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THE WORLD BANK

ISRAEL WATER SECTOR REVIEW

PAST ACHIEVEMENTS, CURRENT PROBLEMS AND FUTURE OPTIONS

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December 16, 1990

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Dear Sirs,

Re: Israel Water Sector Study - Contract A-24943

We take pleasure in submitting herewith our final report, entitled "Israel Water Sector Review," prepared under your Contract No. A-24943 of June 8, 1990. The report summarizes past achievements, current problems and future options of water management policy in Israel.

The report discusses current problems such as overdraft, decline in water quality, allocation of scarce resources, and conflicts between water users. It also presents future scenarios of resource availability (in terms of quantity and quality), demand and supply of water, demographic patterns, technological patterns, institutional structures, and pricing arrangements, as specified in the TOR prepared by the World Bank. Policy instruments in the domains of legislation, administration, financing, promotion, and planning are analyzed and their likely impacts on the Israeli water sector are assessed.

Separate chapters have been included on water quality, which is the main problem of water resources management in Israel, as well as on artificial recharge, which is an important water resources management tool. Also presented are relevant data on and evaluation of urban and industrial water use, including a review of current problems and future options, and the necessary steps for implementation of these options, taking into consideration costs, prices, and legal and institutional revisions.

A preliminary draft was submitted to you on October 15, 1990, and valuable comments were received from reviewers. The report has been revised in accordance with your comments, as well as those of Prof. D. Yaron, Dr. Y. Danin, Dr. D. Hamberg, Prof. C. Tseruya and Mr. M. Kantor.

The present report is based on previous plans and papers published by TAHAL - Water Planning for Israel, as well as other treatises published in the past (a list of which appears in the Bibliography). Dr. Y. Shevach assisted in collection and assessment of background material.

We sincerely hope that the present review will assist other nations in adopting the achievements and avoiding the mistakes of Israel's water sector.

Yours sincerely,

[redacted]

Jehoshua Schwarz

IS/212A/Wat-Sec.let

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LIST OF ABBREVIATIONS

CA	Coastal Aquifer
cu.m	Cubic metres
DSS	Design Support System
EC	European Community
ha	Hectare
kWh	Kilowatt hour
LK	Lake Kinneret
MCM	Million cubic metres
mg/l	Milligrams per litre (or parts per million)
NWC	National Water Carrier
NWS	National Water System
SAR	Sodium Adsorption Ratio
SAT	Soil Aquifer Treatment
TOE	Ton Oil Equivalent
yr	Year
YT	Yarqon-Tanninim Aquifer

INTRODUCTION

The rapid growth in Israel's economy following independence in 1948 has been accompanied by the development of an advanced water sector. Over a relatively short period of about 30 years, Israel has developed all available natural water resources and constructed an extensive supply grid, distributing an annual quantity of about 2,000 MCM (million cu.m) for domestic, industrial and agricultural use.

Having exhausted all alternatives for development of natural resources, the country has embarked on development of marginal water resources - brackish water and domestic wastewater - which are treated and used for large-scale irrigation.

In the near future, Israel like many other countries, will face, in addition to frequent droughts, the serious problems of depleted water resources, over-exploitation and deterioration in water quality as a result of human activities.

For the more distant future Israel has a few difficult options: curtailment of water supply, expensive production of desalinized seawater, or importation of water from other countries.

The present document reviews past achievements, current problems and future options in the development and management of water resources in Israel.

1. BACKGROUND

1.1 Location and Area

Israel, situated in the eastern Mediterranean, extends some 500 km from north to south, and on an average about 60 km from east to west. Its total area is about 22,000 sq.km.

1.2 Physiography

The topography of the country is characterized by a central mountain range, originating as a continuation of the Lebanon Mountains in the north and running all the way south to the Sinai border. The chain is interrupted north of Mount Carmel by the Yizre'el Valley. On the west, the mountain range slopes down to the Mediterranean Coastal Plain, which is narrow in the north and wider in the south; on the east, it drops more steeply to the Jordan Rift Valley and its southern continuation, the Arava.

1.3 Climate

The climate is semi-arid, with an annual long-term, average rainfall in the central and northern regions of the country ranging from 400 to 1,000 mm. In the southern arid region, rainfall varies from 250 mm on its northern fringe to 25 mm at Elat, the southernmost part of the country (see Fig. 1-1). The total mean annual precipitation over the catchment areas feeding Israel's various water sources amounts to about 10,000 MCM; of this only 18% is utilizable, the rest being lost to the atmosphere or to the Mediterranean and Dead Seas. Rainfall is concentrated in the five winter months of November to March. Rainfall also varies greatly from year to year, both in distribution pattern and volume, with a typical 30% coefficient of variation in the north and 40% in the south.

Temperatures in the dry months of April to October are very high, with resultant high evapotranspiration. Few crops can, therefore, be grown during this period without irrigation.

1.4 Population*

The population of Israel at the end of 1988 reached 4.5 million vs. only 0.9 million in 1948. The mean

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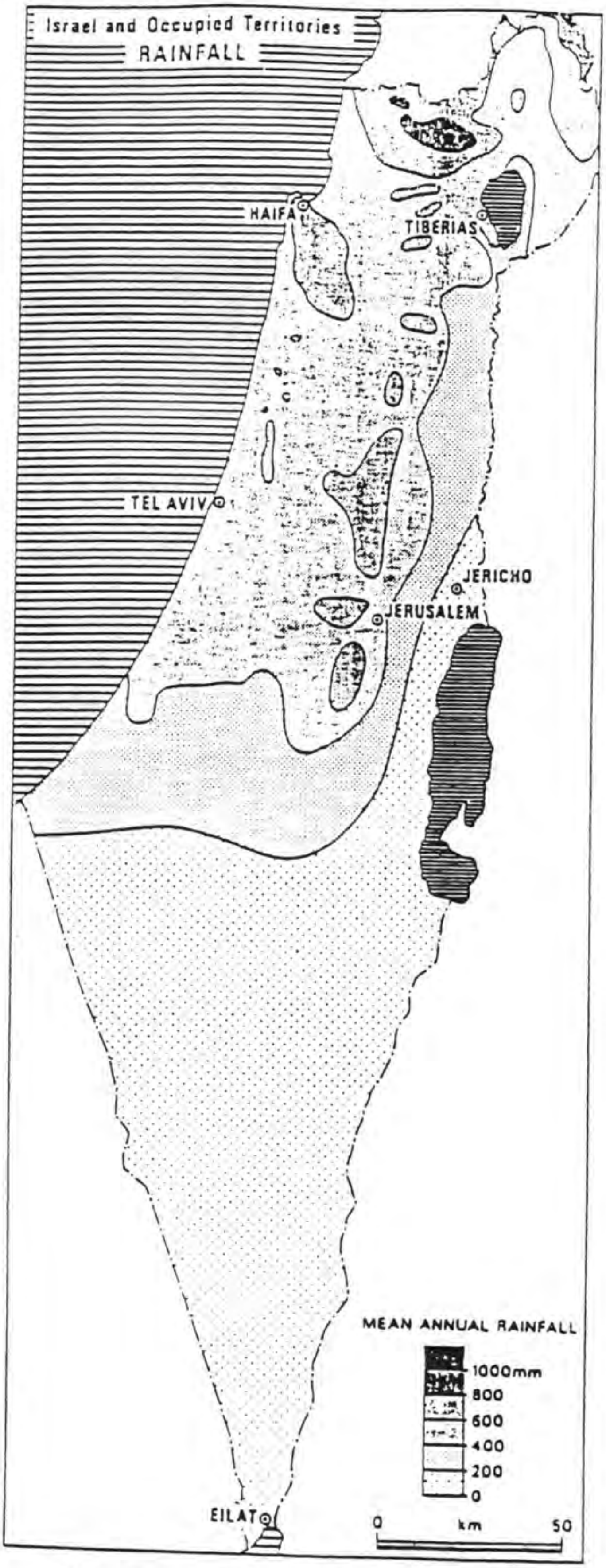
* According to Statistical Abstract, 1989.



Source: Atlas of Israel, 1985

annual growth rate during the period 1948 to 1960 was 8.2%. In the 1960s this dropped to 3.2%, and in the years 1983-1988 to a mere 1.8%. The percentage of the immigration balance in the total growth decreased from 65% in the first period to 38% in the second, and to 5% in the last five years. In 1988 the growth rate was 1.6%, with negligible immigration. A large increase in population is expected due to waves of immigrants arriving in 1990.

The population density of Israel at the end of 1988 was 205.1 per sq.km. The number of households was 1.166 million, with an average of 3.61 persons per household.

The urban sector, with 90% of the population, includes 168 localities with populations exceeding 2,000. The three main cities - Jerusalem, Tel Aviv and Haifa - are inhabited by 23% of the population. Eleven localities, with population exceeding 100,000, are inhabitated by 45% of the population. Most of the population is concentrated in the Coastal Plain (see Fig. 1-2).

The population of Judea and Samaria at the end of 1988 was 0.9 million, with an annual growth rate of some 3%. In the Gaza area the population is 0.6 million, with a growth rate of 3.5%.

1.5 Economic Indicators*

The civilian labour force in 1988 numbered 1.533 million, comprising 51.4% of the population above 14 years of age (males 63.2%, females 40.0%). Unemployment stood at 6.4% of the labour force. The percentage of the population employed in agriculture in 1988 was 4.6% (vs. 17.6% in 1950).

The Gross National Product (GNP) in 1988 was NIS 65,071 million. The per capita GNP in 1988 was US$ 9,427, with no growth in that year.

The annual external trade deficit in 1988 was US$ 5,326 million (US$ 1,165 per capita). The balance of payments in 1988 was US$ -675 million. Net foreign obligations per capita at the end of 1988 were US$ 4,190.

Per capita daily consumption of calories was 3,059 kcal, proteins 96.9 g and fat 122 g.

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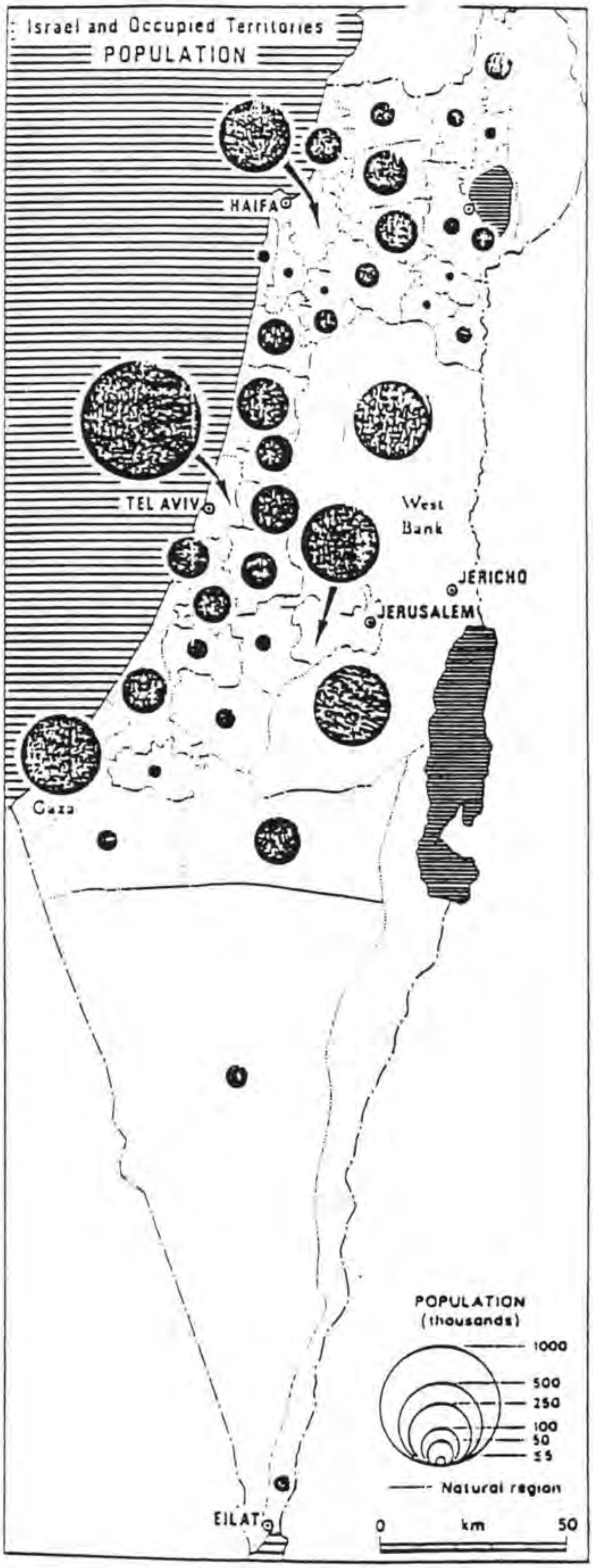
* According to Statistical Abstract, 1989.



Source: Atlas of Israel, 1985

The total annual energy requirement per capita was 2.250 TOE. Final consumption of energy per capita was 1.481 TOE and of electricity 0.317 TOE (of which 12% was used for pumping of water).

The per capita GNP in Judea and Samaria in 1987 was US$ 1,990 and in the Gaza area US$ 1,376.

The daily per capita consumption of calories in Judea and Samaria, and in the Gaza area was 2,931 and 2,612 kcal, respectively. Daily consumption of proteins was 86.7 and 73.7 g, respectively, and of fats 80.8 and 68.9, respectively.

2. WATER RESOURCES

2.1 General

Owing to the geographical conditions and rainfall regime, about 80% of the country's water resources are located in the northern regions and about 20% in the south. On the other hand, 65% of the country's arable lands are found in the southern regions; hence, large quantities of water must be conveyed over a distance of about 200 km to irrigate the arid south.

In addition to their adverse geographical distribution, Israel's water resources have a weighted average elevation of 82 m below average ground surface. Exploitation of all groundwater and surface water sources, therefore, necessitates pumping. A total of some 2,038 million kWh of electricity was supplied in 1988 to lift and deliver water from its sources to consumers. Around 12% of Israel's electric power consumption is used for pumping of water.

The country's total annual renewable fresh water resources amount to some 1,600 MCM/yr, all of which (and more) are exploited for irrigation, domestic and industrial use. There is at present overexploitation of many of the sources.

The existing sources of water supply and their planned use are shown in Table 2-1. Three water qualities are defined: <u>fresh water</u>, with salinity not exceeding 400 mg/l chlorides; <u>brackish water</u>, with salinity exceeding 400 mg/l chlorides; and <u>irrigation water</u>, which is composed of recycled wastewater and floodwater, utilized by means of seasonal storage in open reservoirs. An additional breakdown by salinity levels is given in Section 6.1.

TABLE 2-1: DISTRIBUTION OF SUPPLY BY SOURCE

MCM per year

Source	1984/5				2000			
	Fresh	Brackish	Irrigation	Total	Fresh	Brackish	Irrigation	Total
Groundwater	1205	135	-	1340	955	160		[illegible]
Jordan basins	620	-	-	620	660	-		[illegible]
Floodwater	15	10	15	40	30	-	50	[illegible]
Recycled wastewater	30	-	80	110	-	-	275-345	275-345
Total production	1870	145	95	2110	1645	160	325-395	[illegible]
Losses	-60			-60	-40			[illegible]
Total supply	1810	145	95	2050	1605	160	325-395	[illegible]

Of the annual fresh water potential of 1,600 MCM, about 35% derives from the Jordan River basin and must be pumped from Lake Kinneret (LK), the country's main storage reservoir, located at an elevation of 212 m below sea level. About 60 % is from groundwater, i.e. water flowing in underground aquifers, although some of this water emerges in the form of springs. The remaining 5% is from floods, which can be intercepted and stored for use in groundwater reservoirs. Other water resources include principally non-renewable resources and reclaimed wastewater.

About 60% of the groundwater potential is found in the country's two largest aquifers: the Yarqon-Tanninim Aquifer (YT) and the Coastal Plain Aquifer (CA). These two aquifers, together with LK, constitute the Three-Basin System of Israel's National Water System (NWS). This system, encompassing some 65% of Israel's total natural water potential, has been the subject of many management studies carried out during the past 10-15 years in the framework of establishment of national water resources development and operation policies. The three sources are interlinked by the National Water Carrier (NWC), which allows massive transfers of water from LK in the north to the central and the south of the country, as also transfers of water from one source to another (see Fig. 2-1).

The main sources in their order of relative importance are:

- the Upper Jordan and its tributaries, including LK.

- The main groundwater aquifers: the CA, which consists of a shallow coastal sandstone aquifer; and the mountainous aquifer, the deep limestone dolomite aquifer (YT).

- Minor groundwater aquifers in the north: Western Galilee and Bet She'an springs.

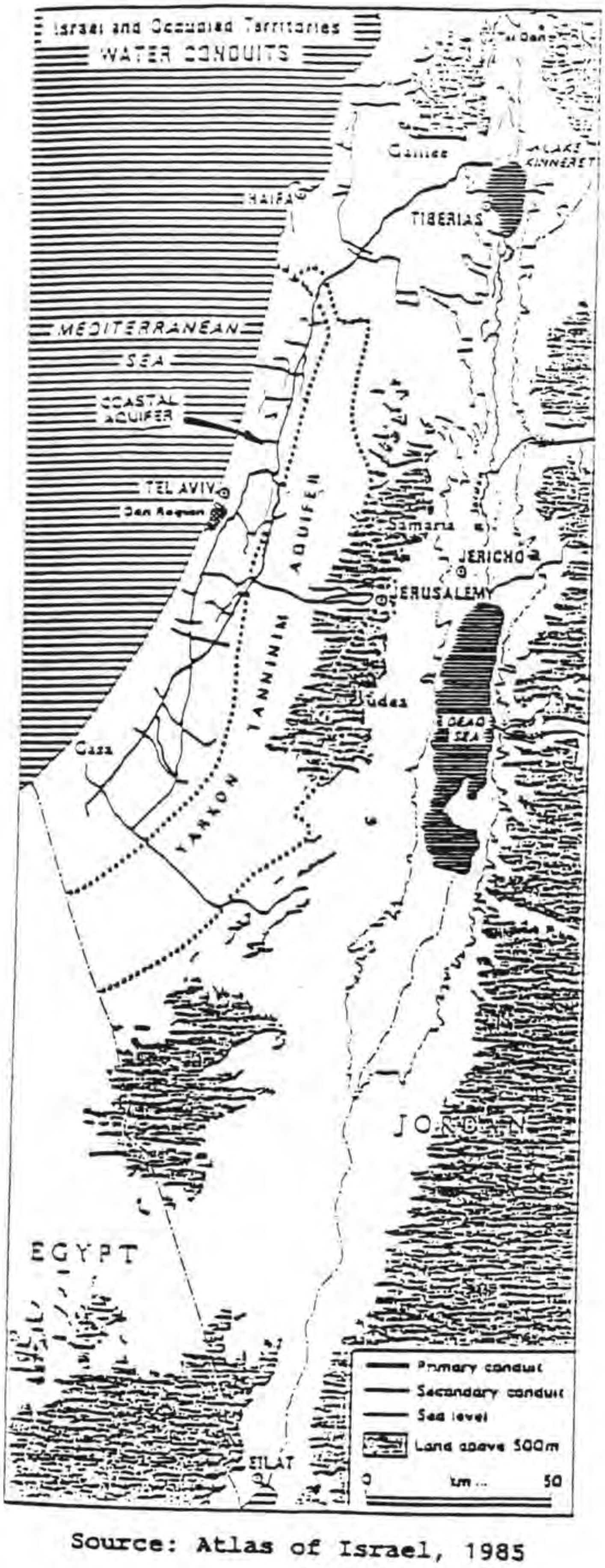
- Reclaimed wastewater from the greater Tel Aviv area, with a population of over 1 million. The treated wastewater is recharged into the coastal aquifer, and by the time it is repumped reaches almost drinking water quality.

- Reclaimed wastewater from other localities.

- Limited local supplies of groundwater in the southern Negev and Arava regions.

- Storm runoff from intermittent coastal streams, stored by artificial recharge to the CA.

Fig [illegible]



Source: Atlas of Israel, 1985

- Desalination of sea and brackish waters. At present this is confined to the town of Elat and small-scale desalination of brackish water for small settlements in the Arava.

A short description of these sources is given in the following.

2.2 The Jordan Basin

The Jordan Basin is divided into the Upper Jordan, with LK as its main reservoir, and the Lower Jordan, with the Yarmuk River as its main tributary.

2.2.1 Lake Kinneret and the Upper Jordan

Lake Kinneret is Israel's largest natural fresh water reservoir. It has a catchment area of 2,730 sq.km and a mean annual net inflow (after deduction of evaporation and upstream diversions) of about 510 MCM. The Deganya Gates, on the outlet of the lake to the Lower Jordan River, regulate outflows, permitting losses of fresh water from LK to the Dead Sea to be minimized, and maintaining water levels in the lake between a maximum of -209 m and a minimum of -213 m. The lake's deepest point is -253 m. The total volume under the maximum level is 4,300 MCM.

The 4 m difference between -209 m and -213 m contains a water volume of about 670 MCM, which is the lake's operational storage volume. An operation policy has been formulated, whereby monthly withdrawals of water to the NWS and releases to the Lower Jordan are so regulated as to reduce losses to an average of 40 MCM/yr. Hence, the lake's utilizable water yield, on the basis of a mean annual inflow of 510 MCM, is at present 470 MCM/yr. Of this, 80 MCM/yr is used by local consumers, leaving 390 MCM/yr for pumping to the NWS. Annual pumpage from LK to the NWS during the past 25 years averaged 380 MCM. An additional amount of about 110 MCM/yr of the Kinneret catchment yield is diverted from the Upper Jordan and its tributaries, or pumped from aquifers which drain to the lake or to the Jordan and its tributaries.

2.2.2 Yarmuk River

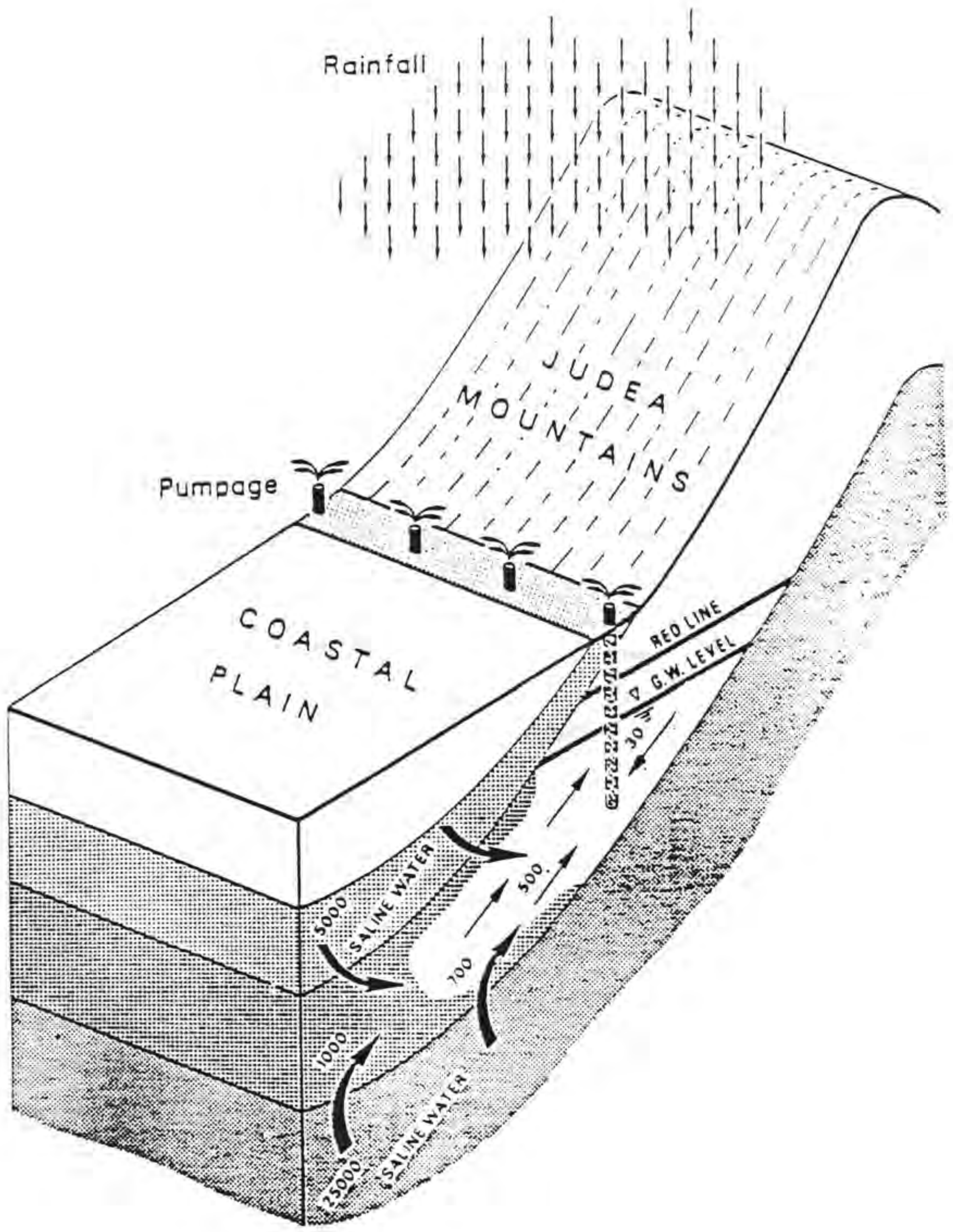
The Yarmuk River, with a mean annual yield of 450 MCM, enters the Lower Jordan River 8 km south of LK. Most of the river's water is diverted or is planned for diversion by Syria in its upper reaches, as well as by the Hashemite Kingdom of Jordan for irrigation on the eastern side of the Lower Jordan. Considerable storage is planned upstream, leaving about 70 MCM/yr for utilization by Israel. About 25 MCM/yr is utilized in the summer months directly by Israeli users located on the banks of the Yarmuk River. In addition, some 45 MCM/yr, which would otherwise be wasted, is diverted during the winter months from the Yarmuk River to LK. The 1984/5 balance shown in Table 2.1 includes only 40 MCM/yr of Yarmuk River water in the figure of 620 MCM/yr for the Jordan Basin.

2.3 Yarqon-Tanninim Aquifer

This aquifer is named after its two main natural outlets: the Yarqon Springs, which rise 15 km east of Tel Aviv, and the Tanninim Springs, 60 km to the north. It consists of Cenomanian and Turonian dolomite and limestone rock strata, dipping from their outcrops in the highlands of the Judea and Samaria mountains to depths of a few tens to a few hundred metres below the Eocene foothhills and the Pliocene-Pleistocene-Recent Coastal Plain (see Fig. 2-2). The main body of the aquiferous strata resembles a 150 km long flat trough, lying roughly in a south-north direction and sloping gently from the Be'er Sheva well field at its southern end to the Tanninim Springs at its northern end. An unproven direct outlet of water from the YT to the Mediterranean Sea possibly exists not far from the Tanninim Springs. Natural replenishment of the aquifer comes from rainfall over its outcrops in the Judea and Samaria highlands.

Relatively high yields and low drawdowns are typical of most of the production wells in this aquifer (the transmissivity of the aquifer generally ranges from 10,000 to 200,000 sq.m/day). Massive pumpage from the YT Aquifer began in the early 1950s, causing widespread lowering of water tables (see Fig. 2-3). By 1963 water levels had fallen below the elevation of the Yarqon Springs (+16.5 m), bringing an end to their discharge. This was considered to be a favourable development from the point of view of aquifer management, since wasteful outflows to the Mediterranean Sea were prevented, and efficient storage by artificial recharge became possible. In the meantime, to prevent occasional renewal of spring discharge, the spring outlet crest was raised to an elevation of +21.5 m.

The Tanninim Springs, situated at an elevation of +3.5 m, continue to flow at a rate of 30-50 MCM/yr. Part of the flow, which is brackish, is utilized at present for fishponds. The mixing mechanism, which causes the fresh water in the aquifer to turn brackish on its way to the Tanninim Springs, is not yet completely understood. However, it has been shown that unless an outflow of some 40 MCM/yr is maintained in these springs, irreversible movement of saline water



YARQON - TANNINIM AQUIFER
SOURCES OF SALINITY

into the main body of fresh water in the aquifer may occur. To maintain this outflow and prevent salinity, while at the same time preventing excessively high outflows in the Tannimim Springs or renewal of outflows from the Yarqon Springs, an average water table between a minimum of +10 m and a maximum of +19 m is maintained throughout the aquifer. Excessive lowering of the water table could also cause increased salinity in other parts of the aquifer where connate bodies of highly saline groundwater lie beneath, and at times above, the fresh water (see Fig. 2-2).

The total safe yield of the YT is estimated at 340 MCM/yr, of which 300 MCM/yr is fresh water and 40 MCM/yr brackish water (in the Tanninim Springs). The aquifer is tapped by about 300 deep wells, with a mean annual net pumpage capacity of 375 MCM. This exceeds by far the estimated safe yield of 300 MCM/yr. Artificial replenishment maintains the aquifer above the minimum level. Artificial recharge of the YT by water from LK is effected through single and dual purpose deep wells connected to the NWS, with an annual recharge capacity of 40 MCM.

2.4 Coastal Aquifer

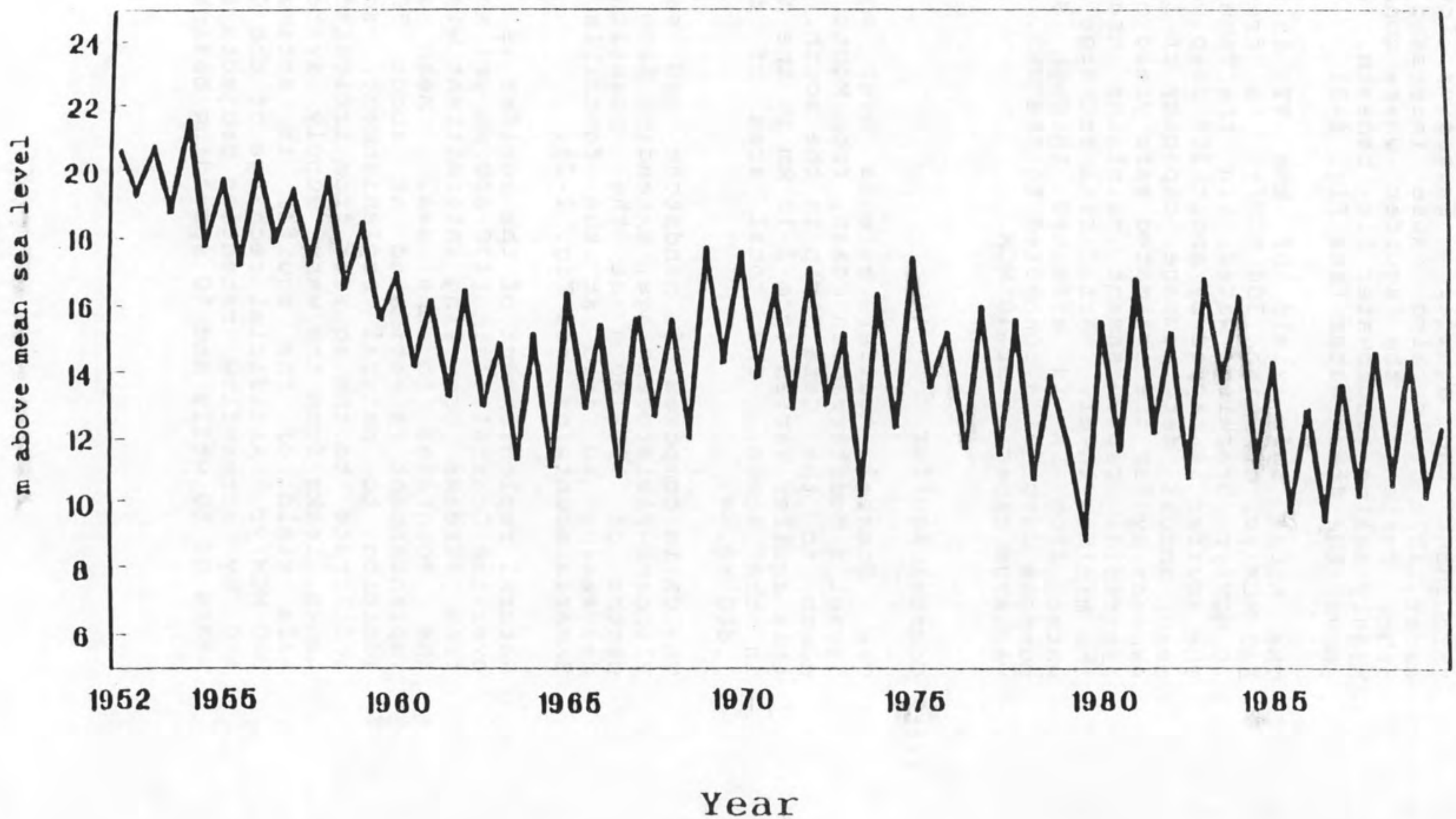
The Coastal Aquifer extends over some 120 km of Israel's Mediterranean coast, from Mount Carmel in the north to the Gaza Strip in the south. The width of this aquifer varies from 3-10 km in the north to 20 km in the south. The total area of the aquifer is 1,800 sq.km.

The CA is composed of sandstone and sand layers of Pliocene-Pleistocene age, extending from the surface to depths of 150-180 m at the coastline; eastwards decreasing to zero at the foothills of the Judea-Samaria mountains (see Fig. 2-2).

Natural replenishment of the aquifer is from rainfall over the Coastal Plain (400-600 mm/yr) and infiltration from streams conveying intermittent winter flows from the mountains to the sea. Mean annual natural replenishment is estimated at about 300 MCM/yr. In addition to natural replenishment, some 90 MCM/yr infiltrate to the aquifer from irrigated areas, septic tanks, leaks from the water supply system, etc. The safe yield of the aquifer is estimated at 240-300 MCM/yr. Artificial recharge of the CA from the NWS and by streamflow retention projects is practised by means of 60 wells and 10 spreading basins.

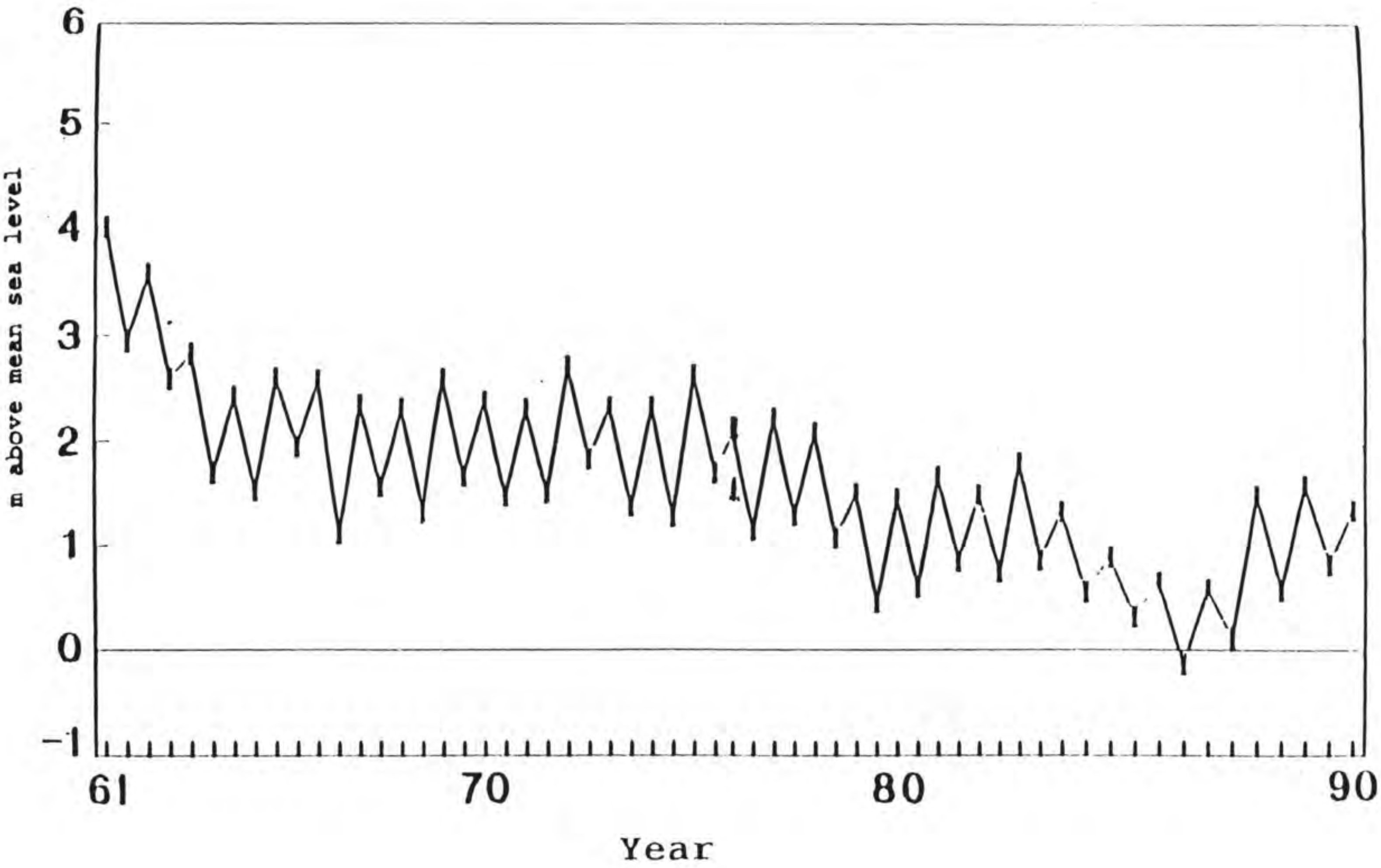
YARQON-TANNINIM AQUIFER

WATER LEVEL IN REPRESENTATIVE WELL



COASTAL AQUIFER

MEAN WATER LEVEL IN 17 OBSERVATION WELLS



Seawater intrudes the aquifer in wedgelike form, with a sharp interface between seawater and fresh water. The toe of the interface intrudes inland as a function of the fresh water level. An acceptable distance of intrusion has been established in order to allow optimal water abstraction for beneficial uses.

Specific well yields and hydraulic transmissivities vary quite markedly due to the heterogeneity of the aquifer. Transmissivities are also much lower than those of the YT, and range from 1,000 to 2,000 sq.m/day.

With a storage volume of some thousands of million cubic metres, the CA is the largest reservoir in the Three-Basin System of the NWS and its principal regulatory tool, both for short-term storage of winter surpluses in the system and for long-term balancing of demand with supply in the entire NWS. The trend in recent years has been one of continual overdrawing from the CA, causing ever-increasing lowering of the water table and depletion of reserves. The future state of the aquifer and its capability for fulfilling its central functions are therefore severely endangered.

Water levels declined steeply in the 1950s and early 1960s, until the NWC was commissioned (see Fig. 2-4). Mining of the aquifer in this period temporarily supported the expansion of irrigated areas that were later supplied from the NWC. In the late 1960s and early 1970s, water levels were partly recovered by large-scale artificial recharge and reduced pumping. Overexploitation in the 1980s resulted in the continued decline of water levels, which stopped only in 1986.

Owing to the aquifer's heterogeneity and low transmissivity, as well as overexploitation in certain areas, water levels in some regions have declined much more than in others, creating water table depressions below sea level (see Table 2-2). In addition, the seawater-groundwater interface has moved inland in the overexploited parts of the aquifer, to an extent which has caused a high increase in salinity of production wells. To counteract these effects, some 20 to 70 MCM/yr are artificially recharged into the aquifer, and pumpage in some areas has been substituted by water imported from the NWC.

Table 2-2 shows measured water levels in the CA in the spring of 1989 compared with red line levels and desirable levels. The red line was defined to bar seawater intrusion beyond an acceptable distance. The desirable level is established, taking into account the provision of a reserve for drought years. The red line is defined by a 0% slope east of the interface toe. The desirable level is defined by a 1% slope east of the toe (the Hydrological Service, 1989).

TABLE 2-2: REPRESENTATIVE HYDROLOGICAL DATA ON THE COASTAL AQUIFER

Well	Area	Measured Level Spring 1989 m above MSL	Desirable Level m above MSL	Red Lines m above MSL
53/28	Hadera	-2.27	4.9	1.1
43/2	Sharon N	-0.46	5.1	1.7
38/2	Sharon S	-1.77	5.5	1.7
Tel Aviv Arlozorov	Dan Area	0.06	2.8	1.5
Bat Yam 5	Holon-Bat Yam	-3.11	4.4	1.7
15/4	Yavne	-1.36	9.9	1.3
13/6	Be'er Tuvia	2.69	13.5	2.0
6/3	Ashqelon	1.94	0.9	1.7

The policy to be followed in order to balance pumpage and artificial recharge over the different parts of the aquifer with aquifer yield, the position of the interface, and the residual outflow to the sea, has been the subject of many studies, using detailed physical and numerical models. It has been established that the seawater-groundwater interface should be maintained at an average distance of no more than 1,500 m inland from the coastline, by appropriate distribution of pumpage and artificial recharge operations and containing water table fluctuations within predetermined levels for each part of the aquifer.

Hydrological monitoring of the CA is based on a network of 300 observation wells on a 2 km grid penetrating below the groundwater level. In the west a line of special multi-piped observation wells has been installed to monitor seawater intrusion.

2.5 Other Aquifers

The remaining aquifers are more limited in size and are generally exploited locally, most of them having no connection with the NWS. These aquifers are described below.

2.5.1 Western Galilee Aquifers

An aquifer of Cenomanian-Turonian age underlies the western slopes of the Galilee Mountains. Subterranean water flow is towards two springs, Na'aman and Kabri, the former being saline. Annual replenishment averages 115 MCM. The aquifer is almost entirely exploited by about 110 wells and the above two springs.

There are several smaller aquifers in the area. One is on the Western Galilee Coast and Haifa Basin, with an annual potential of 20 MCM. In the eastern Zevulun Valley there is an Eocene Age aquifer exploited by 18 wells, with an annual yield of about 10 MCM. Another small aquifer borders the western Yizre'el Valley; its annual yield is about 10 MCM.

2.5.2 Eastern Galilee Aquifers

The potential of the aquifers draining to LK is included in the water balance of the lake. These include the basalt aquifers in the Golan Heights, eastern Galilee and Yavne'el Valley, as well as the strata in the Jordan Depression, which drain towards LK. There is also a large aquifer in the Bet Netofa area, near the divide between LK and the Mediterranean Sea. Exploitation from these aquifers is at present low, i.e. about 8 MCM/yr. Another basalt aquifer lies in the lower Galilee; its safe yield is estimated at 25 MCM/yr, of which 10 MCM is brackish.

2.5.3 Carmel Basin

A group of small aquifers exists in the Carmel Mountains. Their yield of 39 MCM/yr (8 MCM/yr of which is brackish) is fully exploited by scores of wells. The Ephraim Mountain aquifer of the Menashe Syncline is composed of rocks of Eocene Age. Its safe yield is estimated at 22 MCM/yr. A brackish aquifer of Pliocene-Pleistocene Age, with an estimated yield of 7 MCM/yr, is found on the western Carmel coast, and is exploited by means of wells.

2.5.4 Eastern Basins

The eastern basins cover the eastern slopes of Judea and Samaria, from the Bet She'an Valley in the north to the southern tip of the Dead Sea. Two aquifers lie in the Gilboa-Bet She'an area, one of Cenomanian-Turonian age, and the other Eocene. They are exploited by wells, but mainly by springs. Part of the water mixes with saline water and becomes brackish. The safe yield of Gilboa-Bet She'an aquifers is approximately 140 MCM/yr. The yield of other aquifers to the south is estimated at 100 MCM/yr.

2.5.5 Arava

Local aquifers which at present store large quantities of water are found in several parts of the Arava. Their annual replenishment is relatively low (25 MCM, of which 16 MCM is brackish). These aquifers could be mined for an interim period to exploit some 60 MCM/yr.

2.5.6 Coastal Basins in the Gaza Region

This region is not considered as part of the Israel water sector. The coastal aquifer in this region has no significant connection with the water resources of Israel. As in the case of the CA connected to the NWS, the Gaza Basin occupies sand and sandstone layers, and is replenished from rainfall over the plain. Its total safe yield is estimated at 65 MCM/yr; however, present pumpage from this aquifer is estimated at 90 MCM/yr, resulting in severe salination (see Section 3.6). As early as in 1976, salinity exceeded 500 mg/l chlorides in more than 70% of the area.

2.6 Flood Water

Surface runoff in most watersheds in Israel is intermittent, occurring for only a small number of days during the year, after relatively heavy rains. Dry years without any streamflows are common, their likelihood increasing from north to south. The total mean annual runoff is estimated at 140 MCM/yr and the total mean annual exploitable yield, 90 MCM/yr. To date six schemes have been set up, of which three (Dalya and Menashe in the north, and Shiqma in the south), are used for artificial recharge, while the other three (Qishon, Ayalon and Nekarot) are regular surface water impounding reservoirs. In addition, a large number of private consumers have constructed earth reservoirs for surface storage of sewage and flood water. The total mean yield of flood water is at present about 40 MCM/yr.

Due to the increasing cost of land required for storage reservoirs and the high streamflow peak, reclamation of a great part of the unutilized flows is considered to be prohibitively expensive, and therefore plans in this field are being continuously postponed.

2.7 Reclaimed Wastewater

The total quantity of wastewater from municipal and industrial uses was in 1989 estimated at 293 MCM. Of this, 80 MCM was discharged unutilized to the sea and rivers and an additional 18 MCM lost to cesspool infiltration.

The quantity of effluents currently used amounts to 195 MCM/yr, or about 65% of the total. Most of the effluents (114 MCM/yr) are used for irrigation of limited industrial crops in all parts of the country (see Section 4.6). In some regions (Haifa and the northern Valleys), the practice is well-established and virtually the entire quantity of effluents available is utilized; in others (Western Galilee and the northern coastal plain), the practice is just beginning and utilization is only partial. A smaller part of the effluents (81 MCM) is recharged underground.

At present about 19,000 ha are irrigated with reclaimed sewage effluents. The irrigated area and crops are, however, limited by various quality constraints (see Section 6.3).

2.8 Other Sources

Other non-conventional sources, such as cloud seeding, seawater desalination and importation of water, are not yet part of the present water resource base of Israel. However they are considered in future plans (see Sections 10.3.3, 10.3.4 and 10.3.5).

3. WATER CONSUMPTION

3.1 General

Figs. 3-1 and 3-2 show past increases in water supply by sector. Domestic water supply increased from 200 MCM/yr in 1960 to 450 MCM/yr in the late 1980s. Industrial water supply increased in the same period from 40 to 110 MCM/yr, and irrigation water supply from 1,000 to 1,300 MCM/yr. The geographic distribution of consumption is shown in Fig. 3-3.

In most cases, domestic and irrigation water supply is combined in a single system, with a decreasing share going to irrigation (77% of 1,300 MCM in 1960, 68% of 1,900 MCM at present, expected to reach 62% of 2,100 MCM in the year 2000).

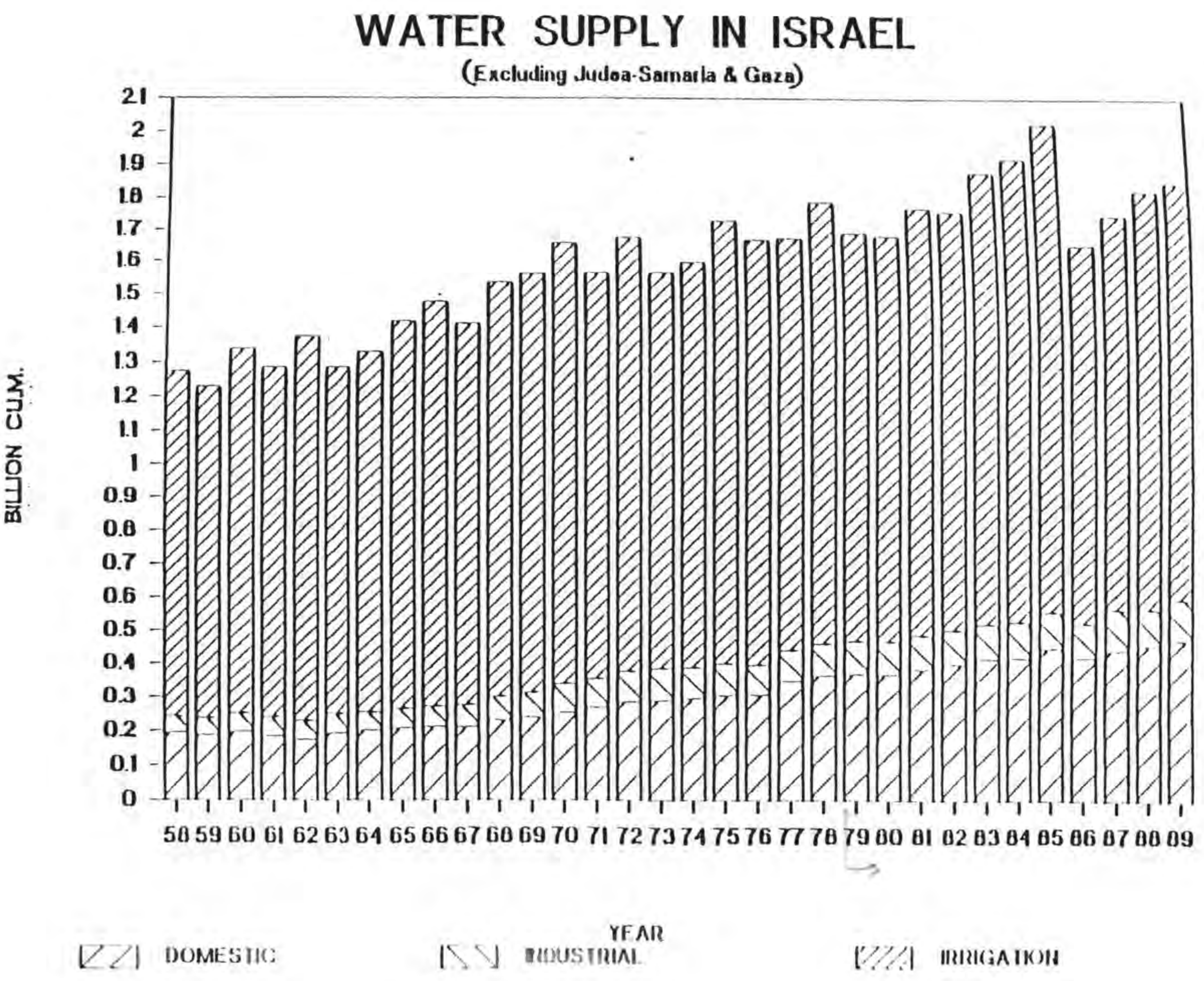
3.2 Domestic Water Consumption

Domestic water consumption is known to a fairly accurate extent, since virtually every consumer in Israel has a water meter installed on the premises. Progressive water charges are imposed by the local authorities (see Section 9.3) in coordination with the Water Commissioner, and these, combined with a general public awareness of the scarcity of the country's water resources, are an incentive for consumers to economize on water consumption. Per capita domestic consumption (including institutional and commercial use) is at present about 100 cu.m/yr on a countrywide average, and has been increasing at an average rate of 0.6% per year over the past decade. Total domestic consumption, at present amounting to about 450 MCM/yr, increased during the same period at an average rate of 2.5% per year (for a population growth of 1.9% per year).

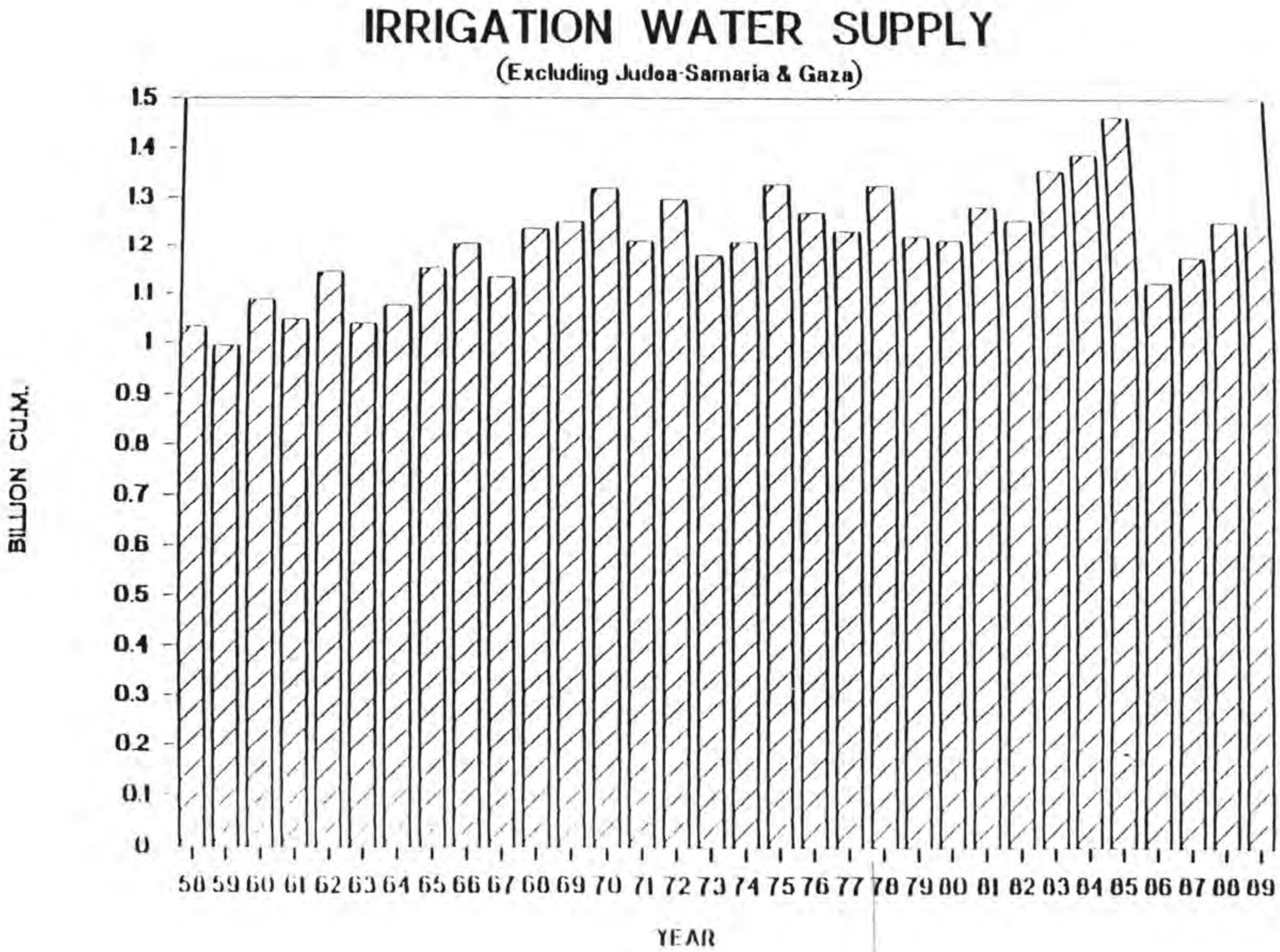
Israel's population at the end of 1988 was about 4,476,000. The urban sector includes 168 localities with populations of over 2,000, the total population of the urban sector at the end of 1988 being 4,022,700. The three largest cities are Jerusalem (population 354,000), Tel Aviv (population 307,000), and Haifa (population 202,000).

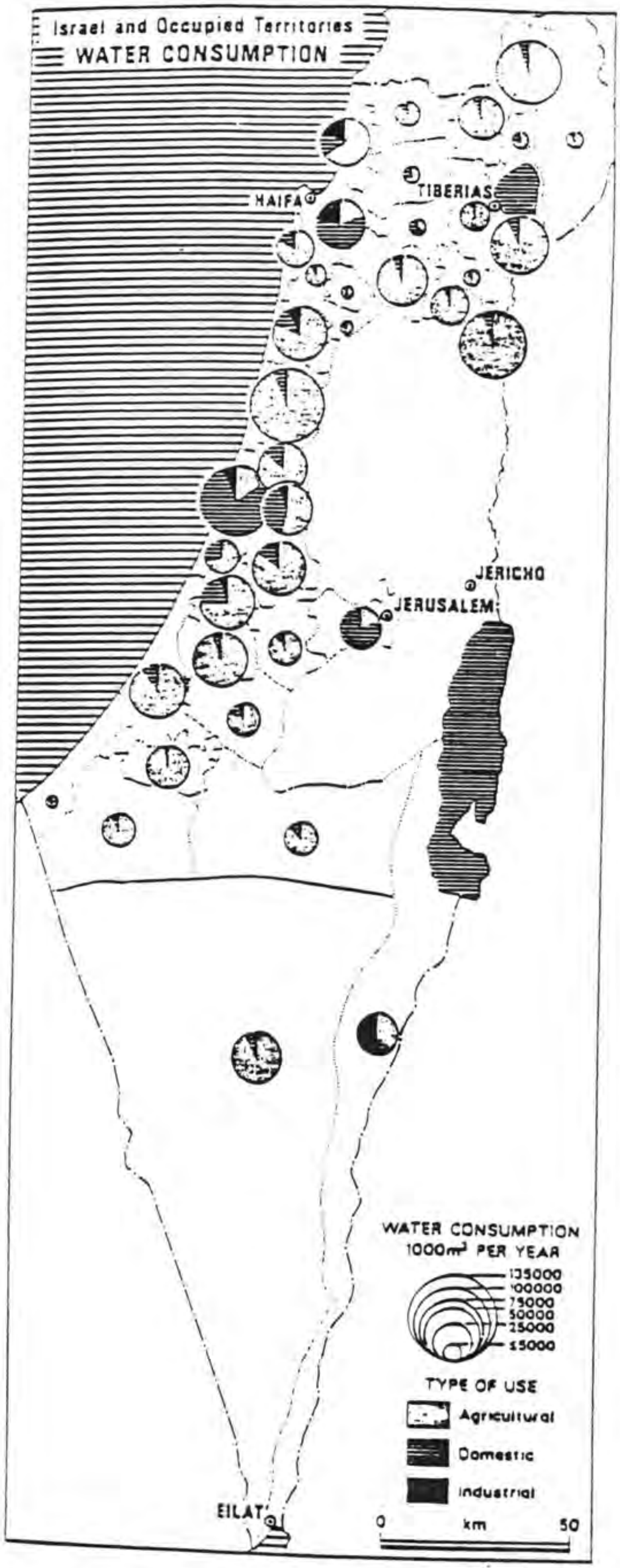
The mean per capita water consumption in the urban sector varies from 90 cu.m/yr in the small municipalities to 85 cu.m/yr in the larger ones and 35 cu.m/yr in the low income municipalities. In the largest cities, the per capita water consumption varies from 117 cu.m/yr in Tel Aviv to 89 cu.m/yr in Haifa to 67 cu.m/yr in Jerusalem.

The rural sector includes 985 localities, with a total population of 454,100. Of the annual domestic water



WATER SUPPLY IN ISRAEL
(Excluding Judea-Samaria & Gaza)
BILLION CU.M.
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89
YEAR
DOMESTIC
INDUSTRIAL
IRRIGATION


IRRIGATION WATER SUPPLY
(Excluding Judea-Samaria & Gaza)
BILLION CU.M.
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89
YEAR



Source: Atlas of Israel, 1985

supply amounting to 423 MCM in 1986/7, consumption by the rural sector was 89 MCM and the per capita consumption in this sector was 196 cu.m/yr.

3.3 Industrial Water Demand

Industrial water consumption has been increasing steadily. At present, industrial consumption is approximately 110 MCM/yr, of which about 30 MCM/yr is brackish water exceeding 400 mg/l chlorides. Most of the industrial water (40%) is consumed in the Negev region.

The average amount of water consumed per unit value of produce has shown a steady decline. There are several reasons for this, including water-saving measures such as recycling, and the growth in science-based industries such as electronics, which use very little water. Much of the cooling water is either seawater (not included in the breakdown) or recycled water. Apart from the food industry, much of the process water is not potable, being brackish or treated sewage effluents.

In the past, industrial consumption increased at a rate of about 4% per year. The forecast is for an increase of about 1.4% per year - from 110 MCM in 1985 to 135 MCM in the year 2000 (see Section 10.2.2).

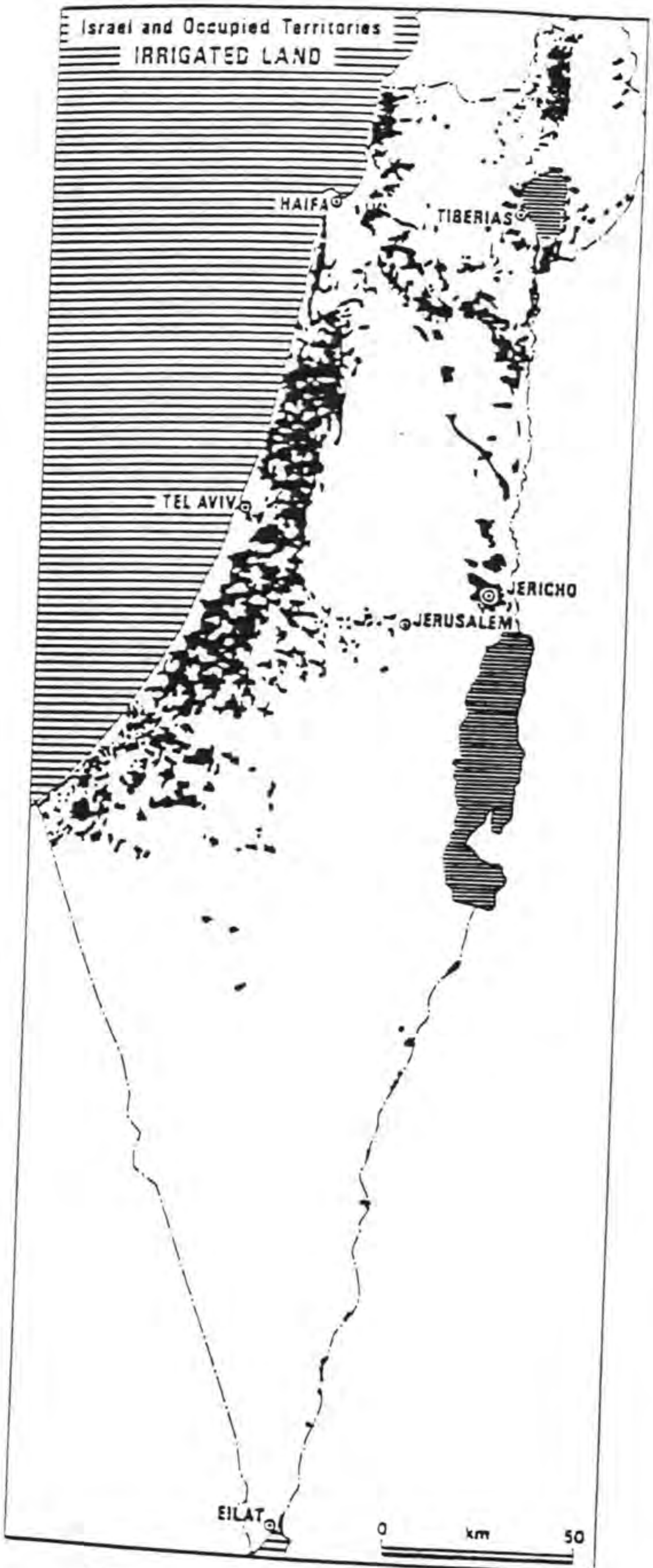
3.4 Irrigation Water Demand

Irrigation is highly developed in Israel. Of a total of about 430,000 ha under cultivation, some 215,000 ha are irrigated, using 1,300 MCM in 1988. The distribution of irrigated lands is shown in Fig. 3-4.

Agricultural water consumption has remained relatively constant in the past ten years, fluctuating from 1,200-1,450 MCM/yr, according to rainfall (see Fig. 3-2).

Agricultural water usage and irrigated crops are shown in Table 3-1.

Owing to the scarcity of water, Israel has had to develop and adopt efficient irrigation techniques. In the process of increasing water use efficiency, gravity irrigation was deliberately eliminated in favour of sprinkler and drip irrigation. Sprinkler irrigation, when properly designed, can be operated with efficiencies in excess of 80%.



Source: Atlas of Israel, 1985

TABLE 3-1: PRESENT AGRICULTURAL WATER USAGE (1989)

Crop	Area ('000 ha)		Irrigation Water	
	Non-Irrig.	Irrig.	MCM	%
Citrus	-	35	256	21
Other tree plant.	13	40	303	24
Vegetables	6	30	169	14
Cotton	-	35	171	14
Other field crops	130	72	213	17
Flowers	-	2	22	2
Fishponds	-	3	100	8
Total	149	217	1234	100

The principle behind drip irrigation is the ability to discharge small quantities of water and fertilizer at frequent intervals in the root zone. The frequent irrigation washes the salts downwards and to the edges of the wetted area, causing less stress in the plant.

The effect of drip irrigation on water application rates and yields is demonstrated by the results obtained on a 700 ha banana plantation, given in Table 3-2. The table shows that water consumption is reduced by half for the same unit yield.

TABLE 3-2: INCREASE IN 700 HA BANANA AREA UNDER DRIP IRRIGATION IN THE JORDAN VALLEY, 1972-1981

Year	% of area under drip irrigation	Annual water applications cu.m/ha	Yields tons/ha/year	Water Consumption l/kg yield
1972	0	50,000	30.5	1,640
1973	8.3	47,000	26.9	1,750
1974	14.1	42,740	24.2	1,770
1975	20.7	45,580	39.1	1,170
1976	35.6	39,000	42.4	920
1977	48.3	40,700	36.1	1,130
1978	61.3	38,300	41.7	920
1979	77.8	37,170	44.2	840
1980	75.8	32,030	40.2	800
1981	80.6	28,540	40.9	700

Drip irrigation is believed to have many advantages: it has made it possible to use water previously considered too saline for irrigation and to cultivate saline desert soils. Saline water containing between 2,500 and 3,000 mg/l of TDS, which includes over 600 mg/l of chlorides and about 700 mg/l of sulphates, are currently used for crop irrigation, although it is necessary to pre-irrigate with sprinklers between croppings to wash out the salt of the soil.

Irrigation water is now applied mainly according to predetermined irrigation schedules based on well-researched and tested water application rates. Most farms use automated systems or devices which automatically shut off the water once the predetermined quantity has been applied.

Upgrading of irrigation techniques and increased irrigation efficiency have been achieved by introducing drip irrigation, computerized automated control and irrigation machines. This process has been accompanied by the introduction of new crops and agrotechniques, in particular sophisticated fertilization techniques, based on the results of agricultural research.

The improvements over the past few years have made it possible to increase significantly the area under irrigation without increasing water use, as well as to increase the product value. Average water use has decreased from 8,700 cu.m/ha to about 5,800 cu.m/ha, while the agricultural product per hectare has increased.

Fig. 3-5 shows the marked increase in yield per unit water application for the principal crops.

3.5 Water Consumption in Judea and Samaria

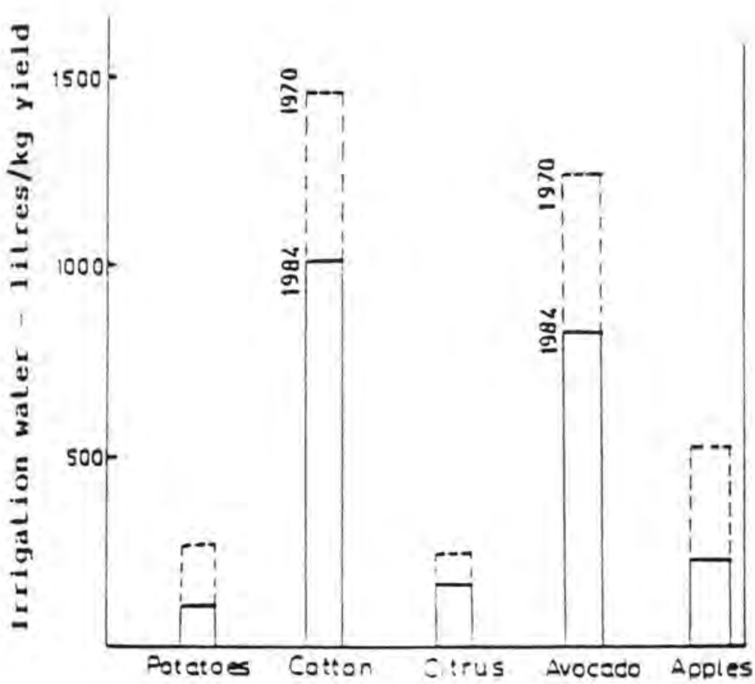
The population of Judea and Samaria (not including Israeli settlements, which are included in the census of Israel) was 0.9 million in 1989 vs. 0.6 million in 1967. All the population has access to drinking water supply, with 5% having access only to communal sources. Running water exists in 62% of the households, courtyard taps in 14% and courtyard cisterns in 19%.

Water is supplied from local wells and from regional systems existing in most of the areas, but without interregional connections. Ample groundwater satisfies all regional requirements.

The present per capita consumption is estimated at 35 cu.m/yr. The total domestic and industrial water supply is estimated at 31 MCM/yr.

IRRIGATION WATER APPLICATION RATES

FOR MAJOR CROPS, 1970 AND 1984



Irrigation water supply is estimated at 80 MCM/yr. The total irrigated area is estimated at 10,000 ha while the irrigable area is estimated at 31,000 ha. An additional 32,000 ha of irrigable lands are not considered for irrigation due to low soil classification (high slopes and small, scattered plots).

The source of water is mainly groundwater: 24 MCM/yr from YT, 24 MCM/yr from northern aquifers flowing to the Bet She'an Valley, and 59 MCM/yr from the eastern basins. A total of 3 MCM/yr is imported from Israel.

The northern and YT aquifers are major aquifers of the Israel NWS. Of the YT, 94% is utilized in Israel, and of the northern Bet She'an Aquifer, 85% is utilized in Israel.

3.6 Water Consumption in the Gaza Region

The population of the Gaza Region was 0.6 million in 1989. All the population has access to drinking water supply, with only 2.5% depending on communal sources. Running water exists in 75% of the households, with courtyard taps in 22%.

The present per capita consumption is estimated at 35 cu.m/yr. The total domestic and industrial water supply is estimated at 23 MCM/yr. Irrigation water supply was estimated in 1985 at 67 MCM/yr.

All the water is supplied from local wells tapping local aquifers, which resemble the CA in Israel in structure and hydrogeological characteristics. The amount of water withdrawn annually from the aquifer exceeds the safe yield of 65 MCM/yr by 25 MCM/yr. Irrigation water requirements used to be higher in the past, and overexploitation was then estimated at 50 MCM/yr.

As a result of the above, the water tables are low, with deep seawater intrusion inland and severe salination, amounting to an increase of 10-20 mg/l chlorides per year in some locations. Salinity exceeds 500 mg/l chlorides in most of the area.

The situation demands an immediate end to over-exploitation, by reducing pumping from 90 to 60 MCM/yr.

4. WATER SUPPLY SYSTEMS

4.1 Introduction

The limited quantity, non-uniform distribution, and in some cases, poor quality of the country's water resources have led to the planning and construction of a highly flexible and integrated water supply system.

With the completion of the National Water Carrier (NWC) in 1964, Israel's widely dispersed distribution facilities were incorporated into a fully integrated water grid through pipelines and groundwater aquifers (see Fig. 4-1). In addition, a management regime was formulated for optimal overall utilization of the country's water resources.

4.2 The National Water System

The National Water System (NWS) connects the rainy north with the dry south, with interconnected regional water grids, including surface water and groundwater. The NWS also serves to bridge the temporal gaps between water supply and demand.

The NWS, which was completed and put into operation in 1964, supplies about 1,100 MCM/yr, of which some 400 MCM/yr originate in the Jordan Basin.

Israel's NWS resembles a tree, whose trunk is the NWC and whose branches are the regional water schemes. The principal function of the NWC is to convey water from the country's relatively water-rich north to the centre and south of the country, which have more irrigable lands than can be irrigated by local water resources. The system is energy-intensive, and the unit cost of water supply is relatively high (see Section 9.2).

The point of origin of the NWC is the Sapir pumping station at Tabgha on the northwestern shore of LK, which lifts up to 20 cu.m/sec from the lake (mean water level -211 m) to El. +152 m. From this point the water flows across the Yizre'el Valley and along the Coastal Plain to the south by gravity over a distance of 110 km via a 23-km long canal and an 87-km long 2.7 m dia. pipeline (see Fig. 4-1).

From the terminal point of the NWC near the Yarqon Springs, a system of two pipelines (the eastern and western Yarqon-Negev pipelines), with diameters of 1.7 and 1.8 m, respectively, booster stations and regulating reservoirs, carries the water southwards over a distance of some 95 km to the arid Negev region.

Several regional systems branch off from the NWC. Depending on the varying demands and the state of groundwater levels in local aquifers, the regional schemes either receive water from the NWC for supply to consumers, mainly in the summer months, or contribute water from local aquifers to the NWC, mainly in the winter months. Part of the water from the NWC is used during the winter for artificial recharge of the aquifers.

A third pipeline has been constructed recently from the Dan Region Sewage Reclamation Project. This pipeline runs parallel to the western Yarqon conduit, and conveys reclaimed effluents which have undergone tertiary treatment. These effluents are then recharged to the aquifer for pumping by batteries of wells. The water obtained thus is earmarked for irrigation only, and its supply to numerous villages and settlements in the south has necessitated the construction of separate systems for domestic water supply.

4.3 Regional Water Supply Systems

4.3.1 Regional Supply Systems of Mekorot

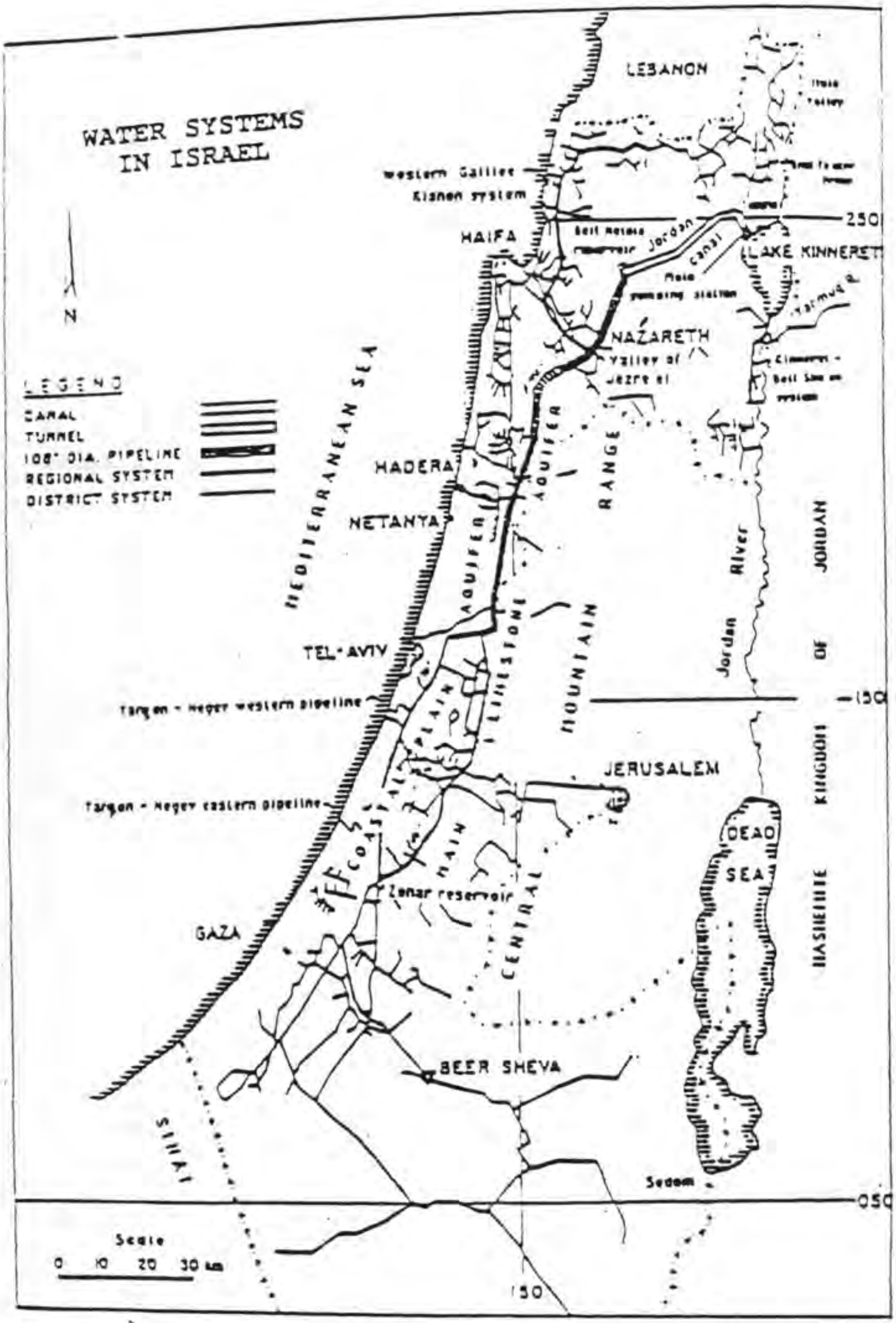
Construction of regional systems began in the late 1930s, when Mekorot Water Co. was founded. At present these waterworks extend throughout the country, from Mt. Hermon in the north to Elat in the south. Most of the systems are interlinked with the NWS, either by physical linkage with the NWC or by indirect connection (via the principal groundwater basins and the Kinneret basin). They supply about 1,100 MCM/yr. The principal schemes are listed below.

The Upper Galilee System (Eastern Galilee, 'En Aviv, Senir, 'En Zahav and 'En Ziv) draws water from the headwaters of the Jordan River in the Hula Valley, from springs and from boreholes. It supplies water to the entire Upper, Central and Eastern Galilee region, as well as the northern and southern Hula Valley in the Upper Jordan basin.

The Western Galilee-Qishon System draws water from springs, groundwater and the NWC. It supplies a total of 130 MCM/yr fresh water to the entire Western Galilee region, from Rosh Haniqra to Haifa and the Zevulun, Yizre'el and Ta'anach Valleys, as well as to the Nazareth region. It constitutes the largest regional water supply system in the northern part of the country.

The principal element of the system is the 48"-24" dia. main, which originates at Nahal Qeren in the north. It bisects the Zevulun and Yizre'el Valleys before

Fig. 4


WATER SYSTEMS IN ISRAEL
LEGEND
CANAL
TUNNEL
108" DIA. PIPELINE
REGIONAL SYSTEM
DISTRICT SYSTEM
N
LEBANON
Western Galilee
Kishon system
HAIFA
Jordan Canal
LAKE KINNERET
NAZARETH
Valley of Jezre el
HADERA
NETANYA
TEL-AVIV
MEDITERRANEAN SEA
AQUIFER
RANGE
Jordan River
HASHEMITE KINGDOM OF JORDAN
MOUNTAIN
LIMESTONE
COASTAL PLAIN
Yarqon - Negev western pipeline
Yarqon - Negev eastern pipeline
JERUSALEM
DEAD SEA
MAIN
Zohar reservoir
CENTRAL
GAZA
BEER SHEVA
SINAI
Sedom
Scale
0 10 20 30 km
250
150
050
150

reaching the Mizra reservoir, where it bifurcates southwards to the Ta'anakh Valley and eastwards to the Merhavya, Dovrat and 'En Dor regions.

The Qishon Irrigation Water Supply System conveys the sewage effluents of the Haifa Region Association of Towns (Sewage) at a rate of 20 MCM/yr by means of a 36" dia. main to the 12 MCM Ma'aleh Ha-Qishon reservoir in the Yizre'el Valley south of Nazareth. The centre of the system is the adjacent 9 MCM Kefar Barukh Reservoir, whose function is to store the floodwaters of the Upper Qishon, as well as water from the NWC. Both reservoirs feed an irrigation water system parallel to the Western Galilee-Qishon potable water system, in its southeastern stretches.

The Golan Heights System draws water from surface waters, local boreholes and LK, and supplies water to all the settlements in the region.

The Kinneret-Lower Galilee and Kinneret Bet She'an System draws most of its water from LK and supplies it to all the settlements in the Lower Galilee (up to Kefar Tavor in the west), Ramot Yisakhar and the southern Jordan Valley, up to Bet She'an.

The Hof HaCarmel-Nahal Oren System draws groundwater via boreholes in the Mt. Carmel foothills and supplies the entire region between Zikhron Ya'aqov in the south and Haifa in the north.

The Shomron and Sharon Systems - Giv'at 'Ada, Pardes Hanna, Hadera-Menashe, Gevul Meshulash, Northern Sharon and Southern Sharon. These systems draw water from the YT, the CA, winter flows, and water of the NWC to improve hydrologic conditions in the CA. These systems supply agricultural and municipal settlements, from Zikhron Ya'aqov in the north to the Yarqon River in the south. Several hundred small private water supply works also exist in this area.

The Yarqon-Negev and Related Systems. The Yarqon-Negev system is part and parcel of the NWS and supplies water from Rosh Ha'ayin - the terminal point of the NWC - to the south. A number of regional systems - Shiflat Lod, Ayalon, Yavne, Gat and Lakhish - are all linked to the Yarqon-Negev System and draw water from the NWC, as well as from the YT and CA. They supply water to settlements in the plain, the Jerusalem Corridor and to Jerusalem itself.

South of the Zohar reservoir in the Lakhish region, the Yarqon-Negev system provides water to the Shoval, Tequma and Har-Hanegev systems, and is also linked with the Gevar'am, Nira'am and Yad Mordekhai systems in the western Negev, which also draw water from the CA. A

50-km long, 42" dia. Zohar-Ze'elim main line supplies water to the entire eastern Negev region between Zohar and Mizpe-Ramon. The principal water sources are LK and the YT.

The new 70"-54" dia. main linked to the Dan Region Sewage Reclamation Scheme conveys reclaimed effluents from this scheme for irrigation of agricultural lands south of Lake Zohar, in parallel with the Yarqon-Negev and Zohar-Ze'elim fresh water systems.

The Jordan Valley System. A number of systems have been constructed in this region since 1967. They draw mainly deep groundwater and supply the entire valley from Mekhola, south of Bet She'an in the north, to Mizpe Shalom near the Dead Sea in the south.

The Jordan River constitutes an additional water source; however, its water in this area is brackish and can be used for only a very few crops.

The Arava System. All the Arava settlements are supplied with groundwater which is partly derived from the Nubian Sandstone Basin. Most of the water in the region is brackish and part of it is desalinated, so that it can be supplied as drinking water to the town of Elat. Elat used to be supplied with desalinated seawater at a cost of US$ 4/cu.m. At present it is supplied with desalinated groundwater at a cost of US$ 0.5/cu.m and from the major Arava System, namely, the 100 km long, 20"-24" dia. Paran-Elat pipeline, which also supplies water to the Arava settlements.

4.3.2 Local Schemes Not Owned by Mekorot

Water supply systems in Israel were developed in stages. The systems constructed initially were surface water or shallow groundwater schemes which could be implemented with relatively small investments, and in which conveyance distances were short. Up to establishment of the State in 1948, these systems supplied 200 MCM/yr.

At present, these waterworks supply 600 MCM/yr; most of them are very small and are based on shallow wells. The larger systems are listed below (from north to south).

The Hazbani-Dan System draws water from the Dan River in the Upper Jordan and supplies the western region of the Northern Hula Valley via a 70" dia. pipeline under pressure for irrigation.

The Eastern Dan System draws water from the Dan River and supplies it under pressure by means of a 40" dia. main to the eastern region of the northern Hula Valley.

The Jordan Valley System obtains water from LK and the Yarmuk River, and supplies it to the older established settlements in the Jordan Valley (between Kevuzat Kinneret and Ashdot Ya'aqov), known as the Yarmuk Triangle.

The Harod System draws water from the Harod Springs as well as from boreholes in the region, and supplies the settlements in the region (between Kefar Yehezqel and Bet Alfa).

Water Supply Systems of the Large Municipal Authorities. These systems - such as those of Nahariyya, Hadera, Netanya, Herzliyya, Ra'anana, Kefar Sava, Ramat HaSharon, Petah Tiqva, Bene Beraq, Ramat Gan, Giv'atayim, Holon, Bat Yam, Rishon Le'Zion and Rehovot - draw groundwater pumped from boreholes located within the limits of these authorities in the coastal basins. Recently these systems have gradually been replacing pumping from their deteriorated CA boreholes by supply from the NWC.

4.4 Water Resources Management

Two distinct periods may be identified in the development of water resources management in Israel: a period of rapid growth from 1948 to 1965, and a period of stabilization after 1965. The two periods are described below.

4.4.1 Water Resources Management in the Period 1948 to 1965

During this period, water management focused mainly on the development of new water sources for economic development of the newly created state. Such developments raised two important problems. First, it was necessary to establish the country's approximate water balance in order to have an idea of the renewable amounts that could be made available annually for water supply. The second problem related to the fact that large expanses of arable land in central Israel and the northern Negev are far from the humid Galilee. This led to the concept of centralized water supply, conveying water from areas of abundant precipitation to those of high demographic density and intense agricultural development. Since 1965, LK water has been conveyed via the large conduit of the NWC to the arid Negev.

In the practically virgin aquifers of the early 1950s, water levels were high, accompanied by high outflows from natural outlets to the sea,and to springs (in the YT). In the coastal area, the freshwater-seawater interface toe was located near the sea and the CA had an operative storage of about 2 billion cu.m, with a salinity value of 80 mg/l chlorides. In the YT, similarly high levels were accompanied by a salinity value of about 100 mg/l chlorides. Therefore it was decided to "mine" water from these aquifers (i.e. to pump more than the annual recharge) until completion of the NWC, to allow gradual development of water supply in central and southern Israel.

The exploitation of aquifers in this period resulted only partly in lowering of water tables. A great part of the exploitation was at the expense of reducing flows to natural outlets, thus replacing uncontrolled and unused outflows with controlled abstraction.

In contrast to the low groundwater salinity in this early period, LK showed relatively high salinity (300-400 mg/l chloride). In the late 1950s, the lake also began to receive large amounts of nitrates and organic matter as a consequence of the drainage of Lake Hula. Mixing of LK water on its way south with groundwater was therefore an important component of water resources management of the NWS in 1965.

4.4.2 Water Resources Management After 1965

Availability of abundant water nearly everywhere as a result of the NWC was a major factor in economic development. From 1962 to 1975, the population leaped from 2.33 to 3.49 million, and the total water consumption from 1,100 to 1,600 MCM/yr, some 80% accounted for by a rapidly growing agricultural sector.

The mining of "one-time reserves" did not stop after commissioning of the NWC, and this lowered the water table to a dangerous extent, causing landward migration of the interface.

The demographic and economic growth also led to increased production of sewage which was not treated and found its way into rivers and wadis (Shuval, 1980), as well as to the use of fertilizers and pesticides which slowly reached the aquifers. These processes were particularly marked in the CA owing to the dense population on the land over the aquifer, but were also observed in the YT.

Table 6-1 shows a comparison of quality parameters developing in the three main reservoirs. In the CA, a 100% increase in salinity and a 350% increase in nitrates is noted. In the YT, no significant overall increase in salinity is detected, but nitrates increased by 50%. Conversely, salinity in LK dropped by 50% as a result of diversion of the coastal salty springs into the "salt canal" in 1965. Moreover, a 40% decrease in input of organic N from the Jordan River was observed in the 1980s, probably owing to the storage of polluted waters in the Kiryat Shemona and Einan Reservoirs, built for this purpose.

Another interesting result of the above processes occurring in the underground aquifers and LK is the difference in chloride concentrations between underground water and lake water. In 1960 this difference was as high as 270 to 300 mg/l. At present it does not exceed 50 mg/l.

Intensive efforts to dilute the NWC with less saline water from YT wells were required when operation of the NWC was commenced in 1965. However, this was discontinued after some years when the difference in salinity was no longer significant.

4.4.3 Operation and Management of the Major Aquifers

The underground reservoirs have been considered as a long-term storage system for maintaining interannual storage, capable of guaranteeing uninterrupted water supply even during periods of several consecutive dry years.

Although the two major aquifers contain large quantities of water, excessive withdrawal rates from these aquifers must be avoided to prevent seawater intrusion. The fresh water in the deeper, karstic limestone groundwater reservoir has contact with highly saline water, a fact which also limits permissible withdrawal.

Total annual withdrawals must remain below natural annual replenishment plus artificial recharge from surface waters.

The NWS is now operated such that in years of high rainfall, LK water is used to a maximum extent, and use of the underground resources, which are connected to the NWS, is kept to a minimum. Any surplus surface water is, wherever possible, recharged to the underground storage reservoirs to replenish areas which have been overexploited and to provide additional storage which can be drawn upon in years of low rainfall. On the other hand, in order to utilize groundwater reserves to the maximum, a series of shallow wells ("Coastal Collectors") have been drilled very close to the coast to collect this flow and decrease the amount reaching the Mediterranean Sea.

Integrated management of the country's water resources and national water supply system has reached a sophisticated and complex level of development, involving the application of numerous mathematical models to establish, among others, interbasin transfers, artificial groundwater recharge and agricultural water allocations.

4.5 Operation and Maintenance of the Water Supply Systems

Routine operation and maintenance of the water supply systems are the responsibility of the district offices of Mekorot and the independent regional water supply organizations. Technological development with respect to these functions has focused recently on two areas: automatic control and energy conservation. These are discussed below.

4.5.1 Automatic Control

Advanced techniques in electronics, computers and telemetry are used for monitoring and remote control of the water supply and regulation facilities. Electronic SCADA (Supervision Control and Data Acquisition) systems have been installed in many of the districts and regions. However, most of the automatic controls are local (operation of single pumping stations as a function of water level in a commanding reservoir). These systems have already resulted in considerable savings in energy and manpower, and minimization of leaks and water losses. Expert systems for automatic control of complex systems are also being developed.

4.5.2 Energy Conservation

Energy expenditure in the Israeli water supply systems amounts to about 40% of the total operational costs. Installed pumping capacity of Mekorot (65% of the national water supply) amounts to about 400 MW. Great efforts are therefore invested in energy saving.

Energy conservation measures include:

- Improvement in operational efficiency of pumping facilities.

- Management of the power load to exploit low time load tariffs.

- Increased automation and improved monitoring systems.

- Hydroelectric retrieval of energy in locations of gravitational drops, such as artificial recharge wells.

As a result, an average drop of 1% per year (in fixed prices) has been observed in energy expenditure in the past few years.

4.6 Reuse of Wastewater Effluents

Great advances have been made in this field in the past decade, with the result that reclaimed wastewater is being increasingly used for irrigation. Major projects include:

Dan Region Project. This project, which serves the Tel Aviv Metropolitan Area, including its satellite cities, is designed to process about 120 MCM/yr of wastewater, to be conveyed to an area south of Tel Aviv for treatment and reclamation in a system incorporating aquifer recharge. The wastewater is treated mechanically and biologically, and then recharged to the aquifer for a storage period of about 400 days. Percolation through, detention in, and absorption by, pervious soils in the recharge areas provide additional treatment. This, in conjunction with similar processes in the aquifer, provides a very efficient secondary effluent treatment system known as SAT (Soil Aquifer Treatment). Results obtained so far indicate that the SAT system is effective in purifying secondary effluents and upgrading them to a level suitable for unrestricted irrigation as well as for a variety of industrial and non-potable municipal uses. The quality parameters of the reclaimed effluents after SAT reach drinking water standards, and are accepted by the health authorities for occasional drinking but not for reticulated water supply. A total of 65 wells located on the periphery of the recharge area pump the water to the irrigation fields in the Negev via a separate 70" dia. main pipeline running parallel to the western Yarqon conduit (see Section 4.3.1).

The Dan Region Sewage Reclamation Plant will produce by the end of the century about 150 MCM/yr, i.e. all the wastes of a population of 2.0 million (see also Section 5.4).

Qishon Multi-Source Scheme. In this scheme, as well as in a number of other schemes, a less sophisticated, less costly approach is applied for treatment and reuse of effluents from smaller cities, towns and settlements.

The schemes use biological treatment to produce effluents restricted to the irrigation of non-edible crops. The Qishon Scheme, the most significant of these schemes, reclaims the wastewaters of the Haifa Metropolitan Area (25 MCM/yr). After conventional activated sludge treatment, the effluents are conveyed to the Yizre'el Valley, some 30 km east of Haifa, where they are impounded, together with other local wastewater and floodwater, in a 12 MCM surface reservoir for summer irrigation of cotton and other non-edible crops (see Section 4.3.1).

Other Schemes. In addition to the above, a number of other small schemes employing different treatment processes have been developed for the treatment and utilization of sewage from medium and small sized towns. The level of treatment in these schemes ranges from advanced treatment of the activated sludge type to aerated lagoons. These schemes usually include seasonal storage and irrigation systems.

Storage of Effluents. The key element in the effluent reuse systems is seasonal storage to obtain effluents of varying quality in winter months, and their release to agricultural areas during the dry summer months. A total of 152 storage facilities, with an overall volume of 70 MCM, were recently recorded. Most of the effluents currently utilized for irrigation are stored in seasonal reservoirs after treatment in aerobic ponds excavated adjacent to the reservoirs.

5. ARTIFICIAL GROUNDWATER RECHARGE

5.1 Objectives and Methods

The term artificial groundwater recharge is applied to the artificial introduction of water into an aquifer. The objectives of artificial groundwater recharge are:

- Seasonal or long-term underground storage of surplus water.
- Upgrading of water of excessive contaminant content or salinity.
- Improvement of the hydrological situation in the aquifer.

Artificial groundwater recharge is one of the most important means available today to attain conjunctive and optimal utilization of surface runoff and groundwater.

Two methods are used for artificial groundwater recharge: spreading and injection through wells. Selection of the method to be applied in a specific case depends greatly on the given geological and hydrological conditions, the nature of the water available for recharge, and many other conditions. In spreading, water must percolate through the unsaturated zone, undergoing natural filtration and other changes in the process. When the recharged water reaches the saturated zone by percolation, or by injection through wells into the saturated zone of the aquifer, a sequence of interactions takes place between the injected water, the natural water of the aquifer and the aquifer medium. These interactions are not yet sufficiently understood, and for this reason, the success of artificial groundwater recharge operations still relies to a great extent on experience.

Israel on a national scale, has acquired over the last three decades extensive experience with artificial groundwater recharge, mainly for the purpose of aquifer management, utilization of the storage capacity of aquifers and reuse of treated effluents.

Examples of artificial groundwater recharge in Israel are described briefly in the following sections.

5.2 Artificial Groundwater Recharge Schemes in the Arid Negev

The Negev, in the southern part of Israel, is located in the northern fringe of the sub-tropical desert belt. The region receives an average annual rainfall of 50-300 mm. Rain falls in the form of short, intense storms. Deep infiltration over groundwater catchments is on the whole negligible, and most natural recharge of shallow aquifers is effected by infiltration of ephemeral surface flow in natural stream channels.

Several artificial groundwater recharge schemes have been designed in this region to increase the quantity of exploitable water. A typical scheme consists of an earth dam creating a reservoir for interception and short-term storage of flood water, and provisions to ensure infiltration of the water into the aquifer. Recharge takes place in the reservoir itself and/or on adjacent spreading grounds. Exploitation of the recharged water is effected by pumping from existing or specially drilled wells. Preparatory investigations included studies of the dam sites and the reservoir area, and mathematical simulation of the expected recharge process, ensuing changes in the groundwater flow as well as recovery of the recharged water through wells.

5.3 Artificial Groundwater Recharge Schemes in the Coastal Plain

Artificial recharge in the Coastal Plain serves five different purposes:

- Restoration of groundwater to higher levels to counteract further intrusion of seawater.

- Balancing of present and future withdrawals with long-term average annual recharge.

- Seasonal and long-term underground storage of winter surpluses from the NWC and stormwater runoff.

- Local improvement of groundwater quality.

- Upgrading of low quality recharge water by mixing with innate groundwater of superior quality.

Owing to the available storage capacity of the aquifer and distribution of wells, loss of recharged water through outflow to the sea may be minimized. Indeed, as stated earlier, chains of shallow wells ("Coastal Collectors") have been constructed near the seashore in order to intercept remaining outflows.

Water used for recharge derives from three sources:

- Water from the NWC (LK).
- Groundwater from the carbonate YT aquifer.
- Stormwater runoff.

Recharge is carried out through wells and spreading grounds, mainly during the rainy winter season, when water demand for irrigation is minimal, surpluses are available from the NWC, and many wells are idle and can be utilized for injection.

Recharge is performed partly through dual purpose wells. The wells are normally recharged at about the same rate as their pumping yield, which may be as high as 250 cu.m/hr in the sand and sandstone aquifer, and about 1,000 cu.m/hr in the limestone aquifer.

Total recharge varies from year to year, in accordance with hydrological and technical conditions in the NWS. Available recharge capacity is about 100 MCM per season, of which about 70% is supplied by the NWC.

In some areas, NWC water is recharged first to the YT carbonate aquifer, and subsequently repumped and recharged to the CA. Mixing of lake water with groundwater in the YT greatly improves the seasonal recharge capacity of the CA wells.

Two schemes have been constructed in the coastal sand dune areas of the Shiqma and Nahalei Menashe basins to intercept and spread floodwaters from their respective upstream basins, and thereby replenish groundwater.

5.4 Combined Application of Wastewater Treatment and Artificial Groundwater Recharge

Artificial recharge of sewage effluents aims at seasonal storage and quality upgrading by SAT (Soil Aquifer Treatment). The greatest quantity of effluents, amounting to over 100 MCM/yr, is produced by the Tel Aviv Metropolitan Area (known as the Dan Region). A combined sewage-reclamation and recharge project was designed and constructed for this region. The project was conceived to solve both environmental hazards and water resources management problems. It now provides 70 MCM/yr of high quality water that is used for unrestricted irrigation in the southern part of the coastal plain, alleviating the severe overdrawing of local groundwater there.

The project consists of two steps, one comprising sewage reclamation and the other recharge of the reclaimed water into the CA.

Treatment of the sewage is based on the high-rate activated sludge method (in addition to treatment of part of the sewage by facultative recirculation ponds in an older part of the plant). Recharge is carried out in spreading grounds located in sand dunes. The water is recovered from a battery of wells encircling the recharge grounds (see also Section 4.6).

6. WATER QUALITY

Water quality is at present a major problem in water resources management in Israel. Some of the major problems are described in the following.

6.1 Mineral Quality of Water Resources

The quality of supplied water in Israel varies from low salinity water, containing only 10-12 mg/l of chlorides, in the Upper Jordan River, to water in LK, with 200 mg/l of chlorides, to wells in the Negev, containing up to 1,500 mg/l of chlorides.

As a result of full exploitation, the natural flow patterns in the aquifers are changing, and the fluxes of fresh water are decreasing. On the other hand, the influx of pollutants from catchment surfaces has been increasing owing to heavy fertilizer applications and other human activities. Thus the content of minerals and contaminants in the groundwater has been constantly increasing, as described in the following.

Groundwater. The present distribution of chlorides in pumped groundwater is shown in Fig. 6-1. The total pumped volume, containing more than 250 mg/l chlorides, is at present about 200 MCM/yr (18% of the total) and is expected to increase in ten years to 320 MCM/yr (25% of the sample). This forecast is based on the extrapolation of past salinity trends, shown in Fig. 6-2 and summarized in Table 6-1.

TABLE 6-1: CHEMICAL COMPONENTS IN WATER PUMPED FROM UNDERGROUND AQUIFERS

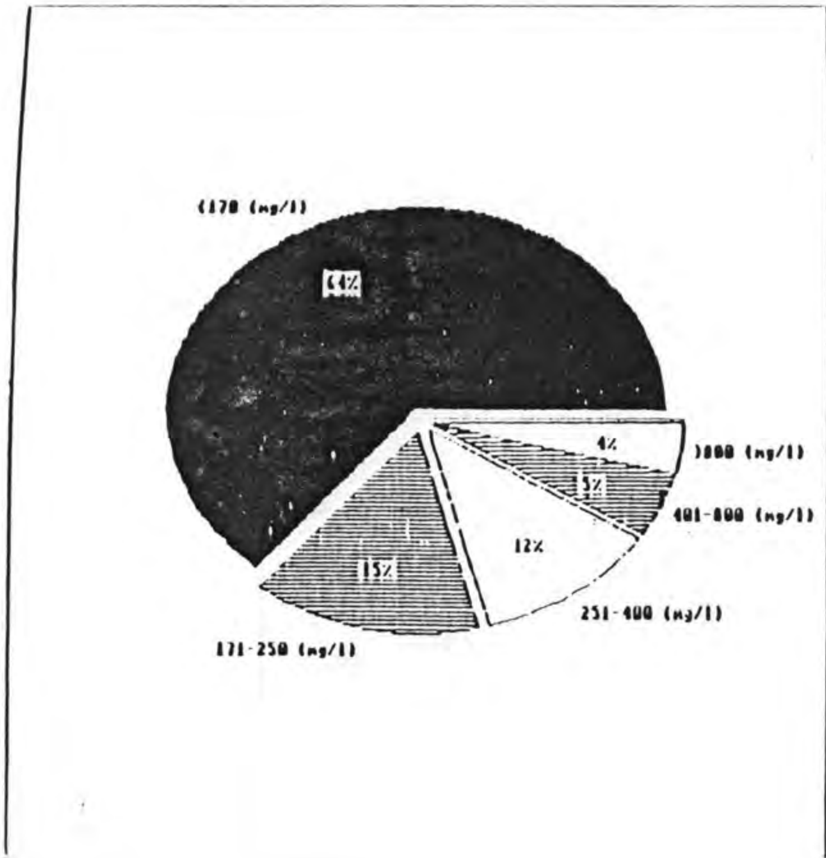
Basin	Mean Chloride Conc. mg/l			Mean Nitrate Conc. mg/l		
	1950	1960	1985	1950	1960	1985
Coastal Aquifer	80	115	150	10	25	45
Yarqon-Tanninim Aquifer	180	160	150	10	10	15

Source: Kahanovitz and Schwarz, 1985.

Table 6-1 shows the build up of salinity in the CA, which is typical of many other basins. Recent studies show that the flux of salts from the unsaturated zone into the CA is expected to grow in the future.

CHLORIDES IN GROUNDWATER

1985



2010

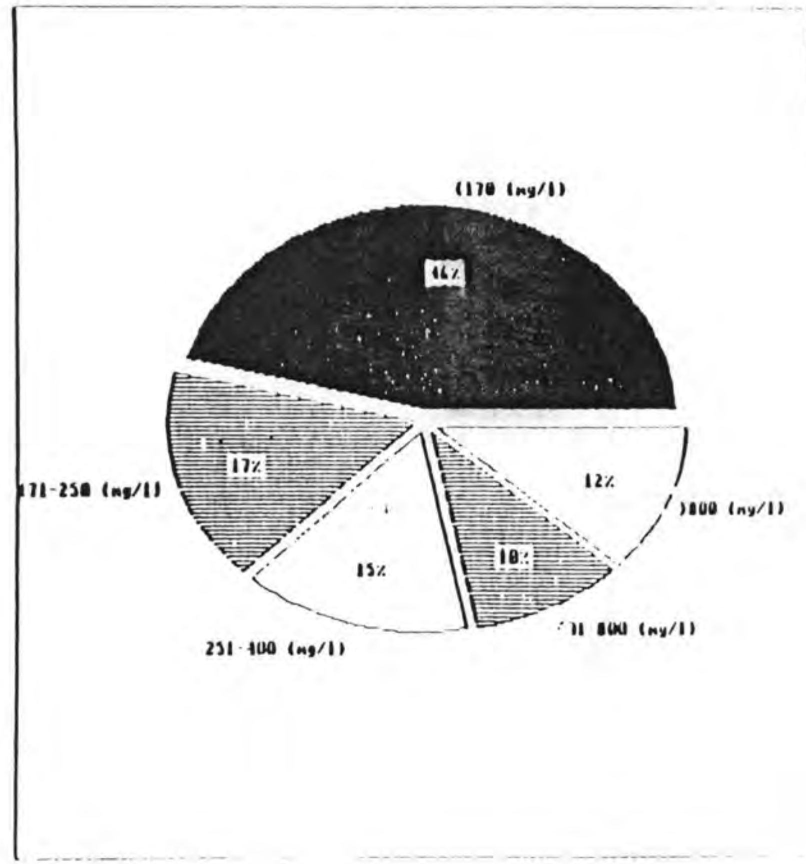
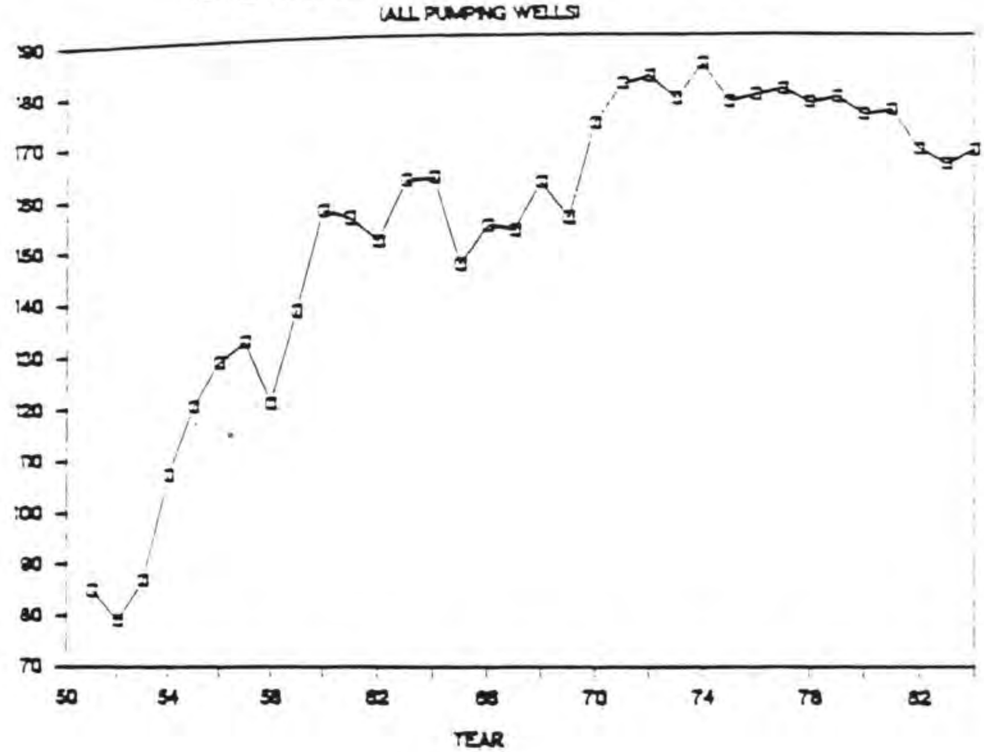


Fig 8

CHLORIDES IN GROUNDWATER

(ALL PUMPING WELLS)



The apparent decrease in salinity in water pumped from the YT basin is a result of changes in the deployment of pumping to less saline zones. The result is a build up of salinity in the aquifer. Owing to this, there will be an increase in pumping well salinity in the future.

In light of the above, salinity in both the CA and YT is considered to be a "time bomb," threatening their future use. The data summarized in Fig. 6-1 and Table 6-2 reflect only a part of this danger.

TABLE 6-2: PERCENTAGE OF WATER PUMPED FROM UNDERGROUND AQUIFERS AND LAKE KINNERET BY CHLORIDE CONCENTRATION

Source	Year	Chloride Concentration (mg/l)				
		0-100	100-150	150-250	250-400	400-
Underground	1973	40	18	26	11	5
	1981	36	24	21	12	7
	2000	32	20	23	15	10
Kinneret	1967	0	0	0	100	0
	1973	0	0	100	0	0
	1981	0	0	100	0	0

Source: Kahanovitz and Schwarz, 1985

Lake Kinneret. The salinity of the lake, which was initially about 350 mg/l chlorides, has declined steadily over the past two decades. This is due to the diversion of saline springs, whose flows are prevented from discharging into the lake, and are conveyed instead to the lower Jordan River, just below Deganya. Since initiation of the system, salinity has been declining asymptotically toward 200 mg/l chlorides.

6.2 Irrigation Water and Soil Salinity

Present agriculture was planned in accordance with previous low salinity in the water supply systems, while irrigated areas supplied from sources destined to become saline will be adversely affected in the future. Part of the areas in question are today under salt-tolerant crops, but the greater part is under crops sensitive to salinity (avocados, Jaffa oranges on sweet lime rootstocks, flowers and strawberries).

The following steps are envisaged in order to overcome the salinity problem:

- Preparation and updating of regional water supply plans must pay special attention to potential salinity sources and existing salt-sensitive crops.

- Salt-tolerant rootstocks should be used when renewing or establishing new plantations, and salt-sensitive crops and varieties avoided.

- Pumping distribution should be adjusted to crop distribution, earmarking low-salinity water for the most sensitive crops.

- Dual water supply pipe networks of two different water qualities should be installed to permit selective water supply according to crop requirements. Another possibility is appropriate scheduling within a single network, in which the two water qualities would be alternated.

- Price policy and the water charges adjustment fund should be in accordance with water quality: lower prices should be charged for lower qualities.

The negative effect of irrigation on soil productivity may be illustrated by the case of the Yizre'el Valley. This valley, which extends over an area of 25,000 ha, is characterized by a closed irrigation water supply system in which surface and groundwater, sewage effluents and imported water are all utilized through a regional system (the Qishon Irrigation Water Supply System - see Section 4.3.1) and local small storage facilities. The reservoirs also recirculate the return flow and drainage water, leading to excessive salt concentration in the irrigation water and subsequently to soil salinity.

Excessive irrigation and leakage from the reservoirs result in waterlogging and intensify salinity hazards. Two kinds of salinity damage are encountered: the increase in the soil water chloride content reduces crop yields; and a high SAR destroys the texture of clays, resulting in the devastation of arable lands.

Recent surveys by the Drainage Authority indicate that salinity already affects 300 ha of the 14,000 ha irrigated (SAR 40). An additional 2,000 ha are also affected (SAR 10 to 40). Projections indicate that areas with salinity problems will increase to about 6,000 ha by the year 2000 if corrective action is not taken.

The Valley Drainage Plan is based on a main drain discharging into the Haifa Bay, tile drains and deep well pumping.

Soil reclamation is carried out by replacement of exchangeable sodium with calcium, followed by leaching. The most common additive is gypsum (calcium sulphate), which is mixed into the soil or dissolved in the irrigation water. Acid or acid-forming additives include sulphuric acid, iron sulphate, aluminium sulphate, and sulphur.

Incorporation of organic residues into the surface soil improves hydraulic permeability. Animal manure applied at a rate of 50 tons/ha doubles water infiltration rates.

Similar soil reclamation methods have been successfully applied for more than a decade as a preventive means when using saline groundwater in the Negev. However, these methods are expensive and their feasibility is questionable.

6.3 Quality Aspects in the Use of Sewage Effluents for Irrigation

The selection of lands and crops for irrigation with sewage effluents is restricted by public health authorities and by protection of water resources quality. Regulations on the use of effluents for irrigation have not yet been enacted but this use is permitted by the health authorities, with the following qualifications:

- The use of secondary treatment effluents (activated sludge, trickling filters and oxidation ponds with seasonal detention) is restricted to industrial field crops (mainly cotton), fodder crops, forests and pastures.

- The use of tertiary effluents (activated sludge and seasonal detention, or activated sludge with sand filtration) is restricted to canned fruits, vegetables for cooking and to fruits with non-edible peels.

- Only the use of reclaimed effluents after tertiary treatment, followed by SAT is unrestricted.

Clogging of drip irrigation system nozzles was encountered in the use of poor quality effluents with inadequate treatment.

The need to protect water resources also imposes limitations on the quality of effluents in irrigation. The use of secondary effluents is forbidden in the catchment areas.

In some areas, restrictions on the use of effluents for irrigation stem from salinity problems and not from public health restrictions.

6.4 NWC and Lake Kinneret Water Quality

Lake Kinneret constitutes a highly productive system, with relatively high organic loads. Therefore it poses severe problems in its use as a source of drinking water.

The amount of drinking water supplied from LK varies according to the season. In summer, when irrigation water is needed, most groundwater wells are in operation and part of their output is supplied to municipal consumers, so that the municipal supply consists of a mixture of NWC water and groundwater. In winter, when there is no irrigation, few wells are in operation and municipal supply consists almost exclusively of NWC water.

The quality of the water supplied by the NWC met previous Israeli drinking water standards, as follows:

Bacteriological Quality. Heavy chlorination is carried out at the Eshkol Reservoir, and additional chlorination at various points along the NWC system. Chlorine gas and chlorine dioxide systems have been in operation continuously at the outlet of the Eshkol Reservoir. The results in the NWC have been satisfactory. However, apparent bacteriological regrowth in local municipal systems has been observed occasionally.

Chemical Parameters. Only two parameters deviate from the drinking water standards: hardness, which varies from 220-260 mg/l as $CaCO_3$ (above the recommended standard of 200 mg/l), and fluoride concentration, which varies from 0.15-0.3 mg/l (below the recommended standard of 0.6 mg/l). These parameters are of little significance with respect to public health, especially since corrective measures are applied at the point of consumption.

Organic Substances. These are present in relatively high concentrations - COD from 12-20 mg/l, TOC from 3-5 mg/l; the significance with respect to public health of these parameters, which are not included in the present drinking water standards, is not yet known.

Physical Quality (turbidity, colour, taste and odour). Physical quality is the main cause of complaints from the public. Turbidity is usually 2-4 NTU, above the present standard, and occasionally rises above the previous recommended standard of 5 NTU. Daily suspended solids concentration varies from 3-12 mg/l; about 50% of the suspended matter is organic.

A detailed analysis of the above data leads to the following conclusions:

- Treatment of the NWC water by chlorination produces water which generally meets the requirements of present drinking water standards. However, a combination of adverse conditions, which usually occur in winter and which may reduce disinfection efficiency, may cause a certain public health risk.

- Sanitary protection of the LK catchment area is carried out to prevent further deterioration in water quality; however, this measure alone cannot solve all water quality problems.

- Various alternative systems have been considered to improve water quality for drinking purposes, namely:

  * Single System - under which all water supplied by the NWC would undergo treatment in a large central water treatment plant, to be constructed for this purpose at the Eshkol site.

  * Multiple System - under which individual solutions suited to the circumstances would be found for each region or community, for example: (i) supply of drinking water from unpolluted groundwater sources such as YT; and (ii) individual water treatment plants on branches of the NWC for municipal and industrial water only.

  * Seasonal System - the NWC will continue to supply water for all uses in summer; in winter, drinking water will be supplied from groundwater sources, NWC water being recharged to the aquifer.

At present (1990) the Multiple System is adopted. However, opinions are being widely expressed for a reconsideration of the Single System; this would provide the required quality to all communities and regions and also improve artificial recharge conditions, eliminating clogging and contamination of wells in the CA.

6.5 Nitrate Contamination

Human activity in the Coastal Plain is relatively intensive. The population density there is 765 per sq.km compared with the countrywide figure of 205 per sq.km. One of the results of heavy use of fertilizers in agriculture is a high and ever-increasing concentration of nitrates (see Fig. 6-3). More than 50% of the water pumped from the CA has a concentration exceeding 45 mg/l nitrates. A detailed study of single wells showed that in more than 5% of the cases nitrate concentration exceeded the previous Israeli drinking water standard of 90 mg/l.

Many wells have been abandoned as drinking water sources, while others are diluted carefully with NWC water, low in nitrates. Denitrification in situ or in treatment plants is also considered as a future solution.

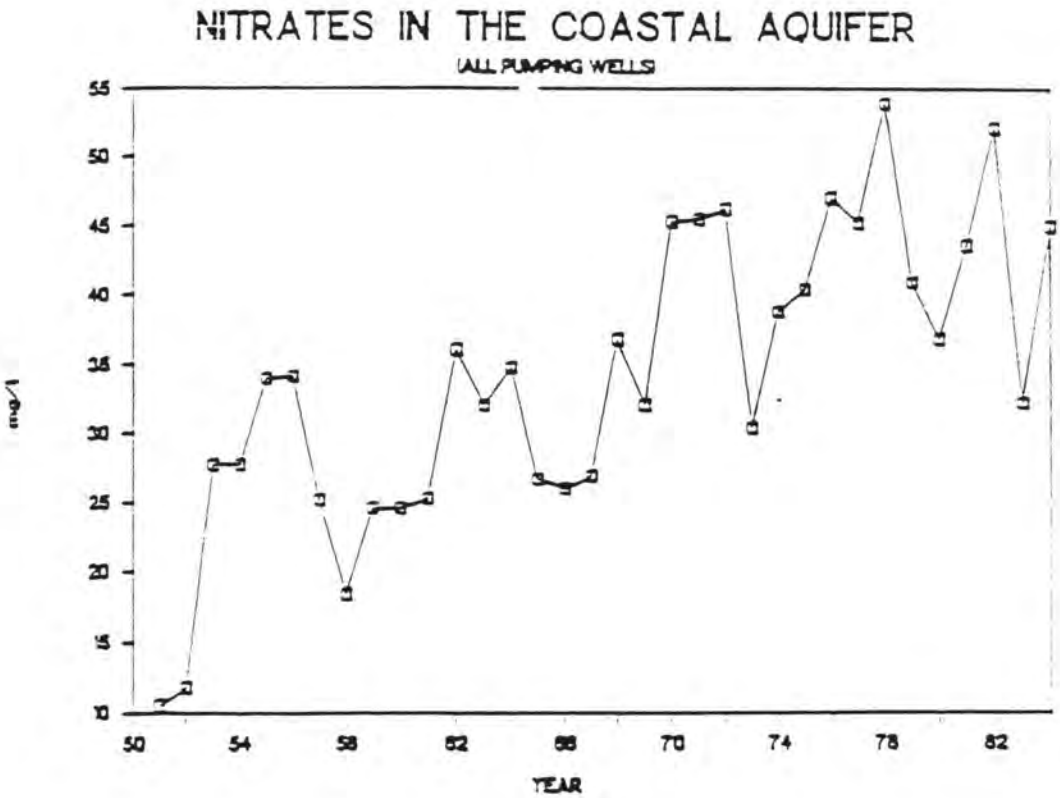
6.6 Potable Water Treatment

Water quality in open reservoirs is maintained by biological means, including stocking of the reservoirs with fish. This measure contributes to maintaining the biological equilibrium in the reservoirs, thus preventing the incidence of nuisance factors, such as taste, odour, algae growth, submerged vegetation, snails, etc.

Filtration plants to solve the problem of quality in LK water in the NWC are at present in the planning phase. Potable water supplied from LK is already filtered in some of the local schemes supplied directly from the lake.

Disinfection, required to maintain water quality in accordance with potable water criteria, includes the use of chlorine, chlorine dioxide, ultra-violet rays and ozone.

Other treatment processes and facilities are also used, where necessary, for the removal of iron and hydrogen sulphide. An advanced automated plant has recently been commissioned for injection of fluorine in water supplied to the Greater Tel Aviv Region. The plant ensures addition of the required amounts of fluorine in drinking water, and is equipped with advanced metering and monitoring instrumentation.


NITRATES IN THE COASTAL AQUIFER
(ALL PUMPING WELLS)
55
50
45
40
35
30
25
20
15
10
mg/l
50
54
58
62
66
70
74
78
82
YEAR

7. LEGISLATION AND ORGANIZATION

7.1 Legislation

The Government of Israel, fully cognizant of the scarcity of its water resources and of the necessity of water for accelerated development, started as early as 1952 the process of preparing comprehensive water legislation, culminating in the Water Law of 1959. This law, as well as its precedent laws and by-laws, have been aimed at stringent control and efficient utilization of the available resources.

The law begins with a clear refutation of private rights on a water source which were rooted in previous Ottoman and British laws. The water sources in the State are public property, subject to the control of the State and destined for the requirements of its inhabitants and the development of the country.

The term water source is defined as ".... springs, streams, rivers, lakes, and other currents and accumulations of water, whether above ground or underground, whether natural, regulated or improved and whether water rises, flows or stands therein at all time or intermittently, and includes drainage water and sewage." In other words, the term covers all internal sources of water, including the intermittent flow of wadis, as well as sewage sources. The act further grants each person the right to receive and use water; however, such right is contingent upon use that will not reduce the quantity of the water or lead to its salination. Furthermore, rights to water are contingent upon one of the following beneficial uses: household, agricultural, industrial, handicraft, commerce, and services and public services. If the use ceases, the right to use also ceases.

In addition, the Minister of Agriculture has the power to set standards for the quantity, quality and use of water within the framework for beneficial uses. The law forbids the supply of water except in accordance with the standards set by the Minister of Agriculture. The law includes a section concerning protection of water sources. Water pollution is forbidden on pain of fine or imprisonment. In the event of pollution, the Water Commissioner (see Section 7.2) is empowered to take all measures necessary to rectify the situation. He may order the offending party to stop his polluting activity and rectify his wrong. On failure of the offender to take proper measures, the Water Commissioner may rectify the situation at the polluter's expense.

Further provisions for the protection of water sources authorize the Water Commissioner to declare protective strips around a water source. Once such strip has been declared by order of the Water Commissioner, no one is permitted to cross such a protective strip without permission from the Water Commissioner.

Authority for executing the Water Law is vested in the Minister of Agriculture. Power over its operational provisions is vested in the Water Commissioner. The Water Commissioner is responsible to the Minister of Agriculture and the National Water Council, appointed by the Government to advise the Minister of Agriculture on water affairs.

A Water Court was also set up to hear all cases concerning compensation for loss of land or water rights, as well as appeals of decisions of the Water Commissioner affecting water use.

Two important laws providing the Water Commissioner with means of control preceded the 1959 Water Law: the Water Drilling Control Law and the Water Metering Law.

The Water Drilling Control Law, adopted in 1955, prohibits the drilling of wells without a licence from the Water Commissioner. The law empowers the Water Commissioner to refuse a request for a licence if he feels that a new well will cause salination of groundwater or depletion of groundwater supplies, or if it will interfere with supply of water for household uses. The law empowers a magistrate court judge to close any well dug without a licence from the Water Commissioner.

The Water Metering Law forbids the supply and abstraction of water without its measurement.

Water Charges. The law stipulates the basic rules for central control of water charges, and provides for the establishment of a Water Charge Adjustment Fund "to reduce differences in water charges in various parts of the country."

Major breaches of the Water Commissioner's authority over water affairs occurred in the early 1970s in connection with drinking water quality and wastewater reuse. An amendment to the Public Health Ordinance of 1940 authorizes the Minister of Health to set standards for the quality of drinking water and food processing water, and to set health standards for water sources earmarked for drinking purposes. Tests for water quality are to be performed by the supplier, according to standards and methods set by the Minister of Health in the form of regulations.

Another amendment empowers the Minister of Health to devise rules for purification of sewage to be used for irrigation and other commercial purposes.

7.2 Organizational Structure

The Water Law vests in the Ministry of Agriculture responsibility for the country's water sector. This authority is vested in the Water Commission (headed by the Water Commissioner), which functions as a separate entity under the jurisdiction of the Ministry of Agriculture. The Water Commission is responsible for the planning, management and supervision of all matters related to water, according to the policy of the Ministry. In this the Minister of Agriculture is advised by a National Water Council. Two-thirds of its members represent the general public and one-third represent the Government. The Knesset, Israel's parliament, also has a Water Committee, acting as a parliamentary supervisory body over the water sector, and in particular over the determination of water charges.

7.2.1 Water Commission

Following are the main divisions of the Water Commission and their principal tasks:

Allocation and Licensing Division: Licensing of annual water abstractions and recharge activities according to hydrological conditions, water requirements, water qualities and supply possibilities; supervision of production and consumption of water according to the licensing provisions; collection and processing of abstraction and consumption data; and, in general, implementation of the Water Law and its various regulations.

The Hydrological Service: Establishment of the hydrological data base for planning and licensing; routine measurements, recording and processing of water levels, flows and qualities; publication of the Hydrological Yearbook; supervision over actions required to protect the quality and conserve the quantity of water resources; initiation and follow-up of hydrological investigations.

Efficient Water Utilization Division: Five units operate within this division:

- Irrigation Efficiency Unit: Research initiation and guidance of development of water-saving devices and methods, including automatic control systems, aimed at reducing consumption of water per unit crop area and per unit crop yield; advising and checking plans to improve irrigation system efficiencies.

- Industrial Water Unit: Initiation and guidance of plans and devices designed to reduce water consumption and emission of pollutants by factories, mainly through water recycling; establishment of normative water consumption charges in various industrial processes, and determination of water allocation to individual factories.

- Urban Water Unit: Initiating development of domestic water saving devices, leak detection and prevention methods, accurate water measurement and recording instruments, etc., surveying urban water consumption, detecting wasteful users and publishing annual reports on urban water consumption.

- Agricultural Sewage Utilization Unit: Initiation and guidance of activities aimed at expanding reuse of sewage water in agriculture and preventing pollution of water resources by untreated sewage.

- Water Pollution Prevention Unit: Control and initiation of activities aimed at preventing water resources pollution by fertilizers, fuels, sewage, domestic and industrial wastes, etc.

Economic Division: Responsible for introduction of changes in water charges by means of levies, subsidies and tariffs, and review of the economic aspects of water development plans.

Judicial Division: In charge of enacting regulations and all matters related to implementation of the Water Law, supervising implementation of the Law, drafting contracts and imposing pollution prevention regulations.

Agricultural and Water Infrastructure Planning Division: Founded jointly by the Water Commissioner and the planning authority of the Ministry of Agriculture to coordinate the planning of waterworks with agricultural development plans.

7.2.2 Other Organizations

TAHAL - Water Planning for Israel Ltd. is the official water planning agency for the water sector at all levels, including long-range planning, master planning and design. It also acts as consultant to the Water Commissioner on management policies with respect to water resources and water demand.

Mekorot Water Co. Ltd. is the national water company, supplying about 65% of the water used in Israel from various water supply systems constructed and maintained by it. For this purpose, it operates regional supply divisions, each responsible for a particular geographical region. Mekorot is also the trustee of the Government for operation and maintenance of the NWC. The Company is in addition responsible for supplying water for artificial recharge, cloud seeding, desalination facilities, and research and design of desalination plants.

Drainage Boards. Regional drainage boards are organizations to which the Water Commisioner delegates part of his authorities. The most important and active of these boards is the Kinneret Water Authority, which plans and implements pollution prevention measures such as sewage and solid waste collection. It also develops and maintains the Lake Kinneret beaches.

Municipalities are organized in a national municipal authorities centre, with a special water affairs committee.

Regional Agricultural Water Associations. In some parts of the country, water is abstracted and supplied by regional associations. These associations were formed, usually in the agricultural sector, with the intention of improving local water supply conditions, increasing local use of floodwater and sewage effluents, saving energy, and reducing construction and operation costs.

Israel Centre of Waterworks Appliances. This Centre was founded jointly by the Water Commission and the Israel Standards Institute in order to assist in promoting the developent of high quality equipment for water supply and irrigation systems, contributing to more efficient use of water in the agricultural and urban sectors.

Irrigation and Soils Field Service is a division of the Ministry of Agriculture, and deals with soil surveys, soil tests and determination of irrigation requirements by field tests and experimental plots.

Israel Water Works Association is a voluntary organization which now encompasses hundreds of cooperatives and individual farmers. The association deals with technical extension of irrigation practices, training of technicians, and control over irrigation equipment manufacturers and contractors.

8. PLANNING AND DECISION SUPPORT SYSTEMS

8.1 Planning and Decision Making

Planning of the water sector deals with decision making with respect to: (i) Operation of abstraction and supply systems; (ii) Allocation of water sources to users; and (iii) Construction of new installations, as well as replacement and upgrading of existing installations. The planning process establishes the principles and framework in which ongoing decisions are made. Operation and allocation activities are usually planned once a year, while expansion of water works is planned once in a decade or more.

The water sector is planned on three levels:

- Conceptual comprehensive planning: national master plans, national operation plans, and policy analysis.

- General master planning: regional plans, feasibility studies.

- Detailed project planning: design and implementation plans.

Conceptual planning imposes guidelines on the master planning, in particular with respect to allocation of national resources such as population and transferable water resources. Master planning determines the outlines and capacities of water supply systems that are subsequently designed at the project planning level.

Feedback from the project planning level to the master planning level is principally in the form of cost estimates, and hydrologic feasibility evaluation.

Feedback from master planning to conceptual planning comprises principally data on regional water resources and requirements, and overall cost estimates.

Conceptual and master planning are the responsibility of TAHAL (see Section 7.2.2), while most project planning is also carried out by this company. The relevant units of the Water Commission and Mekorot take part in planning of water allocation and operation of the supply systems, respectively.

8.1.1 Application of Analytical Tools in the Planning Process

The analysis of alternative courses of action in water resources management and development can be supported by analytical tools. In Israel the following tools were applied in planning the development and operation of the water sector:

(1) Water resources data bases and data management routines, including information on water requirements, supply systems, abstraction, consumption, water levels, and water quality (see also Section 8.2).

(2) Hydrometeorological models for quantitative assessment of water resources, and their spatial and temporal variations.

(3) Agroclimatic models for assessing irrigation water requirements.

(4) Statistical models for analyzing past trends, assessing the present state, and predicting future situations as regards natural replenishment, water requirements, flows, water levels and water quality.

(5) Mathematical models of mass transport in soil-aquifer systems, used to explain past trends in water quality and to assess future hazards, as well as to predict and physically evaluate the impacts of preventive and corrective water resources conservation measures.

(6) Econometric modelling and economic analysis of agricultural production in relation to irrigation development.

(7) Economic analysis of damage suffered by agriculture as a result of changes in water supply patterns or of poor quality water supply.

(8) Systems analysis of water supply, including modelling of combinations of water sources, users and links. The decision variables in such analysis are: transportation, water treatment, water inventory management in natural and artificial reservoirs, mixing and dilution, exploitation and artificial recharge of groundwater, allocation and rationing of water, and capacity expansion (of intakes, wells, pumps, treatment plants and conduits). The objective function is usually economic, and takes into account direct capital and operation costs, losses resulting from unmet demands, losses resulting from exceeding the

maximum permissible values of water quality parameters, and sometimes also the product value of water. Multi-objective analysis is applied to deal with social, political and environmental objectives, which are sometimes expressed as constraints.

(9) Simulation and optimization models of water supply networks, used in operational planning and planning of automatic control systems.

A hierarchical interactive approach was employed in the application of these tools to comprehensive planning of the water sector. Systems analysis models (item 8 above), such as linear programming and dynamic programming models, were used in the upper level of the hierarchy to prescribe policy parameters such as: (i) Timing of future investments in water resources development and in expansion of water supply systems; (ii) Allocation of water resources to users; (iii) Curtailment of water supply as a function of available water in storage.

The comprehensive process of mathematical programming requires aggregation of sources, users and supply systems to large areal units. The time in these models is also aggregated into long time units of a year or periods of a few years.

Operational models of the water supply (item 9) and production models of the agricultural sector (item 7) were applied in the second level. Rules for abstraction from LK and from the main groundwater resources are generated at this level. Product values of water by regions are also generated at this level in line with future scenarios of agricultural production. Water resources at this level are represented by basins. Users are aggregated by sector, crop and geographic region.

Detailed models of flow and mass transport in groundwater basins (item 5) and of the hydraulics of the water supply networks (item 9) are applied in the third and lowest level of the hierarchy. In these models the results obtained in the higher levels are deployed over small geographic units to test the hydrologic and hydraulic feasibility of results.

A feedback process was developed among the models at the different levels: policies and operation rules are generated in upper level models and fed into the lower level models. Data on constraints (e.g. hydrological, hydraulic) and on price coefficients of the objective function (e.g. supply costs, product value of water) are extracted from the lower level models and fed into the higher level models.

Basic data for all these models are derived from data bases (item 1) and generated from hydrometeorological models (item 2), agroclimatic models (item 3), statistical models (item 4), and economic analysis (items 6, 7).

The models may be classified into prescriptive optimization models and descriptive simulation models. The former encompass all courses of action, and search for the optimal one. The latter require a priori definition of the course of action and answers "what if" questions. Optimization models are usually mathematical programming models that are limited in dimensions and require simplification and aggregation of the field situation. Their results are therefore often questionable. Simulation models are closer to field realities but require tedious repetition of trial and error tests for a relatively large number of alternative courses of action.

Some of the major management issues of the Israel water sector were analyzed with the help of these models. The red lines of the groundwater systems were assessed by mathematical simulation models of aquifers. The conjunctive management policy of storage in the major basins was assessed by a second level simulation model of the three basin system. The economic-hydrologic trade off between a fixed water supply, on the one hand, and flexible, inventory dependent, supply, on the other, was studied with the help of a first level dynamic programming model. The extent and timing of sewage effluent reclamation had also been forecast using these models in the late 1960s and early 1970s.

Some important lessons may be drawn from this experience with regard to modelling and systems analysis. The construction, debugging, calibration, validation and updating of some models, especially the more detailed ones, have turned out to be a very time consuming processes. For models sensitive to policy and economic factors this means that results may become obsolete long before they are printed by the computer. The more aggregative, less "exact" models are usually more manageable and useful.

The type of data amassed from the numerous sensitivity runs provided a solid information base, even as the status quo in the water system - politically, hydraulically and hydrologically - changed. Decisions with regard to i) resource management in a changing geopolitical setting and ii) immediate operational policy in the face of drought, could be made without having to resort to the relatively arduous and complicated process of running the entire array of models. As a result of the findings of the models some of the basic concepts of the system operation have been improved.

Operational rules suggested by the models were however not always accepted literally because they did not represent the real world sufficiently well. For example the conditions in LK - one of the three major reservoirs in the system - including maintenance, local pumping requirement, and the recreational function of the lake - were constantly varied during the planning process. It was often found efficient not to run the models each time constraints or data were redefined but to properly adapt previous results.

The search for optimality has usually been set aside due to the intricacies of defining objective functions for the planning problems. In the existing multi-institutional framework no consensus could be achieved, not only on objectives but also on constraints. However, ad hoc planning problems were still resolved with the aid of the information that had been generated through the model studies.

We are equipped with a great deal of knowledge of, as Bellman stated, "the structure of the solution," with much more insight into the interactions of the complex elements. This was the key for identifying heuristically the acceptable solutions which were sufficiently compatible with most of the objectives and constraints of Israel's water sector.

Many attempts were made to employ the analytic systems approach as a tool in resolving conflicts among sectors and institutions as well as in political decision making.

It was, however, found that rigorous mathematical modelling could not be applied directly in the political decision making process. The main reasons were lack of concensus on explicit objectives and lack of transparency of the decision making tools, which were a "blackbox" - unclear and therefore unacceptable to the decision maker. Analytical tools and mathematical models are, on the other hand, widely used by planners and analysts for making their own expert evaluations and proposals.

Mathematical modelling to a limited extent enables the analysts to participate and assist in the decision making process not by generation of directly acceptable prescriptive solutions but rather by clarifying the issues. Explicit and inclusive definitions of alternative options, of basic data and of basic assumptions and hypothesis were their first contribution. The second contribution was in quantitative assessments of physical and economic results of a particular course of action.

In these aspects the analyst may be helpful in future dialogues aimed at resolving intersectorial and international conflicts.

8.1.2 Decision Support Systems

A decision support model (DSS) was suggested as a replacement for the mathematical model. The DSS is based on surveys within the decision making and expert community relating firstly to the relative order of objectives and criteria, and secondly to the relative achievements of suggested projects with respect to these objectives. A DSS was suggested and developed in a study carried out by the Samuel Neeman Institute (1985), based on mathematical weighing and trade-off methods according to de Graan-Saaty.

However, as in the case of the mathematical models, these models were not accepted by the decision makers. Consequently, policy decisions are now made heuristically after public hearings by the political establishment, and in many cases personally by the Water Commissioner.

8.1.3 Definition of Objectives and Criteria

Formal analyses with models or DSS require explicit definition of objectives. Part of the objectives are quantifiable and part are assigned values by ordinary preference methods. For project and policy evaluations the following criteria were identified in a recent study (Neeman, 1985):

- Conservation of water resources.
- Total water supply.
- Water supply by sectors.
- Total cost.
- Total investment.
- Net benefits.
- Reliability of supply.
- Environmental impacts.
- Complexity of control.
- Equity.
- Public health.
- Public finance required.
- Energy requirements.

Unit cost per cu.m supplied is used as the only criterion in routine project evaluations on the conceptual and general planning levels. All the other above criteria are taken as constraints in routine planning.

8.1.4 Planning Uncertainties

Uncertainties in planning of the water sector in Israel relate to climatic, hydrologic, political, demographic, technological and economic factors.

Rainfall variations in Israel are high, with typical coefficients of variation in annual replenishment of 35% (Lake Kinneret net inflow). The National Master Plan (see Section 10.1) postulates, therefore, that deviations from the mean may accumulate during a decade to the full value of the mean at a probability level of 10%.

Global analyses of long-term climatic trends reveal the possibility of future dry conditions in comparison with the last half-century, which serves as the statistical base for the Master Plan assumptions. Regular climatic variations are handled by determining storage requirements (mainly in groundwater - see Section 5.4), while unknown future trends are considered as uncertainties.

Political uncertainties are involved in future arrangements for and water requirements of Judea-Samaria and Gaza, and in other international water resources (see Section 11.1). Political uncertainties are also involved in the possibility of importing water to Israel (see Section 10.3.5). The total quantity of water available to Israel may vary among different scenarios to the extent of 5-20%.

Demographic uncertainties relate primarily to future population estimates, which are highly dependent on immigration. The Master Plan estimate of 5.7 million for the year 2000 has been changed recently to 6.7 million, which means an increase of about 100 MCM/yr in water demand in the domestic sector. A future increase in the standard of living and per capita water requirement (see Section 10.2.1) is another uncertainity which may affect water requirements to the extent of 50 MCM/yr in the year 2000. Drinking water quality requirements are also uncertain, and may impose additional strains on the water sector by necessitating excessive investments in treatment plants.

Technological and economic uncertainties relate mainly to future development of irrigation and land use. Of special importance are possible changes in water requirements per hectare due to improvements in irrigation technology. Changes in irrigated crop area may result from worldwide and regional changes in the food markets. Techno-economic changes may permit seawater desalination earlier then planned, and change the supply side of the future water balance.

Several approaches have been adopted to deal with these uncertainties:

- Adoption of a single scenario with most probable values, assigned to the uncertain variables as estimated by the planner. A balanced scenario is selected in some cases, with deviations in some of the variables offsetting deviations in others.

- Adoption of a single scenario and presentation of other scenarios to the decision maker.

- Adoption of a single scenario and presentation of the sensitivity of some planning criteria to variations in single variables.

- Assumption (subjectively in most cases) of the probability distribution of the single uncertain variables, generating scenarios at random (according to Reutlinger, 1970), and presentation of the resulting probability distribution of some of the planning criteria.

The first two approaches are commonly used in the planning process. However, there are difficulties in reaching a consensus on the assumed values of the uncertain variables.

The third approach to uncertainty is sometimes applied. The fourth approach was applied in the National Master Plan (see Section 10.1) but was not accepted.

A typical problem of uncertainty is the present (1990) planning of water allocation and operation for the year 1991 with practically empty reservoirs. Three scenarios were prepared: mean rainfall, lower 10 percentile rainfall, and upper 10 percentile rainfall. The adopted plan is based on mean rainfall, but consideration of risk aversion to depleted resources calls for the lower percentile scenario, with a 200 MCM reduction in water supply.

8.2 Data Collection and Dissemination

The purpose of data collection and dissemination is to monitor the system, allow corrective measures, permit decision making in matters that depend on the state of the system, and provide data for research and planning.

Data on water resources, water use, and water in the supply systems are continuously collected, appraised and reported by the Water Commission and the affiliated agencies. Collection is carried out daily, weekly, monthly, quarterly, seasonally, annually or only once, the frequency depending on the rate of change, importance and redundancy (correlation with other data). The frequency of dissemination depends on its relevance to current decisions.

8.2.1 Water Resources Data

The main subjects relevant to management of the water sector are outlined below.

Source Water Quantity and Water Levels

Surface water flows as well as groundwater levels in observation wells are recorded by the Hydrological Service. These measurements are carried out monthly. Abstraction of water is metered and recorded by well owners and water supply companies. They report monthly to the Water Commission, which appraises the reports in two ways:

- Systematic comparison between electricity records and irrigated area on the one hand, and reported water abstraction on the other.

- Spot checks of meters, carried out at a frequency of not less than once a year.

Annual reports on water levels are published by the Hydrological Service, and on abstraction by the Allocation and Licensing Division. Monthly reports for a small number of key points are distributed by the Hydrological Service for operational decisions. Daily data are reported to persons responsible for daily operations at Mekorot.

Surface water gauges and part of the observation wells are equipped with automatic recorders.

Source Water Quality

Monitoring of water quality is regulated by recent amendments to the Public Health Ordinance. Samples of water are collected by Mekorot and other major suppliers. Sources of small suppliers are sampled by the Ministry of Health, which supervises all monitoring activities. The Water Commission samples part of the sources.

Three levels of chemical analysis are defined:

- Limited: chlorides, nitrates, anionic detergents.

- Partial: chlorides, nitrates, anionic detergents, iron, sulphates, magnesium, TDS, calcium, hardness, pH, colour, turbidity, sodium, potassium, fluoride, UV absorption and ammonia.

- Full: this includes, in addition to the components of partial analysis: mercury, selenium, cadmium, arsenic, chromium, lead, cyanide, barium, phenols, oils, manganese, trihalomethanes, copper, zinc, taste and colour, alpha radiation, beta radiation, and fluorides.

Two levels of microbial analysis are defined:

- Regular: coliforms or fecal coliforms.

- Full: in addition to the above, fecal streptococci, total count.

Full chemical analyses are carried out on initial utilization of a new water source, and thereafter once every ten years. Partial chemical analyses are carried out once every five years. Limited chemical analyses are carried out 2-3 times a year.

Full microbial analyses are carried out in new water sources. Regular microbial analyses in water sources are carried out at 3-month intervals.

Special analyses are carried out as part of certain projects, such as monitoring of groundwater surrounding the recharge ponds of the Dan Region Sewage Reclamation Project (see Section 4.6), and monitoring of the Qishon Multi-Source Scheme (see Section 4.6).

Annual reports by basin are prepared by the Hydrological Service. Reports on bacteriological quality are prepared annually by the Ministry of Health. Results exceeding drinking water standards are reported immediately to the responsible water supply authority, and monitoring continues under its supervision.

<u>Supply Systems</u>

Flows in the supply systems are metered only in the main trunks of Mekorot. On installation of SCADA (Supervision Control and Data Acquisition) Systems, flow data will increase both temporally and spatially.

Water quality in the supply systems is sampled by Mekorot and other suppliers, or by the Ministry of Health according to the public health regulations. Regular microbial analyses are carried out and residual disinfectants monitored - monthly for populations of less than 1,000 and daily for populations exceeding 500,000.

Monitoring of the physical condition of the water supply system is the responsibility of the water supply companies, in particular Mekorot.

Reports on operation of the supply system of the water supply companies are meant for internal use only.

Municipal Water Use

Municipal water use is monitored by consumer meters and by the meters of the water supply authority, which is usually the municipality. The difference is the deficit, which amounts at present to 13% as a national mean. Water charges records serve as a basis for differentiation between various uses: domestic, commercial, hotels, public gardens, etc. An annual report is prepared by the Urban Water Unit of the Water Commission.

Industrial Water Use

Industrial water use is monitored by meters at each enterprise, with a differentiation between water qualities. Thirty percent of this subsector consumes saline water and even seawater. An annual report is prepared by the Industrial Water Unit of the Water Commission.

Irrigation Water Use

Irrigation water use is also metered. Reports by users are published annually by the Allocation and Licensing Division of the Water Commission. Estimates of regional water consumption by crops are based on land use data, and are published annually by the Rural Planning Authority of the Ministry of Agriculture.

Financial Accounts of Water Supply Organizations

Assessments of water supply costs are based on annual accounts that are prepared by Mekorot, and to a small extent also by other water suppliers. These accounts are controlled and evaluated by the Economic Division of the Water Commission.

Financial Accounts of Irrigators

Input-output estimates by crop and climatic-ecologic zones were prepared in the past by the Planning Authority of the Ministry of Agriculture. These estimates also included an assessment of input and product values, allowing the product value of water to be estimated (see Section 9.4). The estimates represented mean values in a highly variable ensemble. No marginal values (of the extremely efficient and inefficient farms) were available for marginal analysis. In recent years these data have become less reliable due to inflation and the financial crisis in the agricultural sector.

General Statistical Data

Data on demography, economy and energy for water resources planning are collected by the Central Bureau of Statistics and published in annual abstracts. Periodicals and special publications include current data and results of current statistical projects.

8.2.2 Dissemination and Publication of Data

Restrictions imposed by security and privacy regulations limit the publication and dissemination of water resources data at the detailed level of single users and single abstraction structures. However, summaries by hydrological basins, geographic-administrative zones and even subsectors are readily available and are circulated to the relevant decision makers.

8.2.3 Reliability and Adequacy of Data

The Water Metering Law, which in 1959 became part of the Water Law, guarantees the accuracy of data on water abstraction and supply.

Hydrological data are measured regularly by the Hydrological Service. Network studies on redundancy of data or insufficient data are carried out and the network is improved accordingly.

The most severe lack of hydrological data is in deep formations which contain saline water and therefore do not justify the drilling of regular abstraction wells. Special wells for monitoring salinity in these zones are very expensive and therefore insufficient in number. Geophysical methods for remote sensing of saline water underground are constantly being developed to replace special monitoring wells.

9. ECONOMIC ASPECTS

9.1 General

Economic aspects to be considered relate to the main factors characteristic of Israel's water sector, namely, scarcity of water, centralized public management, overexploitation of resources, rationing of water and other incentives for water conservation, and mobility of water in the highly integrated water supply grids and in groundwater aquifers.

In the past, the objective of population dispersion overruled economic considerations in water resources development. As a result, a great part of the water supply has been subsidized by the government from the national budget. Under the regulated water prices, the demand for water exceeds the available resources, and water rationing is therefore necessary.

Water in Israel is shared both in the natural sources as well as in the highly integrated national and regional water supply grids. Externalities have therefore to be introduced in the water costs to reflect the opportunity cost of water in the overexploited sources.

Revisions in the dominant policy have recently been suggested with a view to meeting economic objectives. These include real pricing of water and mobility of water according to economic demands. These revisions have not yet been accepted.

The water market, when dominated by the public, is governed by the differences between regulated prices, real costs and product value. These economic criteria must therefore be considered in the study of water resources management in Israel.

9.2 Cost of Water Supply

The current average cost of water production and supply by Mekorot, as presented in its 1990 budget, is 19.5 cents/cu.m for a planned supply of 1,227 MCM. The cost is accounted according to the present practice, without adjustment of historic investments for inflation, and without taking into consideration interest on these investments. The above cost is composed of capital (15%), energy (42%), salaries (14%) and miscellaneous (29%) costs.

In contrast, when considering full capital costs, including adjustments for inflation, the average cost would rise to 33 cents/cu.m, composed of capital (50%), energy (25%), salaries (8%) and miscellaneous (17%)

costs. This estimate is also based on Mekorot's 1990 budget, with an annual capital recovery of 8%, and an estimate of the total value of water supply installations operated by Mekorot in 1988, amounting to US$ 2,450 million.

The average cost represents a highly variable set of production costs, from 3 cents/cu.m in the low lift, small distance schemes to 50 cents/cu.m in the high lift, long distance supplies from LK to peripheral consumers located on high elevations.

Low costs are typical of some water supply systems in the abundant north, such as gravity systems from the Bet She'an springs; systems with very low pumping lift from LK directly to local consumers; and small, low lift pumpage from wells in the CA directly to local consumers.

An additional variation in pumping costs is introduced by seasonal variations in supply. In pressure systems, the hydraulic energy losses increase exponentially with flow rates, and therefore the marginal cost in peak months may be up to three times the mean energy cost.

No indirect costs of water resources conservation are included in water supply cost assessments.

9.3 Water Charges

The Water Law stipulates the basic rules for central control of water charges, and provides for the establishment of a Water Charges Adjustment Fund "to reduce differences in water charges in various parts of the country."

In 1987, 40% to 45% of the water was sold at prices lower than production costs (as presented by Mekorot). The difference is financed by government subsidies paid to Mekorot.

The low cost water supply systems are charged an adjustment fund payment when the cost of supply is lower than the legal nominal water charge. This payment is, however, limited at present to 3 cents/cu.m.

The current (July 1990) water charges for the agricultural sector are progressive in order to encourage conservation and mobility of water for efficient uses: 80% of the allocation is charged at 12.5 cents/cu.m, and the remaining 20% is charged at 20 cents/cu.m. Consumption above the allocation is charged at 26 cents/cu.m.

In the past (till 1990) seasonal pricing encouraged water saving during peak months and increased off-season irrigation. According to this arrangement, a 40% higher price was charged in peak months (July-August).

The current water charge for the domestic sector is uniform throughout the country, i.e. 26 cents/cu.m. This is the charge at the municipal inlet, paid by the municipalities to Mekorot. Additional distribution costs are paid by the individual domestic users, with a wide progressive rate structure. A typical household (four persons) is now charged in its monthly bill 32 cents/cu.m for the first 8 cu.m, 75 cents/cu.m for the next 8 cu.m and 123 cents/cu.m for consumption over and above this. In addition, a sewage disposal charge of 32 cents is added for each cu.m consumed.

The charge for industrial use is 15 cents/cu.m.

9.4 Product Value

The agricultural net product value of water is a function of crop water requirements, crop prices, and the costs of other agricultural production inputs.

In the period 1954/55 to 1977/78, the estimated marginal product value of water grew at an average annual rate of 4.5% in real terms (Water Resources Management in Israel, 1983).

The profitability of the agricultural sector has decreased drastically in recent years. In the case of cotton, the marginal product value of water (Kislev, 1989) was 23 cents/cu.m in 1981 (1988 values). Thereafter it decreased steadily, reaching 0 in the year 1985, and continued to drop to -11 cents/cu.m in 1988. These figures are countrywide means representing temporal trends. However, variations over geographical regions and farms are high.

A recent survey published in "Water and Irrigation" (Z. Shimron, June 1990) presents estimates of the present product value of water in irrigation. The value shows a high variability, according to crop and yield level. Four crop groups and two yield levels were identified. Twenty-five percent of the high yielding farms have a lower product value than the production cost of water (as presented by Mekorot, see Section 9.2) - field crops 46%, fruit plantations 21%, citrus 29%, and vegetables 20%. In low yielding farms, a much higher percentage (61%) fails to reach the cost (field crops 88%, fruit plantations 60%, citrus 50%, vegetables 56%).

The difference between the net product value and reduced water charge, as set by the administration, is lower: in high yield farms it is 8% (field crops 8%, fruit plantations 13%, citrus 8%, vegetables 5%). In low yield farms a larger percentage (42%) is not able to cover the water charge (field crops 54%, fruit plantation 45%, citrus 29%, vegetables 39%).

These differences between product value and cost or charge raise questions about the extent of future water supply for irrigation and the need for expanding or even replacing existing water supply schemes for irrigation. These questions must be considered, however, in light of future trends in agriculture production in Israel and world markets, and not according to the present crisis situation.

9.5 Economic Evaluation of Water Projects

As a public service, water supply is evaluated using the economic criterion of cost effectiveness. On the other hand, water is also an input commodity in the agricultural production process, and as such it should be evaluated according to cost-benefit criteria. In Israel, the most common criterion for comparing alternative water supply projects is cost effectiveness, measured in cents/cu.m.

For projects with time varying costs and time varying water quantities, a present value criterion is applied by dividing the present value of the future expected flow of investments and operational costs (discounted at 8%) by the present value of the future volumes of water to be supplied (similarly discounted).

The difficulties in this analysis - mostly resolved in the planning process - stem from the following factors:

- If different alternative plans derive water from different sources, what are the costs at the source to be considered? In the case of the NWC, should marginal costs or mean costs be considered? In the case of groundwater in overexploited aquifers, it should also include some aquifer opportunity cost.

- If projects are constructed as extensions or expansions of existing schemes, the calculation should be carried out marginally, i.e. by taking into account differences in future water quantities and costs before and after the project.

- Comparison of large projects with small ones may be misleading. Functional ensembles of projects achieving similar results should be compared.

- Upgrading of reliability or quality is not covered by the water unit cost criterion.

- Projects with such additional purposes (reliability, quality) are sometimes economically analyzed by using alternative costs required to reach the same level of reliability or quality (additional storage, desalination). However, these also have other side benefits that must be considered.

- The interest rate to be applied is usually dictated by the Ministry of Finance and even by the Water Commissioner (recently 8%). However, it does not necessarily reflect the alternative value of capital in the economy.

- Energy costs vary largely according to world oil prices. Usually current electricity prices are used in estimating future energy costs; however, they do not necessarily reflect future costs, and are highly variable.

No full cost-benefit analyses have been carried out in the development of the Israeli water sector. However, an upper limit of 35 cents/cu.m was set in the Master Plan (see Section 10.1) for development of new water resources. This reflects an optimistic approach to the future marginal product value of water. It also reflects assumptions regarding the losses that would be caused by cutting back water supply to agriculture. It is not clear whether compensation for cutting back water supply (as demanded by the farmers, and accepted in preliminary debates in the Knesset) should be regarded as transfer payment and therefore not taken into account in the estimate of the upper limit for the cost of new water resources.

10. FUTURE DEVELOPMENT OF WATER RESOURCES

10.1 Water Sector Master Plan

After a long period of development, aimed at economic growth and dispersion of population, future efforts will concentrate on protecting the existing water system, conserving its sources and safeguarding the quality of water supply.

From 1986 to 1988, a new and comprehensive Master Plan for the Israeli water sector was elaborated (TAHAL, 1988), taking into consideration new objectives, and relating to the development and management of water resources on a national and regional basis. The Master Plan emphasizes economic aspects and problems of water quality.

The plan faced problems that are still acute. Five principal problems were defined:

- Present needs exceed annual replenishment of water resources: in 1984-85, more than 2,000 MCM/yr were supplied, whereas average annual replenishment does not exceed 1,750 MCM/yr.
- Long-term storage is exhausted, causing a deficit of 1,500-2,000 MCM.
- The quality of water is deteriorating. Whereas in the past, conveyance from sources to consumers was the main component of investments in water works, future investments will also have to cover quality upgrading.
- Due to demographic increase, a 30% increase is expected in the demand for fresh water.
- Replacement of the old water systems constructed in the 1940s and 1950s will become a necessity in the near future.

10.1.1 Future Management Problems

The problem of meeting Israel's future water requirements presents severe decision issues, centering on:

- The probability of declining resources after a series of dry years.
- Deterioration of water quality in the sources, coupled with increasingly stringent water quality standards.

- Technological uncertainty and high investment costs of possible corrective measures, such as treatment systems for marginal waters and seawater desalination.

- Prohibitive energy and operational costs of some of the proposed water supply systems.

- Strong lobbies of vested interest groups which oppose the necessary reallocation of water and redirection of potable water from irrigation to domestic use.

- Uncertainties with respect to planning parameters such as future quality standards, future socio-economic development affecting water requirements, future climate, available financing for development, and gaps in knowledge of the hydrogeological systems and processes.

10.1.2 Future Management Measures

Possible water resources management measures which would contribute to alleviating the situation cover a wide range of actions in several technical and non-technical domains. Some of these measures, which include both remedial and preventive intervention, have been applied in the past. The main possibilities are:

- Conjunctive use of surface water and groundwater, including artificial recharge, aimed at seasonal and long-term storage, alleviation of drought, and upgrading of quality.

- Reuse of sewage effluents for irrigation and industrial purposes.

- Improvement in the administration of water systems and natural basins by legislation, licensing, pricing, and proper organizational structure.

- Increase in the potential of existing sources by cloud seeding and by decreasing uncontrolled outflows of floodwater and groundwater to the sea.

- Control of water losses in the supply systems.

- Encouragement of water saving on the part of consumers.

- Reduction of low-profit, water-consuming agricultural production.

- Conservation and rehabilitation of aquifers by controlled exploitation, redistribution of pumping, artificial recharge, and hydraulic barriers.
- Control of pollution in catchment basins.
- Intensification of treatment for potable uses, either centrally in the main trunks or near the consumers.
- Blending of water from different sources, whereby poorer and better quality water are mixed in order to meet the required standards.
- Dual water supply systems of different qualities for different uses.

10.1.3 Policy Scenarios in the Master Plan

The Master Plan formulated two water policy scenarios: a status quo scenario and an innovation scenario. In the first, policy consists of continuing supply of water to the agricultural sector at about the present level and allocating water on an administrative basis. The second scenario emphasizes the fact that the water charge should reflect its cost and should play a role in water allocation. It was found that the status quo policy is questionable because it endangers water sources and requires investments in expensive water works.

10.1.4 Contents of the Master Plan

The Master Plan includes an assessment of future water demand, a plan for water resources development and management, an investment plan, and a general outline of policy called for with respect to administration, prices, R & D and international plans.

10.2 Future Water Demand

The forecast of future water requirements is subject to wide uncertainties with respect to estimates of future economic, political and demographic trends. Therefore, more than one scenario is possible. However, for decision making some of the scenarios are rejected and a single scenario is assumed.

Five sub-sectors are considered in planning the use and management of water resources in Israel:

- Urban demand.
- Industrial demand.
- Agricultural demand.
- Demand in Judea and Samaria.
- Demand in Gaza.

The last two sub-sectors are administered separately, although the fourth sub-sector uses the same sources as the first three. Gaza has its own severe problems, which may be partially relieved with the aid of water resources and water supply systems belonging to the Israel water sector.

Year 2000 forecasts by subsectors and water quality as compared with 1984/85 are shown in Table 10-1. The definitions of water quality are identical to those used in Table 2-1 in Chapter 2.

TABLE 10-1: ALLOCATION OF WATER OF DIFFERENT QUALITIES TO THE VARIOUS SECTORS

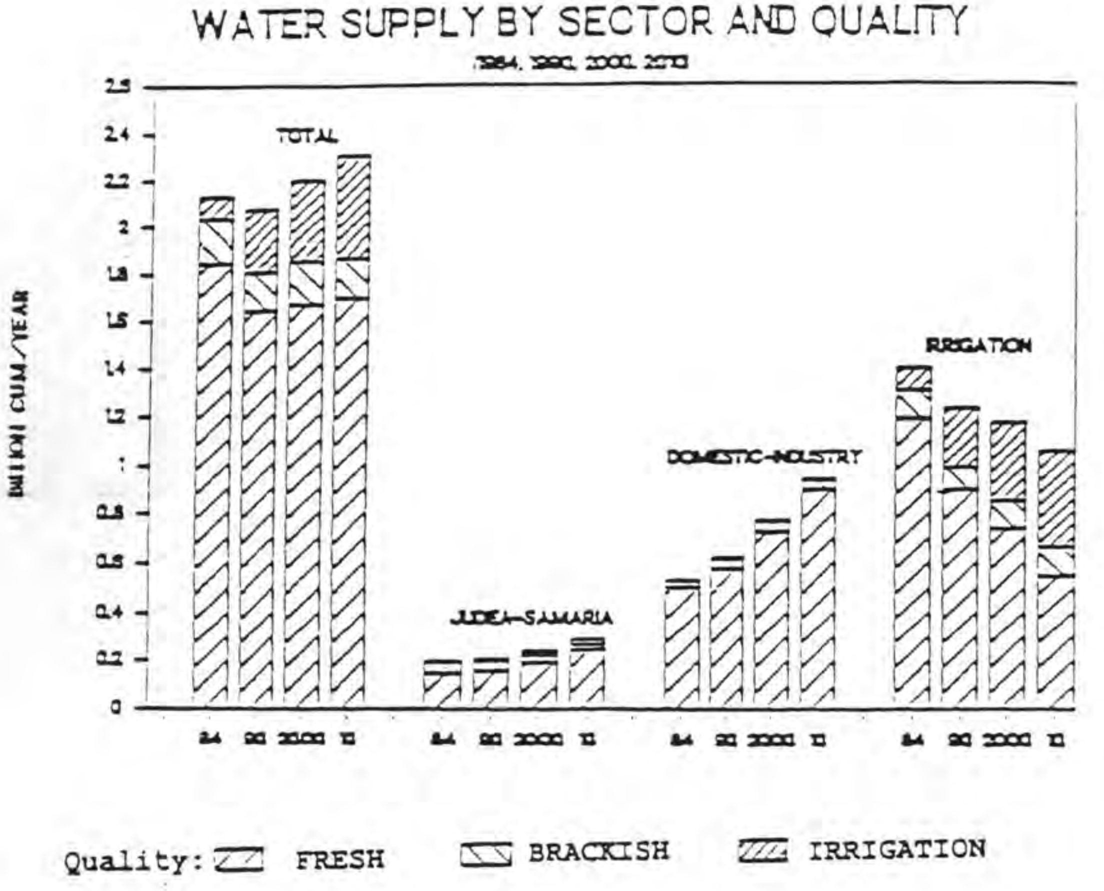
MCM/yr

Sector	1984/5				2000			
	Fresh	Brackish	Irrigation	Total	Fresh	Brackish	Irrigation	Total
Domestic	420	-	-	420	640	-	-	640
Industry	80	30	-	110	90	40	5	135
Agriculture	1200	115	95	1410	740	120	320-390	1180-1250
Adjoining areas	110	-	-	110	135	-	-	135
Total	1810	145	95	2050	1605	160	325-395	2090-2160

Forecasts for the years 1990, 2000 and 2010 are shown in Fig. 10-1.

10.2.1 Urban Demand

Population projections are published by the Central Bureau of Statistics. Recent (1989) forecasts for the year 2000 are 5.18 million (low), 5.37 million (medium) and 5.54 (high); and for the year 2010, 5.74 million (low), 6.16 million (medium) and 6.56 million (high). These forecasts assumed 1985 population and three levels of decreasing women fertility and decreasing immigration balance. The Water Sector Master Plan (see Fig. 10-2) adopted a forecast with a somewhat higher immigration balance than the high projection.


WATER SUPPLY BY SECTOR AND QUALITY
1984, 1990, 2000, 2010
BILLION CUM/YEAR
TOTAL
JUDEA-SAMARIA
DOMESTIC-INDUSTRY
IRRIGATION
Quality: FRESH BRACKISH IRRIGATION

Recently (1990), immigration to Israel has increased dramatically, and a new projection was prepared for the year 2000, which is higher by 1 million (see Fig. 10-2).

These projections are overall national projections. The distribution by locality was elaborated in a Master Plan for Population Distribution, prepared by the Ministry of the Interior for future populations of 5.4 million and 7.0 million. These projections by locality were adopted in the Water Sector Master Plan.

The Master Plan for Geographic Population Distribution is based on past trends and present policies. Low growth is projected in the centre of the country in general, and in densely populated urban centres such as Tel Aviv and Haifa in particular. A policy of accelerated growth is adopted for the peripheral northern and southern regions.

Population projections for each locality are based on a weighted average of three approaches: (i) physical population capacity, based on municipal master plans; (ii) extrapolation of present growth trends; and (iii) forecasts according to natural growth without immigration. The weights assigned are based on national and regional policies.

A new plan for dispersion of the new immigration is being prepared at present (1990). However, updating of the water plans according to the new immigration dispersion projections have not yet been finalized.

There are a total of 168 urban localities with a population of over 2,000, and statistics of water consumption in these localities have been adopted as the basis for projections of per capita domestic water consumption.

Trends in future per capita water consumption per locality were estimated according to progressive principles. In localities where present per capita consumption is less than 50 cu.m/yr, a future annual growth rate of 1 cu.m/yr was assumed. For localities with a per capita consumption in the range of 50-100 cu.m/yr, a growth rate of 0.6 cu.m/yr was assumed. No growth was assumed in localities exceeding the 100 cu.m/yr per capita level.

In rural localities, the per capita consumption was assumed to be a constant 130 cu.m/yr. Where no permanent population may be identified, i.e. in tourist and army centres, an annual growth of 2.5% in total water consumption was assumed.

Based on these statistics, it is expected that overall

POPULATION PROJECTIONS

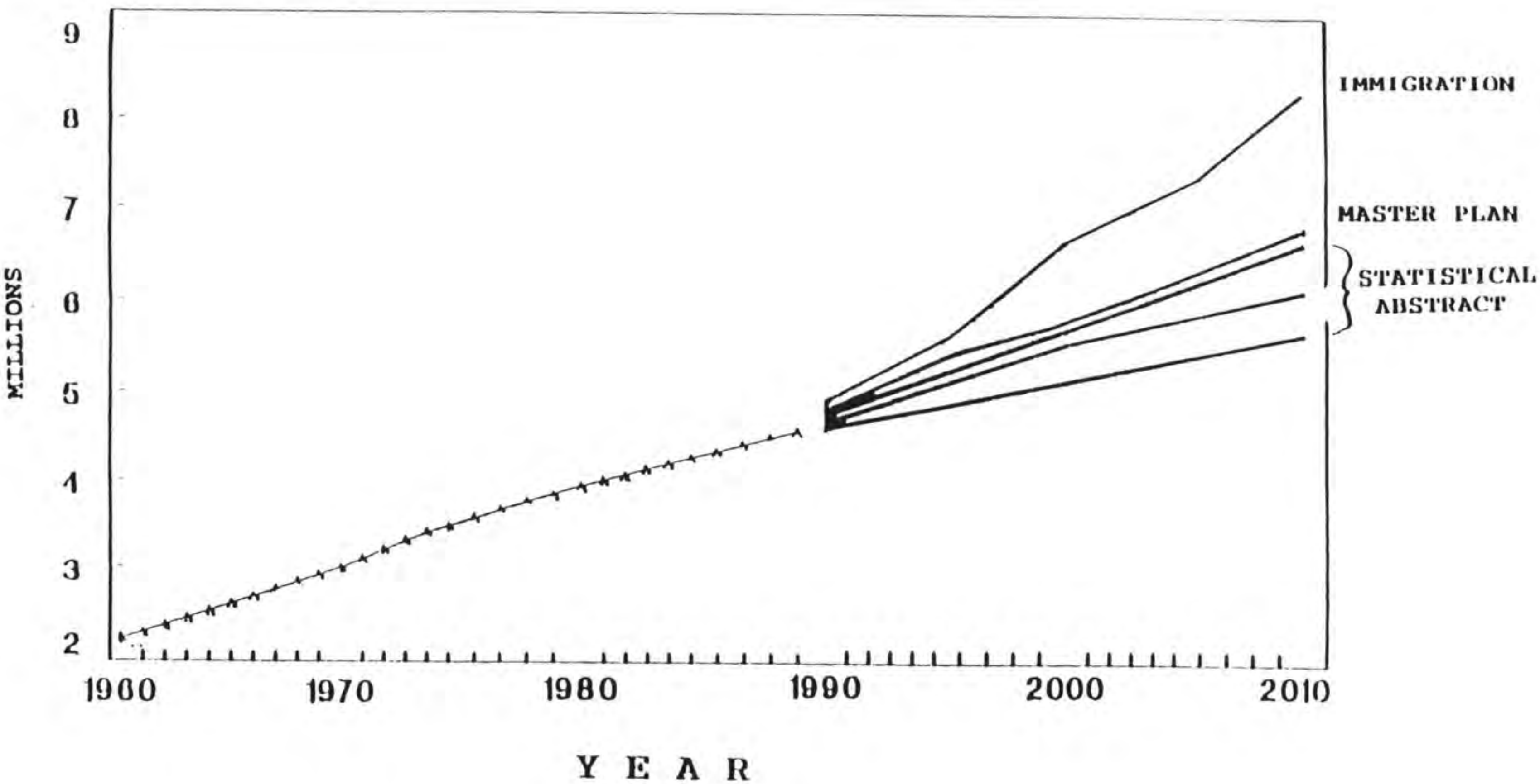


Fig. 10-2

average per capita domestic consumption will increase in the coming years at a rate of 0.7% per year, reaching 110 cu.m/yr per capita in the year 2000 (see Fig. 10-3). Thus Israel's total domestic water consumption according to the Water Sector Master Plan will be 560 MCM/yr in 2000 and 662 MCM/yr in 2010.

A low forecast was also elaborated, assuming effective water conservation measures in the urban subsector (see Fig. 10-3). Growth rates in the low levels up to 95 cu.m/yr are similar to the high forecast. A reduction to this value is assumed in the high per capita consuption localities.

10.2.2 Industrial Water Demand

Only industries consuming more than 5,000 cu.m/yr are included in the industrial subsector. The rest are part of the "domestic" subsector. The total present consumption of 110 MCM/yr is divided into: mining industries, 28 MCM (22 enterprises); chemical industries, 29 MCM (22 enterprises); and food industries, 20 MCM (159 enterprises). All other industries together consume 33 MCM (477 enterprises). The mining and chemical industries consume about half of the subsector water.

In the past, industrial consumption increased at a rate of about 4% per year. The forecast is for an increase of about 1.4% per year - from 110 MCM in 1985 to 135 MCM in 2000.

The forecast in terms of geographical breakdown was based in principle on trends observed in recent years, namely:

- Continuing decrease in industrial activities in the densely populated urban centres.

- Increase in industries in special parks and small municipalities.

- Increase in mining and chemical industries in the southern Negev.

A major unknown is the possible installation of inland power generation stations with an high water demand (15-30 MCM/yr). Environmental authorities have demanded location of new power stations inland to reduce the strain on the coastal zone, where all power stations are at present located. The decisions of the energy planning authorities have changed during the past few years in respect of the expected commissioning time of the first inland station, which is now beyond the planning horizon.

PER CAPITA WATER CONSUMPTION IN THE DOMESTIC SECTOR

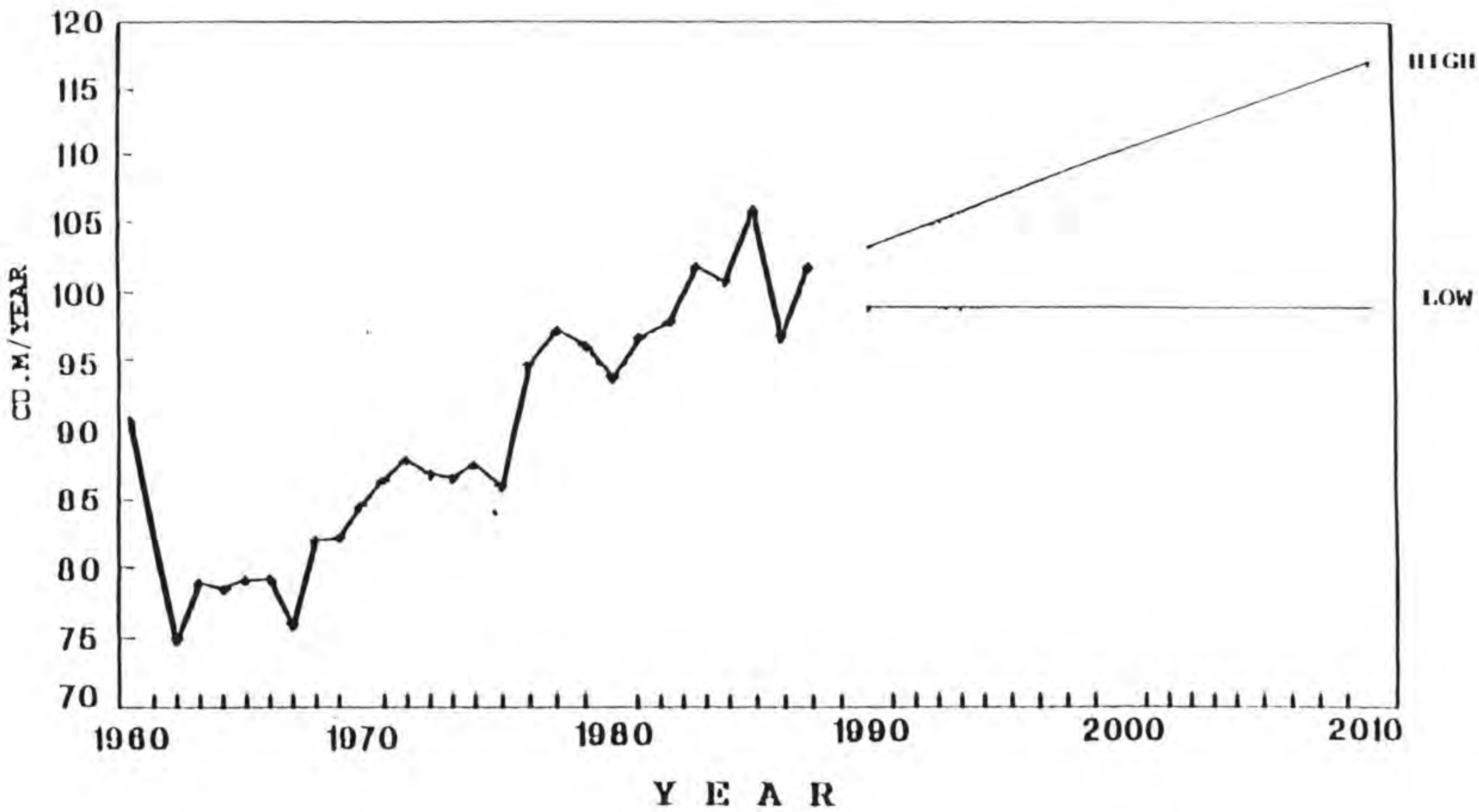


Fig. 10-3

10.2.3 Irrigation Water Supply

Present irrigation consumption is about 1,300 MCM/yr, and it is projected that by 2000 a smaller amount will be available unless additional and expensive water supply is developed.

The increase in water demand for domestic and industrial purposes due to the expected population growth will be compensated by a reduction in good quality water supply to agriculture, and an overall 15% reduction of water supply to this sector.

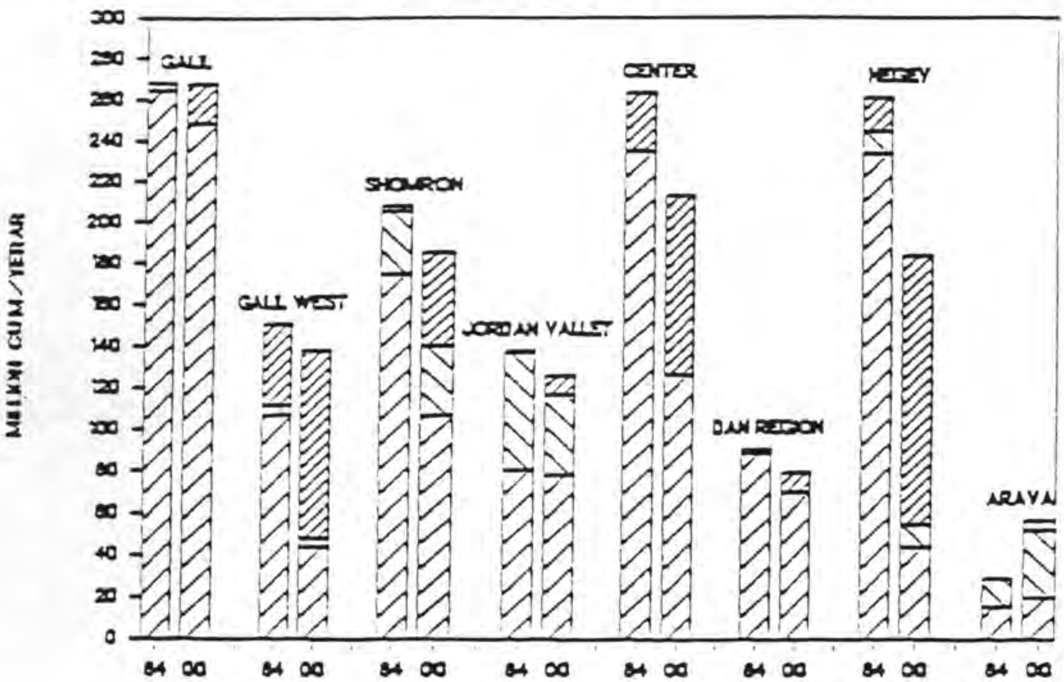
Until the year 2000 all the subsectors, except for agriculture, will increase their demand from the present 640 MCM/yr to 910 MCM/yr. This increase relates to fresh water only. The combined effect of increasing demand and reduced exploitation of good quality groundwater will gradually lower the amount of fresh water available to agriculture from 1,200 MCM/yr to 740 MCM/yr.

The supply of 1,180 MCM to agriculture in the year 2000 is dependent on an investment program of US$ 100 million per year in the period 1988-2000, including expansion and upgrading of wastewater use. A reduction in the budget to an average of US$ 30 million per year (as at present) will prevent implementation of vital conservation and development programs. As a consequence, not only will water supply reliability and water quality be affected, but there will also be a reduction in water supply to agriculture from 1,180 to 1,000 MCM in the year 2000.

Increase in water requirements in other sectors due to immigration or to accelerated growth in the standard of living would also impose an additional reduction in water supply to agriculture. Immigration to the extent of 1 million persons would reduce fresh water available to agriculture by an additional 100 MCM, but increase reclaimed wastewater effluents by some 60 MCM.

Curtailment of water supply will vary in the different regions, according to quality (see Fig. 10-4). Cutbacks in fresh water will be more severe near urban centres and in the south, where fresh water requirements by other sectors will increase, and where reclaimed effluents will be available for replacement. High replacement rates in the Negev and Western Galilee (see Fig. 10-4) are assumed owing to the high quality of the effluents that would be available in these regions. However, in the western Galilee, which has highly sensitive tree plantations, the problem of high salinity in effluents has not yet been solved.

IRRIGATION WATER SUPPLY, 1984 AND 2000



Quality: FRESH BRACKISH IRRIGATION

10.2.4 Water Demand in Judea and Samaria

The water demand forecast for the domestic sector in these areas depends on the population forecast, with a particular uncertainty regarding immigration balance. It also depends on the future increase in the standard of living and the per capita water consumption. Both are at present lower than in Israel (see Sections 1.5 and 3.5), as is the standard of living, represented by the relevant indicators (see Section 1.5).

The projections adopted for Judea and Samaria in the Israel Master Plan were:

Year	Population (Thousands)	Per Capita Consumption (cu.m/yr)	Total Domestic Demand MCM
1985	798	35	28
1990	881	40	35
2000	1074	50	54
2010	1309	60	78

The projected increase in per capita consumption was estimated to be similar to the accelerated increase in the low per capita consumption localities in Israel (see Section 10.2.1). Other projections with a more rapid growth in the standard of living, reaching a per capita consumption of 100 cu.m/yr at an early stage, are also considered.

Owing to the scarcity of water in the region, it was estimated that future irrigation water supply will not exceed its present level of 80 MCM/yr. Only reuse of sewage effluents would result in some relaxation of this constraint.

10.2.5 Water Demand in the Gaza Region

Projections of domestic water supply for the Gaza region were prepared on the basis of principles similar to Judea and Samaria, namely:

Year	Population (Thousands)	Per Capita Consumption (cu.m/yr)	Total Domestic Demand MCM
1985	518	35	18
1990	586	45	26
2000	751	50	37
2010	961	60	57

Future plans are aimed at preserving irrigation water supply at 60 MCM/yr.

The difference between these requirements and the available local groundwater resources of 65 MCM/yr is therefore estimated at 40 MCM/yr in 2000, including 3 MCM industrial demand, and 57 MCM in 2010, including 5 MCM industrial demand.

Seven alternatives and combinations thereof are considered to overcome the discrepancy between water demand and supply in the Gaza Region:

- Reuse of reclaimed sewage.
- Reduction of the irrigated area.
- Seawater desalination.
- Import of water from Israel.
- Import of water from the Nile River via Sinai.
- Import of water from the Litani or Yarmuk Rivers via the Israeli system.
- Import of water by sea from Turkey or other alternative sources.

Water supply is greatly dependent on feasible solutions to the financial, economic and political difficulties involved in implementation of these alternatives.

10.3 Water Resources Development

The existing renewable resources are already fully utilized. Therefore, future growth in water supply depends on:

- Reuse of sewage effluents.
- Use of marginal floodwater and saline sources.
- Cloud seeding.
- Seawater desalination.
- Import of water.
- Water resources management.

The ultimate answer to water problems in Israel in particular, and in the Middle East in general, is large-scale desalination of seawater. However, for economic reasons, needs for the near future should be met by development of marginal resources, such as reuse of wastewater, floodwater utilization and cloud seeding.

10.3.1 Wastewater Reuse

The main wastewater reuse projects, namely the Dan Region Sewage Reclamation Project and the Qishon Multi-Source Scheme, are already in operation (see Section 4.6). Future extension of wastewater reuse will take the form of installation of new schemes, increase in the capacities of existing schemes, and upgrading of effluent quality to extend the range of crops that can be irrigated without public health limitations, including edible crops (see Section 6.3). From the present figure of 200 MCM/yr, use of reclaimed wastewater in the year 2000 is expected to reach 350 MCM. This estimate assumes that small localities will also be able to treat their sewage to give effluents of a quality permitting their use in irrigation.

10.3.2 Use of Marginal Floodwater and Saline Sources

The use of ephemeral floodwater requires large intake and storage facilities, which increase cost. The use of saline sources is limited to salt-tolerant crops. Due to these limitations, present use of these sources is limited and defined as marginal.

Within the cost constraint of 35 cents/cu.m established in the Master Plan, minor development of these sources is still possible.

Use of floodwater will increase from 40 to 80 MCM/yr in the year 2000. In the Jordan Basin, use of the lower Jordan River floods will cease as a result of excessive salinity, and will be replaced by diversion of unused Yarmuk River floods to Lake Kinneret.

In the western basins, use of intermittent streams will increase. Of special importance will be utilization of part of the urban runoff by artificial recharge. A sum of US$ 50 million will be required for these facilities.

Brackish water sources exist in groundwater formations, mainly in the southern parts of the country and in the Jordan Rift Valley. Use of brackish water is planned to increase from 145 to 160 MCM/yr in the year 2000, partly by desalination for domestic uses (Elat in the south, Haifa in the north and probably also some of the

Lake Kinneret saline springs). Despite the advances made in reverse osmosis technology, desalination of saline groundwater is still prohibitively expensive. A great part of the brackish water will therefore be used to increase irrigation of salt-tolerant crops, with appropriate soil reclamation (see Section 6.2), and for aquaculture. Industrial uses of brackish water will be developed in the south.

10.3.3 Cloud Seeding

Artificial rainfall stimulation by cloud seeding using silver iodide started as early as 1961 on an experimental scale. Cloud seeding is carried out by airplanes and by ground based generators aided by radar-scanning for selecting target cloud formations.

Routine cloud seeding operations over the Kinneret Basin have been carried out since 1976. Statistical models show that an annual increase in rainfall of some 5% may be expected. Experiments are continuing in the southern parts of the country to establish the effect of cloud seeding on rainfall in this arid region.

Full-scale cloud seeding with improved techniques of target selection may increase natural replenishment by 50-100 MCM/yr.

10.3.4 Desalination

Considerable efforts have been made over the past 25 years in seawater desalination. However, high energy costs during the 1970s have largely dispelled expectations for a low-cost technology. Nevertheless, multi-stage flash distillation plants have been set up in Elat for desalting of seawater, while a number of plants for desalting of brackish groundwater, using the reverse osmosis and electrodialysis processes, have operated in the Negev. A 18,000 cu.m/day multi-stage flash demonstration plant was set up at the Ashdod power station, but is not in use at present due to the obsolence of the station.

Currently, desalination in Israel is centered around the reverse osmosis process, which is used for desalination of brackish groundwater, and is less costly than desalination of seawater by any known method. Consequently, the Elat seawater desalination plants were shut down and replaced by a plant for desalination of brackish groundwater using a reverse osmosis process. This plant, which was orignally built for a capacity of 700 cu.m/day, has been expanded recently to a capacity of 13,500 cu.m/day. In addition, some 20 small plants are operating in various settlements in the Negev.

The operational cost of the Elat groundwater desalination plant was estimated by Mekorot at 50 cents/cu.m. The operational cost of future large-scale seawater desalination plants, based on both the reverse osmosis and distillation processes, is estimated at 60 cents/cu.m. This is well above the 35 cents/cu.m limit for development of new water resources in the Master Plan.

In light of the above, developments in this field, albeit of importance, are not expected to add significantly to the country's water resources in the near future. However, such options are reserved by investments in R & D and by constant dialogue with the Israel Electricity Corporation to include sufficient area for desalination plants in its future sites.

10.3.5 Import of Water

Supply of water to Israel from abundant water sources in basins located on the northeastern Mediterranean coasts has been evaluated in the past. Two limitations were always considered: high transportation costs and the necessity for secure long-term supply from the political point of view.

Owing to the above limitations, the Master Plan rejected the possibility of importing water. However, a new technology has recently been studied for shipping water in large (1 MCM) vinyl bags. This technology is at present considered to be much less expensive than conventional tankers (about 25 cents/cu.m compared with 100 cents/cu.m). However, it is still in the R & D stage, and its technological feasibility has not yet been ascertained.

10.3.6 Water Resources Management

The Master Plan proposed building up of a reasonable long-term storage in the CA by systematically reduced pumping from this aquifer for water supply over a 20-year period. During this restoration period, large towns would be supplied from the YT, or with treated LK water.

Operational policy for LK, owing to its relatively small storage capacity, is dynamic, aiming on the one hand to prevent overflow from the lake, and on the other hand to diminish the danger of water shortage. Different operational possibilities were investigated and it was finally recommended to exploit water according to the volume existing in the lake and the expected seasonal inflow, the latter being highly variable in the winter and autumn months. In the summer a very high serial correlation guarantees stable forecasts. In the future, when reliability requirements will increase, a more conservative operational policy would be required, with the time horizon extended to more than one year. This would in most cases necessitate maintaining water in storage at the end of the year, with the exception of extreme successive droughts, when storage would be consumed.

The YT serves as the main source of potable water for large towns by means of separate water systems, as a water source for the NWC, and as the main regulation reservoir of NWC. Therefore, in this aquifer too the volume of water maintained in regular storage will be increased in the future.

Restoration of aquifers would be partly achieved by increasing artificial recharge in rainy years. In dry years, water would be supplied from aquifers, and idle wells in the CA would be reactivated.

A small probability (2%) of water shortage may still be expected: 200 MCM/yr in the short term and 70 MCM/yr in the long term, after build up of storage.

10.4 Regional (International) Plans

Regional programs for power and water development with international cooperation were suggested in the past but were never pursued due to the conflicts in the eastern Mediterranean region. The following plans are worthy of note:

- Import of Nile River water via Sinai to the Gaza Region and to Judea and Samaria.
- Import of Yarmuk River water to Judea and Samaria, mainly to meet requirements in the Jordan Valley.
- Import of water from the above sources or from the Litani River to supply water to Judea-Samaria and Gaza either directly or by means of the Israeli NWS. Some of the surplus winter water may also be recharged to the CA for seasonal storage.
- Import to Israel, during droughts, of part of the Litani River water that is used solely for power generation, in exchange for power supply from Israel to Lebanon. The water will be received by LK. Spare power generation capacity will be available in Israel in dry years as a result of reduced pumping of water.

- Desalination or import of water by sea to the Coastal Plain of Israel, and sharing the product between Israel and Jordan. This would involve replacement of the supply to Israel from LK by the imported water and supply of LK water to Jordan instead.

A plan has recently been drawn up for Jordan, according to which a power plant would be built on the Gaza Strip coast for local power needs as well as for desalination of seawater.

10.5 Safeguarding of Potable Water Supply Quality

It is assumed that all urban areas should be supplied with good quality water and that there should be no recourse to bottled water.

Most of the problems anticipated in future water supply concern water quality. The first problem relates to the quality of water in the NWC (see Section 6.4), principally turbidity and other parameters which are at present within the limits of drinking water standards. However, deviations from standards will probably occur in the future, since standards are expected to become more stringent.

The NWC will continue to function as a system which integrates the main water sources of Israel, and which supplies all-purpose water, including potable water. However, the quality of drinking water in the major urban centres will be guaranteed through regional or local solutions based on groundwater. In the near future, the Greater Tel Aviv area, Jerusalem and Be'er Sheva will be supplied from groundwater sources. A simultaneous increase in recharge of the YT aquifer with NWC water will take place. Improvement in water quality in small towns and villages will be carried out gradually, partly by means of treatment plants.

In order to guarantee the supply of potable water from underground sources, protected areas have been defined and mapped. Special steps should be taken in these areas to prevent pollution at the surface (including restricted irrigation with treated sewage water, and strict control of fertilization and other agrotechnical polluting activities). Priority should be given to artificial recharge of these areas with good quality water having very low pollutant levels.

In the future, nitrate removing processes will probably be introduced, based on a technology which is at present being investigated. In addition, the quality requirements of treated sewage reused for irrigation will be high, since it is not possible to completely control the courses of this water.

10.6 Regional Transfers

The increasing demand in the urban centres will necessitate an increased supply of good quality water which has been supplied to the Negev in the past, but which will be diverted in the future to the central part of the country.

The composition of water supply by quality will vary considerably from region to region, since regional transfer is expensive and therefore not practised (see Fig. 10-4). However, it will still be necessary to convey effluents southward from the Dan as well as from the Haifa regions.

The cost of reclaimed wastewater transfers may reach the maximum assumed in the Master Plan (see Section 9.5). Excess effluents which, owing to high costs, cannot be conveyed via the existing and planned conveyance systems, would be supplied locally without exchange of superior quality water.

10.7 Management and Administrative Measures

The Master Plan also deals with the conservation of water resources, and concentrates on management and administrative measures related to these aspects. It suggests creation of basin authorities that will be responsible for the management of single basins or groups of basins. These authorities would establish water abstraction limits, purchase water for artificial recharge from the NWC authority, collect exploitation fees from all users, and would be responsible for monitoring and conservation. The national authority - the Water Commission - would supervise and control all basin authorities.

10.8 Investment Program

The Master Plan includes a program of investment in projects for supplying planned water quantities with an acceptable reliability, according to expected water quality standards. Some US$ 100 million are required annually for this purpose. A breakdown by objectives (see Table 10-2) shows that 25% of the investments up to the year 2000 are required for increasing water supply capacity, mainly to urban centres, 30% for developing water sources, mainly reclaimed wastewater, 16% for improving water quality and conserving resources, and 20% for renewing existing water works.

TABLE 10-2: BREAKDOWN OF INVESTMENTS BY PROJECT OBJECTIVE

Project Objective*	Investment ('000 $)				
	Immediate Term 1988-1990	Short Term 1991-1995	Medium Term 1996-2000	Total Up to 2000	Long Term 2000+
Development of Sources:					
Fresh water	15,833	14,960	25,659	56,452	15,800
Flood water	2,000	20,470	27,620	50,090	56,020
Reclaimed wastewater	54,970	88,856	77,010	220,836	42,825
Brackish water	-	2,000	2,900	4,900	-
Seawater desalination	-	-	-	-	130,000
Total	72,803	126,286	133,189	332,278	244,645
Increase of supply:					
Domestic and industry - fresh water	37,365	39,530	66,995	193,890	66,423
Agriculture in new settlements	19,910	9,563	14,000	43,473	9,400
Agriculture in old settlements	5,950	1,150	0	7,100	5,310
Industry	1,100	4,440	27,300	32,840	7,500
Total	64,325	104,683	108,295	277,303	88,633
Improvement in Water Quality:					
Potable	17,030	34,550	17,680	69,260	78,000
Irrigation	4,290	3,000	1,600	8,890	4,000
Total	21,320	37,550	19,280	78,150	82,000
Conservation and Rehabilitation of Water Sources:					
Groundwater	13,860	38,440	29,500	81,800	18,000
Surface water	1,000	1,000	1,000	3,000	0
Lake Kinneret	4,300	6,600	7,500	18,900	3,500
Total	19,660	46,040	38,000	103,700	21,500
Improvement of Operating Efficiency & Reliability:					
General	14,190	32,880	17,900	64,970	2,600
Energy conservation	2,000	3,000	6,000	11,000	0
Total	16,190	35,880	23,900	75,970	2,600
Renewal of Deteriorating Systems					
	39,141	74,200	117,200	230,541	404,500
Total	39,141	74,200	117,200	230,541	404,500
Total investments	233,439	424,639	439,864	1,097,942	843,878
Total investments per year	77,813	84,928	87,973	84,457	
Total investments per year, incl. planning, administration and supervision (15%)	89,485	97,667	101,167	97,125	

* Projects with several objectives are defined according to the principle one.

The financial resources available to the water sector for development and expansion are limited due to the grievous state of the economy, with external obligations amounting to US$ 4,150 per capita, and an annual external trade deficit of more than US$ 1,000 per capita compared with a GNP of US$ 9,400 per capita. Although the volume of government expenditures amounts to about 40% of the GNP, budget allocations for water resources development are insufficient.

The required budget is 2.5 times the 1988 budget. New ways of financing, such as increasing water charges and privatization (see Section 12.4), will be required to prevent deterioration of the system.

An investment budget limited to present levels would result in a reduction of some 20% in agricultural water supply, and more importantly, in lower water quality, inadequate supply reliability, and uncontrolled deterioration of water resources.

10.9 Temporarily Rejected Projects

Some projects were rejected in the Master Plan due to exceedingly high costs or uncertainties, although their feasibility is still under study. These projects include:

- Seawater desalination and import of water.
- Central treatment of NWC water to the quality required by future drinking water standards.
- Exploitation by galleries or wells of eastern watersheds at present discharging into the Dead Sea.
- Conveyance of surplus effluents from the western Galilee to the southern parts of Israel.
- Direct supply from the Jordan sources to the NWC in order to save energy and decrease salinity in the NWS.
- Exploitation and mining of possible reserves in the southern Negev and their conveyance to the north.

The above projects are mutually exclusive, in the sense that implementation of one decreases the need for, and at times the feasibility of, the other.

10.10 Future Uncertainties

The application of technologies which cannot be implemented economically at present, such as seawater desalination or import of water from water-abundant countries, will remove restrictions to development of agriculture in Israel. In light of this, the study of these technologies is given high priority. On the other hand uncertainties exist, essentially in the domain of climatic changes, demographic changes and Israel's foreign policy, which might increase the water deficit beyond the forecasts of the Master Plan.

The Master Plan assumes a balanced scenario (see Section 8.1.4) among these uncertainties: possible future deviations in technological innovations may probably offset deviations in the other water demanding variables.

11. PAST AND PRESENT POLICIES AFFECTING WATER RESOURCES USE, ALLOCATION AND DEVELOPMENT

11.1 General Policies

Since its inception, the State of Israel has adopted policies governing use, allocation and development of water resources, induced by the need to support the economy, welfare and security of the land and its people. In the initial decades, these policies called for rapid growth. In the past decade, the need was for stabilization, while in the future, the keyword will be conservation of water resources.

During past decades, Israel's water sector was faced with decisions that shaped its present form. The major issues can be summarized as follows:

- Water Rights Doctrine: prior users' rights, riparian rights or temporary rights granted by public administration.
- Priority by sectors: irrigation, domestic and industrial.
- The role of social and political objectives vis-a-vis economic viability in evaluating the feasibility of new water works.
- Public or private financing of new water works construction.
- Pricing of water according to its costs or according to the ability of the consumers to pay.
- Integration of regional water supply systems in the NWC.
- North-south water transfers, taking into consideration the high costs involved.
- Temporary overexploitation of groundwater, taking into consideration hazards relating to quality deterioration on the one hand, and the availability of cheap, though temporary, water supply on the other hand.
- Priority of interventions in pollution prevention, taking into consideration activities such as waste disposal, fertilization and pest control.
- Drought mitigation in the major reservoirs.
- Reliability of water supply: justification of investments in reservoirs, redundant supply capacity and automated control systems.

- Water quality in the NWC: quality of potable or raw water.
- Water quality in Lake Kinneret: quality of potable, raw or non-potable water.
- Use of reclaimed sewage in irrigation: upgrading of effluent quality to allow unlimited use for all crops, or minimum treatment to minimize costs and limit use to industrial crops only.
- Use of brackish water in industry, irrigation and aquaculture.
- Substitution of good quality irrigation water with poor quality water.
- Public or private administration of water works.
- Israeli water rights in the Upper Jordan and Yarmouk basins, which conflict with the claims of neighbouring countries.

The resolution of these issues constitutes to all intents and purposes the Water Resources Policy of Israel, arrived at as a result of national principles governing regional (international), socio-economic, institutional and environmental policies.

The above policies and their reflection on the water sector are discussed in the following sections.

11.2 Past and Present Regional (International) Policies

The Israeli-Arab conflict is closely related to water resources conflicts. The borders of Israel were not delineated on the basis of hydraulic considerations, as a result of which river basins as well as groundwater basins have been divided by political boundaries. The layouts of the major water works in Israel (such as the NWC) were planned and designed on the basis of such geopolitical constraints. The major problems in this connection are:

- Division of the Jordan Basin water between Israel, Syria and Jordan. Prior to 1967, conflicts focused on the Upper Jordan; at present they are concentrated on the Yarmuk River, the major tributary of the Lower Jordan.
- Division of Yarqon-Tanninim and Bet She'an groundwater between the West Bank and pre-1967 Israel.

- Local scarcity of water in the Gaza Region.
- The feasibility of importing water from the Litani and Nile basins.

Israel's policy has been to strive towards obtaining international agreements on the use of international basins, quantitative and qualitative conservation of these basins, and reservation of Israel's rights and shares in water.

A comprehensive settlement on the Jordan Basin, and distribution of water between Jordan, Israel and Syria was drawn up in the early 1950s by E. Jonston, a special US ambassador to the Middle East. Although no consensus could be obtained regarding the plan and no explicit agreement was reached, Israel and Jordan did proceed with national water development in accordance with the plan.

The principles of future international water sharing would be similar to those applied within the Israeli water sector: priority to domestic users and cutback of water supplied to irrigation at an equitable rate. R & D and technical extension would be applied to upgrade technologies that would allow agricultural production to be maintained and even expanded with smaller water quantities.

As a result of the conflict in the region, Israel's present water plans include use of water from its resources in status quo quantities. Plans for international cooperation in the development of new water resources and their conjunctive use (see Section 10.4) still await a change in the direction of more peaceful relations between Israel and its neighbours.

Ideas for cooperation in technological developments as well as sharing of information and know-how on evolution of water rights and users' participation in the management of water resources have been suggested, but still await implementation. Technological exchange in scientific circles may not only precede political cooperation but may also promote it.

11.3 Past and Present Socio-Economic Policies

The agricultural sector played a major role in the pioneering stage of settling the land in Israel, facilitating the absorption of immigrants and economic growth. A large part of the sector was based on the cooperative system, which provided a successful way of transforming unskilled urban populations without capital of their own to farming communities with initially a very low standard of living. Development of the sector necessitated, in a climate such as Israel's, water in the form of irrigation, as a principal input.

In the first decade after independence, the major objectives of the Israeli economy were to support rapid economic growth and secure food production. Growth of the agricultural sector and increase of irrigated crops were consequently given prime importance, and the irrigated area increased from 30,000 ha in 1949 to 124,000 ha in 1959.

Other economic sectors received priority in the second decade, and the irrigated area increased at a slower rate to 166,000 ha in 1969. A still smaller increase to 207,000 ha was observed in the third decade, and in the fourth decade (1988) it increased to 216,000 ha.

Increase of the irrigated area in the first decade was achieved by rapid construction of water supply systems, including hundreds of wells for tapping of groundwater. In the second decade, the growth trend continued, with installation of the NWC, which contributed partly to increasing the irrigated areas and partly to rehabilitation of the overexploited groundwater aquifers.

During the third decade, the major factor contributing to the expansion of irrigated areas was the increase in irrigation efficiency and decrease in water application rates from some 6,800 cu.m/ha in the mid-1960s to about 5,500 cu.m/ha in the 1970s and some 4,500 cu.m/ha in recent years.

The increase of irrigated areas in the fourth decade was due mainly to the introduction of sewage reclamation schemes and local schemes for floodwater utilization.

The economic policies allowing such development comprised primarily allocation of national funds to investments in the water sector. In the first decade these investments (partly financed by international loans) amounted to 1.8% of the GNP. In the second decade, this percentage was reduced to 0.8% and in the fourth to a mere 0.15% of the GNP.

In the third decade a new economic policy was introduced to encourage investments in water conservation - by upgrading irrigation methods and equipment - rather than investments in new water works. Loans were granted to water users for installing more efficient irrigation equipment and water application control devices. This resulted in a decrease in water application rates per unit area, as well as an increase in irrigated area.

Pricing of water was not a sufficient incentive to increasing efficiency of use; however, the scarcity of water and financial support for investment in water conservation devices led to consumer initiatives to increase the efficiency of water use.

In the fourth decade, the development of local marginal resources by local organizations was encouraged. Loans were granted to local organizations for investments in local water development.

Socio-economic policies in Israel have always been subject to the country's major objective of survival and secure borders. This has resulted in population distribution throughout the country, with a special emphasis on remote border settlements for the purpose of encouraging peaceful activities near the borders.

This policy has also resulted in an extensive spread of infrastructure, including water works branching from the main national and regional trunks and reaching practically all parts of the country. Most of the peripheral water works are expensive in terms of both capital and operational costs due to long distances, high lifts and small quantities of water (see Section 9.2).

Irrigation schemes were installed by farmers in regions with abundant and cheap water supply. In peripheral regions requiring long distance conveyance of water or high lift, water works were constructed and operated by government authorities. With respect to water policy, support was provided by the government to the agricultural sector in three ways:

- Allocation of water according to requirements, based on national farming plans. These plans included an assessment of unit water quota per farm type, by region. The total quota of a settlement is a product of the number of farming units (or families on a cooperative farm) and the unit farm quota.

- Differentiation of prices in favour of the agricultural (and industrial) sector. Water charges were used as a policy tool to subsidize use by consumers in remote and high locations, where the cost of water supply is high. The special Adjustment Fund (see Sections 7.1 and 9.3) was used for transferring money from low to high cost regions. However, no selection was possible under this policy to support the more needy consumers, and a flat rate was charged for the agricultural sector throughout the country. Similar assistance was granted through water charges to the industrial sector, although with a high degree of differentiation, originally intended to support needy industries. Recently, however, the differential price structure for industrial uses became too complex and was abandoned.

- National investments in regional water works and soft loans to farm irrigation schemes, as described above.

In the past decade, which saw local inflation, and increased difficulties in international marketing, the agricultural sector in Israel shrank to 3% of the GNP, vs. 12% in 1960. At the same time, the debts of the sector increased to a prohibitively non-liquid level.

National agricultural policy is now undergoing revision in view of the present local crisis and the anticipated 1992 EC united market. Demands for increased support to the agricultural sector are opposed by demands for decreasing government involvement and strengthening market incentives in the sector.

Calls for more realistic water prices have become more widespread and may be accepted within the expected reform in government economic policy.

The priority of the domestic sector is widely recognized. The transfer of water from irrigation to domestic use is part of all stated policies and plans, and is based on the Water Law (see Section 7.1), which allows allocation of water in accordance with the requirements of the inhabitants. The law abrogates by declaration riparian rights and prior rights.

Strong opposition to the above principles is now being raised by members of the agricultural sector claiming prior rights to water resources, and suggesting that the expected increased demand of the domestic sector be met by expensive seawater desalination. These claims are supported by quoting the present economic crisis in the agricultural sector and its need for support.

11.4 Past and Present Institutional Policies

The institutional structure of the water sector is a reflection of the water management needs and political style of the country.

Israel developed a centralized economy system with intensive government involvement. This was a result of rapid growth, necessitating funds (including foreign aid) that could be raised only by the government. In addition, as mentioned in Section 11.3, some national goals, such as population distribution, require government support up to the present time. As a result, a mixed economy evolved, in which economic activities, managed to a great extent by the government or by government controlled corporations, existed side by side with a private business sector.

In the past decade government policy has changed, and its stated objective is now to decrease its direct involvement in economic activities and to privatize existing government corporations. Implementation of this policy, however, is not proceeding according to plan due to strong opposition, in particular by trade unions.

The institutional framework of the water sector was determined and developed according to similar principles, which were also formulated in the 1959 Water Law (see Section 7.1).

The Water Commission (see Section 7.2) is responsible by law for all water affairs, including supervision of water supply, use and conservation of resources, and allocation of water. In the past decade, its responsibilities also included supervision of capital outlays within the government budget.

The government company of Mekorot supplies at present some 65% of the water in Israel, including all expensive, long distance and high lift water conveyance. Mekorot was established by the government in the first decade following independence by merging regional water supply companies. Mekorot was trusted with construction and operation of the NWC and all major regional systems. The positions of company directors and chief executives are filled by political appointments by the Minister of Agriculture, according to the common practice in goverment-owned corporations. Planning activities are the responsibility of TAHAL Consulting Engineers Ltd., which was founded and operates similarly to Mekorot.

Regional and private systems, accounting for 35% of water supply in Israel, exist side by side with Mekorot. However, they are also under the supervision of the Water Commission as regards abstraction from sources and allocation to consumers.

Water users in the agricultural sector are organized in regional and national organizations. Regional organizations exist in most parts of the country; in the water abundant northeastern regions, they also manage and operate their own water works. The agricultural sector is also represented on the national level by political movements supporting settlements by political identification. The municipal sector is organized nationally.

All the above organizations are recognized in the Israeli political system and in the water institutional structure. Representatives of political and sectorial organizations are members of the National Water Council (see Section 7.2), and of other ad hoc planning commissions. Public hearings on specific issues take place, in which representatives from national and regional organizations take part.

Plans for decentralized reorganization of the water sector were suggested in the past but always rejected. These plans would delegate more authority to regional organizations by division of the country into some ten regions, with autonomous users' organizations operating and maintaining the regional water systems. A national organization would continue to operate and maintain the NWC.

In parallel with the government trend in the past decade to decrease its involvement in the sector, the dominating role of government corporations in Israel's economy has also decreased. This tendency is also reflected in reforms in the water supply institutions. Some major water works have been installed and consequently managed by regional organizations. The financing of Mekorot is no longer fully guaranteed by the government, and demands have been made to separate regional water supply systems from Mekorot. The role of TAHAL as national planning agency is also being questioned, and demands are being made to privatize its planning and design activities.

The power of the trade unions in Israel, backed by law, guarantees to a very high degree the employment of permanent staff, and the implementation of institutional reforms is therefore very difficult. The trade unions are at present the major opponents to institutional changes in water works management.

Reforms in the supervisory institutions are also being considered. A conflict of interests exists between the short-term need to supply irrigation water in high quantities to allow continued agricultural production at the existing level and the long-term need to avoid overexploitation of water resources. It is claimed that as a result of the priority given to short-term objectives over long-term ones, conservation of water resources has not been sufficiently supported. Suggestions have therefore been made to transfer the Water Commission from the Ministry of Agriculture to the Ministry of National Resources or to the Ministry of the Environment. However, these suggestions have not been accepted due to the power of the agricultural lobby.

Issues relating to water quality are at present handled by three different authorities: the Water Commission, the Ministry of Health, and the Ministry of the Environment. Regulation of water quality control, with respect to both drinking water and wastewater reuse for irrigation, are under the jurisdiction of the Ministry of Health (see Section 7.1). The Water Commission is empowered to take action to rectify adverse developments with respect to water resources and water supply systems. Many problems arose in the past due to the above division of responsibility, and suggestions to empower the Water Commission with full authority for water quality have been frequently raised.

11.5 Past and Present Environmental Policies

In the early decades following independence, public attention in Israel was directed almost entirely to growth, and little to environmental protection.

Awareness of environment issues grew side by side with the increase of the standard of living, with the global awareness of "greening," and with lessons learnt from public health failures and outbreaks of epidemics resulting from water pollution.

Environmental interests were first raised by voluntary organizations (e.g. The Society for the Protection of Nature). An environmental protection department was established within the Ministry of the Interior in the early 1970s, while the Ministry of the Environment was established in the late 1980s. The Water Pollution Prevention Unit of the Water Commission (see Section 7.2.1) was also established in the 1970s.

Protection of water resources from man-made pollution has always been one of the major objectives of environmental policy, and of the Water Law (see Section 7.1). Preservation of natural water flows and landscapes is another objective of the undeclared environmental policy. The purpose is to provide recreational infrastructure, preserve natural habitats and wildlife, and improve the quality of life rather than raise the standard of living.

The interests of the water sector coincide with environmental policy with respect to conservation of water quality.

Large-scale sewage reclamation and reuse of effluents in irrigation are today one of the most important means of maintaining lands under irrigation. They are also one of the most efficient means of sewage disposal without harming the environment. Since alternative environmentally safe means of disposal are usually more expensive or less reliable, sewage treatment costs are shared by the agricultural users and municipalities. Financial support to small municipalities is needed in order to encourage environmentally safe sewage reclamation.

Restrictions regarding the use of reclaimed sewage, and requirements with respect to quality and treatment of effluents to avoid pollution of water sources are also in line with the objectives of the water sector. Additional restrictions and treatment according to crop type are required by the public health authorities (see Section 6.3), and these at times conflict with the need of the water sector to reuse water in large quantities, without limitations, and at low cost.

One of the requirements regarding natural preservation is to avoid harnessing springs at their source, and to leave a flow for natural preservation by constructing intakes some distance downstream. This practice resulted in pollution problems and limitations on the use of springs for drinking water. A solution to this problem was found in the form of abstraction of water upstream of springs by wells. This was obviously only a means of gaining legal permission for abstraction, for diversion of water in this manner is also at the expense of the natural flow.

The conflict between the water sector and environmentalists is demonstrated in the Tanninim River, which drains the Tanninim springs to the Mediterranean Sea (see Section 2.3). The objective of the water sector is to reduce wasteful flows to the sea, while environmentalists are concerned with preserving most of the present flow to conserve fresh water-seawater fauna in the single perennial stream that exists today in the coastal plain of Israel.

11.6 Past and Present Water Resources Management Policies

Israel's water resources management policy has always been guided by the clear understanding that the balance between available water resources and exploitation must be maintained. This approach reflects the desire to bequeath to coming generations unimpaired water resources, in terms of both quality and quantity.

The intention of maintaining such a balance has, unfortunately, not been able to withstand the ever-present pressures to increase water allocations for various apparently indispensable needs. By succumbing to such pressures, depletion of the CA - the only long-term regulatory storage means in the system - has been triggered, and earlier plans to rehabilitate the CA have become impracticable (see Section 5.3).

The choice has always been between two principles: gradually restoring the balance between sources and consumption, or allowing excessive exploitation of the limited resources to continue.

The stated policy in the past decade has been one of balanced exploitation. However, the adjustment of water allocations to this principle, necessitating curtailment to the agricultural sector, have been only partially implemented, resulting in continued overexploitation.

Some institutional measures have, however, been provided for implementing a conservative water resources management policy. LK and its watershed have been managed as an hydrological unit, with the clear objective of preventing deterioration of lake water quality. Mekorot, and later the Kinneret Water Authority (see Section 7.2), assisted by locally based research groups as well as scientists and engineers from other institutions, have been instrumental in preserving lake water quality. Based on previous studies, and measurements and conclusions of the Kinneret Limnological Laboratory and the Mekorot Watershed Unit, a long-term master plan of the lake watershed was elaborated. This plan considerably limited the types and volumes of activity in the lake watershed, and determined the ways and means by which development should be pursued.

No similar water authority or administrative framework has been created to manage the underground aquifers, to combat overpumping and land abuse, and to prevent seawater intrusion and other hydrological damage such as reduction in the volume of the freshwater aquifers, and downward leaching of fertilizers, pesticides and heavy metals.

12. POLICY INSTRUMENTS AND THEIR EFFECTIVENESS

12.1 General

In order to implement the policies of the water sector, the Water Commissioner is empowered to apply necessary instruments in the domains of legislation, administration, financing, promotion and education, planning and R & D. These instruments affect the exploitation of water resources and the use of water. The policy instruments are applied in order to achieve the objectives of water policy, namely, most beneficial uses of water and conservation of water resources. However, it has not been possible to apply some of the instruments effectively due to legal, political and socio-economic constraints.

Some of the policy instruments are applied also by water supply institutions: Mekorot and the municipalities.

12.2 Legislation

The most important legislative powers given to the Water Commission are:

- Allocation of water to individuals or for common use.

- Licensing of water abstraction.

- Prevention of pollution and diversion of pollution sources.

- Declaration of protected areas and land use limitations to prevent pollution of water resources.

- Water pricing.

- Authorization of other agencies: Mekorot, basin authorities, municipal authorities and user associations.

Establishment of water quality standards and restrictions on water use with inferior quality are the responsibility of the Ministry of Health.

Legislation is effective as long as there is sufficient administrative power to enforce laws and regulations. This is the task of the Allocation and Licensing Division. As a result of its activities, total abstractions do not usually exceed total licensed volumes. However, deviations may be found on the part of individuals undeterred by penalties, although these are usually offset by persons not utilizing their full allocation. Metering of water is the most important administrative instrument for enforcing allocations.

Transfer of water rights is permitted only with the endorsement of the Water Commission. However, illegal transfers of rights by individuals in the agricultural sector have been frequently observed.

12.3 Administration

The primary administrative task of the Water Commission, carried out by its Allocation and Licensing Division, is the allocation of water - to individuals, sectors, regions and nationwide - and supervision of its use. Allocation of sources to users is a complementary task carried out within the constraints on use of sources established by the Hydrological Service and TAHAL.

Water works are constructed, operated and maintained by Mekorot (65%) and other small suppliers (35%).

Licensing of abstraction works is also the task of the Allocation and Licensing Division, and is carried out within similar constraints, all of which are controlled by a special committee of the Water Commission, with the participation of all other relevant organizations. Control over construction activities by Mekorot is more effective than control over small, private water suppliers.

Approval of planning is by a special planning committee set up by the Water Commission, with the participation of all interested organizations.

Metering of water supply and abstraction is the responsibility of the licensed individual or organization. Meter reports are collected, verified and compared with allocation by the Water Commission.

Hydrological monitoring and appraisal is the responsibility of the Hydrological Service as the basis for the above activities. Metering of abstraction is monitored directly by the Allocation and Licensing Division; however, it is appraised by the Hydrological Service and TAHAL.

12.4 Financing

Financing instruments include water pricing and cost recovery, public credits and government subsidies. These are discussed below.

12.4.1 Water Pricing

In addition to their financial role in recovering operational and capital costs, water charges also serve as policy instruments. Two conflicting objectives underlie water pricing policies in Israel: economic efficiency and conservation of water on the one hand, and social equity and population dispersion on the other. Therefore, water charges are under strict government control and are subject to hearing and approval in the National Water Council and in the Finance Committee of the Knesset.

Payment according to metered consumption was the first and most effective tool for water conservation.

Uniform charges countrywide, despite the large cost variations, have assisted in population dispersion and in encouraging settlement of remote but politically vital locations.

Indirect economic support to the agricultural sector has been achieved by subsidizing water charges to this sector.

Increase in the operational efficiency of the water supply system has been achieved by seasonal water charges, with a 40% increased charge in peak months, when the energy required per unit supply increases due to increased hydraulic losses in the overloaded pipelines.

A progressive water charge has been established recently as an incentive to reduce demand to 80% of the quota (see Section 9.3).

The relatively low water charges in the past encouraged excessive demands. Realistic water charges would no doubt restrain demand and reduce overpumping.

The main principles of such charging are as follows:

- Charges determined as a function of real costs.
- Realistic pricing of water sources (aquifers) by their shadow prices.
- Redistribution of "system costs" (such as expenses due to recharge or conveyance of water from the north) to all consumers, including private well-owners pumping from the recharged aquifers.
- Management of the water system as a closed economy. This would include self-financing of equipment replacement and the development budget.

The tendency towards a perfect water market would always be challenged by practical and ideological objections, as outlined in the following section. Progressive water charges that would be set according to the ability to pay and the willingness of farmers to give up part of their water rights seem to be the only practical means of water charging for conservation purposes.

12.4.2 Cost Recovery

Operational costs are at present recovered partly by water charges and partly by government subsidies. Capital costs are recovered only to a negligible extent without adjusting for inflation (see Section 9.2).

Claims for full cost recovery have met with strong opposition from the agricultural sector, which is the main water consumer. Six reasons are raised:

- Subsidization of the agricultural sector is accepted worldwide and many competing producers in other countries enjoy government assistance.

- The replacement value of water supply installations is lower than their historic investment value due to advanced technologies available at present, and the likelihood of a more efficient design based on better knowledge of the system than that available at the time of construction. Therefore, assessment of capital costs based on inflated historic investments is unjustified.

- It is unjustified to recover from water consumers investments made in the past in security and sabotage protecting measures, such as reinforced concrete buildings or subsurface structures for pumping stations.

- The capital costs of the national water supply system should be considered as a public infrastructure investment, and therefore should be borne by the entire public through government outlays and not only by the water consumers.

- The national water supplier, Mekorot, is monopolistic. The cost of its probable inefficiencies should not be borne by the water consumers.

- It is unjustified to recover from the agricultural sector the costs involved in safeguarding drinking water quality, high supply reliability and peak hour supply capacity, which are all required only by the domestic sector sharing the same water supply works.

These reasons have been accepted and therefore water charges have not been raised significantly; consequently, cost recovery is not possible. Lack of a capital recovery fund does not allow renewal of outdated waterworks, resulting in a decreasing reliability of water supply.

12.4.3 Public Investments

Most of the investments in waterworks have been financed by government budgets. Budgeting of the investment in water works and budget control by the treasurer have been an important tool for orienting development of the water sector according to national policies. This is true despite disputes over priorities in setting up annual budgets and decisions regarding inclusion or exclusion of projects in current annual budgets.

12.5 Promotion and Education

Financial incentives encourage only to a small extent a willingness on the part of farmers to accept painful reductions in water supply and improve irrigation practices. This is also true with regard to the willingness on the part of householders to save water and reduce consumption.

A considerable role is played by education and advertising in acceptance by the public. Education in schools includes the subject of water. Special kits have been prepared by the Water Commission and Mekorot for four age levels, including information and specially devised toys explaining national water problems, with a special emphasis on water shortages and the resulting need for saving water.

Frequent participation by the Water Commission and TAHAL staff in user association meetings have been devoted to the explanation of the water shortage and the necessary conservation means.

Mass media, in particular TV, are used to denounce wastage of water, and to demonstrate pollution prevention and conservation measures.

Water problems are widely discussed in the Knesset, in the Government, in courts, by the State Comptroller, and are widely covered by the media, resulting in high public awareness. These activities are intensified when water reaches low levels or during the rare (once in a decade) suspected outbreaks of waterborne epidemics.

Voluntary associations of professors from all academic institutions in Israel have raised their voices in the administration and the media, demanding more extreme conservation measures.

Most universities in Israel have water resources units within their civil engineering and agriculture faculties.

Training of technicians in the techniques of irrigation, water supply and sewerage is part of the activities of the Israel Water Works Association (see Section 7.2).

12.6 Planning

Planning precedes and shapes actions in the field. Therefore, it is an important instrument in policy implementation. Most planning is supervised by the Water Commission through a special committee, which represents the interests of consumers and other interest groups, but which is dominated by the representatives of the Water Commission itself. Comprehensive plans and regional master plans are controlled by the same committee.

Project plans are usually prepared by TAHAL, and controlled by the Water Commission and Mekorot. Municipal plans and plans of non-Mekorot water supply companies are also controlled by a special committee of the Water Commissioner. The planning hierarchy (see Section 8.1) results in transfer of the accepted policies from comprehensive plans to master plans and subsequently to project plans.

A detailed description of planning tools and their usefulness is given in Section 8.1.

12.7 Research and Development

Selection of R & D subjects is governed to a great extent by the needs of conservation and development of water resources. Research projects financed directly by the Water Commission are also controlled directly by it. In other programs, such as bilateral international R & D, the Water Commission participates in the steering committees.

As a result a considerable portion of R & D in the 1960s was devoted to water resources management. In the 1970s, R & D was devoted to desalination, and in the 1980s to sewage reclamation, each considered at the time to be the principal technological problem of the water sector.

The 1988 Water Sector Master Plan has set up the following order of priorities for R & D objectives according to their importance to the water sector and the estimated knowledge gaps: (i) Identification of ways and means to increase the water resources base (desalination, marine import); (ii) Decrease in losses (decrease in seaward underground and surface flows, and decrease in evaporation); (iii) Water saving in agricultural irrigation and domestic gardening; (iv) Introduction of salt-tolerant crops and agrotechnologies suited to the increased salinities expected in part of the water supply systems; (v) Development of preventive and remedial measures to protect drinking water quality; (vi) Upgrading of wastewater reuse; (vii) Increase in supply reliability; (viii) Energy conservation in water supply systems; and (ix) Provision of water for recreation and natural preservation.

13. FUTURE POLICY SCENARIOS AND THEIR LIKELY IMPACTS

13.1 General

The major policy issues expected in the near and distant future may be summarized as follows:

- Transfer of water rights from agriculture to urban users.
- Substitution of fresh water uses by reclaimed sewage and determination of the quality of reclaimed sewage for the various uses.
- Seawater desalination or import of water to relieve water scarcity and to prevent, or at least decrease, cutback of water to agriculture.
- Conservation vs. continued deterioration of the coastal groundwater aquifer.
- Target quality for Lake Kinneret water: drinking, recreation or fishing.
- Operation policy: establishment of minimum levels (red lines) in the major water sources. Adoption of a risk aversion approach in the absence of sufficient data on geohydrological processes.
- Potable water supply: bottled water vs. advanced treatment in central or local water supply systems.
- Replacement and maintenance of the water supply system and the required level of reliability.
- Pricing of water according to production costs vs. the ability of the consumers to pay.
- Financing of the water sector, and the extent of government support.
- Investments in R & D.
- Water supply in the West Bank: use and management of sources shared with Israel.
- Water supply in the Gaza Region: no intervention, curtailment of supply, local desalination or import from Israel.

These issues are discussed below in the framework of four scenarios that were outlined for the present review by the World Bank, namely:

- Continuation of present trends without any overt policy actions.
- Allocation of water based on preservation of environmental quality.
- Allocation of water to agriculture, with other sectors claiming the residual water.
- Allocation of water to municipal and industrial sectors, with agriculture claiming the residual water.

The first scenario assumes no changes in the present inadequate practices of incentives, and public supervision and intervention. In this scenario conservation of resources as a policy will be relaxed; as a result, deterioration of water quality, and eventually of water resources, is expected. This scenario is therefore short-lived by definition, and will be followed by drastic policy interventions, accompanied by high technology inputs such as seawater desalination and aquifer restoration procedures using technologies that still await development.

The second scenario constitutes an alternative to the first, and branches into the third and fourth scenarios, with their particular constraints for the different sectors.

13.2 Scenario 1: Continuation of Present Trends Without Policy Changes

The present policy is heavily bound by obligations to existing consumers. Though the Water Law empowers the Water Commissioner to cut back existing allocations, this has been practised only to a very limited extent. As a result, the major groundwater resources are already overexploited.

In the present situation, lack of action is tantamount to a water crisis. Overexploitation will cause lowering of water tables and consequently encroachment of seawater into the major aquifers or intrusion of other highly saline water contained in stagnant regions of aquifer formations. As a result, a short period, marked by supply of water with ever-increasing salinity, will be followed by unpredictable curtailments in water production and supply.

Another result of the no action policy will be pollution of water resources. As a result, far-reaching changes in drinking water supplies will be necessitated, with two main alternative courses of action in sight:

- Abandonment of public responsibility for drinking water quality. Consumers will find bottled water to be their compulsory alternative: already a large part of the public accepts bottled drinking water of its own volition, and sales of bottled water have increased dramatically in the past few years.

- Installation and upgrading of treatment facilities in all regional and local water supply systems to a considerable extent, necessitating high costs.

The actual onset of the crisis and its extent are difficult to predict. However, it is very likely that in a period of one decade from now, some hundreds of MCM will be curtailed.

Such a policy would provoke a delayed and stepped-up response, including five courses of action:

- Adaptation of agriculture to smaller water quantities, at a considerably higher price. This could be achieved by the introduction of new crops, still to be developed.

- Adaptation of irrigation practices and crops to higher salinities.

- Desalination of contaminated groundwater.

- Desalination of seawater.

- Upgrading of rainfed crops to utilize lands that will no longer be irrigated.

In addition, social policies will be required to assist weak farms that will not be able to bear the high costs of the expensive technologies, and which cannot assume responsibility for the deterioration of their water sources.

13.3 Scenario 2: Allocation of Water Based on Preservation of Environmental Quality

A policy aimed at conserving water resources is conceptually accepted in Israel, and is part of the background to the National Water Sector Master Plan. In practical terms, however, it has not yet been fully implemented.

The preservation of environmental quality also involves preservation of water as a habitat for wildlife, and in particular preservation of natural water flows. This is an accepted goal, and is practised at present to the extent that it is not in contradiction with water supply needs. A strict environmental policy would lower the existing water supply potential by some 50 MCM.

The principal characteristic of this scenario is the limitation of water production and supply to "safe yield" quantities, which are lower than the present quantities supplied. Water levels would be maintained considerably above their present ones in order to build up hydraulic pressures that would prevent encroachment of saline water.

It is now estimated that some 1,500 MCM are required for the restoration of aquifers, this being the order of magnitude of annual production of water. Maintaining such a high level would involve a loss of 70 MCM to the boundaries of the aquifers, and a consequent decrease in available yield in the same amount (over and above curtailment of present overexploitation by about 200 MCM). However, this is the price that would have to be paid for maintaining hydraulic barriers and reserves for drought conditions. The result of this scenario would be a cutback in water supply to agriculture (Scenario 4) or to other sectors (Scenario 3).

13.4 Scenario 3: Allocation of Water to Agriculture, With Other Sectors Claiming the Residual Water

This is a product of Scenario 2, which imposes severe restrictions on the production of water.

Prior user rights are only partly recognized by the Israeli Water Law, although in the three and half decades of its observance by the Water Commission, rights have been granted to all prior users. Water supply was curtailed only once in 1986 under conditions of scarcity in the reservoirs, following which strong demands were made to restore the supply or at least to maintain the quota, i.e. preserve supply rights. Under the social and political conditions prevailing in the past, this policy was acceptable; however, the present crisis in the agricultural sector may result in a decrease in water demand.

Four major impacts are anticipated under this scenario:

- A pressing need for and economic justification of seawater desalination for the domestic sector. Under this policy, separate financial accounts would be maintained for the different sectors: the agricultural sector would receive water from existing sources and facilities at the present charge levels (probably without subsidies, and including full capital costs); the urban subsector would bear the costs of seawater desalination and conveyance of water from the coast inland. Costs for inland urban centres may in some cases be reduced by exchange of sources with coastal agricultural users.

- Demands for separate supply systems are expected in order to obtain a clear-cut separation of costs. This will affect the planning and layout of future water supply systems.

- Separate supply systems would allow improved quality control of potable water, which will be supplied from treatment plants with facilities for continuous monitoring. Domestic water will flow in separate systems, permitting improved maintenance.

- Decreased demand for reclaimed sewage in the irrigation subsector compared with Scenario 4 (which requires reduction of fresh water supply for irrigation and substitution of fresh water with reclaimed sewage). Elimination of irrigation as a recipient of sewage effluents may give rise to a problem of waste disposal, endangering the environment and public health. Conventional waste disposal schemes with sea outfalls will be required together with advanced and expensive treatment to meet the new international Mediterranean Sea preservation policies.

13.5 Scenario 4: Allocation of Water to Municipal and Industrial Sectors, With Agriculture Claiming the Residual Water

This policy is formally accepted and underlies the Water Sector Master Plan.

The total fresh water available for irrigation will decrease, from 1,200 MCM in the year 1985 to 750 MCM in the year 2000 and 550 MCM in the year 2010. This is expected as a result of: (i) Expected (1988) population growth; (i) Increase in the standard of living and per capita water consumption; and (iii) Required reduction in exploitation of water resources.

Seven major impacts are anticipated under this scenario:

- A new socio-political approach and policy would be required to assist the agricultural sector in coping with fresh water cutbacks in two ways: assisting in the implementation of more advanced agrotechnologies, and compensating those who are willing to forgo agricultural production for other economic activities.

- The extensive reallocation of water in the irrigation subsector and its unequal distribution (see Fig. 10-4) may necessitate a reform in policy instruments. Administrative allocation may be given up in favour of pricing and probably free marketing.

- Weakening of agricultural activities may harm rural life in Israel. New and innovative rural economic activities will have to be encouraged in order to stem migration from rural to urban areas. Such activities would comprise mainly industry, tourism and services.

- With smaller volumes of fresh water, efficiency of use will have to be increased. Introduction of new cash crops and agrotechniques, such as greenhouses and artificial soil columns, should be the major objectives of public investments in R & D activities.

- Lower incentives to develop seawater desalination are expected when there is an option to obtaining water for the growing urban demand by curtailment of irrigation water, which in many cases is less expensive to compensate.

- Increased demand for sewage effluents for irrigation as a substitute for fresh water will relieve most of the sewage waste disposal problems. However, due to water scarcity, this water will also be used for edible crops, with strict public health quality requirements. Advanced processes of sewage treatment will therefore be necessary, including in many cases processes such as SAT (see Section 4.6). A dispute on cost sharing in the advanced treatment is expected.

- Scarcity of water will result in idle farm lands. Consequently, rainfed crops would have to be revived, necessitating special R & D to develop improved crops and agrotechniques for rainfed agriculture.

13.6 Evaluation of Policy Scenarios

The status quo policy, amounting to a continuation of present trends, is shortsighted. Such a policy is destined to create one of the other scenarios described, with its inherent difficulties, that are expected to be greatly magnified the longer the status quo prevails.

Preservation and even restoration of water resources is therefore the preferred policy, with priority given to urban users (in accordance with Scenario 4), which reflects the nation's expected socio-economic policies.

The preferred policy requires investments for replacement of a large part of the existing water supply to the agricultural sector with: (i) Other low quality water such as wastewater; or (ii) Expensive water that would be supplied only if the ability to pay of the agricultural subsector is increased substantially, either by greater efficiency or higher subsidies. Agriculture must cope with the expected decrease in water quality and the increase in its costs. Therefore, the preferred water policy calls for transformation and upgrading of agriculture, in conjunction with the water sector policy.

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