed (See Figure 2).

It is expected to fall to just over 500 m^3 in 2025 due to high population growth rates and increased urban as well as rural water use. In many parts of the region dwindling water resources are threatening people's livelihood, the environment, and economic growth. Intermittent water supply is common in many cities and agricultural water supply faces the challenge of competing water demands (Haddad 1998, WRI, 1996, and WWF 2003).

If we consider the broader ME region from Turkey, in the North, to Yemen in the South and from Iran, in the East, to Libya in the West, the following notes could result out of the analysis of water supply and demand and its relation to available water resources (see Table 1 and Figure 1):

- countries of the Middle East (ME) are expected to be in a state of absolute water scarcity by 2025. Only Turkey and Lebanon are considered to be in relatively good water conditions. Iran and Syria will be on the edge.
- These countries do not have sufficient annual water resources to meet reasonable pro capita water needs for their rapidly expanding populations. Expected domestic water needs in the majority of ME countries had been suspended at current levels meaning that pro capita domestic water use will decrease throughout the time leading to precarious human conditions.
- Most of the ME countries will almost certainly have to reduce the amount of water used for irrigated agriculture and transfer it to other sectors while importing more food.
- If importing more food is a viable option for wealthier countries, it would impose additional burdens on others leading to more poverty, political and economic instability and, possibly, conflicts about water (in the absence of any basin agreements such as the case of the Jordan River Basin).

- Most of the ME countries will also have to increase their dependency on expensive and energy-consuming desalinization plants to meet domestic as well as economic development needs.

Estimates of future water demand for the ME countries indicate that, although some countries such as Jordan and Israel will substantially decrease their total pro capita water withdrawal by the year 2025, water demands will be increasing over the naturally available and renewable water resources. Expected irrigation water demands for the same period were 24 to 50% of the existing ones for most of the ME countries. If such a reduction in the expected irrigation demand does not parallel high investments aiming at improving irrigation techniques and management drastic reductions in the agricultural production, food supply would take place in those countries leading to an increased poverty those countries such as Jordan and Palestine.

Many countries of the ME are reported to have excess water but very few were investigated as feasible sources for importation. As Turkey is the closest country to the region to e taken into account (Jordan, Palestine and Israel), Turkish water resources were subjects of investigation for possible imports. The case of importing water by the sea the Manavgat River system in Turkey was subject of many investigations. Although other sources could be feasible for imports, costs relative to water importation would be higher in as much as transporting distance to the region became bigger. The absolute minimum flow recorded in the main bridge of the city of the Manavgat (Kopru Hydrological Station) is 60 cubic meters per second (1892.16 MCM/a). This means that 1892.16 MCM/a can be considered as the minimum discharge available for transportation to other locations because all irritable soils are already under cultivation and no further irrigation development is envisioned. Thus, a volume of more than 1892 MCM/a is available for further usage from the Manavgat River.

Table 1 Water Supply and Demand in the ME

Country			Libya	Saudi Arabia	United Arab Emirates	Kuwait	Oman
Surface Area in Km²			1759.05.00	2149.07.00	83.06.00	17.08	309.05.00
Population		1990	4.05	16.00	1.07	2.01	1.08
		2025	12.07	42.06.00	3.00	2.08	6.03
Annual Per Capita Water Withdrawal (m³)	Domestic	1990	96	94	266	129	36
		2025	96	94	266	129	73
	Industrial	1990	19	10	100	7	15
		2025	20	21	100	14	29
	Agricultural	1990	765	936	742	212	677
		2025	186	623	478	106	452
	Total	1990	880	1040	1108	348	728
		2025	302	738	844	249	554
		2025 as % of AWR	999	999	999	349	343
Country			Jordan	Yemen	Israel	Egypt	Iraq
Surface Area in Km²			89.02.00	528.00.00	21.01	1001.05.00	438.03.00
Population		1990	4.03	11.03	4.07	56.03.00	18.01
		2025	12.02	33.07.00	7.09	97.04.00	42.07.00
Annual Per Capita Water Withdrawal (m³)	Domestic	1990	54	18	65	53	71
		2025	54	20	126	53	71
	Industrial	1990	7	3	20	79	118
		2025	15	5	41	79	118
	Agricultural	1990	185	231	322	781	2178
		2025	145	231	229	664	1663
	Total	1990	246	252	407	913	2367
		2025	214	256	396	796	1852
		2025 as % of AWR	292	210	141	113	105
Country			Iran	Turkey	Syria	Lebanon	Palestine (1)
Surface Area in Km²			1648.02.00	774.08.00	185.02.00	10.04	5.09
Population		1990	58.09.00	56.01.00	12.03	2.06	1.09
		2025	123.07.00	90.09.00	33.03.00	4.05	6.02
Annual Per Capita Water Withdrawal (m³)	Domestic	1990	65	87	41	124	38
		2025	65	87	41	124	50
	Industrial	1990	22	60	20	18	0
		2025	36	86	23	36	0
	Agricultural	1990	1004	395	956	302	150
		2025	938	380	642	161	140
	Total	1990	1091	542	1017	444	188
		2025	1039	553	706	321	190
		2025 as % of AWR	93	27	90	32	????

Note: (1) Assuming Current Israeli Military Occupation and control of Palestinian Land and Water Continues
AWR = Available Water Resources
Data Source:World Resources, 1996/1997

2.2 Palestine

Palestine, Palestinian Territory or the Occupied Palestinian Territory (OPT), as mentioned in this paper, consists of the West Bank including East Jerusalem and the Gaza Strip. The West Bank and the Gaza Strip are those parts of Historic Palestine which were occupied by the Israeli army during the 1967 war between Israel and Egypt, Syria, and Jordan. The land area of the West Bank is estimated at 5572 km^2 which extends for about 155 km in length and about 60 km in width. The Gaza Strip has an area of 367 km^2 extending for approximately 41 kilometers in length and approximately 7 to 9 kilometers in width (see Figure 1, Abdel Salam 1990, and Haddad 1998).

Palestinian population expectations reveal that mid year population in 2008 is 4.048 millions, pf whom a number of 2.513 live in the West Bank and 1.535 in the Gaza Strip (PCBS, 2010).

Regardless of the political status, water resources in Palestine is relatively limited due to the country's hydrological, geographical and geological and demographic conditions. Average annual rainfall over historic Palestine was estimated at 409 mm. As listed in Table 2, the estimated average annual ground water recharge in Palestine is 703 mcm/yr (648 mcm/yr in the West Bank and 55 mcm/yr in the Gaza Strip). This groundwater is laying in four major aquifers: the Western, the Northern, North-Eastern and the coastal aquifer basin.

The only surface water source in the West Bank is the Jordan river and its tributaries. In the Johnston plan, the Palestinian share in the Jordan River of 257 was considered as part of the Jordanian share of 774 mcm/yr as the West Bank was under the Jordanian rule. Since 1967 up to now, Palestinians were prohibited by the Israeli army from using the Jordan river water so that lands and farms located along the Western side of the river were confiscated and the area was declared as a restricted security zone (Haddad 1993).

Table 2. Groundwater Balance in Palestine

Hydrologic Parameter	Contribution to Water Balance				
	West Bank		Gaza Strip		Palestine
	%	mcm/yr	%	mcm/yr	mcm/yr
Annual Rainfall	100	2248	100	101	2349
Evapotranspiration	-68	-1529	-52.5	-53	-1582
Surface Runoff	- 3.2	-71	-1.98	-2	-72
Groundwater Recharge	28.8	648	45.5	46	694
Return Flow (RF)	-----	RF	8.9	9	9 + RF
Overall Balance		648 + RF		55	703 + RF

RF = Return Flow Source: Haddad 1993

The other major Palestinian surface water to take into account is the Dead Sea, linked to Lake Tibrias (or the Sea of Galilee) by the Jordan River. While this is not a source of drinking water, it is a major tourist and industry spot as well as an important environmental ecosystem. At 422 meters below the mean sea level, the Dead Sea is already the lowest point on the surface of the Earth (Wikipedia 2010). The mean problem facing the Dead Sea is that its water level drops approximately by one meter annually, leading to the loss of one-third of the sea's original surface area (FOEME, 1999). This decline is expected to continue so that the surface level reaches 430 meters below the sea level by 2020. The cause of this precipitous decline is a reduction in water inflow levels up to 10% of their original volume. This trend is expected to get worse with annual inflows expected to decrease from 375 mcm/yr to 135 mcm/yr in the near future (FOEME, 1999).

Current Water scarcity in Palestine is not natural due to the prolonged Israeli military occupation and control of the Palestinian people, land and natural resources including water. Palestinian People lead several national uprising to counter measure and resist the Israeli military occupation with no success. As a result, at present there is no access and mobility for Palestinians to their water resources. Israelis illegally withdraw about 85% of the Palestinian water, illegally colonize over 42% of the West Bank land area so that Palestinian water supply and use is inefficient, water institutions and infrastructures become poor and cause other negative harmful consequences. High risks facing Palestinian people and natural resources were found due to harmful consequences after Israeli military occupation (Haddad 2011).

According to PWA (2008), the total Palestinian water supply was 308.7 mcm/yr, 73.1% of which is pumped from wells, 8.17% comes from springs and 18.73% through the Israeli company commissioned by Israeli occupation authorities (see Table 3 and 4).

Table 3 Available Water Supply in Palestine by Year and Source

Indicator	2002	2003	2004	2005	2006	2007	2008
Annual Available Water Quantity (million m^3/yr)	279.9	..	295.8	315.2	319.1	335.4	308.7
Annual Pumped Quantity from Groundwater Wells (million m^3/year)	203.4	..	196.1	214.7	223.5	241.2	225.7
Annual Discharge of Springs Water (million m^3/year)	38.1	60.5	52.7	53.6	51.7	44.8	25.2
Annual Quantity of Water Purchased from Israeli Water Company	38.4	43.1	42.6	42.2	43.9	49.4	52.8
Annual Quantity of Water Supply for Domestic Sector (million m^3/year)	125.2	..	142.9	153.2	160.2	175.6	185.5
Annual Quantity of Water Supply for Agricultural Sector (million m^3/year)	154.7	--	152.9	162.0	158.9	159.8	123.2
Percent of Agricultural water to Total Water	55.3	--	51.7	51.4	49.8	47.6	40.0

Data Source: Palestinian Water Authority, 2009. Water Database. Ramallah - Palestine

As shown in Table 3, there is an annual decrease trend from he period 2002 to 2008 in the agricultural water use from 55.3% of total water supplied in the year 2002 to the 40 % in 2008. If this trend continues, agriculture in Palestine will diminish drastically in the next 20 up to 40 years.

The total number of Palestinian water wells in the West Bank was 306 wells, 84% of that was used in agriculture and 16% for domestic purposes (see Table 4). For the Gaza Strip data available indicate domestic wells only (143 wells).

Table 4 Available Water Supply in Palestine by Region and Source, 2008

Region	Water Source			
	Water Purchased from Israeli Company (Mekorot)	**Springs Discharge**	**Water Pumped from Wells**	**Total**
Palestinian Territory	57,726.3	25,237.8	225,695.3	308,659.4
West Bank	52,926.3	25,237.8	66,268.3	144,432.4
Gaza Strip	4,800.0	0	159,427.0	164,227.0

Data Source: PCBS 2008

The expected fresh water gap is estimated for three scenarios: suppressed scenario (continuation of existing political conditions), compromised scenario (limited political solution is reached) and full state scenario (where Palestinians obtain a full State recognition according to the 242 UN resolution). The overall fresh water gaps for the year 2030 range from 263 mcm/yr for the suppressed scenario to 341 mcm/yr for the full state scenario. For the year 2050 the overall fresh water gaps range from 646.6 mcm/yr for the compromise scenario to 1390.3 mcm/yr for the full state scenario (Haddad 2010).

The above expected freshwater gap estimates do not include potential wastewater reuse quantities due to the fact that treatment plants need to be considered in the political agenda for its realization (planning design, construction, operation and maintenance, and conveyance to reuse sites) since it would need large funding and a period of 15-25 year time for construction.

3. Potential Non-Conventional Solutions and Options

The mobilisation of "new and additional" water is technically feasible. However, all regional development options are associated to political implications and a certain interdependence amongst core parties. Several options would also depend on third parties.

3.1. Water imports by Sea

Water importation by the sea involves transportation of fresh water from proposed sources to unloading terminals in the region. Two methods of water transportation by sea were investigated. Those are:

1. transport by tankers, second hand old tankers or new ones.
2. transport by large vinyl bags.

However, water importations by sea require the following:

1. Water diversion systems (intake structure and conveyance) close loading facilities,
2. The process of water loading through a loading terminal,
3. The transportation method: bag or tanker,
4. The water unloading process (unloading terminal),

5. Water storage and conveyance to major demand centers.

The above systems or structures require significant initial investment in addition to running cost (operation and maintenance). Costs will depend on the total amount of water to be imported. There are no serious technical limitations to the construction of loading, unloading terminals or to other diversion structures. However, there are some limitations on possible sizes of bags that can be used for imports.

Transport by Bags

As water is worth much cheaper than crude oil, a different technology might be employed to move it. To reduce the costs of its transport per unit, larger and cheaper containers could be used. As environmental impacts of sea accidents amongst water transporting vehicles are minimal (a fresh water spill is harmless compared to an oil spill), cheaper and less durable transporting facilities could be used, such as large flexible vinyl bags.

The size and shape of the water carrying bags can be flexibly designed to suit diverse situations, taking into consideration such factors as the fabric used, towing costs, annual delivery volumes, and the coastal characteristics of the delivery route itself (Clarke, and Barlow, 2003).

Bags up to 10,000m^3 were tested by the Norwegian Nordic Water Company. Since 2000, the Nordic Company has been using a 19,000 m^3 UV-resistant water bag made of polyester fabric coated on both sides with a polymer mixture, towed by tugboat, used for transporting fresh drinking water from the Turkish port of Antalya to northern Cyprus (Clarke, and Barlow, 2003).

The Alaska Department of Water Resources considered huge seagoing polyethylene bags for the water transport to Southern Nevada and Southern California, Mexico and Pacific Rim countries including South Korea and Japan (Stein 1998).

Although the largest bag developed and tested by Medusa

Corporation was 3,000 m^3, this corporation had much bigger ambitions. Tugs were needed to pull bags involving energy not only for transportation but also for pumping water into and out of bags (Clarke, and Barlow, 2003, Medusa 1990 and Cran 1994).

In the U.K. the Aquarius Water Transportation Co. were the first company which began to commercialized deliveries of fresh water using polyurethane bags towed by tugboats. The company's bag fleet consisted of eight 720-ton and two 2,000-ton water-capacity bags. Aquarius has been delivering water to the Greek Islands since 1997 using water-bag technology (Clarke, and Barlow, 2003, and Horn 1999).

Spragg has been developing a train method whereby up to 50 smaller bags (holding approximately 17,000 cubic meters each) were towed (Clarke, and Barlow, 2003).

Transport by Tankers

In addition to using new tankers it is possible to use old tankers (usually second hand) to transport water. Old tankers could be used to reduce the cost of water transport. Due to the excessive capacity of oil tankers, there is a possibility to convert oil tankers to water tankers. A realistic life span of an oil tanker is about 30 years. However, after the age of 20 and 22 years, solid maintenance programs are needed to preserve new environmental protection laws. Therefore, as tankers become 20 years older, maintenance needs increase while their selling prices go down. Thus, at a reasonable price, it is possible to buy 20-22 years old tankers and convert them to water tankers after coating them with a new lining.

The most important technical concern in using oil tankers to transport water is the tanker cleaning process to guarantee adequate and acceptable water quality. Water transport in tankers could be done at a speed of 14 knots. A significant time is needed for tankers to transport as well as for loading and unloading processes.

In March 2004 Israel and Turkey signed an agreement by which Israel will import 50 mcm/yr of fresh water from Turkey for the next twenty years. The importation cost was estimated to be as the cost of water as 0.70 to 1.0 US$/m^3 which is higher than desalination (Yedioth Ahronoth, 2004, and Friedman, 2004).

3.2. Imports by Land

A large net of conveyance pipelines would be needed to convey fresh water to the region (see Figure 3). This will require agreements between these countries to allow conveyance pipelines passage. However, the cost involved in such a project is greater especially as an initial cost. Net cost was estimated to be as US$ 1.5-2.16 per cubic meter depending on the target demand point (Amman, Tel Aviv or Gaza, GTZ 1996). In addition, royalty fees of water sources as well as the following ones are risky and are influenced by the political stability and international relations within the region. It was estimated that royalty fees of water sources is ranging between 0.25 and 1.5 US$/m^3 (UN 1985).

3.3. Two seas canal

The Dead Sea is located at a height of 400 meters below the sea level. Due to an extensive water diversion from the Jordan River basin and river by Israel and Jordan the amount of water reaching the Dead Sea has declined considerably. Historically, the Jordan River used to deliver 1300 MCM/a to the Dead Sea. As a result of the decline in the amount delivered to the Dead Sea, the elevation of the Dead Sea has declined together with its surface area. It is possible to deliver sea water from the Mediterranean or Red seas to the Dead Sea in order to allow the elevation to go back to its normal elevation. Larger amounts could be delivered to increase its elevation and surface area. After the elevation's drop (400 meters) hydropower would be generated. This hydropower could be used to desalinate water in places close to inland demand centers such as Amman. Net cost of water by such project is estimated as US$ 0.72-1.01 per cubic meter (depending on the scheme and the demand point).

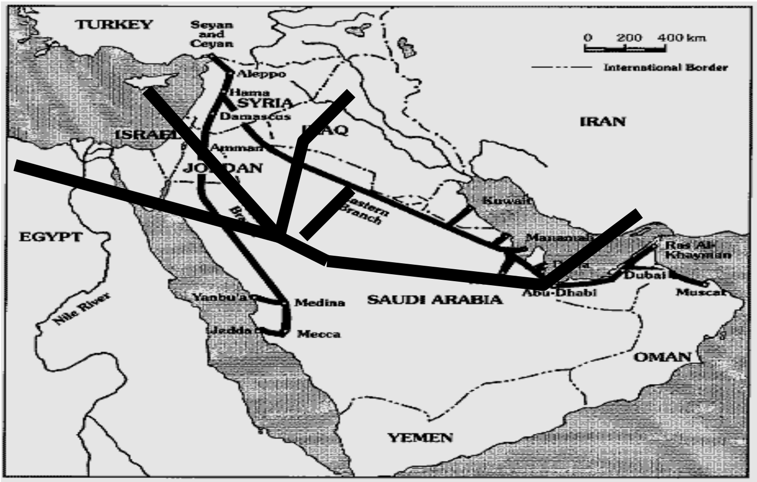

Figure 3 Potential Regional Water Import Schemes by Land and by Sea

There are two main schemes for such a project. The Red-Dead Inter-sea scheme where the Red Sea water will be delivered through a main canal from the Gulf of Aqaba to the Dead Sea. Recently, in the attempt to alleviate the serious water shortage, Jordan took the decision to start implementation studies on this scheme.

The second scheme is the Med-Dead Inter-sea scheme where water will be delivered from the Mediterranean sea through a canal for the first 20 Km and a tunnel for the rest of the alignment (80 Km). Although the distance is much less than that for the other scheme, Israeli estimations costs of this scheme are much higher than the Jordanian ones considered for the Red-Dead scheme.

Despite environmental impacts and economic feasibility, both schemes have high initial costs and require agreements, arrangements and coordination between the three parties involved (Israel, Jordan, and Palestine).

4. Water Desalination

Based on the desalination process, desalination plants can be categorized into two types. The first are changing phase process plants. In these plants, desalination takes place while there is a phase changing, i.e. freezing or evaporation. These include:
i. Multi- Stage Flash (M.S.F.)
ii. Multi- Effect Distillation (M.E.D.)
iii. Vapor Compression (V.C.)
iv. Solar Distillation
v. Freezing

The second type of desalination plants are those which follow a single-phase process. In these plants salt extraction takes place while the solution remains in the liquid phase. These include:
vi. Reverse Osmosis (R.O.)
vii. Electro dialysis (E.D.)

Around the world and on a commercial scale, the MSF and the RO are most widely used for economics. Each type of desalination plant has its own advantages and disadvantages. In general, changing-phase processes are applied for seawater desalination. The mostly used types for brackish water desalination are the membrane processes (RO and ED).

In general, the sea world capacity and brackish water desalination has increased explosively over the last twenty years. The reported increase rate in desalination has been by the 6% per year, approximately doubling the volume of desalinated water every twelve years (Bremere, et. Al., 2001).

Desalination capacity in the ME tripled between 1970 and 1976 and has increased six-folds ever since to around 18 million m^3/d in 1994. Saudi Arabia used to account for 50% of the world capacity according to 1985 figures (Al-Mutaz, 1991). Worldwide, the M.S.F. accounts for 62% of the total capacity. However, other alternatives, notably as reverse osmosis, (RO) have been developed as far as getting the majority of the market.

Costs of desalination processes are a constraining factor. Not only are operation costs higher but there are also high investment costs. The total per cubic meter cost of brackish water was ranging from 0.3 to 1.00 US$ while for sea water desalination the cost range from 0.84 to 1.70 US$.

Recent reports indicated great reductions in sea water desalination capital energy as well as operation and maintenance costs (between 0.61 and 1.55 US$/$m^3$ or in average of 0.70 US$/$m^3$) due to lower interest rates, lower energy consumption and unit price, better more durable cheaper membranes, cheaper equipment and pre-treatment chemicals, larger in size plants, and more efficient plant management approaches such as the Build-Own-Operate or Build-Own-Operate-Transfer systems or combined desalination and energy production plants (Murakami and Musiake 1991, Leitner 1998, Glueckstern and Priel,1998, Semiat, 2000, and Glueckstern 2004).

5. Discussion

The discussion about non conventional water development options, including large water transport projects and desalination of sea and brackish water for an increase in water supply, was conducted in general terms for the ME and in specific for Palestine. As runoff regulation, harvesting and treated wastewater reuse is country specific, what follows is a discussion for Palestine only.

5.1 ME in General

Using a five levels' feasibility evaluation criteria for environmental, political, economic and technical aspects of non conventional water development options, it was found that the highest total score was given to sea desalination and brackish water, followed by water transport by sea using new tankers. The least feasible option was water transport by land (see Table 5, Haddad and Mizyed 2004).

Environmental impact assessments will be important but – except for the intersea schemes – these impacts are expected to depend less on the selected option than on the total volumes supplied.

Water import by land from Turkey as well as from Iraq, to places in the region other than Amman are much more expensive than other options and have considerable political risks. Water import from Lebanon appears to be as the least cost solution. However, there is any confirmation yet regarding the willingness to sell water and it is not clear about how much water could be obtained and for how long. Consequently, the following options deserve further assessment:

- Coast desalination would be least dependent on political and technical preconditions. Economic considerations suggest that desalinated water should, first of all, be used near the coast. Intersea scheme desalination whihc is the cheapest supply option to the inland demand centres. However, uncertainty with respect to environmental impacts of this option is higher than for other options.
- Import by used tankers appears to be competitive with sea water desalination but available capacities of used tankers are probably insufficient and limited in time. Import by new tankers is significantly more expensive.
- Import by sea would be advantageous if very large bags (1,75 MCM) would be developed and become available in terms of expected costs (GTZ 1997, 1998 , Haddad and Lindner 1999, and Haddad and Mizyed 2004).

Levelised discounted water costs for the provision of additional water to the region are estimated to be at least US$ 0.70/m^3 in the coastal areas and at US$ 1.00/m^3 in the mountains. After comparison, current costs for water production and conveyance are about US$ 0.35/m^3 at the level of the coast. These costs have to be added to water treatment and distribution expenses until leading to tariffs of more than US$ 1.00/m^3 at locations where cost covering tariffs are charged. The question is if authorities are generally able and willing to recover considerably higher water costs through appropriate tariffs. This ability will, furthermore, depend on overall future macro-economics and social situations in the core parties' areas. Therefore, cross-subsidisation is generally recognised as a tool for compensating social inequalities, thus, allowing full cost recovery (GTZ 1997, 1998 , Haddad and Lindner 1999, and Haddad and Mizyed 2004).

The mobilisation of the total investment cost, as required for regional projects of non-conventional water development options in the next 40-50 years could prove difficult because of shortage of funding by multilateral donors or by the participation of the private sector.

Table 5 Evaluation of Non-Conventional Water Development Options

Option	Net Cost/m³ US$	Evaluation Criteria				
		Environ mental	Political /Legal	Economi/Fi nancial	Technical/ Tecnological	Total
Import by Land	1.50-2.16	3	1	1	3	8
Import by Sea						
a.New Tankers	0.73-1.36	4	4	3	4	15
b.Old Tankers	0.73-1.36	2	4	2	3	11
c. Bags	1-6	4	4	1	2	10
Desalination						
a. Bracckish	0.3-1.0	4	5	3	5	17
b. Sea	0.84-1.7	4	5	3	5	17
Two Seas Canal	0.72-1.01	3	2	3	3	11

Note: Evaluation Criteria (5) = Excellent/Highly Feasible
Evaluation Criteria (4) = Good/ Feasible
Evaluation Criteria (3) = Average Probability
Evaluation Criteria (2) = Poor/Questionable Feasibility
Evaluation Criteria (1) = Very Poor/In-Feasible

Source: Haddad and Mizyed 2004

Regardless of the above listed developments and advantages, water carrying-bag technology is still in its early development stage and one can not be sure that it would be economically feasible and ecologically and environmentally safe.

Although interest in bulk water exports continues to stimulate international interest, it always provides evidence to be either too expensive and/or politically undesirable.

In addition to water royalty cost (for the option of water transport by land), there is the cost of allowing water to pass through one or more countries before reaching its final destination. Because water will be distributed in accordance with existing infrastructures that would cause potential environmental impacts, some countries might oppose, at least initially, that water would be transferred across their boundaries to other countries. This concern must be satisfied in advance and before any serious planning of any water transfer through the land.

In addition to the above discussion, for any ME regional non-conventional water development option, the following additional important issues should be considered:

Institutional Considerations and Options

the success of any non-conventional water management option requires the application of the best institutional structures and procedures. These structures and procedures should not contradict the local institutional systems of the regional parties involved or their constitutional and legal framework.

Legal and Political Considerations and Impacts

there has been a reluctance to initiate regional non-conventional water development projects due to serious concerns over legal and political aspects such as: what are the priorities between overlying users or sectors owning the project and who has the relative power in the decision making, how should local and regional joint water usage programs be made compatible with local water management operations, who has the right of jurisdiction, authority and ownership over the water resource to be transferred, the abandonment of any historic rivalry for jurisdiction over water resources aspects and areas of origin, etc, etc.

Technical and Hydrologic Considerations

the level of technologies to be used in developing any of the non-conventional water projects are very important and directly related to (1) the project capital and running cost and (2) the sustainability of these projects as a whole.
Modern, appropriate and efficient technologies are essential including those related to infrastructure, planning, design, and management as well as those related to the use such as irrigation technologies.

Socio-Economic Considerations

it was shown that substantial economies might be achieved by organizing and financing water resource development on a regional basis. However, decisions to develop regional non-conventional water resources need to be based on and include socio-economic considerations in addition to other important aspects such as technical, environmental, legal, and others. In meeting sociological feasibility, equity/equality in distribution, water pricing and unification of regions' social agendas should be carefully considered.

Environmental Considerations and Impacts

detailed short, medium and long-term assessment of potential environmental impacts need to be a prerequisite to any non-conventional water development option.

Sustainability

sustainability of supply in terms of quantity and quality as well as in time and space need to be considered. This is especially important for the water import option and it depends on the source of supply and the mode of transportation. However, it is our belief that a better sustainability could be achieved and maintained through a project that serves the region as a whole, and not as a single entity.

Non Conventional and Demand Management Practices and Options

non-conventional water development option should be closely connected and/or integrated with other water demand management options including various water conservation and treated wastewater reuse.

Regionalism

the analysis of local versus regional non-conventional water development option is crucial in as much as peaceful, political and economic stability for the ME and its environment is crucial. In this regard, the international community will benefit from implementing large non-conventional water development projects in the ME where greater investment opportunities will be available.

5.2 Palestine

The following discussion will cover each of the regional and local non-conventional water development options in Palestine. Table 6 shows regional sub-options for mobilization of non-conventional water options.

Water Harvesting and Runoff Management

It was estimated that the urban runoff in the West Bank is about 14.4 mcm/yr (WESC 1996). Urban runoff in the Gaza Strip is increasing significantly due to high population as built up areas increase. It was assumed that 10% of annual rainfall in the Gaza Strip or 10.1 mcm/yr will be harvested. This will bring the potential harvested water in Palestine to 24.5 mcm/yr.

Wastewater Reuse

Treated wastewater available by the year 2050 under the full state scenario range between 375 mcm/yr if only available water was treated and 918 mcm/yr if all water demand was met and collected wastewater was treated. Treated wastewater available by the year 2050 for the compromise scenario, 199 mcm/yr if only available water was treated and 434 mcm/yr if all water demand was met and collected wastewater was treated. Treated wastewater available by the year 2050 for the compromise scenario, 154 mcm/yr if only available water was treated and 488 mcm/yr if all water demand was met and collected wastewater was treated.

As mentioned before, future agricultural expansion in Palestine will be based only on using treated effluent for irrigation. If all water demanded was fulfilled, 70% of the irrigable land area of the West Bank and all that of the Gaza Strip will be irrigated with treated effluent by the year 2050. A treated effluent surplus in the Gaza strip will be available in both cases (if demand is fully met or if only available water is used) and could be used in artificial recharge of local aquifers.

Brackish and Sea Water desalination

Coastal desalination plants at various locations along the Mediterranean coast in the Gaza Strip, with a necessary energy provided by electric power plants (fuelled by coal, oil or atomic energy), could be implemented to fulfill future fresh water gaps either for the Gaza Strip and/or the West Bank.

Water Demand Management Practices

There are several water demand management practices and measures that could be taken or implemented to help bridging the water supply/demand gap including:

- Water use efficiency improvements: such as (a) minimization of existing water leakages and losses in water distribution systems which amount to an average of 42% of total water supply or 77.6 mcm/yr. If 50% of this lost water could be recovered through urban systems rehabilitation this will save 38.8 mcm/yr, (b) optimization of water use in agriculture through farmers support by using modern irrigation techniques and cropping systems, (c) better water conservation programs for urban systems and users, and (d) better regulation and follow-up procedures to control water use and withdrawal.

- Employment of effective water tariff based on cost recovery principles.
- Rehabilitation of water springs and wells and pumping equipments.
- Better public knowledge and understanding of water system problems and deficiencies.

Import of water by land

This option is based on the availability of surplus river water in Turkey (Seyhan and Ceyhan rivers), in Iraq (Euphrates River) and in Lebanon (Litani River). Raw water would be conveyed through a pipeline system (including pumping stations and reservoirs) to Jordan (direct supply of Amman) and to the lower Jordan River to supply Israel, the West Bank and the Gaza Strip with treatment plants at the respective terminal points. In the perspective of specific maximum technical and operational parameters a module size of 150 mcm/yr was adopted in determining the number of parallel pipes and capacities of pumping stations, storage reservoirs and treatment plants (GTZ 1996 and Haddad and Lindner 2001).

Table 6 Regional Sub-Options for Mobilization of Non-Conventional Water

Regional Option	Sub-Option	Module Size (MCM/a)	Delivery Point	Production Unit Water Cost (US$/m³)	Total Unit Water Cost to Demand Centers (US$/m³) Gaza Strip	West Bank
Sea Water Desalination	Single RO Desalination Plant	50	Med Coast	0.68	0.70	0.84
	Med-Dead Inter-sea Scheme	800	Dead Sea	0.42	n.a.	0.72
	Red-Dead Inter-sea Scheme	850	Dead Sea	n.a.	n.a.	0.98
Water Import by Sea[4]	Used Tankers	200	Med Coast	0.83	0.85	0.99
	New Water Tankers	200	Med Coast	1.12	1.14	1.28
Manavgat R.	Large Vinyl Bags	200	Med Coast	0.55	0.57	0.71
Water Import by Land	Pipeline from Turkey Seyhan-Ceyhan Rivers	150	Lower Jordan R	1.44	2.16	n.a.
			Amman	1.65		
		200	Lower Jordan R	1.36	2.13	n.a.
			Amman	1.54		
	Pipeline from Iraq Euphrates River	150	Lower Jordan R	0.94	1.59	n.a.
			Amman	1.13		
	Pipeline from Lebanon Litani River	150	Lower Jordan R	0.15	1.18	n.a.
			Amman	0.68		

MCM/a = million cubic meter per year, n.a. = Not available
Source: GTZ 1996 and Haddad and Lindner 2001

Import of water by sea:

This option is also based on the availability of surplus river water in other countries but in this case the choice is, in principle, open "globally" to all water surplus countries located on any sea coast that are interested in selling water. However, only Turkey has been considered: for one thing, it has already constructed loading terminals on its Southern coast for surplus water from the Manavgat River. Raw water would be shipped by means of large used crude oil tankers (250,000 dwt), new water tankers of the same size or in very large vinyl bags (1.75 mcm), towed from the Manavgat River to unloading terminals at the Mediterranean coast (Gaza Strip and Israel). The module size adopted for this option was 200 mcm/yr (Haddad and Lindner 2001).

6. Concluding Remarks

Meeting future water demands and alleviating water scarcity in the ME countries require the consideration of non-conventional water development options. In the decision making process on a non-conventional water development project and on differences found in terms of levels of economic growth and development amongst the ME countries, several technical, technological, environmental, institutional, administrative, legal, political conditions and policy questions need to be addressed.

Water shortages in each country of the Middle East region can be solved separately and individually by each country of the region. However, in order to meet cheaper costs, enhance peace and stability in the region, guarantee a better quality of life, it is preferable that countries of the region co-operate and work jointly to solve those shortages

Large scale desalination projects could certainly bridge the gap between supply and demand in the ME, nevertheless, the implementation of these projects should be accompanied by a sustainable economic growth.

Sociological feasibility of non-conventional water development options is not enough, the success or failure of any non-conventional water project should also be judged by its technical-engineering and economic feasibility.

Regulating supply and demand can be accomplished with small funding and investment by regulating the domestic pro capita water consumption and shift water use in other sectors so that water goes to places where it is most needed and delivered efficiently and in a beneficial manner.

As far as Palestine is concerned, current water deficits are due to Israeli military occupation which limit as well as control Palestinians' access and mobility to their national waters. In addition, integrating conventional and non-conventional water development options is the best way to bridge future water gaps.

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