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## **REPORT**

# **WATER RESOURCES MANAGEMENT STRATEGIES IN THE MIDDLE EAST (ISRAEL, PALESTINE, JORDAN)**

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## **THE ECONOMIES OF WATER RESOURCES IN THE MIDDLE EAST. PROBLEMS AND SOLUTIONS**

In this lecture we will address the dilemma of solving the water shortage West of the Jordan River. The same points are then articulated for the area East of the Jordan River and for the entire Middle East. Given the significant population growth in the area, it is demonstrated that managing water resources more efficiently and utilizing the price system with less distortion can alleviate part of the gap between expected demand and available supply. However, the significant increase in demand due to population growth requires the creation of new sources of water.

Concerning the area West of the Jordan River, the available supply today is approximately two billion cubic meters per year. The population is already more than eight million people. By 2040, we will have some nineteen million people West of the Jordan River. If we assume that the Palestinian population's per capita water consumption will over time become approximately the same as the Israelis, we can project that the demand will be four billion cubic meters per year, double the available supply.

Some say that the solution to solving the water problem is to dispose of agriculture. We do not think so. While agricultural methods need to change in structure and location, it is evident that agriculture is not the main source of the problem, but rather part of the solution. The rapid increase in urban population is creating a tremendous amount of waste water which might destroy the quality of the water in the Mediterranean aquifer within a decade. Therefore, the first order of business is to invest in the purification of waste water. The outcome of this purification process would produce water to be recycled for agriculture (one billion cubic meters by 2040). Israeli's agriculture would be located mostly in the northern Negev using recycled purified waste and brackish water.

As for urban and industrial use, purified wastewater lacks necessary quality levels. Importing water from Turkey is not the answer. Rather, the solution to the industrial demand for water in the future must be desalination - not only desalination of brackish water, but major desalination of sea water. We will discuss the cost, structure of investment and logistics of desalination, including the necessary investment in research and development.

## **NATURAL WATER RESOURCES OF ISRAEL AND THE WEST BANK. PRESENT AND FUTURE**

The natural water resources of Israel comprise three major groups: Groundwater (63%), Lake Kinneret basin (33%) and other surface water (4%).

Most of the resources are completely exploited or have been overexploited for some decades. The assessments of replenishment and future yields are deducted from water balances based on records.

The groundwater resources are utilized by about 2,600 pumping wells. Springs which are also considered groundwater comprise a great part of the Kinneret water sources (the Jordan springs). Most of the groundwater is of potable quality but the salinity range of the pumped water is wide: 80% of the pumped water have a salinity below 250 ppm Cl<sup>-</sup>, 11% have salinities of 250-400 ppm Cl<sup>-</sup> and for 9% salinity exceeds 400 ppm Cl<sup>-</sup>.

The widespread and intensive exploitation of the various aquifers all over the country and the interlinkage of the three main basins (Lake Kinneret, Yarkon-Taninim-Beer Sheva and Coastal Plain basins) by the National Water Carrier allows for the national water supply system great operational flexibility: Short-term (seasonal) and long-term storage capacity, large scale interregional conveyance capabilities and flexibility in overcoming local failures of the water supply systems.

The groundwater resources of Israel belong to three major aquifer groups:

### **1. Upper Clastic Aquifer Group:**

Built mainly of sand, sandstone and conglomerates, including also the Basaltic aquifers of the northern part of the country. The aquifers are of Neogene-Pleistocene age. Their major occurrence is in the coastal plain, the inner valleys and the Jordan rift valley and its margins.

### **2. Middle Carbonaceous Aquifer Group**

Built mainly of limestone and dolomite of Cretaceous to Tertiary age. Their main occurrence is on the anticlinal ranges of the Syrian arc: Judea, Samaria, Galilee and the Negev highland mountains and their margins.

### **3. Lower Clastic Aquifer:**

Built mainly of sandstone ("Nubian Sandstone Aquifer") of Lower Cretaceous to Paleozoic age. Its major occurrences are in the Negev and the Arava.

The Upper Clastic and Middle Carbonaceous aquifers receive natural replenishment from rain on their outcrops and are generally of good (fresh) water quality whereas the Lower Clastic aquifers receive only a negligible natural replenishment and are considered as mined aquifers.

The various aquifers are distributed over the country in a number of major groundwater basins as follows:

1. Western Galilee basins
2. Kinneret basin-West
3. Hermon and Golan basins
4. Gilboa-Beit Shean basins
5. Carmel basins
6. Beer Sheva-Yarkon-Taninim basin (Yartan)
7. Eastern basins

8. Coastal plain basins
9. Negev basins
10. Arava basins
11. Other.

Lake Kinneret is the single natural surface reservoir of Israel and is one of the three basins constituting the national water supply system connected through the National Water Carrier.

The lake's utilizable yield, on the basis of mean annual flows, is estimated at 620 MCM/year.

The total average annual amount of floodwater to the Mediterranean sea that normally appears in the water balance is about 150 MCM/year. In addition, there are about 8-15 MCM/year of floodwater that drains into the Lower Jordan Valley, south of Lake Kinneret, and about 10-12 MCM/year of floodwater that drains to the Arava Valley.

The annual fluctuations of the flood runoff are typically very high. In rainy years, the runoff reaches hundreds of MCM/years, whereas in dry years, most of wadis are dry. Even in wet years, the flow period is very short, generally a few days. The total exploitable potential of flood runoff, excluding the Upper Jordan Valley, Lake Kinneret and the Yarmouk river, adds up to 100-120 MCM/year.

#### Natural Water Resources (MCM/year)

	Basin	Planned Exploitation
Groundwater	Western Galilee	120
	Kinneret-West	45
	Golan H. & Hermon	incl. in Kinneret
	Gilboa-Beit Shean	145
	Carmel	30
	Yarkon-Taninim	362
	Eastern Basins	172
	Coastal Plain	240
	Negev	70
	Arava	40
	Others	20
	<b>Total Groundwater</b>	<b>1,244</b>
Kinneret Basin	Upper Jordan	
	Groundwater	
	Surface Runoff	
	Net Evaporation	
	Spills and Saltwater	
	<b>Total Kinneret</b>	<b>620</b>
	Yarmouk river *	25
	<b>Total Jordan Basins</b>	<b>645</b>
<b>Surface Runoff</b>		<b>80</b>
<b>Total Natural Water</b>		<b>1,969</b>

\* As cited in the Jordan-Israel Peace Treaty

## MANAGING SCARCE WATER RESOURCES. THE ISRAELI EXPERIENCE

This paper will focus on demand management (also termed water conservation, water saving strategies or the programme for increased efficient of water use). The policy of Israel to meet the growing demand for water focuses on supply and demand activities and investment. The long range solution lies with sea-water desalination. All other activities are aimed at delaying the high investments and the associated costs involved with this expensive process.

### *1. Re-use of sewage effluents.*

Recent regulations have increased the quality of sewage treatment in order to maximize its use and minimize the health and environmental risks as well as enhance the trading instruments for the exchange of fresh water allocations, with treated effluents mainly for irrigation.

### *2. Water conservation improved efficiency of water use*

Policies and achievements concentrate on mixed instruments including:

- (a) allocations, norms and progressive block rates for each sector, and
- (b) research, development and the implementation of agronomic techniques as well as technological means to improve water use efficiency and reduce water consumption in the home, office, industry and parks.

### *3. Sectoral water allocations*

Recently major changes in the approach towards the allocation system have been initiated, including elimination of urban allocations, imposing sanctions of unaccounted water use rises above approved levels and the possible introduction of 'water market' trading with allocations on an economic basis. Out of approximately 600 MCM/year being supplied to the urban and industrial sectors in Israel, it is possible and feasible to reduce the water demand by 15-20 per cent. It is assumed that if the proper programme is implemented 80-120 MCM of water per year can be saved. It can delay a future sea water desalination plant (at an estimated investment cost of approximately US\$ 400 million) and will save present running costs (energy, chemicals etc.) of approximately US\$ 0.15-0.20/m<sup>3</sup>.

Since most of the incremental demand growth will be concentrated in the urban/industrial sector, a comprehensive demand management policy should become a major component of the regional water policy. In the year 2020, when the population West of the River Jordan will rise to over 12 million, the potential savings would amount to approximately 200 MCM/year and if multiplied by present sea-water desalination costs it may reach a saving of US\$ 200 million per year. This huge sum of money could be used for indefinite coverage of water conservation and effluent re-use projects throughout the region.

Increasing efficiency of water use in agriculture could by itself generate substantial increase in production per unit of water (of effluent) and/or absolute savings. It is estimated that the cost per cubic metre of water saved (or its comparable value in production) will be, based on Israeli experience, approximately 10-15 US cents which is much lower than the forecast marginal cost of additional water in Israel.

## **WATER RESOURCES DEVELOPMENT IN ISRAEL**

Water demand in Israel and adjacent territories is expected to increase, and the ensuing development gap between existing resources and forecast demand will call for mobilization of additional resources.

Part of this development gap can be closed by additional exploitation of natural water resources and reclaimed sewage. By and large, natural water resources are overexploited, and no substantial increase in their availability may be expected. An exception are floodwater sources, which have not yet been exploited to their feasible limit. Use of reclaimed sewage is expected to grow substantially as a result of higher water supply to the domestic and industrial sectors and increased re-use applications.

Development of the natural and reclaimed water calls for financial resources whose availability is not certain. In addition, solutions must be found to complex engineering problems resulting from competing land uses, and public health and environmental requirements. Such developments are nevertheless taken into consideration in assessing the extent of the water resources development gap.

The gap remaining after full development of the above resources would be closed only by utilization of unconventional sources, namely, sea water desalination or import of water from abroad.

The future increase in water supply may therefor be achieved by increasing:

- Reuse of sewage effluents
- Use of marginal floodwater and saline sources
- Seawater desalination
- Import of water
- Reduction of losses by improving water resources management.

The ultimate answer to water problems in Israel in particular, and in the Middle East in general, is large-scale desalination of seawater. However, for economic reasons, needs for the near future should be met by development of marginal resources, such as re-use of wastewater and floodwater utilization.

## **CLOUD SEEDING FOR RAIN ENHANCEMENT- A POTENTIAL SOURCE IN WATER MANAGEMENT**

Cloud seeding for rain enhancement, from the water management point of view, could be the most cost effective method to increase water resources. It was estimated that the cost of obtaining water by enhancing rainfall could be as low as \$0.05 per m<sup>3</sup>. The advantage of

cloud seeding is not only in the direct increase in water resources, but also in saving energy for irrigation, in wide distribution of water, in increasing snow pack and more.

Unfortunately, most rain enhancement projects around the world are operational in nature, from which no data is collected about the actual amounts of rain increase. To make things worse, many of the experiments of rain enhancement around the world have been terminated due to funding problems or for lack of clear positive results. There are a few experiments in which positive results are reported, but they are mostly based only on statistical evaluation. The physical reason behind the success or failure are not yet clear.

Modern research tools such as fast computers, better numerical models and new instruments for in site and remote measurements, make it possible now to better study the processes that lead to rain formation.

In the review lecture, some of the deficiencies of the existing methods of cloud seeding with ice forming nuclei, such as silver iodide, will be described. A new, but still experimental, potentially more effective method for rain enhancement using hygroscopic particles will also be discussed.

### **WASTEWATER TREATMENT AND GROUNDWATER RECHARGE FOR REUSE IN AGRICULTURE. DAN REGION RECLAMATION PROJECT AND THE THIRD LINE**

The Dan Region Project is the largest wastewater reclamation project in Israel. The wastewater from the Greater Tel Aviv metropolitan area (220 sq. Km., 1.3 million inhabitants) is biologically treated, most of it (85%) in an extended aeration activated sludge treatment plant, and some of it (15%) in recycled oxidation ponds. On average 280,000m<sup>3</sup> are treated every day. The effluent is then further treated through recharge into the aquifer and subsequent recovery using a special soil-aquifer treatment (SAT) developed at the Dan Region Project. The SAT adds to purification of the effluents by processes of slow sand filtration, chemical precipitation, adsorption, ion exchange, biological degradation, nitrification and de-nitrification. In addition to the water quality improvement, SAT constitutes a seasonal and multi-annual water storage system. Water recovered after soil aquifer treatment is of extremely high quality, and can be used for unlimited agricultural irrigation. In 1995, a total of some 80 million m<sup>3</sup> were recharged and recovered in the Dan Region Reclamation Project.

The influent wastewater collected from the Dan region is mostly household sewage. Typical wastewater parameters are an average BOD of ~400 mg/l (COD of 840 mg/l), suspended solids ~400 mg/l, and ~40 mg/l of ammonia. After the activated sludge treatment suspended solids are reduced by 95% to 19 mg/l, BOD is reduced to 22 mg/l (95%), and ammonia is reduced by 70% to 11 mg/l. The oxidation pond effluents are of lower quality, typical values being suspended solids concentrations of 180 mg/l, BOD of 100 mg/l, and ammonia levels of 19 mg/l.

Effluent quality is further improved through SAT. Soil aquifer treatment consists of intermittent flooding and drying of recharge basins with the treated effluents, so that each of the basins is flooded for one day and then left to dry for 3-4 days. Hydraulic loads vary between 80-180 m/year, depending on the infiltration capacity of the basins. The recharged water is recovered through a ring of recovery wells which surround each infiltration basin, at a radial distance of 500-1500 meters from the basins. Observation wells between the infiltration basins and the recovery wells supply information on the recharged water quality. Typical parameters for water following SAT are suspended solids concentrations of less than 1 mg/l (>99% removal), BOD of <0.5 mg/l (>99% removal), and ammonia levels of 0.3-0.8 mg/l (95-98% removal). Trace elements and microbial parameters after SAT are also all well within the requirements for unlimited agricultural use.

The reclaimed water is collected and transported some 80 km. south, to the Northern Negev. This is done through a 70 inch line (which tapers to 48" towards the south) constructed especially for this purpose, and 6 open reservoirs that regulate the flow. At a number of points along the way it is possible to add potable water, in order to increase water quantities supplied. Water in the reservoirs is regularly treated biologically and chemically in order to prevent the development of algae and other microorganisms. In 1995, 130 MCM (million cubic meters) were supplied to the Negev, 109.6 MCM of which were reclaimed treated effluent.

## **THE WATER ECONOMY AT A CROSSROAD**

The water economy of Israel is facing difficult choices. In the future, if demographic trends continue, it will not be possible to provide for expected growth of urban consumption, both in Israel and the Palestinian entities, from conventional supplies. It seems now that seawater desalination will be the principal solution. If agriculture can be made to release potable water - now used for irrigation - expensive desalination can be postponed and significant resources saved. A policy of diversion of water from agriculture to alternative uses implies a change in the basic structure of the water economy. Among other measures, the reform should include charges for water in their resources (shadow prices), differential prices by location and perhaps also season, identical prices to different users, and effective control of natural monopolies. Increased utilization of reclaimed sewage will require rationalization also of this sector of the water economy.

## **SHORT AND LONG TERM DESALINATION OPTIONS FOR ENHANCEMENT AND QUALITY IMPROVEMENT OF WATER SUPPLY**

For some decades desalination of seawater - and more recently - of brackish water, has been a solution to water problems in various areas in the world, and especially in the Middle East. Desalination can now be considered a mature and reliable technology. The prevention of its wide-spread use is in many cases related to economics.



The cost difference between desalination of brackish and other low salinity sources, and seawater is in the range of 1 to 4. The comparative cost of seawater is also much dependent on site specific conditions. Local conditions, such as energy availability and cost, type of raw-water and other site specific and macro-economic factors, strongly affect the preferred alternative regarding the desalination system process and technology. The aim of this presentation is to review and discuss the short and long term desalination options to ease the severe water shortage of Israel, Jordan and the Palestinians.

Available brackish water sources, especially at inland locations, should be fully exploited before large scale seawater desalination plants are put into operation. However because of the limited brackish sources, medium size (10 Mm<sup>3</sup>/year) seawater desalination plants will be needed, especially for water supply to large urban centers located on the sea shore. For this capacity range and for the prevailing conditions, the dominant technology is Reverse Osmosis and in some cases hybrid Multi-Effect Distillation/Reverse Osmosis (MED/SWRO) coupled to Diesel power stations.

For long-term applications and large scale desalination in the next decade and onwards, a variety of additional options, will probably evolve. Large advanced SWRO and hybrid MED/SWRO will most probably be the preferred system for sea shore plants, while large hydrostatic SWRO systems in conjunction with an inter-sea canal connecting the Red Sea with the Dead Sea, may eventually be the adequate means to supply desalted water to Jordan, to the Hebron Hights and to the Eastern Negev. Another interesting option, pending on further progress in solar technology, is large scale solar desalination on both sides of the Red-Dead canal.

### **CONSIDERATIONS GOVERNING THE SELECTION AND DESIGN OF OPTIMAL SEAWATER DESALINATION PLANTS FOR INTEGRATION WITHIN CONVENTIONAL REGIONAL WATER SUPPLY SYSTEMS**

The region east and west of Jordan River relies today on ground and surface water supply systems. Sooner or later, when demand exceeds these conventional water sources and the limited quantities of other, less costly, marginal sources, e.g. desalinated brackish waters, seawater desalination, on a large, regional scale, will have to be adopted.

Even with the most efficient and cost-effective plant sizes and designs, desalinated seawater will always represent a water supply sources significantly more expensive than average system unit water costs. On the other hand, this water will also most likely be the highest quality water in the system, with lowest levels of hardness, organic and non-organic contaminants, bacteria, pathogens, etc. If desired, also overall product salinity can be minimal, with important benefits for reclaimed sewage re-use for irrigation.

Integrating and applying this new water source properly and wisely within the existing water supply system, including the choice of plant sizes, installation schedule, siting, design and operating regimes, water quality improvement, etc., requires, therefore, meticulous planning. The most urgent issue is reserving suitable plant sites.

The Israel Water Commission has already commenced planning for such integration of future seawater desalination plants. This planning involves identifying and considering alternative scenarios for rates of growth of water supply shortage, urban areas where particularly high growth in demand is anticipated, existing water distribution system and storage capacities and projected requirements for new investments therein, the current and future water supply quality map, etc. Studies are being conducted also on seawater quality (contamination levels) and intake system requirements at various potential plant sites, and on the optimal seawater desalination technologies, energy sources, plant schemes, including hybrid and water and power cogeneration, product quality, and operating regimes.

### **SOLUTIONS TO THE WATER SCARCITY IN THE MIDDLE EAST**

It is easy to write a check list of all possible means that can improve the water situation in the Middle East, but a thorough check list cannot be a proposal for a policy.

The most important group of means is to lean using the water efficiently. A proof for that is the fact that one country has high agricultural production and exports based on water sources of less than 400m<sup>3</sup> per capital per year, and another country suffers of water shortage with 2000m<sup>3</sup> per capita per year.

Improved water use efficiency calls for the most difficult technical, educational and organizational changes. However, it is a prerequisite to any large scale water source development because otherwise the specific cost in the new developments is going to be prohibitive.

Following a more rational water management, avoiding waste, recycling and reduction in the water salinity, the Middle East must revert to the production of water by desalination.

There are several technological and economical niches for water desalination where the cost of marginally added water is low, so low that advanced agriculture can afford it.

A major effort must be made in order to develop new desalination technologies. One such technology has been matured in Israel and it is called "Energy Towers". Preparations are made for the construction of a large pilot plant and the design of a commercial station.

The "Energy Towers" is a proven technology to produce electricity from renewable solar sources. The energy is completely free of pollution. The projected cost is less than the electricity produced from natural gas. It has been proven that in association with "Energy Towers" it is possible to desalinate water in very large quantities and at less than half the investment, and nearly half the energy.

The "Energy Towers" technology uses hot and dry air that is found in great bounty in the Middle East and also sea water.

Israel is looking for cooperation with its neighbors in applying this novel technology that may turn the predicament of the deserts, their dry and hot air into their asset. It will serve also as a breakthrough in the attempt to mitigate warming and dwelling water sources.