Water Conveyance Systems for Freshwater Deficit Coverage in Jordan and Palestine

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KEY FINDINGS

Covering the projected water deficits in 2050 will require constructing new large-scale hydro-infrastructure and multiplying the capacity of the existing water infrastructure of Jordan and Palestine by about twice and four times, respectively.

It is reasonable to expand primary infrastructure in stages along existing conveyance systems.

Developing alternative water transfer options will allow for more flexibility and security with regards to the water supply situation of the region.

MOTIVATION

By 2050, freshwater quantities of about 1,140 Mio. m^3 per year (Jordan) and 1,040 Mio. m^3 per year (Palestine) will have to be distributed to 11 Jordanian and 6 Palestinian demand clusters (West Bank and Gaza). This amount is 80% (Jordan) and 340 % (Palestine) higher than the 2020 water demands. Most of the water in Jordan is currently produced on national territory, less than 10% is imported (Lake Tiberias). Palestine, in agreement with Israel, covers about 52% of the current freshwater demand from internal sources while 48% are imported. The water deficits in these two countries in 2050 indicate the need for producing an additional 712 Mio. m^3/a (62% of total demand) for Jordan and 605 Mio. m^3/a of water (58% of total demand) for Palestine. The huge increase in water production, as well as the high water demands in 2050, will require a tremendous extension and modernization not only of the conveyance systems but also of the distribution networks. The water infrastructure needs to be expanded according to the population's growth and industrial expansion per demand cluster. As internal water sources, i.e. well yield, are gradually depleting due to overexploitation, and because of the effects of climate change, water scarcity in the region is increasing rapidly. Pragmatic and economic solutions for reliable alternative freshwater sources from Seawater Desalination (SWD) Plants in combination with major conveyance systems must be developed and implemented over the next two to three decades.

METHODOLOGY

The water produced at potential SWD locations on the Rea Sea (Aqaba) and along the Mediterranean Sea needs to be supplied to the demand clusters in Jordan and Palestine which are projected to suffer from significant water deficits in 2035 and 2050. It is expected that some clusters such as the Eastern Cluster, the Jordan Valley, and Aqaba have a surplus of water production, which will continue to be exported to clusters with water gaps. This reduces the amount of water to be provided from the SWD to these benefiting clusters and has been taken into consideration in the analysis of the required conveyance systems. The desalinated water must be transported via newly planned and constructed water transmission systems (WTS) including transmission lines, reservoirs, and pumping stations. The assessment of digitalized network data in GIS in combination with an evaluation of system schematics and inquiries at responsible water companies leads to the identification of relevant conveyance systems and potential routing of the new WTS. The location and capacities of planned SWD on the one hand [On- and Offshore Solutions for Large-Scale Seawater Desalination at the Mediterranean Coast, p. 26], and the water deficit calculations per demand on the other hand determine the needed capacities and routes of the proposed WTS. The sizing of the transmission lines between the SWD plants and the demand centers is based on the required conveyed quantity. The topography, length, and dimension of the pipe will result in the required pump head, and thus energy demand and operational costs. The elevation profile of each WTS is prepared using GIS to determine the length and static head for each system. The friction loss is estimated at about 2 m/km pipe length. The energy consumption per WTS is calculated assuming a 75% system efficiency. The energy requirement in kWh per m^3 conveyed water for each WTS is the key indicator for comparing the systems' efficiencies and operational costs.

Water production and transfer strategies were developed and are detailed in [Water Production and Transfer Strategies, p. 22]. To evaluate the technical feasibility of all strategies, an analysis was carried out using a decision-making matrix comparing different water transfer options required to cover the 2050 water deficits. The three technical criteria taken into consideration are the connectivity to the existing water infrastructure, the technical complexity, and the length of the network, which provides an indication about the duration of hydroinfrastructure implementation.

RESULTS

12 alternative water transfer strategies were assessed with technical criteria. Supplying the West Bank from Netanya or Ashdod requires a shorter network than from Haifa or Gaza, which likely means that the construction time will be lower. Differences in the length of the alternative transfer paths are comparatively lower in Jordan than in Palestine. It could be noted that the cost-minimal option in Jordan has the longest network length hence highest duration of implementation among all transfer strategies. As a tunnel should be built between Haifa and Lake Tiberias, transferring water from Haifa will be more technically challenging as from other desalination plants. The strategies with a direct pipeline between Jenin and Ramallah have a good connectivity to the water distribution infrastructure in the West Bank. Strategies where Central Jordan is supplied by 2 sources rather than just one perform better on the criterion „connectivity to the existing water infrastructure". Supplying the West Bank from a SWD plant in Netanya (strategy 1a) and Jordan from SWD plants in Haifa and Aqaba (strategy 3e) is in technical terms the most feasible option and will be here further described.

The annual freshwater deficit for Jordan is 386 Mio. m^3 for 2035 and 712 Mio. m^3 for 2050 [Future Freshwater Deficits in Palestine and Jordan, p. 18]. The planned Amman Aqaba Water Desalination and Conveyance System (AAWDC), with 300 Mio. m^3 capacity, is planned to be in operation by 2030. Under consideration of the AAWDC, the future freshwater deficits can be covered by conveying 86 Mio. m^3 for 2035 and 412 Mio. m^3 for 2050 from the Haifa SWD. The Palestinian annual freshwater deficit is estimated including the Gaza Strip's water demand. The total deficit amounts for 268 Mio. m^3 for 2035 and 605 Mio. m^3 for 2050. To cover this deficit, Netanya SWD is to convey 156.4 Mio. m^3 to the West Bank by 2035 and 323 Mio. m^3 in 2050. Having the highest deficits of all clusters, the Gaza Strip would be directly supplied from Gaza SWD producing 116.6 Mio. m^3 in 2035 and 287.3 Mio. m^3 in 2050.

Table 1 sums up key technical characteristics of the regional solution to cover freshwater deficits in 2050 in Palestine and Jordan: Jordan would receive desalinated water from Aqaba and Haifa while the West Bank would obtain water from SWD at Netanya. This option, together with potential WTS alternatives, is illustrated in Figure 1.

CONCLUSIONS

Options for expanding the water transfer systems in Jordan and Palestine have been investigated and evaluated in technical terms. The water transfer systems relate to different water production and transfer strategies described in [Water Production and Transfer Strategies, p. 22]. A multi-criteria decision-making tool will support the ranking of these alternatives [Multi-Criteria Analysis of Water Resources Planning Options, p. 80]. The energy demand for producing and conveying 1 m^3 of water to the demand center is a key decision criterion. Therefore, topographical conditions along transfer routes have a major impact on water costs. In contrast, the length of the water transmission network is of minor significance in economic terms. Coordination between the energy and water sectors is required for cost optimization in view of the exorbitant energy requirement for water production and transport on

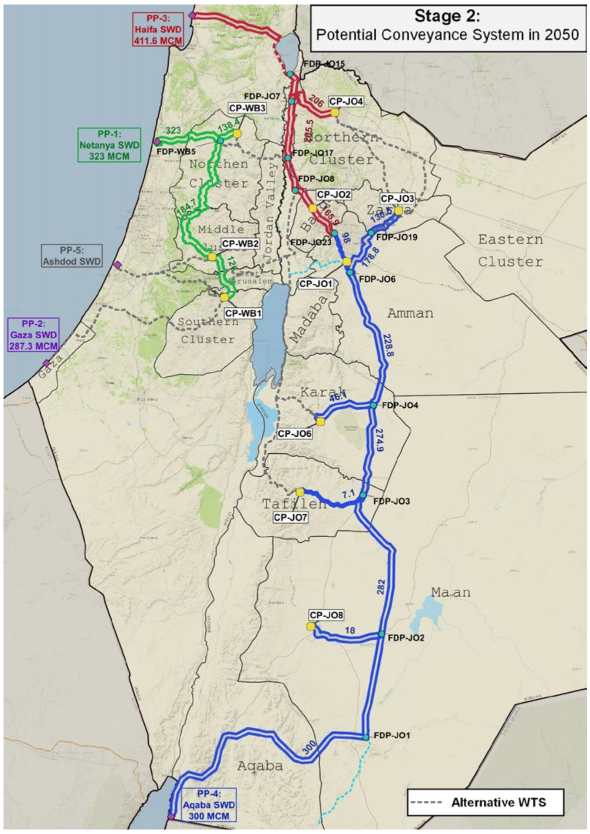

Figure 1: A regional solution to transfer water to the demand clusters in 2050.

the one hand, and the increasing production of renewable energy in the region on the other hand. The expansion of the hydro-infrastructure will require huge investments and operation costs. Current prices for water services are too low to ensure sustainable service provision; the operation of such high-capacity systems will require substantially higher contributions from users. All financing options, including potentials for Private Sector Participation (PSP), should be assessed. PSP considerations need to include social aspects of direct users (ability to pay for water) and complementary public budget implications.

SOURCE	SECTION / BRANCH	SUPPLIED CLUSTER	LENGTH (KM)	2050 FLOW (MIO. M³/A)	DN WTS (MM)
Aqaba SWD (300 Mio. m³/a))	PP-4 to FDP-JO2		190	300,0	2x2000
	FDP-JO2 to CP-JO8	Ma'an	40	**18,0**	700
	FDP-JO2 to FDP-JO3		78	282,0	2x2000
	FDP-JO3 to CP-JO7	Tafilah	39	**7,1**	500
	FDP-JO3 to FDP-JO4		47	274,9	2x2000
	FDP-JO4 to CP-JO6	Karak	34	**46,1**	1200
	FDP-JO4 to FDP-JO6		74	228,8	2x1800
	FDP-JO6 to CP-JO3	Zarqa	47	**130,5**	2x1400
	FDP-JO6 to FDP-JO23	Amman	40	**98,3**	1700
Haifa SWD (412 Mio. m³/a))	FDP-JO15 to FDP-JO7		15	411,6	3x2000
	FDP-JO7 to CP-JO4	NC Jordan	31	**206,0**	2x1700
	FDP-JO7 to FDP-JO8		46	205,6	2x1700
	FDP-JO8 to CP-JO2	Balqa / Amman	14	205,5	2x1700
	CP-JO2 to FDP-JO23	Amman	18	**165,9**	2x1500
Netanya SWD (323 Mio. m³/a))	PP-2a to FDP-WB5		38	323,0	2x2100
	FDP-WB5 to CP-WB3	NC Palestine	11	**138,4**	2x1400
	FDP-WB5 to CP-WB2	MC / SC Palestine	94	184,7	2x1600
	CP-WB2 to CP-WB1	SC Palestine	33	**126,0**	2x1400
Gaza SWD		Gaza		**287,3**	

Notes: PP= Production Point, CP=Cluster Center, FDP=Flow division point, DN=Nominal Diameter (of WTS pipe)

Table 1: Key technical characteristics of the regional solution

TECHNICAL BACKGROUND

The alternative water transmission systems have been technically analyzed with regards to elevation, length, dimension, investment cost, and energy demand for water conveyance. The routing of the conveyors was chosen based on existing water systems, roads to allow for enhanced connectivity and topography. This approach, in combination with the utilization of available capacities of installed systems, reduces capital and operational costs. Costs are also optimized minimizing friction losses by keeping the flow velocity below 1.5 m/s and laying several parallel pipes instead of a single large pipe to allow for gradual expansion (maximum pipe diameter of 2,200 mm).

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Funding code: 02WM1533H

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