Pergamon

Renewable Energy, Vol. 13, No. 4, pp. 537–542, 1998

Printed in Great Britain
PII: S0960-1481(98)00028-7
0960-1481/98 $19.00+0.00

TECHNICAL NOTE

Potentials for development of hydro-powered water desalination in Jordan

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(*Received* 20 *September* 1997; *accepted* 16 *February* 1998)

Abstract—Due to the increase in population and development in agriculture, Jordan will deplete all of its renewable sources of fresh water in the next few years. On the other hand, the level of the Dead Sea has been falling at a high rate for the past three decades, due to the diversion of water from the Jordan River for irrigation. The solution to these issues could be in finding other alternatives such as the development of hydro-powered water desalination plan. Desalted water would be produced in order to make up for the shortage of fresh water using membrane technology, and thus reserve fresh ground water for future generations. The brine from this process is discharged into the Dead Sea to allow restoring the sea level. This paper finds, on an annual basis, that about 2133 million cubic meters (MCM) of water can be drawn from the Red Sea. The power generated due to difference in elevation is used to desalinate Red Sea water. About 533 MCM of fresh water is produced in such a process. The brine, which is about 1600 MCM, is discharged into the Dead Sea. © 1998 Elsevier Science Ltd. All rights reserved.

1. INTRODUCTION

By the beginning of the next century Jordan, among other countries of the region, will have depleted all of their renewable sources of fresh water if current patterns of consumption remain unaltered [1–6]. However, due to the growth in population and development in agriculture, additional sources of fresh water will be needed. The solution would have to be in finding other alternatives such as considering desalination and reuse and treatment of waste waters [7].

Jordan consumes about 1000 million cubic meters (MCM) of water annually [8]. Its current population is about 4.3 million, and by the year 2010 it is expected to increase beyond 7 million, assuming an annual increase of about 3.5%. By then, water demand for municipal and industrial uses could reach 500 and 100 MCM, respectively. The projected water resources may reach a maximum value of 1200–1300 MCM, which includes restored water rights from the Jordan River [9]. Considering these figures and assuming that agricultural demand for water remains unaltered, the expected annual needs of water would be about 1350 MCM. Clearly, by then, the country will be facing a serious water problem.

Jordan is a non-oil producing country, and energy issues, like water become critical matters. The need for desalination from non-conventional energy sources becomes very attractive, which includes nuclear, solar, wind energy, and hydro-power [10]. However, these types of technologies are not fully

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developed. In this paper, desalination of sea water with hydro-power energy is considered. A potential development of hydro-power scheme is possible by linking the Red Sea with the Dead Sea. This hydro-power (due to difference in elevation) is then used in a reverse osmosis (RO) technology for desalting sea water.

2. BACKGROUND

Figure 1 shows the distribution of water in terms of both, resources and consumption in Jordan during 1993. Clearly, it can be shown that over 50% of water resources were of groundwater aquifers. It is believed that these resources can be reserved for future generations, especially, fresh water will probably be the world's most important issue in the near future. One may consider treatment of more waste water, development of surface water resources, such as building dams, etc., or the use of other alternatives. Oil-producing countries of the region, for example, use fuel energy for desalination of sea water using membrane technology. Jordan cannot afford to rely on such technology, since oil has to be imported. Consideration of hydro-power for water desalination looks very attractive, and must be taken very seriously, especially, construction and operation may take a long time.

Other benefits could result from this kind of project, such as the construction of recreation lakes and fish farms along the route of the canal. It is well known that Jordan lacks sea shores except for the Gulf of Aqaba, the only sea outlet. having artificial recreational lakes will boost and add more benefits to the local tourism. Along with other benefits, this can be considered as one of the major benefits of the proposed project.

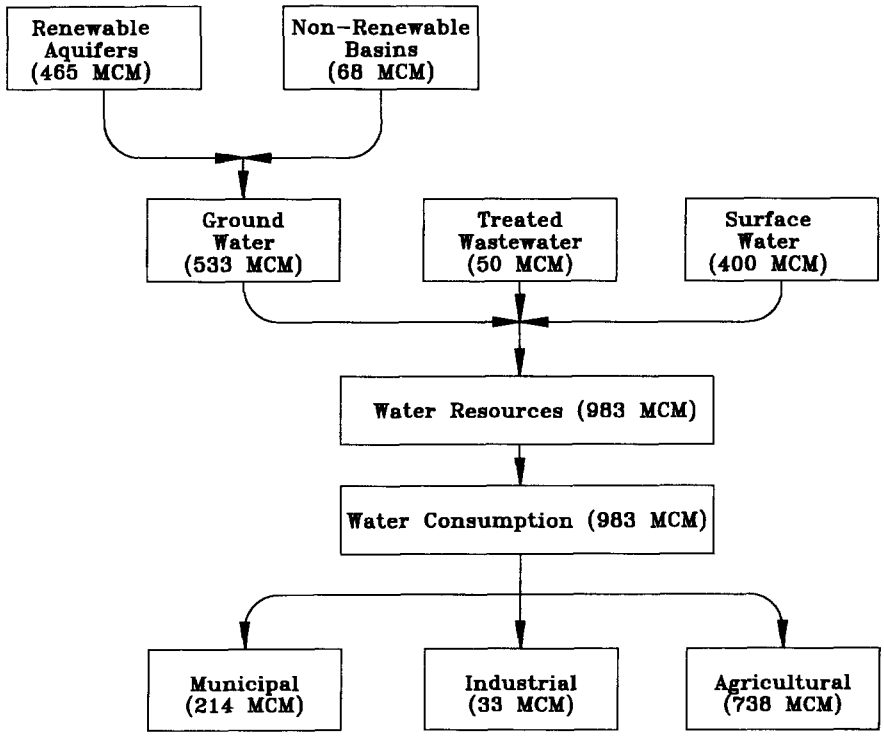

Fig. 1. Distribution of water resources and consumption in Jordan (1993).

3. THE DEAD SEA

The surface of the Dead Sea is considered to be the lowest point on Earth. In 1930, the surface of the Dead Sea was measured at an elevation of about 390 m below sea level (El. −390 m). The Jordan River is considered the main tributary of the Dead Sea. Over the years, due to increase in population and agricultural development, water was diverted for irrigation. Therefore, the Dead Sea surface elevation was forced to drop drastically. Currently, it is estimated to be at an elevation of about El. −408 m. The Dead Sea consists mainly of two basins, referred to as the North Basin and the South Basin. Lisan Peninsula, located on the east bank, partially separates the two. The South Basin is shallow having a flat bottom. It is considered to have been dried out now. In the past its maximum depth of water was estimated to be about 2 m; it has a surface area of about 220 km^2. The North Basin has a much greater depth of water. It has steep side slopes with an almost flat bottom. Its maximum depth reaches about 400 m [11].

The Dead Sea has a drainage area of 40,000 km^2, with an average annual precipitation of about 70 mm. Along with the Jordan River there is a number of small springs which flow into the Dead Sea which has no outlets. Water flowing into the sea does not flow out except by evaporation. Over the years, and until about 1967, the sea maintained an equilibrium of water flowing in from the Jordan River and leaving out by evaporation, only. This cycle is now interrupted due to the diversion of water from the Jordan River to meet the water demand of an increasing population in the region—causing the level of the sea to fall and the South Basin to dry out.

4. DISCUSSION

Sea water from the Gulf of Aqaba located on the Red Sea, which is about 220 km to the south of the Dead Sea, can be used in hydro-power development for the production of desalted water. This would serve as a source of water needed to be diverted into the Dead Sea. The water from such scheme can be used either to maintain the sea at its current elevation or even to make up for the drop in the Dead Sea level of water over the years as shown in Fig. 2. If this trend in sea level is allowed

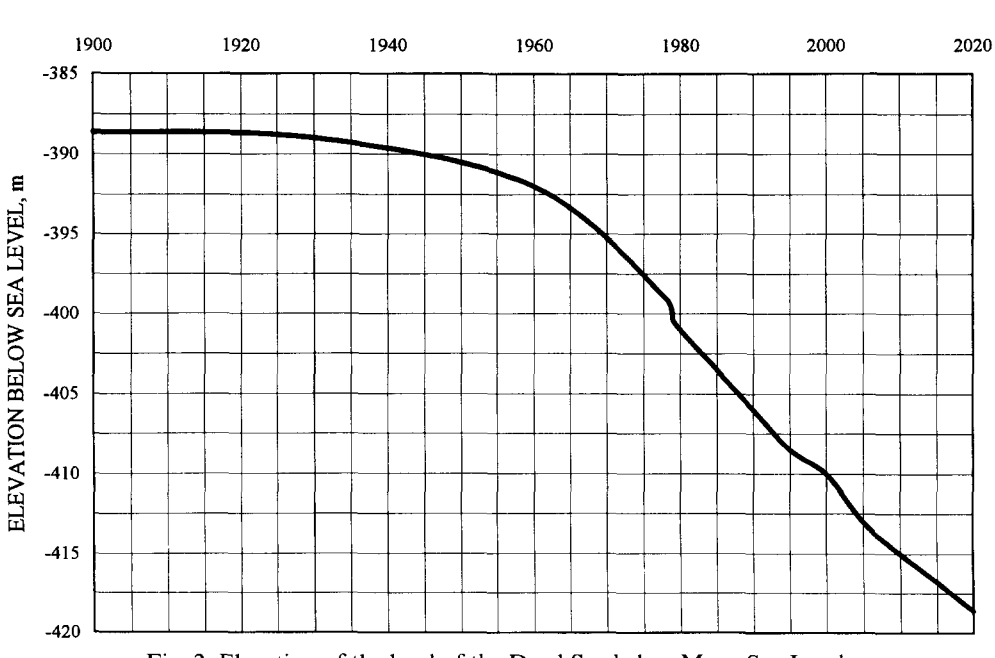

Fig. 2. Elevation of the level of the Dead Sea below Mean Sea Level.

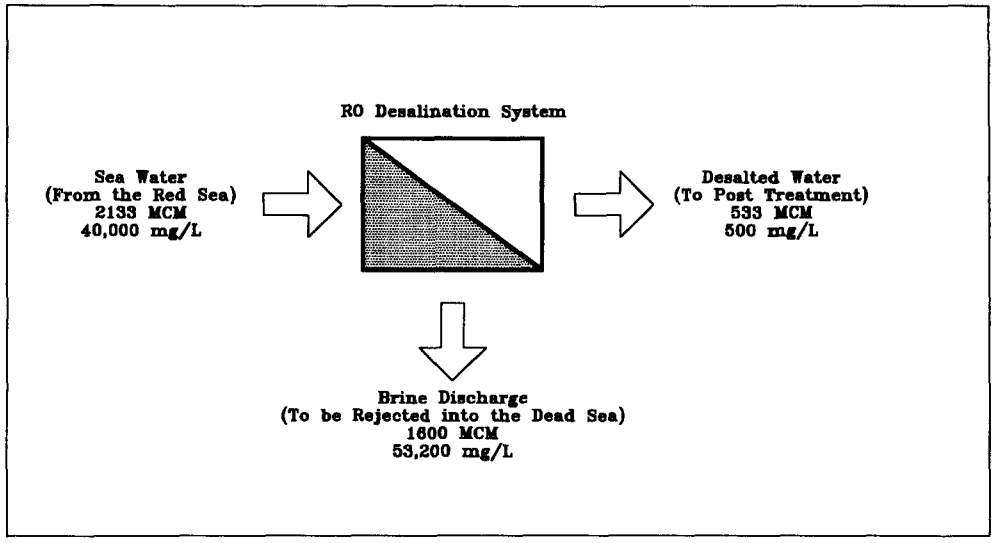

Fig. 3. Schematic and flow diagram of RO desalination process.

to continue, then by year 2010 it would reach a value of El. −415 m. The power obtained from such process can be used to desalinate water for drinking usage as well as other purposes.

It is estimated that the annual amount of water that evaporates from the Dead Sea is about 1600 MCM [4]. Therefore, if an equal amount of water is allowed to flow back into the sea, an equilibrium would be maintained and this would make up for the water leaving the sea. On the other hand more water can be diverted from the Jordan River for different usage such as drinking water, water for fish ponds, for the industrial sector and even for recreational purposes such as artificial lakes. The water which would be allowed into the sea is saline water, a reject from the hydro-power desalination plant. Mass balance across the RO desalination plant indicates that 2133 MCM, at 40,000 mg l^{-1}, can be diverted from the Red Sea. It is based on 25% recovery by RO desalination unit. Fresh drinking water at 500 mgL^{-1} can be produced annually in the capacity of 533 MCM. The brine which is 1600 MCM, at 53,200 mg l^{-1} will be discharged into the Dead Sea, annually. Discharging saline water into the Dead Sea will not have any negative effects on the sea itself. The salinity of the sea ranges from 300,000 to 330,000 mg l^{-1}. A schematic diagram showing the desalination process is presented in Fig. 3.

The proposed system is shown in Fig. 4. It is a schematic diagram of the scheme, of which sea water is pumped from the Gulf of Aqaba, at an elevation of sea level to a reservoir (No. 1), located at an elevation of 100 m above sea level at a distance of 20 km to the north. The water is then allowed to travel through a canal for about a distance of 50 km to the north of the Gulf of Aqaba with a very small slope. It is then pumped to second reservoir (No. 2) located at an elevation of 200 m above sea level. From reservoir No. 2 water can then travel through another small-sloped canal at a horizontal distance of about 200 km to reservoir No. 3. From there on, it is then allowed to drop to an elevation of about 400 m below sea level (total head of water of 600 m). It is sufficient for water desalination and flow of discharge of fresh water [12]. A pipeline is used in the final stage of the process. The scope of the proposed project could expand even more depending upon cost and financing and if the private sector becomes involved.

5. CONCLUSIONS

This paper finds solutions to two major problems in Jordan. First, solution to the shortage in fresh water that the country is suffering from, which would probably become a major issue in the near

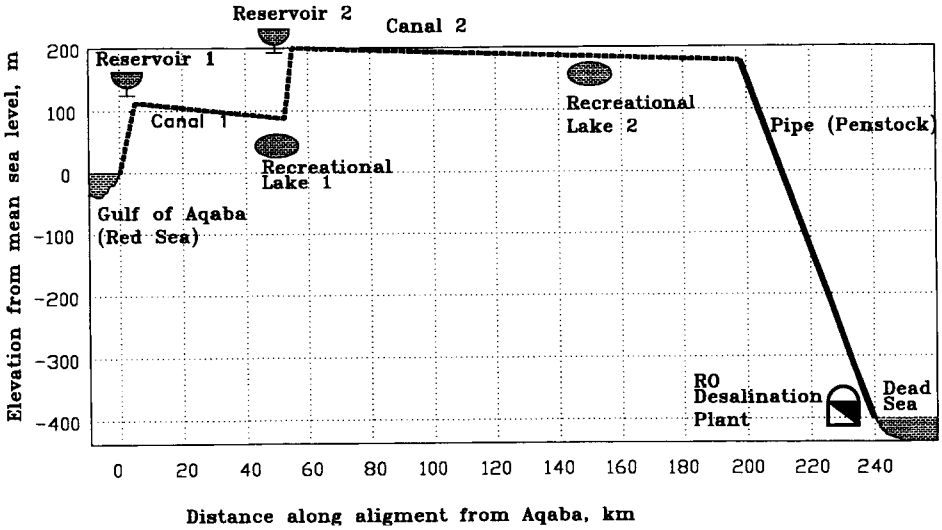

Fig. 4. Schematic diagram of the proposed system.

future. Second, restoring the currently falling level of the Dead Sea. A potential of hydro-powered water desalination plan can provide an annual production rate of about 533 MCM of fresh water, as well as 1600 MCM of brine to be discharged into the Dead Sea.

Other benefits can be obtained from this project, such as the construction of recreation lakes and lakes for fish farms along the path of the canal. The local industry can also benefit from this project. For example, the Jordan Potash Co. does not have to pump Dead Sea water, which is the main source of chemical supply, for very long distances.

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