Israel Water Context

1. Abstract – Introduction

Israel is a modern state that has a developed, efficient and reliable water economy. The water management of the state is based mainly on rains falling during the winter in the northern half of the country where a Mediterranean Sea climate prevails. The rainwater fills Lake Kinneret, which is in the north of Israel, and the groundwater reservoirs in the center of the country. Against this, in the southern half of the country a dry desert climate prevails as a result of Israel's location bordering the world desert belt. The water required throughout the country for drinking and for agriculture is transported through various water projects from the more rainy north to the arid southern part.

The three large water sources are the mountain aquifer, the coastal aquifer and Lake Kinneret. Small aquifers and exploitation of surface water constitute other sources. With the increase in the consumption of water and the exhausting of the natural water potential, other sources have been developed in Israel – desalination and purification of sewage waters.

2. Geographic Background

The Country

Israel is located in the southeastern basin of the Mediterranean Sea, between the Mediterranean Sea (in the west), Egypt (in the southwest), Jordan and Syria (in the east) and Lebanon (in the north). (click here to see map).

It comprises an area of 28,000 km^2 (of which around 6000 km^2 is in Judea and Samaria), extending over a long and narrow strip. Its length from north to south is around 430 km; its average width in the northern and central part ranges between -70 and -100 km and in its southern half it narrows down to its southernmost point, at Elat.

The country is divided into several geographic districts, from west to east: the coastal plain; the Shefela (foothills), the mountain strip; and the rift valley. The coastal plain is a low flat region, extending from the Mediterranean Sea coast eastward, over a strip that broadens towards the south from about 5 km in the north to about 20 km in the south. The climate in this area is moderate and moist because of its proximity to the sea. The region is built of calcareous sandstone (locally named kurkar) and sand of Pleistocene age, which constitute the coastal aquifer.

The Shefela foothills district, to the east of the coastal plain, is a region of moderate to hilly (up to a height of 300 m) topography. It is built of soft carbonate rocks and of a young alluvium cover in which there are broad agricultural areas. The Shefela is also wide in the south, narrowing greatly in the north of the country.

The mountain strip cuts across the entire length of Israel, from the Galilee in the north to the central Negev in the south. This mountainous district lies at an altitude of 700-00 m, with peaks at Mount Meron (1208+ m), Mount Ba'al Hazor (1016+ m) and Mount Ramon (1035+ m), and hence the temperatures in the region are also lower than in the rest of the districts. The strip of mountains is actually the heart of an anticline whose axis is oriented north-south. Exposed at the heart of the anticline are limestone and dolomite rocks of Cenomanian-Turonian age, which constitute an excellent aquifer. These rocks are covered by a thick layer of younger impermeable rocks (aquiclude) that are exposed on both sides of the anticline, though are particularly thick in the Shefela.

The Jordan Valley is a narrow valley that formed as a result of tectonic movements of geologic plates. The Jordan River flows in the valley, beginning at its sources, flowing from the slopes of Mount Hermon, through Lake Kinneret, at a -210 m altitude, down to the Dead Sea at -400 m below sea level (the lowest place on earth!). The climate in the rift valley is hotter and drier than in the other districts in the country. In the north, rising beyond the rift is Mount Hermon (the highest mountain in Israel, 2224+ m) and the basalt plateau in the Golan. In the center of the country, between the mountain strip and the rift, lies the Judea Desert in which hot and dry conditions prevail as it falls in the " rain shadow" – that is, the clouds arriving from the west rain down most of the water collected in them while rising to the mountain ridge, and after passing the water divide, dropping relatively little rain..

The climate in most of Israel is Mediterranean – a long, clear, hot and dry summer, a cloudy, cold and rainy winter (the rains) – which is dictated by the proximity of the country to the Mediterranean Sea. In the mountains in the north of the country precipitation is around 900 mm per year, in the centre, around 600 mm/yr, whereas in the south of the country it is less than 20 mm/yr. A 200 mm/yr isohyet (a line of equal rainfall) passing close to Beer Sheva, divides the country into two parts – the north, in which there is natural vegetation and non-irrigated crops, and the Judea Desert and the south that are dry, and is thus called the "desert boundary." The southern half of Israel is part of the world desert belt (latitude 20-40) and there, with its distancing from the Mediterranean Sea, the climate becomes arid and dry.

The natural manifestation of the climatic differences is the development of different phytogeographic provinces (vegetation provinces). Four phytogeographic provinces meet in Israel: the Mediterranean, the Irano-Turanian, the Saharo-Arabic, and the Sudanic. The Mediterranean province spreads across the northern part of Israel, to Ashqelon and to the southern Judea Mountains. Formerly, the area was covered with natural forests of oak, terebinth, and carob trees, etc., but today, the natural vegetation has almost disappeared. In its place many pine groves were planted and lower vegetation, such as spiny broom (*Calicotome villosa*), sage (*Salvia*), rockrose (*Cistus*), prickly burnet (*Sarcopoterium spinosum*), and more, has spread. The Irano-Turanian province includes the Hermon, the Jordan Valley, the Judea Desert and the north and central Negev. These regions are characterized by more extreme climatic conditions – by both a cold winter and a hot summer. The natural vegetation constitutes low bushes such as lotus jujube (Zi*ziphus lotus*), white wormwood (*Artemisia sieberi*), and more. In the south of the country some large Atlantic terebinth trees, remnants of different climatic conditions in the historic past, have even been preserved. The Saharo-Arabic province includes the Judea Desert and the Negev that are characterized by a very short rainy season with comfortable temperatures and a very long, dry, hot season. The amounts of rain are not sufficient to sustain vegetation, except in the channels and in the depressions that drain the water. The Sudanic province includes a small part of the southern Arava, and it is characterized by plants that adapt to insignificant amounts of precipitation.

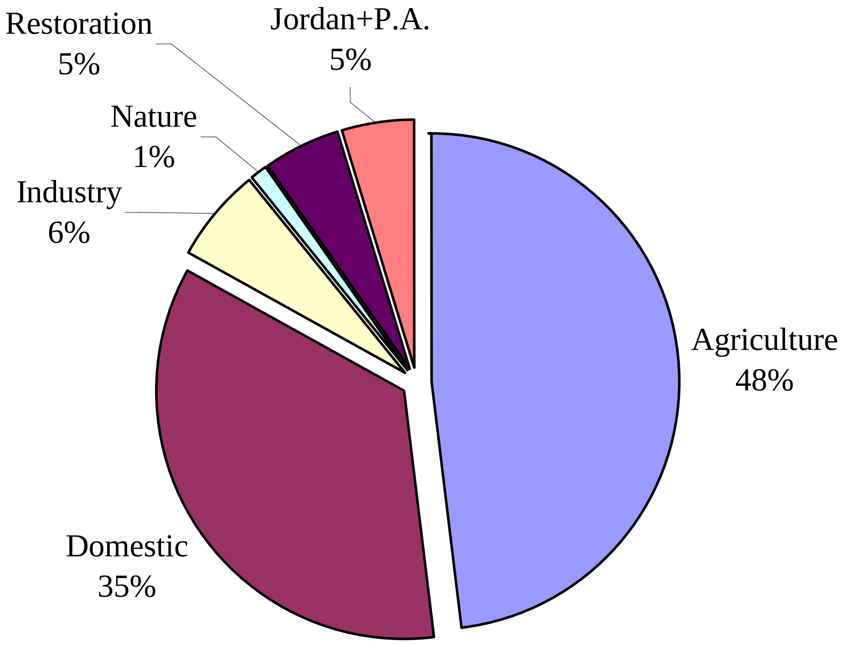
The Population

The population of Israel numbers around 6.9 million persons, around 6.3 million (92%) of them living in urban settlements. Around two-thirds of the population and most of the industrial plants and commercial centers are concentrated in the coastal plain, from Akko (Acre) in the north to Ashqelon in the south. Other cities are spread further inland, the largest among them: Jerusalem, Rehovot, Beer Sheva, Modi'in and Karmiel.

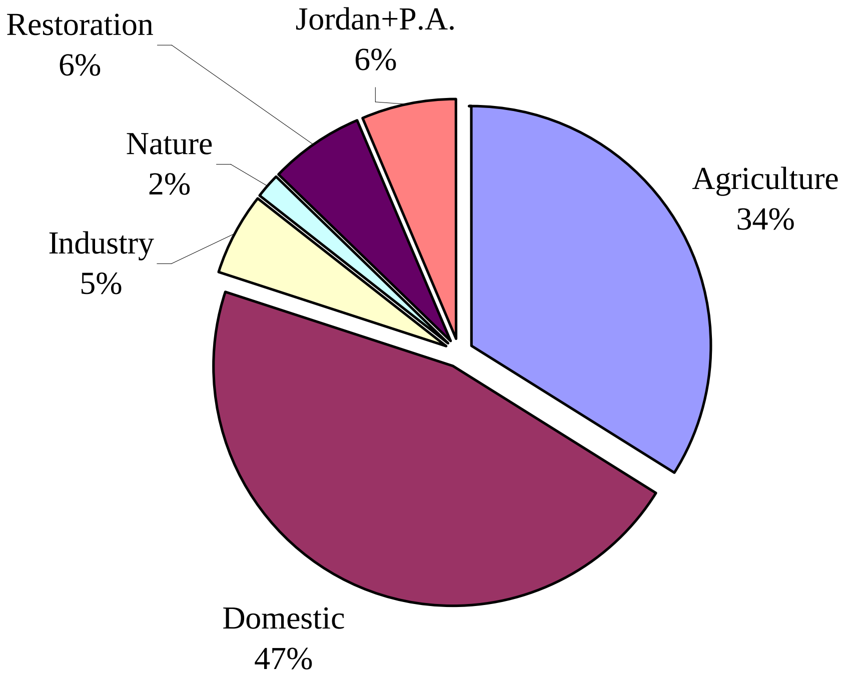
3. Water Consumption

The total water consumption in Israel grew drastically in the second half of the 20^{th} century, from ~230 million m^3/yr in 1948 to ~2060 million m^3/yr today. Half the total consumption demand is from the agricultural sector, mainly for irrigation. The remaining demand comes from the domestic-urban sector (720 million m^3/yr) and from the industrial sector (120 million m^3/yr). The remainder is devoted to restoration of the aquifer (100 million m^3/yr), and according to law, is allocated to the Kingdom of Jordan and the Palestinian Authority (100 million m^3/yr), and to the continuing maintenance of the natural plant habitat of the country (25 million m^3/yr). An additional amount of water (~30 million m^3/yr), which is not included in the total consumption, leaks from the coastal aquifers naturally to the Mediterranean Sea, preventing intrusion of saline water to these aquifers.

The total consumption in Israel is supplied at various water qualities, in accord with the demand of each and every sector and the decentralization capability of the water transport systems. The demand for potable (drinking) water constitutes around 75% of the total consumption. Most of the drinking water is supplied to the domestic-urban sector (720 million m^3/yr) and to the agricultural sector (530-560 million m^3/yr). Many industrial plants are found near concentrations of the population and therefore they too use the potable water (85 million m^3/yr). The quality of the potable water supplied to all the sectors meets the strict standards set by the Israeli Ministry of Health, in accord with the scientific and technological progress in the world. The demand for purified water constitutes around 15% of the total consumption and is supplied only to the agricultural sector. The demand for saline water constitutes around 10% of the total consumption and is supplied to agriculture for resistant agricultural crops (160 million m^3/yr) and to the large chemical plants in the Negev and at the Dead Sea (40 million m^3/yr).



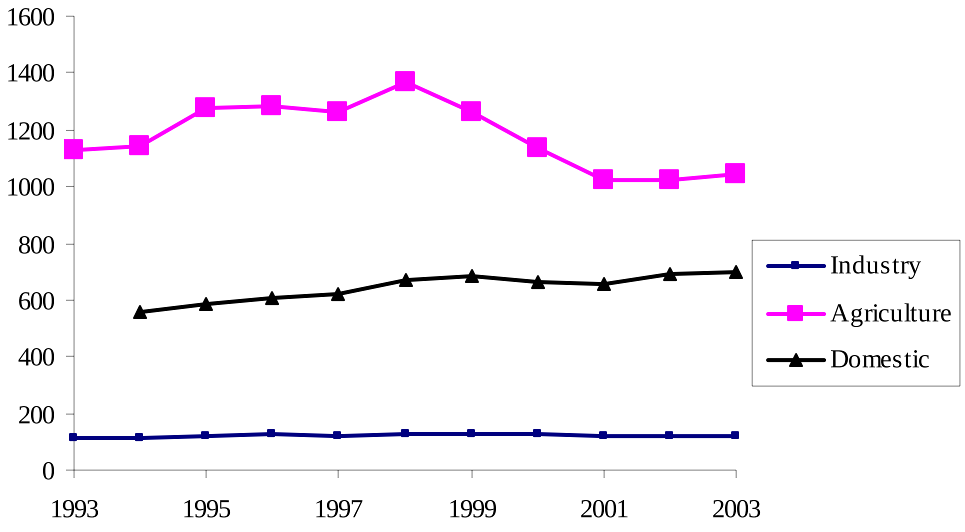
Distribution of the total water consumption, according to use.



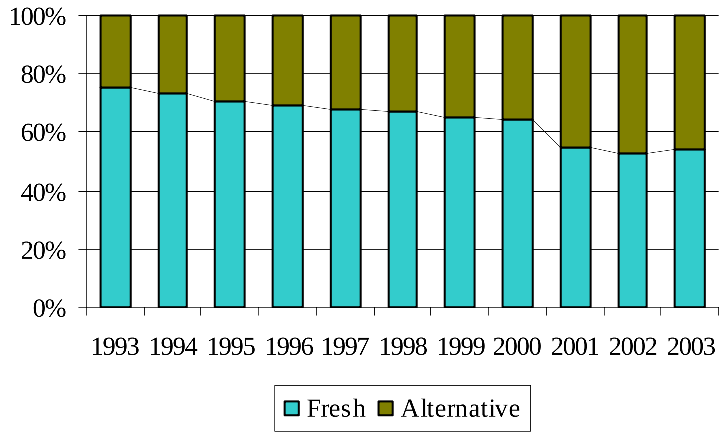
Distribution of potable water consumption according to use.

Fluctuations occurred in the demand for water in the different sectors in the course of the years. Consumption of the industrial sector steadily rose slowly, from ~40 million m^3/yr in the 1960s up to ~120 million m^3/yr today. The consumption of the domestic-urban sector also rose steadily as a result of the growth in population and the rise in standard of living. In 1997 the domestic consumption was ~600 million m^3/yr and it rose to ~720 million m^3/yr today. The consumption of the agricultural sector changes in accord with the expansion of agricultural areas, on the one hand, and with the cuts in the water allocations because of economic considerations or operations, on the other. In the last two decades many agricultural areas and the transport systems to them were converted to irrigation with saline or purified water. As evidence, despite being the largest consumer of water in the country, the agricultural sector is only the second largest consumer of drinking- quality water,. In the northern Negev, for example, the purified water constitutes around 70% of all the irrigation water.

On the whole, total water consumption in Israel increased, beginning in the 1990s, by about 30-50 million m^3/yr, and is expected to reach ~2800 million m^3/yr in the year 2020.



The change in annual consumption in the main sectors (agriculture, domestic, industrial) between 1993 and 2003.

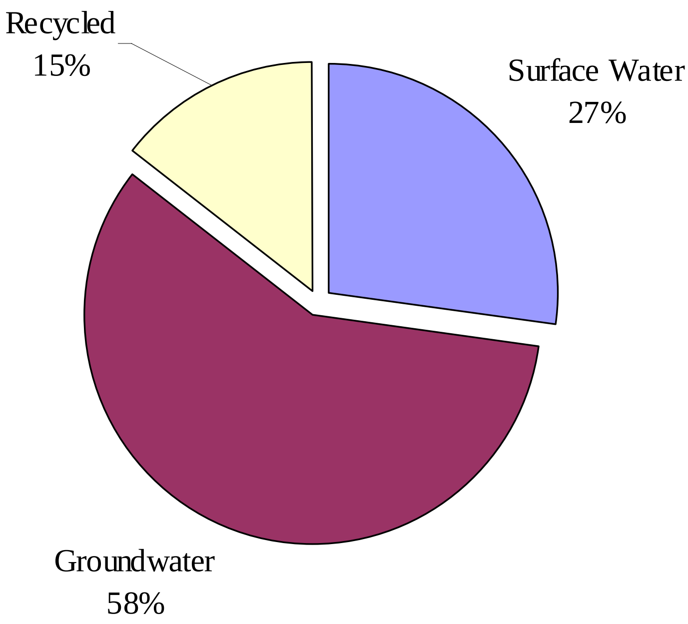


Distribution of water consumption of the agricultural sector by water quality, 1993-2003.

The adaptable consumption of water per person, that is, the total consumption minus the agricultural and industrial consumption divided by the number of residents in the country, has been stable for at least around ten years and is estimated to be around 105 m^3 per person per year. This volume includes within it also the allocation of water given to the local authorities for many uses in their areas (amortization, municipal irrigation, swimming pools, fire extinguishing, etc.). The adaptable consumption of water for domiciles only is lower and is estimated as ~60 m^3/yr per person.

4. The Water Sources

The Israeli water economy, which today consumes ~2000 million m^3/yr, relies mainly (85%) on natural water sources – surface waters (~560 million m^3/yr) and groundwater (~1200 million m^3/yr). However, with the increase in demand for water, and in view of the full exploitation of the natural sources of water, a need to find other sources was created. Thus, purified sewage waters that are utilized for the agricultural sector (15%) and a scant amount of desalinized waters from various sources are exploited. Beginning in 2005, a large amount of desalinized water from the Mediterranean Sea is also being supplied, which according to the forecast will constitute around 22% of the water consumption foreseen in 2020.



Distribution of the water sources of the Israeli water economy according to type (before the beginning of desalinization).

Surface Water

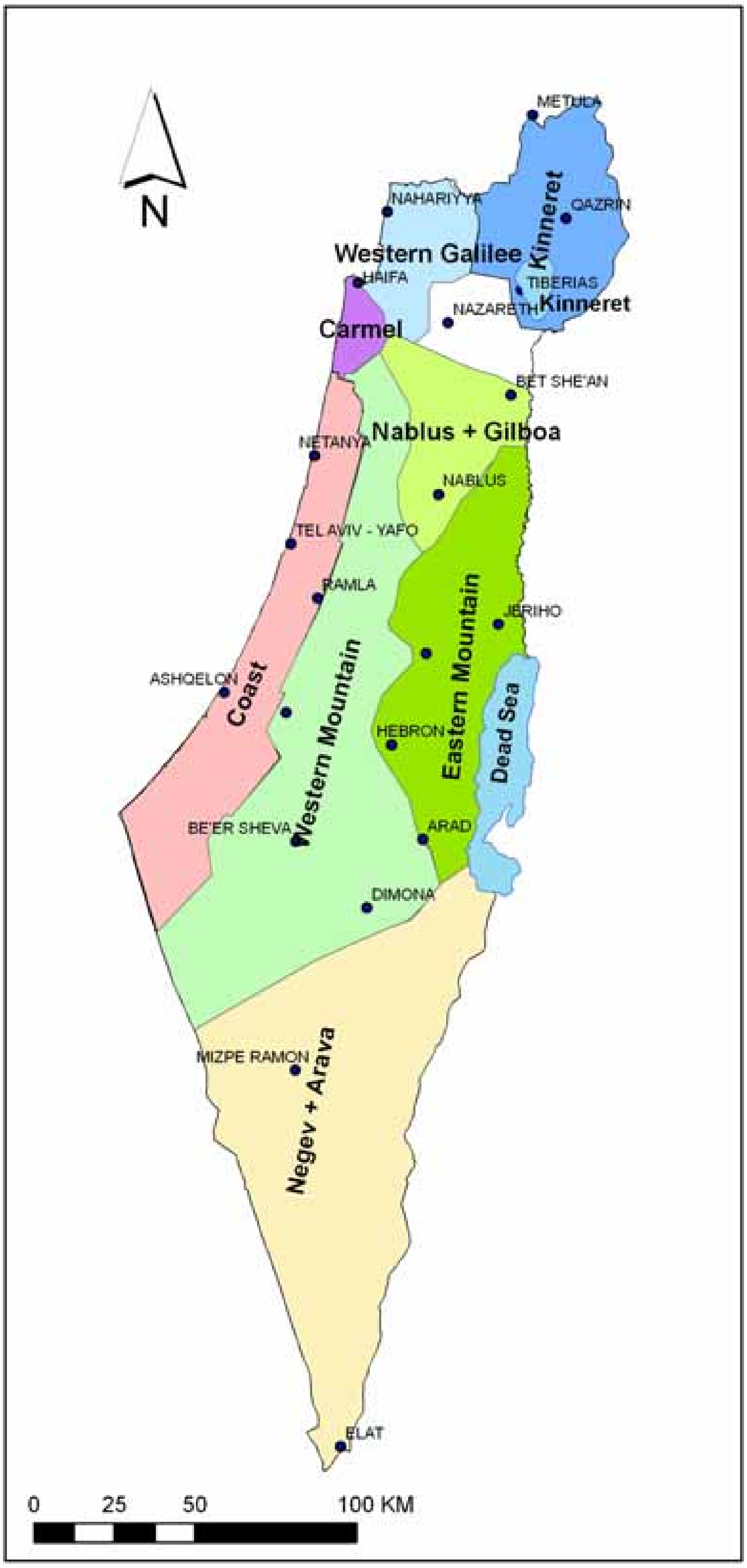
Surface waters are mainly exploited in northern Israel, in the catchment basin of Lake Kinneret. The surface waters flow from the Galilee and Golan mountains to the northern part of the Jordan River (~460 million m^3/yr) and to Lake Kinneret, lying at an altitude of -200 m. It should be noted that the amounts of surface water depends directly on the amounts of precipitation each year, and therefore there are large perennial changes. From the Kinneret the waters are pumped to the national water carrier, which transports the water westward and southward, regulating the supply on its way by means of large reservoirs. The quality of the water of the

Kinneret basin is good to medium, but requires mechanical, biological and chemical treatment to bring it up to drinking-water standard.

In a large number of the streams flowing to the Mediterranean Sea and to the Dead Sea the floodwaters (the winter swellings) are collected and exploited. In the Taninim stream, for example, around 2/3 of the surface runoff water (~12 million m^3/yr out of ~18 million m^3/yr) is caught, and penetrated through boreholes into the coastal aquifer in order to enrich it. The quality of the waters in the reservoirs is medium to poor, and their use is accordingly limited to agriculture and to enriching the aquifers.

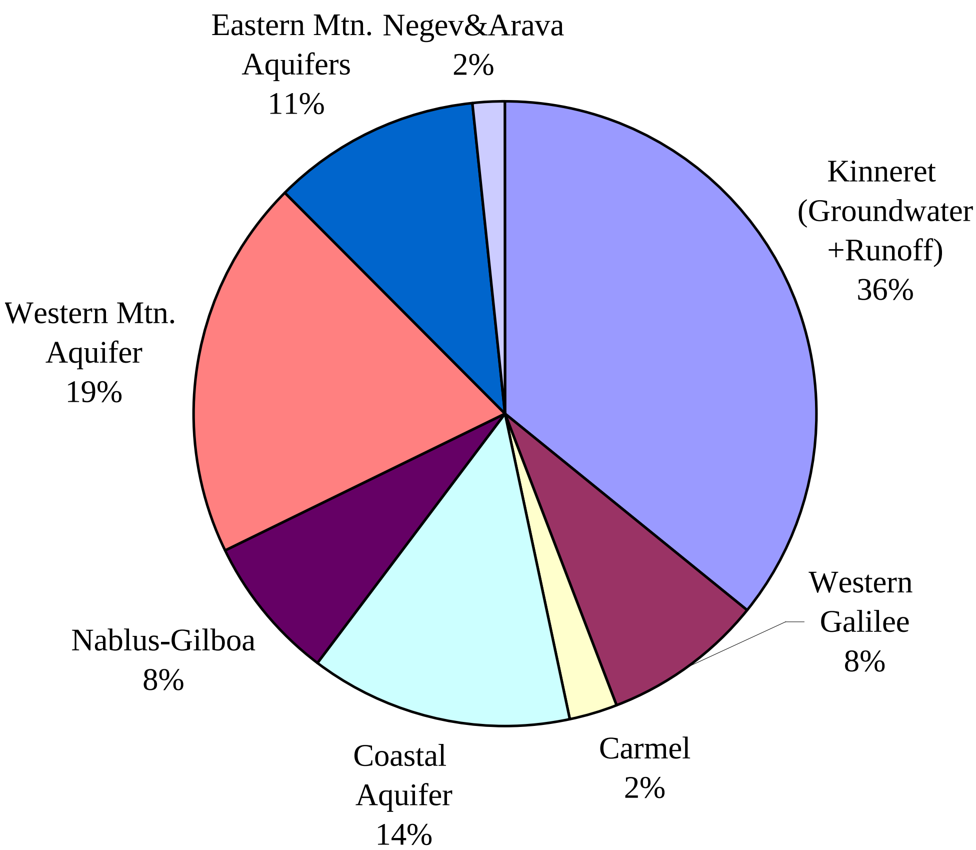
Groundwater

The main groundwater reservoirs (aquifers) of Israel are the coastal aquifer and the mountain aquifer. The mountain aquifer is divided into a number of basins: Shekhem (Nablus)-Gilboa; Yarqon-Taninim; and the eastern mountain basins. In addition to these there are several smaller basins (from north to south): eastern Galilee and Golan (Kinneret); western Galilee; Karmel (Carmel); and Negev-Arava. The flow direction in each of these basins is dictated by the geologic structure and end drainage: the Jordan Valley in the east or the Mediterranean Sea in the west.



Map of the main groundwater basins.

Exploitation of the groundwater from the aquifers is based on the perennial forecast, and thus it is relatively stable. The waters are exploited through many boreholes, most of them by the national water company "Mekorot," and the rest of them, by private wells. The quality of the groundwater is for the most part high to very high, and is of drinking quality after chlorination and fluorination (addition of chlorine to purify the water and the addition of fluorine for dental health), as required by law. In the 1990s there was a decline in both the quality and in the level of the water in some of the aquifers, and today the Water Commission is carrying out a plan to rehabilitate them.



Average annual recharge to each of the different basins.

Reuse of treated water

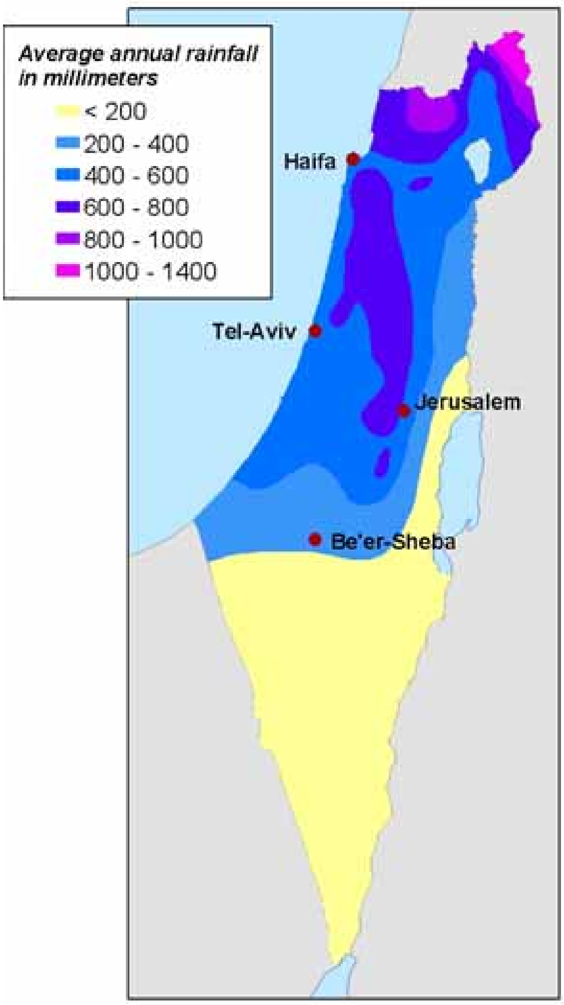
The state of Israel is numbered among the countries in which purified sewage water is intensive. Today, around 40% of the domestic-urban sector consumption is restored (recycled), whereas the maximum exploitation potential is around 60-65% of the consumption. Most of the treated water is supplied to agriculture, and a little of it, that of a good quality and up to the standard, is discharged to nature. Treatment of the sewage is carried out in more than 120 purification plants that are scattered throughout the country, the newer ones using the reactive sludge method. The largest plant is located close to Rishon LeZiyyon and recycles the sewage for the Dan metropolitan area, in which around 1.5 million inhabitants live, and industrial sewage in the range of ~10 million m^3/yr. Additional large plants recycle the sewage of Haifa (~40 million m^3/yr) and Jerusalem (~20 million m^3/yr). The restored purified sewage water must meet the standards of the Ministry of Health and today its quality is considered only good for irrigation. This water is transported through separate pipelines to the agricultural areas.

Desalinization

Up to the year 2005 water was desalinized only for local use and in minimal quantities, except by the desalinization installation in the city of Elat. Beginning in 2005, desalinization of water from the Mediterranean Sea was also started on a large scale, in one of four installations planned at this stage. The volume of annual production from the four installations is expected to reach ~300 million m^3/yr, that is, an addition of around 14% to the water economy of Israel.

5. Rainfall

In Israel, where the Mediterranean climate prevails, rains fall only in the winter, which extends from November until March-April. The source of most of the winter rains is in the barometric lows that move across the Mediterranean Sea from west to east. The lows, which are accompanied by clouds saturated with water, reach Israel on average once a week. The rains fall generally for three days in the north, two days in the center and one day (if at all) in the south. In the transition season the frequency of the lows decreases and the duration of their effect is shortened. On average, around 13-14 rainstorms occur in Israel every year, and the number of rainy days ranges from 70 in the north of the country to only a few days in the south.



Average annual precipitation, 1961-1990
(after the Meteorological Service, 1990).

In addition to the regional climatic system, the amount of rain in every region is also influenced by local characteristics such as proximity to the sea, altitude, aspect, and latitudes: the amount of precipitation increases with proximity to the sea, in the slopes facing westward, with the increase in latitude and in altitude. The largest amount of rain – up to 1300 mm/yr, is measured at Mount Hermon, the highest of Israel's mountains (2224+ m). Large amounts (700-900 mm) are measured in the Golan and the Galilee mountains and in the south Karmel (Carmel). In the Samarian, Jerusalem and Hebron mountains around 550-650 mm/yr are measured. In all of these regions one or two snowstorms a year are even possible. Small amounts of 300-400 mm/yr are measured in the northern part of the Jordan Valley. In the coastal plain the rain thickness ranges between ~600mm/yr in the north and ~300 mm in the south. A 200 mm isohyet, which denotes the "desert boundary", crosses the country from the sea in the west to west of Beer Sheva, where it takes a turn northward in the direction of the rift. The "desert boundary" separates the region with vegetation to the north of it from the dry region to the south. In the south of the Negev and in the Elat mountains amounts of rain even lower than 25 mm/yr are measured. The total volume of rainwater is, on average, ~7,900 million m^3/yr, and ranges from12,000 million m^3 in the very rainy years to less than 4,000 million m^3 in the dry years. Most of the water (around 70%) evaporates back to the atmosphere, and only around 30% (about 2,400 million m^3) is available to exploit, either as runoff in the streams or as groundwater.

Despite what is stated above, the amounts of rain change greatly from year to year. In rainy years the amounts of precipitation measured are double relative to the perennial average, and in dry years the amounts reach even less than half the average. In the past, several successive dry years occurred which, following the paucity of rain, resulted in low recharge to the aquifers and a resultant drop in the water levels there. The Israeli water economy must hence prepare also for a reliable supply of water under dry climatic conditions. This is being done by a perennial plan and collection of "surplus" water in rainy years, mainly in the coastal aquifer, for use in dry years.

6. Surface Water

The surface water constitutes around 30% of the natural water in Israel, and its average contribution is estimated as around 550 million m^3/yr. The amount of surface water depends directly on the amount of precipitation and its distribution in the course of the season. Since the amounts of precipitation are very different from year to year, so are the amounts of surface runoff, and therefore it is more difficult to predict the potential of surface water each year or to rely on it exclusively.

The surface waters can be divided into constant flows and to flood flows. Constant flows (in perennial streams) occur only in channels fed by permanent subsurface water sources, and therefore these flow all year round. Flood flows (winter swelling) are flows that occur at the time and immediately after rainstorms, and have a high intensity that rapidly dies out. In Israel there are very few perennial streams and most of them are concentrated in the Kinneret basin; the largest of them is the Jordan River. Many streams, both long and short are ephemeral and flow only in the winter season and drain only the flood flows.

The surface runoff flows on the surface in streams and in winter swellings and are drained in accord with the topography. The primary water divide, which crosses Israel from north to south on the central mountain ridge, separates the flows to two main drainage basins. The area to the west of the water divide is drained to the Mediterranean Sea; and, except for the most southern part, which drains to the Red Sea, the area to the east of the water divide drains to the Dead Sea.

The regions that are drained to the Mediterranean Sea constitute an area of around 11,400 km^2. The surface runoff in this area is estimated to be ~200 million m^3/yr, flowing in approximately 20 main streams. Most of the water flows to the sea and a minor part of it is exploited in reservoirs. The largest streams are the Yarqon in the Tel Aviv area (50 million m^3/yr) and the Qishon in the Haifa Bay area (30 million m^3/yr).Today most of the streams in this area are ephemeral; in some there is a weak perennial flow. In the historical past the Yarqon River was fed from springs whose waters originated in the mountain aquifer, but today these are dried up. Most of the streams are today in a process of rehabilitation that includes regulating the drainage, cleaning the flow channel and preventing flow pollutants.

The area of the Dead Sea drainage basin is around 29,000 km^2, but only half of it is within Israel. In its northern part, the catchment basin of the Kinneret, the surface water flows from the Galilee and Golan mountains to the upper part of the Jordan River and to the Kinneret, -210 m below sea level. The basin area is around 2730 km^2, and is the richest area in surface runoff. The surface runoff potential is estimated to be ~500 million m^3/yr, and is fully exploited by pumping from the Jordan and its tributaries, from the Kinneret, and from reservoirs in the Golan . The quality of the water in the Kinneret basin is good to medium, but requires mechanical, biological and chemical treatment to bring it up to drinking-water standard.

In the central part the water flows to the southern Jordan riverbed. The area back of the mountain, which is characterized by relatively low precipitation, is drained to this part. The streams in the area are dry most of the year, except for short segments in the slope that are fed by groundwater. The potential of the surface runoff in this area is relatively low, and a small part of it is exploited in a reservoir established in Nahal Tirza (which drains an area of around 330 km^2) before its entry into the Jordan.

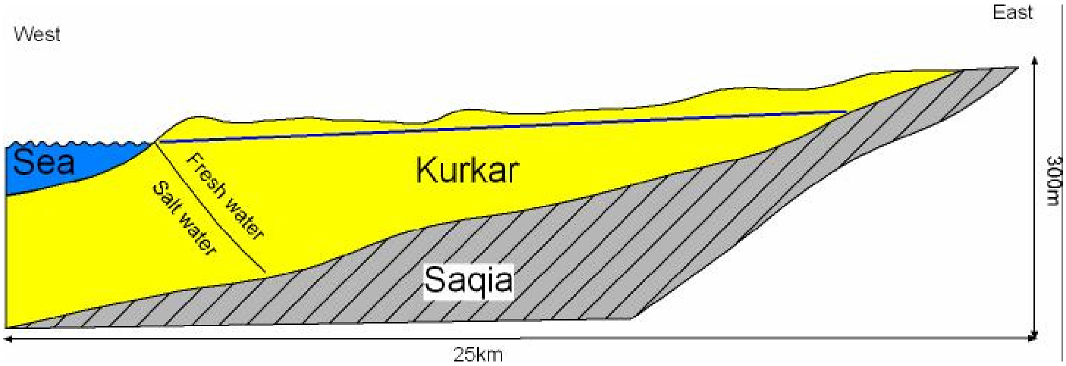
In the southern part, which includes the Judea Desert and the Negev, the water flows to the Dead Sea or to the Arava stream and from there to the Dead Sea. In this part the flow is only from floods. All the streams in the area, in which precipitation is meager, are ephemeral. However, during rainstorms, with the wetting, the clayey ground is immediately sealed, thus enabling the surface flow of floods. The floods occur just a few times a year in the fall and for the most part continue for only a few hours. The intensity of the floods can be particularly strong, exceeding 1000 m^3/sec, even causing destruction or damage to the infrastructure (roads, bridges). In some of the streams intensities of peak discharges even greater than 1000 m^3/sec were measured. The surface water coming from the Judea Desert to the Dead Sea can neither be collected nor exploited. In the south along the Arava stream and its tributaries, six dams were built in the last years that enable collecting some of the floodwaters. These waters serve the farmers in the area.

As stated, only a small part of the surface runoff potential is collectable and/or exploitable. Two plants set up on streams that drain to the Mediterranean Sea exploit the surface runoff for purposes of enriching the coastal aquifer. In the Nahal Taninim basin (an area of 180 km^2) around 2/3 of the surface runoff waters (12 million m^3 out of ~18 million m^3) is caught and penetrated into the aquifer. In the Nahal Shiqma basin (around 760 km2) around half the surface runoff water (3 million m^3 out of ~6 million m^3) is caught and penetrated. Other reservoirs enable storing the water flowing in winter and using them for irrigation in the summer season. The reservoirs have another important role in that they reduce the extreme swelling flows and prevent flooding downstream. The quality of the water in the reservoirs is medium to poor, and their use is accordingly limited to agriculture or to enriching the aquifers.

7. The Coastal Aquifer

The coastal aquifer is a groundwater reservoir extending in the sand and kurkar rocks beneath the coastal plain of Israel. The aquifer extends over an area of about 1800 km^2 from the Karmel (Carmel) in the north to the Gaza district in the south and to the width of the Gaza strip that continues 7-20 km eastwards from the coastline in the west. The natural recharge to this aquifer is estimated at ~250 million m^3/yr (around 15% of the total consumption in Israel), and is exploited fully through hundreds of boreholes spread throughout its area.

The coastal aquifer in vertical section is triangular in shape, expanding from several meters in the east to around 150-200 m in the west. Its upper flank is parallel to the surface. Its lower flank, which is the base of the aquifer, overlies thick layers of clay and is inclined westward. These layers seal the aquifer at its base and sever it from the deep aquifers. The aquifer itself is built mainly of calcareous sandstone (locally named kurkar) with lenses and thin layers of clay. The sandstone has high hydraulic conductivity and high porosity. The hydraulic conductivity of the clay lenses is lower by several orders. The clay layers thicken in the west and constitute partitioning layers that divide the aquifer into several sub-aquifers.



Schematic E-W cross section of the coastal aquifer.

The third side of the aquifer connects the coastline (surface) with the sealed base. This flank is outlined on the interface (the imaginary surface that constitutes a boundary between the freshwater body in the east and the saline water body, the Mediterranean seawater, in the west). The exact location of the interface depends on the volume of the water flowing to the sea and on the hydraulic gradient (the slope of the groundwater level) of the aquifer. In a natural state, wherein the gradient of the groundwater is 1-2 ‰, the edge of the interface penetrates a few hundred meters westwards. To the extent that the gradient of the water level increases, the interface retreats towards the west, and vice versa, to the extent that the gradient decreases, the interface advances eastwards. This matter is of utmost importance in planning the exploitation of the aquifer – overpumping is liable to bring about an eastward penetration of the interface and the intrusion of saline water into the pumping wells.

On the one hand, the shallow depth of the coastal aquifer makes it available and very convenient to exploit, but on the other hand, highly sensitive to contamination. The unsaturated zone naturally constitutes a natural "sieve" for the water infiltrating from the surface. The water infiltrating through it undergoes various chemical processes and reaches the aquifer "cleansed" of different contaminants. In several areas, particularly in the west of the aquifer, the unsaturated zone is quite thin and the passage time through it is relatively fast. Thus, precisely under the most settled and industrialized area in the country the aquifer is the most sensitive. This sensitivity is manifested in the penetration of contaminants from different sources – beginning with seepage from garbage dumps and ending with fuel leaks. In addition, there is infiltration from surplus irrigation of fields situated above the aquifer. Nevertheless, the quality of the water in half the wells in the aquifer is good – with less than 250 mg/Cl/l (maximum concentration desirable according the Ministry of Health) and less than 45 mg/NO_3^-/l. In the rest of the wells the chloride concentration is higher and reaches around 600 mg/l or the nitrate concentration is higher and reaches around 70 mg/l (the maximum concentrations allowed according to the Ministry of Health) and in the remaining minority [of wells], the water is of bad quality, mainly as a result of the nitrate concentrations that exceed 70 mg/l.

In average years the contribution of water from the coastal aquifer to the Israeli water economy has been ~240-300 million m^3/yr, putting it in third place after the mountain aquifer and the Kinneret. However, this aquifer constitutes an important operational reservoir because it is the only one that can store a large volume of water perennially. And therefore, in very rainy years water that is collected in other reservoirs in the country and floodwaters are penetrated into the aquifer at various points.

8. The Kinneret Basin

The Kinneret basin occupies the northeastern part of Israel, and has the highest precipitation in the country. The basin includes Lake Kinneret, lying at -210 m altitude, and the entire area that drains to it from the Hermon mountain, the eastern Galilee and the Golan mountains. The contribution of the basin to the water economy is estimated as ~560 million m^3/yr, that is, around 25% of the consumption of water in Israel. Contrary to the rest of the basins, in this basin mainly surface water which flows in the Jordan River throughout the year and in a few of the perennial streams, or in ephemeral streams, is exploited.

Groundwater is only exploited to a small extent. Up to the 1990s ~35 million m^3/yr was pumped, on average, mainly in the eastern upper Galilee (around 20 million m^3/yr). Production began to grow in scope in the 1990s to ~60 million m^3/yr as a result of borehole development in the Golan (around 10 million m^3/yr), and in the lower Galilee, to the west of the Kinneret (around 30 million m^3/yr).

Lake Kinneret, which is in the Jordan Rift, is the only lake existing within Israeli territory. It is around 168 km^2 in area, around 20 km from north to south, its average depth is around 25 m (its maximum depth is around 45 m) and its volume is around 4,140 million m^3. This lake is a tourist attraction for recreation and pilgrims from both in and outside of the country, a source of livelihood for the tourism industry and for fishermen, is surrounded by a unique and ecological landscape, and is an important source of water. However, beneath the lake there is brine that is liable to cause serious salinity in the lake and deterioration of the water quality. Because of this the quality of the water is safe-guarded by constant monitoring, and there is strict surveillance of the water level.

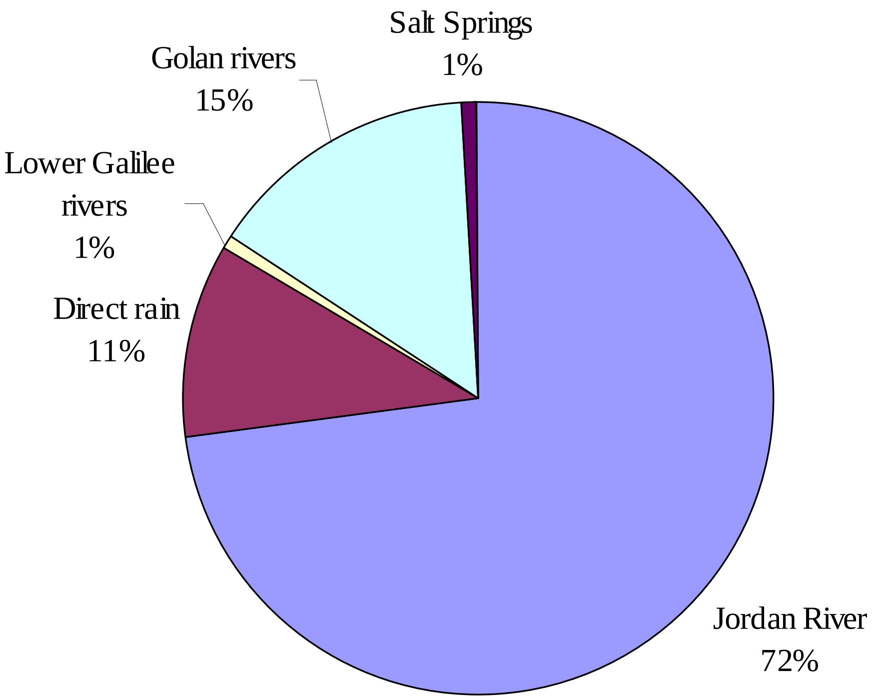
The brine leaks into Lake Kinneret through several large springs at its margins (at concentrations of about 2,000-20,000 mg/Cl/l) and, to a lesser extent, through the lake bottom. The "saline water carrier", which was completed in 1967, drains the large saline springs as well as the brine pumped in boreholes to the northwest of the Kinneret, and transports the water to the southern Jordan River. The saline carrier drains around 17 million m^3 of saline water every year. Already in the first five years of its operation the saline carrier brought to a decrease in the chloride concentration in the Kinneret from around 350-400 mg/l to around 200-250 mg/l.

The natural drain of Lake Kinneret is the southern Jordan River, which flows to the Dead Sea. As of 1932, its natural outlet was dammed, and the water level of the lake is regulated between the maximum level set to prevent flooding of the settlements around the lake (-2008.8 m) and the minimum level set, necessitated for preserving the quality of the water (-212 m altitude), in accord with the operational considerations. Since then, the minimum level has been lowered several times, down to the -215.5 altitude at the peak of the continuous water crisis. The decision to lower the level was accompanied by hydrological and ecological studies, most of which showed that lowering the water level of the Kinneret would not hurt the quality of the water. In 2004 the minimum level was raised to -213 m in the framework of the Water Commission's plan for rehabilitating the aquifers. The volume of water that can be regulated between the minimum and maximum level, ~680 million m^3/yr, is called the "active store" and it constitutes around 16% of the lake's volume.

The natural drainage is now replaced by the "National Carrier" project, which transports the water from the Kinneret westward and southward, regulating the supply on the way with the help of large collecting pools. The pumping station pumping the water into the national carrier is located at the north of the Kinneret and pumps on average ~340 million m^3/yr. The pumping is spread over the whole year and is increased in the summer months, depending on the availability of the water in the rest of the reservoirs.

The catchment area of Lake Kinneret is around 2730 km^2 and includes the sources of the Jordan River, The Golan, and the eastern Galilee. The sources of the Jordan River are the Dan (270 million m^3/yr), the Banyas (120 million m^3/yr) and the Snir (120 million m^3/yr) springs that flow at the foot of the Hermon Mountain. The spring waters drain to the Hula Valley and join to form the Jordan River. Adding to the upper part of the Jordan are surface waters from streams (20 million m^3/yr) and spring waters (50 million m^3/yr). Against this, local consumption in this area and consumption for agriculture in the Galilee mountains takes away from the Jordan a total of ~120 million m^3/yr. The discharge of the Jordan before it enters the Kinneret is thus ~ 460 million m^3/yr. Other sources of Kinneret water are from direct rain on the lake (67 million m^3/yr), saline springs at the lake's margins (6 million m^3/yr, after diversion) and surface runoff from the

Galilee and the Golan (~100 million m^3/yr). Upstream those flowing to the Kinneret from the Golan there are large reservoirs in which an additional amount of ~25 million m^3/yr can be accumulated from the flood flow that occurs in the winter season.



Percentage of waters entering the Kinneret from the different sources

(perennial average).

.

The Jordan River, whose water salinity is around 20 mg/Cl/l, contributes most of the water in the lake, thereby introducing on average around 9,000 ton/Cl/yr into the lake. In comparison, the saline springs that contribute only about 1% of the water (after diversion of most of its waters by the saline carrier) contribute most of the salt to the lake (around 90,000 ton/Cl/yr on average).

9. The Mountain Aquifer

The mountain aquifer is the largest of the subsurface water reservoirs in Israel. It extends from the Beer Sheva-Dimona-Dead Sea area in the south to the Binyamina-Bet Shean area in the north and its contribution to the water economy is estimated at ~600 million m^3/yr, that is, around 30% the total consumption. The aquifer is fed from rains falling on the limestone and dolomite exposures of the Judea Group (of Albian-Turonian age) and on the mountain ridge, and flows to the natural drainage areas. The mountain aquifer is divided into three main basins, in accord with the direction of flow in them: in the western and southern part, the Yarqon-Taninim basin; in the northern part, the Shekhem (Nablus)-Gilboa basin; and in the eastern part, several small basins – the eastern basins.

The water potential in the Yarqon-Taninim basin is, on average, ~360 million m^3/yr, and today is fully exploited in hundreds of boreholes. Most of the boreholes are located at the foot of the central mountain ridge. To the east the thickness of the active aquifer thins and conductivity is low, and further west boreholes must be drilled to great depth in order to penetrate the layers covering the aquifer. The natural outlets of the Yarqon-Taninim basin were two large springs – the Yarqon springs in the Tel Aviv area, ~220 million m^3/yr, and the Taninim springs in the Qesarya (Caesaria) area, ~100 million m^3/yr, in addition to the small seepage to the Mediterranean Sea. Today the basin is exploited intensively, and as a result, the flow from the Yarqon springs almost completely diminished and the discharge from the Taninim springs decreased by around 70%. In order to prevent various salinization phenomena resulting from the intensive pumping, the Water Commission set minimal levels which must not be exceeded, and the aquifer is monitored in around 200 boreholes. Because of its size, the basin also serves as a reservoir for absorbing surplus water from other reservoirs, and as of 1970 ~16 million m^3/yr, on average, has been penetrated into it (wherein the last ten years the average amounts dropped below 2 million m^3/yr).

The drainage in the Shekhem (Nablus)-Gilboa basin is from the city of Shekhem (Nablus) northward to Jenin and Bet Shean. In addition to rains falling on the Judea Group, the aquifer is also fed by rains falling on the Avedat Group (of Eocene age). The water potential in the basin is ~140 million m^3/yr, whereby its discharge today at its natural outlets in springs flowing at the foot of the Gilboa Mountain, in the Bet Shean Valley and in the north of the Rift is ~70 million m^3/yr. In addition to this a total of ~76 million m^3/yr is exploited in the basin in tens of shallow boreholes concentrated in population centers in the mountain area and also in the area around their outlets.

The area extends from the east to the ridge of the mountains, from Bardala in the north, through Ramallah, Jerusalem and Hebron to the Arad Valley in the south, drains to several small basins in the Jordan Valley and to the Dead Sea. In its northern part, its natural outlets are small springs in wadis that lead to the rift: Wadi el-Malih, Nahal Tirza (Fari'a), Peza'el (Fasayil) and Perat (Qelet) (in the Jericho area), and a little surplus flow to the Jordan River channel. In its southern part, its natural outlets are large springs at the Dead Sea shore: Zuqim (65 million m^3/yr), Qane and Samar (35 million m^3/yr) and En Gedi (~3 million m^3/yr), and also non-monitored sub-marine flows, adjacent to the Dead Sea itself. The small basins in the Jordan Valley are exploited in boreholes in two main areas: the mountain ridge area (in some of the places, such as in the Herodian area, most intensively), and in the Jericho area, where pumping ranges between ~31 and ~42 million m^3/yr.

The quality of the water in the mountain aquifer is very good. The salinity of the water in the area of the exposures is 30-50 mg/Cl/l and increases with distances from the areas of the exposures to about 200-300 mg/Cl/l. In sharp contact beneath the freshwater body in the Yarqon-Taninim basin, there is a saline water body. Intensive exploitation of the Yarqon-Taninim basin will lead, among others, to an increase in the salinity of the water in the layers currently saturated with fresh water. In the north of the basin, the phenomenon was observed as a result of overpumping in the well located at the foot of the mountain ridge. In the northern

Negev, pumping is done parallelly from two water bodies (the fresh and the saline) in order to prevent the spread of the saline water northward.

10. Small Basins

In addition to the main basins in Israel there are several smaller basins that are reviewed here from north to south. These basins are exploited through boreholes or drafting spring flows and are connected to the national water system (with the exclusion of the Negev-Arava basin). See **"Kinneret Basin"** regarding the aquifers draining to the Kinneret,

The Western Galilee Basin

The western Galilee basin drains the western Galilee mountains to the Mediterranean Sea. The basin extends from the seacoast in the west to the water divide in the east, and from the Yizre'el (Jezreel) Valley in the south to the Israel-Lebanon border in the north. Included in the realm of the basin are two aquifer units: limestone and dolomite rocks of Cenomanian-Turonian age, which are exposed on the mountains in the eastern basin; and sandstone and kurkar rocks of Pleistocene age, which are exposed in the west of the basin. The two aquifer units are joined at their westernmost parts.

The replenishment to the western Galilee basin is estimated to be, on average, ~150 million m^3/yr. The chief natural outlets of the basin are the Kabri and Na'aman springs, whose historical discharge was ~70 million m^3/yr, in addition to their seepage to the Mediterranean Sea. Today the entire flow is drafted and the basin is exploited through many boreholes. In the last ten years ~90 million m^3/yr was pumped from the basin and the total discharge of the springs diminished, on average, to ~40 million m^3/yr, ranging between ~20 and ~-55 million m^3/yr. As a result of this, the amount of water naturally flowing to the sea also decreased.

The quality of the water in the basin is very good in its mountainous part, and suffices in the coastal part. In this area trends of rising concentrations of chloride and nitrate were observed in the last decades. It should be noted that, just like the coastal aquifer, the coastal section of the western Galilee basin is sensitive to contaminants originating on the surface and also to salinization from the Mediterranean Sea. The high concentration of settlements, fish ponds, industrial plants, barns, and the like, above the coastal belt obligates ongoing monitoring to prevent deterioration of the quality of the water in the basin.

The Karmel (Carmel) Basin

The Karmel ridge extends south of Haifa Bay. It is around 30 km long and it widens from around 5 km in the north to more than 20 km in the south. The Karmel rises to around 500 m above sea level, and slopes steeply to the Mediterranean Sea in the west and to the Yizre'el Valley in the east. In the subsurface, a water divide separates the eastward drainage to the Yizre'el Valley and the westward drainage to the Mediterranean Sea.

The replenishment to the aquifer is estimated at ~44 million m^3/yr, of which 20 million m^3/yr infiltrate in the eastern part, and the rest, in the western part. Two aquiferial units are included in the Karmel: limestone and dolomite rocks of Cenomanian-Turonian age that are exposed on the mountain in the eastern basin; and sandstone and kurkar rocks of Pleistocene age that are exposed in the western basin. As in the western Galilee, the two aquiferial units are connected in the westernmost part, and water from the limestone aquifer drains to the sandy one and from there to the Mediterranean Sea. In the westernmost area, the Karmel coast, the quality of the water is not high and is characterized by large amounts of chloride that reach a level exceeding 900 mg/Cl/l, and therefore various desalination installations have been set up in the last years in Maagan Mikhael, Atlit, and in Maayan Zevi, which treat more than 12 million m^3/yr and efficiently exploit this water. In the eastern basin the water quality is good and the water is exploited without any treatment.

The Negev-Arava Basin

The Negev-Arava basin extends from the Ashqelon-Mezada line southward. Despite its large area, the replenishment to the basin is estimated to be only ~30 million m^3/yr; this is because of the low amount of precipitation and because most of the rain waters in the Negev flow as surface runoff in strong floods. Three aquiferial units are included in the basin: sandstone of Early Cretaceous age (exposed in very small outcrops) in the Negev; limestone and dolomite rocks of Cenomanian-Turonian age (exposed in the Negev); and clastic rocks (sand and conglomerate) of Neogene age exposed in the Arava (the "Arava Fill" aquifer). The flow of water in every one of the aquifers in the Negev is in the direction of the Arava Fill aquifer. The larger part of the Arava is drained to the Dead Sea and the southern pat is drained to the Gulf of Elat (Aqaba). In the last years ~90 million m^3/yr (of them ~60 million m^3/yr of saline water) was produced from the aquifer at the expense of the one-time store. Around 60% of the exploitation is from the Arava Fill aquifer. Half of the water produced is highly saline, around 600 mg/Cl/l, and is supplied to the heavy industry plants or for desalination in Elat. The rest of the water is supplied to the Arava settlements for drinking and for agriculture.

11. The Water Conveyance System

Israel's water management is based mainly on rains, most of which fall in the northern half of the country. The water, which is required for drinking and for agriculture throughout the country, must be transported from the northern to the central and southern parts of the country. Already in the 1960s the directors of the Israeli water economy were wise enough to establish a country-wide network for transporting water. The basis of the transport system is the national carrier, which pumps water from the Kinneret and conveys it in channels and closed pipelines as far as the northern Negev. Smaller local projects are connected to the national carrier, thus a water transport network is created that enables supplying water when needed to almost every settlement in the country, as far as Sede Boqer in the south. The water is supplied to the southern Negev and Arava settlements by a separate regional transport system, which is based on local boreholes and desalination of saline water. The national water transport system connects the three main water sources of the country: Lake Kinneret, the Yarqon-Taninim basin, and the coastal aquifer, and supplies the water to consumers in the Haifa area, the coastal plain, Jerusalem and the northern Negev.

12. Alternative Water Sources

Currently, Israel exploits its natural sources of water almost completely. Against this, consumption of water is gradually increasing with the increase in population and the rise in the quality of life. In order to meet the demand for water Israel is constantly developing alternative water sources, such as desalination of seawater and reuse of treated sewage water.

Desalination

The first desalination installations were established in Israel in 1965 in the south of the country, to cover the demands for drinking water in the arid areas. Today there are around 30 small desalination plants operating that desalinate ~30 million m^3/yr. Most of these installations are spread in the Arava and the Negev. The largest of them (~11 million m^3/yr) is located in Elat and desalinates saline water and Red Sea water for use of the city's inhabitants.

Recently, the Israeli government decided to take action towards establishing large desalination installations along the coast of the Mediterranean Sea. According to this plan, these installations would supply 305 million m^3/yr of desalinated water by the year 2010 and 500 million m^3/yr by 2015. This amount would constitute a quarter of the total fresh water in Israel. The first installation, using the reverse osmosis method, was established near Ashqelon and began to provide 100 million m^3/yr at the end of 2005. Four other installations are in different stages of planning and establishment, two in the north (130 million m^3/yr) and two in the south (75 million m^3/yr).

There is a lot of advantage in desalinating sea water. Firstly, this means an addition of potable water to the Israeli water economy. Attaching a permanent source of water to the national water system that is not dependent on rain will improve the reliability of the supply. In addition, with the desalination of water, saline water which today cannot be used will be able to be utilized, by diluting it to the level of drinking water. "Surplus" water deriving directly from desalinated water or water diluted with desalinated water, can be penetrated into the aquifers to rehabilitate them.

Reuse of treated sewage water

The recycling process of sewage is of great importance. First and foremost it constitutes a solution to the problem of environmental hazards, which include contamination of soils, coasts and water reservoirs, and damage to vegetable and animal life. Furthermore, after the recycling process, the purified water can be returned to agricultural usage. It should be noted that sewage contains around 99.8% water and only 0.2% waste materials, and therefore proper treatment of this water can remove the waste and create a substitute source of water.

The purification potential of purified sewage water can reach to around two-thirds of the total domestic and industrial consumption, which is estimated today at ~840 million m^3/yr; thus the purified sewage potential stands at ~55 million m^3/yr. This amount constitutes around a quarter of the total consumption of water in Israel and around half of the total consumption of agriculture.

Today more than 95% of all the sewage is collected in sewers, the rest flows to cesspits or is not collected. Over 90% is treated in the various sewage purification plants, though as of today, only ~300 million m^3/yr is exploited for agriculture.

Operating in Israel today are more than 120 purification installations spread throughout the country, the newest of them operating the activated sludge method. The largest plant is located in the Rishon LeZiyyon area and recycles the sewage of the metropolitan Dan area in which around 1.5 million people live. In addition, the plant treats ~10 million m^3/yr of industrial effluents. In total, the plant treated ~138 million m^3 in 2003, all of which was transported to the northern

Negev for agricultural use. Other large plants are found in the Haifa area (~40 million m^3/yr) for use of the farmers in the Yizre'el Valley, the Nahal Soreq-west Jerusalem area (20 million m^3/yr), and the Nahal Og and Qidron-east Jerusalem area (5 million m^3/yr).

The purified sewage water that is returned to agriculture must meet the strict standards of the Ministry of Health; as of today its quality is considered only good for irrigation. This water must be transported to the agricultural areas in separate pipelines. However, the infrastructure for it is not yet completed, and therefore a considerable part of the treated water today flows to the sea and is not exploited.