Data Compilation

Water-resources data have been collected by a number of different agencies within the region. Periods of record vary widely. In some areas, data have been collected by different agencies in different time periods. The Core Party water agencies continue their efforts to compile the data into digital data bases. All the data used in the trend analyses were retrieved from these data bases, which are separately maintained by the Israeli Hydrological Service (IHS), the Jordanian Ministry of Water and Irrigation (MWI), and the Palestinian Water Authority (PWA) offices in Gaza and the West Bank.

The main body responsible for collection of hydrological data in the IHS data base is the IHS, although the water-planning company Tahal and the water-supply company Mekorot have contributed data collected from water-supply wells. Data have been collected since the 1930's, but data prior to the 1960's have not been checked satisfactorily for accuracy. Some data, such as nitrate in groundwater, have been collected only since the 1970's. Data are checked routinely for accuracy by hydrologists. Less than 10 percent of data was excluded because of irregularities.

Data in the MWI data base have been collected by the Water Authority of Jordan as well as the MWI. Some data, such as spring discharge, have been collected since the 1930's, but generally, streamflow, groundwater level, and groundwater quality data are available only for the past 20 years. Spring discharge and streamflow measured by the Surface Water Monitoring Division and the data are evaluated by the Surface Water Investigation Division, which also is responsible for the entering data to the data base. Data for this project were retrieved from the data base then checked manually to identify unusual values. Data values determined to be in error were either corrected or excluded from subsequent analysis.

Records in the PWA data base generally start after 1967, although discharge data for some springs extend back to 1953. During the Israeli civil administration, beginning in 1967, the Israeli Ministry of Agriculture (MOA) was responsible for measuring groundwater levels in Gaza, and the Ministry of Health (MOH) was responsible for sampling groundwater quality in municipal domestic wells. Since 1994, the PWA has collected these data in coordination with the MOA and MOH. Data in the West Bank are collected by the West Bank Water Department (WBWD), which was established in 1967 and is now part of the PWA. The WBWD continues to be responsible for measuring groundwater levels, collecting water-quality samples, and measuring discharge from springs and wadis. Unusual values in the data selected for this study were verified and corrected, if necessary, using the following procedure:

- The data were compared to values in the original files;
- The data were plotted to check for patterns;
- Data were compared to other measurements made at nearby locations; and
- Sites were excluded from analysis if there were many missing or estimated data values or if there were irregular patterns in the data.

SELECTION OF DATA FOR TREND ANALYSES

Data selected for trend analyses in this study were groundwater level, groundwater quality (concentrations of chloride and nitrate), spring discharge, and streamflow. Availability of data varied; thus, the periods of record selected for analysis were not the same for all data. All periods were selected to include 1998, which was the last year that had complete data available at the beginning of the study. The shortest analyzed periods were 1984–98 and the longest were 1974–98.

Groundwater data for the Coastal aquifer were analyzed separately from data for other aquifers. This separation was necessary because the Coastal aquifer overlies the Turonian and Cenomanian aquifers in much of the northern part of the basin. Combining trend results for all these aquifers would be misleading, primarily because of differences in recharge sources and ages of the groundwater.

Precipitation was not included in the trend analysis but must be considered in correlation to identified trends. Time-series plots of annual precipitation during the overall period of trend analysis (1974–98) at several locations in the region are shown in figure 4. Precipitation during 1992 was the maximum for almost 150 years of record at Jerusalem and was more than twice the 1974–98 average at Jerusalem, Amman, and Gaza City. This had a major effect on some of the trend results and required splitting some of the time periods into two parts (before and after 1992).

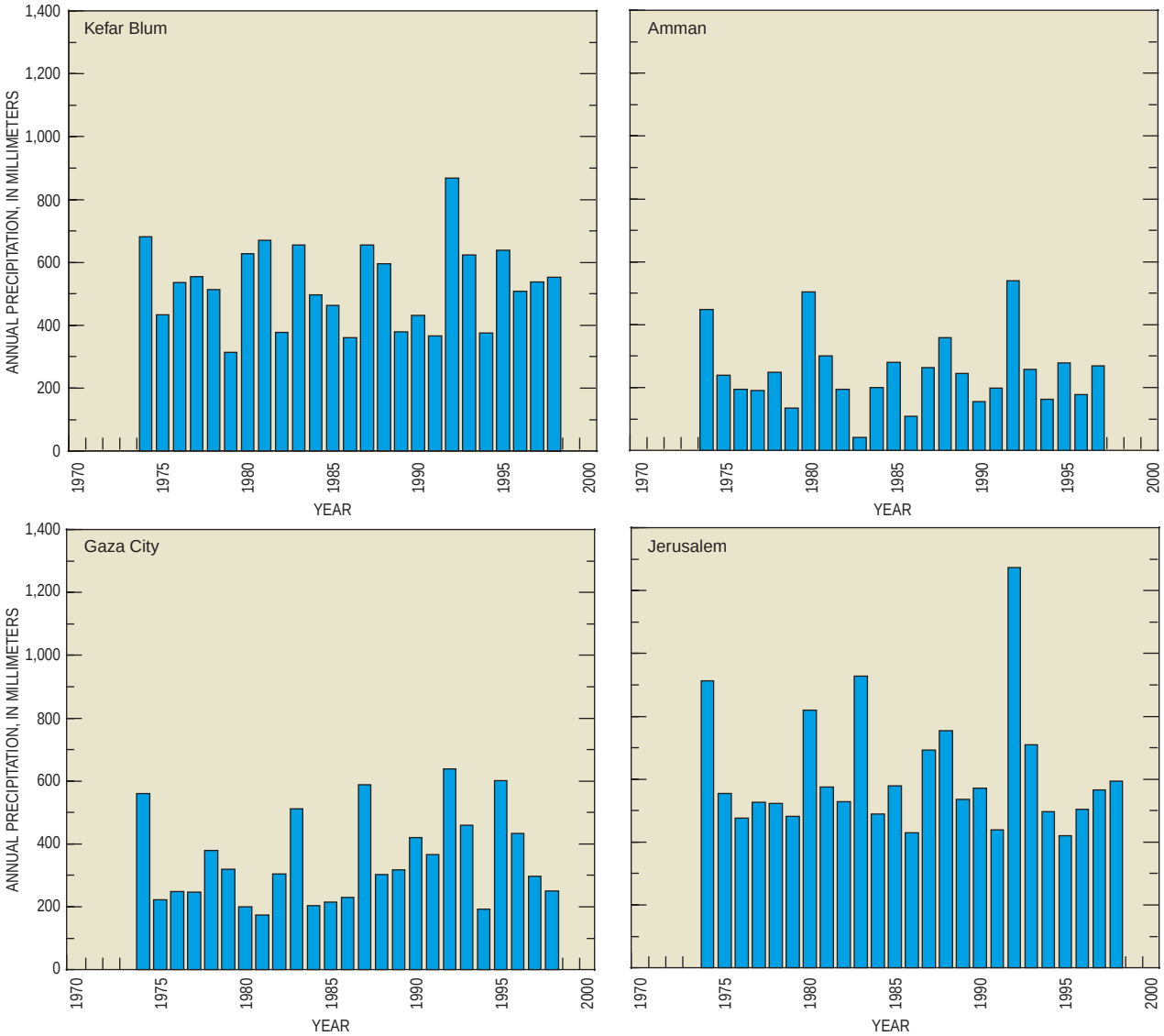

Figure 4. *Graphs showing the time series of annual precipitation at selected cities in the region.*

GROUNDWATER LEVEL

The time period selected for trend analysis of groundwater levels was limited by the consistency of measurements made at monitoring wells. Many wells had been added to the monitoring networks only recently; others had been converted to production wells, and monitoring ceased before 1998. Time periods were selected in an attempt to maximize the spatial coverage of the region and also to provide sufficient data for trend evaluation at individual wells.

For the Coastal aquifer, the period selected was 1984–98. The PWA had data for 132 wells during this period. For the trend analysis, they selected 20 wells at locations distributed to represent Gaza in the southwestern area of the Coastal Basin. The IHS monitors approximately 1,500 wells in the Coastal aquifer. Data for individual wells were used to compute mean groundwater levels in 58 cells defined by a grid covering the northern and central areas of the basin. In addition, 20 individual wells were selected in the southern part of the basin east of Gaza. Overall, trends in groundwater level were evaluated for 98 locations (wells or cells) in the Coastal aquifer.

For all other aquifers, trends were analyzed for two periods: 1982–91 and 1992–98 (following the year of high precipitation). During these two periods, the IHS monitored 300 wells, mostly in

the Western Mountain Basin. For the trend analysis, they selected 214 wells with typical data and no missing values. The PWA monitored 135 wells in the Eastern Mountain, Western Mountain, and Northeastern Basins. They selected 30 wells for trend analysis based on the following requirements:

- Geographic distribution throughout the West Bank;
- Distribution within all groundwater basins and aquifers;
- Location in areas of different land use, such as agricultural, suburban, or undeveloped; and
- Use of water supplied by the well.

The MWI selected 62 wells that were representative of each basin and had complete or almost complete records for 1982–98. Missing values occurred for some years at 35 percent of these wells, but no well was missing more than 3 years of data. Overall, trends in groundwater level were evaluated for 306 wells in 10 aquifers. However, data for 77 wells were insufficient to analyze trends during 1982–91, and data for 34 wells were insufficient to analyze trends during 1992–98.

Measurements of groundwater level are made on various schedules. The IHS measures water levels twice a year (spring and autumn). Since 1986, they have made monthly measurements in a subset of wells, called the reduced network. The PWA measures water levels monthly in Gaza and bimonthly in the West Bank. In Jordan, the MWI measures water levels monthly. For trend analysis, a single water-level value, in meters above sea level, was derived for each year of the selected period. This value was chosen to represent the water level near the end of the dry season. In general, this value was computed as the mean of measurements made during September through November. If no measurements were made during this period for a year, the nearest measurement was used; however, only measurements made during August through December were considered.

GROUNDWATER QUALITY

The time period for analysis of trends in groundwater quality was selected to correspond, in general, to the time periods used for analysis of groundwater levels (1984–98). During this period, adequate data were available for analysis of trends in the concentration of chloride and nitrate. Samples were collected at various frequencies. The IHS collects annual samples, the PWA collects two samples per year (spring and autumn), and the MWI collects monthly samples. For trend analysis, chloride and nitrate concentrations were averaged for the calendar year. In the Coastal aquifer, trend analysis was limited to wells with at least 12 annual values during 1984–98. Because less data were available for other aquifers, trends were evaluated for wells with at least 10 annual values.

For the Coastal aquifer, the PWA has chloride data for 403 wells during 1984–98, but nitrate analyses were not included until 1990. Prior to 1994, samples were analyzed by the Israeli MOA Laboratory; since then, analyses have been done by the PWA Laboratory. Twenty wells were selected for analysis of chloride trends; nitrate trends were not evaluated because of the short period of record. Wells were selected to represent Gaza in the southwestern area of the Coastal Basin. The IHS monitors approximately 1,500 wells in the Coastal aquifer. They selected 951 wells to represent chloride trends in the northern and central parts of the basin and the southern part east of Gaza. A separate set of 251 wells was selected to represent nitrate trends, primarily in the northern and central parts of the basin. Few nitrate data were available from wells in the southern part of the basin.

For other aquifers, most chloride and nitrate data were collected west of the Jordan Rift Valley. The IHS selected 271 wells for analysis of trends in groundwater quality. Most of these were located in the Western Mountain Basin. The PWA sampled 168 wells for chloride and nitrate during 1984–98. Analysis were done by Israeli laboratories until 1997, and since then by the PWA laboratory. The PWA selected 68 wells for trend analysis. Criteria were the same as those used for the selection of wells for analysis of groundwater levels. In addition, all wells in the Pleistocene aquifer were included because chloride and nitrate concentrations are highly variable in this aquifer. East of the Rift Valley, the MWI sampled chloride and nitrate in 42 wells during 1984–98, but only 12 of these had an adequate number of records for trend analysis. Overall, 351 wells were included in the analysis. Data were inadequate for determining trends in 19 wells for chloride and in a another group of 19 wells for nitrate.

SPRING DISCHARGE

Flowing springs are common in the Mountain Belt and along the Jordan Rift Valley. Some of these springs have been important sources of water supply for thousands of years. Measurements of discharge from springs extend back to the 1930's;

however, a majority of springs in the region have much shorter records. Therefore, a 25-year period (1974–98) was selected for analysis of trends in spring discharge.

The IHS made monthly discharge measurements at about 300 springs during the selected time period. They chose 121 representative springs with typical discharge to include in the trend analysis. The PWA measured discharge at 98 springs during 1974–98. The minimum discharge from each of these springs was estimated to be greater than 0.1 liter per second. For the largest springs, where average discharge exceeds 5 liters per second, measurements were made monthly. Otherwise, measurements were made once every 2 or 3 months. Nineteen springs were selected for trend analysis. The geographic criteria were similar to those for the selection of wells used in water-level trend analysis. In addition, the structure, quantity of discharge, and use of the water from the spring were considered. The MWI measured discharge at 800 springs during 1974–98. These were grouped into three classes:

- A—springs measured monthly,
- B—springs measured at 3-month intervals because of difficult access, and
- C—springs measured irregularly because of low discharge.

The MWI selected 110 class A springs to include in the trend analysis. The criteria were that these springs represent aquifers throughout Jordan and that the records were complete and of good quality.

For each spring, the total annual discharge, in million cubic meters, was computed from instantaneous measurements for each hydrologic year from 1974 to 1998. All selected springs had at least 23 annual discharge values during the period.

STREAMFLOW

Perennial streams are uncommon in the region because of generally low precipitation and high evapotranspiration. Streamflow typically is higher in the northern part of the region and on the western side of the Mountain Belt, but few streams outside the Jordan River watershed have adequate base flow to sustain flow throughout the year. Streamflow is measured at few sites in comparison to groundwater and spring-discharge monitoring. The majority of sites have at most 25–30 years of record. Thus, the period for analysis of trends in streamflow was selected to be 1974–98, the same as used for analysis of spring discharge.

The IHS used automatic recorders to make continuous measurement of streamflow at 60 sites during the selected time period. They selected 40 representative stream sites with typical hydrologic characteristics and with adequate data for trend analysis. The MWI made monthly measurements of streamflow at 26 sites during the period. These measurements were used to compute estimates of daily base flow and flood flow. Twelve stream sites were selected for trend analysis based on completeness of records for 1974–98. Some daily values were missing for a few years at three sites, but no site had missing values in more than 15 years. For each of the 52 sites selected, total annual streamflow, in million cubic meters, was computed for each hydrologic year from 1974 through 1998. All sites had at least 15 annual streamflow values during the period.

A limited amount of data for streamflow at 17 sites in the West Bank are available for short periods before 1967 (Rofe and Raffety Consulting Engineers, 1965). More recent data are confined to two sites: Wadi Al Qilt, near Jericho, and Wadi Fari'a, which drains the Nablus area towards the River Jordan. In the past these stations were fully equipped with autographic water-level recorders and cableways, but they are now abandoned. The West Bank Water Department operated these stations and the data were passed to the IHS, who published part of it. None of these data are available in the PWA data bank. There is only one wadi flowing into Gaza and it has not routinely been measured.