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The Environmental Impact and the Economical Feasibility of Disi-Amman Water Conveyor Project

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Abstract

Jordan is considered to be one of the 5 poorest countries worldwide in water resources. The most citizens in Jordan receive water only once a week and the annual available water resources per capita is 150 m3 which is one of the lowest shares in the whole world. The project of water conveyance system from Disi-Mudawarra to Amman would cover part of the water shortage in Jordan, but it will not solve it completely. The Disi Aquifer, also known as Rum aquifer system, is a transboundary aquifer that extends from south of Jordan into Saudi Arabia where it is known as Saq Aquifer System. However, both the Rum and the Saq actually form one aquifer system with the larger portion located within Saudi Arabia. The main objective is to convey additional water to the Greater Amman Area from the Disi Aquifer. The Disi project will have an indirect effect on the quality of wastewater which in turn will lead to better quality water to be used for irrigation as a replacement for valuable freshwater. The Disi water will form a major portion of the extra water that is planned to partially replace the low quality groundwater consumed domestically in Amman. The average abstraction of this well field will be 100 million m3/year. The development and implementation of this project pose a range of significant environmental and social issues since it will be based on the use of a non-renewable fossil groundwater aquifer and require changes in the existing patterns of water use. In the present investigation, the economical, environmental and social assessment for the Disi-Amman water conveyor project, which builds a reliable water supply for Amman, are discussed. The expected negative environmental impacts consist of temporary and permanents factors.

Keywords: Water Shortage in Jordan, Disi-Amman Water Conveyor Project

Introduction

Jordan is considered to be one of the 5 poorest countries worldwide in water resources. The available renewable water resources are dropping drastically to an annual per capita share of 160 m^3 in recent years, compared to 3600 m^3/capita in 1946. The expanding population and the climatic and topographical conditions of the

country have caused enormous pressure on the limited water resources and created a severe water supply-demand imbalance where the deficit is about 220 million m^3/year (MCM/year), e.g. Al-Salaymeh and Zurigat [1]. The water shortages in Jordan can be attributed to the semi-arid climate that is associated with limited annual rainfall, high natural population growth, rural to urban migration and major influxes of population in response to political and economic crises in the Middle East, e.g. [2]. The lack of water resources became more prominent with the increase in water demand in response to the natural and crises driven population growth, improvement of living standards, and the developments of the economic, industrial and touristic sectors, e.g. [2]. Despite the huge investment in the water sector, a considerable water deficit will still be facing Jordan. This deficit will double by 2025 even if all unconventional water sources are used, e.g. [3]. The average total quantity of rainfall which falls on Jordan is approximately 7200 MCM/year, and it varies between 6000 and 11500 MCM/year. Approximately 85% of the rainfall evaporates back to the atmosphere, the rest flows in rivers and wadis as flood flows and recharges groundwater. Jordan's Renewable freshwater resources are estimated to about 850 MCM/year, consisting primarily of surface and ground water. Options for non-conventional water resources that can be mobilized are modest where nearly all of Jordan's renewable water resources have been developed and most citizens in Amman receive water only once a week. The options for augmenting water supply are limited; some additional rainwater can be harvested and some brackish water can be pumped from sandstone aquifers, e.g. [2].

Jordan's water resources comprise surface water, renewable and non-renewable groundwater and treated wastewater, which are used by agriculture (69%), industry (10%) and municipalities (21%). With the exception of springs and the King Abdullah Canal, surface water resources are exclusively used for irrigation, e.g. [4]. The municipal water supply and industry mainly depend upon groundwater and springs, which are limited and often over-drafted. The variability in the surface water resources left no choice but the use of groundwater resources to cover part of the shortage. The total renewable safe yield of the groundwater resources in the whole of Jordan is 277 MCM/year, which does not include the Disi aquifer as this is a non-renewable source, e.g. [3]. Although extraction from these sources exceeded this safe yield by more than 200 MCM/year in recent years, Water Authority of Jordan was unable to meet the substantially increasing demand. Continuation of this overexploitation of groundwater sources at these high levels will lead to mining these sources as well as deteriorating the quality of abstracted water, which will lead at the end to an extensive damage of the aquifers, e.g. [2]. New sources were identified to relief the existing groundwater source and allow the natural recharge of these sources and to restore their water quality which shall relief part of water shortage in Greater Amman area. The water supply in Greater Amman area has been outstripped by the demand and this situation is deteriorating each year by the increase of demand and therefore, MWI had to consider the option of implementing the Disi Project by conveying water from the southern part of Jordan to Amman, e.g. [5]. The contract for the Water Conveyance System from Disi-Mudawarra to Amman was awarded by MWI to a Turkish company last year.

The Disi Aquifer, also known as Rum aquifer system, is a transboundary aquifer that extends from south of Jordan into Saudi Arabia where it is known as Saq Aquifer System. However, both the Rum and the Saq actually form one aquifer system with the larger portion located within Saudi Arabia, e.g. [2]. The main objective of the Disi project is to convey additional water to the Greater Amman Area

from the Disi Aquifer. This project has been on the shelf for many years, postponed due to a lack of funding. However, due to pressing water needs, serious efforts have been made to implement the proposal. Disi is a fossil water aquifer extending from the southern edge of the Dead Sea in Jordan to Tabuk in northwest Saudi Arabia. Significant exploitation of the Jordanian side of the aquifer started in 1980. At present Aqaba city is provided with 16.5 MCM for domestic purposes and 75 MCM for agricultural purposes, e.g. [4].

Objectives

At present, the drinking water for Amman is supplied mainly from the upland aquifers and new developed aquifers to the south such as Lajoun Aquifer. An important aspect of the Disi project is that its implementation will secure an additional source of drinking water to Amman and thus relieve the upland aquifers from over-use. The Disi project will have an indirect effect on the quality of wastewater which in turn will lead to better quality water to be used for irrigation as a replacement for valuable freshwater. The Disi water will form a major portion of the extra water that is planned to partially replace the low quality groundwater consumed domestically in Amman. The average abstraction of this well field will be 100 MCM/year. The development and implementation of this project pose a range of significant environmental and social issues since it will be based on the use of a non-renewable fossil groundwater aquifer and require changes in the existing patterns of water use. While justified under the unique water resources management situation in Jordan, such a development was subjected to a detailed environmental and social impact study, e.g. [2].

In the present investigation, the economical, environmental and social assessment for the Disi-Amman Water Conveyor Project, which builds a reliable water supply for Amman are discussed. The expected negative environmental impacts consist of temporary and permanents factors. The temporary impacts caused by the project include high noise levels, increased dust levels and attendant health problems, groundwater pollution, solid waste generation, and visual impact. The permanent impacts anticipated are landscape damage; change of natural drainage system and local geomorphology; fragmentation of desert habitats; increased human encroachment in relatively remote areas causing interferences with wildlife; the breeding of migratory birds, and introduction of exotic species; water shortages affecting irrigation; cut trees; and restrictions on mobility, e.g. [2].

The main objective of this project is to supply additional high quality water to Greater Amman region from the deep fossil Disi Aquifer by conveying the water a distance of approximately 325 km from Amman. For a number of years water has been outstripped by demand in the Greater Amman Region and MWI has no option but to implement a water rationing program during the summer months. The provision of this reliable additional water supply would provide an opportunity for Jordanian authorities to reduce groundwater abstractions in the Greater Amman Region and allow for partial restoration of renewable resources in this region, e.g. [6]. Another important aspect of the Disi project is that its implementation will secure additional source of drinking water to Amman and thus relieve the upland aquifers from over abstraction. Also, the Disi project will have an indirect effect on the quality of the wastewater which in turn would lead to a better effluent quality to be used for irrigation as a replacement for valuable freshwater, e.g. [7]. However, it should be

noted that the Disi project would cover only part of the water shortage problem but would not close the country's growing water gap.

Water Crisis in Jordan

The water resources in Jordan consist primarily of surface and ground water resources, with treated wastewater being used for irrigation. Renewable water resources are estimated to be around 750 MCM/year, include ground water at 277 MCM/year and surface water at 692 MCM/year of which only 70% is of economic use. An additional 143 MCM/year is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored but at least 50 MCM/year is expected to be accessible for urban uses after desalination, e.g. [8]. The total renewable safe yield of the groundwater sources in the whole of Jordan is 275 MCM/year. Extraction from these basins in the year 1998 was estimated at 416 MCM of which 173 MCM was for municipal use. At present, most renewable groundwater reserves are fully exploited. The groundwater aquifers in Jordan are being exploited at more than double their sustainable yield on average in order to meet the country's growing water demand. Also, the situation has reached a level where the toxicity index (pollution load compared to renewable water resources) is high, e.g. [9]. The Disi-Mudawarra to Amman Water Conveyance System will result in a reliable water supply to Amman especially during the summer. The typical water related problems in Jordan include the inefficient management of national water resources; subsidized water to end users; poor aquifer and surface water quality; inefficient irrigation networks, illegal water use; and inefficient use of irrigation water, e.g. [8]. The water strategy stresses on the need to tap the full potential of surface and ground water to a feasible extent, the marginal quality and brackish water support irrigated agriculture, seawater desalination produce additional water for municipal, industrial and commercial consumption.

The gap between future demands and supply is shown in Figures (1) and (2) and this highlights the importance of the Disi water. Figure (1) shows the historical supply for the period 1985-2001 to the different sectors with future demand forecasting up to the year 2020 according to the Ministry of Water Irrigation projections, e.g. [2]. Demand forecasting is conditioned by water availability which is in turn sensitive to rainfall conditions. The sector most affected by water availability is irrigated agriculture during dry weather years, e.g. [10]. In addition, Figure (1) matches the behavior of irrigation supply, domestic and industrial supply and rainfall. It is clear from this figure that there is no change in the behavior of domestic and industrial supply in response to changing rainfall conditions whereas the behavior of the agricultural supply reveals a similar variation as that of rainfall. Rainfall is the only source of water supply in Jordan to recharge the groundwater aquifers. The groundwater resources distributed all over the groundwater basins constituting Jordan are very scarce and actually vary in quantity and quality. Generally, the surface groundwater basins in Jordan are divided into renewable and non-renewable groundwater resources, e.g. [11]. The surface groundwater basins constituting Jordan are 12 basins, which are subdivided according to the upper most aquifer system, occurred in each of the basins. The only two-groundwater basins, which contain nonrenewable groundwater resources, are the Disi-Mudawarra basin and Jafer basin. The estimated abstracted groundwater amounts from the Mudawarra and Jafer are 125 and 18 MCM/year/50years, respectively, e.g. [2]. The environmental and social impacts of utilizing the Disi (Mudawarra) non-renewable

groundwater for the domestic purposes in Amman will protect the groundwater of those basins from further deterioration and overdraft.

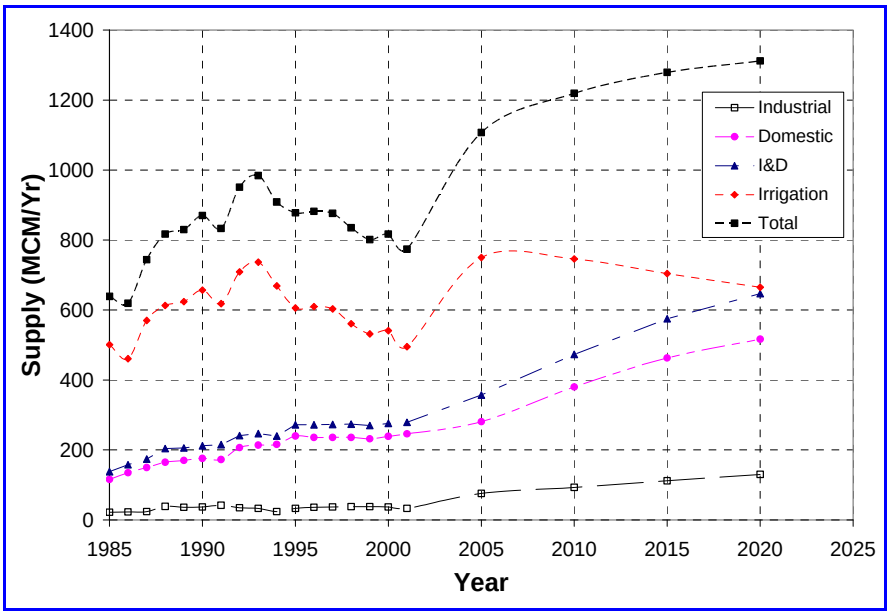

Figure 1: Jordan water supply by sector; historical and future forecasting

The sources of irrigation water are surface water, groundwater, and treated wastewater. The total water supply for irrigation was 540 MCM in the year 2000; of which surface water 40%, groundwater 47%, and treated wastewater 13%, e.g. [5]. The domestic and industrial demand were increased from 22% at the year 1985 to 33% at the year 2005 and to 49% at the year of 2020 out of the total demand according to data of MWA which is shown in Figure (1). 75% of the total available water supplies in Jordan are used for irrigation and one third of this percentage is used for agriculture in the uplands. The irrigation water used in upland areas is drawn from groundwater resources that are under extreme pressure. This contributes to declines in groundwater levels as well as water quality deterioration from overexploitation and from return flows from irrigation. The use of the upland aquifer for agricultural purposes is contributing significantly to the reduction of the renewable groundwater reserve which limits the available water for municipal and industrial supply. The irrigation demand was frozen due to lack of water supply for the agricultural sector, e.g. [10]. No fresh water will be considered for irrigation after few years and a considerable reduction in fresh to brackish water. Treated wastewater could be the only source available for irrigation in the future.

The total municipal consumption in Amman Governorate is about 100 MCM which comes from groundwater sources and water transferred from outside of the Governorate through the King Abdallah Canal-Deir Alla-Zai line. Disi water will be another source for water supply to Amman Governorate which will be used for domestic.

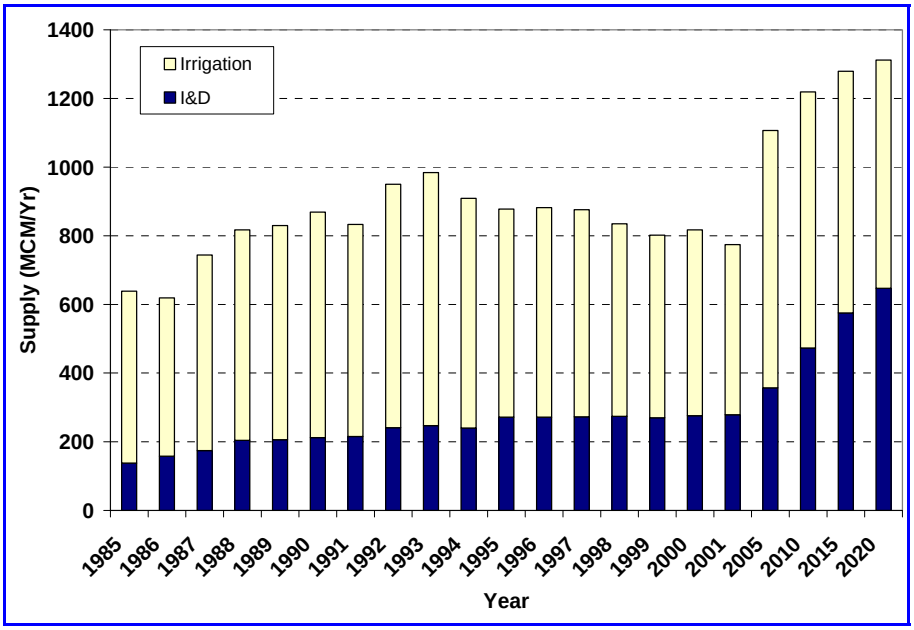

Figure 2: Domestic and industrial percentage compared to irrigation consumption.

Impacts of Disi Project

The Disi water was exploited partially in 1982 for agricultural activities with minimum investment regarding water resource transfer, e.g. [2]. Saudi Arabia started at 1970s to use Disi water for grain production. The implementation of Disi water for domestic use should be carried out soon to improve the quality of domestic water in Amman and to increase the share of per capita for domestic demand. The domestic water in Amman is abstracted mainly from over exploited aquifers, which are suffering from low quality water. The salinity, as an example, is high and above maximum allowable limit set by Jordanian Standards. The high salinity can be detected visually at household appliances, which are continuously suffering from scaling problems. This salinity is also associated with health problems. Disi water will dilute the chemicals in Amman system to much lower concentrations and this will enhance the water quality to levels close to the set standards. The provision of reliable high quality water to Greater Amman will have a significant positive impact on the economy of the region, improve the public health of the water users and contribute to better environmental conditions, e.g. [12]. The over exploitation of water in upland aquifers will be reduced and the damage in quality of groundwater in the relieved aquifers will be also reduced. The low quality of the treated wastewater which damaged soil in Jordan valley will be improved. The reduction in abstraction will enhance the opportunity to rehabilitate and restore these aquifers. Also, the project will reduce the salinity at irrigated lands due to reduction in salinity accumulated in soil column. However, it should be pointed out that although the Disi project would provide significant amounts of water to Greater Amman, it would not close the gap in water demand.

To achieve the required task from the project, the maximum design discharge from the well fields is 150 MCM/year and the estimated average well discharge is 70 l/s. The final number of drilled wells should be at least 75 wells, e.g. [2]. Most of the studies carried out on the Disi Mudawarra groundwater resources restricted the well field location to Dubaydib area in the unconfined aquifer. The detailed study was the Scott Wilson [13], where two abstraction scenarios concentrating on the Dubaydib well field were studied.

These scenarios are as follows, e.g. [2]:

- Abstraction of 120 MCM/year from Dubaydib well field in addition to the current abstraction of 75 MCM/year (for Aqaba domestic and industrial purposes, local supply and agricultural activities) and 977 MCM/year in Tabuk in Saudi Arabia.
- Additional abstraction of 150 MCM/year from Dubaydib well field beside the other existing abstractions in Disi-Mudawarra area as well as in Saudi Arabia in Tabuk.

The estimated drawdown result due to the first scenario is 50-100 years and the development period for the second scenario is also 50-100 years. As it is well-known, the feasible economic water depth is 250 m below ground level. The maximum drawdown due to 100-year abstraction period is corresponding to 190 m below ground level. On the other hand, the estimated drawdown resulting from the second scenario for the 50-year and 100-year abstraction periods are 140 m below ground level and 210 m below ground level, respectively, e.g. [13-16].

The Disi Conveyance System will ultimately provide continuous water supply of best quality to Amman residential area. It will have positive cumulative impact on the public health in the region as well as on other areas in the direct zone of influence where salinity is increasingly affecting drinking water supply from underground resources. A clean water supply combined with good public awareness will have direct and cumulative impact on the household health conditions overtime. It is expected that substantial decline in water borne diseases will occur as a result of the Disi water quality. This will be reflected on the treatment process and the quality of the treated wastewater. The treated wastewater will enhance the condition of irrigated land in the direction of more profitable cropping, e.g. [14-18].

The Disi water resource is a very valuable one and efficient management of it is therefore critical. This high standard of management is needed in order to maximize the benefits of staged development of the resource and onward conveyance system to Greater Amman, e.g. [15, 16]. The government of Jordan should implement several elements to enhance the environmental and social management plan in the water sector such as replacing the fresh water by marginal water in irrigation; limiting the water provided for agriculture and preventing any expansions. Also, the water supply networks should be renewed to reduce losses in addition to prevent any new well without prior licensing. Implementing projects for desalination of brackish water for domestic use and conducting public awareness campaigns related to availability of water and its wise use can help to solve the water crisis in Jordan, e.g. [15].

Conclusions

The people in Jordan have suffered from water shortages due to its semi-arid climate, associated limited annual rainfall, a simultaneous increase in size of population and demand for domestic and industrial users. Also, the population grew at high average annual rate and the municipal water supply over the whole country decreased from 150 liters/capita/day in 1996 to 130 liters/capita/day in 2001. It should be noted that demands in Greater Amman during the summer period increase

dramatically due to a large influx of Jordanians returning from abroad for their holidays in addition to tourists from the region.

Most of the renewable groundwater basins in Jordan are overexploited where some basins are overexploited with more than 150% with respect to their safe yield. It has been clearly shown that in the present work that the Disi conveyance system is required now. The good quality of Disi water will enhance the water distributed to users in Greater Amman and will improve public health and even the performance of household appliances. The use of Disi water will improve the quality of wastewater which will in turn allow for an enhanced treated effluent for agricultural use in the Jordan Valley. Disi water could relieve over extraction of aquifers which supply domestic water to Amman. The water conveyance from Disi-Mudawarra to Amman will not affect the water supply to Aqaba quantitatively or qualitatively. In the case of reducing or stopping the abstractions from the highland aquifer systems in the basins supplying Amman with water, the groundwater in these aquifers will be improved.

The main objective of the Disi water is to supply additional domestic water to the Greater Amman Area. However, even with the availability of the additional water from Disi, there would still be an excessive shortfall in the next few years, particularly in the Greater Amman area. The proposed Red Sea - Dead Sea Water Conveyance Project in addition to Disi project will solve the problem of water shortage in Jordan.

References

[1] Al-Salaymeh, A., Zurigat, Y. (2006). A Comprehensive Study of Greenhouse for Agriculture and Water Desalination for Jordan Valley and Red-Dead Sea Region. The 2nd International Conference on Water Resources and Arid Environment, Riyadh, Kingdom of Saudi Arabia, 26 - 29 November, 2006.

[2] Ministry of Water & Irrigation (2004). Environmental and Social Assessment Disi-Mudawarra to Amman Water Conveyance System, Main Report – Part B: Water Sector Assessment, June 2004.

[3] Al-Salihi, A. (October 1999). Water Deficit Expectation in Jordan-A New Prospective; Dirasat, Eng. Sc. Vol. 26, No. 2.

[4] Ministry of Water and Irrigation Water (MWI). (2002). Water Sector Action Plan 2002 –2006.

[5] Government of Jordan. (2002). Water Sector Planning and Associated Investment Program, 2002–2011.

[6] Ministry of Water and Irrigation Water (MWI). (February 2002). Water Sector Planning and Associated Investment Program 2002-2011.

[7] Brown and Root North Africa. (2001): The Water Conveyance System from Disi-Mudawarra to Amman Phase I; Design Review and Optimization Report, Ministry of Water and Irrigation.

[8] Ministry of Water and Irrigation Water (MWI). (1997). Jordan’s Water Strategy. Government of Jordan.

[9] Caro, R. and Eugleson, P.S. (1981). Estimating Aquifer Recharge due to Rainfall. Journal of Hydrology, Vol. 53, pp. 185-211.

[10] Ministry of Water and Irrigation Water (MWI). (1998). Irrigation Water Policy. Government of Jordan.

[11] M. D. Afonso, J. O. Jaber, and M. S. Mohsen, 2004. Brackish groundwater treatment by reverse osmosis in Jordan, Desalination 164, 157-171.

[12] Jordan National Agenda 21 - Pollution, Environmental Management and Public Health Sector – A Plan of Action, 1999. Amman, The Hashemite Kingdom of Jordan.

[13] Scott Wilson Kirikpatrick Consulting Engineers. (2002): Groundwater Resources Evaluation Report Drilling, Completion and Testing of Two Exploratory Wells and One Piezometric Well in Dubydib Area, Ministry of Water and Irrigation.

[14] Haiste Krikpatrick International in Association with Scott Wilson Kirikpatrick Consulting Engineers. (1995): Qa Disi Aquifer Study - Jordan. UK ODA Technical Cooperation Programme and Ministry of Water and Irrigation - Water Authority of Jordan – Final

[15] HARZA GROUP. (1996). The Water Conveyance System from Disi-Mudawarra to Amman Feasibility Study Report Volume 2 – Environmental Impact Assessment. Water Authority of Jordan, Ministry of Water and Irrigation.

[16] HARZA GROUP. (January 1996). The Water Conveyance System from Disi – Mudawarra to Amman – Final Conceptual Study Report –prepared by the Harza Group for the Ministry of Water & Irrigation, Hashemite Kingdom of Jordan.

[17] El-Naser, H. and Gedeon, R. (1996). Hydrochemistry and Isotopic Composition of the Nubian Sandstone Aquifers of the Disi-Mudawarra Area, South of Jordan; *International Atomic Energy Agency-Technical Document No. 890*, pp. 61-74.

[18] Euro-Med Participatory Water Resources Scenarios, (Egypt, Jordan, the West Bank/Gaza) http://www.empowers.info/page/2105