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Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority

Year Eleven: September 2002 - August 2003

by

H. Allen Wehrmann, Steven D. Wilson, and Nancy E. Westcott

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Illinois State Water Survey
Center for Groundwater Science
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Champaign, Illinois

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Abstract

The Illinois State Water Survey (ISWS), under contract to the Imperial Valley Water Authority (IVWA), has operated a network of rain gauges in Mason and Tazewell Counties since August 1992. The ISWS also established a network of groundwater observation wells in the Mason-Tazewell area in 1994 that is monitored by the IVWA. The purpose of the rain gauge network and the groundwater observation well network is to collect long-term data to determine the impact of groundwater withdrawals in dry periods and during the growing season, and the rate at which the aquifer recharges. This report presents data accumulated from both networks since their inception through August 2003. Precipitation is recorded continuously at 20 rain gauges. Groundwater levels are measured the first of each month at 13 observation wells. The database from these networks consists of 11 years of precipitation data and nine years of groundwater observations.

For the period September 2002-August 2003, the network received an average of 30.06 inches of precipitation, 5.84 inches lower than the network 10-year 1992-2002 average precipitation. Precipitation was below average in the fall, winter, and spring, but above average during the summer of 2003.

In 2002-2003, groundwater levels in many wells tended to follow the now-familiar pattern of rising water levels in early spring and peaks in mid-summer before evapotranspiration demands cause water levels to decline. However, the extremely low precipitation that occurred from the period September 2002 through May 2003 (9.23 inches below the 11-year normal) caused a weak recovery before the irrigation season started. Several wells (MTOW-4, -10, -11, and -13) experienced essentially no water-level recovery during this reporting period. Water levels in MTOW-13, in particular, fell throughout the year. That well is located in northeastern Mason County, the area of lowest precipitation.

Total irrigation for the June-September period was estimated to be 46 billion gallons (bg), the fourth highest total since monitoring began in 1995 and ranked just after the 47 bg in both 2001 and 2002. This can be attributed, in part, to the growth of irrigation systems in the Imperial Valley, which now has 1,867 systems.

To improve our understanding of the relationship between groundwater, stream discharge, and irrigation, an irrigation test site was initiated in April 2003. Nine observation wells were installed in close proximity to an irrigated field that abuts Crane Creek. Transducers with data loggers were installed in two wells in June 2003 to monitor groundwater levels and in Crane Creek to monitor stream stage. Preliminary data are presented.

Introduction

The Imperial Valley area, a portion of which also is called the Havana Lowlands, is located principally in Mason and southern Tazewell Counties in west-central Illinois, just east of the Illinois River (Figure 1). The area overlies the confluence of the ancient Mississippi and the Mahomet-Teays bedrock valleys. The sandy soils and rolling dunes of the confluence area in the western portion of the Imperial Valley stand in stark contrast to the typically flat silt loam soils throughout much of the rest of central Illinois. The sand-and-gravel deposits associated with these two valleys contain an abundant groundwater resource. The area is used primarily for row and specialty crops, all made possible by irrigation from the easily developed groundwater resource that underlies the Imperial Valley.

Regional precipitation variability affects irrigation water demand on the aquifer, recharge of the aquifer, and the extent to which the aquifer can be used for agricultural irrigation, and municipal, industrial, and domestic water supplies. All these factors affect any required water withdrawals from an aquifer. Therefore, knowledge of the precipitation variability and its relationship to groundwater recharge over an extensively irrigated region, such as the area within the Imperial Valley Water Authority (IVWA), should provide useful information for the management of groundwater resources in that region.

The Illinois State Water Survey (ISWS) has a long-term interest in precipitation measurement and related research, and has performed precipitation research in areas such as hydrology, weather modification, climate change, and urban influences on precipitation climate. Scientists and engineers from the ISWS have conducted extensive research on Illinois groundwater resources and have a continued interest in the hydrodynamics and recharge of aquifers in the state.

The objective of this project is to conduct long-term monitoring of precipitation and groundwater levels in the Imperial Valley region to learn how the groundwater resources respond to drought and seasonal irrigation, and to assess groundwater recharge.

Rain Gauge and Observation Well Networks

A number of studies (Walker et al., 1965; Panno et al., 1994; Clark, 1994) have shown that precipitation is the primary source of water for groundwater recharge in the Imperial Valley. Therefore, detailed precipitation measurements are important for understanding its contribution to groundwater levels in the Imperial Valley area.

During the last 50 years, the ISWS has operated rain gauge networks of varying areal gauge densities over various time periods in both rural and urban areas. Sampling requirements, as determined from these past studies (e.g., Huff, 1970), indicate that a 2- to 3-mile gridded rain gauge spacing should be adequate for properly capturing convective precipitation systems (spring and summer), while a 6-mile spacing is adequate for more widespread precipitation-producing systems (fall and winter). The Belfort weighing bucket rain gauge provides precise and reliable precipitation measurements. Given the size of the IVWA area and the above spacing guidelines, a gridded, 25-site rain gauge network (Figure 1) with approximately 5 miles between gauges was established in late August 1992. The network was reduced to 20 sites in September 1996. Results of the previous years of the network operation are reported in Peppler and Hollinger (1994,

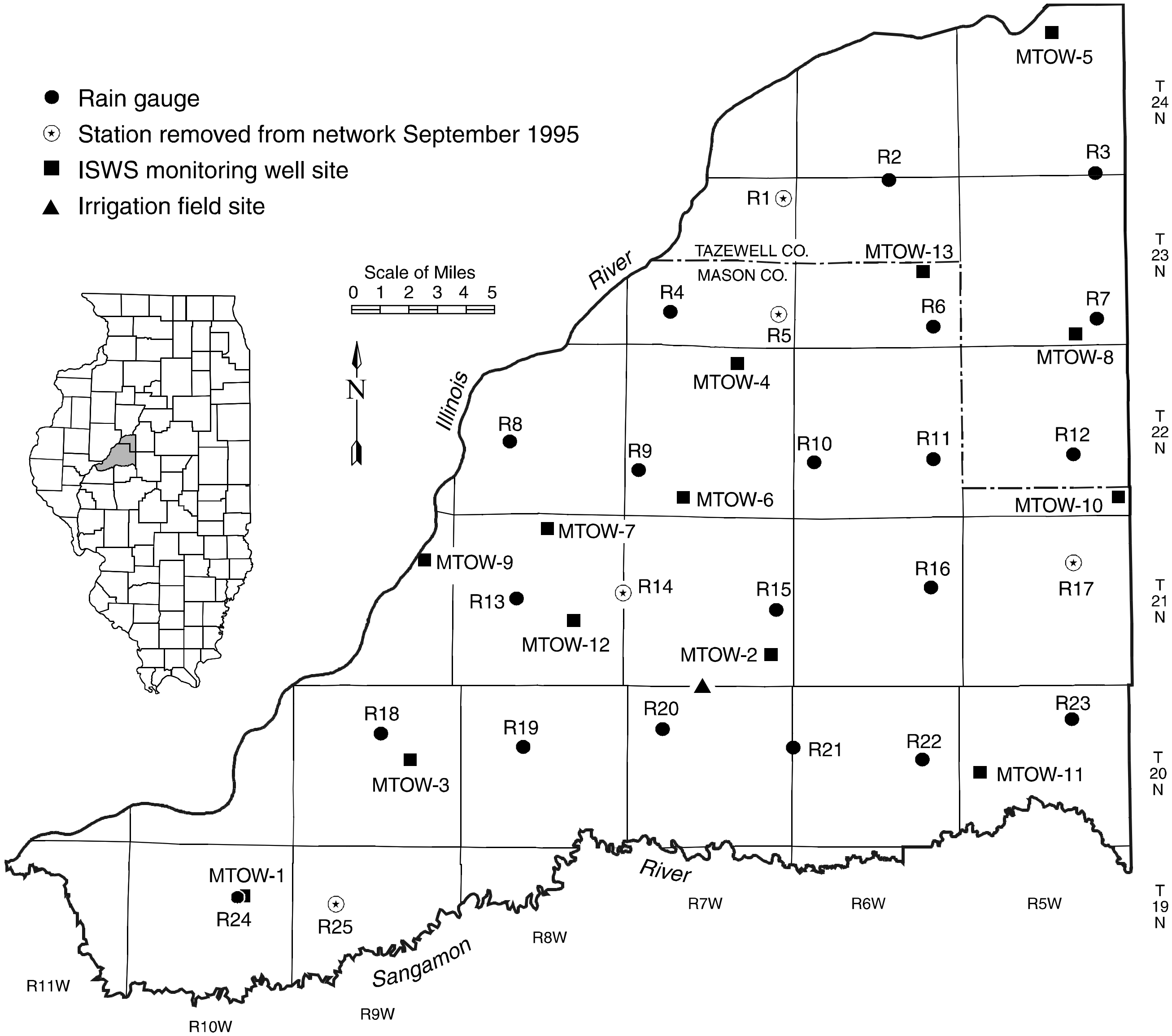

Figure 1. Configuration of the 13-site observation well and 25-site rain gauge networks, and location of the irrigation field site, Imperial Valley, 2002-2003.

1995), Hollinger and Peppler (1996), Hollinger (1997), Hollinger and Scott (1998), Hollinger et al. (1999, 2000), Scott et al. (2001, 2002), and Wehrmann et al. (2004).

The observation well network, originally consisting of 11 wells, Mason-Tazewell Observation Wells (MTOW)-1 through MTOW-11, was established for the IVWA in 1994 by Sanderson and Buck (1995). The IVWA added two wells (MTOW-12 and MTOW-13) in 1995 and 1996 to improve spatial coverage of the network. The 13 observation wells are located fairly uniformly across the Imperial Valley study area (Figure 1). Hollinger et al. (1999) includes the first summary of the groundwater-level data and also statistical analyses of the correlation between precipitation, Illinois River stage, and groundwater levels for the four years that the observation well network had been in operation. Hollinger et al. (2000), Scott et al. (2001, 2002), and Wehrmann et al. (2004) include groundwater-level data and reanalysis of the correlation between precipitation, Illinois River stage, and groundwater levels for the observation well network prior to Year Eleven.

Irrigation Field Site

Understanding the relationship between the regional groundwater discharge to streams and the effects of irrigation on water levels near these streams is a key component in developing a transient model of the Imperial Valley area. In order to model the conditions as they change during the summer, additional input data will be required about the effects of irrigation on groundwater levels and groundwater discharge to streams. Data inputs needed include continuous water-level data, pumping rates and times for irrigation systems, and discharge/stage readings at a nearby stream, all taken in tandem at a location where groundwater is influenced by a stream under nonpumping conditions and the groundwater system is under the influence of irrigation pumpage. A test site was located along Crane Creek in Mason County that has only one center-pivot irrigation system within a half mile of the creek. The site, owned by Jeff Smith, is being used for this project to gather the necessary data to develop a regional flow model and eventually a nested model of the site within the regional model.

Report Objective

This report documents the operation, maintenance, data reduction and analysis, and management of the networks during the eleventh year of the rain gauge network operation and the ninth year of the observation well network operation. A discussion of observed relationships between precipitation, Illinois River stage, irrigation, and groundwater levels is included.

Several appendices document groundwater hydrographs (Appendix A), observed groundwater-level data (Appendix B), rain gauge network site descriptions (Appendix C), instructions for rain gauge technicians (Appendix D), and rain gauge maintenance for the 2002-2003 period (Appendix E). Contour maps of the annual precipitation across the Imperial Valley are presented for Years One-Ten (Appendix F). Documentation also is presented for the monthly and seasonal 1992-2002 precipitation events (Appendix G) and all 2002-2003 heavy storms (Appendix H).

Acknowledgments

This work was conducted for the Imperial Valley Water Authority (IVWA) with partial support from the Illinois State Water Survey (ISWS) General Revenue Fund. The IVWA Board under the direction of Mr. Morris Bell, chairman of the IVWA, administers the project. The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor or of the ISWS. Paul Nelson and Robert Ranson ran the rain gauge network, and Morris Bell collected the monthly groundwater-level data. Kevin Rennels collected groundwater-level and streamgage data at the irrigation site. Linda Hascall drafted the precipitation maps for this report, and Eva Kingston edited the report. Their efforts are greatly appreciated. The ISWS and IVWA also take this opportunity to thank all of the local Mason/Tazewell county observers for their diligence in making this analysis possible. Special thanks to Jeff Smith, Easton, Illinois, for allowing the installation of nine observation wells at his farm and our continual presence there to gather data.

Rain Gauge Network: Description, Operation, and Maintenance

Peppler and Hollinger (1994) described construction of the IVWA rain gauge network and the type and setup of the weighing-bucket rain gauges used. Figure 1 shows locations for gauges R1-R25. Appendix C gives complete site descriptions for the 20 operational rain gauges, as of August 31, 2003. Also included are the locations of five rain gauges removed from the network in 1996. In December 1997, the rain gauges were upgraded to include a data logger and linear potentiometer to automatically record the amount of water in the rain gauges every 10 minutes. This eliminates the necessity to digitize weekly or monthly paper charts, saving 2-3 days of analysis time each month, and provides more accurate time frames for events. Precipitation also is recorded each month on 8-day paper charts for backup if data loggers fail.

The 20 active sites are maintained by a local Mason County resident hired to change the charts once a month, download data from the data loggers, and perform other routine servicing. Rain gauge servicing includes: checking the felt-tipped pen to make sure it is inking properly, emptying the bucket contents from approximately April-October, and noting any unusual problems, including chart-drive malfunction, gauge imbalance or instability, vandalism, unauthorized movement of the gauge, etc. During the warm season, evaporation shields are fitted into the collection orifice above the bucket to minimize evaporation. During the cold season, one quart of antifreeze is added to each rain gauge bucket so that any frozen precipitation collected will melt to allow a proper weight reading, and to prevent freeze damage to the collection bucket. Rain gauges are serviced during the first few days of the month. The memory card with the digital data and also the 20 rain gauge charts are sent monthly to the ISWS. Minor maintenance and repairs also are performed by the Mason County observer. Appendix D presents instructions for the rain gauge technician.

Champaign-based personnel visit the network to perform major maintenance and repairs as needed. This usually consists of a site assessment of an observer-noted problem and determination of a solution. Sometimes problems pertain to the chart drives, and the usual solution is to adjust or replace the chart drive. If replaced, the defective chart drive is cleaned and readied for reuse at the ISWS. Other typical repairs performed on these trips include resoldering wires and battery replacement. The 20 gauges are calibrated annually. If a gauge appears to record consistently high or low precipitation amounts compared with its neighbors, the gauge is first cleaned and calibrated. If the problem persists, the gauge is replaced. Appendix E documents nonroutine maintenance or repairs, including any site relocations, for the 20 rain gauges during Year Eleven.

Groundwater-Level Observation Well Network: Description, Operation, and Maintenance

Table 1 provides a general description of each network well, including well location, depth, and the predominant soil associations in proximity to each well. This provides some determination of relative soil permeability around the wells. Generally, the greater permeabilities associated with the Plainfield-Bloomfield, Sparta-Plainfield-Ade, and Onarga-Dakota-Sparta soil associations (Calsyn, 1995) are found at MTOW-1, -3, -4, -6, -7, -9, and -12, all located in the western portion of the study area (Figure 1). Fine-grained materials found in the upper portion of the geologic profiles at MTOW-10 and MTOW-11 (southeastern portion of the study area) indicate that the water levels in these two wells are under artesian conditions. Because water in these wells is under pressure, water-level responses may be different from those of other wells.

The wells range in depth from 24 to 100 feet. Most network wells were constructed after 1985 as part of special studies within the Imperial Valley or for use in the observation well network. A few wells that existed prior to the development of the network were used for water supply. Well MTOW-1, located at Snicarte, is an inactive, large-diameter, hand-dug domestic well. All of the network wells have been surveyed for well head elevation above mean sea level.

From 1995 through 2001, groundwater levels in the IVWA observation wells were measured at the beginning of each month from March through November (December, January, and February readings typically were not collected). Beginning in 2002, monthly measurements were collected throughout the entire year. A mid-month measurement was collected during the 1995-1997 irrigation seasons (May-October 1995, May-September 1996, and May-August 1997). Groundwater levels are measured manually with a steel tape or electric probe and are entered into a database as depth below land surface. The IVWA collects these measurements, maintains the database, and forwards the resulting data annually to the ISWS.

The Snicarte observation well, MTOW-1, has been monitored by the ISWS since 1958 and has been incorporated into the Shallow Groundwater Well Network of the ISWS Water and Atmospheric Resources Monitoring (WARM) Program. This well is equipped with a Stevens, Type F water-level recorder that produces a continuous record of the groundwater level on a 32-day paper chart. The ISWS staff visit the well monthly to measure the groundwater level, change the recorder chart, and perform recorder maintenance. Therefore, a longer and more complete groundwater level record is available for this well than for any other well in the IVWA network.

Table 1. Imperial Valley Network Observation Wells

Name	*I.D.*	*Location*	*Depth (feet)*	*Generalized Soil Association*	*Remarks*
Snicarte	MTOW-1	Section 11.8b, T.19N., R.10W., Mason County	40.5	Sparta-Plainfield-Ade	Inactive well, continuous record since 1958
Easton	MTOW-2	Section 25.8a, T.21N., R.7W., Mason County	82	Elburn-Plano-Thorp	Abandoned city fire well
Mason County Wildlife Refuge & Recreation Area	MTOW-3	Section 14.8c, T.20N., R.9W., Mason County	24	Plainfield-Bloomfield	Installed in 1985 for ISGS study
Sand Ridge SR-11	MTOW-4	Section 2.8d, T.22N., R.7W., Mason County	27	Plainfield-Bloomfield	Installed in 1989 for ISWS study
Pekin - OW8	MTOW-5	Section 3.6a, T.24N., R.5W., Tazewell County	49	Selma-Harpster	Installed in 1991 for ISWS study
Mason State Tree Nursery	MTOW-6	Section 33.8f, T.22N., R.7W., Mason County	45.5	Onarga-Dakota-Sparta	Installed in 1993
IL Route 136 Rest Area	MTOW-7	Section 3.7e, T.21N., R.8W., Mason County	44	Onarga-Dakota-Sparta	Installed in 1993
Green Valley	MTOW-8	Section 34.1c, T.23N., R.5W., Mason County	53.5	Elburn-Plano-Thorp	Installed in 1993
IDOT - DWR	MTOW-9	Section 12.8e, T.21N., R.9W., Mason County	48	Sparta-Plainfield-Ade	Installed in 1994 for flood study
San Jose	MTOW-10	Section 36.2d, T.22N., R.5W., Mason County	56	Elburn-Plano-Thorp	Old municipal well
Mason City	MTOW-11	Section 18.2a, T.20N., R.5W., Mason County	63	Tama-Ipava	Old municipal well
Hahn Farm	MTOW-12	Section 23.8c, T.21N., R.8W., Mason County	100	Plainfield-Bloomfield	Old turkey farm well
Talbott Tree Farm	MTOW-13	Section 9.4a, T.23N, R.6W., Tazewell County	82	Selma-Harpster	Installed in 1996

Notes: General Soil Map Units are from Calsyn (1995).
MTOW = Mason-Tazewell Observation Well.

Irrigation Field Site: Description, Operation, and Maintenance (Year One)

A site along Crane Creek, southwest of Easton, Illinois, was selected for use as a field site to monitor how groundwater, surface water, and irrigation pumpage interact with use of a center-pivot system. The field is located in Section 4 of Township 20 North, Range 7 West (Crane Creek Township) on property owned by Mr. Jeff Smith (Figure 1). Nine observation wells were installed in April 2003 at the field site: three wells on the north side of Crane Creek and six wells on the south side of Crane Creek. Figure 2 shows the irrigated area, observation well locations, and stream discharge measurement locations for the irrigation well on the south side of Crane Creek. The observation wells range from 31 to 37 feet deep (Table 2), with static water levels less than 10 feet below land surface.

Electronic pressure transducers/data loggers (Global Water®) to monitor groundwater levels were placed in MTOW-3 and MTOW-6 on June 14, 2003. Another transducer to measure stage was placed in Crane Creek on August 26, 2003. Groundwater level and stream stage are measured and recorded every 30 minutes. Two upstream and two downstream discharge measurements were taken in Crane Creek to correlate with stream stage during this reporting period (i.e., prior to September 1, 2003).

Well maintenance included developing each well prior to the initiation of measurements. Batteries in the data loggers were changed when low or at 6 months. Hand measurements were used to verify calibration of the pressure transducers.

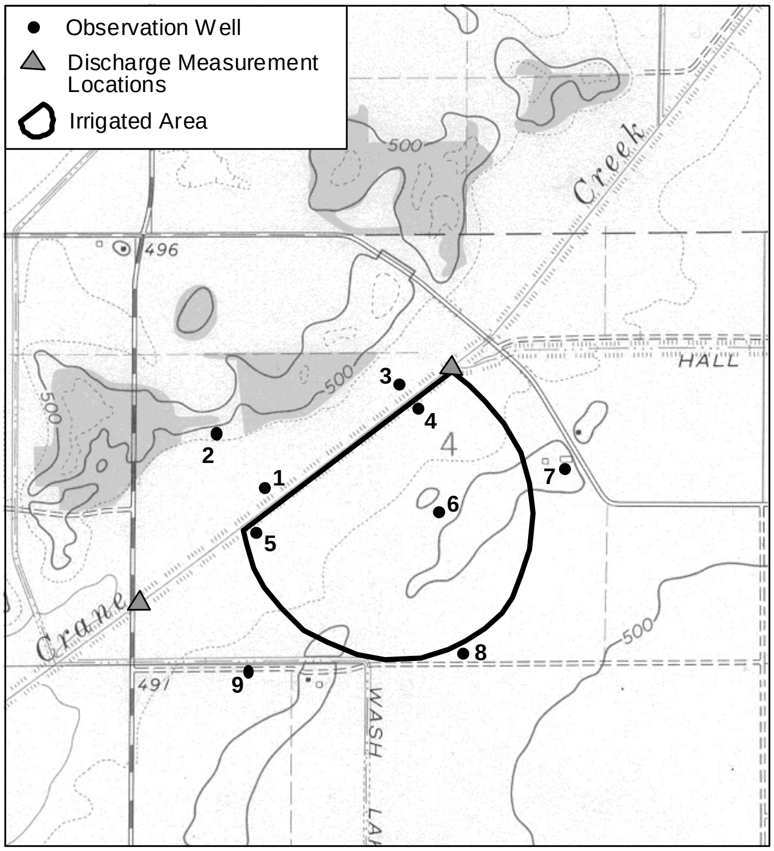

Figure 2. Locations of observatio wells and streamflow discharge measurement points in relation to the irrigation field site.

Table 2. Depths and Installation Dates, Imperial Valley Irrigation Site Observation Wells

Well number	*Depth (feet)*	*Date installed*
1	33.10	4/23/03
2	32.75	4/22/03
3	31.10	4/23/03
4	34.30	4/22/03
5	34.75	4/22/03
6	37.00	4/22/03
7	32.85	4/23/03
8	34.00	4/23/03
9	33.50	4/23/03

Precipitation, Groundwater-Level, and Irrigation Data Analysis

This report presents the rainfall and groundwater-level data for the period September 2002-August 2003, called Year Eleven in this report. Data collected from the rain gauge and observation well networks were maintained in separate databases, but the resulting data were evaluated together to examine the response of groundwater levels to local precipitation. Observed network groundwater levels may be influenced by irrigation pumpage, so an estimate of monthly pumpage also is presented.

Precipitation Analysis

Data reduction activities during Year Eleven of network operation are similar to those performed during the previous ten years (Peppler and Hollinger, 1994, 1995; Hollinger and Peppler, 1996; Hollinger, 1997; Hollinger and Scott, 1998; Hollinger et al., 1999, 2000; Scott et al., 2001, 2002; and Wehrmann et al., 2004). Hourly rainfall amounts are totaled from 10-minute digital data are placed into an array of monthly values for the 20 gauges. This data array is used to check for spatial and temporal consistency between gauges, and to divide the data into storm periods. If the digital data are missing, hourly rainfall amounts from the analog (paper) charts are used. If data from both a data logger and the corresponding chart are missing, an unusual event, the hourly amounts are estimated based on an interpolation of values from the nearest surrounding gauges.

Groundwater-Level Analysis

Monthly Measurements

Groundwater levels for each well for the period of record (1995-2003) are presented graphically (Appendix A) and in tabular form (Appendix B). Graphs of groundwater levels are commonly called hydrographs. Each hydrograph also contains the total monthly precipitation for the nearest rain gauge. For observation wells located between several rain gauges, an average of the surrounding rain gauge data is presented. Groundwater level data are presented as depth to water from land surface. Although the hydrographs do not contain a common y-axis, they do maintain a common y-axis range (25 feet). This allows a greater vertical exaggeration than in previous reports that plotted all hydrographs from a 0- to 40-foot depth to water. For observation wells located relatively near the Illinois River (MTOW-1, -5, and -9), the stage of the river at the nearest U.S. Army Corps of Engineers (USACE) gauging station also is shown. Mean monthly stage data were downloaded for the Beardstown, Havana, and Kingston Mines stations from the USACE Internet site (http://water.mvr.usace.army.mil). Because of an apparently strong correlation between groundwater levels and river stage at MTOW-2 and MTOW-12 (Hollinger et al., 1999), Illinois River stage at Havana also is presented with these hydrographs.

Hollinger et al. (1999) were the first to conduct a quantitative analysis of the correlation between total monthly precipitation and monthly groundwater levels for the Imperial Valley network. Scott et al., 2002 repeated the same analyses with three additional years of data. Observed groundwater levels in each well were correlated to total monthly precipitation at an adjacent rain gauge, or an average of the total monthly precipitation at selected surrounding rain gauges. Observed groundwater levels also were correlated to Illinois River stage for selected wells. No new correlation analyses were performed for this report. Instead, a qualitative description is provided to aid in understanding the data presented.

Continuous Measurements

In previous reports, ISWS scientists correlated single monthly groundwater level measurements with monthly rainfall totals with marginal success. One reason for the lack of correlation may be the difference in data frequency between the rainfall data (continuous) and groundwater levels (monthly). To test this theory, selected historical daily groundwater-level data from recorder chart records for the Snicarte observation well (MTOW-1) were transferred to digital format and graphed with daily rainfall data. By comparing selected daily datasets, it was shown a single monthly water-level measurement may not necessarily reflect the impact of total monthly rainfall. Stated another way, the data show that the lag time between rainfall and groundwater-level response is much less than one month, suggesting that groundwater-level data need to be collected more frequently.

Irrigation Water-Use Analysis

Since 1995, the IVWA has estimated irrigation pumpage from wells in the Imperial Valley based on electric power consumption, using the equation below:

$$Q = 1505 \times KWH \times IRR/MEC$$

where Q is the total estimated monthly irrigation pumpage (in gallons), KWH is the monthly electrical power consumption (in kilowatt hours) used by the irrigation accounts served by Menard Electric Cooperative, IRR is the total number of irrigation systems in the IVWA region, MEC is the number of Menard Electric Cooperative irrigation accounts, and 1505 is a power consumption conversion factor (in gallons/KWH). Irrigation systems in the region receive electric power from the Menard Electric Cooperative and two investor-owned utilities (AmerenCIPS and AmerenCILCO). Menard Electric Cooperative provides the IVWA with electric power consumption data for the irrigation services they serve during the growing season (June-September). Not all the irrigation systems use electric power to pump water, and Menard serves only some of these systems. The pumpage estimate assumed that application rates for the irrigation wells with electric pumps in Menard Electric Cooperative also are representative of other utilities and other energy sources. Past estimates were based on the assumption that 33 percent of the irrigation wells were in Menard Electric Cooperative in 1995-1997, 40 percent in 1998-2001.

In summer 2002, a U.S. Geological Survey (USGS) study indicated the need for a new power consumption conversion factor. An updated conversion factor was determined by recording electrical consumption while closely measuring the pumping rate at 77 irrigation systems. The updated value, 1259 gallons/KWH, is appreciably lower than the previously used factor of 1505 gallons/KWH, suggesting that previous estimates of water withdrawals may have overestimated pumpage by approximately 20 percent (i.e., pumping system efficiency is 20 percent less than previously thought). Therefore, irrigation withdrawals for the years 1997 to the present were recalculated using the new formula, replacing earlier published estimates. Collection of additional data related to the irrigation systems (such as system age and size) and the conversion factors associated with those systems may enhance withdrawal estimates further.

Results

Precipitation

Annual and Monthly Precipitation

The Year Eleven dataset was used to produce the following analyses: 1) monthly and annual (September 2002-August 2003) precipitation amounts for each site in the IVWA network (Table 3), the average precipitation pattern for the 11-year network operation (Figure 3a and b), the average precipitation pattern for Year Eleven (Figure 4), a comparison of total precipitation, precipitation events, and precipitation per event (Table 4), and the average precipitation for each month in Year Eleven (Figures 5-10). The annual precipitation patterns for Years One-Ten also are presented (Appendix F).

The Year Eleven average precipitation, 30.06 inches, was below average, 5.31 inches lower than the network 11-year average precipitation, 5.84 inches below the 10-year average. It was the fourth driest of the 11 years of network operation. Precipitation totals for the current year (Table 3) ranged from 36.8 inches at station 16 northwest of Mason City to 26.5 inches at station 3.

Table 3. Monthly Precipitation Amounts (inches), September 2002-August 2003

	Month												
Station	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	0.46	1.44	0.57	2.45	0.49	0.91	1.50	2.55	3.34	5.41	6.13	3.22	28.47
3	0.14	1.60	0.54	1.45	0.24	1.56	1.45	2.93	3.54	5.50	5.07	2.48	26.50
4	0.13	1.30	0.66	3.01	0.56	1.30	1.70	3.41	3.60	3.88	5.91	3.58	29.04
6	0.29	1.70	0.68	1.34	0.40	0.91	1.48	3.47	4.59	4.14	6.22	3.16	28.38
7	0.72	1.79	0.63	1.20	0.44	0.95	1.52	3.71	4.12	3.66	6.20	3.86	28.80
8	0.16	1.29	0.67	2.41	0.81	1.25	1.44	3.54	3.37	4.25	5.09	5.12	29.40
9	0.43	1.41	0.58	2.14	0.94	0.99	2.31	3.22	3.70	4.47	6.62	3.70	30.51
10	0.28	1.42	0.65	1.42	0.52	0.91	1.58	2.90	3.96	5.26	5.65	3.33	27.88
11	0.42	1.51	0.58	1.33	0.57	1.03	1.55	3.34	2.95	5.2	5.92	4.35	28.75
12	0.45	1.66	0.67	1.29	0.53	1.25	1.63	2.77	3.89	3.93	6.56	4.81	29.44
13	0.28	1.44	0.59	2.78	0.87	1.18	2.05	3.85	2.83	4.35	6.99	4.14	31.35
15	0.20	1.78	0.58	1.68	0.94	0.90	2.30	3.74	2.61	5.67	5.63	5.08	31.11
16	0.64	2.19	0.63	1.80	0.20	1.18	1.79	4.71	4.13	6.69	6.63	6.18	36.77
18	0.24	1.51	0.57	2.80	0.52	0.97	2.07	3.72	2.65	3.29	5.02	4.59	27.95
19	0.30	1.82	0.76	2.33	1.12	1.49	2.57	5.47	2.51	3.47	7.09	5.40	34.33
20	0.34	1.83	0.62	1.84	0.82	0.94	2.42	4.01	2.62	4.91	7.38	4.72	32.45
21	0.46	1.59	0.66	2.05	0.59	1.09	1.97	4.57	1.88	3.59	5.74	4.79	28.98
22	0.51	2.08	0.62	1.39	0.37	1.00	1.66	5.03	2.31	3.87	5.70	4.99	29.53
23	1.01	1.62	0.60	1.75	0.57	1.00	1.51	3.55	2.62	4.36	6.92	6.54	32.05
24	0.29	2.00	0.57	2.63	0.70	0.93	2.29	4.43	2.76	4.10	4.30	4.58	29.58
Average	0.39	1.65	0.62	1.95	0.61	1.09	1.84	3.75	3.20	4.50	6.04	4.43	30.06

Note:
Stations 1, 5, 14, 17, and 25 were removed from the network in September 1995.

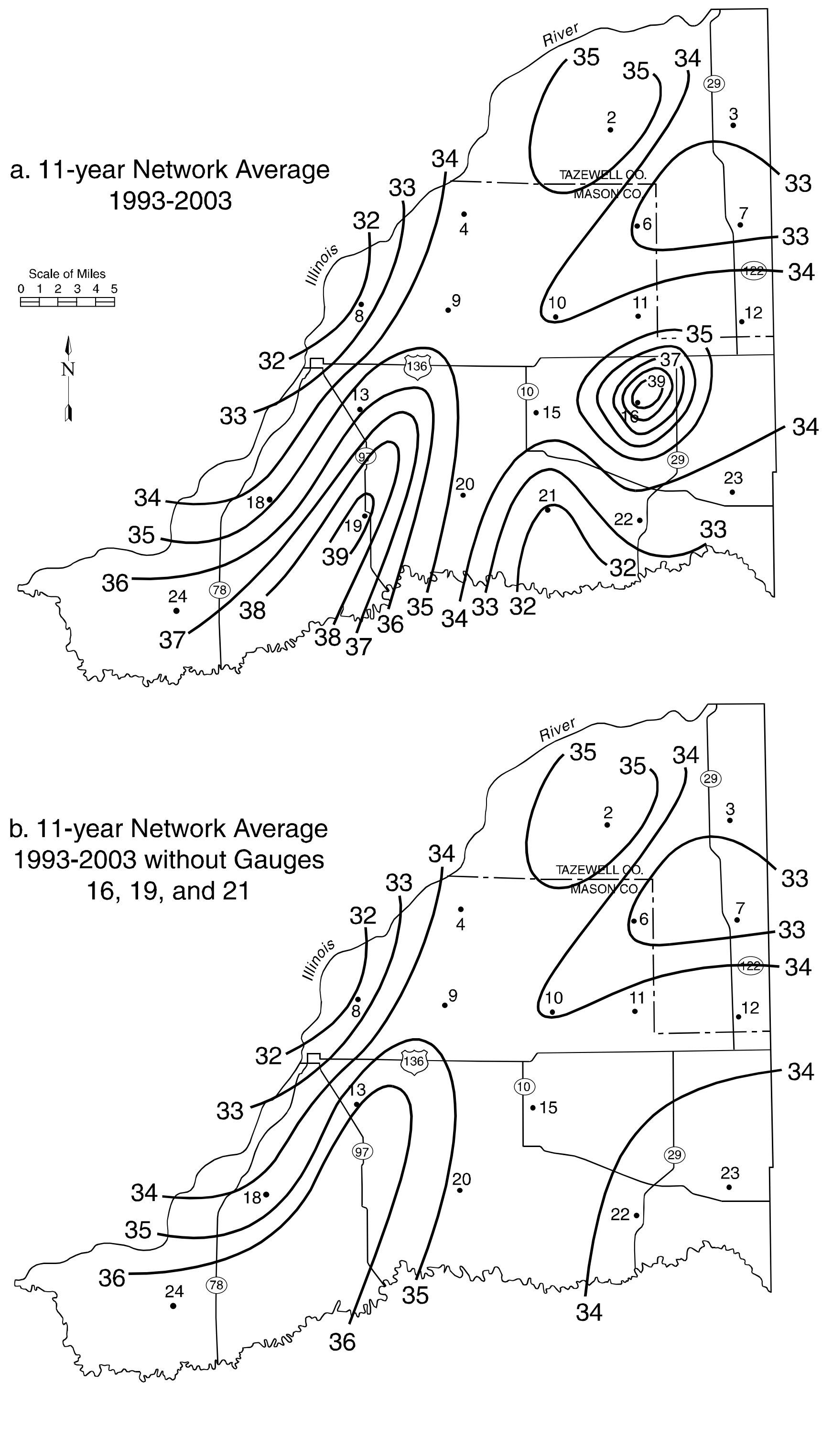

Figure 3. Network average annual precipitation (inches) for September 1993-August 2003
with all gauges and without gauges 16, 19, and 21.

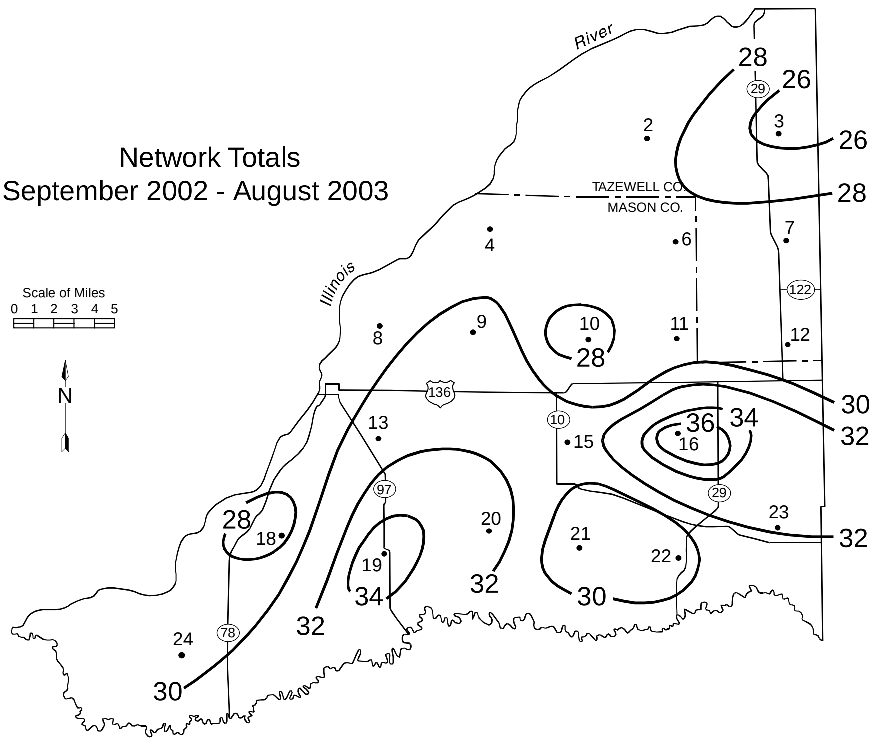

Figure 4. Total precipitation (inches) for September 2002-August 2003.

Table 4. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event by Month and Season, 1992-2002 and 2002-2003

	1992-2002 10-year average			*2002-2003 average*		
Period	*Precipitation*	*Events*	*Inches/event*	*Precipitation*	*Events*	*Inches/event*
Sep	3.02	7.5	0.40	0.39	3	0.13
Oct	2.45	9.3	0.26	1.65	8	0.27
Nov	2.71	10.4	0.26	0.62	7	0.10
Dec	1.45	9.6	0.15	1.95	2	0.65
Jan	2.17	10.7	0.20	0.61	6	0.10
Feb	1.86	8.8	0.21	1.09	5	0.14
Mar	2.12	7.9	0.27	1.84	6	0.23
Apr	3.66	12.6	0.29	3.75	6	0.42
May	4.89	15.3	0.32	3.20	10	0.32
Jun	4.06	12.8	0.32	4.50	11	0.45
Jul	3.92	11.7	0.33	6.04	5	1.01
Aug	3.59	13.6	0.26	4.43	11	0.74
Fall	8.18	27.2	0.30	2.66	18	0.15
Winter	5.48	29.1	0.19	3.65	13	0.28
Spring	10.67	35.8	0.30	8.79	22	0.40
Summer	11.57	38.1	0.30	14.97	27	0.55
Annual	35.90	130.0	0.28	30.06	80	0.38

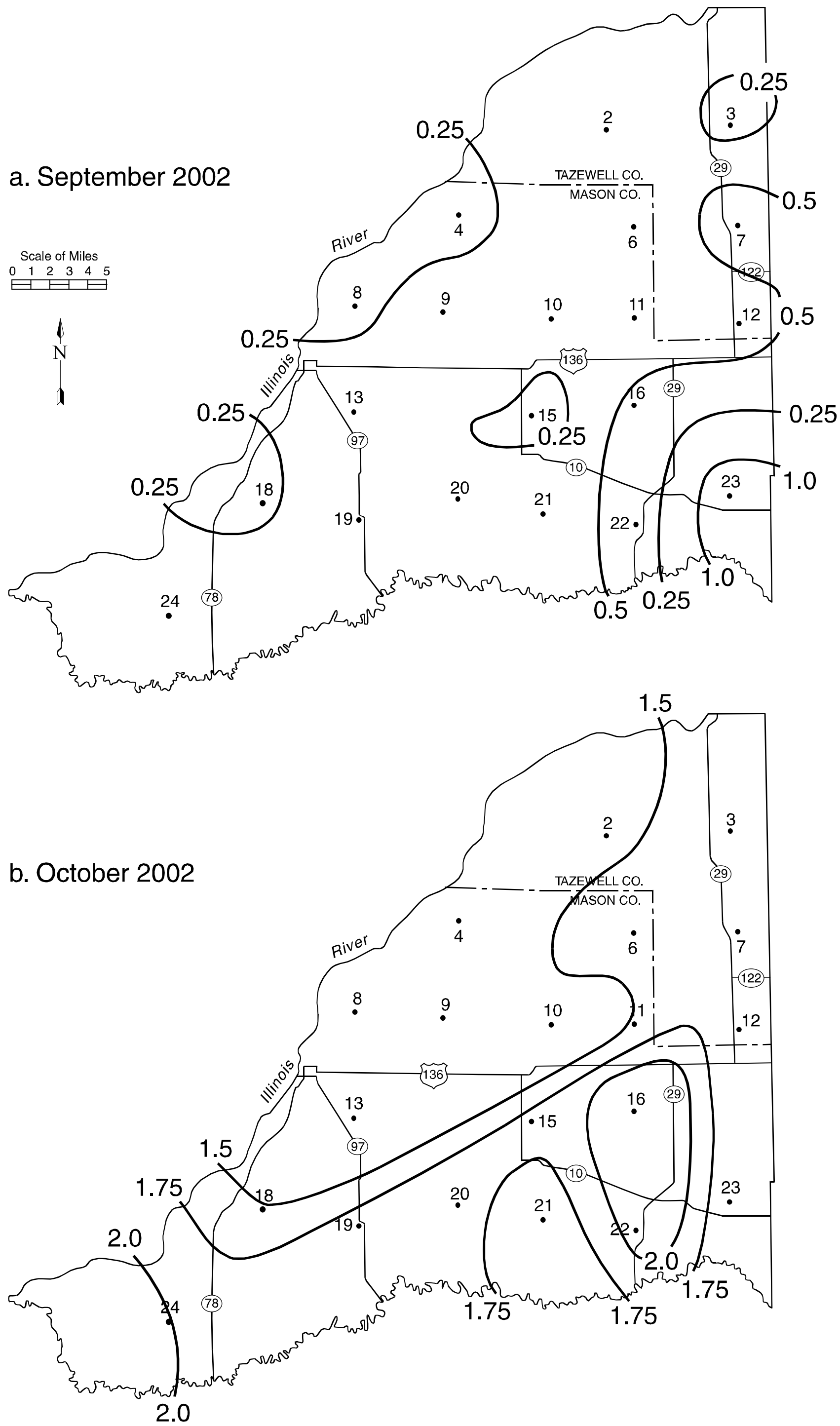

Figure 5. Precipitation (inches) for September 2002 and October 2002.

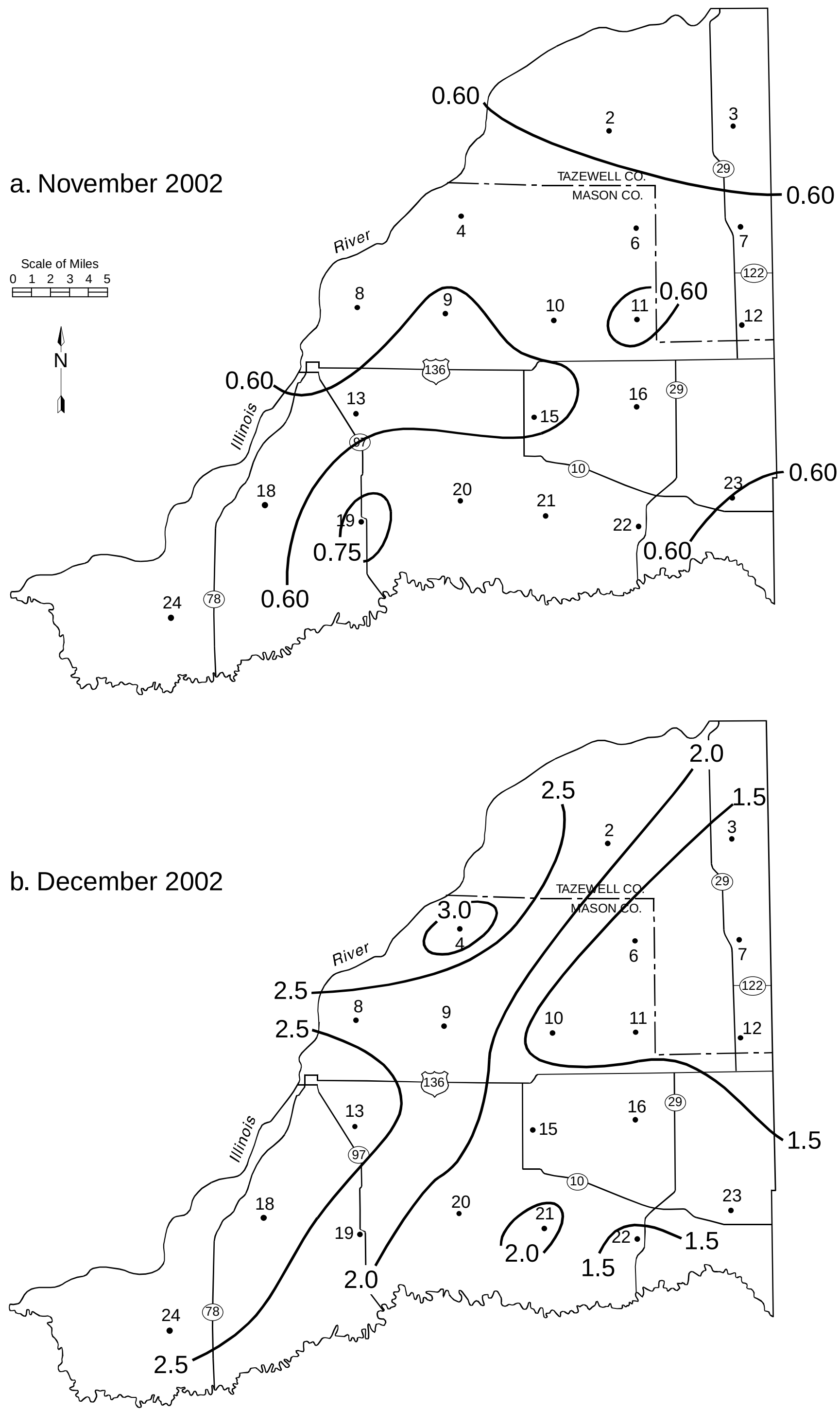

Figure 6. Precipitation (inches) for November 2002 and December 2002.

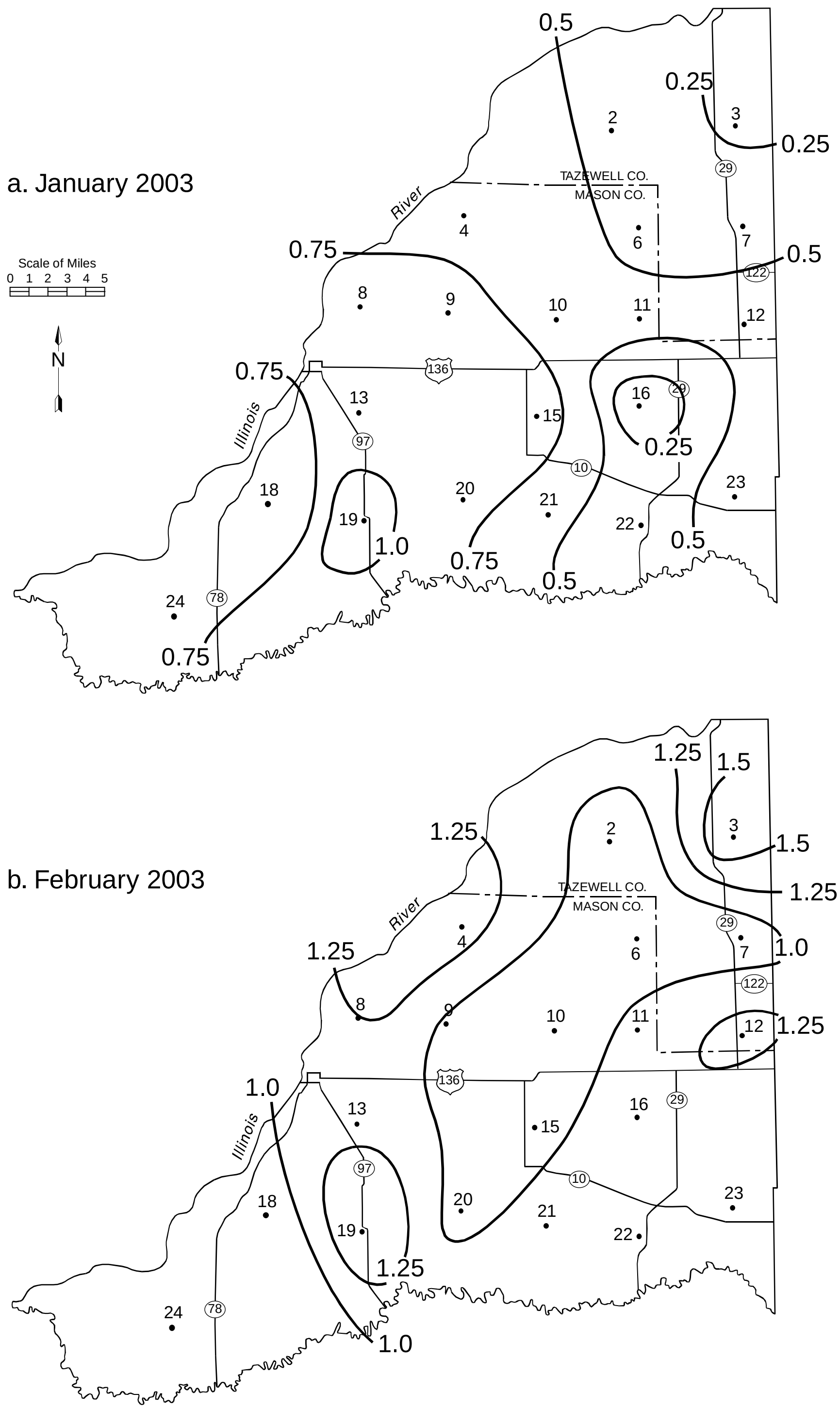

Figure 7. Precipitation (inches) for January 2003 and February 2003.

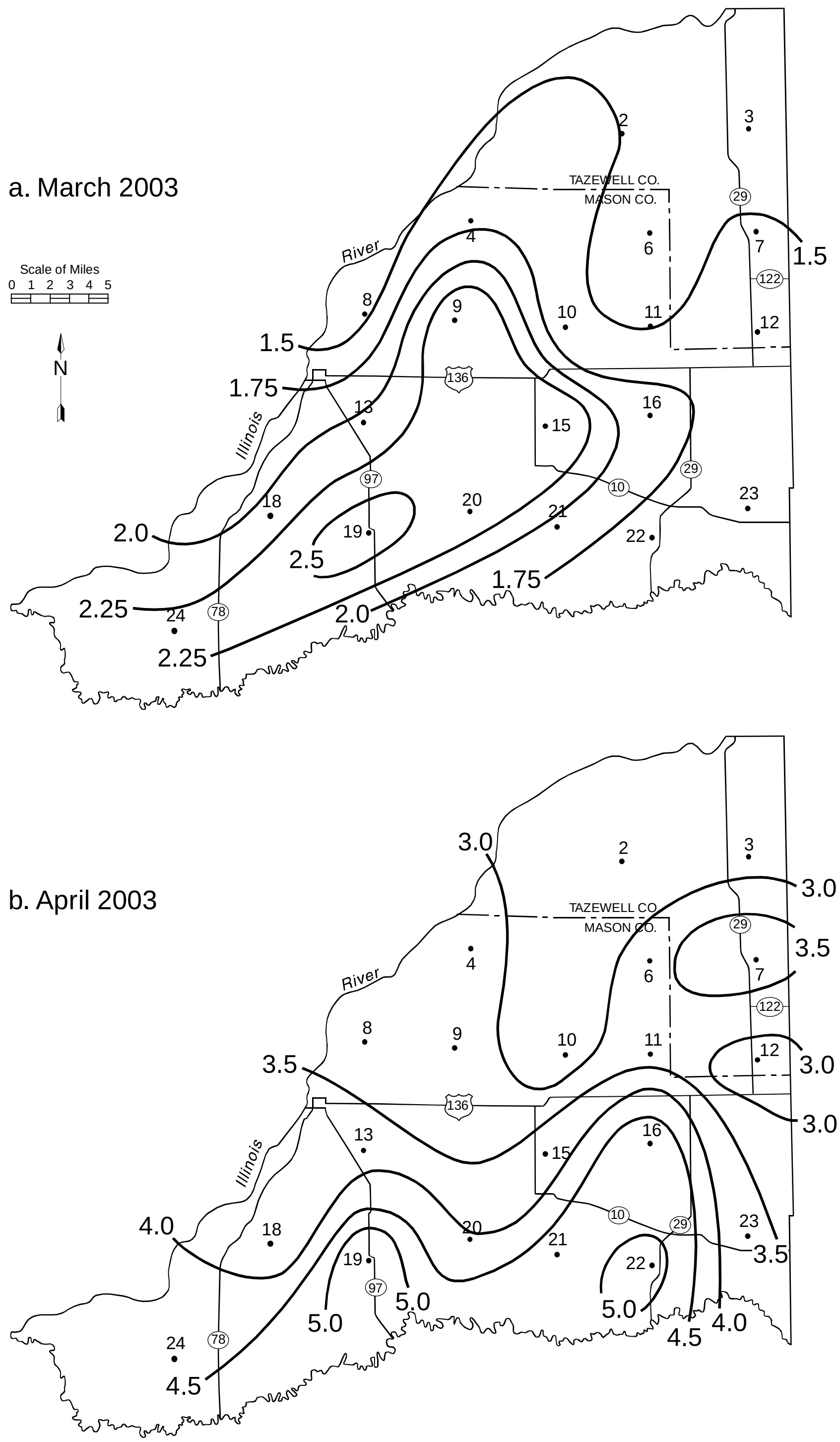

Figure 8. Precipitation (inches) for March 2003 and April 2003.

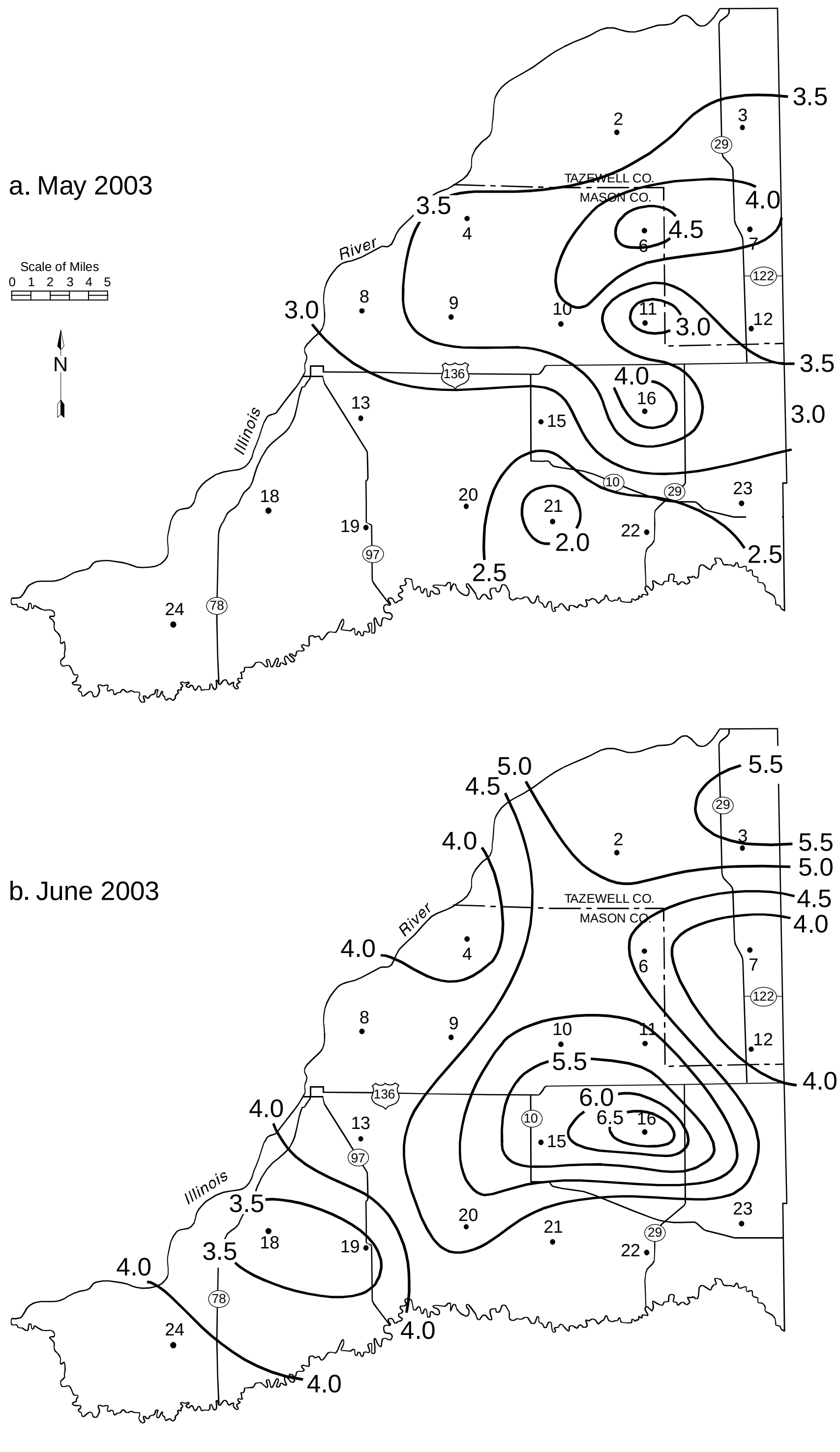

Figure 9. Precipitation (inches) for May 2003 and June 2003.

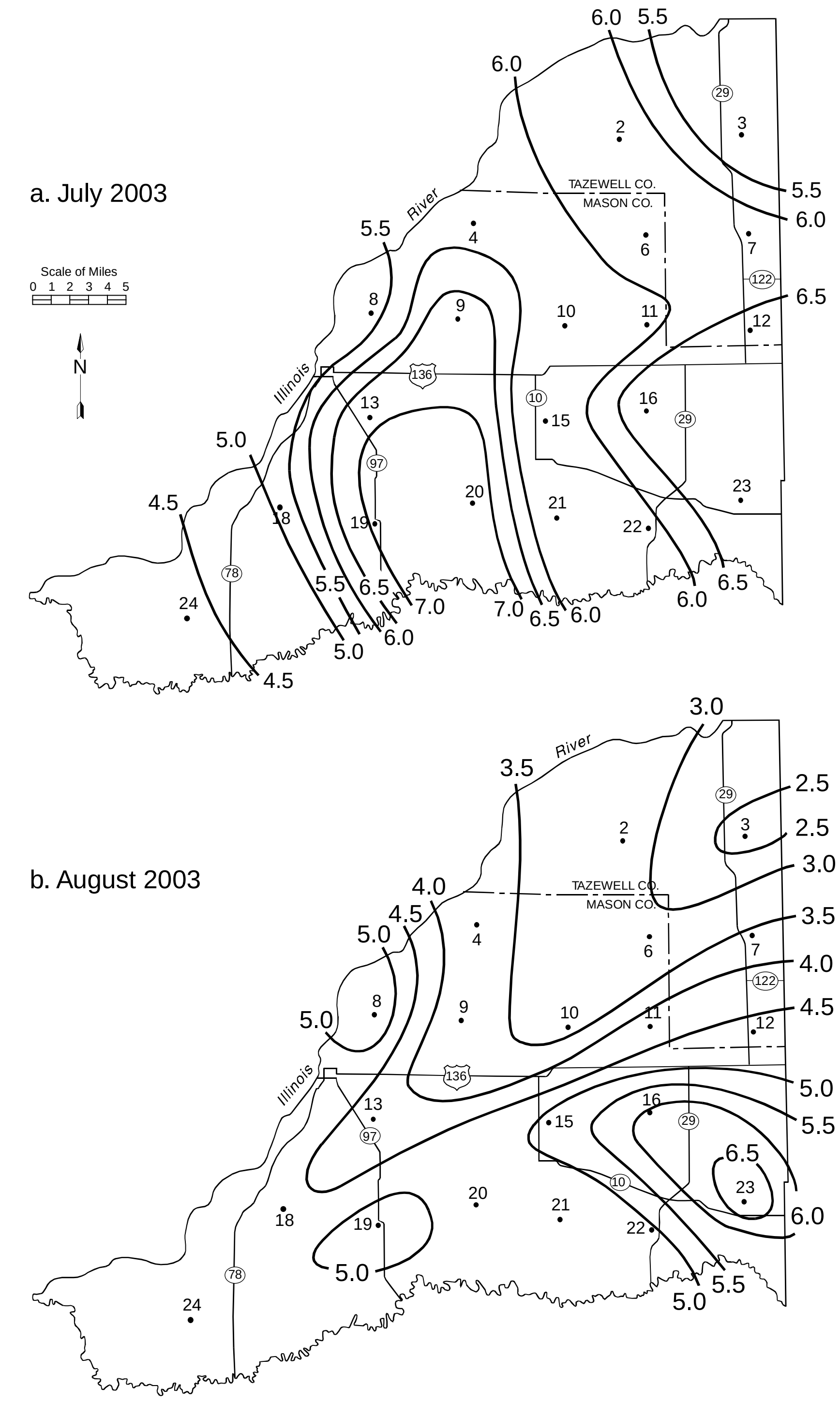

Figure 10. Precipitation (inches) for July 2003 and August 2003.

Figure 4 presents the annual precipitation pattern for Year Eleven. The annual precipitation total at station 16 was been considerably higher than at surrounding gauges during Years Nine and Ten, with the annual difference between that station and adjacent stations of 13.0 and 11.6 inches, respectively. The gauge at station 16 was replaced on May 23, 2002. Monthly totals for the gauge at station 16 were consistent with those at surrounding gauges during the fall, winter, and spring of 2003. During May and June 2003, the values at station 16 were higher than at neighboring gauges although July and August values were again supported by neighboring values. Precipitation from station 16 is included in all analyses for Year Eleven, as the annual difference, 7.0 inches, is much smaller than during the previous two years. (The gauge at station 16, however, was replaced again in the fall of 2003.)

The pattern seen in the 11-year network average (Figure 3a) also is reflected in the precipitation pattern in Year Eleven (Figure 4). On an annual basis, the gauge at station 21 has been low compared to neighboring gauges in six of the past seven years, and the gauge at station 19 has been high in those years. The bias has not been nearly as extreme as that at station 16, and the monthly values for both stations are often comparable to those at neighboring gauges. The bias at both sites was smaller for Year Eleven than for Year Ten. Thus, precipitation data from stations 19 and 21 are included in all analyses, but the gauges at these stations are again scheduled for cleaning and recalibration. Figure 3b depicts the 11-year network average precipitation pattern without the gauges at sites 16, 19, and 21. Note that station 19 is in a region of relatively high values, with annual precipitation amounts decreasing towards the southeastern portion of the network.

July 2003 (Figure 10a), the wettest month of Year Eleven, had a 6.04-inch network average, followed by averages in June 2003 (Figure 9b, 4.50 inches), and August 2003 (Figure 10b, 4.43 inches). Precipitation for those three months totaled 14.97 inches, or approximately 50 percent of the total annual precipitation. September 2002 was the driest month of the year (Figure 5a, 0.39 inches), followed by averages in January 2003 (Figure 7a, 0.61 inches), and November 2002 (Figure 6a, 0.62 inches). Total average precipitation for the network in the three cold season months (December-February) was light, 1.62 inches, or about 5 percent of the yearly total.

Individually, only July 2003 was wetter than the 10-year average by 2 inches or more (see Table 4). September 2002 and November 2002 were drier than average by more than 2 inches, and January 2003 and May 2003 were drier than average by more than 1.5 inches. All other months were within ± 0.85 inches of the 10-year average. The summer of 2003 (June-August) was the wettest season of the year (14.97 inches), followed by spring 2003 (March-May, 8.79 inches), as is the usual case. The summer total precipitation was 3.40 inches above the 10-year network summer average, but the spring total was 1.88 inches below the 10-year network average. Fall amounts (September-November 2002, 2.66 inches) were below normal (-5.52 inches departure from the 10-year network average fall precipitation), due to light September and November precipitation in 2002. Winter precipitation totals (December 2002-February 2003, 3.65 inches) also were below average, a -1.83 inch departure from the 10-year network average winter precipitation.

The annual precipitation total for 2002-2003 was the fourth driest in the 11-year network operation. The network received 25.49 inches less precipitation than in the wettest year (1992-1993) and 4.36 inches more than in the driest year (1995-1996). Year Eleven had the second driest fall (1999 was drier), the second driest winter (only 1995-1996 was drier), and the third driest spring (1997 and 2000 were drier). The summer of 2003, however, was the second wettest summer in the 11-year network operation. Only the summer of 1993 was wetter, with rainfall totals of 4 inches or greater each month in June-August 2003.

Storm Events

The number of network precipitation periods were determined for the 11-year period. Mean monthly, seasonal, and annual number of these precipitation events are presented for each year (Appendix G), and for 2002-2003 (Table 4). The monthly, seasonal, and annual number of precipitation events averaged over the 1992-2002 period also are presented (Table 4). A network storm period was defined as a precipitation event separated from preceding and succeeding events at all network stations by at least three hours. Data for the individual network storm periods also are presented (Appendix H, Tables H-2 and H-3).

During dry Year Eleven, there were 80 precipitation events, the fewest number in all years of network operation. Year Eleven, however, tied for the third highest amount of precipitation per event, 0.38 inches. Two of the wettest years, 1992-1993 and 1993-1994, had averages of 0.38 and 0.39 inches per event, respectively.

Seasonally, the fall, winter, and spring of Year Eleven each had the lowest number of events with precipitation for the given season. The amount of precipitation per event was the lowest in fall of 2002-2003, second only to fall 1999-2000. The winter of Year Eleven had the third highest average amount of precipitation per event, and the spring of Year Eleven had the second highest average amount of precipitation per event. The summer of 2002-2003 had the second highest summer rainfall total, and the lowest number of precipitation events of the ten previous summers. Thus, summer 202-2003 also had the highest average precipitation per event of any of the previous ten summers, 0.55 inches per event.

The plot of the network average monthly precipitation time series (Figure 11) shows the monthly variation of precipitation. As in fall and winter 1999-2000, precipitation in fall and winter 2002-2003 was particularly low, with no month exceeding 2 inches. April and May 2003, however, exceeded at least 3 inches, and June-August 2003 had more than 4 inches of precipitation each month. Months with network average precipitation in excess of 10 inches, which occurred three times during the first three years of observations, have not occurred in any subsequent year.

A total of 1382 network storm periods occurred during the 11-year observation period: 148 in 1992-1993, 102 in 1993-1994, 129 in 1994-1995, 98 in 1995-1996, 121 in 1996-1997, 134 in 1997-1998, 144 in 1998-1999, 156 in 1999-2000, 148 in 2000-2001, 122 in 2001-2002, and 80 in 2002-2003, resulting in a 11-year average of 125.6 storms per year.

Appendix H documents each network storm period for Year Eleven with the date and hour of the start time, duration, number of sites receiving precipitation, network average precipitation, storm average precipitation, maximum precipitation received, station (gauge) where the maximum occurred, and storm recurrence frequency of the maximum observed precipitation. The network average precipitation is the arithmetic mean of the precipitation received at all network stations, while the storm average is the arithmetic mean of the precipitation received at stations reporting precipitation during the storm period.

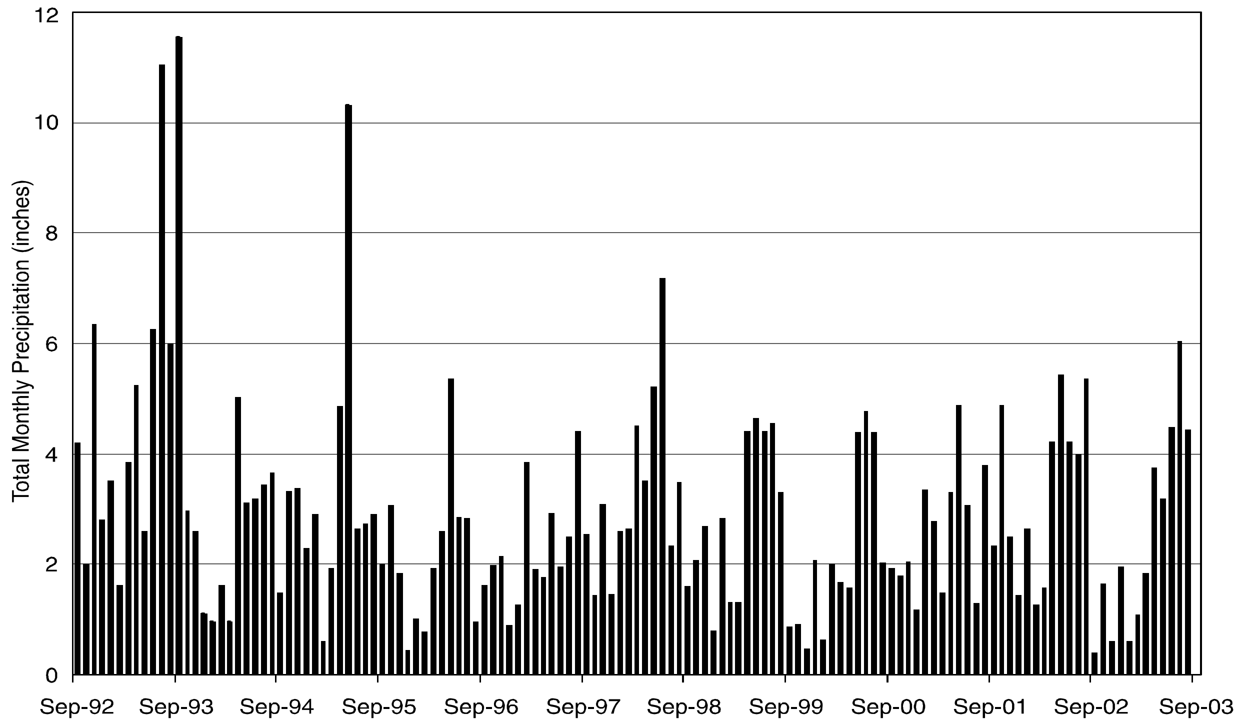

Figure 11. Network average monthly precipitation (inches), September 1992-August 2003.

The storm recurrence frequency is the statistical probability of the recurrence of a storm with the reported precipitation (i.e., a 10-year storm would be expected to occur on average only once every 10 years at a given station, or have a 10 percent chance of occurring in any given year). The recurrence frequencies computed here are based upon the total storm duration for the area. See Appendix H for further explanation. Also included in Appendix H is a table indicating the precipitation received at each of the 20 stations for each network storm period (Table H-3) for Year Eleven. Sites that exceed the one-year or more recurrence frequency are indicated in bold type (Table H-3). Previous years of network storm periods can be found in Scott et al. (2002) and in Wehrmann et al. (2004).

In the first ten years of operation, 49 of the 1302 storm periods produced maximum precipitation at one or more stations with a recurrence frequency greater than one year: 50-year (1 storm), 10-year (3 storms), 5-year (8 storms), 2-year (22 storms), and greater than 1-year but less than 2-year (15 storms). The 50-year storm (storm 153) occurred on 13 September 1993, and the 10-year storms on 16 May 1995 (storm 323), 8 May 1996 (storm 432), and 19 July 1997 (storm 580). The 5-year storms occurred in June 1993 (storm 105) and September 1993 (storm 149), in May 1995 (storm 327), July 1999 (storm 862), August 1999 (storm 872), July 2000 (storm 1006), July 2002 (storm 1290), and August 2002 (storm 1301). These 12 heaviest storms occurred during the warm season months (May-September). Nine storms had a recurrence interval exceeding the one-year or greater recurrence frequency in 1992-1993, five in 1993-1994, six in 1994-1995, one in 1995-1996, three in 1996-1997, four in 1997-1998, four in 1998-1999, five in 1999-2000, and four in 2000-2001, and eight in 2001-2002.

In Year Eleven, seven of the 80 network storm periods exceeded the one-year recurrence frequency. While Year Eleven had a below average number of network storm periods, it had an above average number of heavy rainfall periods. No events, however, exceeded the 5-year or more recurrence frequency. Of the events in Year Eleven, four were 2-year events and three were 1-year events. These 2-year storms occurred during June (storm 1360), July (storms 1367 and 1368), and August (storm 1381). The one-year storms occurred in December (storm 1321), June (storm 1361), and July (storm 1369).

Groundwater Levels

Monthly Measurements

Groundwater levels in observation wells MTOW-5 and MTOW-9, network wells closest to the Illinois River, have been found to fluctuate largely in response to river stage. Up to 80 percent of the variation in water level in these wells can be explained by river stage variation (Scott et al., 2002), and water levels in these wells continued to show that response in the September 2002-August 2003 reporting period. The Illinois River did not peak as high in the spring (2003) as in previous years, and groundwater levels in MTOW-5 and -9 similarly did not show strong recovery in 2003. This would appear to be the result of extremely low precipitation in late 2002 and early 2003. Groundwater levels did recover later in the summer, not hitting their seasonal "highs" until July.

Groundwater levels in the other observation wells, more distant from the Illinois River, also did not show strong recoveries in this reporting period. These wells tended to show more subtle groundwater-level changes, peaking a foot or more lower than in 2002. Several wells showed essentially no recovery (MTOW-4, -10, -11, and especially -13).

As has been done in previous reports (Hollinger et al., 1999, 2000; Scott et al., 2001, 2002; Wehrmann et al., 2004), the timing (i.e., month of occurrence) of the annual maximum water level in each observation well is presented (Table 5). These annual groundwater-level peaks (and subsequent water-level declines) may signify the end of the recharge period (i.e., the last observed time when infiltration exceeds evapotranspiration). Compared to previous years, this reporting period was much different. Unlike any previous year, several wells exhibited their highest water levels in January (although it must be recognized that for several years no measurements were made in January). Also, in most instances, the wells that exhibited January maxima did not actually "peak" in January, but simply exhibited a general downward trend throughout the year. For wells that did show peaks during the spring and summer, the peaks were not as pronounced, and whereas previous years tended to have one month where most of the water levels peaked, this past year did not (other than the month of January).

A determination of when recharge starts may be made by examining water-level "troughs" (i.e., that portion of a hydrograph where declining water levels bottom out and begin to recover), which signify the beginning of the period when infiltration exceeds evapotranspiration. Examination of the September 2002-August 2003 water-level data for when groundwater levels started to recover from preceding water-level declines (Table 6) shows that recharge for many wells started in March 2003. With the initiation of January and February observations in 2002, it

Table 5. Month in Which Observed Groundwater Levels Peaked,
Imperial Valley Observation Well Network, 1995-2003

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
January									4, 8, 10, 11, 13
February									
March		4, 10, 11, 13	4, 8, 10, 11		4	3, 4, 7, 8, 10, 11, 13			
April			2, 5, 9				4, 5, 9		
May	12		1, 6, 7, 13				11		1, 7
June	1, 2, 3, 5, 6, 7, 9, 10	2, 3, 5, 6, 7, 9, 12	3, 12	5, 9	1, 2, 5, 9		10	1, 2, 5, 9	2, 3, 6
July	8, 11	1, 8		1, 2, 6, 7, 10, 12	6, 7, 10, 12	2, 5, 6	1, 2, 3, 6, 7, 8,12, 13	3, 4, 6, 7, 12, 13	5, 9, 12
August	4			3, 8, 11, 13	3, 11	1, 9, 12		8, 10, 11	
September					8, 13				
October									
November				4					
December									

Notes:
Number is observation well number (MTOW-x). Shading represents high water-level periods in wells along trends established when observations were not made (January-February 1995-2000; January-March 2001), that were not true "peaks".

Table 6. Month in Which Observed Groundwater Levels Began Ascending, Imperial Valley Observation Well Network, 1995-2003

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
January				1	1			2, 3, 4, 6, 7, 10, 11, 12, 13	2
February	1?		1			1		1, 5, 8, 9	1, 5
March	2, 3, 4, 5, 6, 7, 8, 9, 10, 12	2	2, 3, 5, 6, 7, 9, 12, 13	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13	2, 3, 5?, 7, 9, 12	5, 9			3, 6, 7, 9, 12
April	11	1, 5, 7, 9			6, 11		2, 3, 5, 6, 7, 8, 9, 10, 12, 13		4?, 8
May		3, 6, 8, 11?, 12		4	4, 8, 10, 13	2?, 6, 10?			10
June						1, 3, 7, 8?, 12			11?
July		10?				11?			
August			10?				11?		
September			4	13		13?			
October									
November									
December									
No Ascent		4, 13	8, 11						13

Notes:
Number is observation well number (MTOW-x). A question mark indicates that the water-level period is not clearly defined for a particular well. The last row contains well numbers for which no increase in water level was seen that year.

can be seen that groundwater levels can start to rise as early as January and February after declining through the previous fall.

Previous reports stated that water-level peaks, and hence groundwater recharge, typically occur in the spring and early summer. The authors continue to believe it is more correct to say that groundwater recharge in the Imperial Valley, as evidenced by a reversal from groundwater-level declines to groundwater-level rises, typically occurs much earlier in the year and during winter months in some years. This past year, with low spring precipitation, recharge was not as pronounced and tended to end earlier than in previous years.

The long-term hydrograph at MTOW-1 (Snicarte) in Figure 12 provides a reference for comparison with the shorter records of the other network wells. The ISWS has recorded water levels in this well since 1958. Annual fluctuations from less than a foot to more than 6 feet have been observed. These annual fluctuations often appear to be superimposed on longer term trends, perhaps up to 10 years in length. For the 45-year record, both the record low and high have been observed within the last 14 years. A detailed look at water levels since 1990 is shown in Figure 13, which exaggerates the vertical scale from the scale of the hydrographs in Appendix A to more clearly portray the annual fluctuations. During and shortly after the drought years of 1988 and 1989, the water level fell below 40.5 feet from September 1989 until April 1990, the only time in its 45-year history that the well went dry. After the 1993 flood, groundwater levels rose almost 10 feet and peaked at approximately 30 feet in September 1993. In the years since then, groundwater levels in MTOW-1 show an almost linear decline until 1998. Water levels rose dramatically during 1998 and in 1999 recovered to peak levels similar to those observed in 1994 and 1995. Then, after the 1999 peak, groundwater levels fell dramatically until mid-summer 2000. Groundwater levels appear to return to somewhat more natural seasonal cycles from 2000 to 2002, but are down approximately 2 feet from levels a year ago.

Irrigation Field Site Measurements

Only a small amount of data has been collected at the field site during this reporting period. Water-level data from well 6 are presented here to provide a preliminary view of the data. Figure 14 is a hydrograph of the transducer data for well 6 from June 14 through August 30, 2003. The sawtooth pattern of short-term drawdowns and recoveries is a result of the intermittent operation of the nearby irrigation well. This pattern is superimposed on a long-term downward seasonal trend influenced by regional irrigation withdrawals.

Streamflow measurements indicate that the difference in flow in the half mile between the upstream and downstream ends of the site (see Figure 2 for the flow measurement locations) is less than the error normally associated with the flow measurement method (~10%). Measurable differences would confirm that the stream is a groundwater discharge point for the aquifer. Reductions in flow differences during irrigation season would suggest that operation of the irrigation well affects the amount of groundwater discharging to the stream. Water-level data indicate that the aquifer discharges into Crane Creek under nonpumping conditions. Although it appears that it will not be possible to confirm the amount of groundwater discharge at the study site, streamflow will continue to be measured under varying rainfall and irrigation conditions to examine the effects of those events on the amount of water flowing to or from Crane Creek.

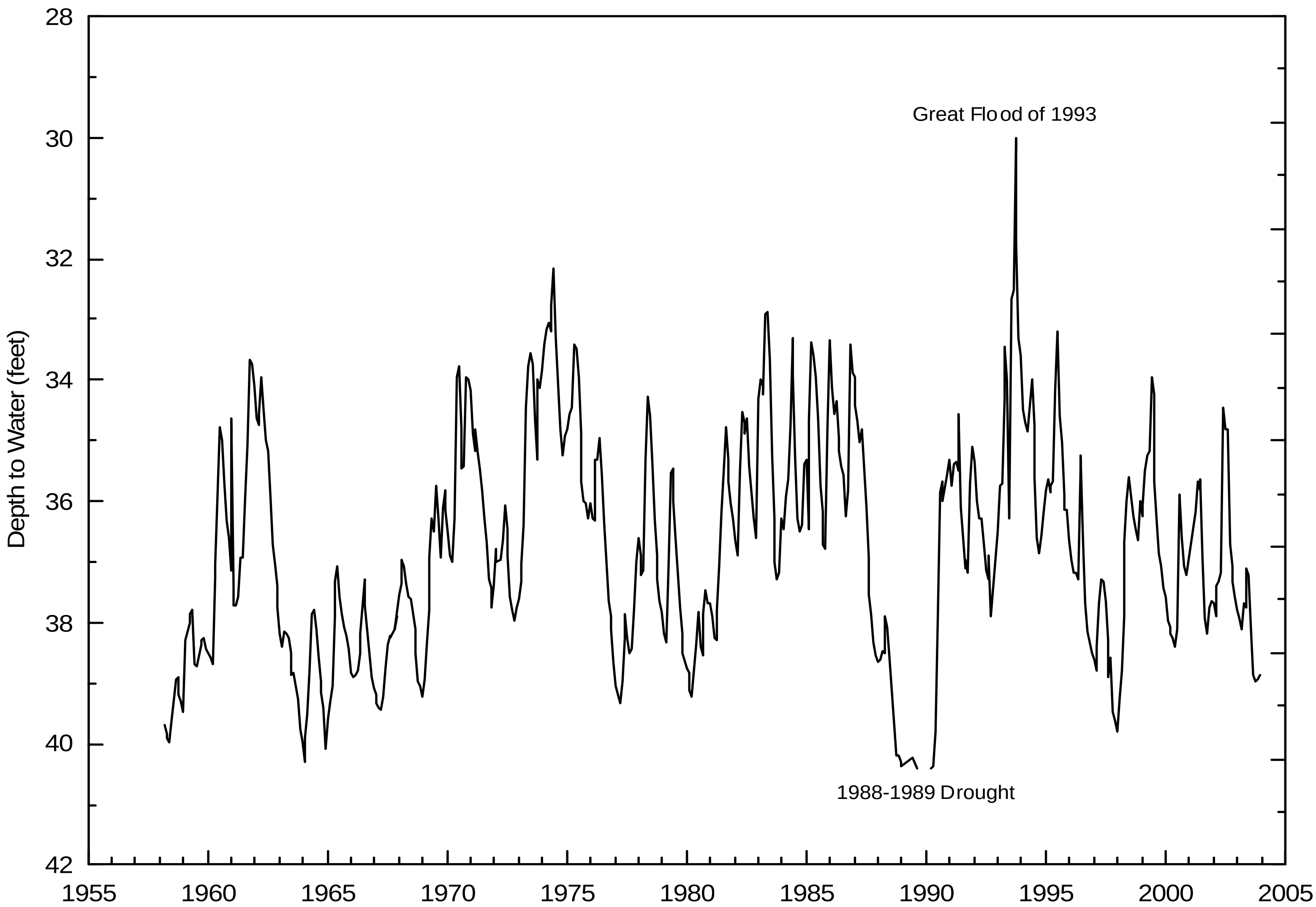

Figure 12. Groundwater levels at the Snicarte well, MTOW-1, 1958-2003.

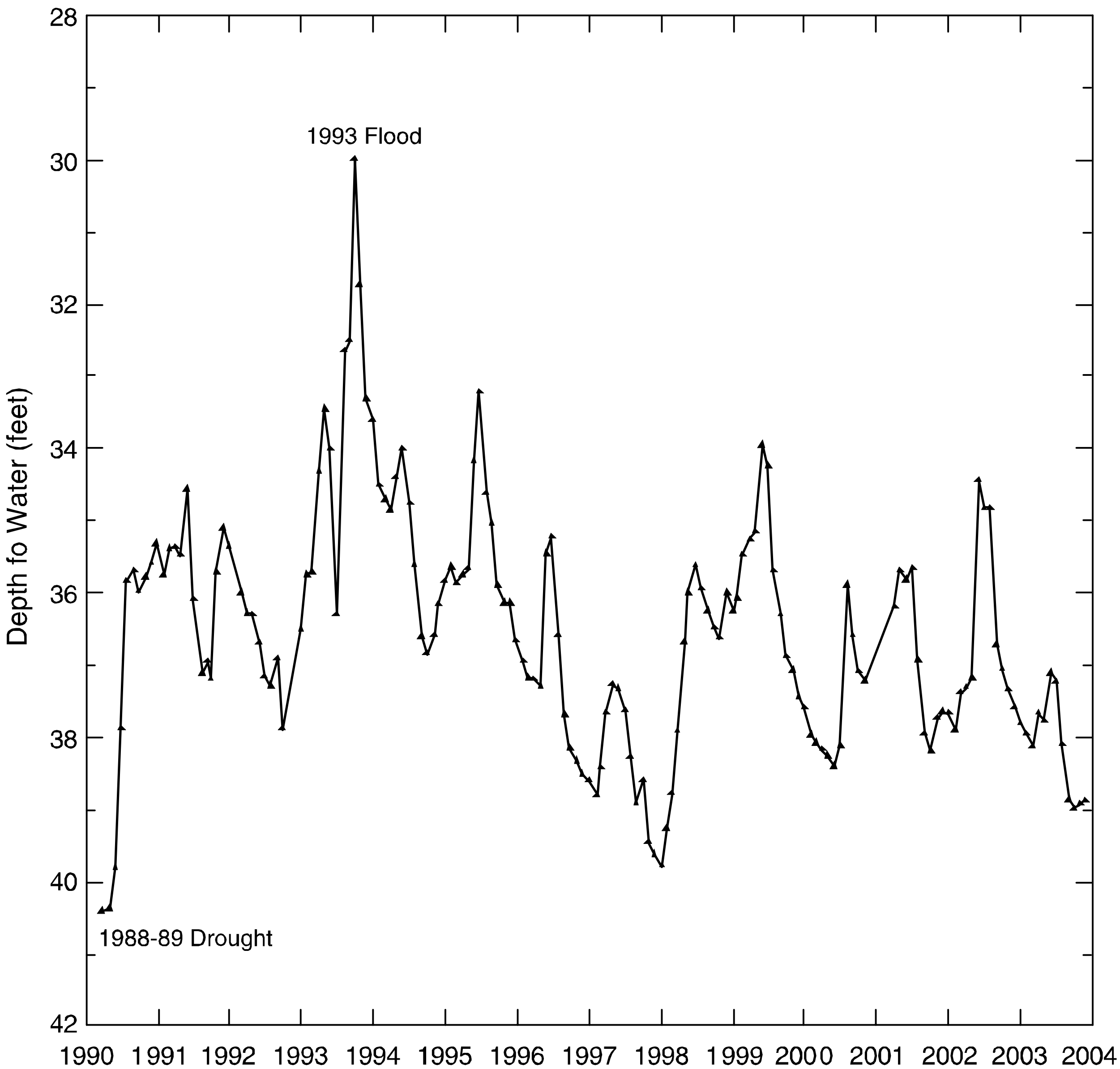

Figure 13. Groundwater levels at the Snicarte well, 1990-2003.

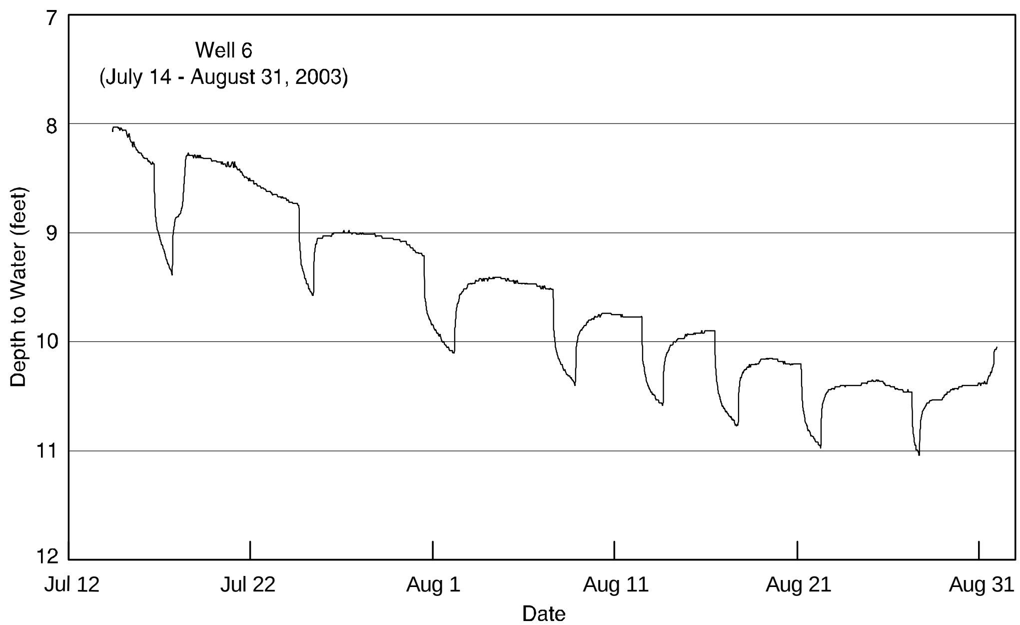

Figure 14. Water-level data recorded in observation well 6, irrigation test site.

Continuous Measurements

Results of an analysis of the continuous record from the Snicarte well (MTOW-1) indicate that recharge often occurs within 1-3 days of the rainfall event and typically lasts 3-5 days after the rainfall event has ended. In other words, recharge occurs on a scale of days, not months; thus, using monthly water-level data to develop correlations with rainfall may not be meaningful. Two small sections of the Snicarte record that show this relationship are shown in two hydrographs (Figure 15), which tell us several things. First, it confirms that aquifer response to rainfall can happen quickly, as one might expect with the permeable surface soils typical of the area. Second, duration of the recharge event may vary, such as in Figure 15a, where groundwater levels continued to rise for several days after the larger rainfall event.

In another year, there will be continuous data for at least two additional observation wells. Similar analyses of those data will determine how recharge events at those sites compare with the Snicarte data. A direct relationship between the onset of recharge and depth to water is expected. Specifically, deeper water tables are expected to exhibit longer lag times between rainfall and the onset of groundwater recharge, as well as a dampening of groundwater-level changes as the depth to the water table increases.

In addition to the analysis of the Snicarte observation well water-level data, two transducers were placed in the Green Valley (MTOW-8) and Route 136 Rest Area (MTOW-7) observation wells to begin collecting continuous water-level data. The Green Valley well, for which the hydrograph is shown (Figure 16), was outfitted with a transducer on July 14, 2003. Subsequent reports will show the hydrograph for a transducer installed in the Rest Area well on August 25, 2003. Small discrepancies between manual measurements and the transducer measurements will be resolved.

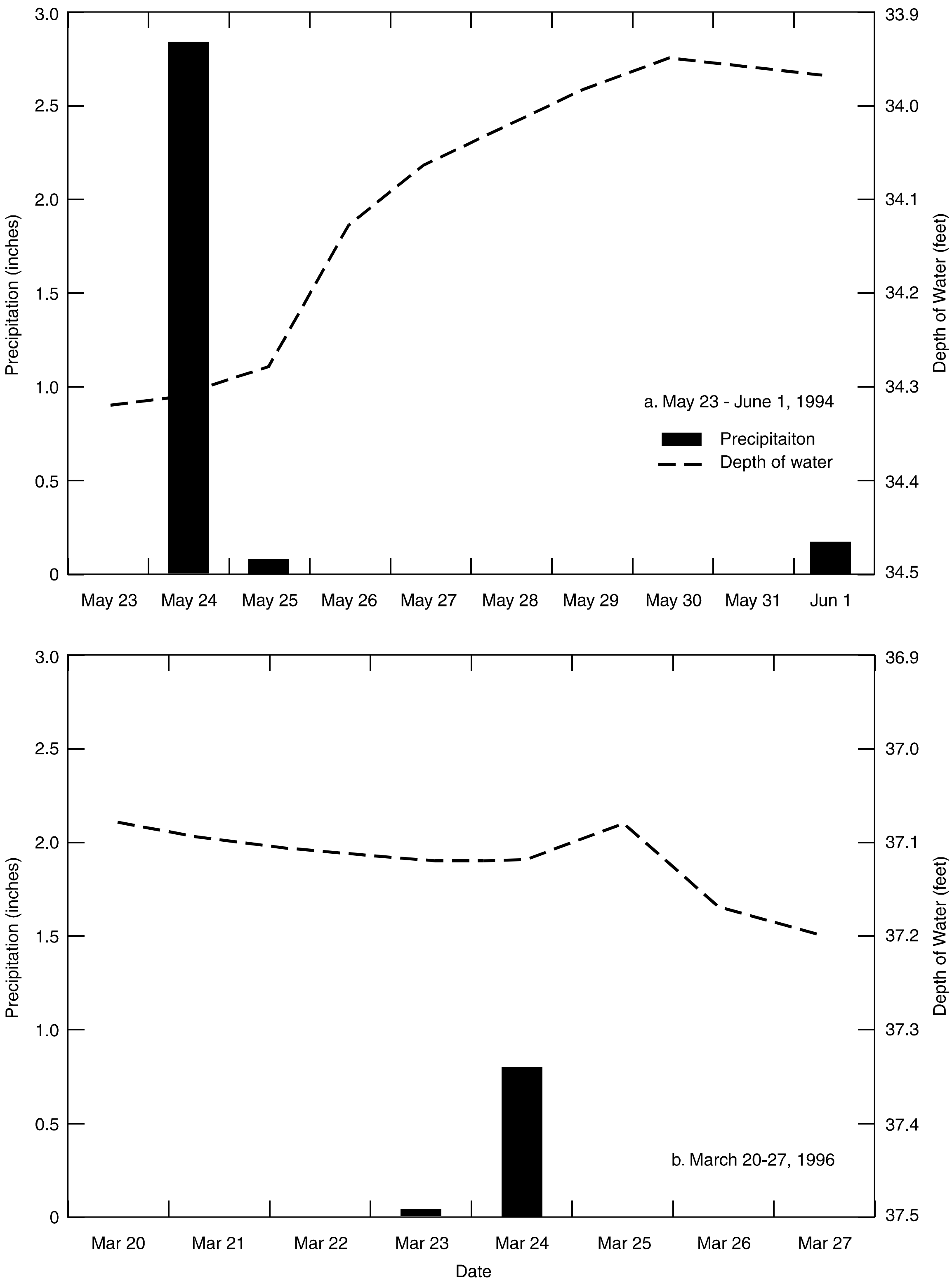

Figure 15. Two excerpts from the continuous hydrograph at Snicarte showing quick responses to precipitation not detected by a single monthly measurement.

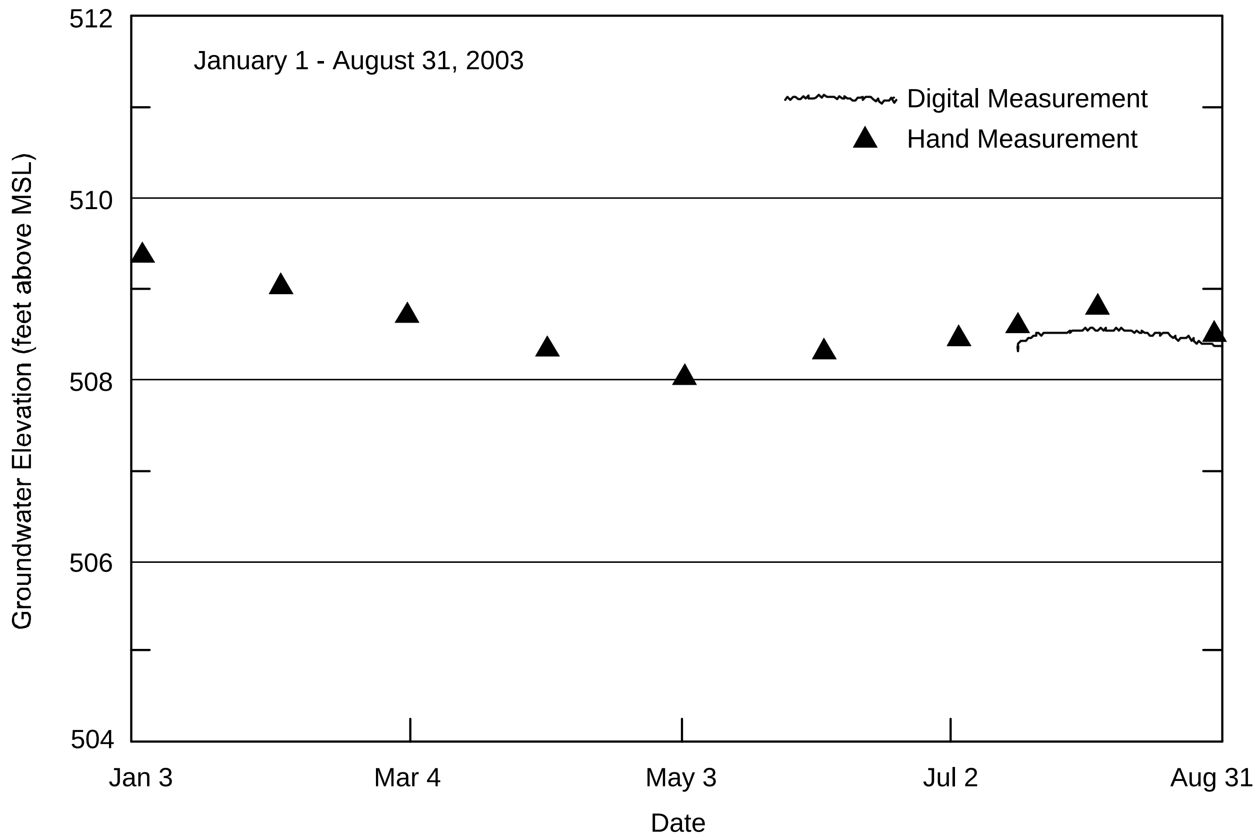

Figure 16. Start of the transducer record and monthly manual measurements, MTOW-8 at Green Valley, 2002-2003.

Irrigation Water Use

Monthly and seasonal estimates of irrigation withdrawals were calculated for the Imperial Valley by previously described methods. Since 1995, irrigation withdrawals have averaged 41 billion gallons (bg) per year, but annual totals have varied from 30 to 52 bg (Table 7). Total annual irrigation withdrawals, from highest to lowest, follow: 1996; 2001 and 2002 (tied); 2003; 1999; 1997 and 1995 (tied); and 1998 and 2000 (tied). In examining these rankings, keep in mind that more irrigation systems are being added every year; for example, more than 200 more systems were reported to be operating in 2002 than in 1998. Probably due in part to these additional systems, other than 1996, the last three years rank as the highest withdrawal years. The greatest average irrigation withdrawals typically occur in July and August, with September and June withdrawals being much less. Estimated irrigation withdrawals show July with the greatest monthly total in seven of the nine years reported, including 2003.

The estimated monthly irrigation pumpage also is displayed graphically in Figure 17 with average monthly network precipitation. These pumpage values show a tendency toward lower irrigation amounts with increasing precipitation and vice versa, but also show that irrigation is dependent on the timing of precipitation. For example, only 30 bg were pumped in 2000 , even though Year Eight showed a deficit of 9.5 inches (Table 8). However, Figure 17 shows that

Table 7. Estimated Monthly Irrigation Withdrawals (billion gallons), Number of Irrigation Systems, and Withdrawal Rank

Year	*June*	*July*	*August*	*September*	*Total*	*# Systems*	*Rank*
1995	2.6	14	10	11	38		5
1996	2.0	20	18	12	52		1
1997	2.6	19	14	2.0	38		5
1998	2.1	7.8	13	6.9	30	1622	6
1999	2.8	18	12	6.0	39	1771	4
2000	6.4	6.0	12	5.6	30	1799	6
2001	4.4	21	17	5.0	47	1818	2
2002	3.4	24	16	3.7	47	1839	2
2003	4.1	16	15	10	46	1867	3
Average	3.4	16	14	6.9	41		

Note:
Total annual withdrawal may differ from sum of monthly withdrawals due to rounding error. Also, data regarding the number of systems in 1995-1997 are unavailable.

Table 8. Average Annual Precipitation, Annual Precipitation Surplus, Running Surplus, and Ranked Annual Precipitation and Irrigation, Imperial Valley Network

September-August period	*Network average precipitation (in.)*	*Annual surplus (in.)*	*Running surplus (in.)*	*Rank*	
				Precip.	*Irrigation*
1992 - 1993	55.55	+20.18	+20.18	1	-
1993 - 1994	40.21	+4.84	+25.02	2	-
1994 - 1995	39.42	+4.05	+29.07	5	5
1995 - 1996	25.70	-9.67	+19.40	11	1
1996 - 1997	27.31	-8.06	+11.34	9	5
1997 - 1998	40.06	+4.69	+16.03	3	6
1998 - 1999	34.02	-1.35	+14.68	6	4
1999 - 2000	25.81	-9.56	+5.12	10	6
2000 - 2001	30.97	-4.40	+0.72	7	2
2001 - 2002	39.91	+4.54	+5.26	4	2
2002 - 2003	30.06	-5.31	-0.05	8	3
1992 - 2003 11-yr average	35.37				
1971 - 2000 30-yr average	37.82 (Havana)				
1971 - 2000 30-yr average	35.70 (Mason City)				

Note:
Site 16 was excluded from network average computations from 1996-1997 through 2001-2002.

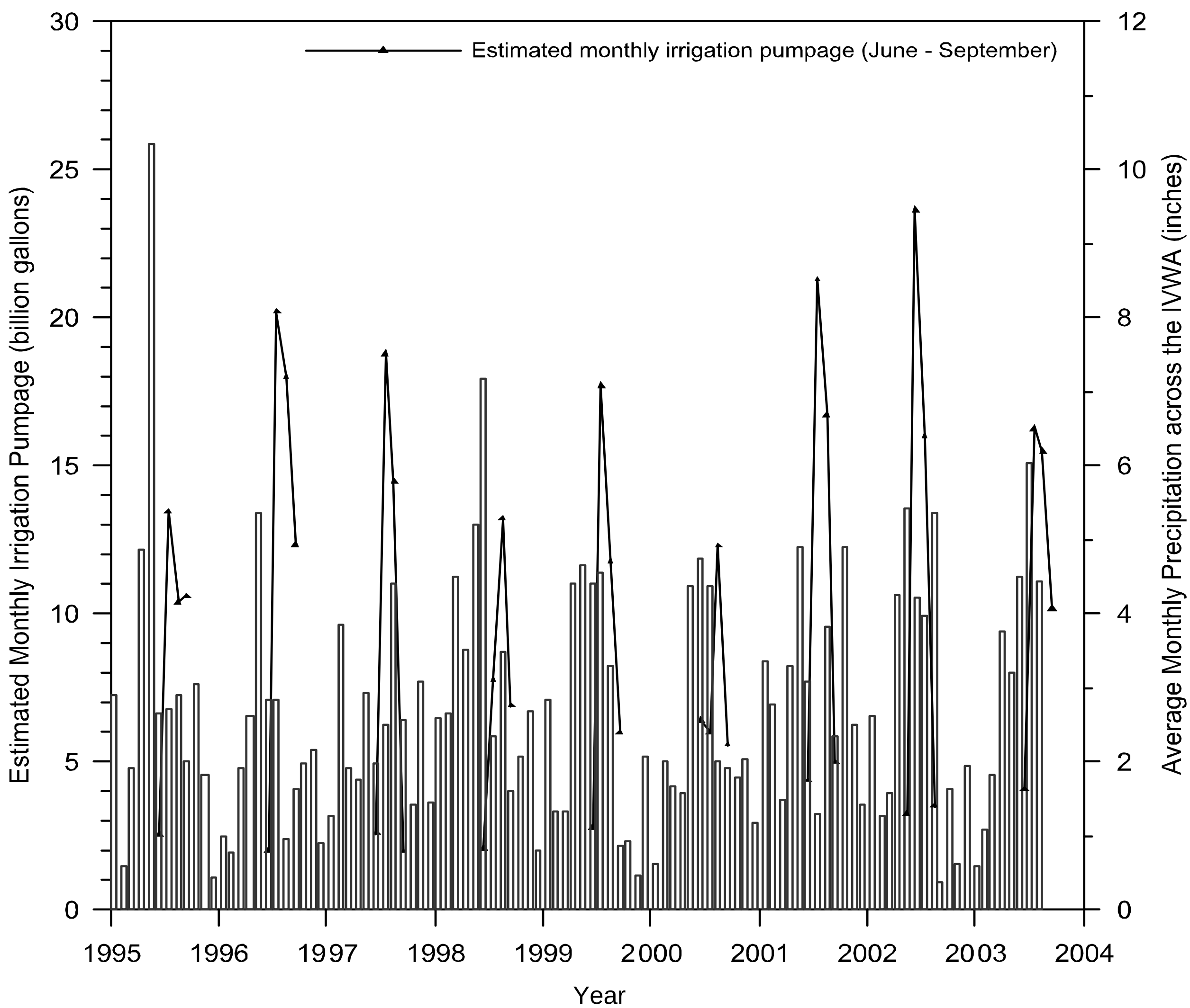

Figure 17. Estimated irrigation pumpage and average monthly precipitation, Imperial Valley.

significant precipitation fell during the summer of 2000, reducing the need for irrigation. Year Eleven was the fourth driest of network operation, 5.84 inches lower than the network 10-year average precipitation (Table 4). This may account for 2003 being the third highest irrigation pumpage season (46 bg, Table 8) since records have been kept. However, most of that deficit was accrued during earlier dry months (4.21 inches below normal in January-May 2003 and 9.23 inches below normal in September 2002-May 2003) while the period June-August 2003 was 3.40 inches above normal (Table 4).

With 245 more systems in 2003 than in 1998, the growth in irrigation systems also must be playing a role in how much water is being applied within the IVWA, potentially making previous years' irrigation amounts uncomparable. Irrigation amounts for June, July, and August were near normal (Table 7), but September 2003 irrigation was well above average and more than twice the combined total of the previous two years' September pumpage.

Summary

For Year 11 of the rain gauge network operation (September 2002-August 2003), the network received an average of 30.06 inches of precipitation, 5.84 inches less than the network 10-year average precipitation. It had the second driest fall (September-November), the second driest winter (December-February), the third driest spring (March-May), but the second wettest summer (June-August) of the 11 years of measurement. Each of the first seven months during Year Eleven had less than 2 inches of precipitation per month. April and May both had more than 3 inches of rain, and each of the last three months of the 2002-2003 study period (June-August) had a network total rain of more than 4 inches.

Groundwater levels tend to peak in most wells in the Imperial Valley during the spring and early summer, then decline in late summer and fall as precipitation is evaporated and transpired back into the atmosphere by growing crops and as a result of seasonal irrigation withdrawals. In 2002-2003, groundwater levels in many wells tended to follow this familiar pattern; however, extremely low precipitation from September 2002 through May 2003 (9.23 inches below the 11-year normal) caused a weak recovery before the irrigation season started. Several wells (MTOW-4, -10, -11, and -13) experienced essentially no water-level recovery during this reporting period. Water levels in MTOW-13, in particular, fell throughout the year. That well is located in northeastern Mason County, corresponding to the area of lowest precipitation.

The continuous paper chart record at MTOW-1 (Snicarte) was examined for selected time periods. The combination of daily precipitation records and these water-level data suggest that recharge is occurring more rapidly than can be assessed by monthly measurement. The analysis indicates that recharge often occurs within 1-3 days of the rainfall event and typically lasts 3-5 days after the rainfall event has ended.

A site along Crane Creek, southwest of Easton, Illinois, was selected for use as a test site to monitor how groundwater, surface water, and irrigation withdrawals interact. Nine observation wells, ranging from 31 to 37 feet deep, were installed in April 2003 with nonpumping water levels 8-15 feet below land surface. Three continuous recorders (electronic pressure transducers with data loggers) also were installed at the site. Transducers were placed in wells 3 and 6 at the test site on June 14, 2003. The third transducer was placed in Crane Creek on August 26, 2003 to measure stage. The observation well network, in combination with streamflow measurements of Crane Creek along several reaches during irrigation season, is designed to examine the influence of irrigation on groundwater discharges (baseflow) to Crane Creek. However, the total difference in discharge between the upstream end of the site and the downstream end of the site is generally less than the error associated with the method. The water-level data do indicate that the aquifer is discharging into Crane Creek under nonpumping conditions. Although it appears that it will not be possible to confirm the amount of groundwater discharge at the study site, the plan is to continue taking discharge readings under varying rainfall and irrigation conditions to determine the effects of those events on the amount of water flowing to or from Crane Creek. Those data will appear in the next report for the 2003-2004 reporting period.

Year Eleven, the fourth driest of network operation, received 5.84 inches less than the network's 10-year average precipitation. This may account for 2003 being the third highest irrigation pumpage season (46 bg) since records have been kept. However, most of that deficit was accrued during earlier dry months (4.2 inches below normal, January-May 2003; 9.23 inches below normal, September 2002-May 2003) while June-August 2003 was 3.40 inches above normal. With 245 more systems in 2003 than in 1998, the increased number of irrigation systems also must play a role in how much water is being applied within the IVWA. Irrigation amounts for June, July, and August were near normal, but September 2003 irrigation was well above average and more than twice the combined total of the previous two years' September pumpage.

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Appendix A. Hydrographs, Imperial Valley Observation Well Network

Appendix A. Hydrographs, Imperial Valley Observation Well Network

This appendix shows hydrographs of groundwater levels in each of the Imperial Valley observation wells. The hydrographs also include monthly precipitation totals from the nearest rain gauge or average of nearby gauges from the Imperial Valley rain gauge network, and Illinois River stage for wells near the river. Groundwater-level data are graphed as depth to water measured from land surface. Although the hydrographs do not contain a common y-axis, they do maintain a common y-axis range (25 feet). Illinois River stage data also are presented as elevations on a similar 25-foot y-axis range.

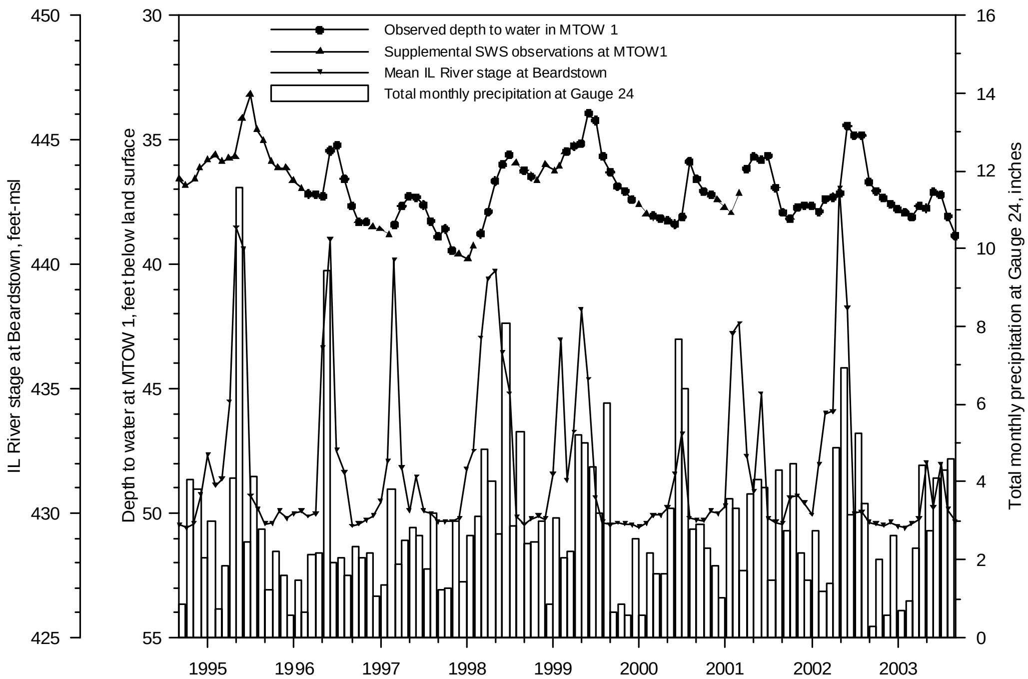


Figure A-1. Groundwater depth, precipitation, and Illinois River stage for MTOW-1.

Appendix A. (continued)

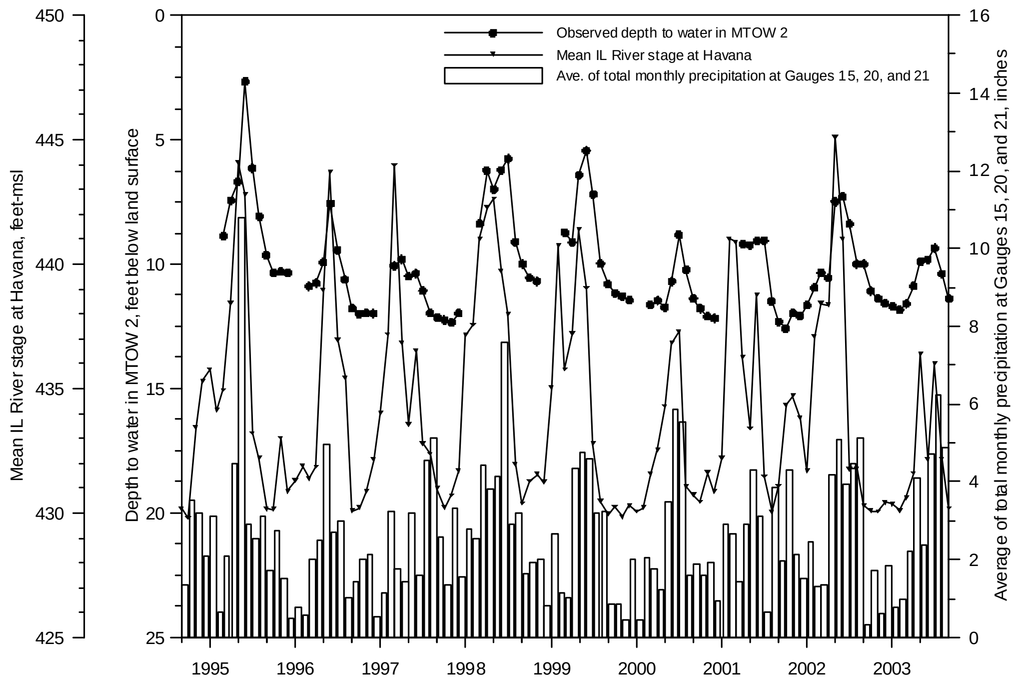


Figure A-2. Groundwater depth, precipitation, and Illinois River stage for MTOW-2.

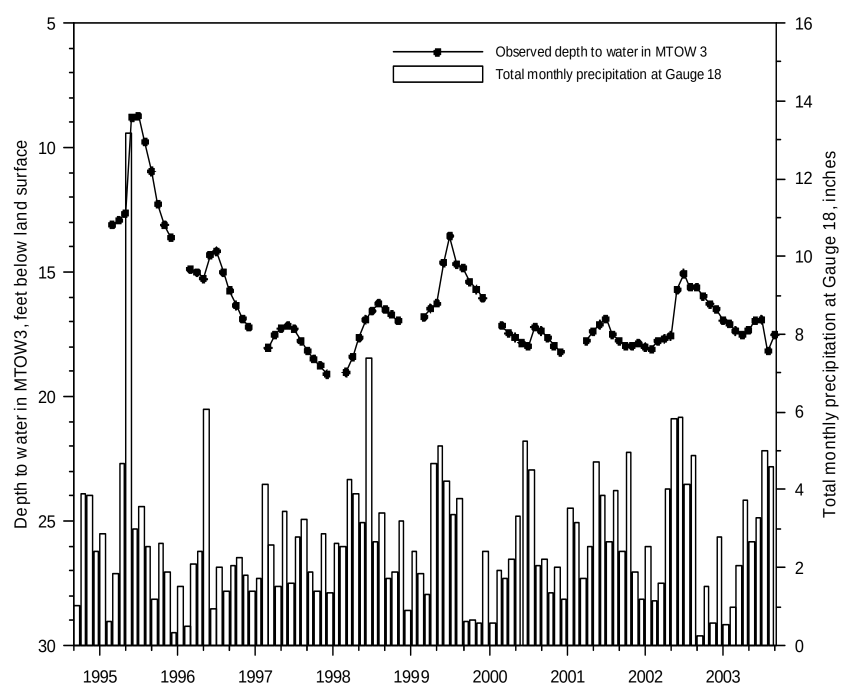


Figure A-3. Groundwater depth and precipitation for MTOW-3.

Appendix A. (continued)

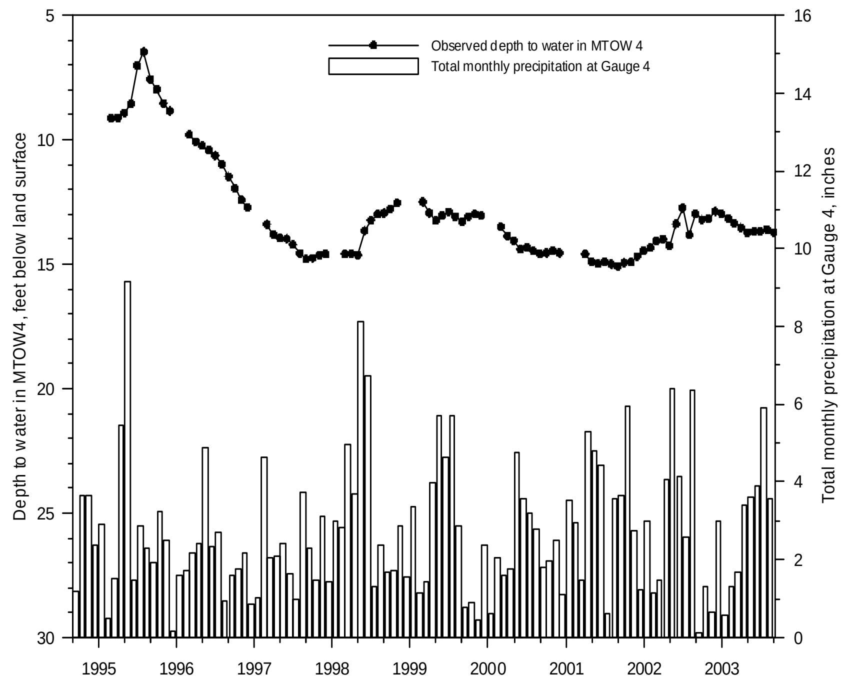


Figure A-4. Groundwater depth and precipitation for MTOW-4.

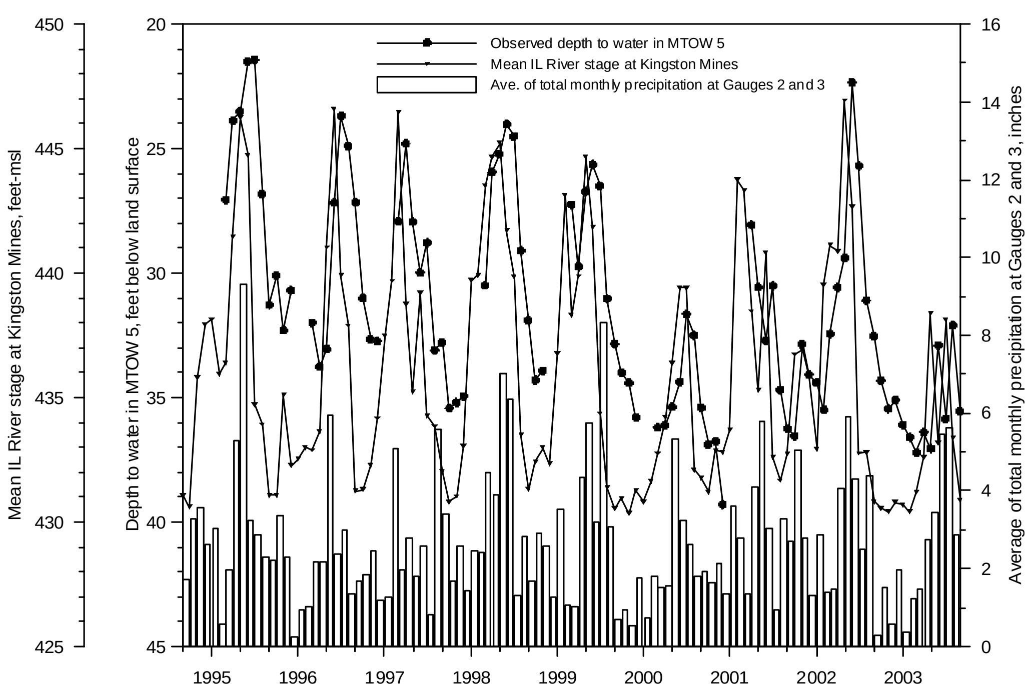


Figure A-5. Groundwater depth, precipitation,
and Illinois River stage for MTOW-5.

Appendix A. (continued)

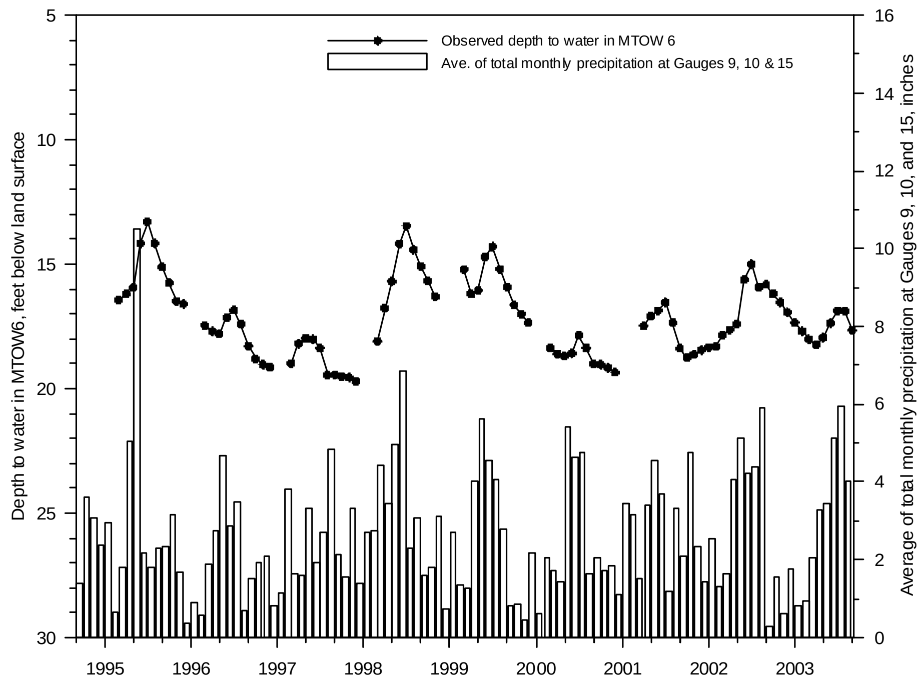


Figure A-6. Groundwater depth and precipitation for MTOW-6.

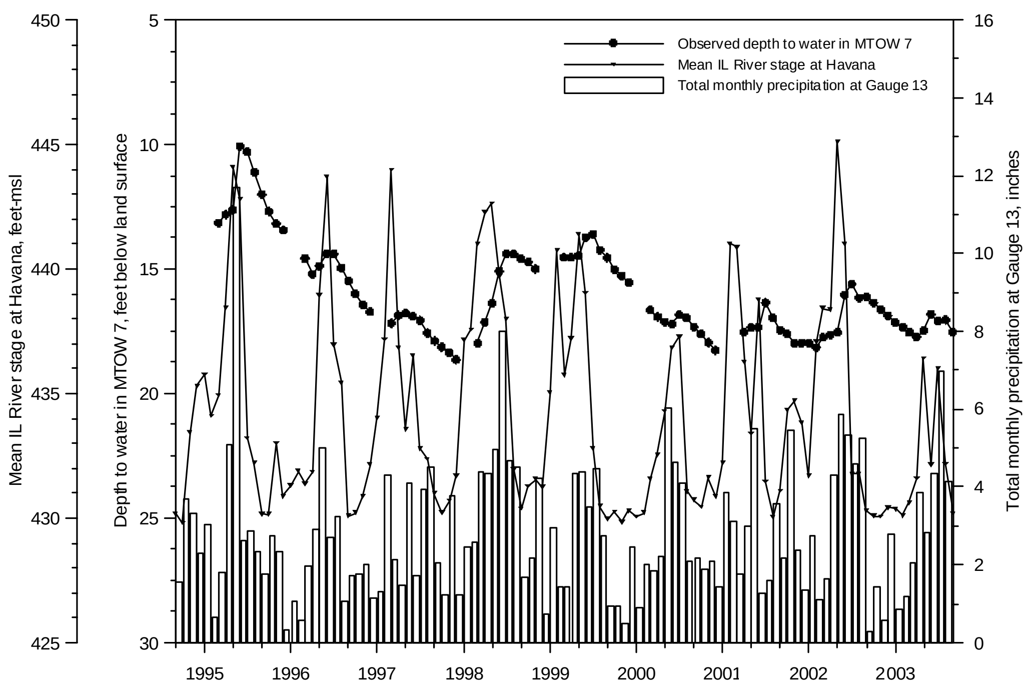


Figure A-7. Groundwater depth, precipitation, and Illinois River stage for MTOW-7.

Appendix A. (continued)

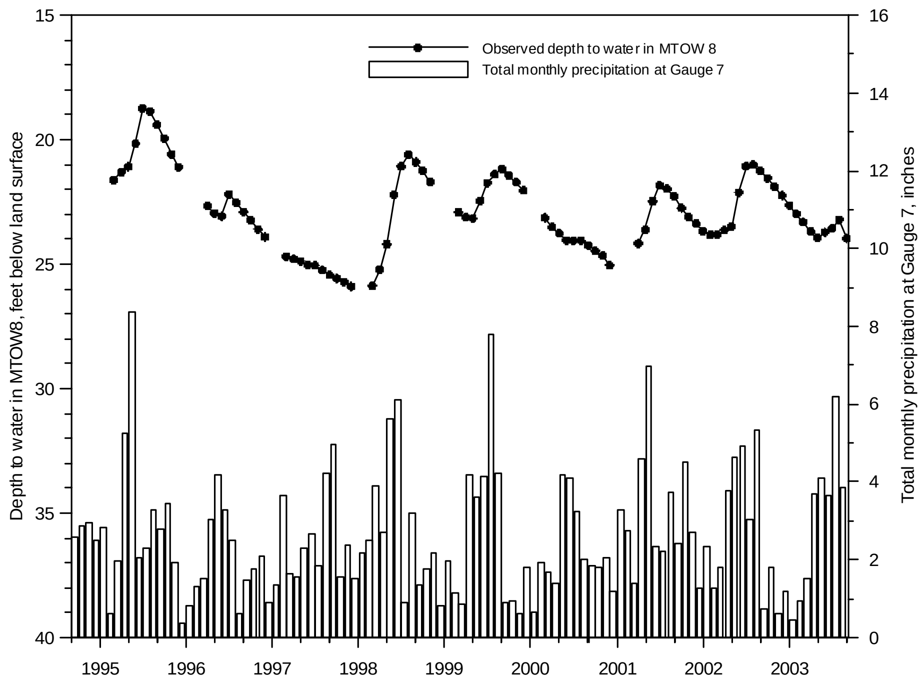


Figure A-8. Groundwater depth and precipitation for MTOW-8.

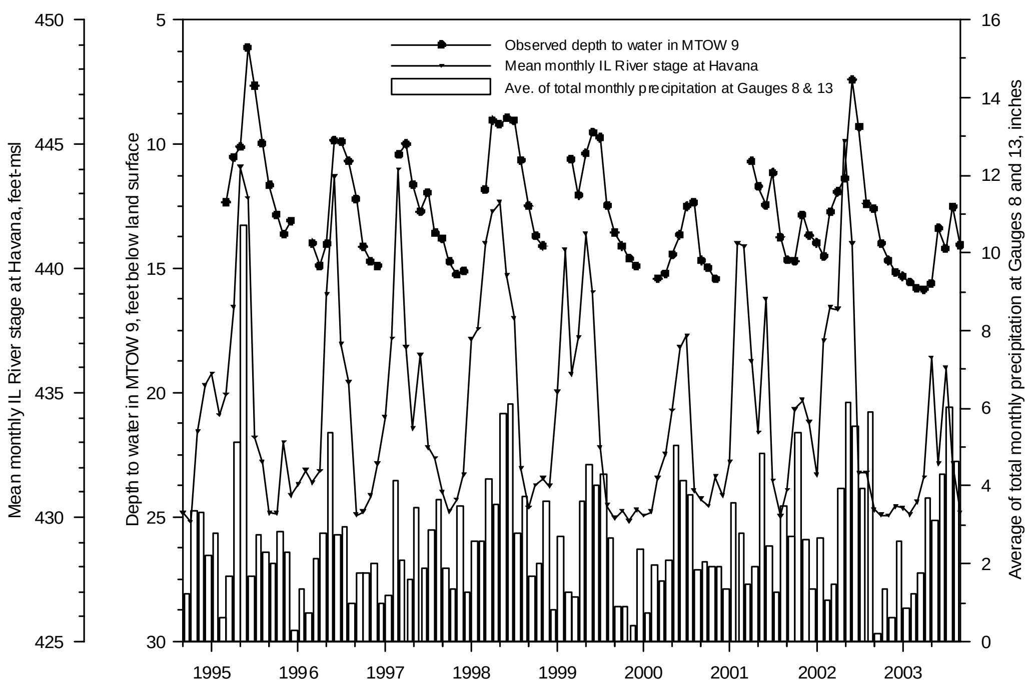


Figure A-9. Groundwater depth, precipitation,
and Illinois River stage for MTOW-9.

Appendix A. (continued)

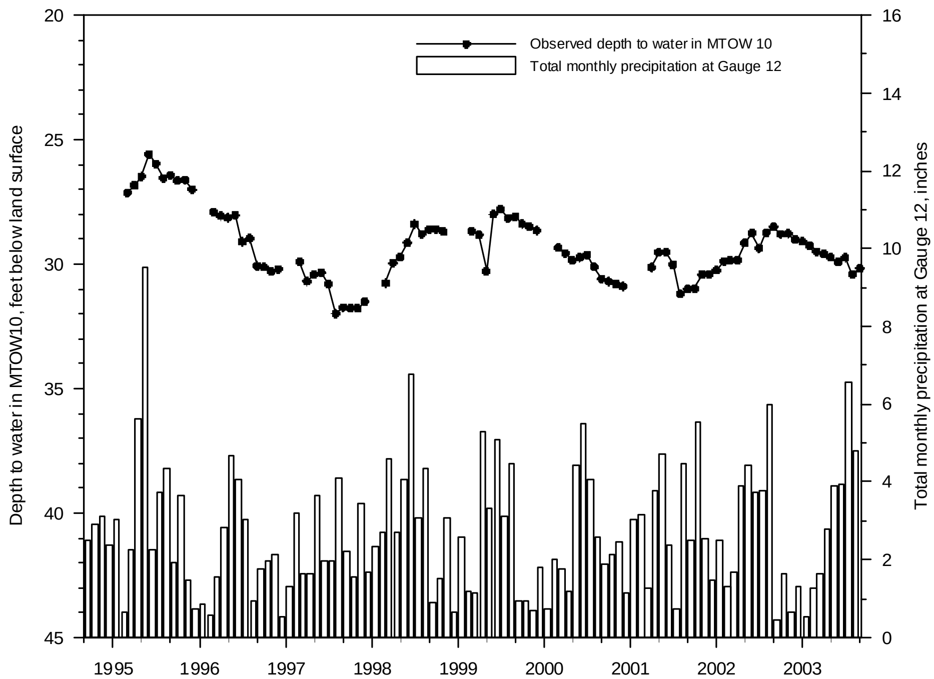


Figure A-10. Groundwater depth and precipitation for MTOW-10.

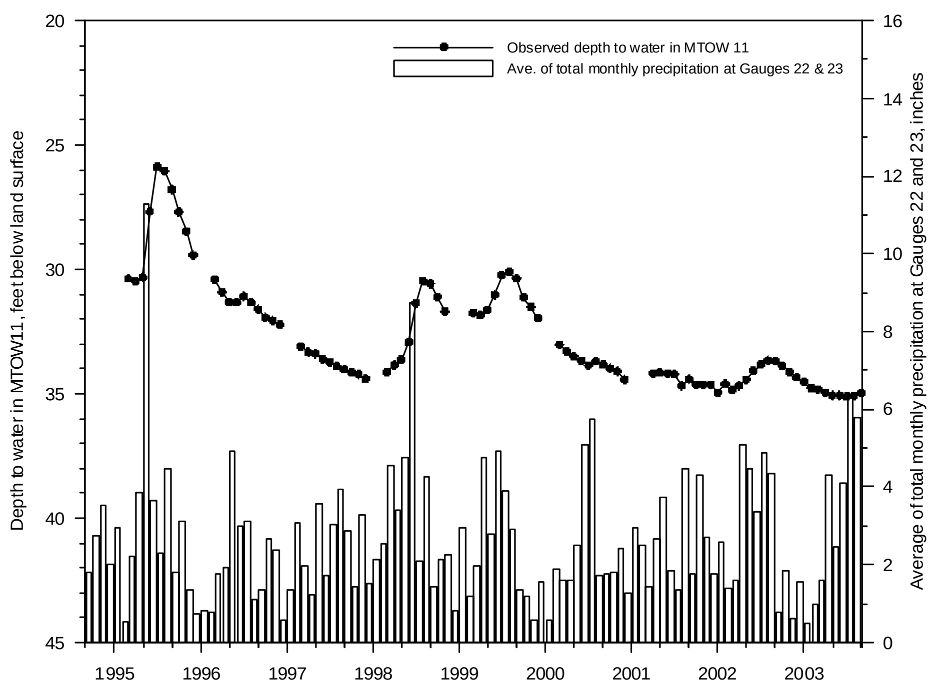


Figure A-11. Groundwater depth and precipitation for MTOW-11.

Appendix A. (concluded)

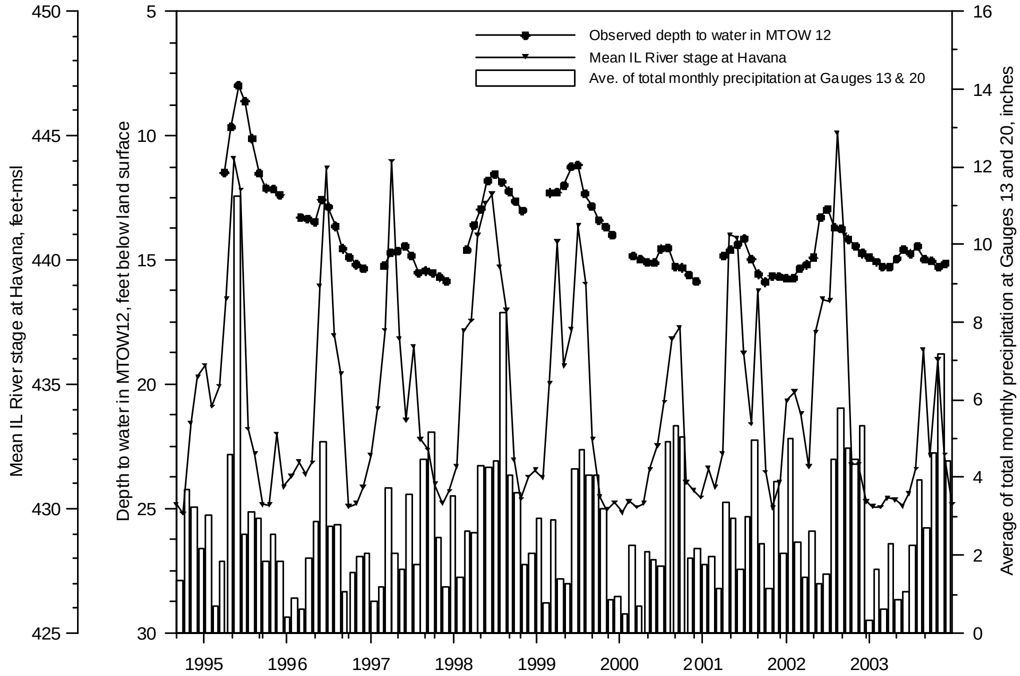


Figure A-12. Groundwater depth, precipitation, and Illinois River stage for MTOW-12.

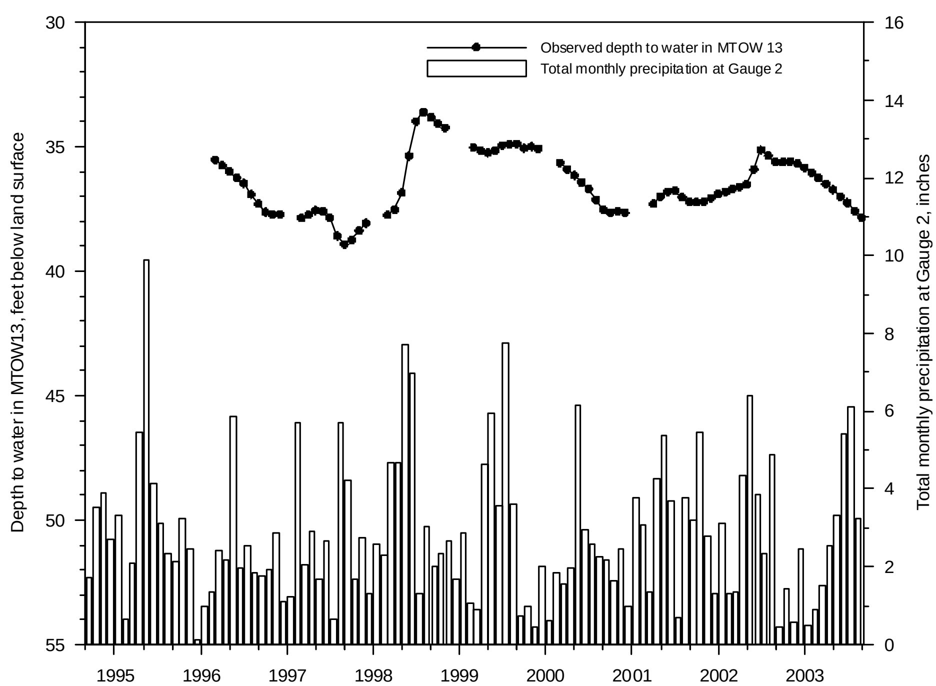


Figure A-13. Groundwater depth and precipitation for MTOW-13.

Appendix B. Observed Groundwater Levels, Imperial Valley Observation Well Network

Appendix B. Observed Groundwater Levels, Imperial Valley Observation Well Network

Date	*Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells*												
	MTOW-1	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-1995	-.--	8.88	13.11	*9.15*	27.06	16.45	13.15	*21.62*	12.54	*27.14*	30.38	-.--	-.--
4-01-1995	-.--	7.45	12.94	9.12	23.87	16.20	12.82	21.31	10.52	26.84	*30.48*	11.49	-.--
5-01-1995	-.--	6.69	12.65	8.92	23.50	15.95	12.63	21.09	10.12	26.48	30.32	9.67	-.--
5-15-1995	-.--	3.50	10.50	8.78	22.67	15.16	11.12	20.80	11.12	25.93	28.76	**7.97**	-.--
6-01-1995	-.--	**2.67**	8.80	8.57	21.50	14.17	10.07	20.16	6.12	**25.60**	27.67	8.00	-.--
6-15-1995	-.--	4.51	**8.07**	7.64	**18.24**	**13.15**	**9.74**	19.03	**5.26**	25.79	26.11	8.68	-.--
7-01-1995	-.--	6.15	8.74	7.03	21.43	13.31	10.30	18.73	7.66	25.97	25.88	8.64	-.--
7-15-1995	-.--	6.10	9.08	6.87	24.49	13.60	10.52	**18.69**	8.80	25.90	**25.68**	9.71	-.--
8-01-1995	-.--	8.10	9.77	**6.47**	26.82	14.17	11.11	18.87	9.98	26.55	26.05	10.13	-.--
8-15-1995	-.--	8.80	10.38	7.33	30.47	14.67	11.41	19.12	11.21	26.01	26.45	11.12	-.--
9-01-1995	-.--	9.65	10.96	7.58	31.28	15.11	12.00	19.40	11.65	26.42	26.79	11.52	-.--
9-15-1995	-.--	10.19	11.65	7.82	31.93	15.47	12.44	19.66	12.24	26.57	27.22	11.86	-.--
10-01-1995	-.--	10.35	12.27	7.99	30.09	15.76	12.69	19.94	12.84	26.64	27.69	12.12	-.--
10-15-1995	-.--	*10.40*	12.81	8.17	*32.79*	16.05	12.95	20.21	13.29	26.75	28.02	12.13	-.--
11-01-1995	-.--	10.30	13.12	8.55	32.30	16.50	13.19	20.60	*13.63*	26.61	28.47	12.17	-.--
12-01-1995	-.--	10.35	*13.62*	8.85	30.70	*16.60*	*13.45*	21.10	13.09	27.00	29.43	*12.39*	-.--
3-01-1996	37.18	10.90	14.89	**9.80**	32.00	17.47	14.58	-.--	13.98	**27.90**	**30.40**	13.30	**35.52**
4-01-1996	37.19	10.77	15.01	10.07	*33.77*	17.70	15.20	22.67	14.90	28.07	30.92	13.34	35.76
5-01-1996	37.28	9.93	15.27	10.24	33.05	17.80	14.88	22.97	14.02	28.14	31.33	13.47	36.00
5-15-1996	-.--	8.84	14.97	10.34	32.04	17.63	14.72	23.09	12.90	28.14	31.36	13.03	36.08
6-01-1996	35.45	**7.57**	14.31	10.43	27.17	17.14	14.38	23.08	9.85	28.04	31.33	12.58	36.25
6-15-1996	-.--	7.62	**14.07**	10.44	**23.36**	**16.78**	**14.25**	22.76	**8.64**	28.01	31.17	**12.54**	36.32
7-01-1996	**35.23**	9.45	14.17	10.64	23.69	16.85	14.40	**22.20**	9.90	29.10	31.09	12.88	36.47
7-15-1996	-.--	10.20	14.65	10.82	25.20	17.38	14.72	22.35	10.51	29.14	31.31	13.37	36.70
8-01-1996	36.58	10.63	15.01	11.00	24.90	17.42	14.95	22.52	10.69	28.97	31.33	13.65	36.92
8-15-1996	-.--	11.30	15.39	11.21	24.41	18.00	15.18	22.69	10.72	30.22	31.45	14.07	37.14
9-01-1996	37.68	11.78	15.75	11.48	27.17	18.29	15.48	22.90	12.20	30.07	31.61	14.55	37.30
9-15-1996	-.--	*12.02*	16.12	11.75	29.16	18.72	15.82	23.09	13.55	30.22	31.85	14.81	37.50
10-01-1996	*38.32*	12.00	16.35	11.95	31.00	18.80	16.00	23.24	14.12	30.12	31.93	14.89	37.63
11-01-1996	38.32	11.97	16.89	12.42	32.66	19.04	16.43	23.60	14.73	*30.30*	32.06	15.19	*37.73*
12-01-1996	-.--	11.99	*17.23*	*12.73*	32.74	*19.15*	*16.72*	*23.91*	*14.90*	30.20	*32.22*	*15.36*	37.71

Note: Bold numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix B. (continued)

Date	*Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells*												
	MTOW-1	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-1997	38.41	10.07	18.05	**13.40**	27.94	19.00	17.18	**24.70**	10.43	**29.90**	**33.10**	15.24	37.87
4-01-1997	37.67	**9.87**	17.53	13.84	**24.80**	18.20	16.86	24.80	**10.00**	30.70	33.33	14.71	37.75
5-01-1997	**37.27**	10.50	17.27	13.95	27.95	**17.98**	**16.78**	24.88	11.62	30.42	33.40	14.65	**37.56**
6-01-1997	37.32	10.38	**17.17**	13.98	29.98	18.02	16.90	25.03	12.71	30.34	33.61	**14.45**	37.60
6-15-1997	-.--	-.--	-.--	-.--	-.--	-.--	-.--	-.--	-.--	31.45	-.--	-.--	-.--
7-01-1997	37.63	11.08	17.29	14.22	28.78	18.38	17.06	25.05	11.95	31.80	33.73	14.85	37.86
7-15-1997	-.--	11.54	17.45	14.35		19.00	17.24	25.12	12.67	31.45	33.78	15.17	38.15
8-01-1997	38.28	11.98	17.77	14.56	33.10	19.44	17.57	25.25	13.57	*31.99*	33.90	15.52	38.59
8-15-1997	-.--	12.19	17.94	14.68	33.70	19.55	17.74	25.35	14.07	31.79	33.97	15.37	38.84
9-01-1997	38.90	12.15	18.17	*14.80*	32.78	19.45	17.89	25.44	13.80	31.74	34.03	15.45	*38.92*
10-01-1997	38.59	12.25	18.51	14.75	*35.43*	19.51	18.14	25.58	14.72	31.77	34.14	15.52	38.75
11-01-1997	*39.46*	*12.36*	18.77	14.64	35.20	19.55	18.35	25.72	*15.24*	31.78	34.23	15.70	38.38
12-01-1997	-.--	11.97	*19.11*	14.60	34.95	*19.70*	*18.65*	*25.90*	15.10	31.51	*34.41*	*15.87*	38.08
3-01-1998	*38.78*	8.38	*19.04*	14.59	30.50	*18.10*	*17.98*	*25.88*	11.84	*30.77*	*34.13*	*14.61*	*37.75*
4-01-1998	37.91	6.25	18.41	14.58	25.95	16.78	17.14	25.21	9.04	29.95	33.85	13.61	37.52
5-01-1998	36.67	7.00	17.65	*14.64*	25.21	15.70	16.38	24.20	9.20	29.73	33.63	12.97	36.85
6-01-1998	36.00	6.23	16.92	13.66	**24.02**	14.18	15.08	22.22	**8.95**	29.15	32.93	11.82	35.38
7-01-1998	**35.61**	**5.77**	16.57	13.24	24.50	**13.47**	**14.40**	21.08	9.05	**28.40**	31.36	**11.55**	33.98
8-01-1998	-.--	9.13	**16.27**	13.00	29.10	14.42	14.40	**20.60**	10.65	28.79	**30.47**	11.87	**33.60**
9-01-1998	36.24	10.00	16.52	12.95	31.90	15.08	14.58	20.90	12.48	28.60	30.58	12.25	33.82
10-01-1998	36.48	10.55	16.72	12.78	*34.30*	15.68	14.72	21.25	13.70	28.60	31.10	12.65	34.07
11-01-1998	-.--	*10.70*	16.97	**12.55**	33.93	16.30	15.00	21.70	*14.10*	28.70	31.69	13.02	34.24
3-01-1999	35.48	8.74	*16.82*	**12.50**	27.25	15.22	14.54	22.92	10.61	28.67	31.75	12.31	35.03
4-01-1999	35.26	9.13	16.47	12.95	29.74	16.20	14.54	23.13	12.05	28.83	*31.85*	12.29	35.15
5-01-1999	35.16	6.42	16.27	13.25	26.73	16.06	14.48	*23.17*	10.38	*30.28*	31.63	12.01	*35.25*
6-01-1999	**33.95**	**5.45**	14.63	13.05	**25.64**	14.70	13.74	22.45	**9.54**	28.00	31.03	11.27	35.15
7-01-1999	34.23	7.19	**13.56**	12.90	26.50	**14.30**	**13.60**	21.74	9.74	**27.80**	30.23	**11.20**	34.94
8-01-1999	35.68	9.98	14.69	13.10	31.03	15.20	14.24	21.40	12.45	28.17	**30.11**	12.35	34.90
9-01-1999	36.30	10.82	14.83	*13.30*	32.84	15.92	14.55	**21.18**	13.56	28.10	30.37	12.85	**34.88**
10-01-1999	*36.87*	11.18	15.40	13.09	34.00	16.64	15.02	21.44	14.10	28.39	31.13	13.41	35.06
11-01-1999	-.--	11.30	15.71	13.00	34.42	17.00	15.28	21.72	14.60	28.50	31.51	13.69	35.00
12-01-1999	*37.43*	*11.45*	16.05	13.05	*35.79*	*17.35*	*15.55*	22.04	*14.91*	28.65	*31.97*	*14.01*	35.08

Note: Bold numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix B. (concluded)

Date	*Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells*												
	MTOW-1	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-2000	38.07	11.65	**17.17**	**13.51**	36.21	18.38	**16.65**	**23.14**	15.40	**29.35**	**33.03**	14.85	**35.65**
4-01-2000	38.17	11.47	17.45	13.87	36.12	18.61	16.92	23.51	15.20	29.56	33.31	14.99	35.92
5-01-2000	38.26	11.74	17.63	14.05	35.38	18.71	17.13	23.77	14.44	29.85	33.51	15.11	36.15
6-01-2000	*38.40*	10.70	17.85	14.40	34.37	18.59	17.21	24.05	13.65	29.74	33.67	15.12	36.44
7-01-2000	38.11	**8.83**	*17.97*	14.34	**31.65**	**17.87**	16.84	24.05	12.50	29.63	33.86	14.56	36.70
8-01-2000	**35.89**	10.24	17.22	14.47	32.50	18.37	16.97	24.05	**12.35**	30.12	33.71	**14.53**	37.14
9-01-2000	36.59	11.39	17.37	*14.60*	35.40	19.02	17.33	24.24	14.68	30.60	33.83	15.27	37.54
10-01-2000	37.08	11.79	17.65	14.55	*36.88*	19.04	17.62	24.47	14.97	30.70	33.98	15.32	*37.65*
11-01-2000	37.22	*12.11*	*17.97*	14.47	36.75	*19.17*	*17.95*	*24.67*	*15.44*	*30.80*	*34.10*	*15.61*	37.60
4-01-2001	36.18	9.19	17.77	**14.59**	**28.07**	17.49	17.54	*24.17*	**10.69**	30.13	34.18	14.83	*37.30*
5-01-2001	35.69	9.25	17.38	14.90	30.57	17.10	17.35	23.62	11.70	29.53	**34.15**	14.61	37.00
6-01-2001	35.82	9.08	17.12	14.98	32.71	16.87	17.35	22.47	12.45	**29.51**	34.18	14.39	36.81
7-01-2001	**35.65**	**9.06**	**16.89**	14.90	30.51	**16.54**	**16.35**	**21.85**	11.15	30.03	34.22	**14.16**	**36.77**
8-01-2001	36.93	11.50	17.51	15.00	34.70	17.35	16.97	21.98	13.75	*31.21*	*34.68*	14.98	37.03
9-01-2001	37.94	12.32	17.77	*15.08*	36.25	18.39	17.45	22.28	14.67	31.00	34.42	15.58	37.23
10-01-2001	*38.18*	*12.58*	*17.97*	14.94	*36.55*	*18.76*	17.60	22.75	*14.70*	30.98	34.63	*15.90*	37.23
11-01-2001	37.74	11.97	*17.97*	14.93	32.85	18.63	*17.98*	23.12	12.84	30.42	34.63	15.65	37.21
12-01-2001	37.64	12.10	17.88	14.69	34.08	18.46	17.97	23.37	13.67	30.40	34.63	15.69	37.06
1-01-2002	37.67	*11.66*	18.02	*14.46*	34.41	*18.34*	17.97	23.68	13.97	*30.25*	*34.95*	*15.75*	*36.90*
2-01-2002	*37.89*	10.95	*18.11*	14.35	*35.49*	18.32	*18.15*	*23.83*	14.51	29.88	34.61	*15.75*	36.81
3-01-2002	37.38	10.35	17.77	14.06	32.44	17.85	17.75	23.82	12.73	29.84	34.85	15.35	36.69
4-01-2002	37.31	10.57	17.69	14.00	30.58	17.64	17.64	23.64	11.92	29.84	34.68	15.19	36.62
5-01-2002	37.17	7.50	17.57	14.25	29.40	17.40	17.54	23.49	11.40	29.15	34.44	14.91	36.53
6-01-2002	**34.44**	**7.30**	15.72	13.39	**22.34**	15.62	16.05	22.12	**7.42**	28.76	34.08	13.30	35.91
7-01-2002	34.82	8.39	**15.07**	**12.75**	25.70	**15.00**	**15.61**	21.08	9.30	29.36	33.83	**12.97**	**35.13**
8-01-2002	34.82	10.00	15.62	13.82	31.10	15.93	16.17	**21.01**	12.40	28.73	**33.66**	13.71	35.36
9-01-2002	36.71	10.00	15.62	12.98	32.55	15.82	16.12	21.25	12.60	**28.50**	33.68	13.76	35.62
10-01-2002	37.06	11.09	15.97	13.21	34.32	16.20	16.36	21.55	14.00	28.79	33.88	14.17	35.62
11-01-2002	37.34	11.40	16.29	13.18	35.45	16.54	16.63	21.90	14.68	28.78	34.12	14.45	35.60
12-01-2002	37.58	11.58	16.49	12.88	35.10	16.93	16.88	22.24	*15.15*	29.02	34.35	14.74	35.68
1-01-2003	37.80	11.70	16.95	**12.98**	36.10	17.36	17.15	**22.64**	15.32	**29.09**	**34.53**	14.91	**35.84**
2-01-2003	37.94	*11.84*	17.10	13.17	36.60	17.70	17.34	23.00	15.57	29.26	34.78	15.07	36.04
3-01-2003	*38.13*	11.60	17.37	13.35	*37.21*	18.02	17.55	23.32	15.79	29.50	34.82	15.27	36.26
4-01-2003	37.67	10.89	17.52	13.53	36.40	*18.24*	*17.73*	23.69	*15.84*	29.60	34.95	*15.29*	36.50
5-01-2003	37.76	9.90	17.34	*13.73*	37.05	17.95	17.47	*23.95*	15.60	29.73	35.07	14.96	36.73
6-01-2003	**37.11**	9.82	16.95	13.69	32.90	17.37	**16.82**	23.72	13.38	29.92	35.07	14.58	37.01
7-01-2003	37.23	**9.36**	**16.92**	13.69	35.85	**16.88**	17.10	23.58	14.20	29.74	*35.11*	14.75	37.25
8-01-2003	38.09	10.40	*18.18*	13.61	**32.10**	**16.88**	17.05	23.22	**12.52**	*30.40*	35.08	**14.46**	*37.59*

Note: **Bold** numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix C. Site Descriptions, Imperial Valley Rain Gauge Network

Appendix C. Site Descriptions, Imperial Valley Rain Gauge Network

This appendix contains site descriptions of each rain gauge site in the IVWA network as of August 31, 2003. Sites that have been relocated since the network was established in August 1992 are so noted in the "Placement" portion of their site description. Sites with shaded descriptions have been removed from the network.

SITE DESCRIPTION		
Site Number: 1		
County: Tazewell	Latitude: 40° 28' 3"	Longitude: 89° 50' 9"
Property Owner: Melvin Fornoff		
Address: 10200 Fornoff Road, Manito, IL 61546		
Telephone: 309-968-6653		
Permission Date: 8-10-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 4695	Gauge ID No.: SWS 5068	
Placement: Near apple/pear trees, northeast of a garage. Property on east side of 450 E in Tazewell County, north of 1000 N. Large dog. Gauge 15 meters northwest of lat/long reading. Station removed from the network in September 1995.		

SITE DESCRIPTION		
Site Number: 2		
County: Tazewell	Latitude: 40° 28' 42"	Longitude: 89° 45' 54"
Property Owner: Ken Becker		
Address: 8479 Townline Road, Manito, IL 61546		
Telephone: 309-545-2207		
Permission Date: 8-15-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 4723	Gauge ID No.: SWS 5030	
Placement: In back yard (grass) near garbage burner. Property on south side of 1100 N in Tazewell County, west of 900 E. Gauge 2 meters west of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 3		
County: Tazewell	Latitude: 40° 28' 56"	Longitude: 89° 37' 33"
Property Owner: Lonn Schleder		
Address: 11177 S. 14th Street, Pekin, IL 61554		
Telephone: 309-348-2447		
Permission Date: 8-10-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 1463	Gauge ID No.: SWS 3693	
Placement: Moved 5-13-94 to a position about 60 meters north-northeast of original position, which was in a back pasture along a wire fence between a white aluminum shed and a large tree. Present position is between a garage and another shed near a well. Property on northwest corner of the intersection of 1600 E and 1100 N. Gauge 50 meters north-northwest of lat/long reading.		

SITE DESCRIPTION		
Site Number: 4		
County: Mason	Latitude: 40° 24' 29"	Longitude: 89° 54' 41"
Property Owner: Ellis Popcorn (Maureen Hanks)		
Address: 24095 County Road 2330 E, Topeka, IL 61567		
Telephone: 309-535-3840		
Permission Date: 8-10-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 7382	Gauge ID No.: SWS 6573	
Placement: South of large white office building, between two trees in a grassy area. Property on east side of 2340 E in Mason County, northeast of Goofy Ridge. Gauge 10 meters south-southwest of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 5		
County: Mason	Latitude: 40° 24' 29"	Longitude: 89° 50' 19"
Property Owner: Joseph Meyer		
Address: 24234 County Road 2750 E, Topeka, IL 61567		
Telephone: 309-968-6378		
Permission Date: 8-10-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 5985	Gauge ID No.: CDA 000130	
Placement: Next to stone drive in a pasture in front of house. Property on west side of 2750 E in Mason County, south of 2500 N. Gauge 3 meters east of lat/long reading. Station removed from network in September 1995.		

SITE DESCRIPTION		
Site Number: 6		
County: Mason	Latitude: 40° 22' 42"	Longitude: 89° 43' 16"
Property Owner: Lawrence Whiteford		
Address: 22172 N County Road 3400 E, Manito, IL 61546-7988		
Telephone: 309-968-6234		
Permission Date: 3/22/01		
Installation Date: 3/22/01		
Gauge Mfrs. No.: 5295	Gauge ID No.: SWS 5309	
Placement: Gauge was moved on 3/22/01 approximately 1.9 miles south-southeast of old location, or about 0.4 miles north of 2180 N on 3400 E, Mason County. New location is in a open area west of machine shed. Old location was on west side of 3300 E in Mason County, just south of 2400 N, 18 meters south of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 7		
County: Tazewell	Latitude: 40° 24' 24"	Longitude: 89° 37' 29"
Property Owner: David Van Orman		
Address: 5801 Warner Road, Green Valley, IL 61534		
Telephone: 309-352-5673		
Permission Date: 8-10-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 5935	Gauge ID No.: --	
Placement: Moved in May 1993 to a position south of a barn with a green roof, near edge of field. Original position was 30 meters to the northeast, north of the same barn. Both positions are northwest of the house. Property located just east of Green Valley on south side of 600 N in Tazewell County, just west of 1600 E. Gauge 17 meters west-northwest of lat/long reading.		

SITE DESCRIPTION		
Site Number: 8		
County: Mason	Latitude: 40° 20' 56"	Longitude: 90° 1' 18"
Property Owner: c/o Steve Havera, Forbes Biological Station		
Address: P.O. Box 49, Havana, IL 62644		
Telephone: 309-543-3950		
Permission Date: 6-3-02		
Installation Date: 6-3-02		
Gauge Mfrs. No.: 2000	Gauge ID No.: US148085	
Placement: New location as of 6-3-02, Illinois Natural History Survey station on Quiver Creek, 0.2 mile northeast of old location. From 4-20-00 to 6-3-02, was on Blakely property located on north side of 1950 N in Mason County west of 1900 E., 0.5 mile northwest of old site east-southeast of house near a small tree.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 9		
County: Mason	Latitude: 40° 19' 41"	Longitude: 89° 55' 55
Property Owner: Mason State Tree Nursery		
Address: 17855 County Road 2400 E, Topeka, IL 61567		
Telephone: 309-535-2185		
Permission Date: 8-9-00		
Installation Date: 8-9-00		
Gauge Mfrs. No.: 5986	Gauge ID No.: CDA 000132	
Placement: Located about 400 yards south of office among several weather stations. Prior location from 5-14-93 to 8-9-00 at R.R. #1, Box 19, Topeka. Original position from 8-24-92 to 5-14-93 was at R.R. #1, Box 6, Topeka.		

SITE DESCRIPTION		
Site Number: 10		
County: Mason	Latitude: 40° 19' 58"	Longitude: 89° 48' 53"
Property Owner: Paul Meeker		
Address: RR # 1, Box 31, Forest City, IL 61532		
Telephone: 309-597-2163		
Permission Date: 8-10-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 4679	Gauge ID No.: SWS 5100	
Placement: West of hedge row on southwest edge of home property. Property is on north side of 1900 N in Mason County, east of 2800 E, and the gauge is about 3 meters north of 1900 E. Gauge 5 meters northeast of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 11		
County: Mason	Latitude: 40° 20' 2"	Longitude: 89° 44' 4"
Property Owner: Louis Moehring		
Address: 32972 E. County Road 1900 N, Manito, IL 61546		
Telephone: 217-482-3320		
Permission Date: 8-10-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 3362	Gauge ID No.: SWS 4450	
Placement: North side (back) of house along a walk. Property is on northwest corner of intersection of 1900 N and 3300 E in Mason County. Gauge 12 meters southwest of lat/long reading.		

SITE DESCRIPTION		
Site Number: 12		
County: Tazewell	Latitude: 40° 20' 16"	Longitude: 89° 38' 26"
Property Owner: Harold Deiss		
Address: 1327 Route 29, San Jose, IL 62682		
Telephone: 309-247-3535		
Permission Date: 8-10-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 3346	Gauge ID No.: SWS 4439	
Placement: East side of Route 29 (1500 E) in Tazewell County in a grassy area southwest of a red shed. Deiss house is 1/4 mile north. Just north of Day Ditch. Gauge 2 meters south of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 13		
County: Mason	Latitude: 40° 15' 43"	Longitude: 90° 0' 48"
Property Owner: Don Hahn		
Address: 18307 E. Hahn/Stelter Rd., Havana, IL 62644		
Telephone: 309-543-4660		
Permission Date: 8-11-92		
Installation Date: 8-25-92		
Gauge Mfrs. No.: 5939	Gauge ID No.: --	
Placement: Left side of front entrance drive near a short fence. Property on south side of the diagonal 1450 N, east of Route 92. Gauge 3 meters north-northeast of lat/long reading.		

SITE DESCRIPTION		
Site Number: 14		
County: Mason	Latitude: 40° 15' 52"	Longitude: 89° 56' 33"
Property Owner: Wayne Patterson (650 E. Taintor Rd., Springfield, IL 62702-1755)		
Address: R.R. #1, Box 220, Easton, IL 62633		
Telephone: 309-543-4664		
Permission Date: 8-11-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 4678	Gauge ID No.: SWS 5098	
Placement: In a small clearing north of house. Property located on east side of 2200 E in Mason County south of 1500 N. Correspondence address changed to that of Wayne Patterson on 3-26-94. Gauge 17 meters northwest of lat/long reading. Station removed from network in September 1995.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 15		
County: Mason	Latitude: 40° 15' 27"	Longitude: 89° 50' 22"
Property Owner: c/o Joe Umbach		
Address: 25989 E. County Road 1300 N, Easton, IL 62633		
Telephone: 309-562-7611		
Permission Date: 8-12-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 6462	Gauge ID No.: CDA 000136	
Placement: Along right side of the house lane which extends north from 1410 N in Mason County between Route 10 and 2800 E. 1410 N runs from southwest to northeast along Central Ditch. Gauge 2 meters north-northeast of lat/long reading.		

SITE DESCRIPTION		
Site Number: 16		
County: Mason	Latitude: 40° 16' 5"	Longitude: 89° 44' 9"
Property Owner: Donald Osborn, Sr.		
Address: 32866 E. County Road 1450 N, Mason City, IL 62664		
Telephone: 217-482-5816		
Permission Date: 8-11-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 4666	Gauge ID No.: SWS 5059	
Placement: Along right side of drive near pigpen and road (1450 N). Property located on north side of 1450 N just west of 3300 E. Gauge 2 meters east of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 17		
County: Mason	Latitude: 40° 16' 51"	Longitude: 89° 38' 25"
Property Owner: Larry Jennings		
Address: 15316 County Road 3800 E, San Jose, IL 62682		
Telephone: 309-274-3781		
Permission Date: 8-11-92		
Installation Date: 8-24-92		
Gauge Mfrs. No.: 5280	Gauge ID No.: SWS 5317	
Placement: West of garage near back fence and animal petting area. Property located on 3800 E in Mason County just north of 1500 N. Gauge 34 meters west of lat/long reading. Station removed from network in September 1995.		

SITE DESCRIPTION		
Site Number: 18		
County: Mason	Latitude: 40° 11' 32"	Longitude: 90° 6' 15"
Property Owner: Vernon Heye		
Address: R.R. #1, Bath, IL 62617		
Telephone: 309-546-2266		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 5278	Gauge ID No.: SWS 5308	
Placement: East of white shed near field on east edge of home property. Property located on north side of 900 N in Mason County about 2 miles east of Bath. Gauge about 37 meters east-northeast of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 19		
County: Mason	Latitude: 40° 11' 1"	Longitude: 90° 0' 19"
Property Owner: Charles W. Lane		
Address: R.R. #1, Box 51, Kilbourne, IL 62655		
Telephone: 309-538-4397		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 4718	Gauge ID No.: SWS 5081	
Placement: Along a wire fence separating home property from pigpen, northwest of house. Property located on west side of Route 97 on southern end of a large curve between 900 N and 800 N. Gauge 14 meters northwest of lat/long reading.		

SITE DESCRIPTION		
Site Number: 20		
County: Mason	Latitude: 40° 11' 46"	Longitude: 89° 54' 56"
Property Owner: Wanda Krause		
Address: R.R. #1, Box 109, Easton, IL 62633		
Telephone: 309-562-7528		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 3371	Gauge ID No.: US 148830	
Placement: In yard of Jon Krause just north of east-west lane and west of lane to the Krause home. The gauge was moved to this position in early 1995. The previous location on the east side of 2400 E in Mason County near Jon Krause mailbox was in a strawberry patch along the same lane about 250 meters to the west on the Wanda Krause property. Gauge 150 meters east of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 21		
County: Mason	Latitude: 40° 11' 10"	Longitude: 89° 49' 39"
Property Owner: John Walters		
Address: 28030 E. County Road 850 N, Mason City, IL 62664		
Telephone: 309-562-7527		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 6294	Gauge ID No.: CDA 00013A	
Placement: East of the house and driveway and southeast of a shed. Property located on a hill on the northeast corner of the intersection of 2800 E and 850 N in Mason County. Position previous to 5-20-94 was between a windmill and a bush about 25 meters west of present position. Gauge 25 meters east of lat/long reading.		

SITE DESCRIPTION		
Site Number: 22		
County: Mason	Latitude: 40° 10' 46"	Longitude: 89° 44' 28"
Property Owner: current resident		
Address: 32706 E. County Road 800 N, Mason City, IL 62664		
Telephone: 217-482-5571		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 4708	Gauge ID No.: SWS 5021	
Placement: On a concrete slab with two two-by-fours attached to the base of the gauge, west of the house and lane on a ridge. Property is located on north side of 800 N in Mason County west of Route 29 and southwest of Mason City. Gauge 25 meters west of lat/long reading.		

Appendix C. (continued)

SITE DESCRIPTION		
Site Number: 23		
County: Mason	Latitude: 40° 12' 0"	Longitude: 89° 38' 28"
Property Owner: Dale C. Fancher		
Address: 9482 N. County Road 3800 E, Mason City, IL 62664-7209		
Telephone: 217-482-3506		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 3773	Gauge ID No.: US 148832	
Placement: On the west edge of a garden located north of a wood shop and the house. Property located on the west side of 3800 E in Mason County about a half mile north of Route 10, east of Mason City. Gauge 30 meters north-northwest of lat/long reading.		

SITE DESCRIPTION		
Site Number: 24		
County: Mason	Latitude: 40° 6' 26"	Longitude: 90° 11' 58"
Property Owner: Norman L. Fletcher		
Address: 3286 N. County Road 800 E, Bath, IL 62617		
Telephone: 309-546-2677		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: --	Gauge ID No.: --	
Placement: North of a garage near a grapevine, northeast of the house. Property located on the east side of 800 E in Mason County west of Route 78, just north of 300 N. Gauge 32 meters northeast of lat/long reading.		

Appendix C. (concluded)

SITE DESCRIPTION		
Site Number: 25		
County: Mason	Latitude: 40° 6' 14"	Longitude: 90° 8' 0"
Property Owner: Rocky Adkins		
Address: 11669 E. County Road 300 N, Chandlerville, IL 62627		
Telephone: 217-458-2587		
Permission Date: 8-11-92		
Installation Date: 8-26-92		
Gauge Mfrs. No.: 5947	Gauge ID No.: --	
Placement: Next to two tanks and a sign in a small grassy area surrounded by truck access. Property located at Adkins Farms on south side of 300 N (east of Route 78) in Mason County. Gauge 2 meters south of lat/long reading. Station removed from network in September 1995.		

Appendix D. Instructions for Rain Gauge Technicians

Appendix D. Instructions for Rain Gauge Technicians

A. Use Central Standard Time Year-Around

From November through March, Illinois is in the Central Standard Time zone, so your watch will indicate the correct time and date to be noted on the chart. From April through October when Illinois is in the Central Daylight Time zone, subtract one hour from your watch reading.

B. Order of Servicing

1) Old Chart

a) Unlock and open (slide up) door on the side of the instrument case and then lock door in place to prevent it from falling.
b) Depress the bucket platform casting to mark the OFF time position on the chart (a vertical trace will be written by the pen).
c) Note the time on your watch, and move the pen point and arm away from the chart by pushing out on the pen shifter.
d) Lift up on the chart cylinder that contains the chart to disengage it from the chart drive, and remove it.
e) Remove the chart from the cylinder and write the OFF date and time on the chart on the red line at the right end of the chart.

2) Bucket

a) Remove the collector from the top of the gauge by rotating it clockwise to disengauge the tongue-and-groove assembly.
b) Carefully lift the bucket off of the weighing platform. If there is water in it and no antifreeze, dump the water on the ground.
c) Reposition the empty bucket on the platform.
d) Reinstall the collector by setting it on top of the rain gauge case and turning it counterclockwise until the tongue-and-groove assembly meshes.
e) During wintertime operation, when 2 inches (about one quart) of antifreeze is in the bucket to prevent freezing, leave the liquid in the bucket until the chart reading passes the 6-inch mark. At that point, pour the bucket contents into a sealed container and dispose of properly. DO NOT POUR SOLUTION ONTO THE GROUND! If wintertime conditions prevail, recharge the empty bucket with 2 inches of antifreeze. Reposition the dry bucket on the platform and reinstall the collector assembly.
f) In the winter, stir the contents of the bucket to keep the antifreeze mixed with the water.
g) At any time of the year, once the collector is repositioned, check the gauge to make sure the collector orifice top edge is level.

3) New Chart

a) Copy the OFF time from the old chart to the ON time on the new chart (another red line on the end of the chart), and write your site number on the chart.
b) Clip the new chart to the cylinder, making sure the crease at the right end of the chart is sharp and the chart is tight on the cylinder.
c) Reinstall the chart cylinder onto the chart drive, making sure the chart cylinder and drive gears mesh. Simply push down on the cylinder and wiggle it a little. You should feel some resistance if done correctly.
d) Move the pen arm and point over to the chart cylinder with the pen bracket and rotate the cylinder counterclockwise until the pen point coincides with the correct ON time position.
e) Let the pen point rest right on the chart and depress the platform casting again to make a small vertical line denoting the ON time position. This also insures that the pen point is writing correctly. If it is not, check the tip of the pen point to see why it is not drawing. Replace if necessary. It helps if the word "ON" is written on the chart near the ON line for later chart editing. Rezero the pen point if necessary by turning the fine adjustment screw. It is a good idea to "zero" the pen near the 0.25-inch mark to prevent evaporation from taking the pen point below the zero line.
g) When you are sure that everything is in order, carefully unlock the door, push the door down, and lock it in place for another month.

4) Data Logger

a) Plug HP200X Palmtop PC into the data logger and download data.
b) Transfer data to flash card.
c) Mail flash card and charts to ISWS.

5) Problems

a) If you notice anything unusual about the gauge or the chart drive, write a note on the upper right corner of the old chart.
b) If you think the problem requires immediate attention, call Nancy Westcott collect at 217-244-0884 or e-mail her at nan@uiuc.edu, to relay the information. Situations worthy of immediate attention include questions concerning the operation described above, premature chart-drive stoppage, data logger problems, or unauthorized tampering with the gauge. Immediate repairs will be scheduled if necessary.
c) Write a note describing problems and send with the charts, when mailing charts to the ISWS.
d) Also, write a note or call when new supplies are needed: antifreeze, pen tips, batteries, charts, spare clock drive, envelopes, and stamps.

6) Annual Tasks

a) In the fall, usually November, the gauges are winterized. The evaporation shield is removed. Antifreeze is added to the bucket. The clock batteries are changed.

b) Usually in December, the batteries in the data loggers are changed by the ISWS field technician.

c) Usually in March or April, the antifreeze is removed as per 2e above, and the evaporation shield is reinstalled.

c) Over the span of two years, all gauges should be recalibrated and cleaned in the field by the ISWS field technician.

C. Change in Site Status

If the gauge is no longer wanted on the property, please contact call Nancy Westcott collect at 217-244-0884 or email her at nan@uiuc.edu immediately so that new arrangements can be made. It is important to try to keep the sites near the same locations during the course of this project because precipitation generally can vary greatly over short distances.

Appendix E. Documentation, Imperial Valley Rain Gauge Network Maintenance, 2002-2003

Appendix E. Documentation, Imperial Valley Rain Gauge Network Maintenance, 2002-2003

This appendix documents major maintenance work carried out at sites in the Imperial Valley rain gauge network from September 1, 2002 through August 31, 2003.

1. Replaced all clock batteries and winterized all gauges on 11-01/02-2002.

2. Resoldered data logger connector wires at site 6 and site 7 on 11-06-2002.

3. Replaced all data logger batteries on 12-09-2002.

4. Resoldered data logger connector wires at site 21 on 01-07-2003.

5. Replaced antifreeze at all sites on 02-04/05-2003.

6. Resoldered data logger connector wires at site 12 on 03-05-2003.

7. Cleaned and recalibrated gauges at sites 8, 19, and 21 on 03-07-2003.

8. Cleaned and recalibrated gauges at sites 3, 7, and 12 on 03-25-2003.

9. Repositioned evaporation shields at sites 21 and 24 on 05-02-2003. Had been knocked into the buckets, probably during the hailstorm on 04-04-2003.

10. Cleaned and recalibrated gauges at sites 19 and 21 on 05-06-2003.

11. Cleaned and recalibrated the gauge at site 18 on 05-22-2003.

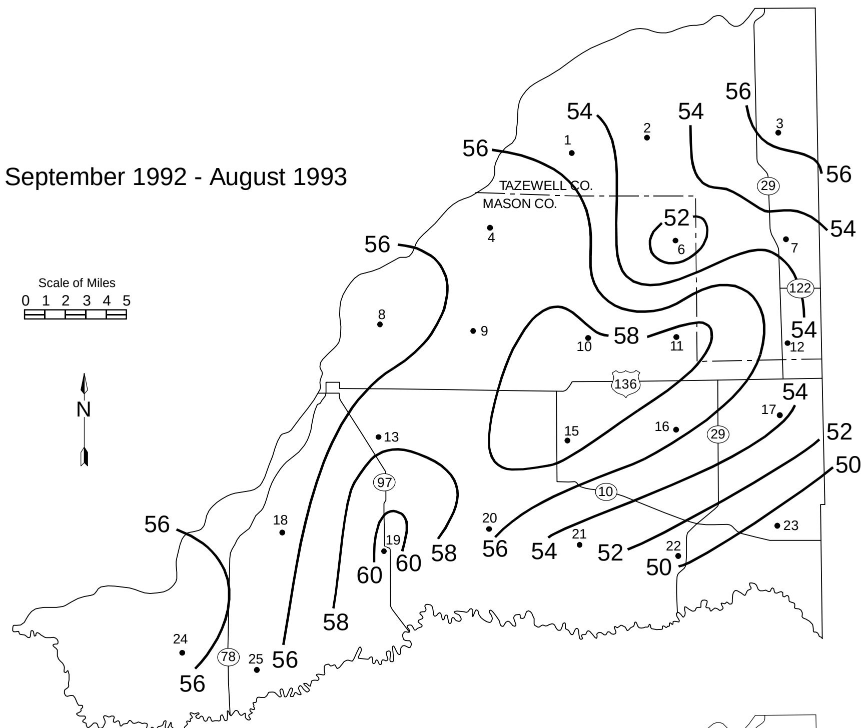
12. Cleaned and recalibrated the gauge at sites 20 and 22 on 06-09-2003.

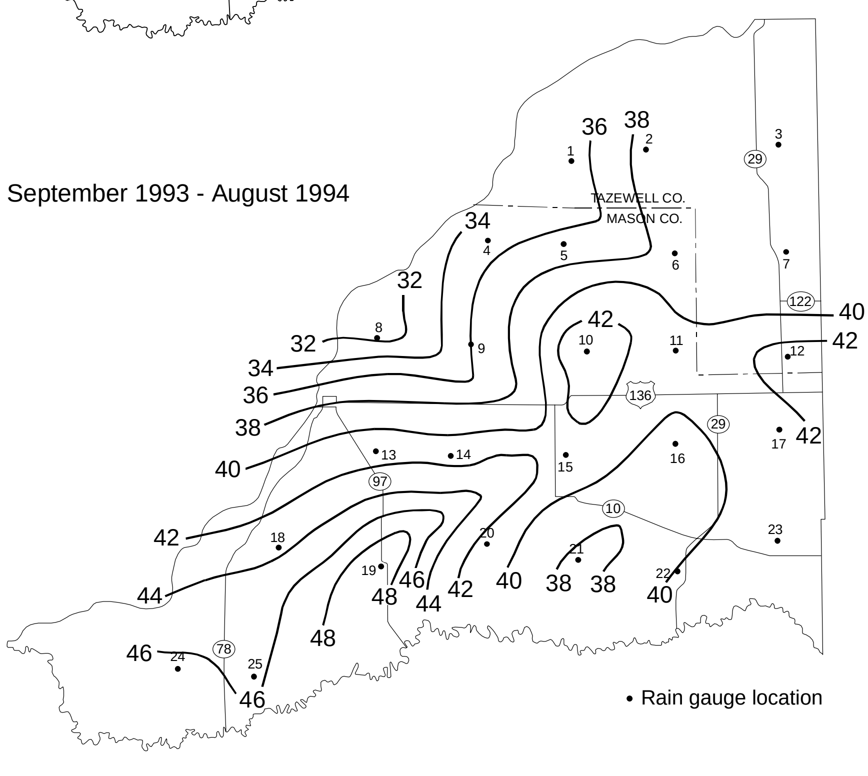
13. Cleaned and recalibrated the gauge at sites 4 and 9 on 07-24-2003.

Appendix F. Annual Precipitation, Years One-Ten

Appendix F. Annual Precipitation, Years One-Ten

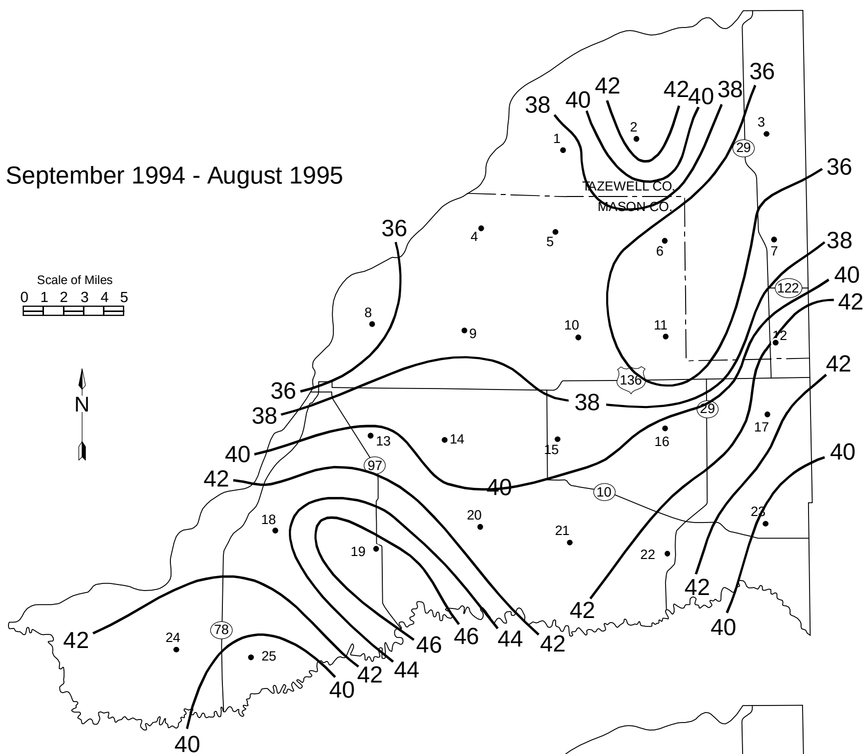
(Rain gauge #16 omitted from Years 5-9)



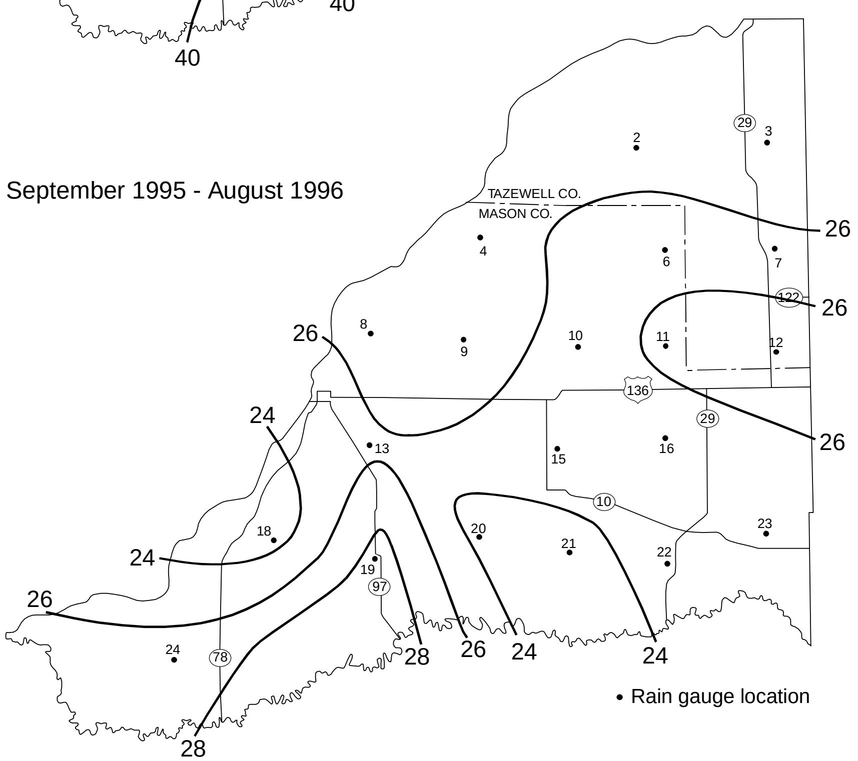


Appendix F. (continued)

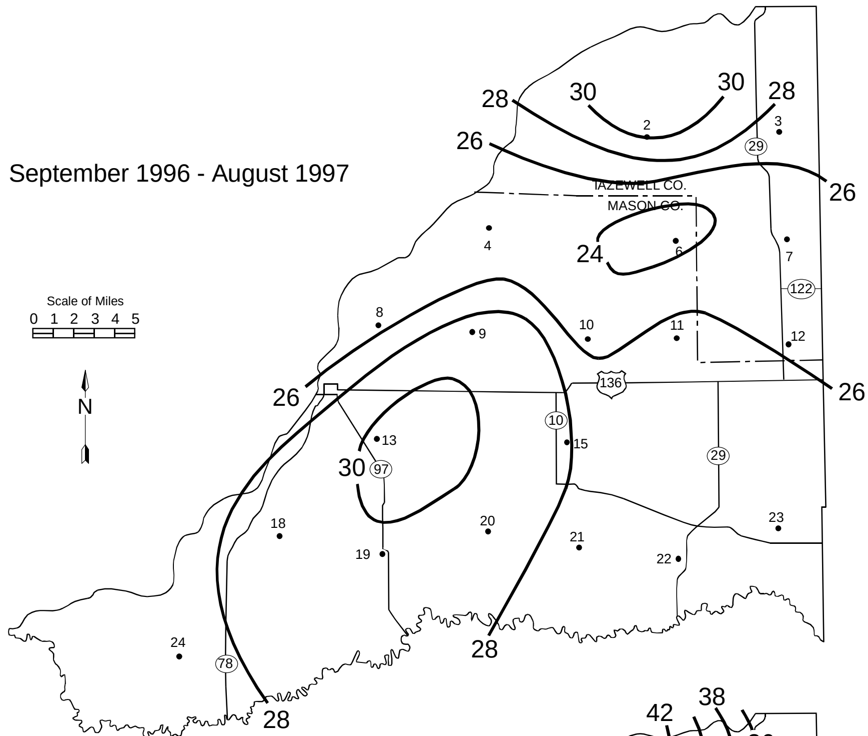
September 1994 - August 1995

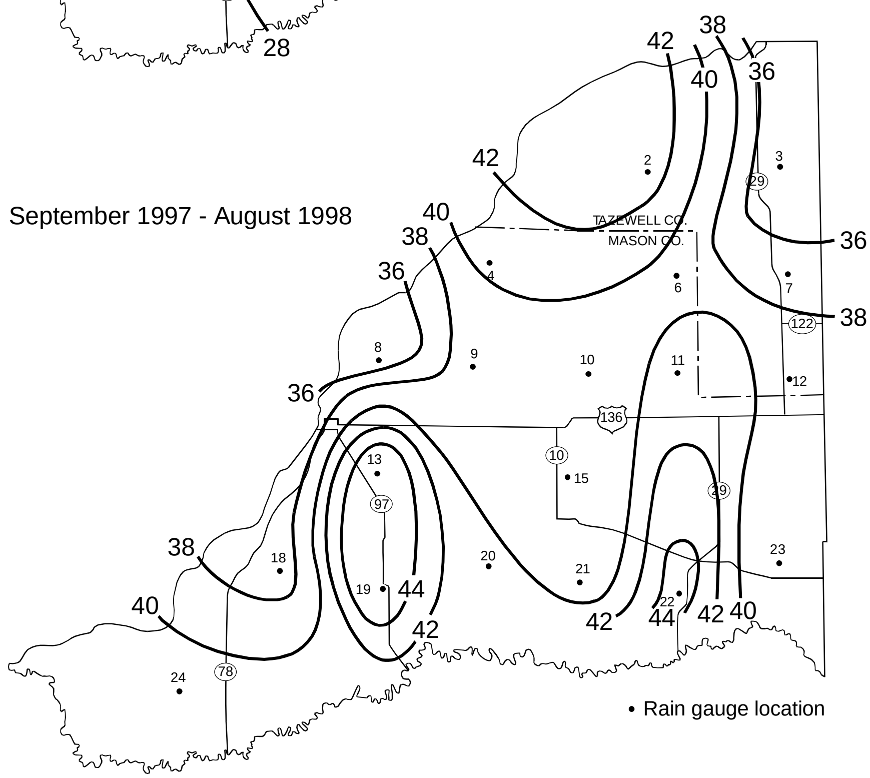


September 1995 - August 1996



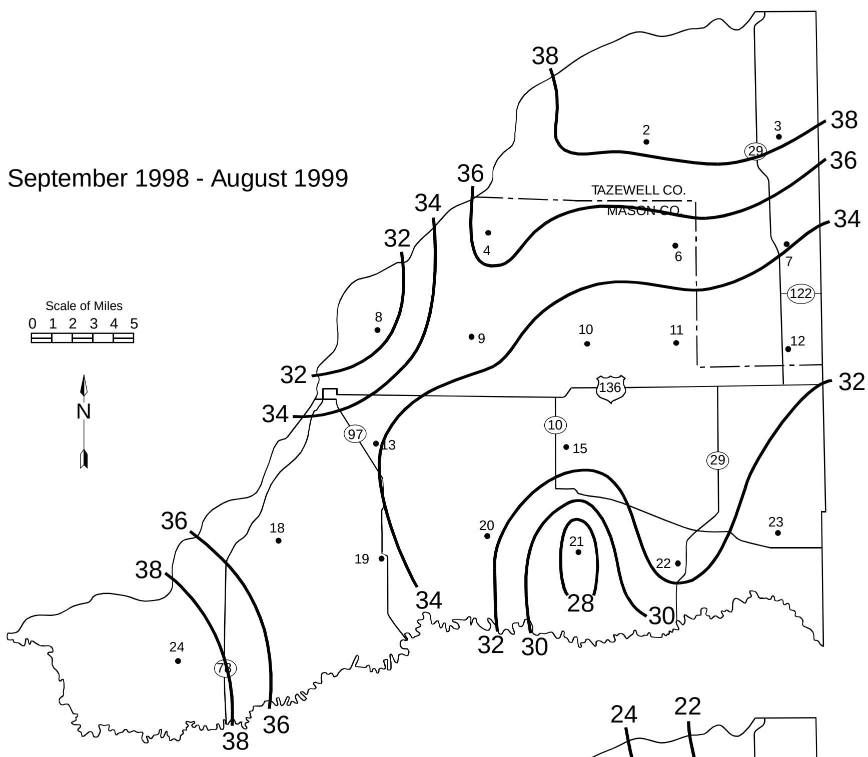
Appendix F. (continued)



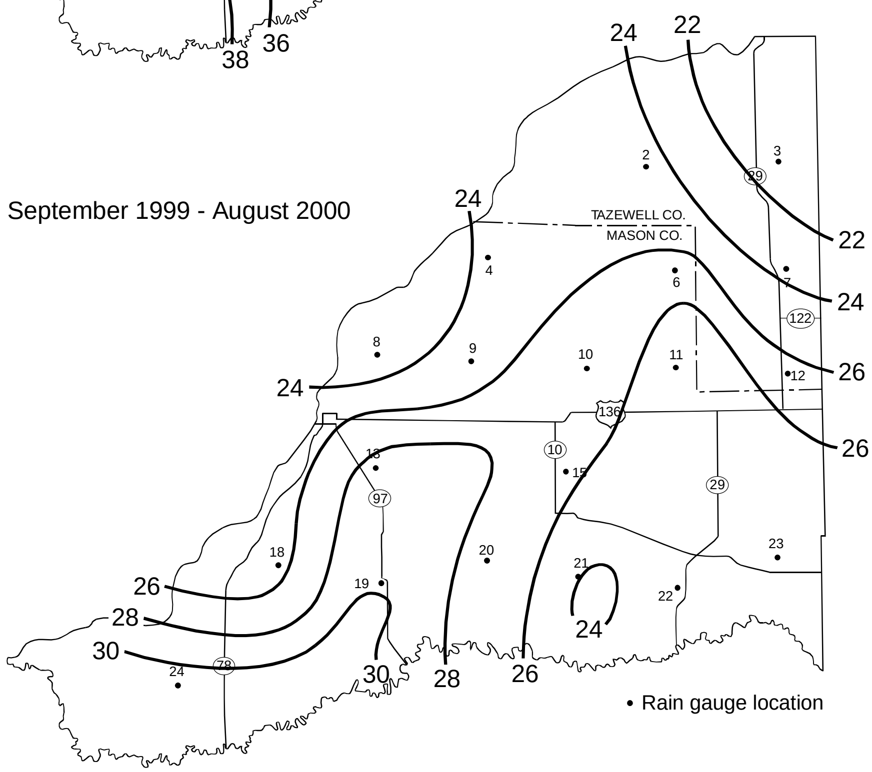


Appendix F. (continued)

September 1998 - August 1999

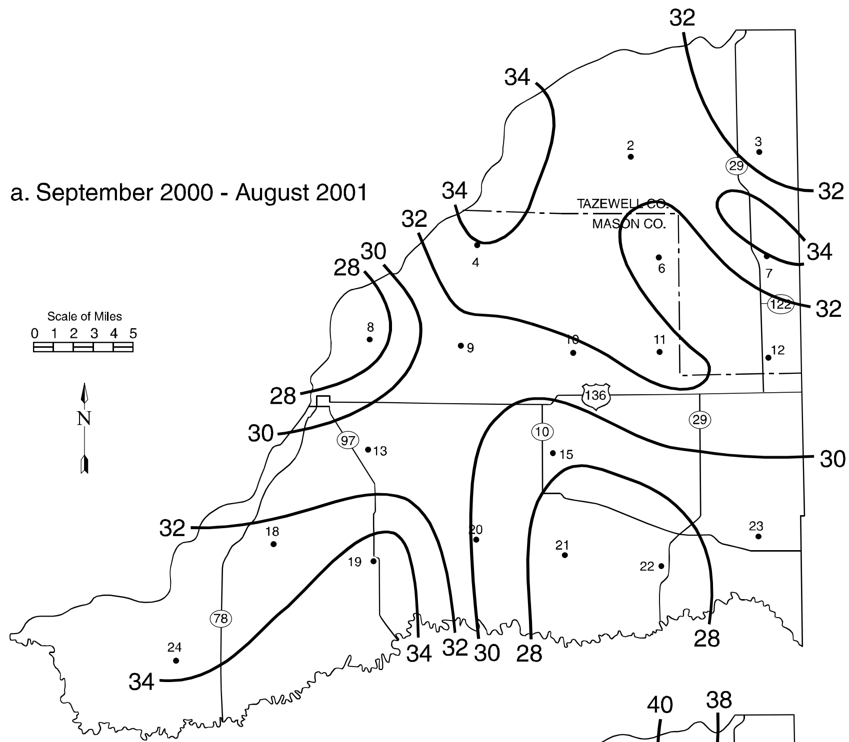


September 1999 - August 2000

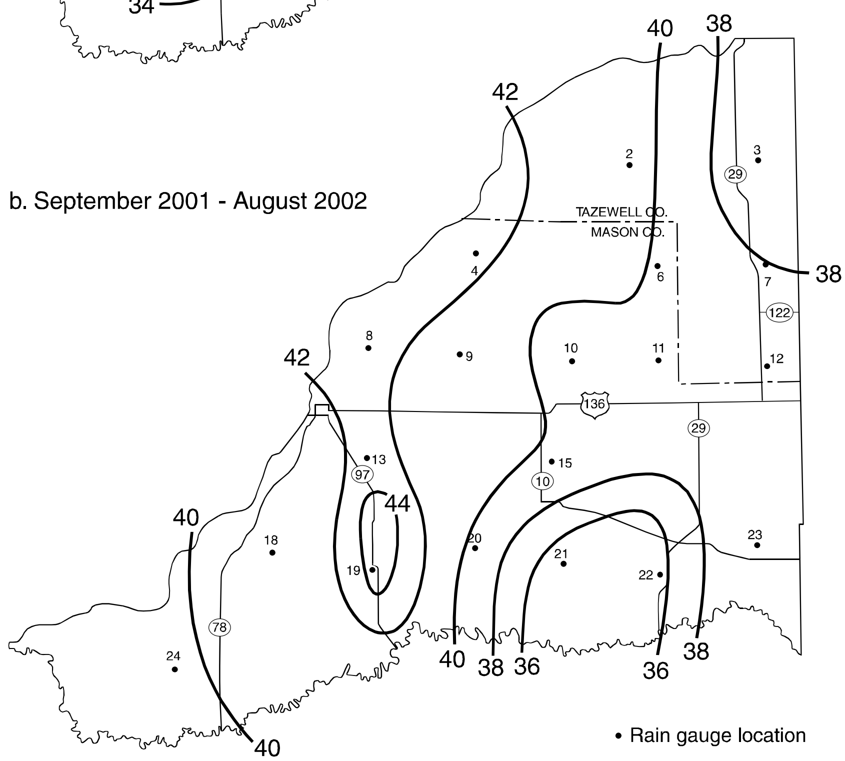


Appendix F. (concluded)

a. September 2000 - August 2001



b. September 2001 - August 2002



Appendix G. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992-2002

Appendix G. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992-2002

	Number of precipitation events									
Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	10	8	6	6	6	6	8	8	10	7
October	10	5	7	9	11	7	11	6	10	17
November	13	7	10	3	9	8	14	17	11	12
December	9	9	8	5	5	10	6	14	21	9
January	9	8	5	8	13	12	19	11	18	4
February	5	6	3	4	8	7	17	21	8	9
March	10	6	6	7	8	8	6	9	7	12
April	11	12	19	6	11	12	18	14	14	9
May	16	7	16	25	15	16	15	16	14	13
June	13	13	15	11	14	17	12	12	11	10
July	21	9	16	10	6	15	9	11	10	10
August	21	12	18	4	15	16	9	17	14	10
Fall	33	20	23	18	26	21	33	31	31	36
Winter	23	23	16	17	26	29	42	46	47	22
Spring	37	25	41	38	34	36	39	39	35	34
Summer	55	34	49	25	35	48	30	40	35	30
Annual	148	102	129	98	121	134	144	156	148	122

	Total precipitation, inches									
Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	4.21	11.56	1.49	2.00	1.63	2.55	1.61	0.87	1.93	2.35
October	2	2.97	3.34	3.06	1.99	1.43	2.07	0.92	1.79	4.89
November	6.35	2.59	3.37	1.84	2.15	3.1	2.7	0.48	2.05	2.5
December	2.82	1.11	2.29	0.45	0.9	1.47	0.81	2.07	1.17	1.43
January	3.52	0.96	2.90	1.01	1.28	2.59	2.84	0.63	3.35	2.64
February	1.64	1.64	0.61	0.77	3.86	2.65	1.32	2	2.78	1.28
March	3.85	0.96	1.93	1.93	1.92	4.51	1.32	1.68	1.5	1.58
April	5.25	5.03	4.87	2.61	1.76	3.53	4.42	1.59	3.31	4.24
May	2.61	3.11	10.33	5.37	2.94	5.21	4.65	4.39	4.89	5.43
June	6.27	3.19	2.65	2.85	1.97	7.19	4.41	4.76	3.08	4.23
July	11.05	3.44	2.73	2.84	2.51	2.34	4.56	4.39	1.3	3.99
August	5.99	3.66	2.90	0.98	4.41	3.5	3.3	2.02	3.81	5.37
Fall	12.56	17.12	8.20	6.89	5.77	7.08	6.38	2.27	5.77	9.74
Winter	7.97	3.70	5.80	2.23	6.04	6.71	4.97	4.7	7.3	5.35
Spring	11.71	9.10	17.14	9.91	6.62	13.25	10.39	7.66	9.7	11.25
Summer	23.31	10.29	8.28	6.68	8.89	13.03	12.27	11.17	8.19	13.59
Annual	55.55	40.21	39.42	25.7	27.31	40.06	34.02	25.81	30.97	39.91

Appendix G. (concluded)

Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
	Inches of precipitation per precipitation event									
September	0.42	1.45	0.25	0.33	0.27	0.43	0.2	0.11	0.19	0.34
October	0.2	0.59	0.48	0.34	0.18	0.2	0.19	0.15	0.18	0.29
November	0.49	0.37	0.34	0.61	0.24	0.39	0.19	0.03	0.19	0.21
December	0.31	0.12	0.29	0.09	0.18	0.15	0.14	0.15	0.06	0.16
January	0.39	0.12	0.58	0.13	0.10	0.22	0.15	0.06	0.19	0.66
February	0.33	0.27	0.20	0.19	0.48	0.38	0.08	0.1	0.35	0.14
March	0.38	0.16	0.32	0.28	0.24	0.56	0.22	0.19	0.21	0.13
April	0.48	0.42	0.26	0.43	0.16	0.29	0.25	0.11	0.24	0.47
May	0.16	0.44	0.65	0.21	0.2	0.33	0.31	0.27	0.35	0.42
June	0.48	0.25	0.18	0.26	0.14	0.42	0.37	0.4	0.28	0.42
July	0.53	0.38	0.17	0.28	0.42	0.16	0.51	0.4	0.13	0.4
August	0.29	0.31	0.16	0.25	0.29	0.22	0.37	0.12	0.27	0.54
Fall	0.38	0.86	0.36	0.38	0.22	0.34	0.19	0.07	0.19	0.27
Winter	0.35	0.16	0.36	0.13	0.23	0.23	0.12	0.1	0.16	0.24
Spring	0.32	0.36	0.42	0.26	0.19	0.37	0.27	0.2	0.28	0.33
Summer	0.42	0.30	0.17	0.27	0.25	0.27	0.41	0.28	0.23	0.45
Annual	0.38	0.39	0.31	0.26	0.23	0.3	0.24	0.17	0.21	0.33

Note:
The tables are based upon the total number of precipitation events in a given month, season or year.

Appendix H. Documentation, Heavy Storm Amounts in the Imperial Valley, 2002-2003

Appendix H. Documentation, Heavy Storm Amounts in the Imperial Valley, 2002-2003

This appendix documents all storm period amounts, start times, and durations, and notes those that exceed an expected event amount (for one-year to 100-year recurrence intervals) during the period September 1, 2002-August 31, 2003. The same information for previous years is found in Wehrmann et al. (2004). Individual network storm durations of one hour to ten days were considered. The precipitation amounts and storm durations for one- to 100-year recurrence intervals for west-central Illinois are given below (Huff and Angel, 1989).

To determine the return frequency of any storm in Table H-2 or H-3, obtain the storm duration from the tables, then look in the left-hand column of Table H-1 to locate the storm duration that equals or just exceeds the storm duration in Table H-2 or H-3. If the precipitation for the event at any gauge in Table H-2 or H-3 exceeds the amount in Table H-1, obtain the return frequency by looking at the heading of the right-hand column that the precipitation amount exceeds. For example, Table H-3 indicates storm number 1367 has a duration of 21 hours. This storm duration falls between the 18- and 24-hour storm duration in Table H-1. Assume an 24-hour storm duration. Table H-3 indicates the gauge at site 13 recorded precipitation equal to 2.54 inches, and the gauge at site 20 recorded 3.10 inches. Therefore, site 13 exceeded the one-year return frequency amount (2.52 inches) for an 18-hour storm, and site 20 exceeded the 2-year return frequency amount (3.02 inches) for an 24-hour storm.

The following table documents for each network storm period, start times (CST), storm duration (hours), number of gauges recording precipitation, average precipitation (inches) over the 20-gauge network, average precipitation (inches) at gauges receiving precipitation during the event, maximum precipitation (inches) at any gauge during the storm period, and gauge location. The last column in the table indicates whether the maximum precipitation for the storm exceeds the expected amount for the observed storm duration (one-year to 100-year recurrence intervals) considered. A storm recurrence frequency of 50 years means that a storm of this intensity and duration would be expected once every 50 years.

Table H-1. Precipitation Amounts for Different Storm Durations and Recurrence Intervals

Storm duration	*Precipitation (inches) for given recurrence interval*						
	1-Yr	*2-Yr*	*5-Yr*	*10-Yr*	*25-Yr*	*50-Yr*	*100-Yr*
1 hour	1.18	1.42	1.77	2.09	2.50	2.86	3.25
2 hours	1.48	1.78	2.22	2.62	3.14	3.59	4.08
3 hours	1.61	1.93	2.41	2.85	3.41	3.89	4.43
6 hours	1.89	2.26	2.82	3.33	3.99	4.56	5.19
12 hours	2.17	2.62	3.27	3.87	4.63	5.29	6.02
18 hours	2.28	2.75	3.46	4.09	4.90	5.59	6.37
24 hours	2.52	3.02	3.76	4.45	5.32	6.08	6.92
48 hours	2.81	3.38	4.19	4.86	5.78	6.62	7.51
72 hours	3.05	3.70	4.55	5.26	6.15	7.25	8.16
5 days	3.48	4.17	5.11	5.84	6.96	7.98	9.21
10 days	4.29	5.12	6.27	7.10	8.19	9.10	10.18

Table H-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2002-2003

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maximum precipitation (inches)*	*Gage no. with maximum*	*Storm recurrence frequency*
					September 2002				
1303	15	300	15	20	0.23	0.23	0.85	23	
1304	19	1800	5	10	0.08	0.16	0.44	7	
1305	20	400	7	19	0.07	0.08	0.13	24	
					October 2002				
1306	4	500	9	20	0.39	0.39	0.59	7	
1307	18	1100	3	4	0.01	0.07	0.09	3	
1308	18	1900	6	20	0.44	0.44	0.93	24	
1309	23	2000	5	3	0.01	0.04	0.05	13	
1310	24	900	2	2	0.00	0.04	0.04	2	
1311	25	200	9	20	0.25	0.25	0.29	13	
1312	29	300	10	20	0.40	0.40	0.68	16	
1313	30	1500	13	20	0.15	0.15	0.24	13	
					November 2002				
1314	3	1000	10	19	0.05	0.06	0.08	2	
1315	4	800	3	7	0.01	0.04	0.04	9	
1316	5	600	11	20	0.39	0.39	0.51	16	
1317	10	1300	1	20	0.04	0.04	0.04	2	
1318	14	1900	13	20	0.07	0.07	0.12	19	
1319	18	2000	2	4	0.01	0.04	0.04	4	
1320	21	1000	4	20	0.04	0.04	0.08	7	
					December 2002				
1321	17	1700	29	20	1.85	1.85	2.85	4	1-yr, 48-hr
1322	24	1500	12	14	0.10	0.14	0.30	21	
					January 2003				
1323	2	200	15	15	0.19	0.25	0.55	19	
1324	4	1900	6	15	0.03	0.05	0.08	6	
1325	16	400	10	17	0.07	0.08	0.16	8	
1326	28	2000	6	18	0.07	0.07	0.12	8	
1327	29	1000	3	6	0.01	0.04	0.04	7	
1328	31	400	14	20	0.24	0.24	0.33	2	
					February 2003				
1329	3	800	16	18	0.05	0.06	0.12	7	
1330	9	2300	19	19	0.04	0.04	0.08	7	
1331	11	200	12	20	0.10	0.10	0.17	18	
1332	11	1900	2	3	0.01	0.04	0.04	10	
1333	14	1000	37	20	0.88	0.88	1.37	3	

Table H-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2002-2003

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maximum precipitation (inches)*	*Gage no. with maximum*	*Storm recurrence frequency*
					March 2003				
1334	4	2300	15	10	0.02	0.05	0.08	2	
1335	18	2100	31	20	0.73	0.73	1.12	24	
1336	20	800	5	9	0.02	0.04	0.08	18	
1337	20	1800	8	20	0.27	0.27	0.58	15	
1338	24	2100	14	20	0.30	0.30	0.61	19	
1339	28	700	10	20	0.50	0.50	0.60	19	
					April 2003				
1340	4	100	17	20	1.56	1.56	2.27	22	
1341	6	2000	9	20	0.47	0.47	0.86	23	
1342	16	1800	15	20	0.33	0.33	0.82	19	
1343	24	800	30	20	0.85	0.85	1.59	19	
1344	28	1200	4	8	0.02	0.06	0.10	13	
1345	30	100	10	20	0.51	0.51	1.25	19	
					May 2003				
1346	1	100	14	19	0.12	0.13	0.26	2	
1347	4	1200	22	20	1.21	1.21	1.93	7	
1348	8	1700	19	20	0.27	0.27	0.51	23	
1349	9	2000	21	20	1.11	1.11	2.12	6	
1350	10	2100	3	14	0.23	0.33	1.02	3	
1351	15	300	10	19	0.15	0.16	0.30	22	
1352	19	1200	5	4	0.03	0.15	0.46	24	
1353	19	2000	2	3	0.04	0.29	0.79	10	
1354	30	1100	2	9	0.01	0.02	0.04	6	
1355	30	1900	2	4	0.02	0.11	0.21	12	
					June 2003				
1356	2	1700	15	20	0.30	0.30	0.46	24	
1357	3	1200	3	2	0.00	0.04	0.04	16	
1358	6	900	8	20	0.41	0.41	0.56	16	
1359	10	500	5	20	0.32	0.32	0.54	24	
1360	11	200	15	16	0.52	0.65	2.76	16	2-yr, 18-hr
1361	13	300	14	20	1.67	1.67	2.74	11	1-yr, 18-hr
1362	25	1900	16	20	1.09	1.09	1.40	9	
1363	28	2200	1	2	0.01	0.06	0.08	2	
1364	29	500	6	7	0.03	0.08	0.17	9	
1365	29	1800	9	11	0.14	0.25	0.76	3	
1366	30	800	5	6	0.01	0.04	0.05	3	

Table H-2. (concluded)

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maximum precipitation (inches)*	*Gage no. with maximum*	*Storm recurrence frequency*
					July 2003				
1367	8	1500	21	20	1.84	1.84	3.10	20	2-yr, 24-hr
1368	9	1800	17	20	2.45	2.45	3.44	2	2-yr, 18-hr
1369	18	300	10	20	0.95	0.95	2.51	24	1-yr, 12-hr
1370	21	100	10	12	0.42	0.70	1.43	12	
1371	28	600	7	20	0.38	0.38	0.51	4	
					August 2003				
1372	1	200	2	4	0.01	0.04	0.04	2	
1373	1	800	2	5	0.01	0.03	0.04	4	
1374	2	1100	7	10	0.16	0.33	1.39	8	
1375	2	2300	3	2	0.03	0.25	0.43	18	
1376	3	1500	17	17	0.42	0.50	2.11	23	
1377	6	300	8	16	0.05	0.06	0.13	22	
1378	7	1600	2	1	0.01	0.25	0.25	18	
1379	11	1600	4	4	0.06	0.30	0.86	19	
1380	12	1600	4	4	0.04	0.18	0.27	13	
1381	29	200	15	20	1.77	1.77	2.79	16	2-yr, 18-hr
1382	31	100	26	20	1.88	1.88	2.52	16	

Appendix H-3. Precipitation (inches) Received at Each Station from Each Storm Period during the 2002-2003 Observation Period

Storm	*Date*	*Hour*	*Duration**	*Rain gauge site no.*																			
				2	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*15*	*16*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
1303	9152002	300	15	0.21	0.09	0.09	0.17	0.20	0.08	0.43	0.20	0.25	0.12	0.14	0.16	0.21	0.16	0.26	0.30	0.21	0.38	0.85	0.16
1304	9192002	1800	5	0.17	0.00	0.00	0.04	0.44	0.00	0.00	0.00	0.09	0.21	0.04	0.00	0.35	0.00	0.00	0.00	0.21	0.04	0.04	0.00
1305	9202002	400	7	0.08	0.05	0.04	0.08	0.08	0.08	0.00	0.08	0.08	0.12	0.10	0.04	0.08	0.08	0.04	0.04	0.04	0.09	0.12	0.13
1306	10042002	500	9	0.54	0.44	0.29	0.50	0.59	0.25	0.46	0.41	0.47	0.47	0.32	0.46	0.56	0.17	0.26	0.39	0.29	0.48	0.26	0.25
1307	10182002	1100	3	0.08	0.09	0.08	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1308	10182002	1900	6	0.08	0.27	0.26	0.40	0.38	0.26	0.21	0.29	0.34	0.35	0.27	0.52	0.48	0.67	0.64	0.65	0.57	0.69	0.51	0.93
1309	10232002	2000	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04
1310	10242002	900	2	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1311	10252002	200	9	0.21	0.24	0.21	0.25	0.25	0.24	0.24	0.24	0.16	0.17	0.29	0.29	0.26	0.24	0.29	0.29	0.24	0.28	0.25	0.28
1312	10292002	300	10	0.33	0.42	0.34	0.40	0.37	0.34	0.34	0.36	0.42	0.51	0.27	0.39	0.68	0.26	0.47	0.34	0.33	0.47	0.52	0.34
1313	10302002	1500	13	0.16	0.14	0.12	0.15	0.16	0.16	0.16	0.12	0.12	0.16	0.24	0.12	0.21	0.17	0.16	0.16	0.16	0.12	0.08	0.16
1314	11032002	1000	10	0.08	0.04	0.04	0.08	0.06	0.08	0.04	0.08	0.08	0.04	0.05	0.04	0.00	0.04	0.08	0.04	0.04	0.04	0.04	0.08
1315	11042002	800	3	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.04	0.00
1316	11052002	600	11	0.37	0.37	0.42	0.40	0.37	0.43	0.34	0.37	0.34	0.43	0.36	0.38	0.51	0.33	0.48	0.34	0.42	0.38	0.40	0.33
1317	11102002	1300	1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1318	11142002	1900	13	0.04	0.05	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.08	0.09	0.08	0.04	0.08	0.12	0.08	0.08	0.08	0.04	0.08
1319	11182002	2000	2	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00
1320	11212002	1000	4	0.04	0.04	0.04	0.04	0.08	0.04	0.04	0.04	0.04	0.08	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1321	12172002	1700	29	2.37	1.45	**2.85**	1.34	1.20	2.12	2.02	1.42	1.25	1.25	2.73	1.60	1.78	2.56	2.08	1.84	1.75	1.35	1.75	2.38
1322	12242002	1500	12	0.08	0.00	0.16	0.00	0.00	0.29	0.12	0.00	0.08	0.04	0.05	0.08	0.02	0.24	0.25	0.00	0.30	0.04	0.00	0.25
1323	1022003	200	15	0.04	0.00	0.16	0.00	0.00	0.29	0.41	0.12	0.08	0.00	0.40	0.45	0.04	0.16	0.55	0.38	0.35	0.00	0.04	0.29
1324	1042003	1900	6	0.00	0.00	0.04	0.08	0.04	0.04	0.04	0.04	0.08	0.04	0.05	0.04	0.00	0.04	0.04	0.04	0.00	0.04	0.04	0.00
1325	1162003	400	10	0.04	0.00	0.08	0.04	0.04	0.16	0.12	0.08	0.08	0.12	0.09	0.12	0.00	0.00	0.12	0.04	0.04	0.04	0.12	0.08
1326	1282003	2000	6	0.08	0.00	0.08	0.08	0.08	0.12	0.12	0.04	0.09	0.12	0.05	0.04	0.00	0.04	0.12	0.08	0.08	0.04	0.04	0.04
1327	1292003	1000	3	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04
1328	1312003	400	14	0.33	0.24	0.20	0.20	0.24	0.20	0.25	0.20	0.20	0.25	0.28	0.25	0.16	0.24	0.29	0.28	0.12	0.25	0.33	0.25
1329	2032003	800	16	0.04	0.05	0.04	0.04	0.12	0.00	0.04	0.04	0.08	0.08	0.00	0.08	0.04	0.04	0.04	0.04	0.08	0.08	0.08	0.04

Notes:
*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Appendix H-3. (continued)

Storm	*Date*	*Hour*	*Duration**	*Rain gauge site no.* 2	3	4	6	7	8	9	10	11	12	13	15	16	18	19	20	21	22	23	24
1330	2092003	2300	19	0.04	0.04	0.00	0.03	0.08	0.04	0.04	0.02	0.04	0.08	0.05	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.04	0.02
1331	2112003	200	12	0.08	0.10	0.08	0.08	0.04	0.08	0.12	0.08	0.04	0.08	0.15	0.08	0.08	0.17	0.16	0.16	0.12	0.12	0.08	0.16
1332	2112003	1900	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00
1333	2142003	1000	37	0.75	1.37	1.18	0.76	0.71	1.13	0.79	0.73	0.87	1.01	0.98	0.70	1.02	0.66	1.25	0.70	0.81	0.76	0.80	0.71
1334	3042003	2300	15	0.08	0.00	0.04	0.00	0.04	0.04	0.08	0.04	0.04	0.00	0.05	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1335	3182003	2100	31	0.41	0.67	0.75	0.46	0.56	0.67	0.93	0.57	0.51	0.62	0.78	0.75	0.98	0.92	0.84	1.02	0.75	0.59	0.68	1.12
1336	3202003	800	5	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.04	0.04	0.04
1337	3202003	1800	8	0.21	0.18	0.29	0.22	0.17	0.18	0.33	0.16	0.17	0.04	0.31	0.58	0.35	0.12	0.52	0.39	0.40	0.26	0.21	0.25
1338	3242003	2100	14	0.20	0.14	0.16	0.30	0.25	0.17	0.38	0.28	0.34	0.47	0.36	0.43	0.04	0.41	0.61	0.42	0.25	0.26	0.16	0.34
1339	3282003	700	10	0.56	0.46	0.46	0.46	0.46	0.38	0.55	0.53	0.45	0.50	0.55	0.50	0.42	0.50	0.60	0.59	0.57	0.51	0.42	0.54
1340	4042003	100	17	0.88	1.35	1.45	2.17	2.24	1.43	1.45	1.29	1.82	1.01	1.56	1.31	1.82	1.64	1.21	1.65	1.97	2.27	1.03	1.68
1341	4062003	2000	9	0.46	0.72	0.38	0.43	0.55	0.24	0.29	0.29	0.38	0.51	0.23	0.46	0.78	0.20	0.51	0.43	0.65	0.73	0.86	0.28
1342	4162003	1800	15	0.25	0.18	0.45	0.25	0.12	0.56	0.34	0.37	0.16	0.16	0.53	0.39	0.08	0.42	0.82	0.38	0.19	0.17	0.12	0.66
1343	4242003	800	30	0.46	0.41	0.66	0.50	0.41	0.89	0.85	0.74	0.68	0.59	0.95	1.03	1.24	0.96	1.59	1.12	1.04	0.85	0.73	1.26
1344	4282003	1200	4	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.10	0.04	0.00	0.04	0.09	0.04	0.01	0.00	0.00	0.09
1345	4302003	100	10	0.50	0.27	0.47	0.12	0.39	0.38	0.29	0.21	0.30	0.50	0.48	0.51	0.79	0.46	1.25	0.39	0.71	1.01	0.81	0.46
1346	5012003	100	14	0.26	0.19	0.17	0.08	0.04	0.25	0.16	0.12	0.08	0.21	0.20	0.04	0.08	0.13	0.08	0.08	0.00	0.08	0.08	0.12
1347	5042003	1200	22	1.05	1.16	1.15	1.48	1.93	1.08	1.11	1.19	1.52	1.33	0.85	1.22	1.87	1.09	1.14	1.17	0.80	0.95	0.98	1.08
1348	5082003	1700	19	0.30	0.36	0.26	0.39	0.39	0.26	0.30	0.25	0.22	0.16	0.05	0.13	0.13	0.20	0.34	0.30	0.16	0.35	0.51	0.42
1349	5092003	2000	21	0.80	0.81	0.86	2.12	1.55	0.91	1.82	1.37	0.90	1.73	1.47	1.06	1.88	1.11	0.72	0.68	0.55	0.59	0.67	0.55
1350	5102003	2100	3	0.85	1.02	1.02	0.26	0.17	0.78	0.13	0.08	0.00	0.00	0.05	0.04	0.00	0.04	0.00	0.04	0.00	0.04	0.13	0.00
1351	5152003	300	10	0.08	0.00	0.08	0.13	0.04	0.08	0.17	0.16	0.13	0.21	0.19	0.12	0.17	0.08	0.13	0.29	0.29	0.30	0.25	0.13
1352	5192003	1200	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.46
1353	5192003	2000	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00
1354	5302003	1100	2	0.00	0.00	0.02	0.04	0.00	0.01	0.01	0.00	0.02	0.04	0.02	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
1355	5302003	1900	2	0.00	0.00	0.04	0.09	0.00	0.00	0.00	0.00	0.08	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1356	6022003	1700	15	0.25	0.23	0.25	0.26	0.26	0.30	0.30	0.28	0.31	0.30	0.37	0.30	0.38	0.02	0.38	0.34	0.34	0.37	0.39	0.46

Notes:
*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Appendix H-3. (concluded)

Storm	*Date*	*Hour*	*Duration**	*Rain gauge site no.* 2	3	4	6	7	8	9	10	11	12	13	15	16	18	19	20	21	22	23	24
1357	6032003	1200	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00
1358	6062003	900	8	0.42	0.46	0.29	0.47	0.46	0.29	0.42	0.41	0.42	0.46	0.40	0.42	0.56	0.04	0.43	0.43	0.43	0.42	0.52	0.42
1359	6102003	500	5	0.33	0.32	0.25	0.30	0.25	0.34	0.34	0.34	0.35	0.30	0.33	0.34	0.35	0.07	0.42	0.39	0.17	0.39	0.35	0.54
1360	6112003	200	15	0.00	0.00	0.00	0.08	0.17	0.00	0.12	0.12	0.17	0.30	0.15	0.97	**2.76**	0.46	0.60	1.46	1.11	0.77	0.99	0.25
1361	6132003	300	14	**2.73**	**2.66**	1.74	1.82	1.45	**2.47**	1.47	**2.65**	**2.74**	1.30	1.72	**2.29**	1.47	1.90	0.80	1.12	0.35	0.34	0.57	1.76
1362	6252003	1900	16	1.18	0.98	1.35	1.00	0.86	0.85	1.40	1.26	1.17	1.18	1.19	1.35	1.13	0.80	0.80	0.91	1.11	1.32	1.24	0.67
1363	6282003	2200	1	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1364	6292003	500	6	0.04	0.00	0.00	0.00	0.04	0.00	0.17	0.12	0.04	0.09	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
1365	6292003	1800	9	0.38	0.76	0.00	0.17	0.17	0.00	0.21	0.04	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.22	0.04	0.26	0.30	0.00
1366	6302003	800	5	0.00	0.05	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1367	7082003	1500	21	0.68	0.91	1.36	1.76	1.50	2.15	2.06	1.69	2.37	2.40	**2.54**	1.51	1.99	1.01	2.47	**3.10**	2.31	2.19	1.76	1.00
1368	7092003	1800	17	**3.44**	2.09	**3.24**	**3.09**	**2.85**	2.04	**2.36**	**2.38**	1.86	2.20	**3.10**	2.17	**2.93**	**3.21**	**3.00**	**2.39**	2.14	1.91	2.19	0.42
1369	7182003	300	10	0.50	0.45	0.38	0.17	0.56	0.60	1.82	0.80	0.30	0.16	1.03	1.53	1.17	0.50	1.24	1.55	0.94	1.04	1.85	**2.51**
1370	7212003	100	10	1.14	1.30	0.42	0.69	0.81	0.00	0.00	0.37	0.91	1.43	0.00	0.04	0.38	0.00	0.00	0.00	0.00	0.22	0.69	0.00
1371	7282003	600	7	0.37	0.32	0.51	0.51	0.48	0.30	0.38	0.41	0.48	0.37	0.32	0.38	0.16	0.30	0.38	0.34	0.35	0.34	0.43	0.37
1372	8012003	200	2	0.04	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1373	8012003	800	2	0.00	0.00	0.04	0.02	0.02	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1374	8022003	1100	7	0.25	0.00	0.54	0.00	0.00	1.39	0.00	0.00	0.00	0.12	0.19	0.00	0.00	0.00	0.04	0.04	0.34	0.26	0.13	0.00
1375	8022003	2300	3	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00
1376	8032003	1500	17	0.33	0.18	0.30	0.12	0.65	0.39	0.37	0.25	0.47	0.21	0.05	0.98	0.87	0.00	0.13	0.00	0.00	0.38	2.11	0.63
1377	8062003	300	8	0.08	0.00	0.04	0.04	0.00	0.04	0.04	0.04	0.04	0.08	0.04	0.04	0.00	0.08	0.04	0.04	0.12	0.13	0.04	0.00
1378	8072003	1600	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
1379	8112003	1600	4	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.86	0.04	0.00	0.00	0.00	0.00
1380	8122003	1600	4	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.27	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1381	8292003	200	15	0.96	0.85	1.00	1.31	1.41	1.51	1.44	1.37	1.91	**2.31**	1.66	2.13	**2.79**	1.85	2.15	**2.42**	**2.40**	2.20	2.06	1.76
1382	8312003	100	26	1.30	1.45	1.62	1.67	1.78	1.63	1.60	1.67	1.85	1.96	1.89	1.89	2.52	1.98	2.18	2.18	1.93	2.02	2.20	2.19

Notes:

*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.