MEDITERRANEAN-DEAD SEA HYDRO-SOLAR DEVELOPMENT FOR CO-GENERATION

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ABSTRACT Concerns over the global environment and the Gulf (oil) crisis in August 1990's Iraq invasion have improved our understanding of the importance of clean energy such as non-polluting hydroelectric power. By the year 2000, water and oil will be the predominant resources issues of the Middle East. A new co-generation method for the Israel/Jordan Mediterranean-Dead Sea hydro-solar scheme is proposed herewith, which aims to exploit both electricity and fresh water by desalination from the Mediterranean Sea, would exploit the 400 m elevation difference between the two seas by including hydro-electric stations and seawater reverse osmosis (RO) desalination plants. The co-generation system could produce 480 MW of electricity and 86,400 m^3 per day of fresh water from Mediterranean Sea. The generated power will be shared by the two countries, while the product of fresh water of 30 MCM($x10^6$) per annum will be used exclusively for the water supply in the central Ghor (Jordan Valley).

Keywords: Arid region, Co-generation, Solar energy, Hydro-power, Desalination

1. INTRODUCTION

Water and oil will be the dominant resources issue of the Middle East by the year 2000. This situation is particularly acute in the non-oil-producing countries in the Middle East such as Jordan and Israel, which states will be using over 80 to 95 per-cent of their conventional water resources such as fresh stream waters and the renewable groundwaters in their territories.

This particular type of hydroelectrical development, also known as a hydro-solar power station, would be made possible by the combination of such factors as the existence of a vast depression at a distance not too far from the sea, and the region's characteristically scarce rainfall (with the resulting high degree of evaporation). Two well known hydro-solar projects have been studied in depth; in Egypt and in Israel. Both plans would involve an initial development stage

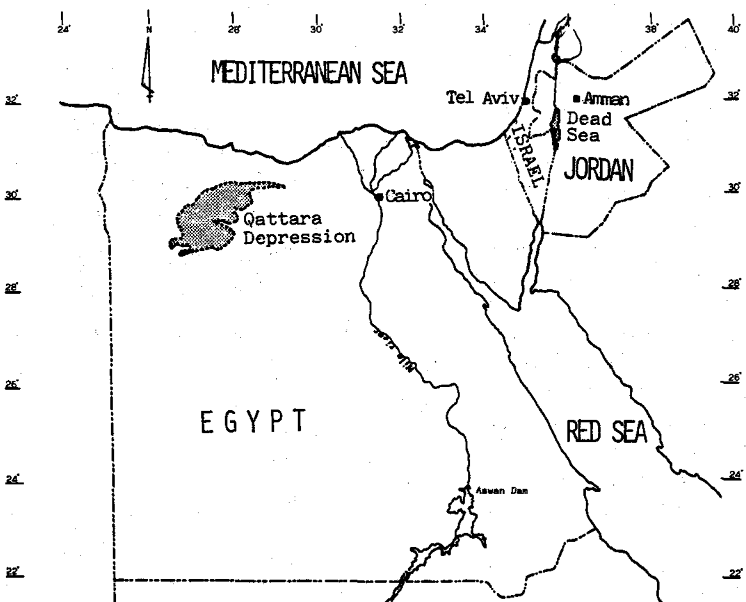

Fig.1 Location Map

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during which the basins would be filled with water from the Mediterranean Sea up to a certain design level that would be maintained thereafter by transfer of water to replace the amount evaporated. Utilization of the Qattara depression (Fig.1) to develop hydro-electric power, was first suggested by the Berlin geographer, Professor Penk in 1912 (Ref.1).

Israel announced its performance of feasibility study on a seawater hydro-electric power generation project in 1980, but this had been proceeded by pre-feasibility studies over many years before this. The Mediterranean-Dead Sea Canal hydropower project, as it was called, was designed to exploit the 400 m elevation difference between the Mediterranean Sea (zero meters) and the Dead Sea (-402 meters) by linking the two seas (Fig.1). After considering 27 alternative link routes to connect the two seas, "Gaza - Ein Bokek" route (Fig.2) was selected to minimize the construction cost.

The selected route, however, crosses the Gaza Strip which is at present politically occupied by Israel. For political reasons, an alternative route was considered which would move the entrance of the canal northwards into Israeli territory (Fig.2). This would add 80 million U.S. dollars to the cost, and 20 km to the planned 100 km-length (Ref.2). However, even if political problems in Gaza Strip are avoided, they will be certainly be encountered in Jordan which shares the Dead Sea with Israel and also extracts minerals such as potassium from it (Fig.2). The effect of the canal would be to raise the level of the Dead Sea by 17 m from -402 to -385 m below sea level. This would mean that the mineral processing plants in both countries would have to be moved and potash production could fall by 15 per-cent (Ref.2).

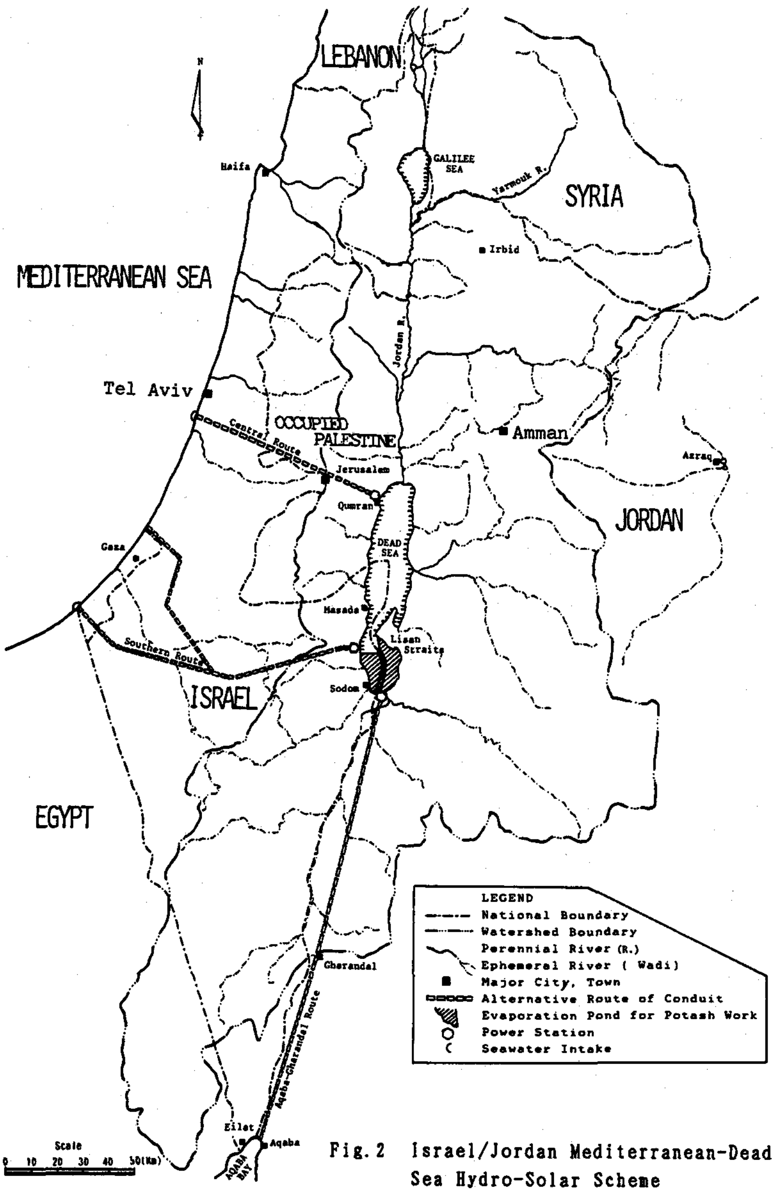

Fig.2 Israel/Jordan Mediterranean-Dead Sea Hydro-Solar Scheme

Jordan vied with Israel over the canal power scheme in 1981, by offering a counter-proposal to bring seawater from Aqaba bay to the Dead Sea. This scheme would exploit the 400 m drop between the Gulf of Aqaba and the Dead Sea to generate electricity. Seawater would be pumped into a network channels and reservoirs from Aqaba to Gharandal, 85 km further north (Fig.2). From there, the water would fall into the Dead Sea to generate about 330 MW for 8 hours a day at peak demand (Ref.3).

The flow of water from the Jordanian carrier would force Israel to cut back its own influx of water into the Dead Sea, or the level would rise so high as to flood the potash worked (of both Israel and Jordan) and the surrounding hotels on the Israeli side. The Mediterranean-Dead Sea hydropower project was put aside, owing to the strong opposition from the Arab states and others, and with the confusion and the drop of the world oil market prices in 1984. Israeli interest turned then to the seawater pumped-storage from the Dead Sea. (Refs.4&5).

Concerns over the global environment and current Middle East crisis, however, have improved our perspective on the importance of exploiting clean energy. The application of solar-hydro with RO desalination, which is a new type of co-generation system proposed herewith, is likely to be a key technological development in this region for the strategic objective of saving fossil energy and the global environment.

2. TOPOGRAPHY OF DEAD SEA AND RIFT VALLEY

The Dead Sea is located at the lowest spot on the earth in the Jordan Rift Valley. It covers an area of 1,000 km^2 at a surface elevation of 400 m below mean sea level and has two basins separated by the Lisan Straits, areas of 720 km^2 and 230 km^2, respectively. The catchment includes parts of Israel, Jordan, Syria, and Egypt. The shortest distance between the Dead Sea and the Mediterranean Sea is 72 km, which corresponds to the proposed Central Alternative (Fig.2), namely the canal-tunnel route "Tel Aviv"-"Jerusalem"-"Qumran".

3. HYDROLOGY AND ACTUAL EVAPORATION FROM DEAD SEA

The climate of the watershed ranges from "hot-arid" in the bottom of Jordan Valley to "Mediterranean semi-arid" in the surrounding highlands. The Sea is a brine water body with the extremely high salinity of 300,000 ppm of total dissolved solids (TDS). The Dead Sea is a closed sea with no outlet except by evaporation which amounts to 1,600 mm per annum (Ref.6).

In the past, the evaporation losses were replenished by an inflow of fresh water from the Jordan River and its tributaries, as well as other sources such as wadi floods, springs and rainfall. The mean volume of water flowing into the sea before 1930 was about $1.6x10^9 m^3$/year, of which $1.1x10^9$m3/year were contributed by the Jordan River (Ref.7). Under these conditions, the Dead Sea had reached an equibrium level of around 393 m below sea level, with some seasonal and annual fluctuation due to variations in the amount of rainfall.
However, since the early 1950s, Israel and later on Jordan, have taken steps to utilize the freshwater flowing into the Dead Sea for intensified irrigation and other purposes, which reduced the amount of water entering the Dead Sea by

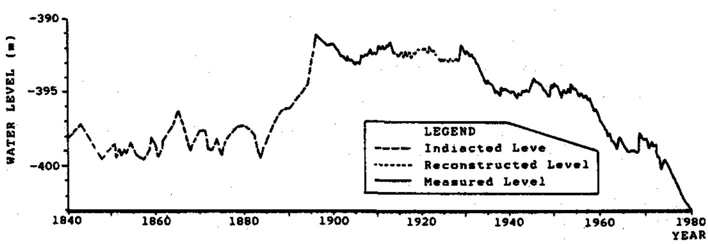

Fig.3 Dead Sea Levels; 1840-1980

The IJMDS plan would have the following major components:

1) An upstream reservoir (the Mediterranean) at zero sea level, with essentially an unlimited amount of water.
2) A water carrier, assuming several alternative schemes, depending the route considered, including a gravitational canal, a tunnel with booster pumping, or an open gravitational canal.
3) An upper reservoir and surge shaft at the outlet of the water carrier to allow for regulating the water flow.
4) A storage type hydroelectric unit capable of reverse operation to allow the system to also work as a pumped storage unit, if required.
5) A downstream reservoir, the Dead Sea, at a present surface elevation of approximately 402 m below sea level.
6) A reverse osmosis (RO) desalination plant, including pre-treatment unit, pressure converter unit, RO unit, energy recovery unit, post-treatment unit, and regulating reservoirs for distribution.

The theoretical hydropotential, installed capacity, and potential power generation (annual output) were preliminarily estimated to be 189 MW, 160 MW and 1.96×10^9 KWh per annum, respectively, by assuming the peak power operation of 8 hours a day and the following conventional equations and design parameters;

$$Pth = 9.8*Ws*Q*He \quad (1)$$
$$P = Pth*Ef \quad (2)$$
$$Wp = 365*24*Gf*P \quad (3)$$

where, Pth : Theoretical hydro-potential (KW)
Ws : Specific weight of water (=1.03); Seawater
Q : Flow discharge (=50.7*24/3=152.1 m^3/sec)
He : Effective difference head of water (=400*0.95=380 m)
P : Installed capacity (KW)
Ef : Synthesized efficiency (=0.85)
Wp : Potential power generation (output) per annum (KWh)
Gf : Generating efficiency (=0.30); 8 hours a day of peak operation
* : Multiple

The co-generation system is an application of annexing a seawater reverse osmosis (RO) desalination unit to the solar-hydro-power system which requires 8 hours a day of peak operation. The marginal operation of the RO system is designed to use the hydro-potential energy in the pipeline-tunnel system (400 m of differential water head) for 16 hours a day of the off-peak time. The feed water requirement to produce 86,400 m^3 per day of permeate with 1,000 ppm of the total dissolved solids (TDS) is estimated to be 2×10^6 m^3 per day by assuming 30 % of recovery ratio of the RO modules.

5. CONCLUSION

The Israel/Jordan Mediterranean-Dead Sea hydro-solar scheme, which aims to exploit both hydro-electric power and fresh water by desalination from the Mediterranean Sea, would exploit the 400 m elevation difference between the two seas by including hydro-electric stations and seawater reverse osmosis (RO) desalination plants. This co-generation system could produce 480 MW of electricity which is equivalent to 12 % of the Israel's national grid's capacity of 4,060 MW, and 86,400 m^3 per day of fresh water.

The generated power would be shared by the two countries to supply their peak demands, while

1x10^{9}m3/year. As a consequence, level of the Dead Sea has declined in recent years, reaching as low as 402 m below sea level today, which is almost 10 m lower than its historic equibrium level. The surface area of the Dead Sea and the volume of evaporation vary only by a few percent between the elevations from -402 to -390 m, while the water levels fluctuate considerably. The variations in Dead Sea levels from the beginning of the nineteenth century to the middle of the twentieth century are shown in Fig. 3.

4. SOLAR-HYDRO SCHEME

The proposed Solar-Hydro Development Plan would exploit the sharp difference in elevation of 400 m between the Mediterranean and Dead Seas. The Dead Sea water level would be maintained at a steady-state level with some seasonal fluctuations of about 2 meters to sustain the sea water level between 402 m and 400 m below mean sea level, during which the inflow into the Dead Sea should balance the evaporation.

The Israel/Jordan Mediterranean-Dead Sea (IJMDS) Canal plan is a co-generation alternative which would combine solar-hydro-power and seawater reverse osmosis (RO) desalination (Fig. 4).

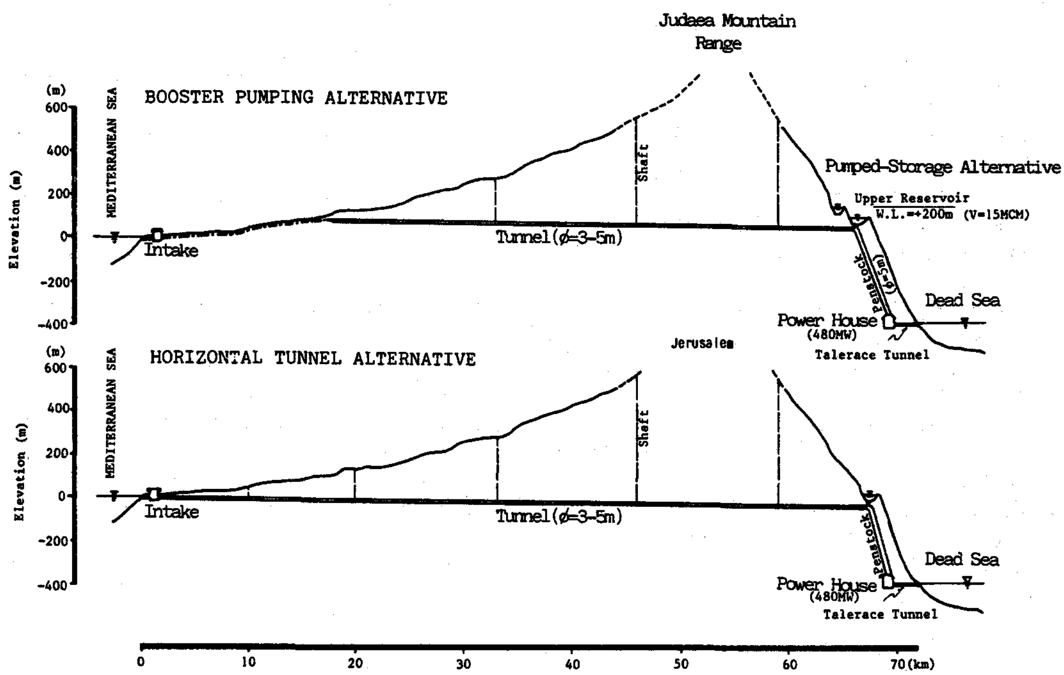

Fig.4 Israel/Jordan Mediterranean-Dead Sea Solar-Hydro Conduit; Development alternatives

the product of fresh water of 30 MCM($x10^6$) per annum would be used exclusively for the water supply in the central Ghor (Jordan Valley).

The "Minimum Route" canal would be 72 km long, including a 15 km section of pipeline which would be open and a 57 km tunnel with 3 m in diameter, of which the economic feasibility would be much improved as compared with the previous 1984s estimates with an economic internal rate of return about 5-10 %. The first 30 km section would cross Israeli territory, and the second 42 km section would traverse occupied Palestine. Could the joint Israel/Jordan Mediterranean-Dead Sea co-generation plan be politically feasible by the year 2000 ?.

This study of hydro-solar development has been made to test the technical feasibility of exploiting seawater resources by taking into account the distinctive nature of the arid zone hydrology in and around the Dead Sea. Reverse osmosis is the cheapest process for desalination today, but it may not be the optimum solution which may be encountered in the 21st century. Further researches will be needed to evaluate its technical feasibility, including 1) rate of evaporation from Dead Sea surface after impounding, 2) corrosion of pipelines, 3) TBM methods of construction for the pipeline tunnel, 4) low pressure (30-50 kg/cm^2) type RO membrane modules for seawater desalination, 5) the energy recovery system in RO, 6) methods of hybrid desalination, 7) other alternatives including fresh water import by medusa bags (Ref.8) and power generation by solar pond.

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