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

Year Twelve: September 2003-August 2004

by
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Champaign, Illinois

A division of the Illinois Department of Natural Resources
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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 2004. 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 12 years of precipitation data and 10 years of groundwater observations.

For the period September 2003-August 2004, the network received an average of 29.64 inches of precipitation, 5.73 inches lower than the network 11-year 1992-2003 average precipitation of 35.37 inches, as well as the 30-year averages at Havana and Mason City (37.82 and 35.70 inches, respectively). Below average precipitation fell in winter and summer months, and average precipitation fell during the fall of 2003 and the spring of 2004.

In 2003-2004, groundwater levels in many wells tended to follow the usual pattern of rising water levels in early spring with peaks in mid-summer before evapotranspiration and irrigation demands caused water levels to decline. However, as in Year Eleven, groundwater levels in some wells experienced essentially no water-level recovery during the spring and summer, and exhibited a general decline throughout the year.

Total irrigation for the June-September period was estimated to be 42 billion gallons (bg), which was the fifth highest total since monitoring began in 1995 and ranked just below the fourth highest total of 46 bg in 2003. The years 2001 and 2002 had the second and third highest total withdrawals, respectively, with only 1996 having more pumpage than each of the last four years. Some of this increase in pumpage can be attributed to the growth of irrigation systems in the Imperial Valley, which now has 1,889 systems.

To improve our understanding of the relationship between groundwater, stream discharge, and irrigation, an irrigation test site was established in April 2003 (Year Eleven) near Easton, Illinois. Nine observation wells were installed in close proximity to an irrigated field that abuts Crane Creek. Transducers with data loggers were installed in three wells in 2003 to monitor groundwater levels, and an additional data logger was installed in Crane Creek to monitor stream stage. Two additional wells were outfitted with data loggers in June 2004. Discharge measurements indicate groundwater discharge into Crane Creek at the test site.

The groundwater data show a rapid (within a day) response of groundwater levels to precipitation, probably due mostly to the increase in stage in Crane Creek in this area of prevalent sandy soils. Shallow water levels also contribute to this rapid response.

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, and it is extensively irrigated from the easily developed groundwater resource that underlies the Imperial Valley.

Regional precipitation variability affects irrigation water demand on the aquifer, recharge to 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.

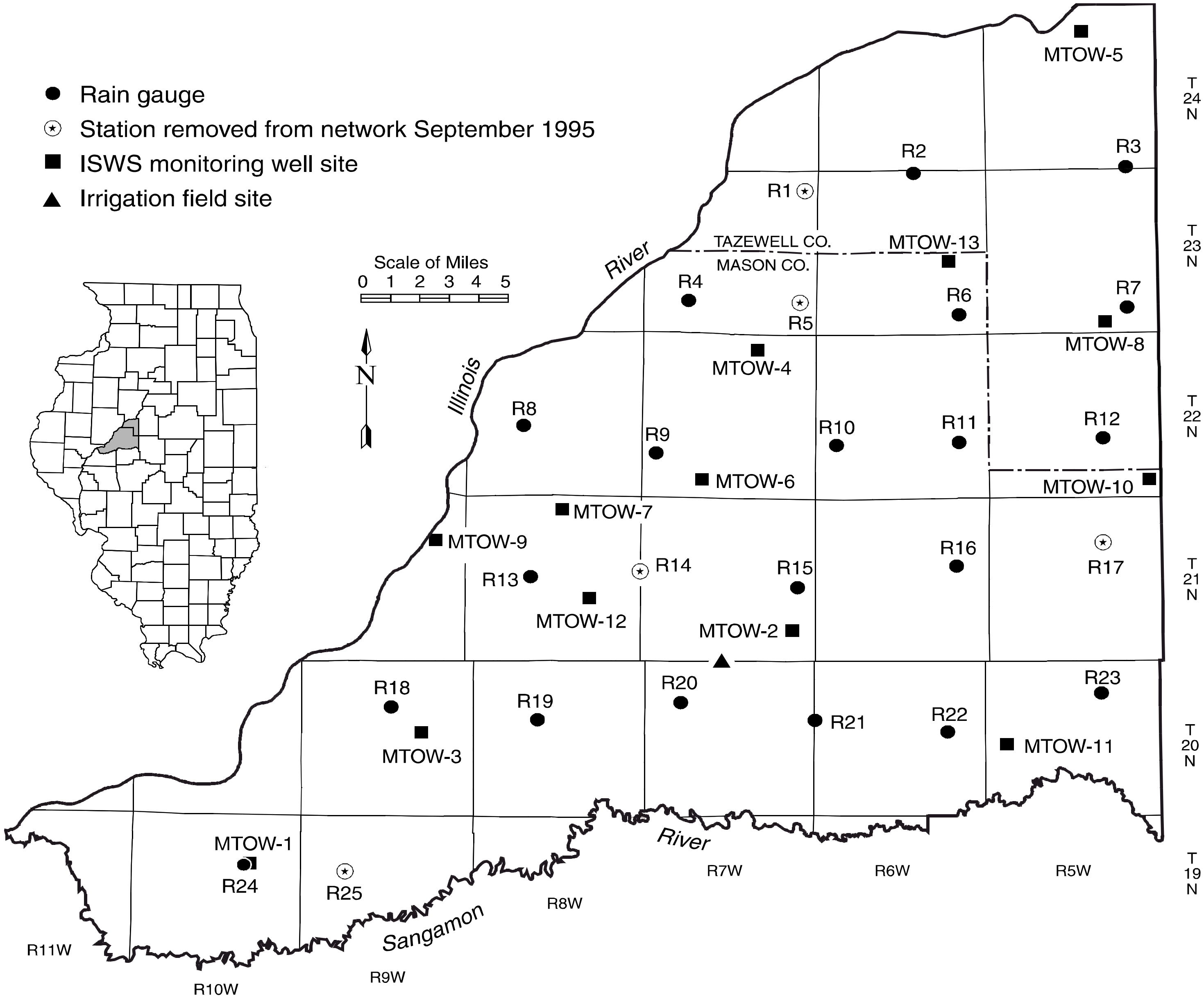

Figure 1. Configuration of the 13-site observation well and 25-site rain gauge networks, and location of the irrigation field site, Imperial Valley, 2003-2004.

Results of the previous years of the network operation are reported in 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, 2005).

The observation well network originally consisted of 11 wells, Mason-Tazewell Observation Wells (MTOW) 1 through 11. The network 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, respectively, 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 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, 2005) 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 Twelve.

Irrigation Test 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. Necessary data inputs for an ideal site include continuous water-level data, pumping rates and times for irrigation systems, and discharge/stage readings at a nearby stream, all at a location where groundwater is influenced by a stream and where the groundwater system is under the influence of irrigation pumpage. A test site meeting these criteria was located along Crane Creek, near Easton, Illinois, in Mason County. The site has only one center-pivot irrigation system within a half mile of the creek, which provides some control over irrigation effects in the immediate vicinity. The site, owned by Jeff Smith, is being studied to gather some of the necessary data for input into 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 twelfth year of the rain gauge network operation and the tenth 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 2003-2004 period (Appendix E). Contour maps of the annual precipitation across the Imperial Valley are presented for Years One-Eleven (Appendix F). Documentation also is presented for the monthly and seasonal 1992-2003 precipitation events (Appendix G), and for all 2003-2004 precipitation events (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, 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 run the rain gauge network, and Morris Bell collected the monthly groundwater-level data. 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 of 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, 2004. 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, saves 2 to 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 to 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 the 20 rain gauge charts are sent monthly to the ISWS. 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 every two years. 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 Twelve.

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, which are 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. All of the network wells have been surveyed for well head elevation above mean sea level.

Well MTOW-1, located at Snicarte, is an inactive, large-diameter, hand-dug domestic well that has been monitored by the ISWS since 1958. MTOW-1 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. 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.

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.

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 Test Site: Description, Operation, and Maintenance (Year Two)

The irrigation test site along Crane Creek, southwest of Easton, Illinois, is located in Section 4 of Township 20 North, Range 7 West (Crane Creek Township) on property owned by Mr. Jeff Smith. Nine observation wells were installed in April 2003. Three are on the north side of Crane Creek and six are on the south side of Crane Creek. The irrigation well is on the south side of Crane Creek; its irrigation pattern, along with the observation well locations, are shown on Figure 2. The observation wells range from 31 to 37 feet deep, and the non-pumping water levels are less than 10 feet below land surface during the off-irrigation season. The depth and date of construction for each well are listed in Table 2. Monitoring included groundwater-level observations (manual and digital), surface water stage (manual and digital), and discharge measurements.

Five continuous water-level data loggers (electronic pressure transducers) were purchased for installation at this site. Transducers were placed in wells 3 and 6 on June 14, 2003. A third transducer was placed in Crane Creek on August 26, 2003, to measure stage. Transducers were placed in wells 4 and 5 on June 4, 2004. The transducer in well 4 subsequently was removed because the data gathered indicated it was not working properly. A transducer also was placed in well 1 on August 17, 2004.

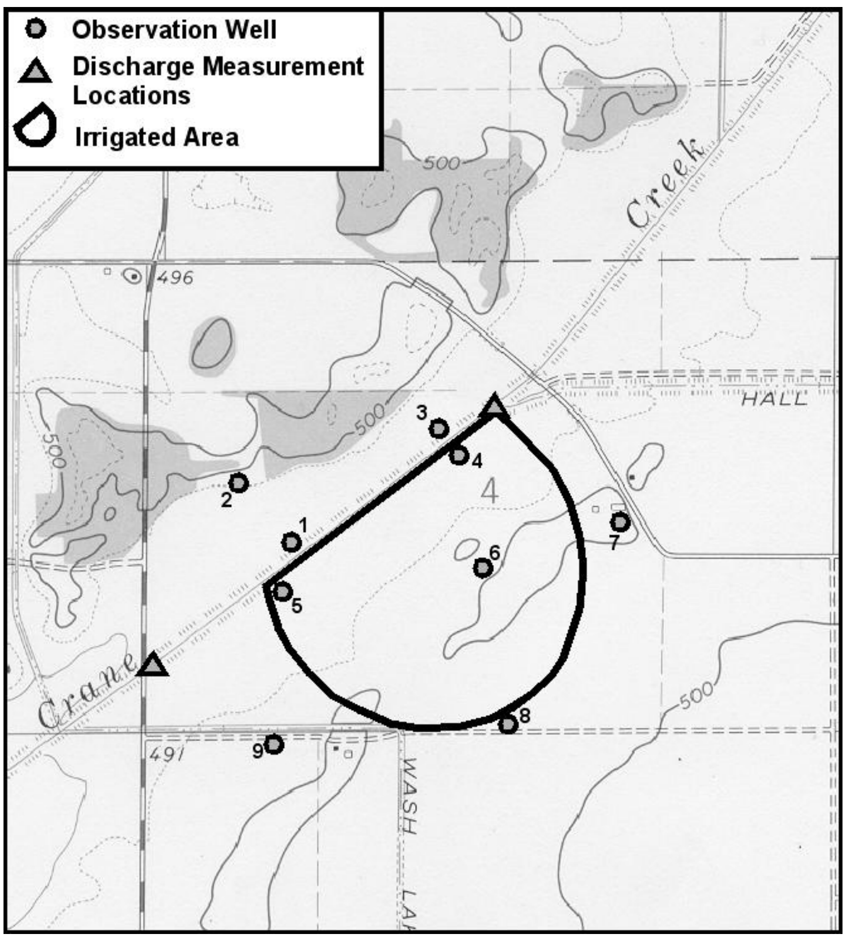

Figure 2. Locations of observation wells and streamflow discharge points in relation to the irrigation test site.

Measuring discharge on the upstream and downstream reaches of Crane Creek was a priority during the 2004 irrigation season. Seventeen sets of upstream and downstream discharge measurements were taken in Crane Creek during this reporting period (i.e., prior to September 1, 2004), all during the 2004 growing season. Continuous stage data from Crane Creek and continuous groundwater-level data in four wells installed for the project now are being collected.

In total, there were 183 groundwater-level measurements, 34 discharge measurements, 26 downloads from the data loggers, and 14 stage measurements completed at the test site during Year Twelve.

Jeff Smith Farm

183 depth-to-water measurements
34 discharge measurements
26 data logger downloads
14 stage Measurements

Monitoring Well Network

16 depth-to-water measurements
16 data logger downloads
2 monitoring wells developed

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 2003-August 2004, Year Twelve. 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 Twelve of network operation are similar to those performed during previous 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, 2005). Hourly rainfall amounts are totaled from 10-minute digital data and 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. In the rare event that data from both a data logger and the corresponding chart are missing, 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 (1995-2004) 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).

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 to 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 using monthly data 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 collection 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 from gauge 24. Results shown in the Year Eleven report indicate a quick response to rainfall at MTOW-1. In response to those findings, transducers were installed in the Green Valley (MTOW-8) and Rest Area (MTOW-7) wells during Year Twelve.

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 estimated to be 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 further may enhance withdrawal estimates.

Crane Creek Discharge Measurements

The discharge measurements indicate that the total difference in discharge between the upstream and downstream ends of the site (where the creek crosses the roads) is less than the error associated with the method. Given that every measurement consistently shows a greater discharge at the downstream gauge than at the upstream gauge, the authors believe the data reflect the influence of groundwater discharge along the stream reach. There appears to be no change in stream stage, even though the water level in the groundwater system is being lowered on both sides of the creek. Groundwater levels may be above the level of the creek, even when the irrigation system is on. Confirmation will be possible when elevations are determined for the observation wells. In order to see a measurable change in the stream stage, water levels in the groundwater system will likely need to be lowered below the stream elevation to reverse the flow direction toward the aquifer. Though any lowering of aquifer water levels should influence the gradient, and thus, the amount of discharge. At the scale of a single field, it appears that the change is insignificant. Differences in discharge measurements are being evaluated to determine if there is any correlation with the irrigation season.

Results

Precipitation

Annual and Monthly Precipitation

The Year Twelve dataset was used to produce the following analyses: 1) monthly and annual (September 2003-August 2004) precipitation amounts for each site in the IVWA network (Table 3); 2) the average precipitation pattern for the 12-year network operation (Figure 3a and b); 3) the total precipitation pattern for Year Twelve (Figure 4); 4) a comparison of total precipitation, precipitation events, and precipitation per event (Table 4); and 5) the average precipitation for each month in Year Twelve (Figures 5-10). The annual precipitation patterns for Years One-Eleven also are presented (Appendix F).

The Year Twelve network precipitation was 5.73 inches below the previous 11-year average. It was the fourth driest period in the 12 years of network operation. Precipitation totals for the current year (Table 3) ranged from 35.39 inches at station 22 to 25.30 inches at station 4.

Table 3. Monthly Precipitation Amounts (inches), September 2003-August 2004

	Month												
Station	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	2.61	1.72	3.66	1.26	0.40	0.32	2.85	2.49	4.14	2.21	3.14	4.84	29.64
3	2.26	1.63	3.83	1.04	0.43	0.20	3.12	2.63	3.48	2.33	1.48	3.76	26.19
4	2.13	1.55	2.68	1.35	0.40	0.28	2.92	1.66	4.73	2.59	0.75	4.26	25.30
6	2.55	1.47	3.47	0.94	0.52	0.36	2.50	1.92	4.20	2.65	1.29	4.01	25.88
7	2.32	1.83	4.21	0.79	0.57	0.32	2.99	1.65	4.83	2.95	1.55	4.49	28.50
8	2.44	1.91	2.40	1.83	0.49	0.32	2.51	1.65	5.47	2.13	1.56	3.88	26.59
9	3.06	1.33	3.19	0.97	0.73	0.36	2.69	1.99	5.08	3.64	1.24	2.55	26.83
10	2.48	1.28	3.65	0.74	0.53	0.28	2.71	1.62	4.40	3.15	2.98	2.74	26.56
11	2.42	1.40	3.77	0.95	0.65	0.37	2.65	1.75	4.49	3.29	3.10	3.65	28.49
12	2.82	1.73	4.49	0.95	0.81	0.44	3.23	1.73	7.72	2.75	4.04	4.01	34.72
13	2.83	1.56	2.74	1.32	0.69	0.36	2.70	1.65	5.38	3.41	2.40	2.51	27.55
15	2.91	1.40	3.74	0.70	0.77	0.24	2.95	1.41	5.43	4.69	2.84	3.64	30.72
16	3.19	1.27	3.87	0.70	0.72	0.32	2.29	1.76	5.76	3.49	2.20	3.20	28.77
18	2.49	1.52	2.97	1.52	0.81	0.44	2.52	1.73	6.05	3.95	2.28	3.77	30.05
19	3.06	1.74	3.33	1.40	0.94	0.41	2.97	1.96	6.30	4.76	1.66	5.19	33.72
20	2.83	1.52	3.45	0.83	0.74	0.28	2.80	1.49	6.66	4.68	2.22	4.06	31.56
21	2.33	1.43	4.28	0.91	0.87	0.24	2.74	1.40	6.95	4.42	2.54	3.62	31.73
22	3.08	1.84	4.53	0.58	0.70	0.28	3.04	1.44	8.40	4.73	4.22	2.55	35.39
23	2.94	1.55	3.74	0.93	0.81	0.41	3.35	1.67	7.17	4.80	2.30	3.35	33.02
24	2.58	1.52	2.88	1.61	0.74	0.40	3.29	2.03	4.46	4.55	2.26	5.36	31.68
Average	2.67	1.56	3.54	1.07	0.67	0.33	2.84	1.78	5.55	3.56	2.30	3.77	29.64

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

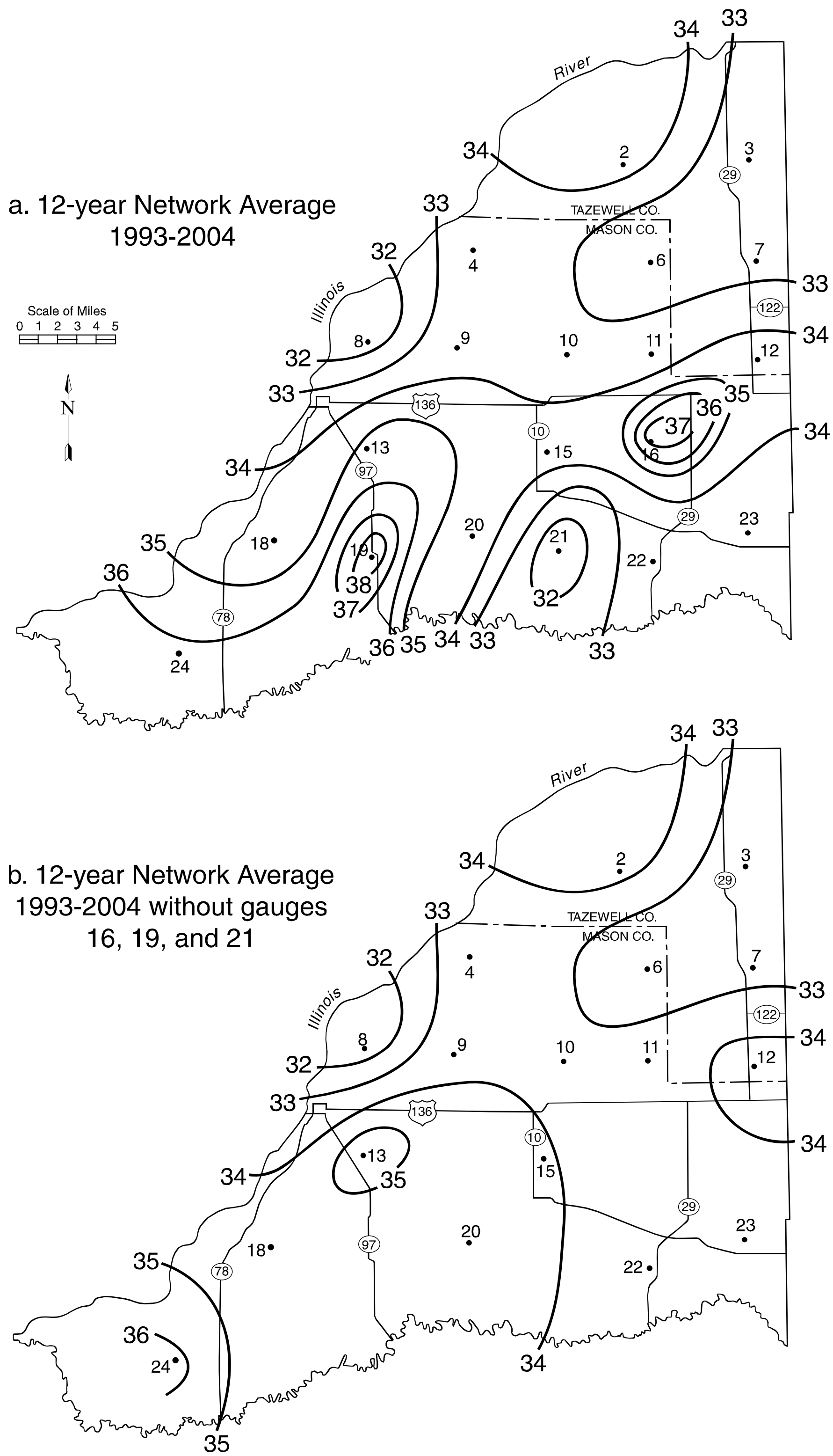

Figure 3. Network average annual precipitation (inches) for September 1992-August 2004
with all gauges and without gauges 16, 19, and 21.

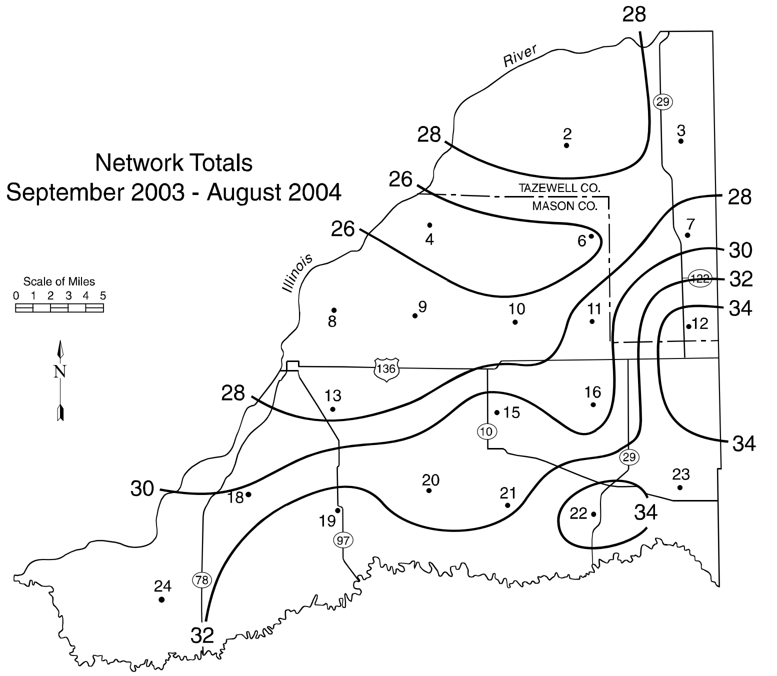

Figure 4. Total precipitation (inches) for September 2003-August 2004.

Table 4. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event by Month and Season, 1992-2003 and 2003-2004

	1992-2003 11-year average			*2003-2004 average*		
Period	*Precipitation*	*Events*	*Inches/event*	*Precipitation*	*Events*	*Inches/event*
Sep	2.78	7.1	0.37	2.67	7	0.38
Oct	2.37	9.7	0.27	1.56	7	0.22
Nov	2.52	10.1	0.29	3.54	9	0.39
Dec	1.50	8.9	0.24	1.07	8	0.13
Jan	2.03	10.3	0.24	0.67	8	0.08
Feb	1.79	8.5	0.25	0.33	6	0.06
Mar	2.09	7.7	0.27	2.84	12	0.24
Apr	3.67	12.0	0.34	1.78	5	0.36
May	4.74	14.8	0.33	5.55	16	0.35
Jun	4.10	12.6	0.33	3.56	7	0.51
Jul	4.11	11.1	0.42	2.30	14	0.16
Aug	3.67	13.4	0.29	3.77	11	0.34
Fall	7.68	26.4	0.31	7.77	23	0.34
Winter	5.31	27.6	0.21	2.07	22	0.09
Spring	10.50	34.5	0.31	10.17	33	0.31
Summer	11.88	37.1	0.33	9.36	32	0.30
Annual	35.37	125.6	0.29	29.64	110	0.27

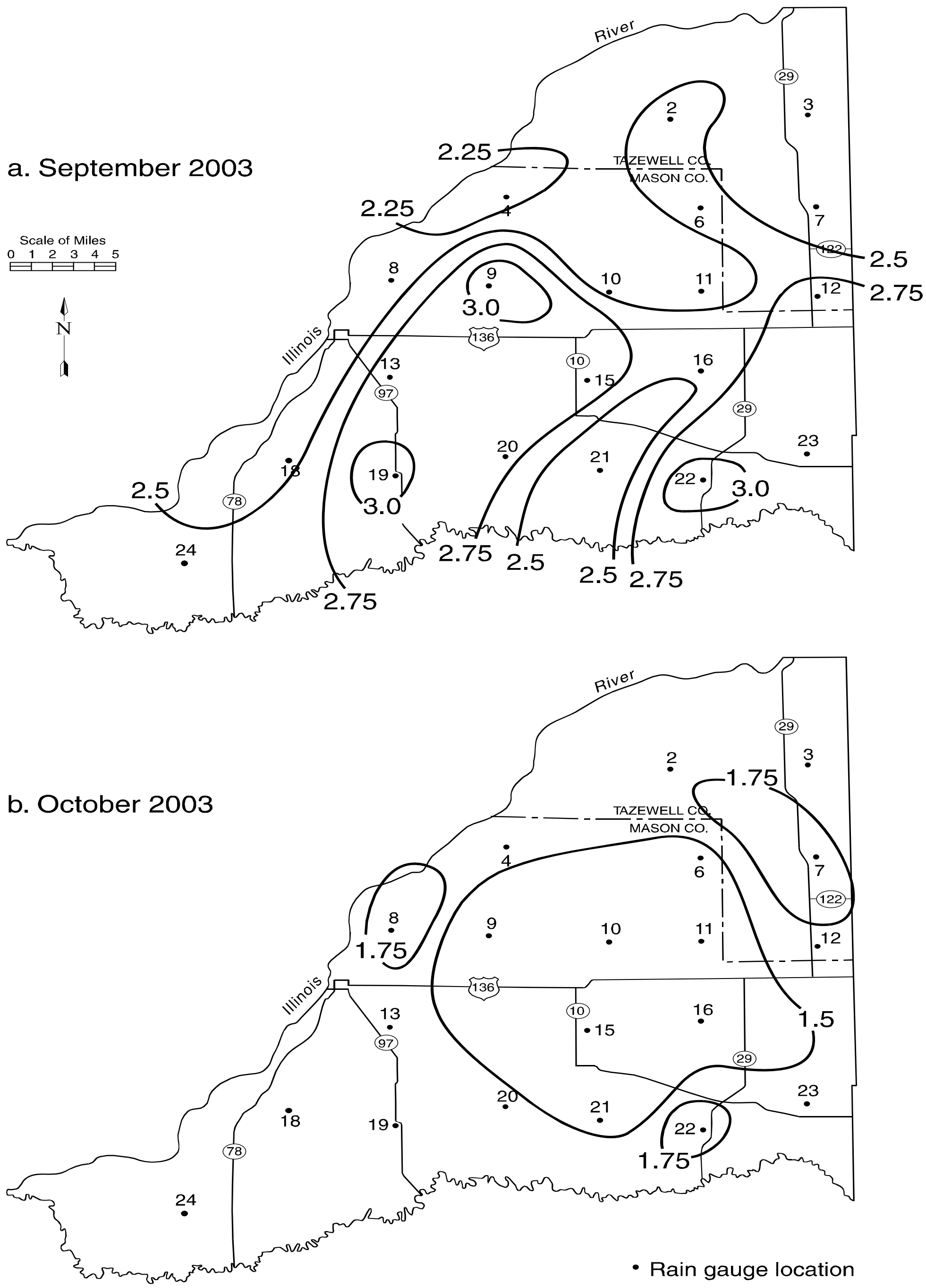

Figure 5. Precipitation (inches) for September 2003 and October 2003.

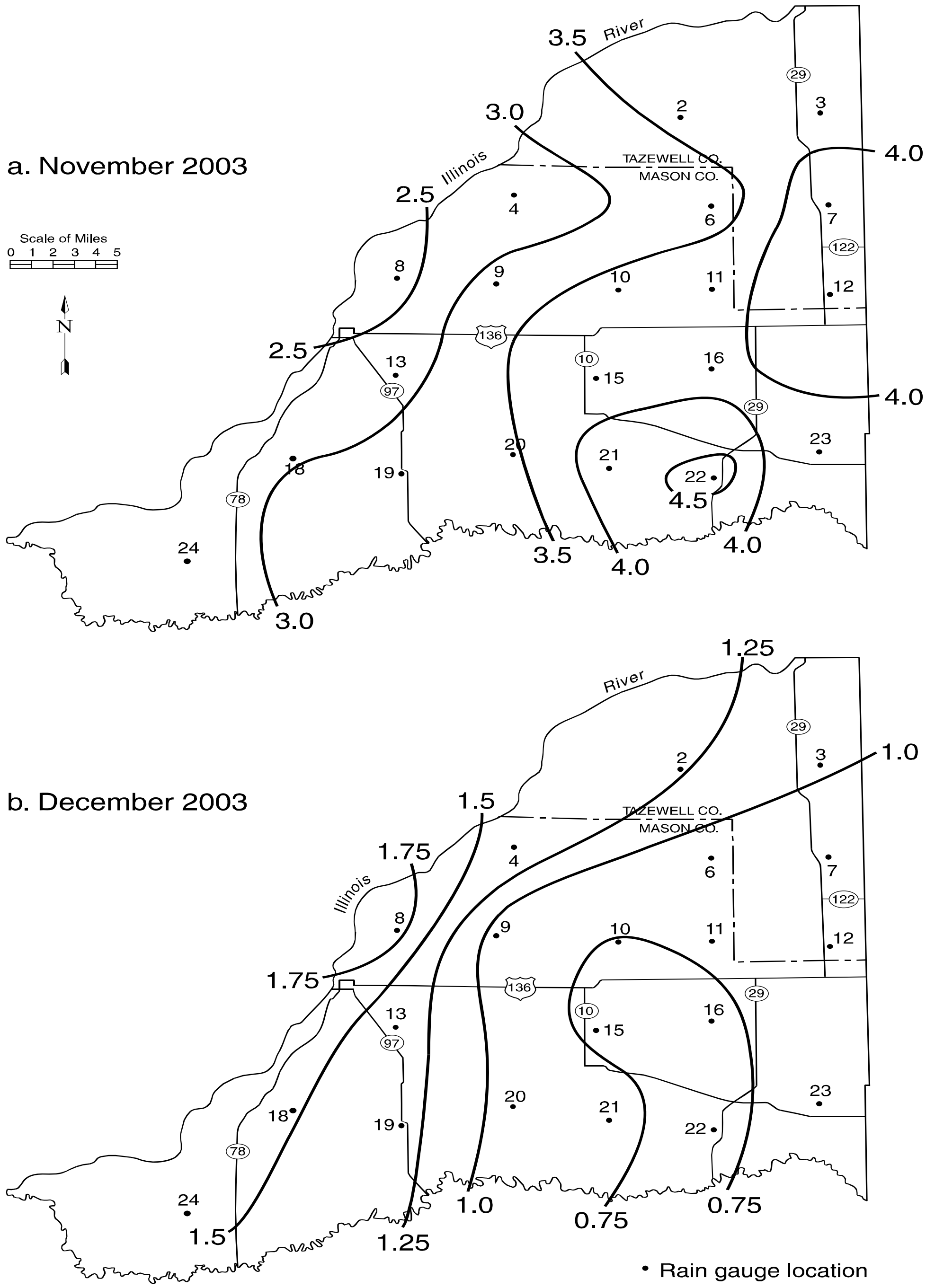

Figure 6. Precipitation (inches) for November 2003 and December 2003.

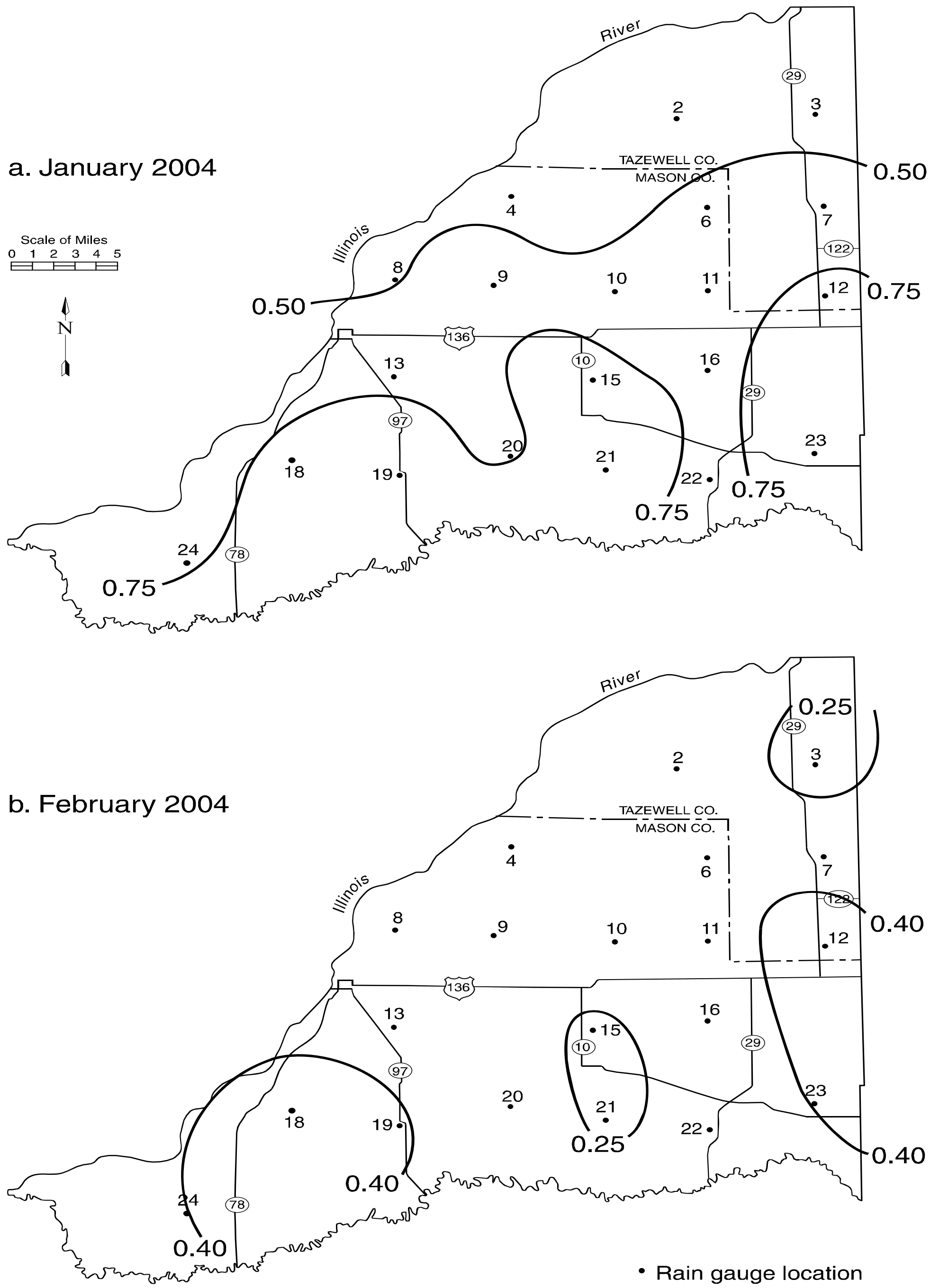

Figure 7. Precipitation (inches) for January 2004 and February 2004.

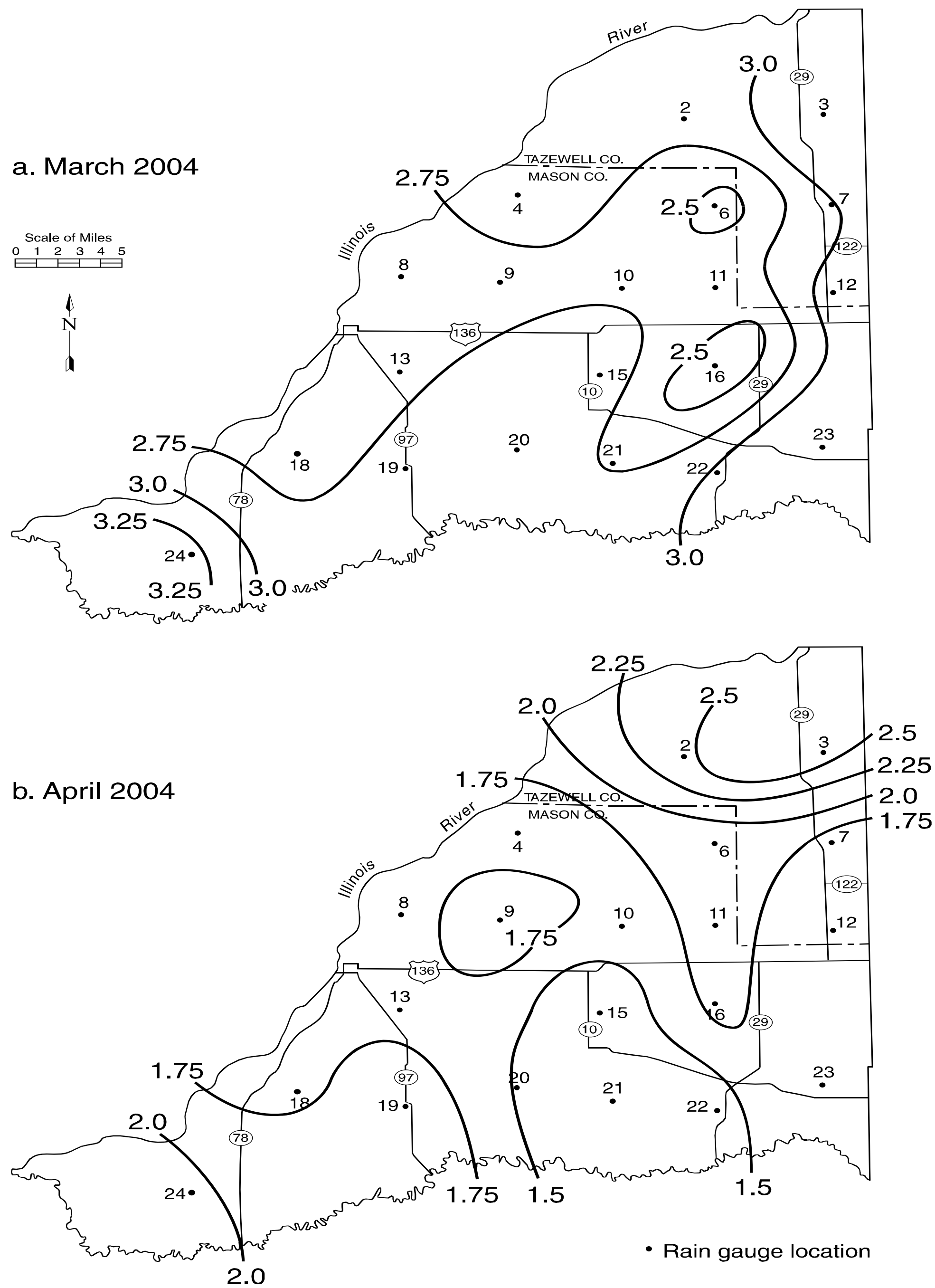

Figure 8. Precipitation (inches) for March 2004 and April 2004.

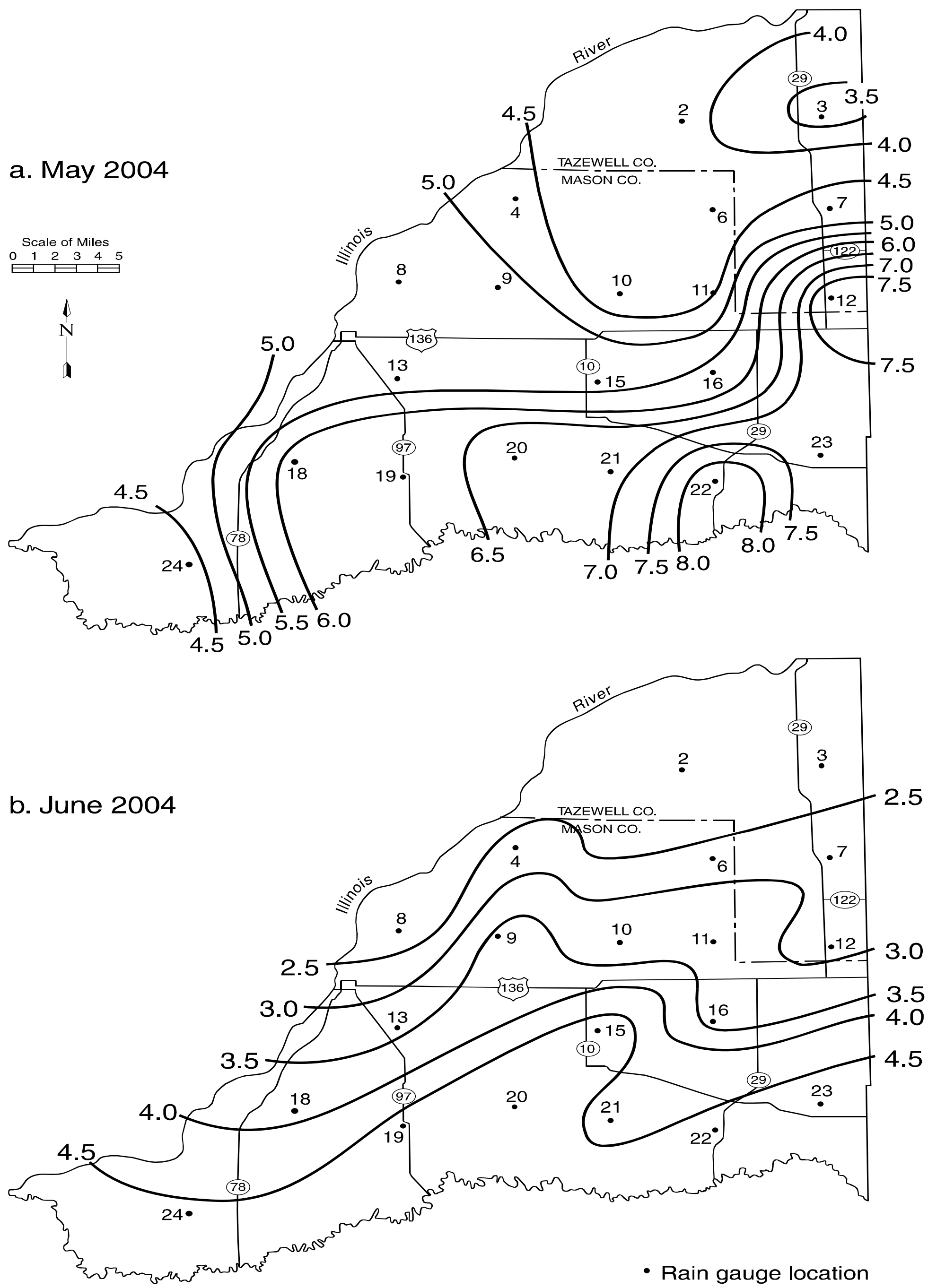

Figure 9. Precipitation (inches) for May 2004 and June 2004.

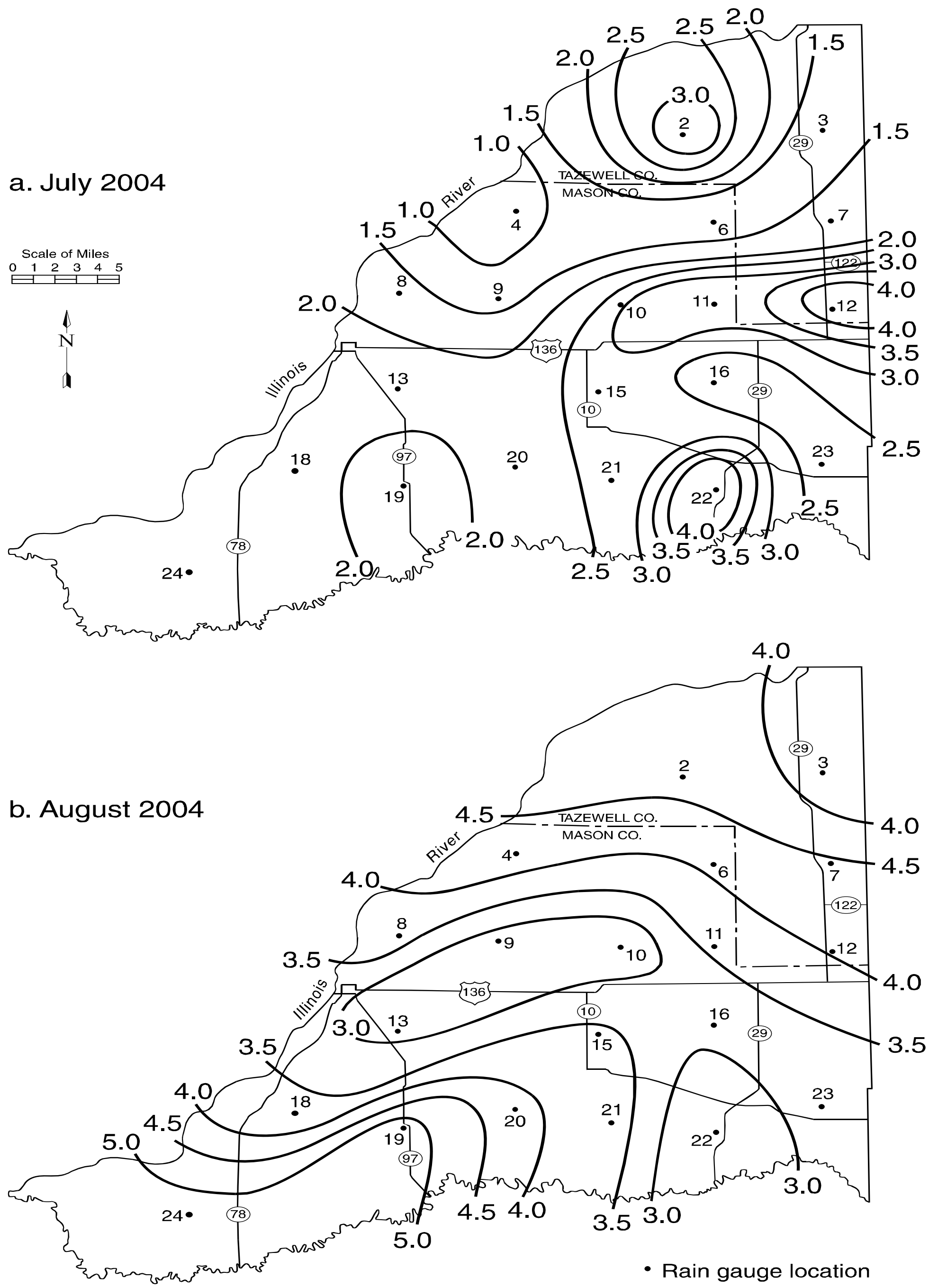

Figure 10. Precipitation (inches) for July 2004 and August 2004.

Figure 4 presents the annual precipitation pattern for Year Twelve. The annual precipitation total at station 16 was 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. During Year Eleven, the annual difference was 7.0 inches. The gauge at station 16 was replaced again in the fall of 2003. During Year Twelve, the annual difference between the gauge at station 16 and its neighbors was -0.20 inches, so all analyses for Year Twelve include station 16 data.

The pattern seen in the 12-year network average (Figure 3a) still dominates values at stations 16, 19, and 21, which generally differed from adjacent stations during the period 1997-2002. The bias at sites 16, 19, and 21 was considerably smaller for Years Eleven and Twelve. Thus, all analysis again included precipitation data from stations 16, 19, and 21. The gauge at station 19 still averaged 4.0 inches higher than its neighbors during Year Twelve, but on a month-to-month basis, it was comparable to its neighboring gauges. It is again scheduled for cleaning and recalibration. The 12-year network average precipitation pattern without the gauges at sites 16, 19, and 21 is displayed (Figure 3b).

May 2004 (Figure 9a) was the wettest month of Year Twelve, with a 5.55-inch network average. This was followed by November 2003 (Figure 6a, 3.54 inches), June 2004 (Figure 9b, 3.56 inches), and August 2004 (Figure 10b, 3.77 inches). Precipitation for these four wettest months totaled 16.42 inches, or approximately 55 percent of the total annual precipitation. February 2004 was the driest month of the year (Figure 7b, 0.33 inches) followed by January 2004 (Figure 7a, 0.67 inches). Total average precipitation for the network in the cold season (December-February) was light, 2.07 inches or about 7 percent of the yearly total.

Comparing individual months, only November 2003 was wetter than the 11-year average by an inch or more (see Table 4). April and July 2004 were drier than average by more than 1.5 inches, and January and February 2004 were drier than average by more than an inch. All other months were within ± 0.85 inches of the 11-year average. Spring 2004 (March-May, 10.17 inches) was the wettest season of the year, followed by summer 2004 (June-August, 9.36 inches). The summer precipitation total was 2.52 inches below the 11-year network summer average, and the spring precipitation total was near average. Fall amounts (September-November 2003, 7.77 inches) also was near normal. The winter precipitation total (December 2003-February 2004, 2.07 inches) was below average, with a -3.24 inch departure from the 11-year network average winter precipitation.

The annual precipitation total for 2003-2004 was the fourth driest of the 12 years of network operation. The network received 25.91 inches less precipitation than in the wettest year (1992-1993) and 3.96 inches more than in the driest year (1995-1996). Year Twelve had the driest winter and the fifth driest summer (1995, 1996, 1997, and 2001 were drier) of the 12 years of network operation.

Storm Events

The number of network precipitation events were determined for the 12-year period. Mean monthly, seasonal, and annual numbers of these precipitation events are presented for each year (Appendix G), and for 2003-2004 (Table 4). The monthly, seasonal, and annual number of precipitation events averaged over the 1992-2003 period also are presented (Table 4). A network storm event 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 events are presented (Appendix H, Tables H-2 and H-3).

Year Twelve, a dry year, had 110 precipitation events, the fourth fewest number of events in the 12 years of network operation. Fewer events than average occurred in all seasons of the year, but more events occurred in the spring and summer as usual. However, in comparison to past years, only two springs (1994 and 2003) had fewer events, and only four summers (1996, 1999, 2002, and 2003) had fewer events. The amount of precipitation per event was near average in the spring and summer of 2004 and in the fall of 2003. The amount of precipitation per event was lowest in the winter as usual, but the amount of precipitation per event in winter 2003-2004 was lowest for all 12 winters of record.

The plot of the network average monthly precipitation time series (Figure 11) shows the monthly variation of precipitation. As in the fall and winter of 1995-1996, 1999-2000, 2002-2003, and the fall and winter of 2003-2004 had low precipitation, with only 2 months exceeding 2 inches. The months of May, June, and August, however, exceeded 3 inches. 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 1492 network storm periods occurred during the 12-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, 80 in 2002-2003, and 110 in 2003-2004, resulting in a 12-year average of 124.3 storms per year.

Appendix H documents each network storm event for Year Twelve 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 event.

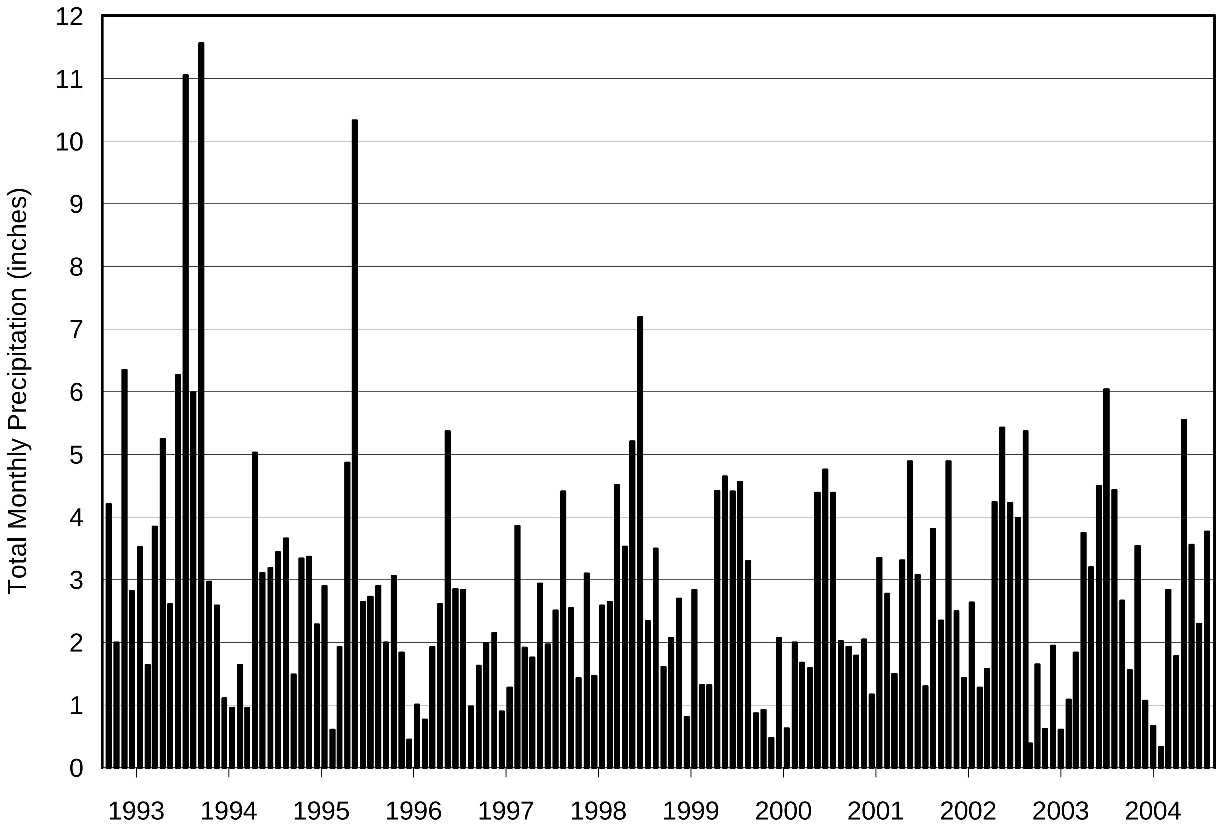

Figure 11. Network average monthly precipitation (inches), September 1992-August 2004.

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 Twelve. Sites that exceed the one-year 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, 2005).

In the first 11 years of operation, 56 of the 1382 storm periods produced maximum precipitation at one or more stations with a recurrence frequency greater than one year as follows: 50-year (1 storm), 10-year (3 storms), 5-year (8 storms), 2-year (26 storms), and greater than 1-year but less than 2-year (18 storms). The 50-year storm (storm 153) occurred on September 13, 1993; the 10-year storms occurred on May 16, 1995 (storm 323), May 8, 1996 (storm 432), and July 19, 1997 (storm 580). These four heaviest storms occurred during the warm season (May-September). Nine storms had a recurrence interval exceeding the one-year 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, four in 2000-2001, eight in 2001-2002, and seven in 2002-2003.

In Year Twelve, five of the 110 network storm periods exceeded the one-year recurrence frequency. Year Twelve had below average numbers of network storm and heavy rainfall periods. No event exceeded the 5-year or more recurrence frequency. The five 2-year storms during Year Twelve occurred during November (storm 1404), May (storm 1457), June (storm 1465), July (storms 1476), and August (storm 1490).

Groundwater Levels

Monthly Measurements

Groundwater levels in observation wells MTOW-5 and MTOW-9, because of their proximity to the Illinois River, have been found to fluctuate largely in response to river stage. The peak Illinois River stage in spring 2004 was lower than in most previous years of the study, and, similarly, groundwater levels in both wells did not show strong groundwater-level recovery in 2004. In addition, it is likely that the groundwater measurement in June 2004, the high value for the reporting period, was not the highest groundwater level in the wells. Measurements taken only once a month could “miss” the high river stage and the corresponding groundwater-level high. With a transducer installed in these wells, however, data are expected to show that groundwater levels closely mimic the Illinois River stage.

Groundwater levels in observation wells more distant from the Illinois River continued to decline slightly, except in MTOW-10 and MTOW-11. These two wells, which are located in the southeastern portion of the study area, show a rise in groundwater levels in May 2004, probably in response to nearly 8 inches of rainfall in May near those locations. Much of the rest of the study area had several inches less rainfall for the same period (see Figure 9).

As has been done in previous reports (Hollinger et al., 1999, 2000; Scott et al., 2001, 2002; Wehrmann et al., 2004, 2005), 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 exceeded evapotranspiration). As in Year Eleven, several wells exhibited their highest water levels in January in Year Twelve (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.

Examination of the September 2003-August 2004 water-level data for the period when groundwater levels started to recover from preceding water-level declines (Table 6) shows recovery only for a short time. Many wells showed increases in water levels for only one or two months. With the initiation of January and February observations in 2002, it can be seen that groundwater levels start to rise as early as January and February after declining through the previous fall. Water-level recovery in the aquifer in Year Twelve occurred later in the year, compared to the general trend observed in the data over the entire 12-year record.

Table 5. Month in Which Observed Groundwater Levels Peaked, Imperial Valley Observation Well Network, 1995-2004

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
January									4, 8, 10, 11, 13	4, 6, 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	2
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	1, 3, 5, 7, 9, 10, 12
August	4			3, 8, 11, 13	3, 11	1, 9, 12		8, 10, 11		8
September					8, 13					11
October										
November				4						
December										

Notes:
Number is observation well number (MTOW-x). The shaded values represent the possibility that the actual high water level for the year could have been during a month when a measurement was not taken (January-February 1995-2000; January-March 2001), meaning that though these values are listed as the high water level for that well for that year, they may not be the true “peak”water level for that well for that year.

Table 6. Month in Which Observed Groundwater Levels Began Rising, Imperial Valley Observation Well Network, 1995-2004

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
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	2, 5, 9, 11
May		3, 6, 8, 11?, 12		4	4, 8, 10, 13	2?, 6, 10?			10	1, 3
June						1, 3, 7, 8?, 12			11?	6, 7, 8, 10, 12
July		10?				11?				
August			10?				11?			
September			4	13		13?				
October										
November										
December										
No Ascent		4, 13	8, 11						13	4, 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.

Based on Table 6, groundwater recharge typically occurs in the spring, though in some years it can occur much earlier if warmer temperatures promote snowmelt, rainfall occurs, or both. Because the aquifer is very near or at land surface in the study area, recharge can occur at any time of the year when rainfall amounts are significant. Year Twelve had low precipitation early in the year, so 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. Based on the data available, these annual fluctuations often appear to be superimposed on longer term trends, perhaps 10 years or more. Over the 46-year record, both the record low and high were observed within the last 15 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 to 40.5 feet below land surface from September 1989 until April 1990, the only time in its 46-year history that the well went dry. During 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, when water levels rose dramatically, recovering to peak levels similar to those observed in 1994 and 1995. In general, there has been a steady, slightly downward trend in groundwater levels since the flood in 1993, with higher than average groundwater levels every three or four years. Water levels in MTOW-1 fluctuated between 37 and 29 feet in Year Twelve.

Irrigation Test Site Measurements

The data for wells 3 and 6 are shown in Figure 14 along with the stage in Crane Creek and the precipitation from gauge 20. The data show both the 2003 and 2004 effects from irrigation pumpage at the site. Effects of heavy rains in late May and early June 2004 are also evident on the graph.

Figure 15 shows discharge values for the upstream and downstream pairs of discharge measurements during the 2004 growing season. The hydrograph indicates a consistently higher downstream discharge than upstream discharge. There is perhaps some confidence these data accurately portray groundwater discharge to the stream at the site. June 2004 values show the discharge after a significant rainfall event, and August 2004 values show discharge during a very dry period. During this dry period, a significant portion, if not all flow, is groundwater discharge at and above the test site.

Quantifying discharge will be beneficial for the groundwater modeling part of this project. In calibrating the model, it will be possible to determine approximate groundwater discharge at the site. Model results then can be compared to the field data and should be within the range of values measured in the field.

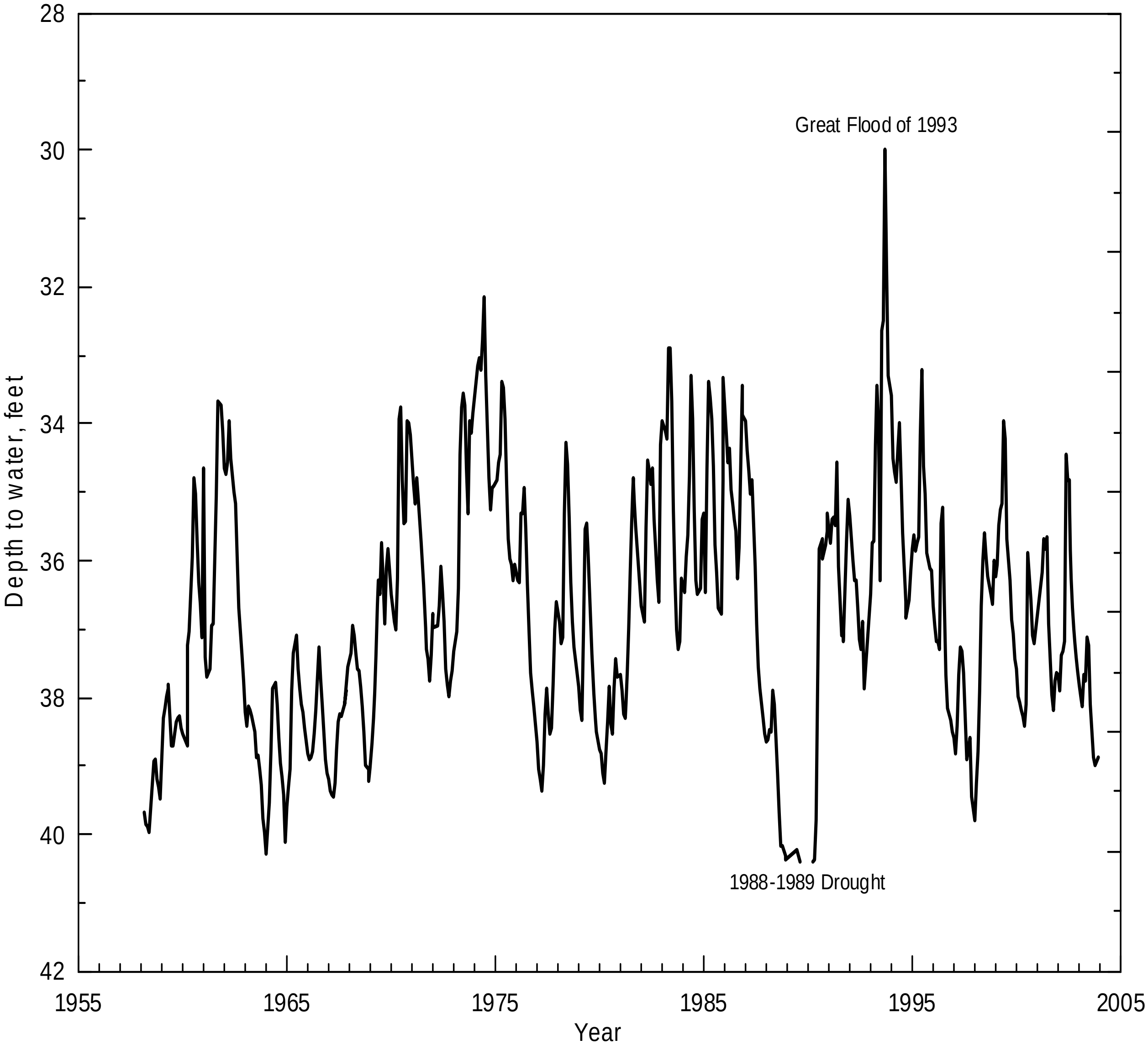

Figure 12. Groundwater levels at the Snicarte well, MTOW-1, 1958-2004.

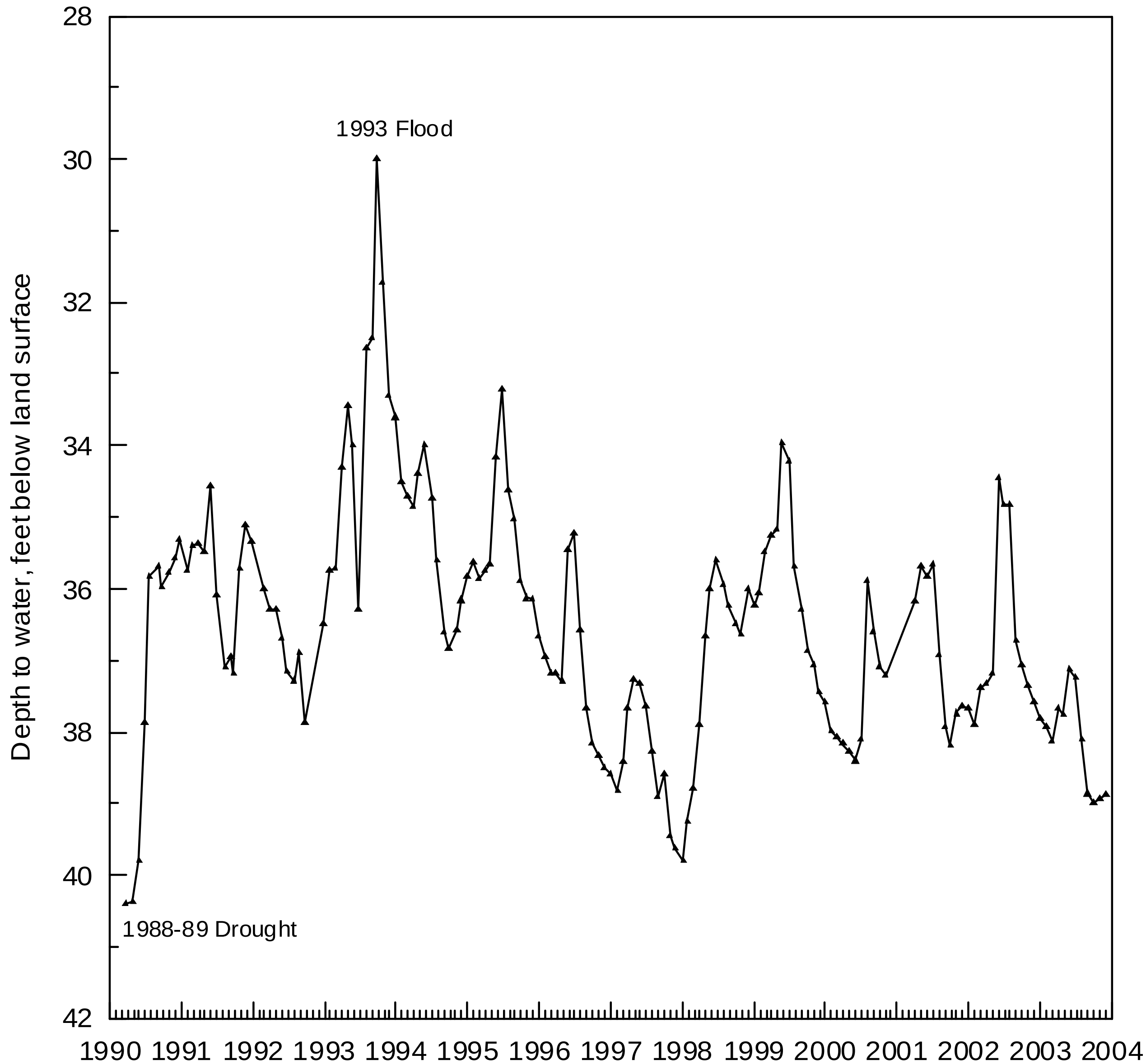

Figure 13. Groundwater levels at the Snicarte well, MTOW-1, 1990-2004.

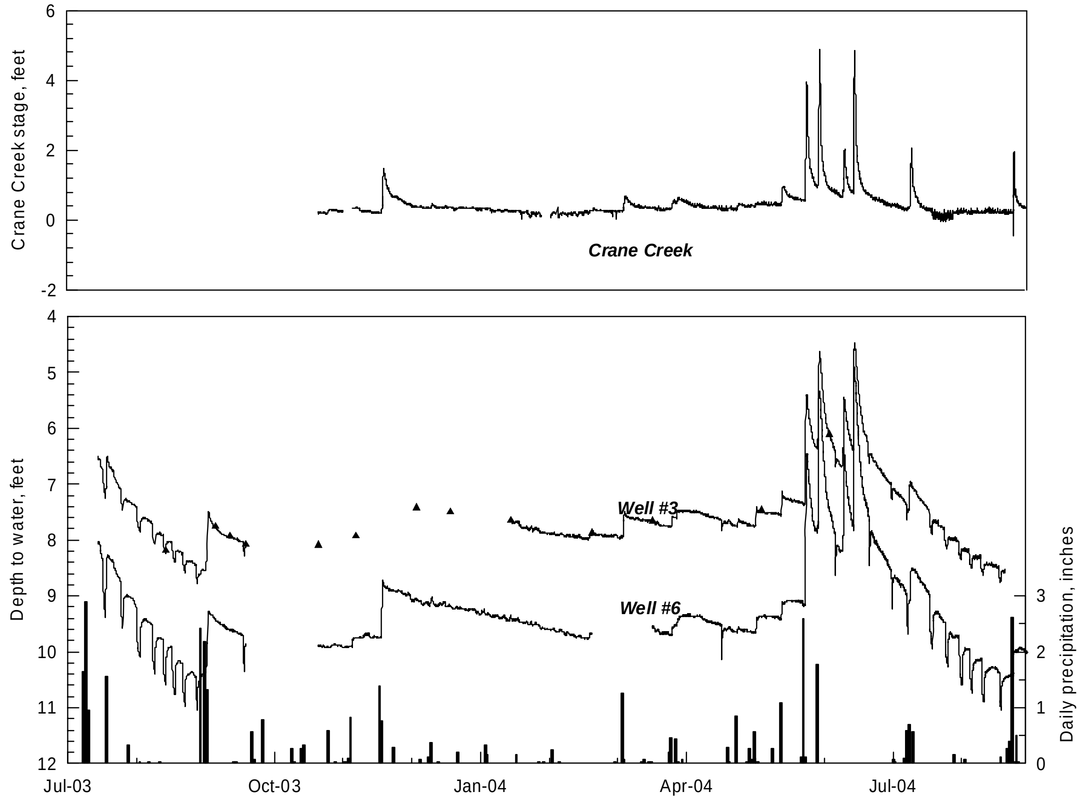

Figure 14. Groundwater level (Wells 3 & 6), Crane Creek stage elevation, and precipitation (Gauge 20) at the irrigation test site. Triangles are manual readings.

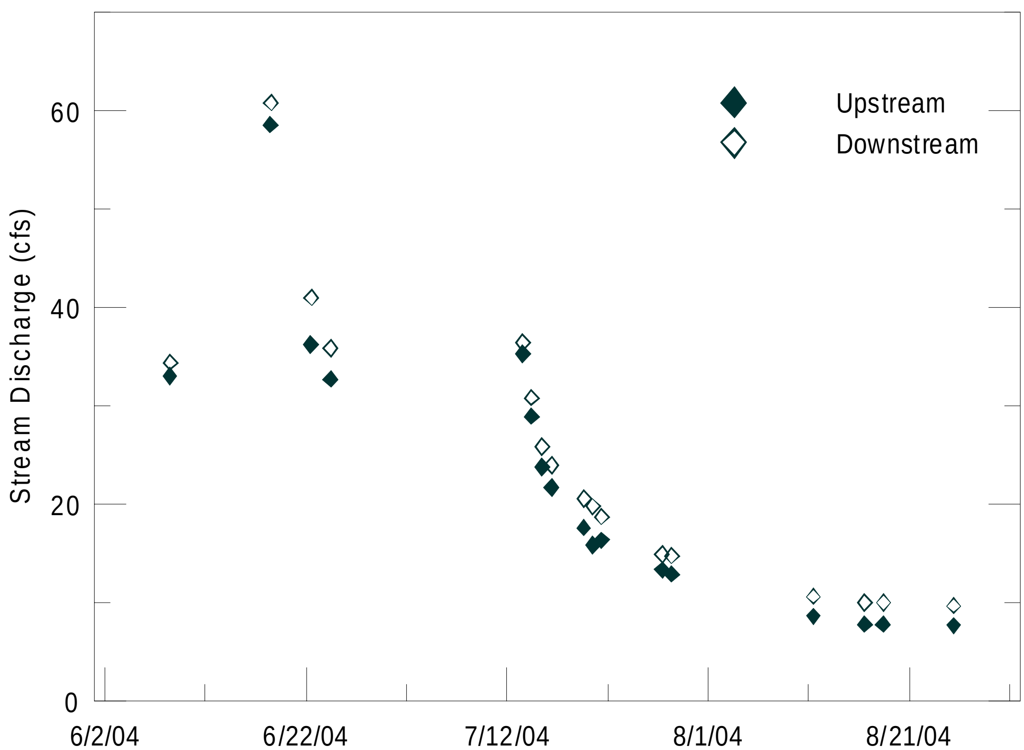

Figure 15. Discharge measurements in Crane Creek at the irrigation test site.

Continuous Measurements

Results of an analysis of the continuous record from the Snicarte well (MTOW-1), in the Year Eleven Report (Wehrmann, et al., 2005), indicated that recharge often occurs within 1 to 3 days of the rainfall event and typically lasts 3 to 5 days after the rainfall event has ended. In other words, recharge occurs on a scale of days, not months after a precipitation event; thus, using monthly water-level data to develop correlations with rainfall may not be meaningful. This reveals several things. First, it confirms that aquifer response to rainfall can happen quickly, as might be expected with the permeable surface soils typical of the area. Second, durations of the recharge events vary based on the magnitude of the rainfall event.

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 was outfitted with a transducer on July 14, 2003. The hydrograph is shown in Figure 16. A transducer was installed in the Rest Area well on August 25, 2003 and is shown in Figure 17.

In reviewing the data from the transducers in MTOW-8 and MTOW-7, recharge occurred after several rainfall events in May 2004. Figures 18 and 19 show the rise in water levels due to recharge after these rainfall events. Figure 19 shows a rise in groundwater levels occurring 2-3 days after the 2-inch rainfall on May 24. The Green Valley well, in Figure 18, shows very little, if any, rise in groundwater levels due to the May 24 event, but there was only 1 inch of rainfall near the Green Valley well versus 2 inches near the Rest Area well. For the May 30 rainfall event, the Green Valley well does show a rise in groundwater levels.

At the irrigation test site, where wells are within several hundred yards of Crane Creek and the depths to water are less than 10 feet, the groundwater level response to rainfall is much more dramatic (see Figure 20).

For the aquifer, depth to water and distance from a river, creek, or stream seem to influence both the timing and magnitude of aquifer recharge after a precipitation event, based on the limited data collected to date. As more data become available and more wells are added to the transducer network, additional data analysis can produce a clearer picture of this relationship.

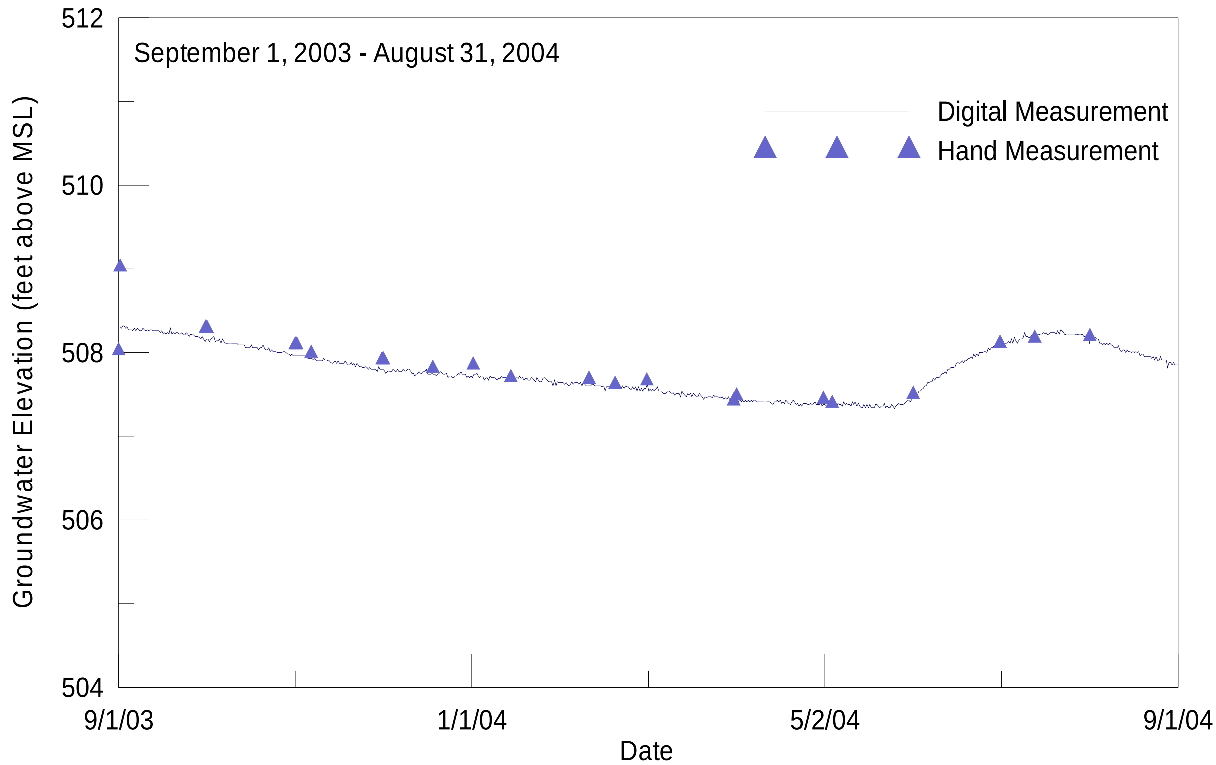

Figure 16. Groundwater elevations at the Green Valley network well (MTOW-8).

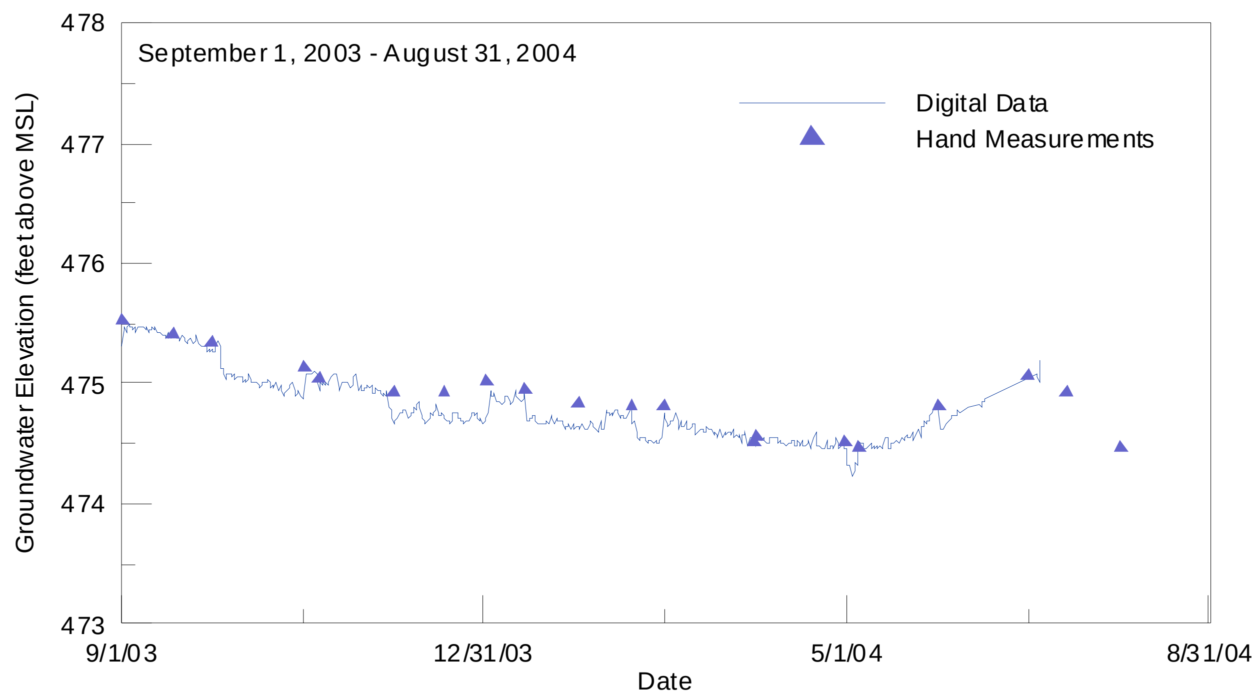

Figure 17. Groundwater elevations at the Rest Area network well (MTOW-7).

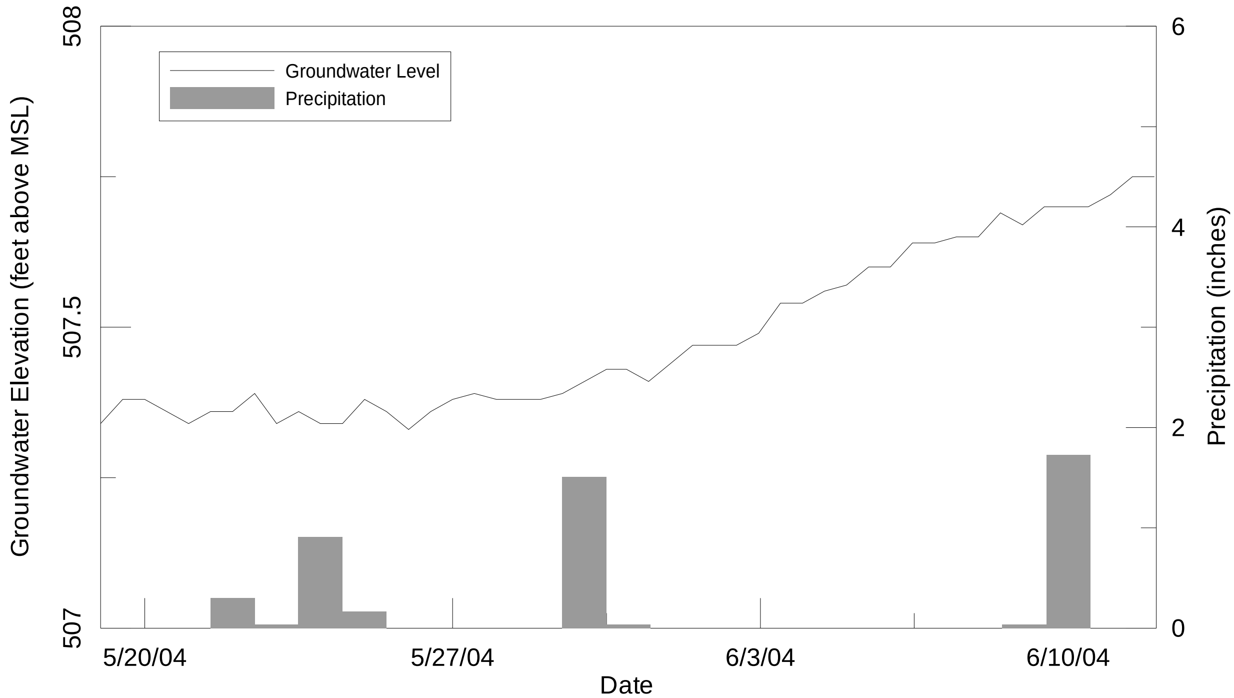

Figure 18. Groundwater elevations and precipitation (Gauge 7) at the Green Valley network well (MTOW-8).

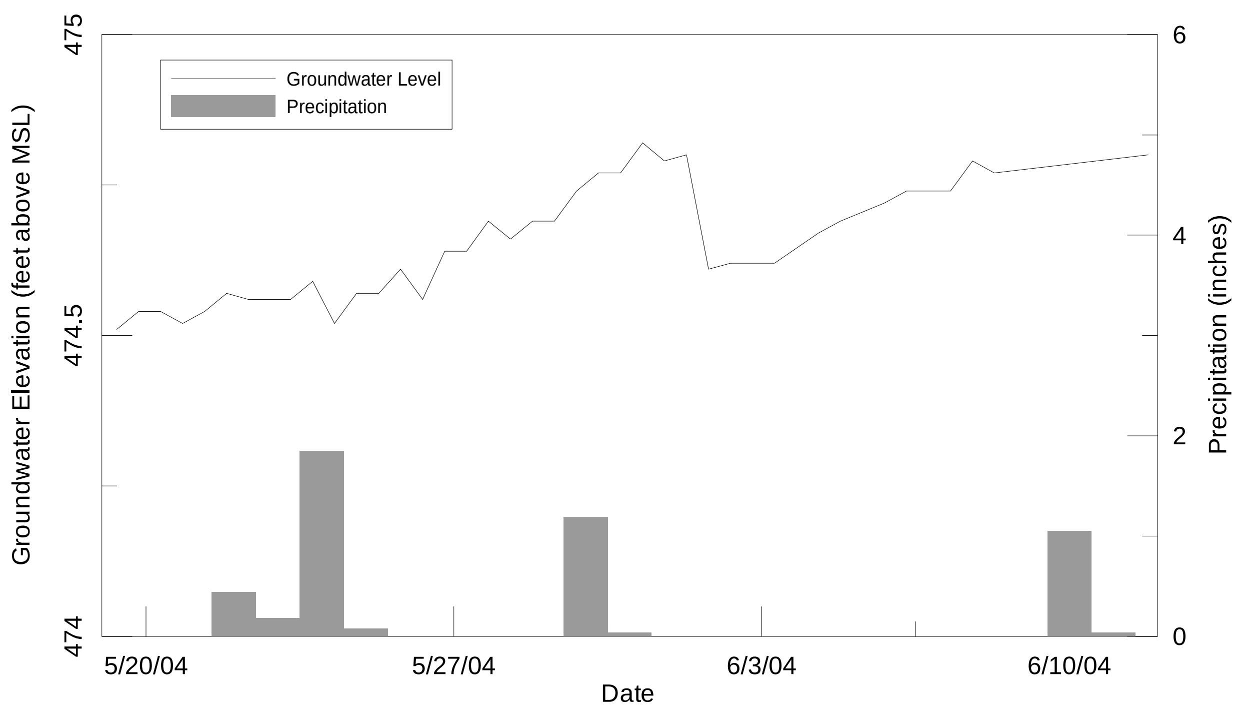

Figure 19. Groundwater elevations and precipitation (Gauge 13) at the Rest Area network well (MTOW-7).

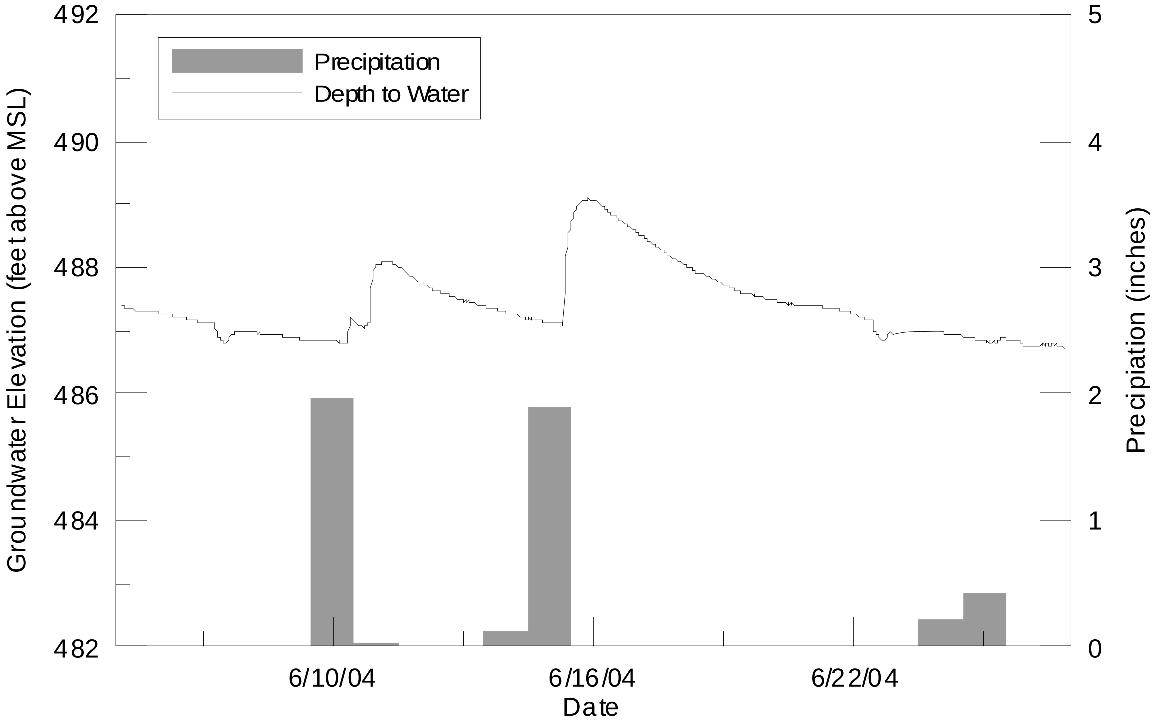

Figure 20. Groundwater elevations and precipitation (Gauge 20) at well 4 at the irrigation test site.

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, occurred in 1996; 2001 and 2002 (equal); 2003; 2004; 1999; 1997 and 1995 (equal); and 1998 and 2000 (equal). In examining these rankings, keep in mind that more irrigation systems are being added every year. Although 3 of the last 4 years had below average precipitation, the high ranking of the last 4 years is partially due to the additional irrigation systems. The greatest average irrigation withdrawals typically occur in July and August, with June and September withdrawals being much less.

The estimated monthly irrigation pumpage also is displayed graphically in Figure 21 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 21 shows that

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

Year	*June*	*July*	*August*	*September*	*Total*	*# Systems*	*BG/system*	*Rank*
1995	2.6	14	10	11	38			7
1996	2.0	20	18	12	52			1
1997	2.6	19	14	2.0	38			7
1998	2.1	7.8	13	6.9	30	1622	.018	9
1999	2.8	18	12	6.0	39	1771	.022	6
2000	6.4	6.0	12	5.6	30	1799	.017	9
2001	4.4	21	17	5.0	47	1818	.026	2
2002	3.4	24	16	3.7	47	1839	.026	2
2003	4.1	16	15	10	46	1867	.025	4
2004	5.3	12	19	5.7	42	1889	.022	5
Average	3.6	16	15	6.8	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

September-August period	*Network average precipitation (in.)*	*Annual surplus (in.)*	*Running surplus (in.)*	*Rank*	
				Precip.	*Irrigation*
1992 - 1993	55.55	+18.79	+18.79	1	-
1993 - 1994	40.21	+3.45	+22.24	2	-
1994 - 1995	39.42	+2.66	+24.90	5	7
1995 - 1996	25.70	-11.06	+13.84	12	1
1996 - 1997	27.31	-9.45	+4.39	10	7
1997 - 1998	40.06	+3.30	+7.69	3	9
1998 - 1999	34.02	-2.74	+4.95	6	6
1999 - 2000	25.81	-10.95	-6.00	11	9
2000 - 2001	30.97	-5.79	-11.79	7	2
2001 - 2002	39.91	+3.15	-8.64	4	2
2002 - 2003	30.06	-6.70	-15.34	8	4
2003 - 2004	29.64	-7.12	-22.46	9	5

1971 - 2000 30-yr average 37.82 (Havana)
1971 - 2000 30-yr average 35.70 (Mason City)
1971 - 2000 30-yr average 36.76 (average of Mason City and Havana used to determine surplus)

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

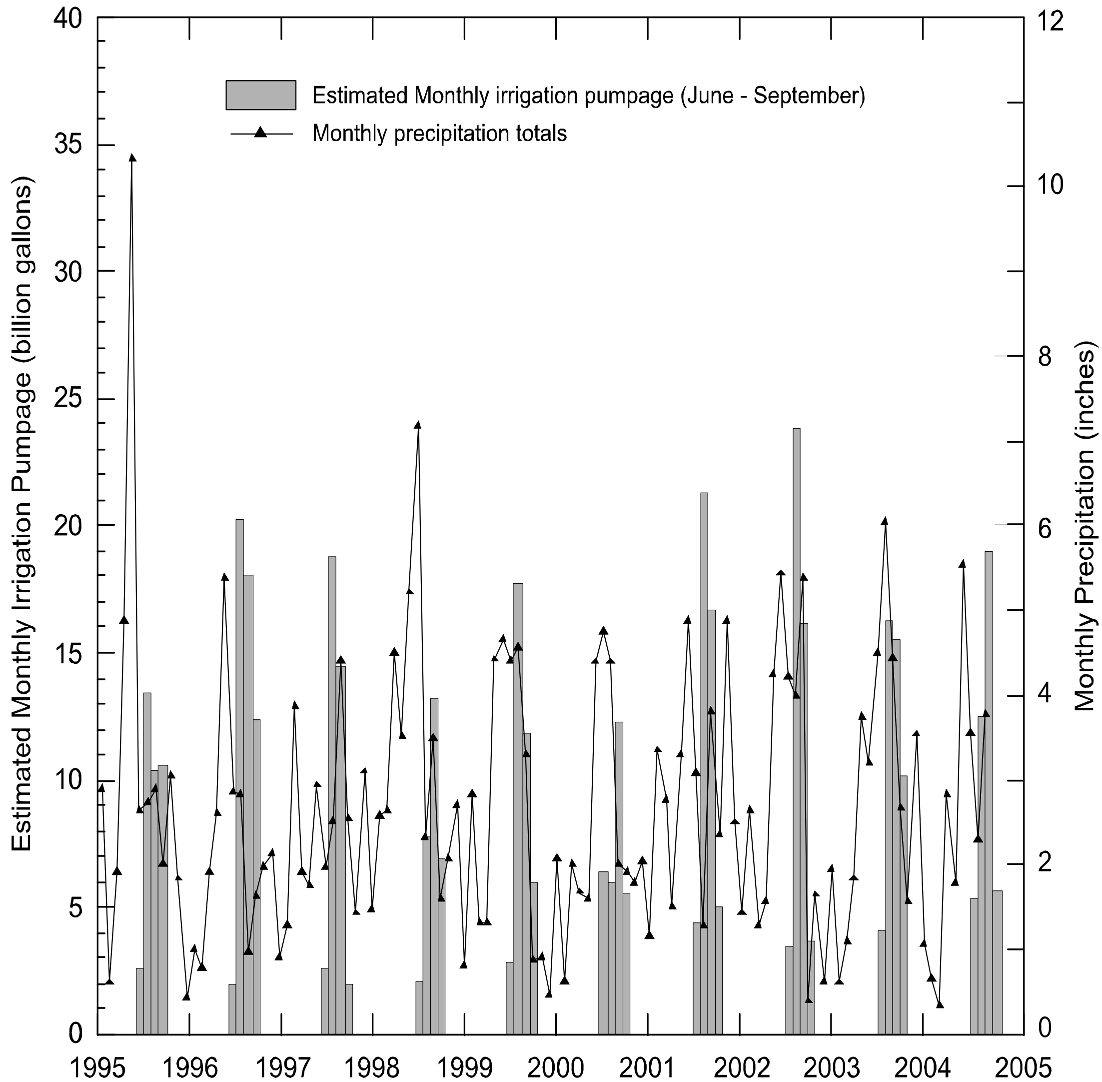

Figure 21. Estimated irrigation pumpage and average monthly precipitation, Imperial Valley.

significant precipitation fell during the summer of 2000, reducing the need for irrigation. Year Twelve was the fourth driest of network operation, 5.73 inches lower than the network's 11-year average precipitation (Table 4).

Table 8 also shows that for 7 of the last 9 years, rainfall was below the 30-year, historical average, although the timing of rainfall during the growing season has the most impact on the amount of irrigation withdrawals.

With 267 more systems in 2004 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 and September were near normal (Table 7) and July was below average, but August 2004 irrigation was the highest single August in the nine years of recorded data.

Summary

For Year Twelve of the rain gauge network operation (September 2003-August 2004), the network received an average of 29.64 inches of precipitation, 5.73 inches less than the network 11-year average precipitation of 35.37 inches. Below average precipitation fell in the winter and summer months, and average rain fell in fall 2003 and the spring of 2004. Year Twelve had the driest winter, and the fifth driest summer of the 12 years of network operation. Only one month (May 2004) had more than 5 inches of rain, and only three other months (November 2003, and June and August 2004) had more than 3 inches of precipitation.

Traditionally, 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 Year Twelve, however, levels in some wells declined throughout the entire year but showed a slight recovery in May 2004. For those wells, the highest water levels for the year were in September 2003.

Based on the record to date, since the 1993 flood there has been a slight downward trend in groundwater levels with a higher than average peak in groundwater levels every 3 to 4 years.

With a full year of data gathered at the irrigation test site, an understanding of the relationship between precipitation, pumpage, streamflow in Crane Creek, and groundwater levels is emerging. These factors are all closely related in this hydraulically connected system. Discharge measurements show that the creek is gaining water along the study area, meaning there is groundwater discharge to the creek occurring even during pumping times. Additional data collection and surveying the well elevations will allow for a more detailed assessment of the site conditions in the upcoming years of the project.

Two pressure transducers installed at the Rest Area (MTOW-7) and Green Valley (MTOW-8) network wells confirm that recharge is occurring over a fairly short time period (several days or less after a significant precipitation event). Initial observations indicate that distance from a river, creek, or stream, and depth to water influence the timing and magnitude of the recharge event. As more data become available and more wells are added to the transducer network, additional data analyses can be completed and a clearer picture of this relationship will develop.

Year Twelve, the fifth driest of network operation, was also the fifth highest irrigation withdrawal season. With 267 more systems in 2004 than in 1998, the increased number of irrigation systems likely plays some role in how much water is being applied within the IVWA. Irrigation amounts in June and September were near normal and July was below average, but August 2004 irrigation was the highest of any single August in the nine years of recorded data.

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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.

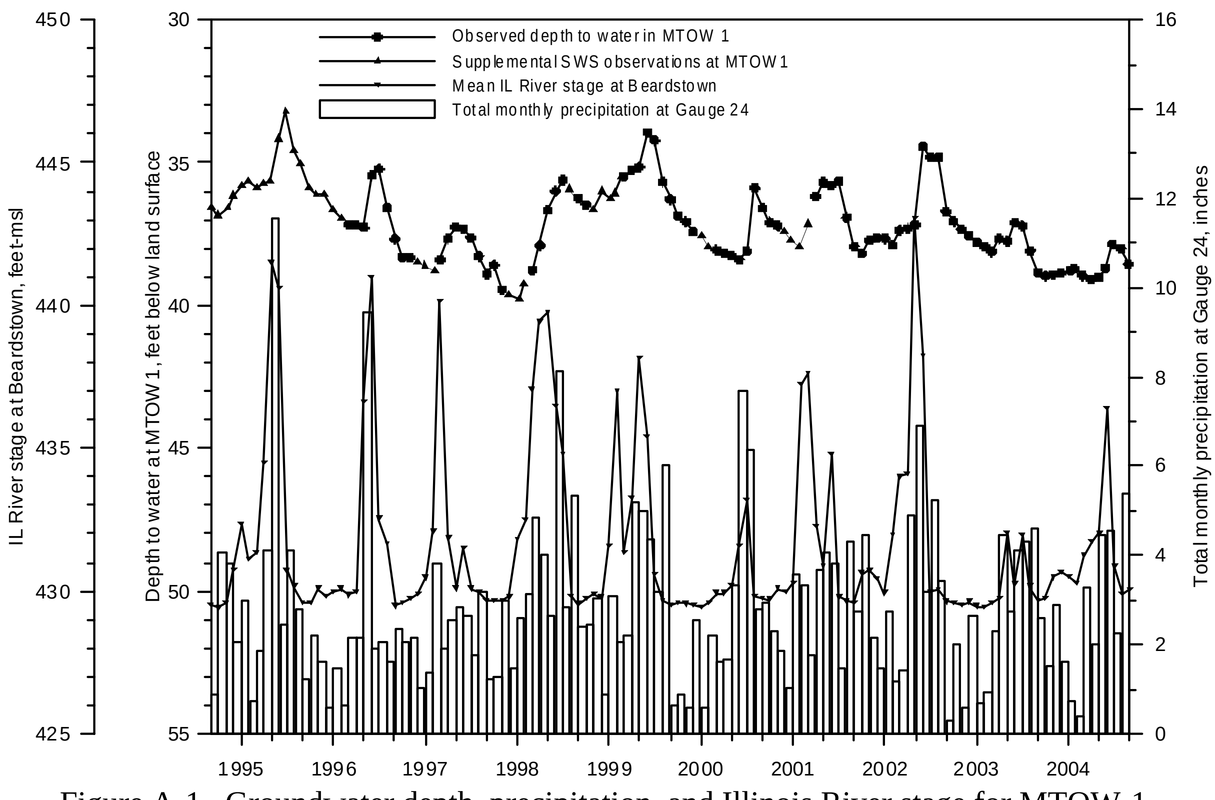


Figure A-1. Groundwater depth, precipitation, and Illinois River stage for MTOW-1.

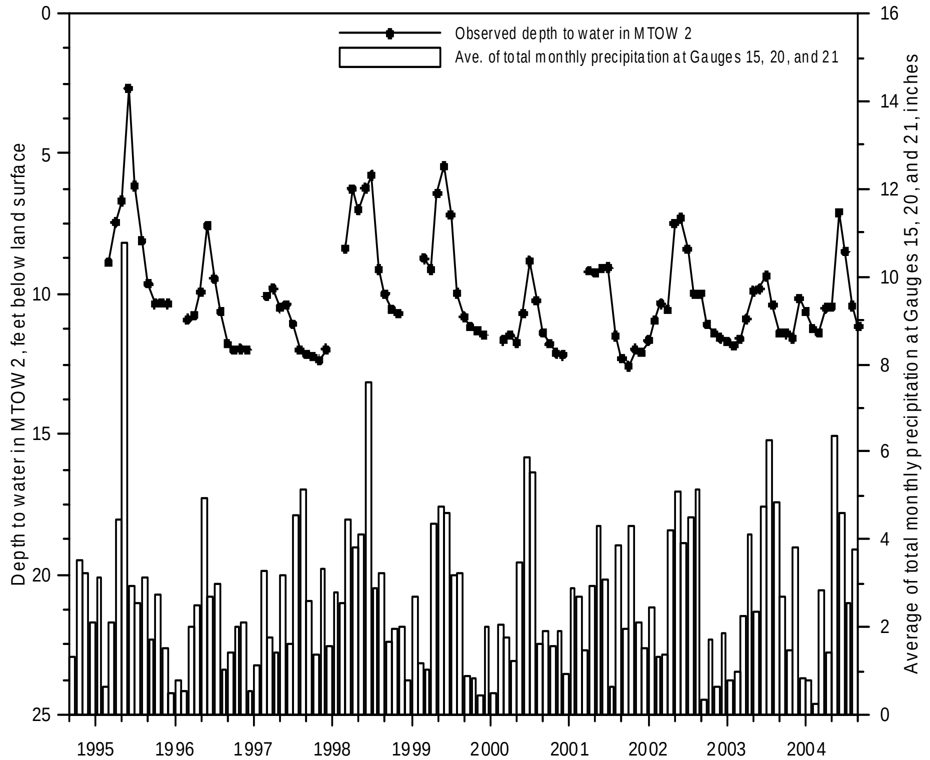


Figure A-2. Groundwater depth and precipitation for MTOW-2.

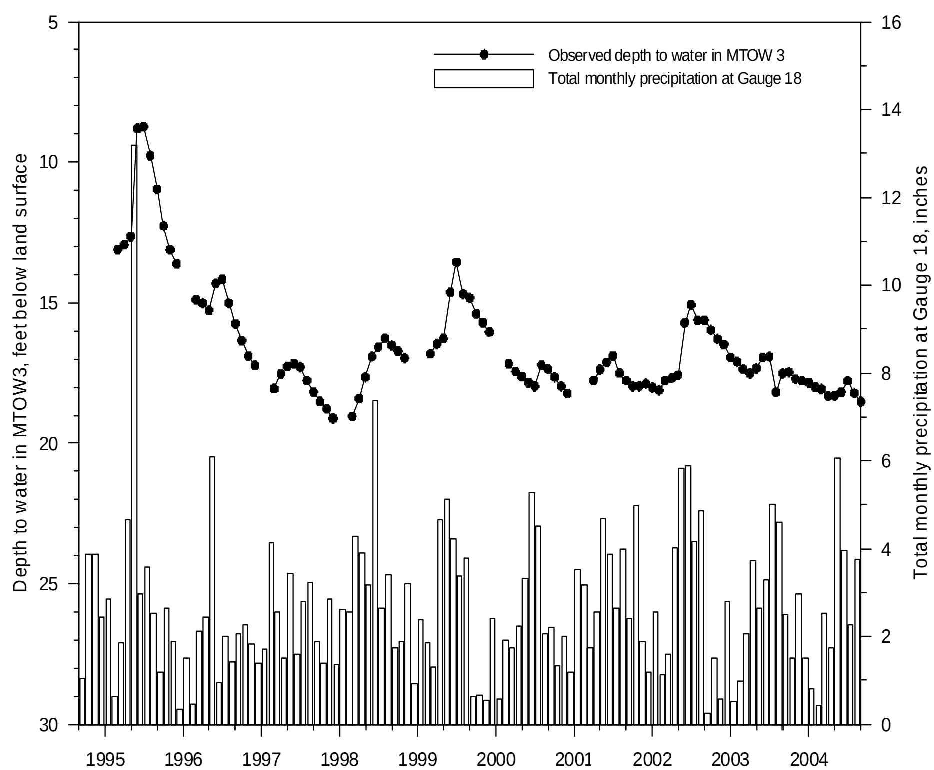


Figure A-3. Groundwater depth and precipitation for MTOW-3.

Appendix A. (continued)

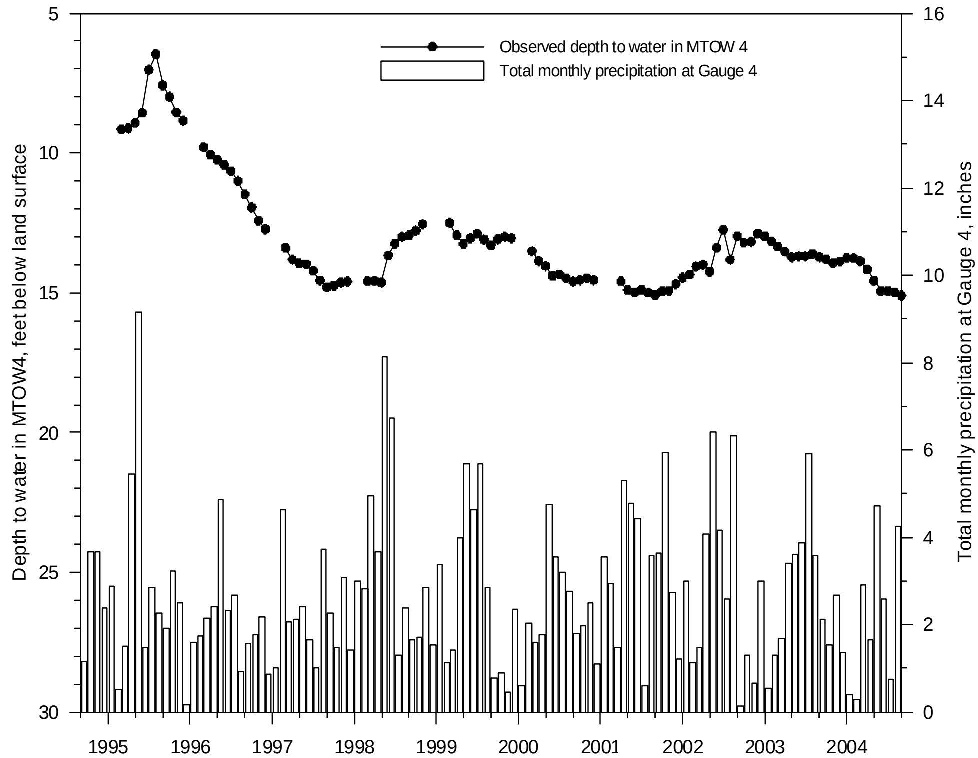


Figure A-4. Groundwater depth and precipitation for MTOW-4.

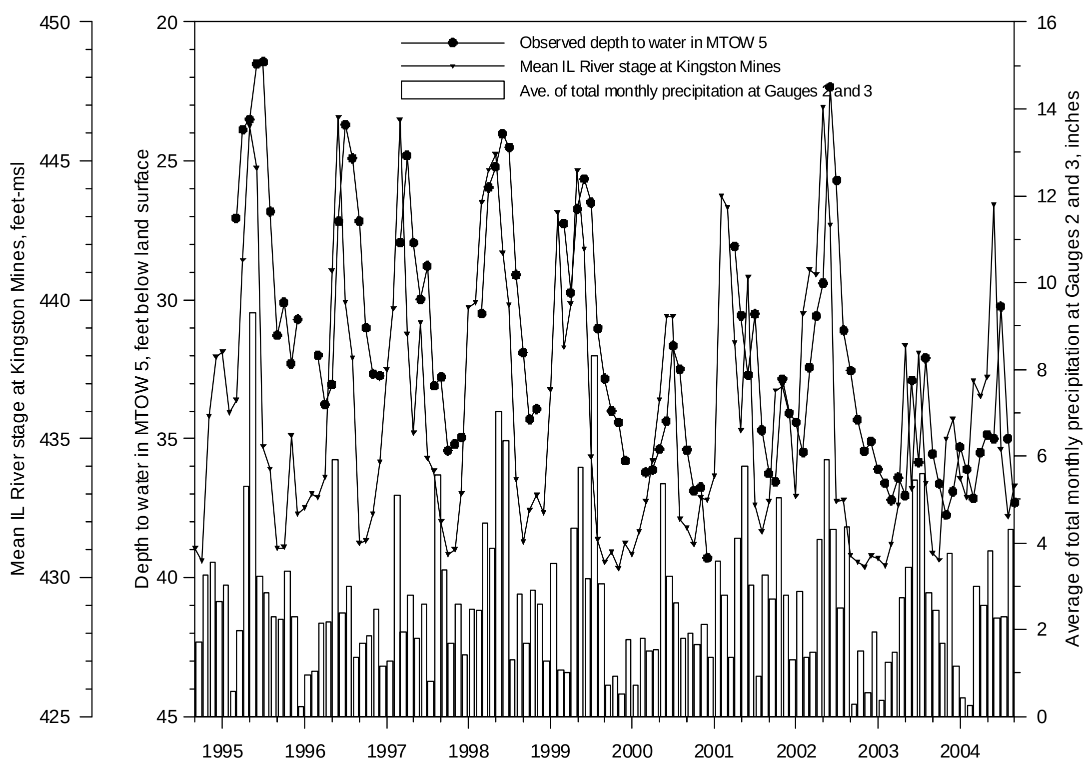


Figure A-5. Groundwater depth, precipitation, and Illinois River stage for MTOW-5.

Appendix A. (continued)

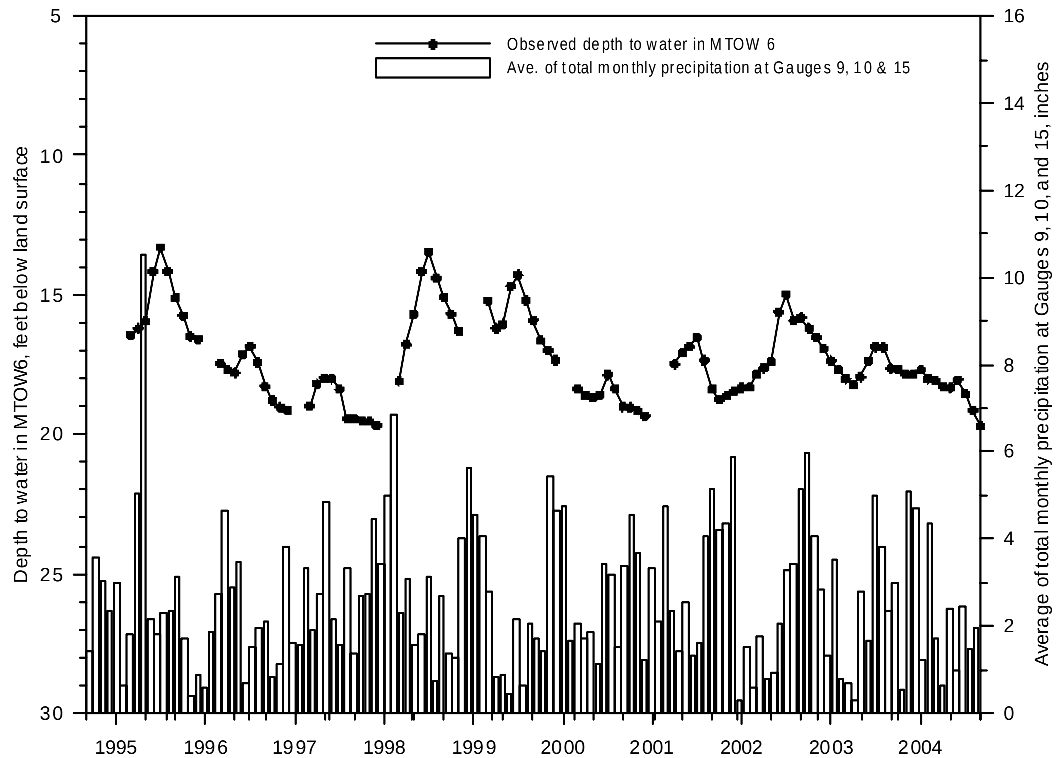


Figure A-6. Groundwater depth and precipitation for MTOW-6.

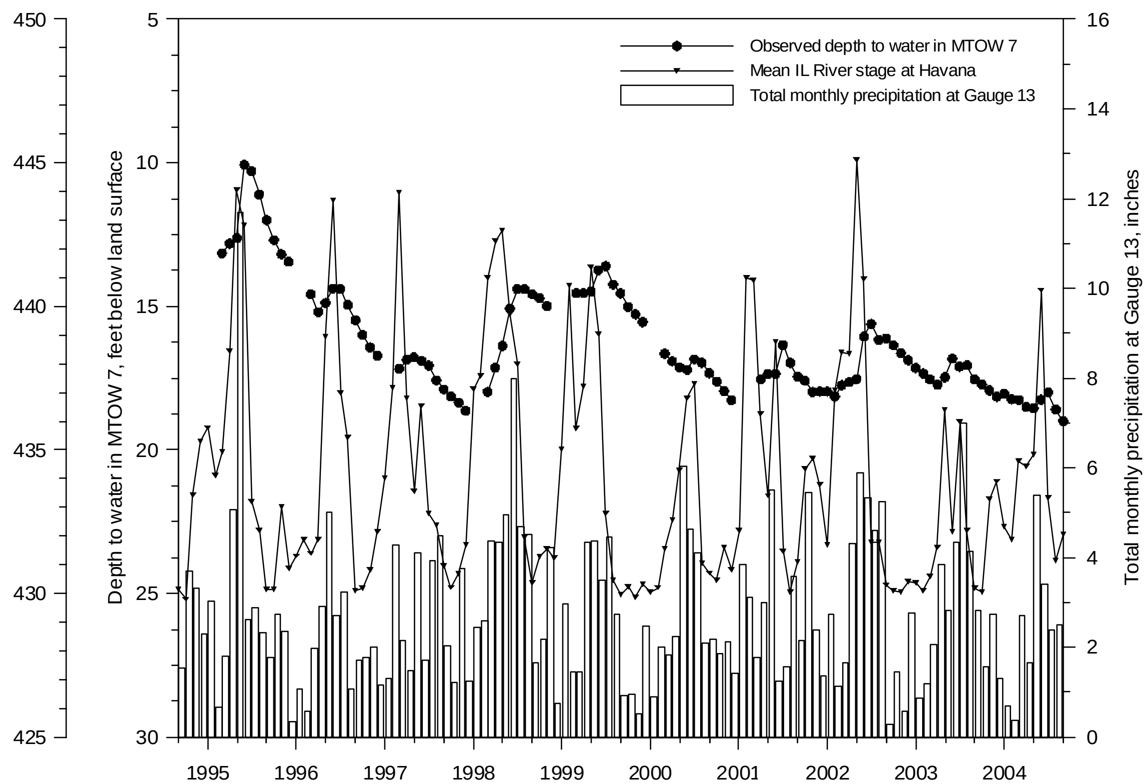


Figure A-7. Groundwater depth, precipitation,
and Illinois River stage for MTOW-7.

Appendix A. (continued)

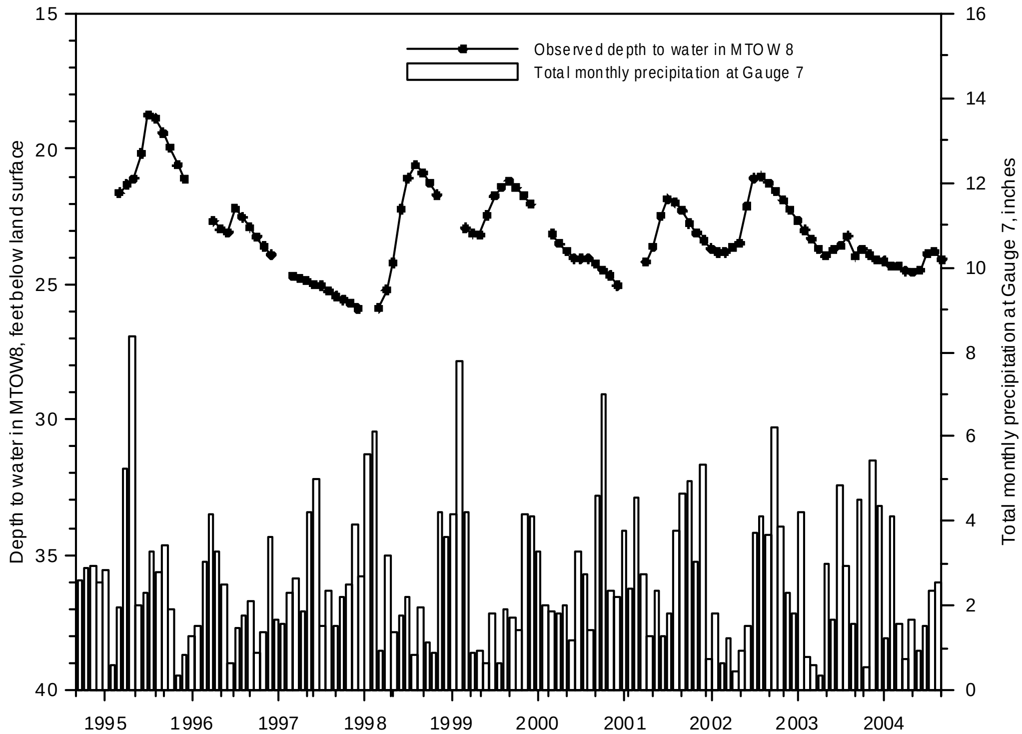


Figure A-8. Groundwater depth and precipitation for MTOW-8.

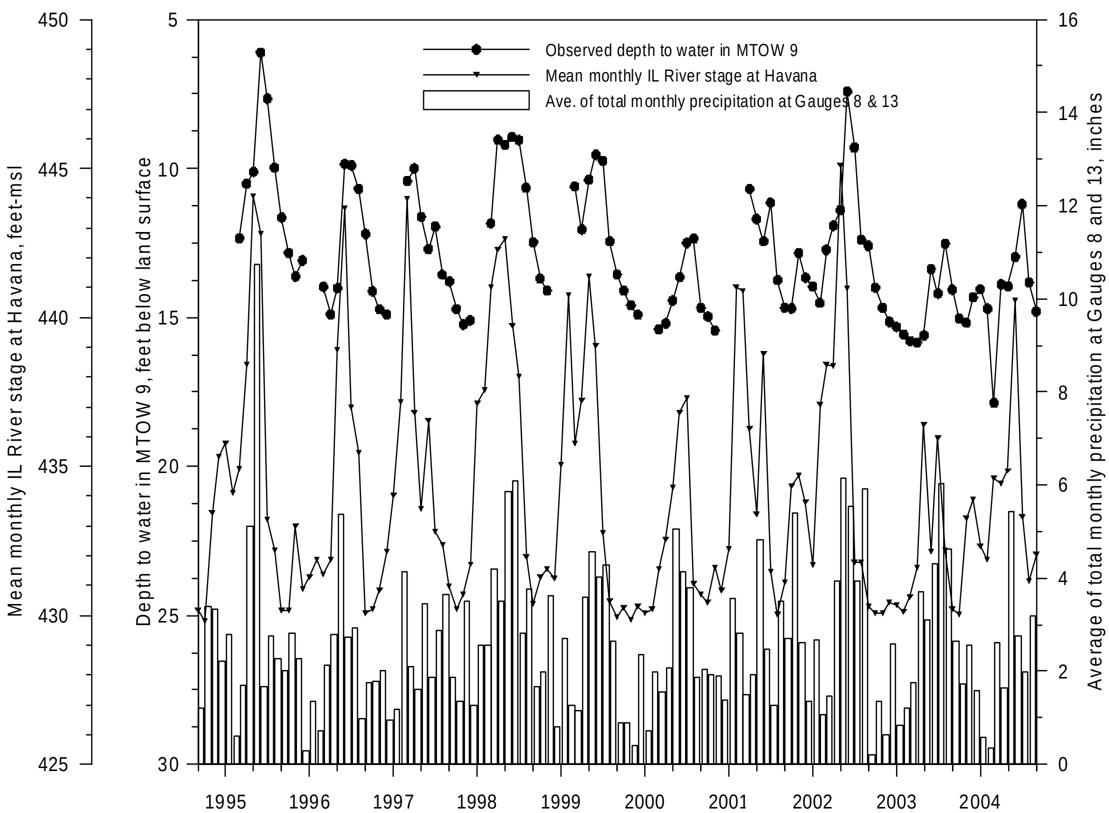


Figure A-9. Groundwater depth, precipitation, and Illinois River stage for MTOW-9.

Appendix A. (continued)

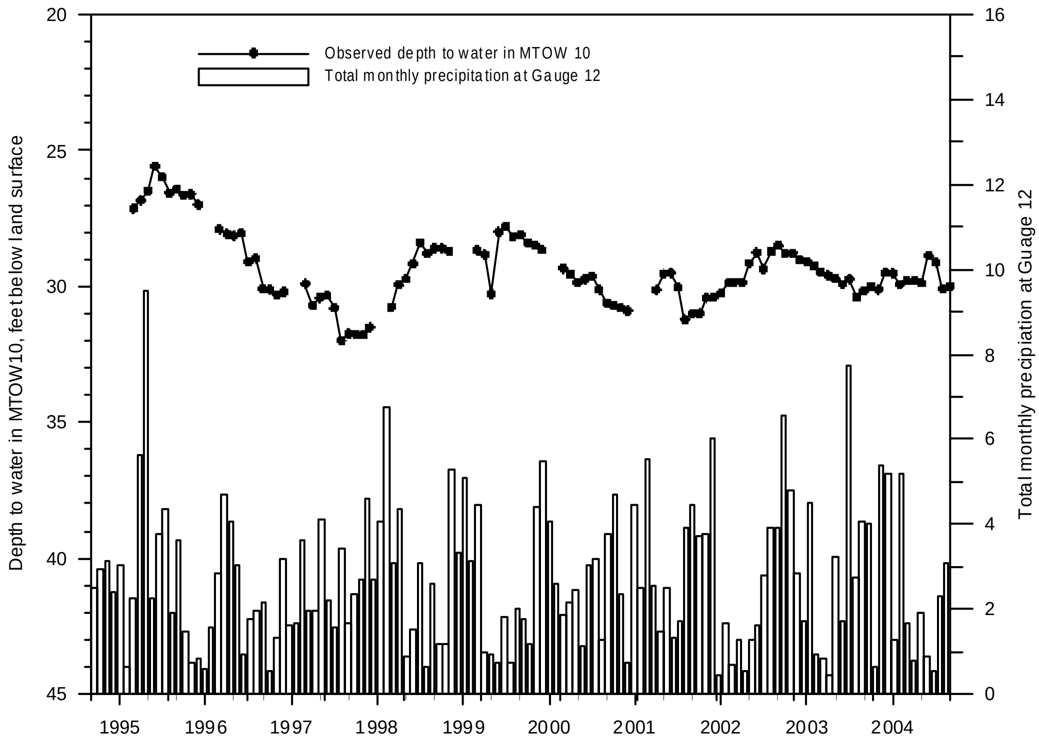


Figure A-10. Groundwater depth and precipitation for MTOW-10.

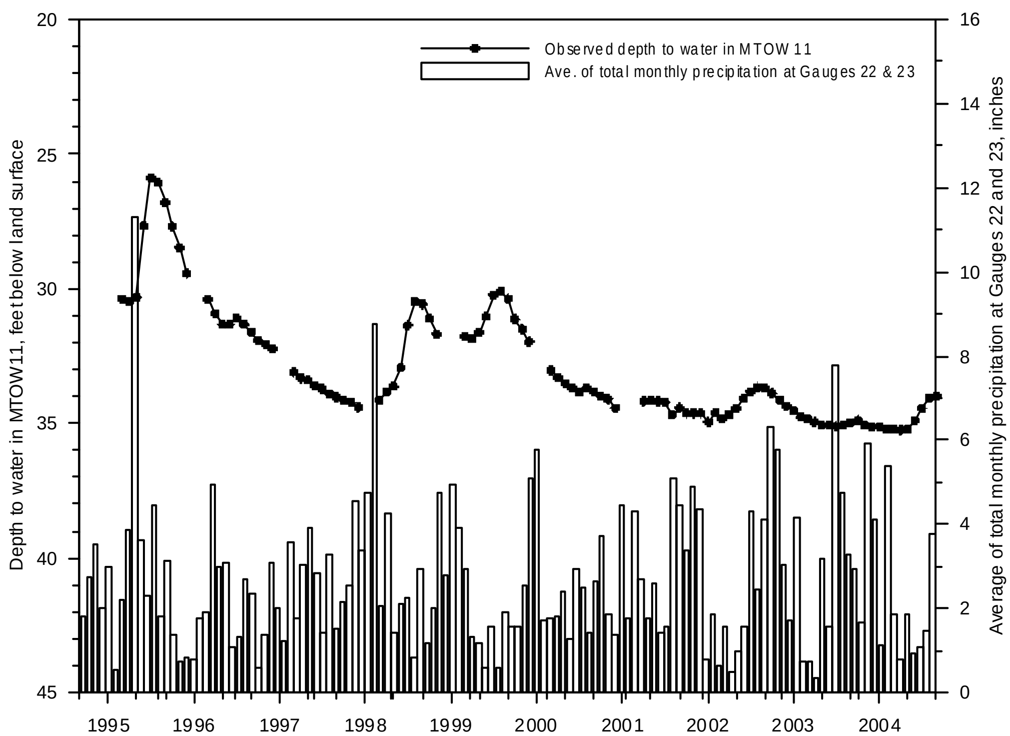


Figure A-11. Groundwater depth and precipitation for MTOW-11.

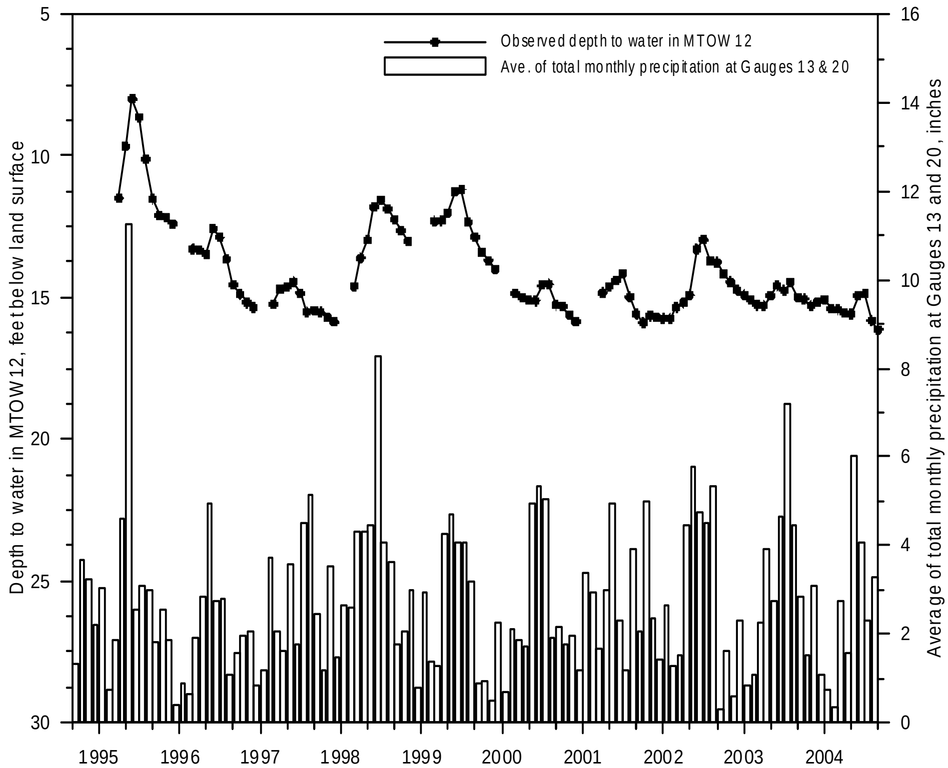


Figure A-12. Groundwater depth and precipitation for MTOW-12.

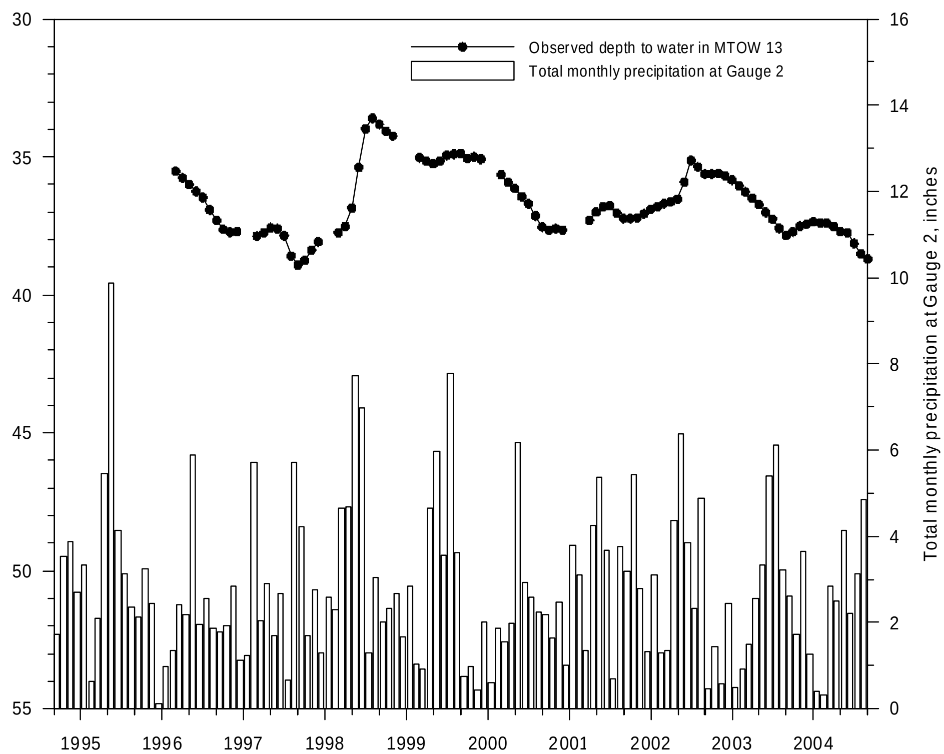


Figure A-13. Groundwater depth and precipitation for MTOW-13.

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

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

	Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells												
Date	*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. (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*
3-01-2000	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 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*
9-01-2003	38.86	11.40	17.52	13.73	35.55	17.65	17.54	22.97	14.07	30.17	34.98	14.99	*37.85*
10-01-2003	*38.98*	11.42	17.47	13.80	36.62	17.68	17.72	23.70	15.04	30.00	34.88	15.06	37.72
11-01-2003	38.92	11.58	17.71	*13.94*	*37.75*	17.85	17.93	23.90	15.18	30.12	35.08	*15.29*	37.51
12-01-2003	38.88	10.15	17.78	13.88	36.90	17.85	*18.15*	*24.08*	14.33	29.50	*35.15*	15.15	37.44
1-01-2004	38.78	10.64	17.85	**13.75**	35.30	**17.71**	**18.05**	**24.14**	14.06	29.52	35.13	15.08	**37.35**
2-10-2004	38.73	11.25	18.01	13.77	36.10	18.02	18.24	24.31	14.71	29.92	35.23	15.39	37.39
3-01-2004	38.97	*11.39*	18.07	13.87	*37.14*	18.05	18.26	24.33	*17.87*	29.80	35.20	15.42	37.40
4-01-2004	*39.10*	10.51	*18.32*	14.16	35.50	18.29	18.51	24.51	13.89	29.78	*35.25*	15.56	37.53
5-01-2004	39.02	10.45	18.30	14.57	34.85	18.34	18.55	*24.55*	13.96	29.88	35.21	15.59	37.70
6-01-2004	38.69	**7.10**	18.17	14.94	35.00	18.05	18.25	24.49	12.97	**28.88**	34.90	14.95	37.75
7-01-2004	**37.86**	8.50	**17.78**	14.93	**30.24**	18.55	18.00	23.88	**11.20**	29.12	34.44	**14.87**	38.14
8-01-2004	38.01	10.43	18.21	*14.98*	35.00	*19.14*	*18.60*	23.80	13.83	*30.10*	**34.07**	*15.82*	*38.52*

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, 2004. 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: Kirk Martin		
Address: 33534 E. County Road 930 N, Mason City, IL 62664		
Telephone: 217-482-3509		
Permission Date: 3-23-04		
Installation Date: 3-26-04		
Gauge Mfrs. No.: 4708	Gauge ID No.: SWS 5021	
Placement: Gauge moved 1.25 mi. north-northeast of previous location, 15-20 feet off local road, with field about 70 feet away. Was 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 and 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 Nancy Westcott. Either call her 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, 2003-2004

Appendix E. Documentation, Imperial Valley Rain Gauge Network Maintenance, 2003-2004

This appendix documents major maintenance work carried out at sites in the Imperial Valley rain gauge network from September 1, 2003 through August 31, 2004.

1. Replaced clock batteries at site 24 on 09-02-2003.

2. Replaced battery linkage at site 8 on 09-08-2003.

3. Replaced clock batteries at site 23 on 10-03-2003.

4. Replaced data logger and gauge at site 16 on 10-13-2003.

5. Cleaned and recalibrated gauges at sites 2, 6, and 24 on 10-24-2003.

6. Winterized, including changing clock batteries, removing evaporation shield and adding anti-freeze to all gauges on 11-03/04-2003.

7. Cleaned and recalibrated gauges at sites 10, 11, 13, 15, and 23 on 11-06/07-2003, and replaced batteries in the data loggers at these sites.

8. Replaced remaining data logger batteries on 11-11-2003.

9. Replaced data logger in gauge at site 16 on 11-21-2003.

10. Replaced data logger and gauge at site 19 on 02-09-2004.

11. Replaced data logger at site 12 on 03-15-2004.

12. Moved site 22 to a location about 1.25 miles to the north-northeast of its current location on 03-26-2004.

13. Replaced the gauge shelter at site 7 on 05-04-2004.

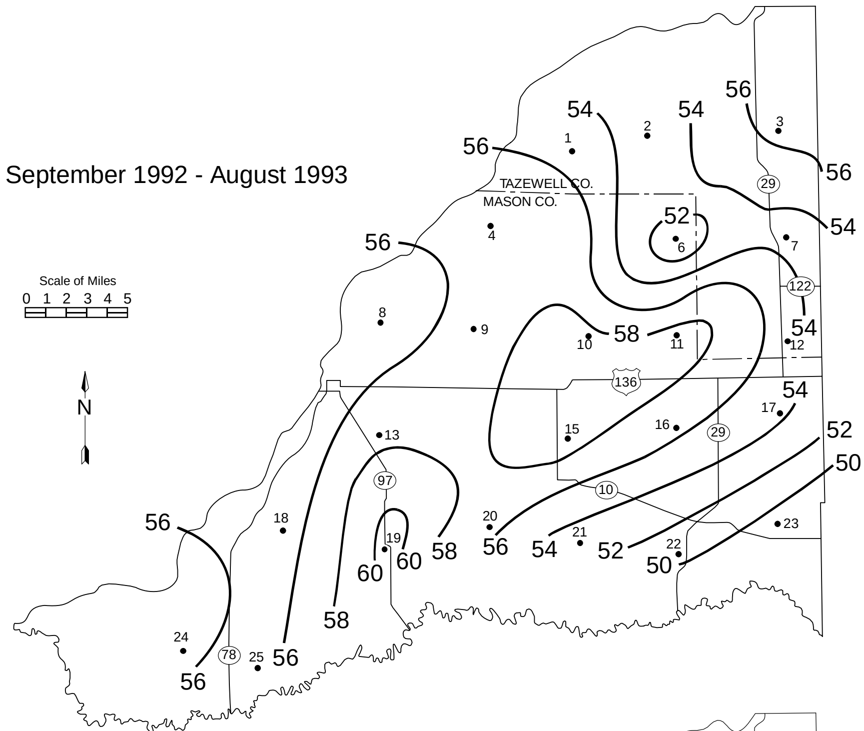
14. Replaced the interface board on the data logger at site 7 on 07-12-2004.

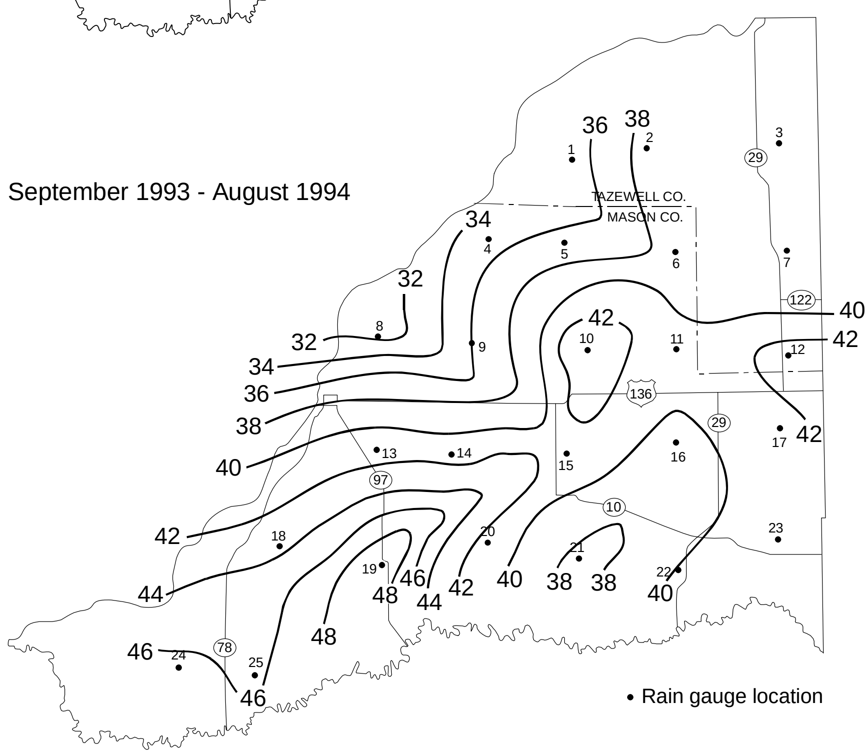
15. Replaced the data logger at site 18 on 08-23-2004.

Appendix F. Annual Precipitation, Years One-Eleven

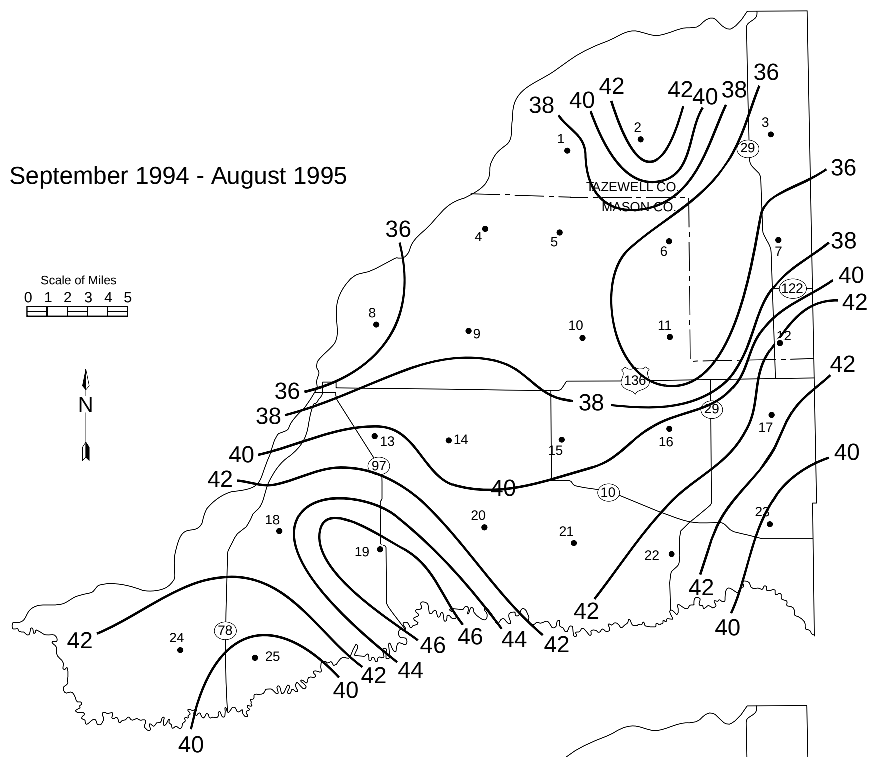
Appendix F. Annual Precipitation, Years One-Eleven

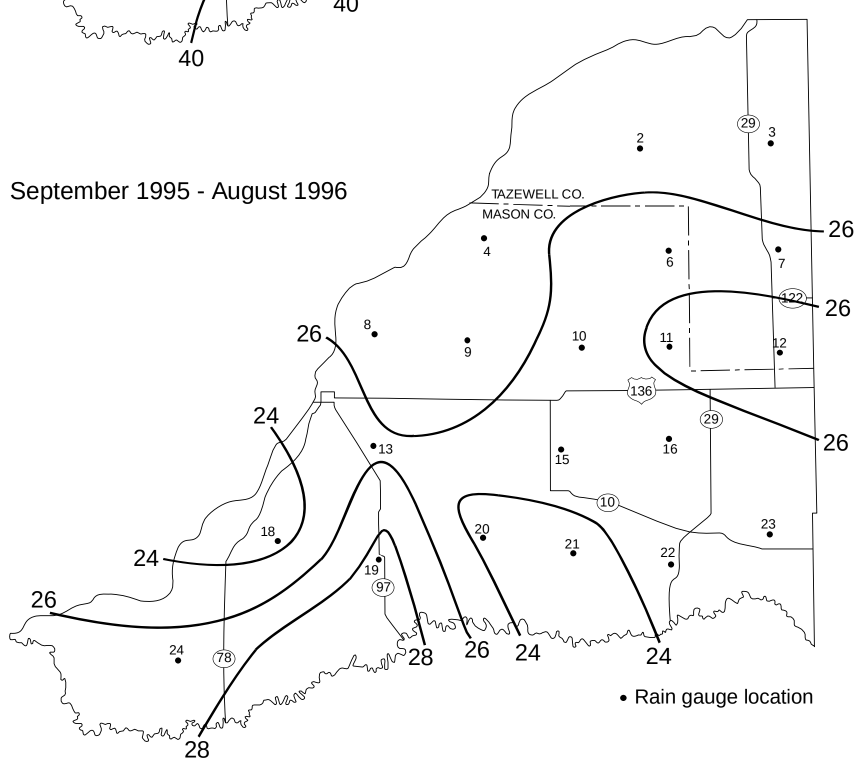
(Rain gauge #16 omitted from Years 5-10)



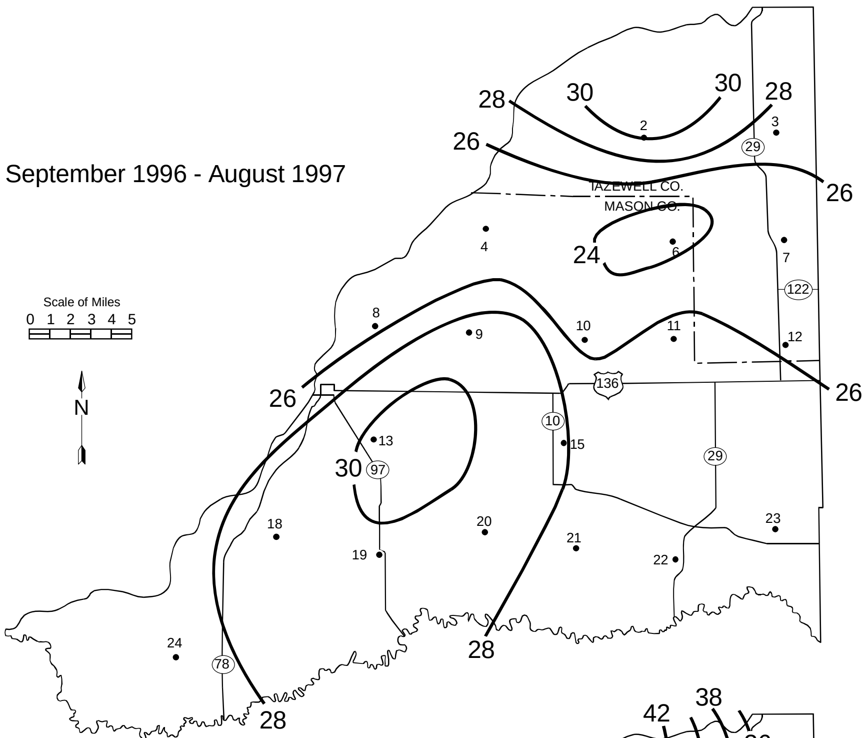


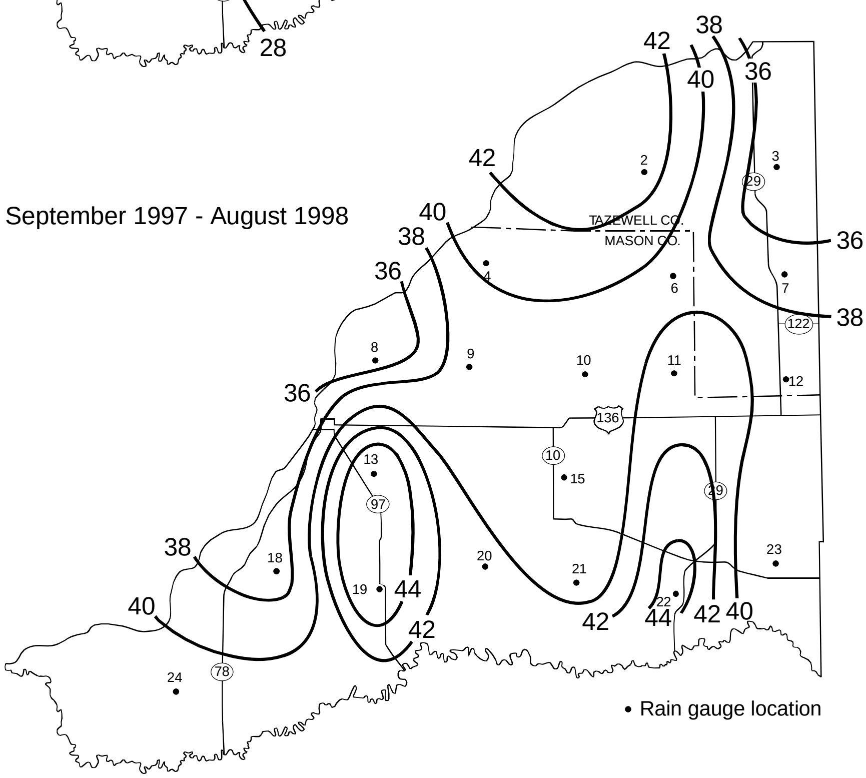
Appendix F. (continued)



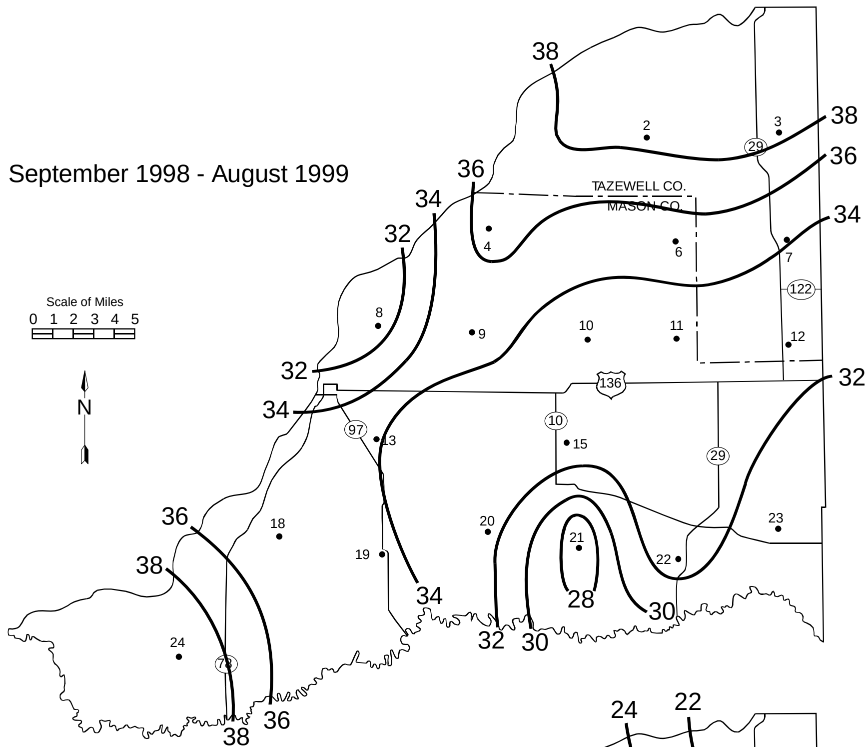


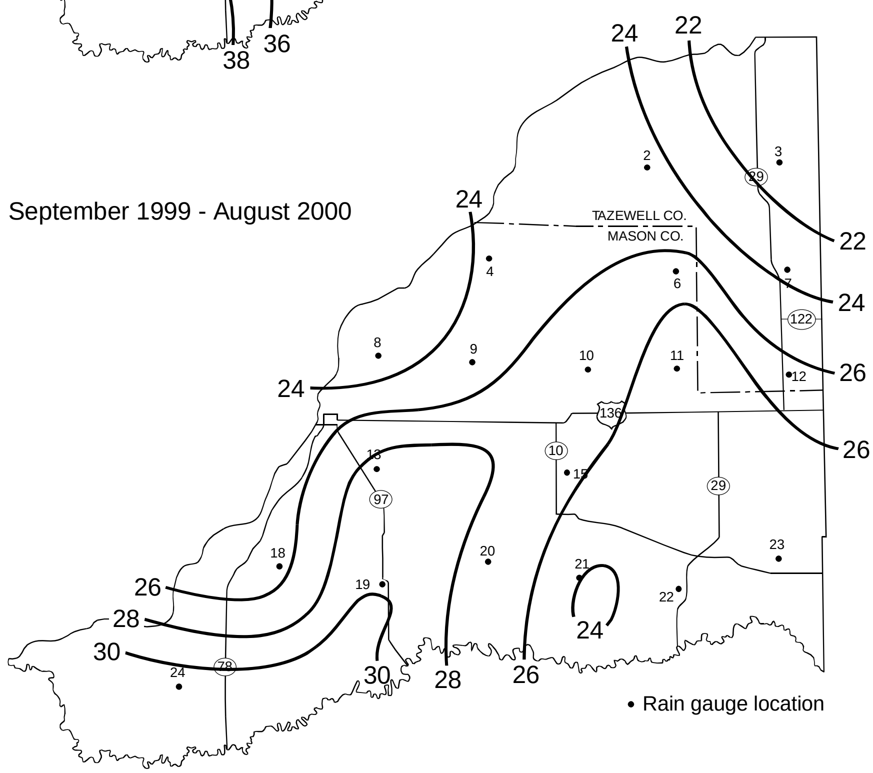
Appendix F. (continued)



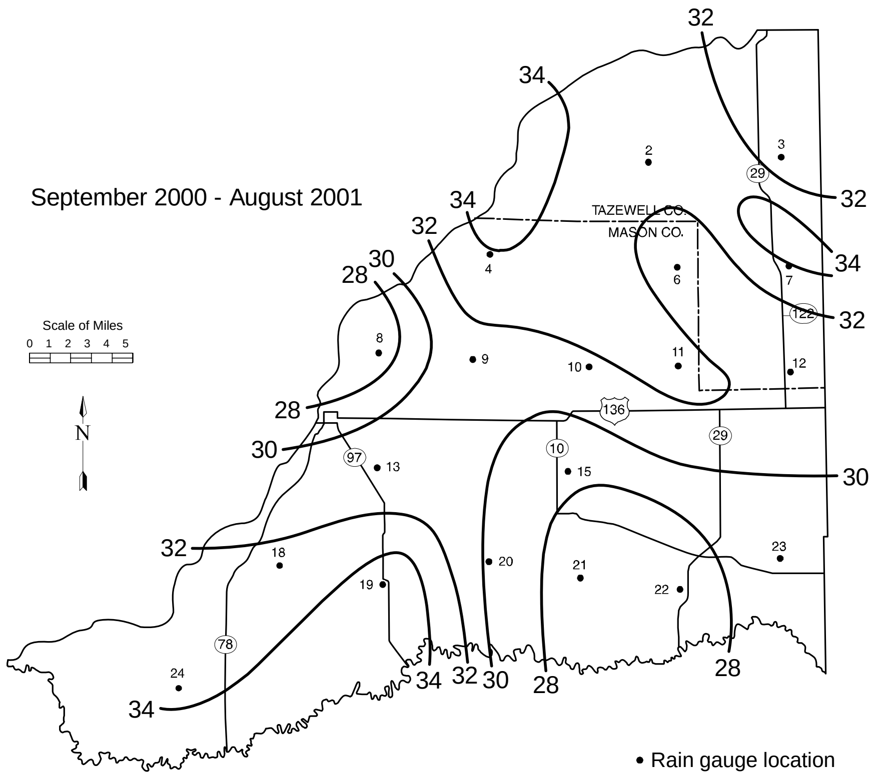


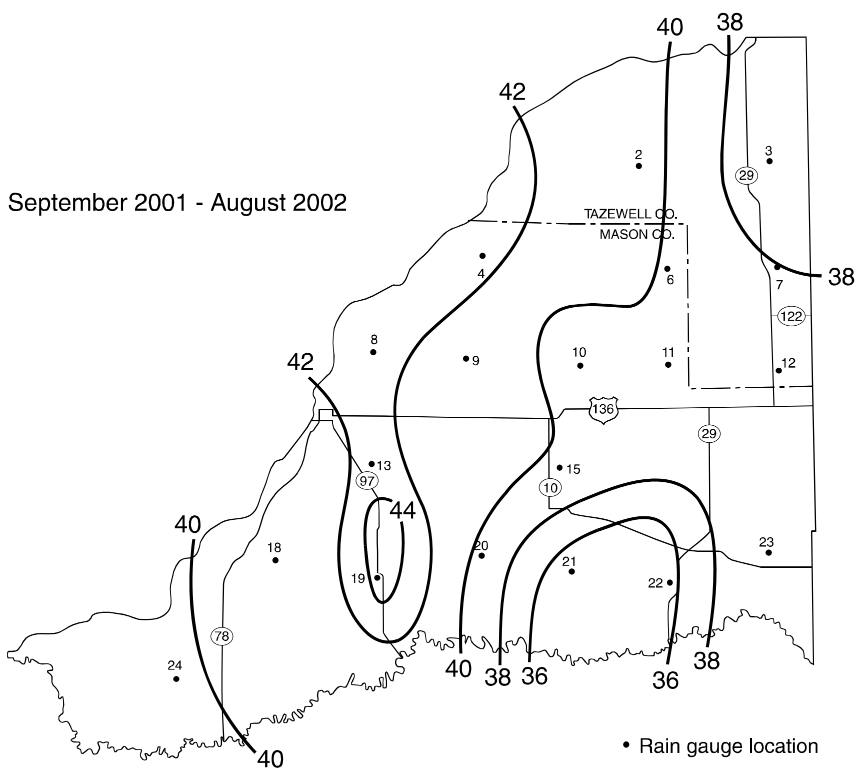
Appendix F. (continued)



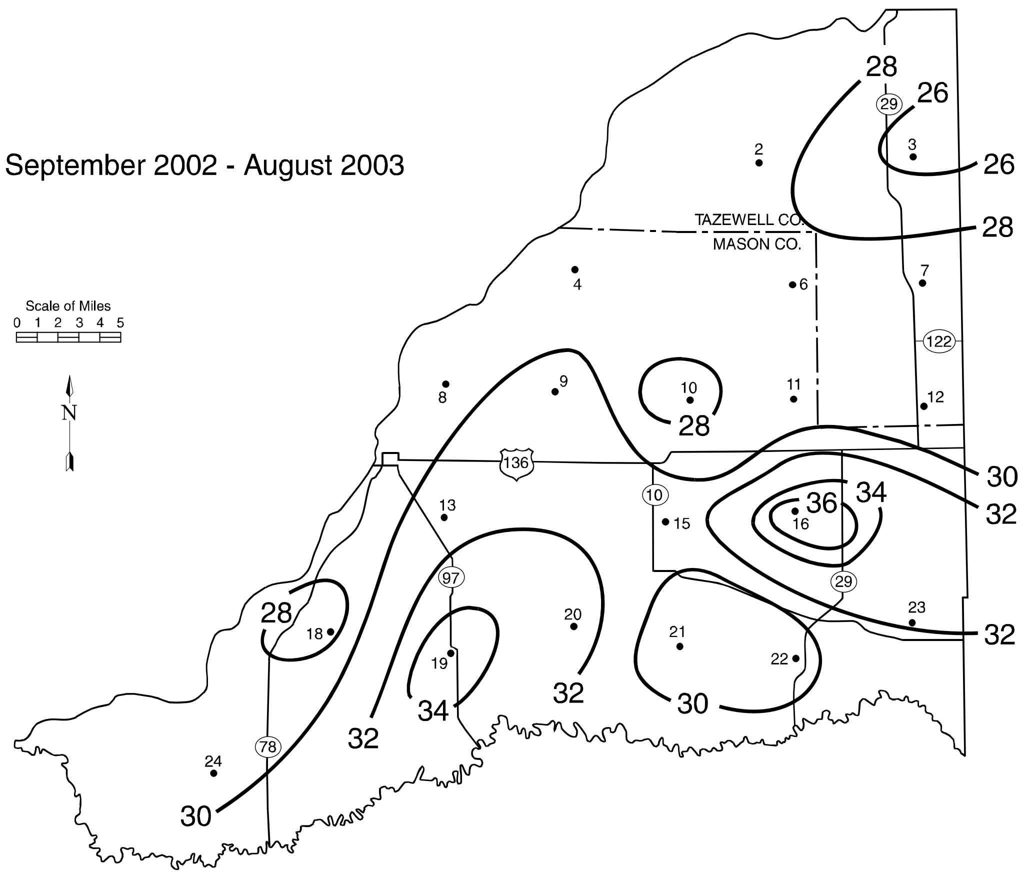


Appendix F. (continued)





Appendix F. (concluded)



Appendix G. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992-2003

Appendix G. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992-2003

	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*	*2002-03*
September	10	8	6	6	6	6	8	8	10	7	3
October	10	5	7	9	11	7	11	6	10	17	8
November	13	7	10	3	9	8	14	17	11	12	7
December	9	9	8	5	5	10	6	14	21	9	2
January	9	8	5	8	13	12	19	11	18	4	6
February	5	6	3	4	8	7	17	21	8	9	5
March	10	6	6	7	8	8	6	9	7	12	6
April	11	12	19	6	11	12	18	14	14	9	6
May	16	7	16	25	15	16	15	16	14	13	10
June	13	13	15	11	14	17	12	12	11	10	11
July	21	9	16	10	6	15	9	11	10	10	5
August	21	12	18	4	15	16	9	17	14	10	11
Fall	33	20	23	18	26	21	33	31	31	36	18
Winter	23	23	16	17	26	29	42	46	47	22	13
Spring	37	25	41	38	34	36	39	39	35	34	22
Summer	55	34	49	25	35	48	30	40	35	30	27
Annual	148	102	129	98	121	134	144	156	148	122	80

	Total precipitation, inches										
Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*	*2002-03*
September	4.21	11.56	1.49	2.00	1.63	2.55	1.61	0.87	1.93	2.35	0.39
October	2.00	2.97	3.34	3.06	1.99	1.43	2.07	0.92	1.79	4.89	1.65
November	6.35	2.59	3.37	1.84	2.15	3.10	2.70	0.48	2.05	2.50	0.62
December	2.82	1.11	2.29	0.45	0.90	1.47	0.81	2.07	1.17	1.43	1.95
January	3.52	0.96	2.90	1.01	1.28	2.59	2.84	0.63	3.35	2.64	0.61
February	1.64	1.64	0.61	0.77	3.86	2.65	1.32	2.00	2.78	1.28	1.09
March	3.85	0.96	1.93	1.93	1.92	4.51	1.32	1.68	1.50	1.58	1.84
April	5.25	5.03	4.87	2.61	1.76	3.53	4.42	1.59	3.31	4.24	3.75
May	2.61	3.11	10.33	5.37	2.94	5.21	4.65	4.39	4.89	5.43	3.20
June	6.27	3.19	2.65	2.85	1.97	7.19	4.41	4.76	3.08	4.23	4.50
July	11.05	3.44	2.73	2.84	2.51	2.34	4.56	4.39	1.30	3.99	6.04
August	5.99	3.66	2.90	0.98	4.41	3.50	3.30	2.02	3.81	5.37	4.43
Fall	12.56	17.12	8.20	6.89	5.77	7.08	6.38	2.27	5.77	9.74	2.66
Winter	7.97	3.70	5.80	2.23	6.04	6.71	4.97	4.70	7.30	5.35	3.65
Spring	11.71	9.10	17.14	9.91	6.62	13.25	10.39	7.66	9.70	11.25	8.79
Summer	23.31	10.29	8.28	6.68	8.89	13.03	12.27	11.17	8.19	13.59	14.97
Annual	55.55	40.21	39.42	25.70	27.31	40.06	34.02	25.81	30.97	39.91	30.06

Appendix G. (concluded)

Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*	*2002-03*
	Inches of precipitation per precipitation event										
September	0.42	1.45	0.25	0.33	0.27	0.43	0.20	0.11	0.19	0.34	0.13
October	0.20	0.59	0.48	0.34	0.18	0.2	0.19	0.15	0.18	0.29	0.27
November	0.49	0.37	0.34	0.61	0.24	0.39	0.19	0.03	0.19	0.21	0.10
December	0.31	0.12	0.29	0.09	0.18	0.15	0.14	0.15	0.06	0.16	0.65
January	0.39	0.12	0.58	0.13	0.10	0.22	0.15	0.06	0.19	0.66	0.10
February	0.33	0.27	0.20	0.19	0.48	0.38	0.08	0.10	0.35	0.14	0.14
March	0.38	0.16	0.32	0.28	0.24	0.56	0.22	0.19	0.21	0.13	0.23
April	0.48	0.42	0.26	0.43	0.16	0.29	0.25	0.11	0.24	0.47	0.42
May	0.16	0.44	0.65	0.21	0.20	0.33	0.31	0.27	0.35	0.42	0.32
June	0.48	0.25	0.18	0.26	0.14	0.42	0.37	0.40	0.28	0.42	0.45
July	0.53	0.38	0.17	0.28	0.42	0.16	0.51	0.40	0.13	0.40	1.01
August	0.29	0.31	0.16	0.25	0.29	0.22	0.37	0.12	0.27	0.54	0.74
Fall	0.38	0.86	0.36	0.38	0.22	0.34	0.19	0.07	0.19	0.27	0.15
Winter	0.35	0.16	0.36	0.13	0.23	0.23	0.12	0.10	0.16	0.24	0.28
Spring	0.32	0.36	0.42	0.26	0.19	0.37	0.27	0.20	0.28	0.33	0.40
Summer	0.42	0.30	0.17	0.27	0.25	0.27	0.41	0.28	0.23	0.45	0.55
Annual	0.38	0.39	0.31	0.26	0.23	0.30	0.24	0.17	0.21	0.33	0.38

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

Appendix H. Documentation of Precipitation Events in the Imperial Valley, 2003-2004

Appendix H. Documentation of Precipitation Events in the Imperial Valley, 2003-2004

This appendix documents all storm event 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, 2003-August 31, 2004 (Table H-2). Table H-3 documents the storm event amounts for each gauge. The maximum storm amount in a given network storm period is used to compute the recurrence interval for a given precipitation event. The same information for previous years is found in Scott et al. (2002) and Wehrmann et al. (2004, 2005). 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 in Table H-1 (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 1490 has a duration of 30 hours. This storm duration falls between the 24- and 48-hour storm duration in Table H-1. Assume a 48-hour storm duration. Table H-3 indicates the gauge at site 19 recorded precipitation equal to 3.49 inches, and the gauge at site 24 recorded 3.19 inches. Therefore, site 19 exceeded the 2-year return frequency amount (3.38 inches) for a 48-hour storm, and site 24 exceeded the one-year return frequency amount (2.81 inches) for a 48-hour storm.

Table H-3 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 (Huff and Angel, 1989)

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, 2003-2004

Storm Number	*Storm* Start Day	*Start* Time (CST)	*Storm* Duration (Hours)	*Number* Gauges with Precipitation	*Network* Average Precipitation (inches)	*Storm* Average Precipitation (inches)	*Network* Maximum Precipitation (inches)	*Gauge No.* with Maximum	*Storm* Recurrence Frequency
					September-03				
1383	1	100	14	20	1.34	1.34	1.99	16	
1384	12	1100	3	5	0.02	0.07	0.13	11	
1385	12	1700	18	13	0.05	0.08	0.20	24	
1386	13	2000	3	13	0.05	0.08	0.10	3	
1387	14	200	11	12	0.02	0.04	0.05	3	
1388	21	2000	15	20	0.44	0.44	0.71	9	
1389	26	1600	3	20	0.74	0.74	1.15	13	
					October-03				
1390	9	700	11	20	0.26	0.26	0.73	8	
1391	9	2400	15	12	0.02	0.04	0.05	13	
1392	13	2300	17	20	0.54	0.54	0.72	22	
1393	24	2400	8	20	0.70	0.70	0.90	19	
1394	25	1400	2	5	0.01	0.04	0.04	15	
1395	28	200	4	9	0.02	0.04	0.04	3	
1396	28	1000	4	5	0.01	0.04	0.05	13	
					November-03				
1397	1	1900	3	3	0.01	0.04	0.04	4	
1398	2	1500	22	20	0.18	0.18	0.33	2	
1399	3	2100	6	7	0.01	0.04	0.04	2	
1400	4	600	8	10	0.02	0.04	0.08	10	
1401	4	1800	8	20	0.94	0.94	1.18	18	
1402	11	800	4	4	0.01	0.04	0.04	11	
1403	17	500	9	7	0.01	0.04	0.04	10	
1404	17	1800	24	20	2.01	2.01	**3.06**	22	2-yr, 24-hr
1405	23	1100	7	20	0.35	0.35	0.64	12	
					December-03				
1406	4	1400	1	2	0.00	0.04	0.04	6	
1407	4	1900	18	20	0.20	0.20	0.42	3	
1408	9	1000	23	20	0.58	0.58	1.18	8	
1409	13	1200	15	17	0.06	0.07	0.16	8	
1410	14	700	7	9	0.02	0.04	0.04	2	
1411	18	500	10	12	0.03	0.05	0.08	2	
1412	22	1600	9	20	0.17	0.17	0.37	23	
1413	28	500	8	4	0.01	0.04	0.04	2	
					January-04				
1414	1	900	8	7	0.01	0.04	0.04	8	
1415	2	900	6	7	0.01	0.04	0.05	3	
1416	3	2100	29	20	0.39	0.39	0.60	16	
1417	16	2400	14	19	0.11	0.12	0.21	22	
1418	17	1700	6	5	0.01	0.04	0.04	7	
1419	27	100	10	20	0.08	0.08	0.20	9	
1420	29	1300	7	10	0.02	0.05	0.08	15	
1421	30	1000	6	9	0.02	0.05	0.08	18	
					February-04				

Table H-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2003-2004

Storm Number	*Storm* Start Day	*Start* Time (CST)	*Storm* Duration (Hours)	*Number* Gauges with Precipitation	*Network* Average Precipitation (inches)	*Storm* Average Precipitation (inches)	*Network* Maximum Precipitation (inches)	*Gauge No.* with Maximum	*Storm* Recurrence Frequency
1422	2	1000	20	20	0.22	0.22	0.36	24	
1423	5	1700	19	19	0.06	0.06	0.12	7	
1424	6	2300	4	6	0.01	0.04	0.04	8	
1425	7	1000	5	5	0.01	0.04	0.04	9	
1426	20	500	8	9	0.02	0.04	0.08	7	
1427	23	800	6	4	0.01	0.04	0.04	6	
					March-04				
1428	1	300	7	6	0.01	0.04	0.05	12	
1429	3	2200	31	20	1.25	1.25	1.43	2	
1430	13	2300	12	20	0.09	0.09	0.16	24	
1431	16	200	10	19	0.12	0.12	0.38	12	
1432	17	300	6	12	0.02	0.04	0.04	4	
1433	17	1200	3	3	0.01	0.04	0.05	12	
1434	18	900	4	7	0.01	0.04	0.04	2	
1435	24	1200	2	2	0.00	0.04	0.04	7	
1436	25	900	29	20	0.86	0.86	1.43	23	
1437	28	1400	6	20	0.40	0.40	0.58	9	
1438	29	700	3	12	0.02	0.04	0.05	3	
1439	31	100	13	17	0.04	0.05	0.08	15	
					April-04				
1440	20	600	13	20	0.36	0.36	0.63	24	
1441	20	2300	4	19	0.07	0.08	0.18	24	
1442	24	1200	11	20	1.03	1.03	1.28	19	
1443	29	1800	12	11	0.03	0.05	0.08	2	
1444	30	1500	8	19	0.29	0.31	1.03	3	
					May-04				
1445	1	600	7	20	0.08	0.08	0.16	23	
1446	1	1900	4	10	0.03	0.05	0.09	11	
1447	2	800	18	19	0.35	0.37	1.30	8	
1448	4	1300	5	6	0.01	0.04	0.04	7	
1449	10	1200	12	15	0.22	0.29	0.56	22	
1450	11	300	8	12	0.02	0.04	0.05	3	
1451	11	1500	6	5	0.03	0.13	0.25	23	
1452	12	1300	8	7	0.05	0.16	0.23	12	
1453	13	1500	23	20	1.22	1.22	2.36	12	
1454	18	1700	3	11	0.13	0.24	0.59	4	
1455	22	1200	4	10	0.17	0.33	0.67	9	
1456	23	600	7	18	0.12	0.13	0.26	23	
1457	24	2100	19	20	1.81	1.81	**3.68**	22	2-yr, 24-hr
1458	30	700	13	20	1.26	1.26	1.94	12	
1459	31	700	7	7	0.01	0.04	0.05	12	
1460	31	1800	2	9	0.03	0.06	0.12	2	
					June-04				
1461	9	1400	1	2	0.00	0.03	0.04	10	
1462	9	2100	1	2	0.00	0.03	0.04	6	

Table H-2. (concluded)

Storm Number	*Storm* Start Day	*Start* Time (CST)	*Storm* Duration (Hours)	*Number* Gauges with Precipitation	*Network* Average Precipitation (inches)	*Storm* Average Precipitation (inches)	*Network* Maximum Precipitation (inches)	*Gauge No.* with Maximum	*Storm* Recurrence Frequency
1463	10	200	33	20	1.52	1.52	2.20	3	
1464	13	300	9	10	0.03	0.06	0.17	13	
1465	14	2200	16	20	1.41	1.41	**3.09**	24	2-yr, 18-hr
1466	21	1000	12	15	0.23	0.31	0.75	4	
1467	24	2300	13	19	0.37	0.39	0.76	18	
					July-04				
1468	1	1100	6	3	0.03	0.20	0.35	19	
1469	2	2300	20	20	0.30	0.30	1.34	24	
1470	4	600	6	9	0.02	0.06	0.13	13	
1471	5	1000	4	3	0.02	0.17	0.25	9	
1472	5	2300	1	2	0.05	0.47	0.59	2	
1473	6	800	4	2	0.00	0.05	0.05	3	
1474	8	1000	2	4	0.03	0.14	0.21	18	
1475	9	300	7	2	0.01	0.13	0.14	12	
1476	9	2000	6	20	1.00	1.00	**2.44**	12	2-yr, 6-hr
1477	10	1500	13	15	0.59	0.79	1.81	22	
1478	11	1600	1	5	0.05	0.22	0.54	12	
1479	12	300	7	10	0.09	0.19	0.56	20	
1480	22	1000	3	2	0.01	0.07	0.09	3	
1481	30	100	12	16	0.09	0.11	0.33	23	
					August-04				
1482	2	900	3	4	0.05	0.23	0.72	24	
1483	4	200	8	20	0.25	0.25	0.67	3	
1484	9	1900	3	2	0.01	0.09	0.13	24	
1485	17	2100	2	1	0.03	0.50	0.50	2	
1486	18	2100	5	3	0.03	0.23	0.30	2	
1487	20	100	15	20	0.17	0.17	0.42	19	
1488	23	1400	5	8	0.14	0.35	0.78	8	
1489	23	2200	13	20	0.29	0.29	0.47	2	
1490	25	600	30	20	1.99	1.99	**3.49**	19	2-yr, 48-hr
1491	27	300	35	20	0.77	0.77	1.43	2	
1492	28	1800	8	2	0.04	0.41	0.47	22	

Appendix H-3. Precipitation (inches) Received at Each Station from Each Storm Period during the 2003-2004 Observation Period

				Rain gauge site no.																			
Storm	Date	Hour	Duration	*2*	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*15*	*16*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
1383	9012003	100	14	1.15	1.17	1.08	1.44	1.41	1.20	1.17	1.16	1.13	1.65	1.12	1.56	1.99	1.12	1.32	1.33	1.36	1.84	1.62	1.05
1384	9122003	1100	3	0.04	0.05	0.00	0.09	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1385	9122003	1700	18	0.08	0.04	0.04	0.04	0.04	0.12	0.08	0.04	0.00	0.00	0.10	0.00	0.00	0.16	0.04	0.04	0.00	0.00	0.00	0.20
1386	9132003	2000	3	0.08	0.10	0.00	0.08	0.09	0.00	0.00	0.08	0.08	0.04	0.05	0.08	0.08	0.00	0.00	0.00	0.08	0.08	0.08	0.00
1387	9142003	200	11	0.04	0.05	0.00	0.04	0.00	0.04	0.04	0.00	0.04	0.04	0.00	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.04
1388	9212003	2000	15	0.50	0.32	0.46	0.34	0.34	0.47	0.71	0.45	0.30	0.38	0.41	0.47	0.40	0.33	0.67	0.64	0.29	0.51	0.47	0.33
1389	9262003	1600	3	0.72	0.53	0.55	0.52	0.44	0.61	1.06	0.75	0.74	0.71	1.15	0.76	0.68	0.84	1.03	0.78	0.60	0.65	0.73	0.96
1390	10092003	700	11	0.51	0.40	0.20	0.17	0.30	0.73	0.04	0.04	0.04	0.41	0.27	0.13	0.12	0.46	0.17	0.26	0.21	0.22	0.22	0.35
1391	10092003	2400	15	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.04	0.00	0.05	0.04	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.00
1392	10132003	2300	17	0.32	0.38	0.42	0.54	0.68	0.33	0.54	0.58	0.55	0.66	0.56	0.54	0.41	0.46	0.63	0.59	0.63	0.72	0.64	0.54
1393	10242003	2400	8	0.89	0.81	0.85	0.68	0.77	0.77	0.67	0.66	0.77	0.62	0.63	0.65	0.70	0.56	0.90	0.59	0.47	0.82	0.61	0.55
1394	10252003	1400	2	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	0.04	0.00	0.04	0.04
1395	10282003	200	4	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00
1396	10282003	1000	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.04
1397	11012003	1900	3	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	0.04	0.00	0.04	0.00	0.00	0.00	0.00
1398	11022003	1500	22	0.33	0.28	0.25	0.17	0.25	0.25	0.21	0.17	0.21	0.20	0.13	0.17	0.17	0.12	0.26	0.13	0.04	0.04	0.04	0.16
1399	11032003	2100	6	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.00
1400	11042003	600	8	0.04	0.05	0.00	0.04	0.00	0.00	0.04	0.08	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.04	0.00
1401	11042003	1800	8	0.92	0.89	0.93	0.78	0.94	0.83	0.97	0.92	0.87	1.14	0.92	0.77	1.04	1.18	1.11	0.82	1.15	0.93	0.68	1.08
1402	11112003	800	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
1403	11172003	500	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00
1404	11172003	1800	24	2.04	2.34	1.21	2.19	2.46	1.06	1.55	2.27	2.24	2.43	1.26	2.34	2.28	1.25	1.66	2.16	2.40	**3.06**	**2.56**	1.34
1405	11232003	1100	7	0.29	0.27	0.21	0.25	0.56	0.26	0.42	0.17	0.33	0.64	0.35	0.34	0.38	0.34	0.26	0.30	0.61	0.46	0.30	0.30
1406	12042003	1400	1	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1407	12042003	1900	18	0.17	0.42	0.24	0.25	0.21	0.20	0.20	0.17	0.25	0.17	0.17	0.17	0.12	0.20	0.25	0.08	0.25	0.17	0.12	0.12
1408	12092003	1000	23	0.69	0.33	0.83	0.41	0.38	1.18	0.53	0.45	0.42	0.38	0.87	0.33	0.37	1.04	0.75	0.50	0.41	0.29	0.36	1.08
1409	12132003	1200	15	0.00	0.05	0.04	0.04	0.08	0.16	0.04	0.04	0.04	0.04	0.12	0.04	0.00	0.08	0.16	0.04	0.00	0.04	0.04	0.16
1410	12142003	700	7	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.04	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.04
1411	12182003	500	10	0.08	0.05	0.04	0.08	0.04	0.04	0.04	0.00	0.04	0.08	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.00
1412	12222003	1600	9	0.24	0.19	0.16	0.12	0.08	0.21	0.12	0.08	0.12	0.20	0.12	0.12	0.17	0.16	0.20	0.21	0.21	0.08	0.37	0.21
1413	12282003	500	8	0.04	0.00	0.04	0.00	0.00	0.04	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

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
1414	1012004	900	8	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00
1415	1022004	900	6	0.00	0.05	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00
1416	1032004	2100	29	0.20	0.19	0.20	0.28	0.37	0.17	0.33	0.29	0.41	0.57	0.33	0.49	0.60	0.37	0.50	0.50	0.51	0.41	0.49	0.50
1417	1162004	2400	14	0.12	0.05	0.12	0.12	0.08	0.12	0.12	0.12	0.12	0.08	0.16	0.12	0.00	0.08	0.12	0.16	0.12	0.21	0.16	0.12
1418	1172004	1700	6	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00
1419	1272004	100	10	0.08	0.09	0.04	0.08	0.04	0.12	0.20	0.08	0.08	0.04	0.12	0.04	0.04	0.16	0.12	0.04	0.12	0.04	0.08	0.04
1420	1292004	1300	7	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.04	0.00	0.08	0.00	0.04	0.08	0.04	0.04	0.00	0.04	0.04
1421	1302004	1000	6	0.00	0.05	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.08	0.04	0.00	0.04	0.04	0.00	0.04
1422	2022004	1000	20	0.24	0.10	0.20	0.24	0.12	0.24	0.20	0.20	0.25	0.20	0.24	0.16	0.24	0.32	0.29	0.24	0.20	0.20	0.25	0.36
1423	2052004	1700	19	0.04	0.10	0.04	0.04	0.12	0.04	0.04	0.04	0.08	0.12	0.04	0.04	0.04	0.04	0.08	0.04	0.00	0.04	0.12	0.04
1424	2062004	2300	4	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.04	0.00	0.00
1425	2072004	1000	5	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1426	2202004	500	8	0.04	0.00	0.04	0.04	0.08	0.00	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
1427	2232004	800	6	0.00	0.00	0.00	0.04	0.00	0.00	0.04	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
1428	3012004	300	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.04
1429	3032004	2200	31	1.43	1.32	1.24	1.24	1.36	1.10	1.22	1.35	1.26	1.24	1.03	1.24	1.22	0.95	1.41	1.33	1.26	1.32	1.22	1.21
1430	3132004	2300	12	0.08	0.05	0.08	0.08	0.12	0.04	0.12	0.04	0.08	0.12	0.08	0.08	0.05	0.08	0.08	0.12	0.08	0.12	0.12	0.16
1431	3162004	200	10	0.08	0.14	0.12	0.04	0.16	0.20	0.08	0.04	0.17	0.38	0.20	0.13	0.04	0.08	0.12	0.04	0.00	0.04	0.13	0.16
1432	3172004	300	6	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.04	0.04	0.04	0.04	0.04	0.04
1433	3172004	1200	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1434	3182004	900	4	0.04	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00
1435	3242004	1200	2	0.00	0.00	0.00	0.00	0.04	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
1436	3252004	900	29	0.71	1.17	0.93	0.67	0.85	0.72	0.57	0.70	0.71	0.94	0.82	0.95	0.73	0.79	0.77	0.67	0.77	1.07	1.43	1.17
1437	3282004	1400	6	0.47	0.35	0.47	0.39	0.42	0.33	0.58	0.42	0.35	0.35	0.53	0.35	0.17	0.50	0.43	0.44	0.43	0.29	0.33	0.43
1438	3292004	700	3	0.00	0.05	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.04	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.04	0.00	0.04
1439	3312004	100	13	0.04	0.00	0.04	0.04	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.00	0.08	0.08	0.08	0.08	0.04	0.04	0.04
1440	4202004	600	13	0.42	0.58	0.33	0.25	0.34	0.34	0.41	0.24	0.39	0.32	0.38	0.25	0.38	0.38	0.42	0.26	0.21	0.33	0.42	0.63
1441	4202004	2300	4	0.08	0.05	0.08	0.04	0.04	0.08	0.16	0.06	0.04	0.04	0.13	0.04	0.00	0.13	0.08	0.08	0.04	0.04	0.04	0.18
1442	4242004	1200	11	1.12	0.92	1.14	0.86	1.06	1.10	1.04	0.77	0.93	1.05	1.07	0.82	1.07	1.14	1.28	0.85	1.03	0.99	1.14	1.18

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
1443	4292004	1800	12	0.08	0.05	0.04	0.04	0.04	0.04	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.07	0.00
1444	4302004	1500	8	0.79	1.03	0.07	0.73	0.17	0.09	0.34	0.55	0.35	0.32	0.07	0.30	0.31	0.08	0.18	0.26	0.12	0.04	0.00	0.04
1445	5012004	600	7	0.08	0.05	0.12	0.08	0.04	0.12	0.04	0.04	0.08	0.10	0.08	0.08	0.08	0.04	0.08	0.08	0.08	0.12	0.16	0.08
1446	5012004	1900	4	0.08	0.04	0.04	0.08	0.04	0.00	0.00	0.04	0.09	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00
1447	5022004	800	18	0.51	0.05	0.67	0.12	0.04	1.30	0.50	0.43	0.35	0.23	0.26	0.30	0.22	0.04	0.04	0.60	0.60	0.47	0.29	0.00
1448	5042004	1300	5	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.00
1449	5102004	1200	12	0.08	0.00	0.12	0.00	0.00	0.00	0.09	0.00	0.04	0.55	0.04	0.22	0.34	0.51	0.38	0.26	0.29	0.56	0.51	0.42
1450	5112004	300	8	0.04	0.05	0.00	0.04	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.04	0.04
1451	5112004	1500	6	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.12	0.25	0.00
1452	5122004	1300	8	0.00	0.00	0.00	0.00	0.12	0.17	0.13	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.12	0.16
1453	5132004	1500	23	1.12	1.14	0.85	1.08	1.06	0.95	1.14	1.17	0.93	2.36	1.04	1.12	1.07	1.18	1.31	1.08	1.20	2.10	1.83	0.71
1454	5182004	1700	3	0.00	0.27	0.59	0.43	0.35	0.17	0.17	0.08	0.13	0.23	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
1455	5222004	1200	4	0.17	0.14	0.25	0.30	0.30	0.31	0.67	0.63	0.13	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1456	5232004	600	7	0.09	0.00	0.08	0.00	0.04	0.16	0.21	0.08	0.04	0.09	0.18	0.13	0.04	0.21	0.13	0.12	0.12	0.13	0.26	0.21
1457	5242004	2100	19	0.59	0.58	0.88	0.95	1.08	1.08	1.34	1.10	1.40	1.80	1.93	2.07	2.12	2.52	3.23	2.71	2.65	3.68	2.89	1.59
1458	5302004	700	13	1.26	1.07	1.13	1.12	1.51	1.13	0.67	0.79	1.26	1.94	1.19	1.47	1.73	1.43	1.09	1.77	1.92	0.95	0.67	1.13
1459	5312004	700	7	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.05	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.02	0.00	0.00
1460	5312004	1800	2	0.12	0.09	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.05	0.00	0.02	0.12
1461	6092004	1400	1	0.00	0.00	0.00	0.00	0.02	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
1462	6092004	2100	1	0.00	0.00	0.00	0.04	0.02	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
1463	6102004	200	33	1.49	2.20	0.91	1.24	1.73	0.68	1.35	1.25	1.67	1.87	1.09	1.58	1.91	0.83	1.66	2.01	2.04	1.98	2.04	0.83
1464	6132004	300	9	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.05	0.17	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.13	0.04
1465	6142004	2200	16	0.30	0.13	0.77	0.82	0.74	0.95	1.59	1.02	1.12	0.41	1.28	**2.38**	1.04	2.11	**2.34**	2.03	1.92	2.15	1.92	**3.09**
1466	6212004	1000	12	0.25	0.00	0.75	0.38	0.32	0.34	0.33	0.68	0.21	0.14	0.35	0.17	0.08	0.21	0.16	0.00	0.00	0.00	0.00	0.21
1467	6242004	2300	13	0.17	0.00	0.12	0.17	0.12	0.16	0.33	0.16	0.25	0.28	0.52	0.56	0.42	0.76	0.56	0.64	0.46	0.60	0.71	0.38
1468	7012004	1100	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.12
1469	7022004	2300	20	0.37	0.36	0.12	0.04	0.21	0.26	0.08	0.20	0.12	0.41	0.08	0.30	0.08	0.46	0.20	0.08	0.46	0.25	0.50	1.34
1470	7042004	600	6	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.13	0.08	0.04	0.00	0.04	0.04	0.04	0.00	0.04	0.00
1471	7052004	1000	4	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.08	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1472	7052004	2300	1	0.59	0.35	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
1473	7062004	800	4	0.04	0.05	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

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
1474	7082004	1000	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	0.21	0.17	0.09	0.00	0.00	0.00	0.09
1475	7092004	300	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1476	7092004	2000	6	1.81	0.58	0.38	1.08	1.25	0.61	0.79	1.27	**2.00**	**2.44**	0.92	0.78	0.83	0.77	0.52	0.60	0.33	1.82	1.05	0.13
1477	7102004	1500	13	0.00	0.00	0.21	0.00	0.00	0.61	0.12	1.35	0.65	0.00	1.01	1.60	1.09	0.68	0.13	0.69	0.99	1.81	0.38	0.50
1478	7112004	1600	1	0.25	0.00	0.00	0.13	0.09	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1479	7122004	300	7	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.14	0.22	0.04	0.00	0.10	0.21	0.56	0.51	0.04	0.00	0.00
1480	7222004	1000	3	0.00	0.09	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	0.00	0.00	0.00	0.00
1481	7302004	100	12	0.08	0.00	0.04	0.00	0.00	0.04	0.00	0.04	0.04	0.18	0.04	0.04	0.08	0.06	0.04	0.16	0.21	0.30	0.33	0.08
1482	8022004	900	3	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.72
1483	8042004	200	8	0.63	0.67	0.47	0.47	0.57	0.18	0.13	0.16	0.12	0.14	0.08	0.17	0.12	0.13	0.13	0.08	0.13	0.26	0.16	0.25
1484	8092004	1900	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	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.13
1485	8172004	2100	2	0.50	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	0.00
1486	8182004	2100	5	0.30	0.10	0.29	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
1487	8202004	100	15	0.32	0.14	0.16	0.33	0.20	0.13	0.12	0.20	0.12	0.19	0.12	0.12	0.08	0.10	0.42	0.12	0.08	0.17	0.21	0.12
1488	8232004	1400	5	0.00	0.14	0.72	0.00	0.00	0.78	0.00	0.00	0.00	0.32	0.13	0.00	0.00	0.25	0.00	0.22	0.00	0.00	0.25	0.00
1489	8232004	2200	13	0.47	0.28	0.45	0.21	0.12	0.43	0.42	0.21	0.21	0.23	0.21	0.26	0.17	0.25	0.26	0.43	0.42	0.25	0.29	0.16
1490	8252004	600	30	1.07	1.35	1.25	1.97	2.33	1.20	1.17	1.60	2.52	2.03	1.27	2.67	2.62	1.98	**3.49**	2.66	2.65	1.03	1.76	**3.19**
1491	8272004	300	35	1.43	1.08	0.92	1.03	1.27	1.16	0.71	0.57	0.68	1.05	0.70	0.42	0.21	0.96	0.89	0.55	0.34	0.37	0.34	0.79
1492	8282004	1800	8	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	0.47	0.34	0.00

Notes:

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