International water resources

Some observations on the water resources development and management transition in Israel

Earlier this year, the South African government signed an agreement with Israel to cooperate on national priority issues such as water and the current drought. Eberhard Braune, an Associate Professor at the University of the Western Cape, shares some thoughts on what lessons can be learnt from the way in which this Middle Eastern country manages its water resources.

Water supply and sanitation in Israel are intricately linked to the historical development of the country. Through its geographic and political situation, Israel cannot rely on external sources of water. Because of the limited size of the country and a policy of unlimited Jewish immigration, the country's land and water resources have had to be developed optimally.

The vision of 'turning the desert into a cultivated land' had to be put into practice. The Terra satellite image of the Middle East in Figure 1 shows the lush, green vegetation along the Mediterranean coast and surrounding the Sea of Galilee in northern Israel and stands in marked contrast to the arid landscape all around. More than 240 million trees have already been planted and even the barren hills of the northern Negev are now dotted with a string of miniature oases of greenery.

Figure 1: Terra satellite image of the Middle East –Jan. 2003 (MODIS Rapid Response Team, NASA/GSFC)

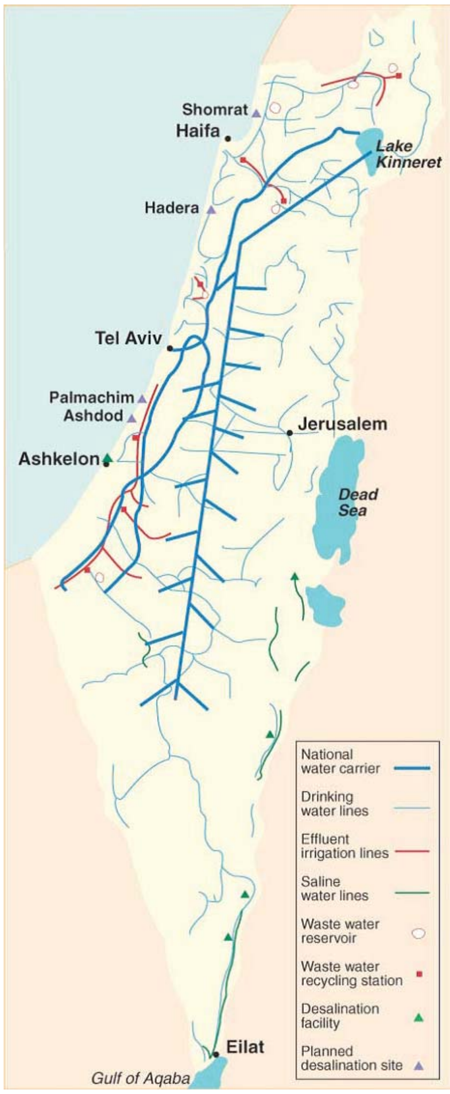

Figure 2: Water supply in Israel (Noah ESS, 2016)

Awareness of water scarcity has prompted a host of innovative solutions. The supply philosophy is the three-reservoir system, a national conjunctive use scheme from the three main reservoirs, i.e. Lake Kinneret (the Sea of Galilee), the Coastal Aquifer and the Mountain Aquifer. The National Water Carrier functions not only as the main supplier of water, but also as an outlet for surplus water from the north in winter and early spring, as well as a source of recharge to the underground aquifers in the coastal region (Figure 2 and Table 1).

The long-term average quantity of replenishable water from major water resources amounts to about 1 800 million m^3/year (see Table 1). The more recent estimate, however, is less than 1 300 million m^3/year, related to declining average rainfall, possibly as a result of climate change.

About 80% of the water resources are located in the North of the country and only 20% in the South. The National Water Carrier (Figure 2), commissioned in 1964, carries water from the Sea of Galilee to the highly populated coastal region and the northern Negev desert through channels, pipes and tunnels.

Table 1: Long-term potential of renewable water

Resource	(million m^3/year)
The Coastal Aquifer	320
The Mountain Aquifer	370
Lake Kinneret (Surface water)	700
Additional regional resources	410
Total Average	1 800

Source: Jewish Virtual Library

The continued expected growth of the urban sector and of the agricultural sector (only with treated wastewater) can be observed from Table 2.

artificially-induced rainfall - cloud seeding; and desalination. The supply philosophy has changed to a five reservoir system, now including treated wastewater and desalinated water.

Aspects of water resources management in Israel

Water policy

In 1959, a comprehensive water law was passed, making water resources public property and regulating water resources exploitation and allocation, as well as pollution prevention and water conservation. Water is a public resource and municipal and regional water corporations have been established to manage water supply to different consumers. Water corporations purchase their entitlements from the central water company (Mekorot) and are legally responsible for their delivery to end users. Entitlements are granted in perpetuity, but conditional upon beneficial use.

Aquifers, a common pool resource, are managed very tightly. All groundwater schemes and single boreholes need a license and this license must be reviewed every year. Recommendations made by the Hydrological Service are based on the state of the aquifer, protection of all users and future plans for the area.

There is now a strong emphasis that water is a commodity. Initial subsidization had to do with the history of the country. The poorest immigrants settled furthest away from any development and could not be punished by giving them more expensive water. They had to be able to compete in the agricultural market and therefore they had to be subsidized. Already in 1977 the feeling in the Water Authority was that the consumer should be subsidized through the end product and not through water and power. This has happened and was a major driver for the water conservation thrust in the agricultural sector and the shift to high-value crops for the export market. Tariffs for the industry and agriculture sectors are planned to gradually increase, until they reflect the full cost of water and subsidies (currently funded by the domestic sector) can be removed.

Table 2: Water consumption per economic sector

Year	Urban	Industry			Agriculture				Supply to regional neighbors	Nature and Landscape		Unforeseeable	Total consumption
	(1) + (4) º	(1)	(2)	Tot.	(1)	(2)	(3)	Tot.		Fresh water	Tolal	(2)	(3)
1977													1500
2010	764	90	30	120	500	144	400	1044	143	10	60	0	2131
2020	902	95	30	125	490	120	528	1138	143	50	95	70	2672
2050	1482	108	30	138	450	100	900	1450	143	50	80	278	3571

By about 1980 Israel had reached the potential of their conventional water resources. Successive years of drought from 1998–2002 and again in 2008 had dramatically lowered water levels in all of the main reservoirs. 1998–1999 was the worst drought year in Israel for the past 100 years. After drawing on nearly all of its readily available water resources and promoting vigorous conservation programs, Israel has embarked on a national mission to stretch existing sources by developing non-conventional water sources, while promoting conservation. These efforts have focused on the following: reclaimed wastewater effluents; intercepted runoff and artificial recharge;

Recent water reforms, aimed to raise efficiency levels, stress holistic water management at a local level and make cooperation between national policy makers, local water utilities and end users, like farmers, essential. They have also required the change from using municipalities as local water managers to creating local water utilities that have the capacity to do holistic management.

The serious and persistent drought of the last decade and the resulting crises experienced by the Israeli water system has highlighted the need for strategic targets and the development of a long term master plan addressing water infrastructure in general, and the water sector in particular. The establishment of a 'National Planning Council' is now seen of great importance (State of Israel, 2012). The planned establishment of a national infrastructure coordination committee (water, gas, transportation, electricity) emphasizes the strategic nature of the water infrastructure.

Water infrastructure
The national water system constitutes a strategic infrastructure in Israel, and a crucial factor in its development and the realization of its national goals.

The state-owned National Water Company (Mekorot) is responsible for bulk water supply through the National Water Carrier. Mekorot supplies 70% of Israel's entire water supply and 80% of its drinking water. It supplies water to about 4,800 intermediary water providers, including municipalities, regional associations, agricultural settlements and industrial consumers. It also operates 31 desalination plants. The company's eight wastewater treatment plants, including the Dan Regional Wastewater Treatment Plant, treat 40% of all Israel's wastewater. Its nine reclamation plants enable 70% of the treated effluent to be reused for agriculture.

A new National Water System is being developed since 2009 with several east-west arteries relying on pumping, complementing and partly substituting the north-south National Water Carrier, which relies on gravity (Figure 2). The new pipelines are connecting the five new desalination plants along the coast with water users. When completed, most drinking water supplied to Israel's residents would come from desalinated seawater. This is in line with the climate change mitigation policy of deployment of a water network seeking to mitigate differences within and between areas.

Water Conservation and Water Use Efficiency
Public water conservation campaigns coupled with technical and economic measures are being applied to reduce consumption and to increase awareness of water scarcity in all sectors. In agriculture, the wide scale adoption of low volume irrigation systems (e.g. from furrow to drip and micro-sprinklers and increasingly to greenhouses) and automation has increased the average efficiency to 90% as compared to 64% for furrow irrigation. As a result, the average requirement of water per unit of land area has decreased from 8,700 m^3/ha in 1975 to the current application rate of 5,500 m^3/ha. At the same time agricultural output has increased twelve fold, while total water consumption by the sector has remained almost constant.

Marginal areas also need development of marginal water supplies e.g. brackish water in the Negev desert accessed with deep boreholes (500m to a maximum of 1200m). Under conditions of minimum and poor quality water use, every effort must be made to reduce the build-up of salts in the soil. The most innovative but costly solution has been a channel filled with just enough soil for production, which is replaced whenever measurement indicate a loss in capacity, e.g. once a year. Such higher production costs are only economically justifiable with high value crops, largely for export (olives, water melon, salmon and wine).

By now 75% of wastewater is treated and later re-used, mainly for agriculture. Treated wastewater is also for industry, gardening, etc. Replacing the use of freshwater with treated wastewater helps to address inter-annual and inter-seasonal variability and to build resilience to climate change. Tariffs vary among treatment facilities. The payment they receive for each cubic meter is significantly higher in summer than winter.

In the domestic and urban sectors, conservation efforts focus on improvements in efficiency, resource management, repair, control and monitoring of municipal water systems. The slogan "Don't waste a drop" is known in every home in Israel. Parks have been placed under a conservation regime, including planting of drought-resistant plants and watering at night. A major concern is that urban distribution networks have not been upgraded in the last 20 years and that up to 40% water losses are occurring in water distribution networks. Under the umbrella of a strong R&D focus, various companies have introduced major technology advances like statistical analysis of existing pipe flow data to detect deviations, airborne leak detection and closing of pinhole leaks without requiring pipeline shutdown and excavation.
In a city-wide project (Jerusalem) presently underway, every segment of pipe network is monitored to detect the smallest of leaks and respond with preventative maintenance.

Treated wastewater
Increasing quantities of sewage water have been finding their way into the environment, endangering groundwater and other sources of fresh water. The pressing need to find alternate sources of water, together with the critical condition of the environment, led the Water Commission to develop the Shafdan plant in 1969, a large-scale project for treating approximately 130 million cubic meters of wastewater per year for reuse in agriculture. About 110 million cubic meters of this purified water is transported annually via a separate pipeline called the 'Third Negev Pipeline' to the western Negev for use in irrigation. Thanks to the high degree of purification of the treated water, it can be used for all crops without risk to health.

However, wastewater from other cities and towns remained largely untreated. In 1970 there was a cholera outbreak because of illegal irrigation of salad with untreated wastewater. This gave rise to major investments in wastewater treatment under the National Sewerage Plan, which emphasised the reuse of treated wastewater. Smaller-scale plants all over the country provide treated sewage water for irrigation of fields located a short distance from the source of the effluent. In many cases treatment is minimal, and use of the treated water is restricted to crops such as cotton in summer. Small projects of this type are reported to be highly cost-effective. It is expected that most of the water allocated for agriculture will eventually consist of purified effluents, so that quality fresh water can eventually be shifted from agricultural to domestic uses.

Artificial groundwater recharge
Artificial groundwater recharge is practiced extensively in Israel, using flood water, potable water from the National Water Carrier and treated wastewater. Artificial recharge has increased groundwater levels in the Coastal Aquifer and counteracted further seawater intrusion. Groundwater recharge from flood water is done by collecting runoff from winter rains in a drainage basin and directing it into recharge ponds. The groundwater is then pumped during summer through wells around the

recharge ponds. About 40–50% more water than the average natural recharge is pumped from the aquifer in order to create a temporary hydrological depression and space for artificial recharge the following winter. The largest recharge plant in Israel is the Menashe plant in the Northern coastal plain, capturing about 12 million m^3 in an average year from a drainage basin of 189 km^2.

Desalination

Seawater and brackish water are expected to provide a third of total water demand in Israel by 2020. At present, desalination already accounts for 80% of drinking water in Israel and also across the border in Jordan. There are three large Reverse Osmosis plants along the Mediterranean, one of them the biggest in the world, all developed in last 10 years.

In 1997, the first reverse osmosis desalination plant in Israel was commissioned in Eilat. In 2002, facing the serious drought situation, the government approved the construction of large seawater desalination plants along the Mediterranean coast. These installations were to supply 305 million m3/year of desalinated water by 2010 and 500 million m^3/year by 2015. This development has been accompanied by major technology research. It allowed IDE Technologies to build the world's largest sea water reverse osmosis plant in Ashkelon and some 400 plants in 40 countries across the world. Considerable work has been carried out on cost and energy saving modular designs and lower outlays for equipment and maintenance.

In addition to these large plants, there are around 30 small mostly brackish water desalination plants that desalinate about 30 million m3/year. Most of these installations are in the Arava and the Negev. Some plants are intended to help rehabilitating the southern part of the coastal aquifer, which has been adversely affected by salinity due to over-extraction.

New infrastructure of dams for storm runoff and reclaimed waste water

To be able to utilize flood runoff and recycled water beneficially, requires local storage and distribution networks. Country-wide some 230 new reservoirs have been constructed to impound runoff, floodwaters and recycled water and provide the water largely to nearby agricultural developments. Over time, each dam will have its agricultural water users, including fish farming. Water not required by consumers is recharged into aquifers, where available, through spreading basins and dual-purpose wells.

A new research emphasis is the management of these storages to utilize the water beneficially and minimize evaporation. The largest roof-covered reservoir has recently been built. A patent has been taken out for novel two piece balls, which, when covering a surface, prevent evaporation, lower the water temperature and reduce algal growth. They have been used extensively by Mekorot since 2011. Smart solutions regarding covering of open surfaces won the Prime Ministers Award for Innovation.

Rainfall enhancement

Cloud seeding for rainfall enhancement, both experimental and operational, has been carried out in Israel since 1960. As part of holistic water management, Israel is continuing with operational programmes of weather modification for managing the local atmospheric level, in particular over open water surfaces. The technology has shifted from cloud seeding via aircraft or rocket to the Russian ionization technology (ion generation from antennas on the surface which attach to condensation nuclei in the clouds and enhance the rate of droplet coalescence).

International water

In the present state of hostilities, the Water Commission with Palestine is the only transboundary instrument still in place. Diversion of over 90% of the water of the Jordan River by Israel, Jordan and Syria has resulted in the water level in the Dead Sea shrinking at a rate of more than one meter per year and its surface area shrinking by about 30% in the last 20 years. This is creating major environmental problems.

A solution under consideration is the Red Sea–Dead Sea Canal, a proposed conduit (pipes and brine canal) which would run from the Red Sea to the Dead Sea. It will provide potable water to Jordan, Israel and the Palestinian territories, bring sea water to stabilize the Dead Sea water level and generate electricity to support the energy needs of the project (Wikipedia). However, lack of trans-boundary cooperation is still hampering any resolution of this major environmental issue (Saab, 2010).

Research

Israel is one of the top R&D spenders per capita internationally, with 4.2% of GDP, compared to the United States' 2.8% and Germany's 2.9% in 2013 (Siegel, 2015). A number of R&D platforms have been created in Israel to encourage and promote R&D leading to industrial application. The Office of the Chief Scientist (OCS) of the Ministry of Industry, Trade and Labor is responsible for implementing the government's policy of encouraging and supporting industrial research and development in Israel through the Law for the Encouragement of Industrial R&D.

Water is regularly receiving innovation funding. The priority for water R&D was recently captured in a government policy statement: The Israeli water system will be a global center for technologies and innovation in professional areas of the water industry, and a groundbreaking example of managing water resources under conditions of shortage.

The Zuckerberg Institute for Water Research, founded in 2002, as part of the Ben-Gurion University of the Negev, links to the founding mission to spearhead development of Israel's southern region while taking its place in the global scientific community. A unique Masters curriculum in "Hydrology and Water Quality" was developed to meet the increasing need for hydrologists, water engineers, and water planners in Israel, the Middle East, and other places around the world. The program is founded on an interdisciplinary approach through the integration of science with engineering.

Outlook

South Africa and Israel have similarities in their physical environment and, despite the very different political and socio-economic conditions, they face similar water resources challenges. Paying attention to issues, approaches, successes and failures in Israel's water and development history, can provide pointers for the challenging water transition in South Africa in coming years.

References available on request