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REPORT
OF THE JAPANESE
BRACKISH GROUNDWATER DESALINATION
STUDY TEAM

April 27, 1993

Brackish Groundwater Desalination in Jordan

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(Summary)

Complying with the consensus request at the second meeting of the Water Resources Working Group, in September 1992, Japan dispatched a Study team to Jordan in January 1993 to ascertain the prospects for brackish ground water disalination.

In Jordan, more than half the water supply is abstracted from underground fresh aquifers, but, brackish water aquifers, which are also abundant, have not been fully utilized. Desalination of such brackish ground water, therefore, would be a very promising method to augment the total water supply.

As the desalination process best suited to the local context, the team recommended that Reverse Osmosis is generally preferable to Electrodialysis, from the energy-efficiency point of view, but that process selection for each plant should be site-specific and carefully investigated on a case-by-case basis.

The team found that when identifying suitable locations for desalination plants in Jordan, (1) raw water availability, (2) disposal of brine (the rejected water from the desalination process) and (3) conveyance of the processed water need to be fully studied. As the Jordanian side suggested the Azraq shallow aquifer and Wadi Sir aquifer, Sukneh (Kurnub Sandstone aquifer),

Hisban and Kaffrein (Zarqa Group), Karameh and Abu Zeigan (Zarga group), Zarqa-main and Zara springs, Karameh and Deir Alla (Alluvial Deposit) as possible sites for plants, the team surveyed those areas to evaluate their suitability as desalination sites, in the light of those factors.

Azraq shallow aquifer, Wadi Sir Aquifer

The ground water south of Azraq is brackish and total deposits have been found to be large enough. However, abstraction might accelerate the shrinkage of the Azraq swamp, which is designated as a sanctuary for migrating birds in the Ramsar Convention. The possible effects on water quality fluctuation and on present fresh-water abstraction are still unclear, and these factors should be the subjects of further study before full-scale abstraction of water from brackish water aquifers is undertaken.

With respect to the Wadi Sir Aquifer, a study of its potential is now underway, funded by EC, and more precise data should soon be available.

The largest problem of desalination there would be disposal of brine, since this site is not close to the Dead Sea and a brine disposal facility would have to be constructed. A new conveyance system would also be needed to convey the processed water to the areas where it would be used.

Sukneh (Kurnub Sandstone aquifer)

Three borehole drilling and pumping tests have so far been made in this area, and the results are very encouraging, but, more detailed study is needed to establish its long-term raw water reliability. Brine disposal would be a serious problem, as the only possible way, transporting it by tanker lorry all the way to the Dead Sea, which would be very costly. On the other hand, as it is situated very close to the Amman-Zarqa Metropolitan area, conveyance of the processed water would not be difficult.

Hisban and Kaffrein (Zarqa Group)

According to the UNDP survey (1991) the raw water yield in this area is estimated to be very reliable, and, as it is located close to the Dead Sea, disposal of brine could be achieved by draining it into there. When conveying the processed water to the Amman area, it would be possible to use the Deir Alla conveyance system, which still has unutilized capacity.

Karameh and Abu Zeigan area (Zarqa Group)

The data for this area are not sufficient to establish the long-term availability of raw water, but borehole testings show results promising enough to justify further study. Situated close to the Jordan Valey, and the Deir Alla conveyance system, brine disposal and conveyance of the desalinated water would not be difficult.

Zarqa-Main and Zara Springs

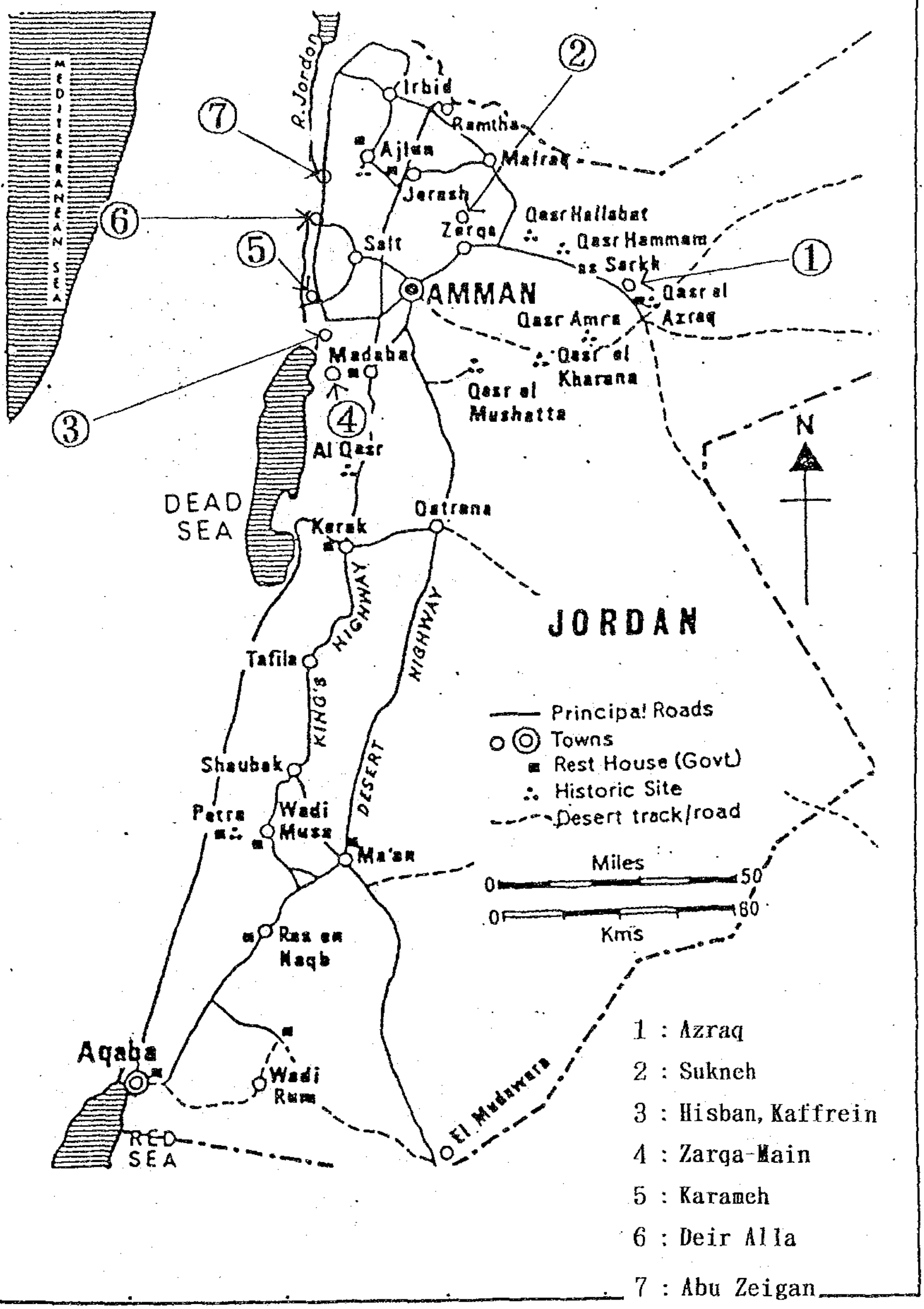
The amount of springflows has already been found to be sufficient, but the raw water in this area is thermal and contains dissolved gases. As springs are widely dispersed, a number of intake facilities would be necessary to collect springwater. Since they are located in the Wadi Zarqa main, flash flood-protection facilities would also be required for plants. Being situated 50 Km southwest of Amman, a pipeline and pumping system would be also required.

Karameh and Deir Alla (Alluvial Deposit)

The yield in this area has been relatively small, and there is a probability that the aquifer, which is situated directly beneath an area where there is considerable agricultural activity, may be contaminated with pesticides.

However, brine disposal and conveyance of processed water would not be problems, as the brine could be disposed of by draining to the Jordan river, and the Deir Alla conveyance system could readily be used.

In the light of the Study Mission's findings, Japan plans to carry out further studies at some of those six sites surveyed.


MEDITERRANEAN SEA
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Azraq
AMMAN
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Mushatta
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Musa
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Ras en
Naqb
Aqaba
Wadi
Rum
El Mudawara
RED
SEA
Principal Roads
Towns
Rest House (Govt.)
Historic Site
Desert track/road
Miles
0
50
0
80
Kms
1 : Azraq
2 : Sukneh
3 : Hisban, Kaffrein
4 : Zarqa-Main
5 : Karameh
6 : Deir Alla
7 : Abu Zeigan

3. Introduction

At the second meeting of the Water Resources Working Group, in Washington DC, in September 1992, it was agreed that the EC and Japan would prepare a report evaluating the available information with a view to assessing prospects for building pilot plants for the desalination of brackish water. In accordance with that Washington consensus, and following coordination with the EC and the US, the gavel-holder of the Working Group, the Government of Japan, dispatched, from January 11 to 19, a brackish ground water development study team to the Hashemite Kingdom of Jordan.

The Study Team had a series of discussions with Dr. Ziad Fariz, Minister of Planning, Dr. Samir Kawar, Minister of Water and Irrigation and other relevant Jordanian government authorities regarding the prospects for brackish groundwater desalination, and gathered quantitative data on groundwater potential, probable salinity levels and the propects for desalination. The mission also carried out field surveys of potential sites for desalination pilot plants. On Feb. 7, based upon the finding of this mission, a follow-on meeting with Water and Irrigation Minister Kawar was held by Mr. Yoshiji Nogami, Depuby Director General of the Middle Eastern and African Bureau, Ministry of Foreign Affairs.

4. The Water Supply-and-Demand Situation in Jordan, and the Significance of Brackish Water Desalination

The present water supply-and-demand situation in Jordan is clearly very much out of balance, with shortage of water already a serious problem. For example, annual water demand for municipal purposes in 1990 was 226 millions m^3 (MCM), whereas supply was only 180 MCM, a shortfall of as much as 46 MCM.

Subterranean water is the main source of water in Jordan, more than half of the nation's water being abstracted from underground fresh water aquifers (note 1). However, water from many of the aquifers is brackish and, thus, has not to date been fully utilized for water supply. If such brackish water were to be be desalinated, those underground deposits could be promising new sources of water, which could help to augment the supply of water in Jordan (note 2).

5. Selection of Desalination Process

(1) The quality of the brackish water should be thoroughly analyzed, as this has an important bearing on selection of the desalination process to be adopted, Reverse Osmosis (RO) or Electrodialysis (ED) (note 3).

(2) The establishment of an effective brackish water desalination project depends on many factors, with energy being of particular importance, especially for Jordan, which relies mainly on imported oil for its energy. In most of the country's existing desalination plants, energy accounts for between 15 and 40 percent of total annual costs and between 15 and 85 percent of daily operating and maintenance costs, with energy costs varying, depending on such factors as a plant's size, energy source, temperature and salinity levels of the raw and treated water and site location.

The RO method is generally accepted as being more energy-efficient than other processes, but the choice of process for each plant should be very site-specific, with careful investigation of all the circumstances and features peculiar to each case.

(3) Whichever method is eventually selected, availability of trained personnel of the technician level for operation and maintenance is extremely important. Training of such staff is urgently needed, if desalination is to be carried out to improve water supply in Jordan.

6. Plant Site Location (Factors Affecting Selection of Plant Site)

The factors affecting the choice of site for desalination with a view to enhancing water supply in the long term and avoiding any adverse impact on the environment include the following:

(1) Raw water availability (reliability of yield)

The quantity and quality of a brackish water source can change daily and seasonally, and the degree of variation is important in the selection of a site and design of a facility, and for successful long-term operation.

(2) Brine disposal method

After desalination, between ten and fifty percent of the brackish water will be left as brine, water with a high TDS (Total Desolved Solids) level, i.e. with a salt content considerably higher than that of the original feed water. This brine is generally too saline to be of use in agriculture or industry, and may contaminate surface and ground water.

No desalination project should, therefore, proceed without a solution to this problem first being found. If plants are constructed by the Dead Sea or by the Jordan river, brine can be discharged into the Dead Sea (note 4), but in the case of inland projects, brine disposal facilities adequate for long-term desalination operation would have to be built. The solutions suggested are the following:

(a) Evaporation in solar ponds

This is a simple process, but a considerable area of land would be required for the ponds. As such a pond has to be sited at a safe distance from the plant, a brine conveyance system is also necessary. When strong wind occurs (which is very frequent in Jordan), it is to be feared that the precipitated salt will be swept up with the sand and other fine particles.

(b) Use of injection wells to dispose of brine in highly permeable zones which are not in use

Since this method may result in contamination of other aquifers, thorough hydrogeological study is required in order to avoid any negative effects on the surrounding zones and areas.

(3) <u>Conveyance of desalinated brackish water</u>

The existence of, or need to construct, a conveyance system could be an important factor, if a desalination plant is to be built inland. When assessing the cost of a desalination plant, therefore, the cost of both boring wells and constructing a conveyance system may have to be considered.

Especially, if a desalination plant is to be sited in the Jordan Valley area, which is abundant in brackish water aquifers and much lower in altitude than Amman, a high-pressure pumping station and long-distance piping system will be needed to pump and pipe the processed water up to Amman.

7. Possible Sites for Desalination Plants to Increase the Water Supply

Fifty-seven percent of the country's total population lives in the Amman-Zarqa area, where shortage of water has become an urgent problem, owing to the increasing population and water consumption (note 5). In order to increase the supply of water to this area, the Government of Jordan has suggested the following six sites as possible sites for desalination plants: Azraq shallow aquifer and Wadi Sir aquifer, Sukneh (Kurnub Sandstone aquifer), Hisban and Kaffrein (Zarqa Group), Karameh and Abu Zeigan (Zarqa Group), Zarqa-Main and Zara Springs, Krameh and Deir Alla (Alluvial Deposit) (note 6).

Following discussions with the Jordanian authorities, the Mission carried out field surveys at the six sites on January 14 to 15, and compared the advantages and disadvantages of each in the light of the above-mentioned factors affecting site selection.

(1) Azraq shallow aquifer and Wadi Sir aquifer

(a) Azraq shallow Aquifer

The Azraq shallow aquifer, which is known as the Basalt-Rijam, is a freshwater (300-600mg/l, TDS) aquifer situated to the north of Azraq. The water levels of this aquifer are between 6 and 40m bgl at Azraq, but the water table is at ground level south of Azraq, forming the Azraq swamp. The ground water to the south and east of Azraq is brackish (1000-5000 mg/1) (CF. Bibliography 11). The interface between fresh and brackish water is clear (cf. Bibliography 17), although the salinity distribution is rather complex.

The total recharge to the aquifer system is estimated to be 34 MCM/yr, but of this, 10 MCM/yr is estimated to drain out to other tributaries. It is, therefore, necessary to limit both municipal and private abstraction to keep the amount (which also includes springflows and seepage to the Azraq swamp) within the limit of 24 MCM/yr in order to maintain underground water storage levels (Note 7). The pumping of water from the fresh water aquifer is carried out at well fields located about 4km north of Azraq (in 1991, at a rate of 18 MCM), which has caused a rapid reduction in springflows, from 13 MCM in 1981 to 0.9 MCM in 1990 (cf. Bibliography 11, 12), and, consequently, in the size of the Azraq swamp.

The abstraction of brackish water will certainly accelerate the shrinking of the Azraq swamp, which is designated as a sanctuary for migratory birds in the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).

Since the salination mechanism of the aquifer has not been fully investigated, the possible effects of abstracting brackish water on water quality fluctuation are not certain. The effects on abstraction of fresh water from the present sources, in terms of both water quality and quantity, are also not clear. These matters should be the subject of further study.

(b) Amman Wadi Sir Aquifer

The Amman Wadi Sir Aquifer occurs at depths of between 300 and 800 b.g.l. Although the average water level of this aquifer is about 90 b.g.l., it is artesian at Azraq. The water quality of this aquifer ranges from 800 to 2500mg/1 in general (cf. Bibliography 11, 14).

Study of the ground water potential of the Wadi Sir aquifer and of the deeper aquifers is in progress, funded by EC, and more precise data will be available when that study has been completed.

(c) Disposal of brine and conveyance

Disposal of the rejected water discharged from a desalination plant and the system for conveying it to the places where it will be used will also be of great importance. Since this site is not close to the Dead Sea, a brine disposal facility would have to be constructed. One feasible option would be to construct a perfectly sealed evaporation pond somewhere in the desert nearby. A new conveyence system would also be needed to convey the processed water, as the existing pipeline system is already used at full capacity.

(2) <u>Sukneh (Kurnub Sandstone Aquifer)</u>

Three borehole drilling and pumping tests have so far been made in the Sukhneh-Zerqa area. The aquifer, partially confined, is about 350 to 500m b.g.l. and its thickness is about 200 to 300m. The analysis of water quality shows TDS of 2300mg/1, but more detailed study is needed in order to evaluate the ground water potential of this aquifer, although the results of the initial pumping tests are encouraging.

A serious problem is that there would be no way to dispose of brine in this area. The only possibility is transporting it all the way to the Dead Sea by tanker lorries, which would be very costly. On the other hand, conveying the processed water to Amman is less problematic, as the area is located close to the Amman-Zerqa metropolitan area.

(3) Hisban and Kaffrein (Zarqa Group)

Twelve boreholes have been made in this area by the Jordan Valley Authority. According to the Charalambous Report, UNDP/DTCD project, most of the boreholes are artesian and two wells in Hisban exhibited an initial artesian flow of more than 500 1/s. The thickness of the aquifer ranges from 107 to 180m and its groundwater quality varies from 3000 to 4600 mg/1. The Charalambous Report concludes that, in the light of present knowledge, an abstraction rate of 8 MCM/yr is possible for 20 years, and more detailed study may establish that a yield of as much as 25 MCM/yr could be saft. (cf. Bibliography 17)

Brine could be disposed by draining it into the Dead Sea through the existing river channels, although there would have to be careful monitoring of the effects in order to avoid probable saline contamination of the local shallow aquifer. On the other hand, the area is located only about 35km south of the existing water-conveyence system at Deir Alla. The capacity of the Deir Alla conveyence system is 45 MCM/yr, while the present operating load is, at most, in the region of 10 MCM/yr, thus, giving enough spare capacity for the processed water. However, due consideration would have to be given to the need to avoid processed water from the plant being mixed with the water that is now conveyed through the system, which is raw water from the Yarmuk River.

(4) Karameh and Abu Zeigan area (Zarqa Group)

Although little information about the Zarqa aquifer in this area is available, sporadic borehole data show results promising enough to justify further study. The average yield of wells is 100 l/hr, with salinity ranging between 3000 and 6000 mg/l.

Disposal of brine can be achieved by draining it into the Jordan River, provided that the salinity of water of the River would not be increased. As for conveying the processed water, the Deir Alla system is located almost in the middle of the area. (cf. Bibliography 29)

(5) Zarqa-Main and Zara Springs

There are 64 springs and seepages in the Zarqa Main area. The total average discharge amounts to about 17

MCM/yr. The salinity range of spring water is rather small, from 800 to 1400 ppm. However, it contains dissolved gases, such as carbon dioxide (3 to 36 mg/l) and hydrogen sulphide (0.08 to 12 mg/l). The Zarqa Main springs are thermal, with temperatures ranging from 34 to 63C (cf. Bibliography 11).

In the Zarqa area, 4km southwest of Zarqa Main, 42 springs and seepages are identified and their total discharge is, on average, about 9 MCM/yr. Springs in Zarqa are thermal (with temperatures ranging from 33 to 60C) and have a rather low salinity, of 1000 to 1400 mg/l (cf. Bibliography 17).

As these springs are widely scattered, a number of intake facilities at different altitudes and several separate pipeline systems would be necessary to collect spring water. As they are located in the Wadi Zarqa Main, facilities to protect against flash floods would also be required. For conveyance to Amman, about 50km to the southwest, a pipeline system with a pumping lift of more than 1000m would be required. (cf. Bibliography 29)

(6) <u>Karameh and Deir Alla (Alluvial Deposit)</u>

There are about 160 private wells in this area. These wells show yields that are relatively small (30 to 60 m^3/hr) compared to large draw downs. The salinity ranges from 500 to 4000 mg/l (cf. Bibliography 17). In addition, the aquifer, which is not confined, is located directly beneath an area where there is much agricultural activity, and there is the probability that ground water is contaminated by pesticides.

Brine disposal would be possible by draining it into the Jordan river, but, from the view point of avoiding any environmental adverse effect, the adequancy of drainage should be carefully examined.

Conveyance would not be a problem in this area, since the Deir Alla conveyance system could be used.

The Government of Japan would like to express its most sincere thanks to the Government of the Hashemite Kingdom of Jordan, which extended every cooperation and assistance for the survey and data collection, and to the Government of the United States, which dispatched a ground water expert to assist the Mission in its work.

In the light of the Study Mission, Japan plans to carry out further studies at the most promising of the sites inspected.

Data collected and information materials regarding desalination and ground water in Jordan are attached in the Bibliography.

8. Notes

(note 1) Water Supply in Jordan, 1990

	ground water	surface water	Total
municipal purposes	150 MCM	30	180
irrigation purposes	329	322	651
industrial purposes	35	8	43
livestock purposes	6		6
TOTAL	520*	360	880

* of which about 195 MCM was mined renewable ground water and 65 MCM mined fossil groundwater

(note 2) To augment the water supply by brackish groundwater desalination, the Jordanian authorities has stressed the necessity to establish a plant of a minimum 5 MCM/yr capacity.

Other possible ways to alleviate the water shortage in Jordan are:

- abstraction of fresh ground water from the Disi sandstone aquifer (1000-1500m deep wells, with the water being piped 350km)
- sea water desalination at the Gulf of Aqaba
- recycling of water from the sewerage system for irrigation, presently more than 90% of treated wastewater is reused in irrigation
- water saving: It is important to note that in 1992, 56 percent of the total water supply in Jordan, was unaccounted for. Leakages from the networks constitute 30-35% of unaccounted water. Those leakages are concentrated in old and aging networks of the major urban centers. Other factors that affect unaccounted water are meter mechanical errors, reading errors and illegal connections. Improved water management and rehabilitation of the water distribution system are undoubtedly important, if the water shortages problem in Jordan is to be solved.

(note 3) For instance, with raw water containing a large amount of silica constituents the ED and Electrodialysis Reversal (EDR) are preferable.

(note 4) Dumping brine into the Dead Sea could hardly cause any significant change in the condition of the Sea, since brine from a brackish water desalination plant is not as saline as the water of the Sea and the possible volume of rejected brine discharged would not be large enough to affect the Sea, even in the long term.

However, there were certain reservations made from Jordanian officials to an idea to drain brine through the Jordan river, as it might cause an increase of salinity of the river water. Therefore in the event of constructing a plant, possible environmental effects caused by its brine drainage, including further salination of the river water, should be carefully examined and necessary precaution measures should be thought out. Depending on the finding of this investigation, additional methods of brine conveyance, such as new channels or pipelines to the Dead Sea may be required.

(note 5) The water supply for municipal use to the Amman-Zarqa area in 1990 was 97 MCM, and the total shortfall 25 MCM.

(note 6) Needless to say, desalination plants constructed in the Jordan Valley area can help augmenting the water supply to the Valley area, which is also facing serious water shortage.

(note 7) A substantial part of the remaining ground water is used for the locality's water supply, both domestic and irrigation, and it is considered that the aquifer system is already fully utilized (cf. Bibliography 11, 12).

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10. List of Counterparts

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