Contract Report 2009-08

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

Year Thirteen: September 2004-August 2005

by
Steven D. Wilson, Nancy E. Westcott,
Kevin L. Rennels, and H. Allen Wehrmann

June 2009

Illinois State Water Survey
Institute of Natural Resource Sustainability
University of Illinois at Urbana-Champaign

Champaign, Illinois

Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority Year Thirteen: September 2004–August 2005

by

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

Illinois State Water Survey
Institute of Natural Resource Sustainability
University of Illinois at Urbana-Champaign
Champaign, IL

I L L I N O I S

Contents

Page

Contents (concluded)

Page

List of Tables

List of Figures

Page

List of Figures (Concluded)

Page

Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority Year Thirteen: September 2004–August 2005

by

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

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, which 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 2005. 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 13 years of precipitation data and 11 years of groundwater observations.

For the period September 2004–August 2005, the network received an average of 27.34 inches of precipitation, 7.55 inches lower than the network 12-year 1992–2004 average precipitation of 34.89 inches. Above average precipitation fell in the fall and winter months, and below average rain fell during the spring and summer of 2005. Year Thirteen had the third wettest fall and the second wettest winter of the 13 years of network operation. The spring and summer of 2005 were the driest warm seasons of the past 13 years.

In 2004–2005, groundwater levels rose in response to the wet fall and winter, then fell dramatically in the spring and summer of 2005 due to a lack of precipitation. The dry growing season also had a dramatic effect on irrigation water demands; irrigation pumpage increased 40 percent from the previous high record of 52 billion gallons (in 1996). Total irrigation for the June–September period was estimated to be 72 billion gallons.

To improve our understanding of the relationship among groundwater, stream discharge, and irrigation, an irrigation test site was established in April 2003 (Year Eleven) near Easton, IL. Nine observation wells were installed in close proximity to an irrigated field that abuts Crane Creek. Transducers with data loggers were installed in various wells since 2003 to monitor groundwater levels, and an additional data logger was installed in Crane Creek to monitor stream stage. Discharge measurements indicate that there is groundwater discharge into Crane Creek at the test site even during irrigation. Groundwater data show a rapid (within 24-hour) response of groundwater levels to precipitation, probably mostly due to the increase in stage in Crane Creek in this area of prevalent sandy soils, though 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. These factors affect water withdrawals from the aquifer. Therefore, knowledge of 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 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 past 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), and a 6-mile spacing is adequate for more widespread precipitation-producing systems (fall and winter). The Belfort weighing bucket rain gauge provides precise and reliable precipitation measurements. Given the size of the IVWA area and the above spacing guidelines, a gridded, 25-site rain gauge network (Figure 1) with approximately 5 miles between gauges was established in late August 1992. The network was reduced to 20 sites in September 1996. Results of the previous years of the network operation are reported in Peppler and

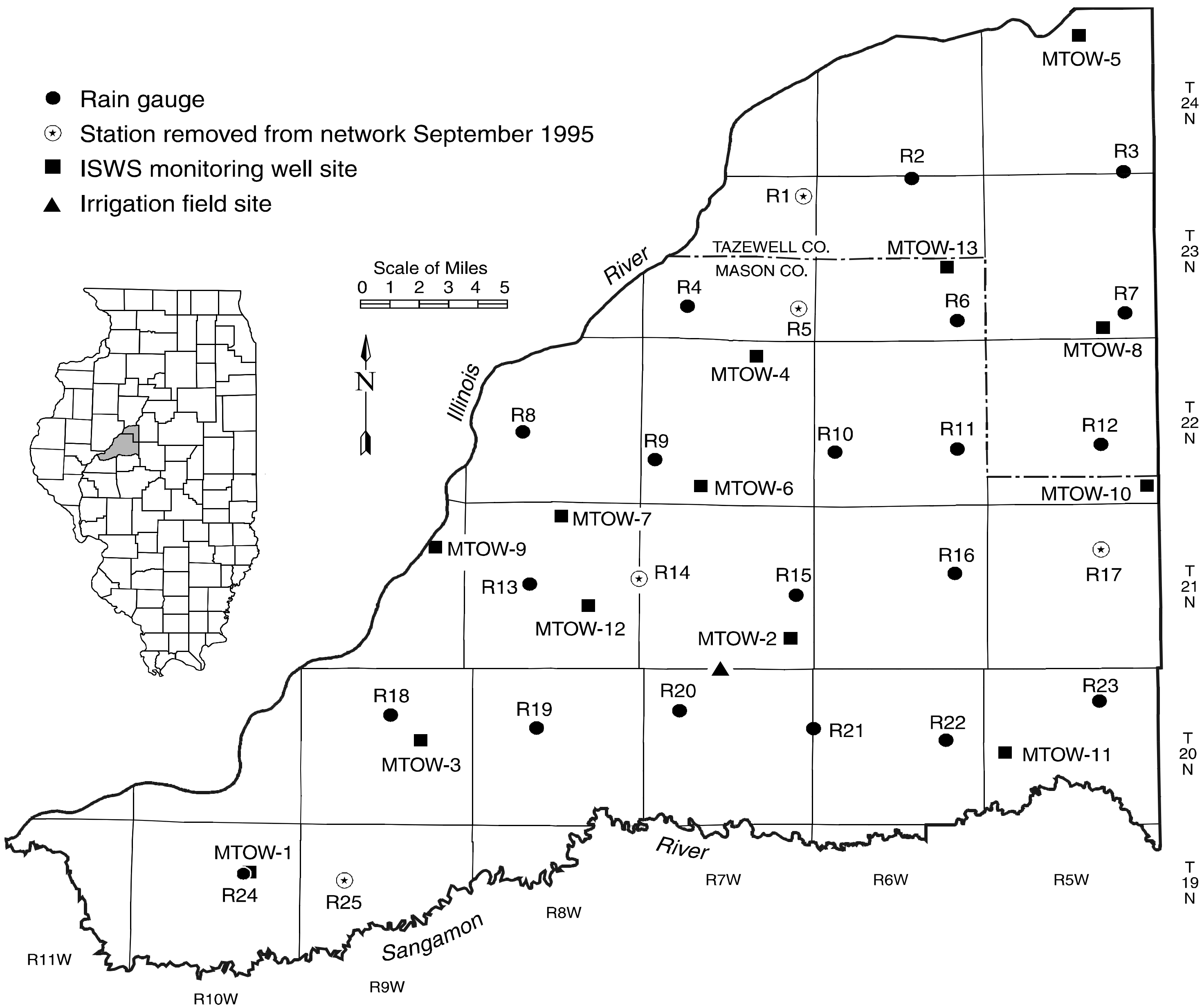


Figure 1. Configuration of the 13-site observation well and 25-site rain gauge networks, and location of the irrigation field site, Imperial Valley, 2004-2005.

Hollinger (1994, 1995), Hollinger and Peppler (1996), Hollinger (1997), Hollinger and Scott (1998), Hollinger et al. (1999, 2000), Scott et al. (2001, 2002), Wehrmann et al. (2004, 2005), and Wilson et al. (2008).

The observation well network originally consisted of 11 wells, termed 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 among 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 among precipitation, Illinois River stage, and groundwater levels for the observation well network prior to Year Thirteen.

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 groundwater 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, IL, 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 thirteenth year of the rain gauge network operation and the eleventh year of the observation well network operation. A discussion of observed relationships among precipitation, Illinois River stage, irrigation, and groundwater levels is included.

The 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 2004–2005 period (Appendix E). The transducer data for the Crane Creek site are included (Appendix F). Contour maps of the annual precipitation across the Imperial Valley are presented for Years One–Twelve (Appendix G). Documentation also is presented for the monthly and seasonal 1992–2004 precipitation events (Appendix H) and for all 2004–2005 precipitation events (Appendix I).

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 Lisa Sheppard 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 goes to Jeff Smith of Easton, Illinois, for allowing the installation of nine observation wells at his farm and our continued 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, 2005. 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 two to three days of analysis time each month, and provides more accurate time frames for events. Precipitation also is recorded each month on eight-day paper charts for backup if data loggers fail.

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

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

Table 1 provides a general description of each network well, including 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 water levels in these two wells are under artesian conditions. Because groundwater 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 the 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 measured manually with a steel tape or electric probe 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.

In January 2005, four of the wells (MTOW -2, -3, -7, -13) were outfitted with pressure transducers and digital data loggers for collecting water level measurements. In Year Fourteen, six additional wells will be outfitted with transducers and data loggers. Manual monthly measurements will be discontinued at wells equipped with digital data loggers.

Manual monthly measurements will be discontinued at wells equipped with the transducer/data logger set up; however, manual measurements will continue to be made when the data loggers are downloaded to ensure the transducers are working properly. When a disagreement is found between manual and transducer measurements, the transducer measurement is corrected.

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 Three)

The irrigation test site along Crane Creek, southwest of Easton, IL, 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. 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), creek discharge measurements, and measurement of well elevations.

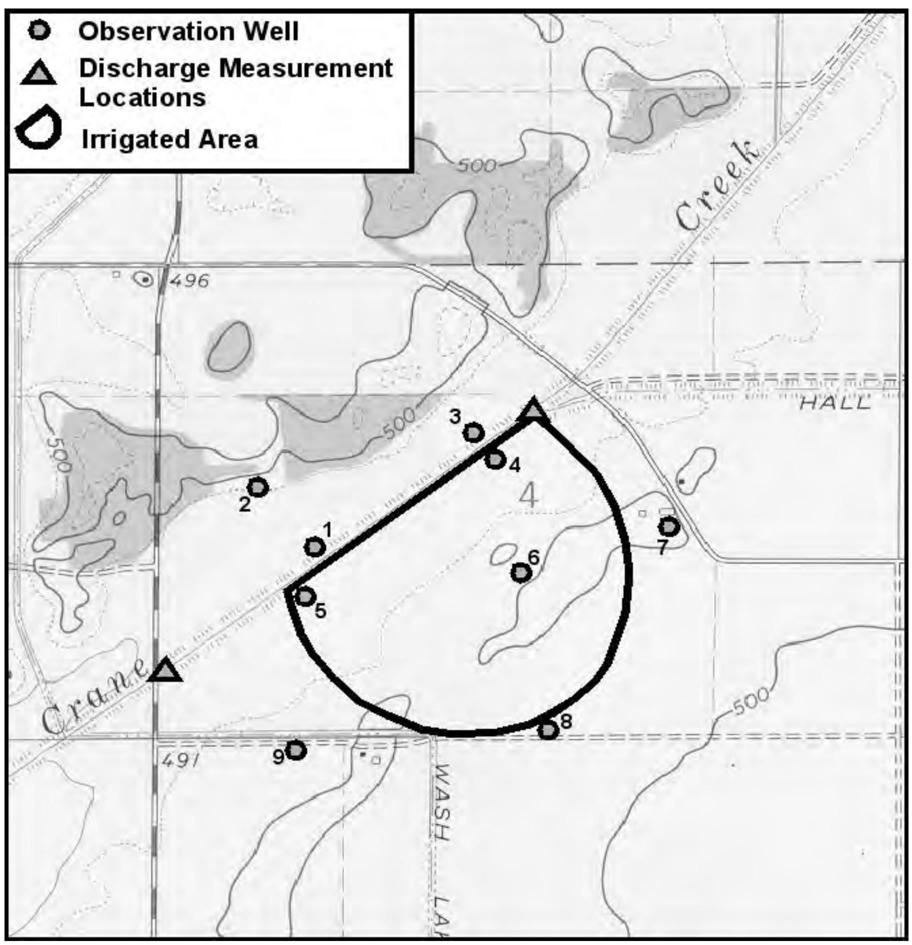


Figure 2. Locations of observation wells and streamflow discharge measurement points in relation to the irrigation test site

As of September 1, 2004, transducers/data loggers were installed in wells 1, 3, 5, and 6 to measure groundwater elevation, and in Crane Creek near the downstream bridge to measure stream elevation. The transducer in well 3 was removed on Feb 17, 2005, as it was on loan from another project. Also, on Feb 17, 2005, the transducer in well 5 was found damaged and data recording had ended. The cable had been caught in a mower accidentally and the unit was destroyed. The data logger in well 1 was removed on Sept 9, 2004. Data were collected from well 6 throughout the year. Transducers were installed in all nine wells in the spring of 2005.

Transducers placed at the test site were set up to collect data at varying intervals. Well 6 and the transducer in Crane Creek collected data on 15-minute intervals. The transducers in wells 4, 5, 8, and 9 were set to collect data every 30 minutes. In wells 1, 2, 3, and 7, the transducers collected data every hour. Hydrographs of the transducer data for the site wells are presented in Appendix F.

In total, there were 75 groundwater level hand measurements, 12 stream discharge measurements, 32 downloads from the transducers, and 18 stage measurements completed at the test site during Year Thirteen. In addition, measuring point elevations of the wells and stage readings were determined based on the downstream bridge elevation of 494.00 feet mean sea level (msl) (taken from the U.S. Geological Survey [USGS] topographic map). Elevations were surveyed from the downstream bridge so that relative water levels could be determined. The exact elevation of the downstream bridge has yet to be determined, but assuming it is 494 feet msl, water levels can be plotted in relative terms to evaluate flow direction and elevation differences between the groundwater system and Crane Creek. The elevations are listed in Table 2.

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

Well number	*Depth (feet)*	*Date installed*	*MP Elevation (ft msl)*
1	33.10	4/23/03	492.45
2	32.75	4/22/03	495.07
3	31.10	4/23/03	493.26
4	34.30	4/22/03	495.03
5	34.75	4/22/03	491.86
6	37.00	4/22/03	495.81
7	32.85	4/23/03	496.27
8	34.00	4/23/03	494.24
9	33.50	4/23/03	492.28
Upstream bridge	----	----	496.61
Downstream bridge	----	----	494.00

Precipitation, Groundwater-Level, and Irrigation Data Analysis

This report presents rainfall and groundwater-level data for the period September 2004–August 2005 (Year Thirteen). Data collected from 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 groundwater levels may be influenced by irrigation pumpage; thus an estimate of monthly pumpage must be presented.

Precipitation Analysis

Data reduction activities during Year Thirteen of network operations are similar to those performed during the previous 12 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; Wehrmann et al., 2004, 2005; Wilson et al., 2008). 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 among 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 (1995–2005) 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 amounts 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. 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).

Continuous Measurements

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. The results, shown in the Year Eleven report, indicate that there is indeed 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, but only marginal success was found in correlating rainfall to groundwater level changes at these two sites. Consequently, in Year Thirteen, four digital water level recorders were purchased and installed in wells MTOW -2, -3, -7, and -13.

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 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 may further impact withdrawal estimates.

Crane Creek Discharge Measurements

The stream discharge measurements indicate that the total difference in discharge between the upstream end of the site and the downstream end of the site (where the creek crosses the roads) is less than the error associated with the discharge measurement method, but given that every measurement consistently shows a greater discharge at the downstream gauge than at the upstream gauge, it is believed that the data are reflecting the influence of groundwater discharge along the stream reach at the site. 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. By surveying the well elevations, it was found that groundwater levels are above the level of the creek, even when the irrigation system is on. In order to see a change in the stream stage, water levels in the groundwater system would need to be lowered below the stream elevation to reverse the flow direction toward the aquifer.

Results

Precipitation

Annual and Monthly Precipitation

The Year Thirteen dataset was used to produce the following analyses: 1) monthly and annual (September 2004–August 2005) precipitation amounts for each site in the IVWA network (Table 3); 2) the average precipitation pattern for the 13-year network operation (Figure 3a and b); 3) the total precipitation pattern for Year Thirteen (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 Thirteen (Figures 5–10). The annual precipitation patterns for Years One–Twelve also are presented (Appendix G).

Year Thirteen network precipitation was below average, 6.96 inches lower than the network 13-year average of 34.31, 7.54 inches below the previous 12-year average of 34.89 inches. It was the fourth driest period in the 13 years of network operation. Spring and summer 2005 had very low monthly precipitation averages, affecting irrigation pumpage significantly.

Table 3. Monthly Precipitation Amounts (inches), September 2004–August 2005

	Month												
Station	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	1.62	5.09	4.79	1.26	4.18	1.7	0.66	2.42	0.54	0.96	2.18	2.62	28.02
3	3.24	5.31	4.73	1.22	3.92	1.35	0.61	1.46	0.85	2.27	1.59	3.47	30.02
4	1.55	4.56	4.70	1.22	4.13	1.58	0.70	2.68	0.58	0.45	1.75	2.65	26.55
6	0.55	4.79	4.31	1.17	4.12	1.56	0.53	1.91	0.85	2.50	1.45	2.05	25.79
7	0.56	5.43	4.33	1.22	4.12	1.56	0.74	1.67	0.94	1.51	2.34	2.52	26.94
8	1.17	4.55	3.44	1.32	4.45	1.44	0.67	2.57	0.81	0.26	1.55	3.11	25.34
9	0.78	5.24	4.98	1.26	4.33	1.89	0.61	2.41	1.16	3.67	1.85	1.86	30.04
10	0.42	5.26	4.19	1.27	4.17	1.59	0.54	2.58	1.03	2.27	1.30	2.19	26.81
11	0.47	5.30	4.56	1.07	4.00	1.35	0.70	1.89	0.73	1.73	1.69	1.97	25.46
12	0.64	5.37	5.18	1.29	5.18	1.64	0.78	1.89	0.87	0.55	2.28	3.08	28.75
13	1.05	4.59	4.44	1.34	4.24	1.45	0.66	2.13	1.03	1.23	1.65	2.04	25.85
15	0.47	4.84	4.93	1.16	4.49	1.62	0.74	2.25	0.68	1.33	1.26	1.83	25.60
16	0.82	4.72	4.05	0.93	4.01	1.47	0.82	1.93	0.77	1.29	1.47	1.79	24.07
18	0.51	5.33	4.66	1.43	4.56	1.82	0.73	2.33	0.86	0.53	1.54	3.09	27.39
19	0.47	5.49	5.22	1.33	5.03	2.12	0.87	1.81	1.06	0.94	1.74	2.18	28.26
20	0.25	4.81	4.89	1.11	4.75	1.82	0.83	1.85	1.23	1.37	1.18	2.44	26.53
21	1.08	5.05	3.81	1.18	4.56	1.44	0.65	1.79	0.79	1.09	1.36	2.68	25.48
22	1.67	5.81	3.98	1.18	5.36	1.87	0.79	2.15	0.93	1.71	1.53	4.24	31.22
23	1.64	6.01	4.22	1.04	5.45	1.86	0.73	1.58	0.88	0.46	1.44	3.34	28.65
24	0.54	5.89	5.46	1.50	4.84	1.77	0.83	2.57	0.99	0.56	1.58	3.62	30.15
Average	0.98	5.17	4.54	1.23	4.49	1.64	0.71	2.09	0.88	1.33	1.64	2.64	27.34

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

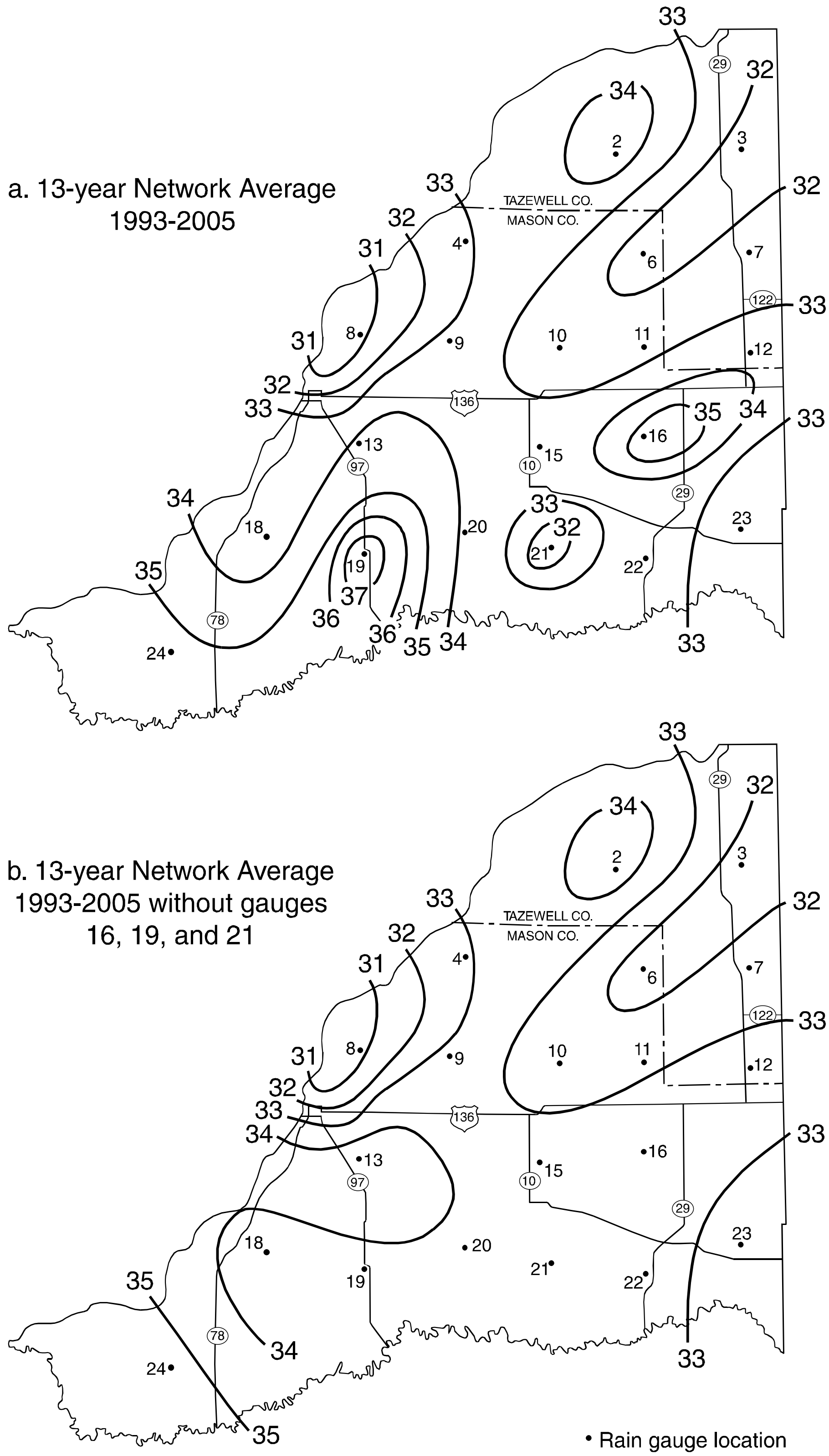


Figure 3. Network average annual precipitation (inches) for September 1992–August 2005 with all gauges (a) and without gauges 16, 19, and 21 (b)

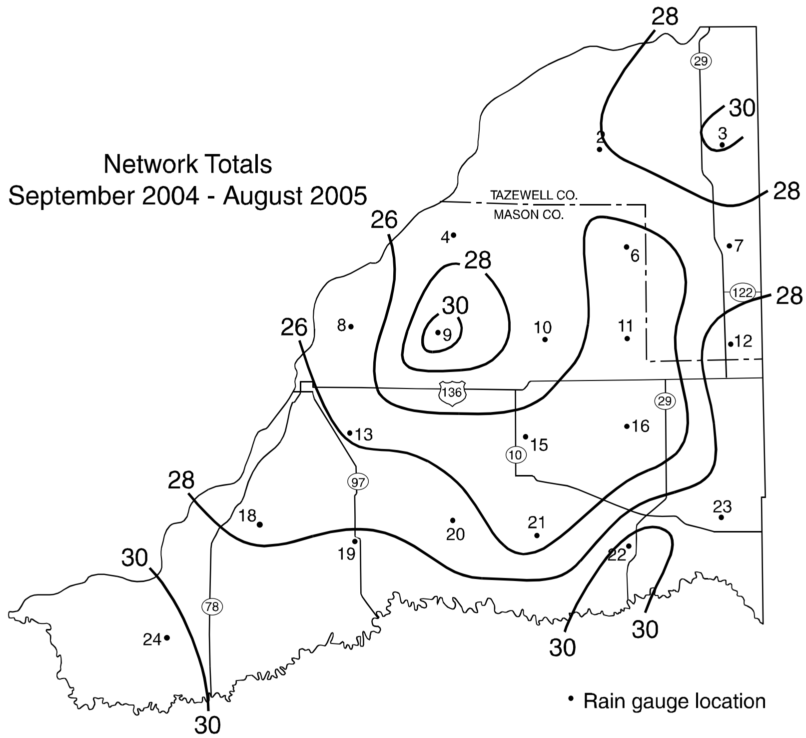


Figure 4. Total precipitation (inches) for September 2004–August 2005

Table 4. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event for Each Month and Season, 1992–2004 and 2004–2005

	1992-2004 12-year average			*2004-2005 average*		
Period	*Precipitation*	*Events*	*Inches/event*	*Precipitation*	*Events*	*Inches/event*
Sep	2.77	7.1	0.39	0.98	4	0.25
Oct	2.31	9.0	0.26	5.17	16	0.32
Nov	2.61	10.0	0.26	4.54	9	0.50
Dec	1.46	8.8	0.17	1.23	5	0.25
Jan	1.92	10.1	0.19	4.49	12	0.37
Feb	1.66	8.3	0.20	1.64	7	0.23
Mar	2.16	8.1	0.27	0.71	4	0.18
Apr	3.51	11.4	0.31	2.09	8	0.26
May	4.81	14.9	0.32	0.88	9	0.10
Jun	4.06	12.2	0.33	1.33	8	0.17
Jul	3.96	11.3	0.35	1.64	5	0.33
Aug	3.68	13.2	0.28	2.64	11	0.24
Fall	7.68	26.1	0.29	10.69	29	0.37
Winter	5.04	27.2	0.19	7.36	24	0.31
Spring	10.47	34.4	0.30	3.68	21	0.18
Summer	11.69	36.7	0.32	5.61	24	0.23
Annual	34.89	124.3	0.28	27.34	98	0.28

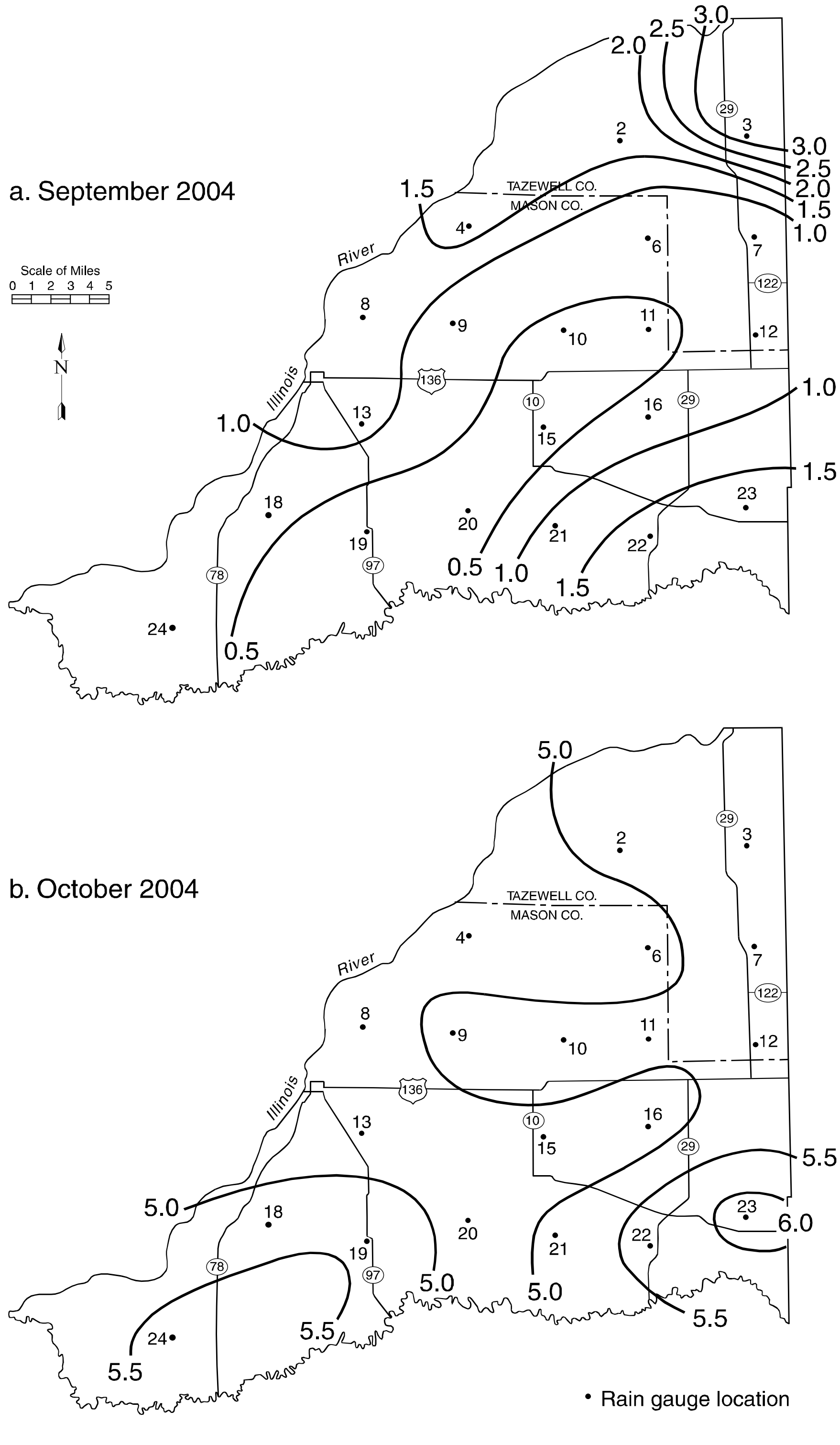


Figure 5. Precipitation (inches) for September 2004 and October 2004

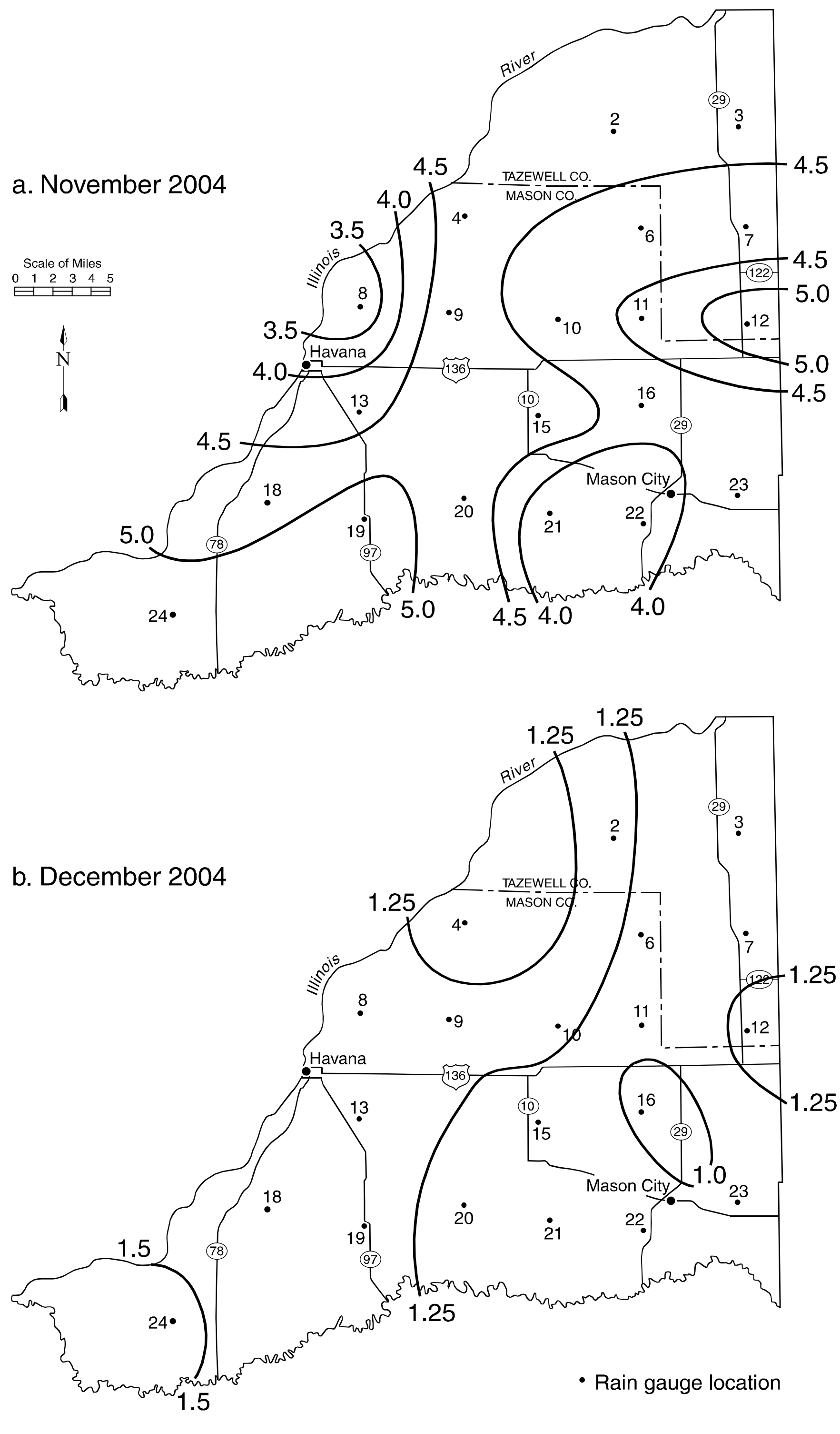


Figure 6. Precipitation (inches) for November 2004 and December 2004

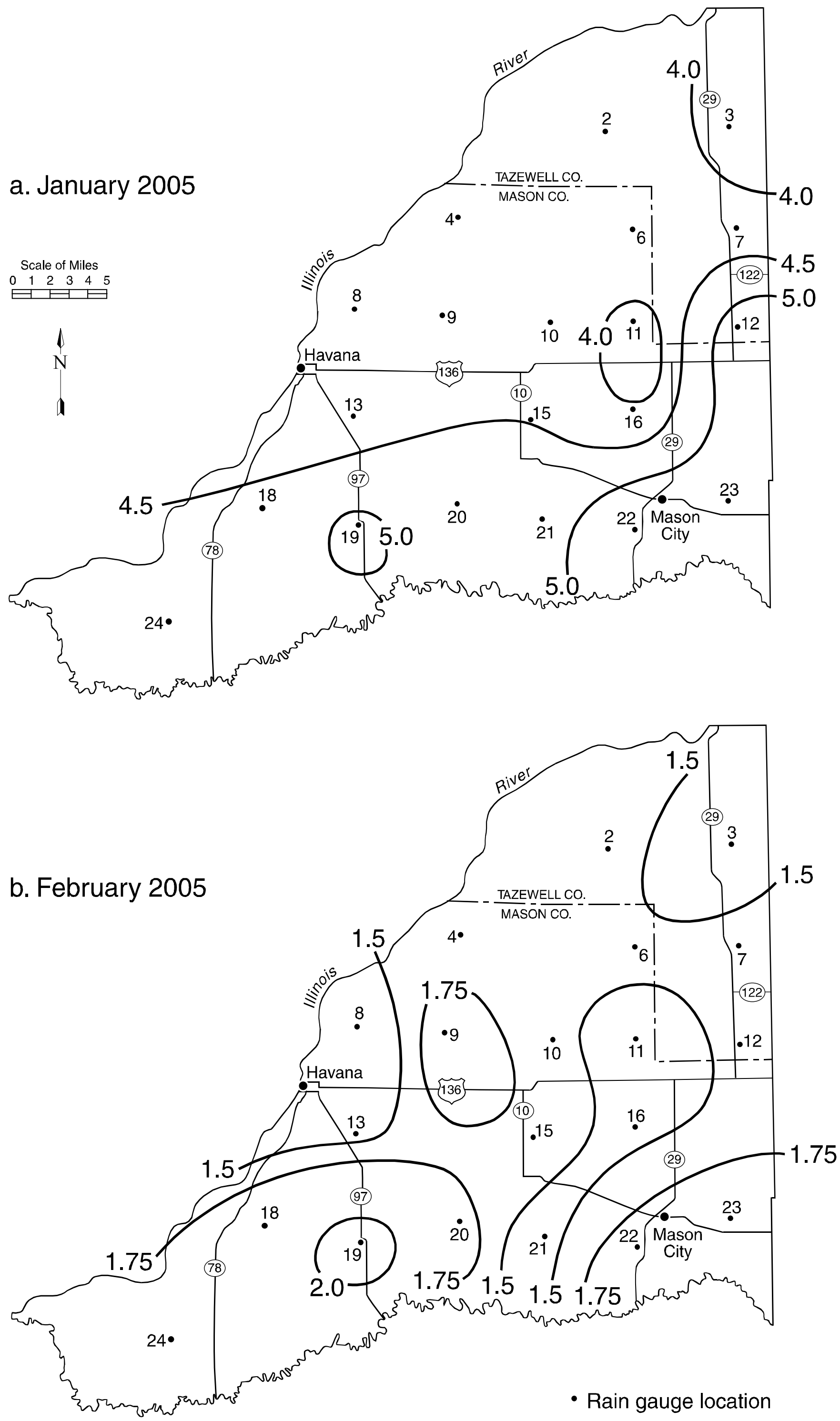


Figure 7. Precipitation (inches) for January 2005 and February 2005

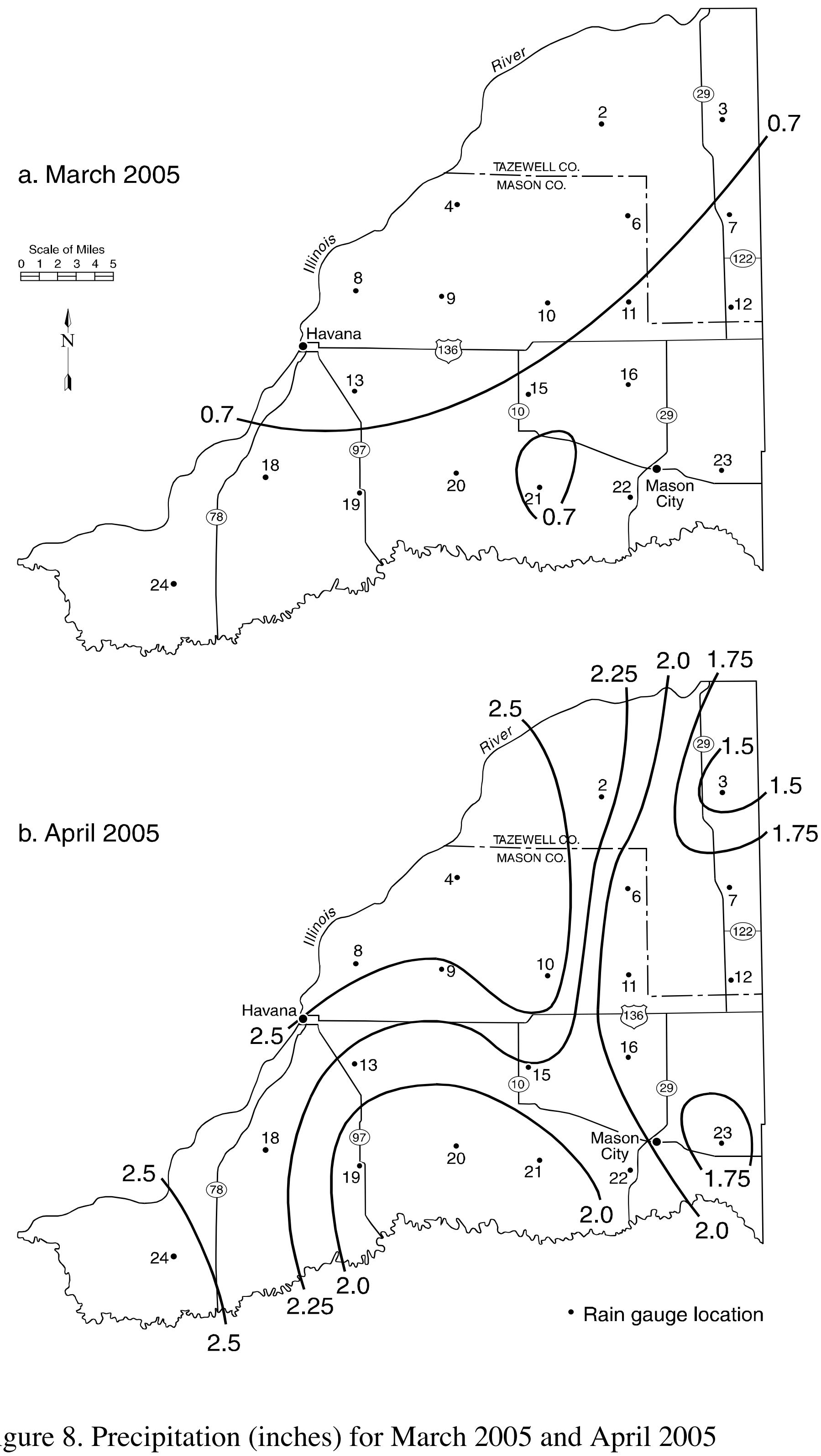


Figure 8. Precipitation (inches) for March 2005 and April 2005

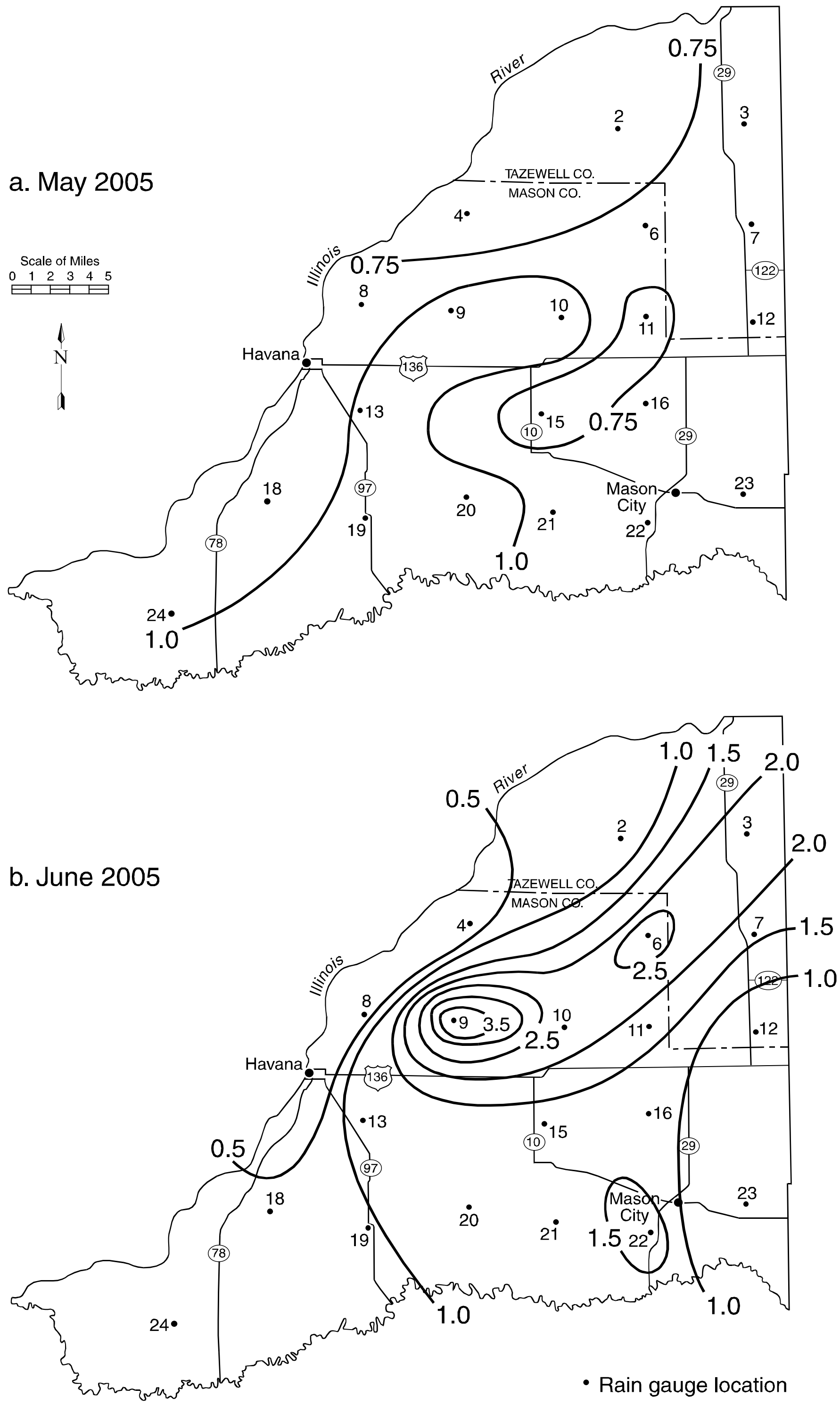


Figure 9. Precipitation (inches) for May 2005 and June 2005

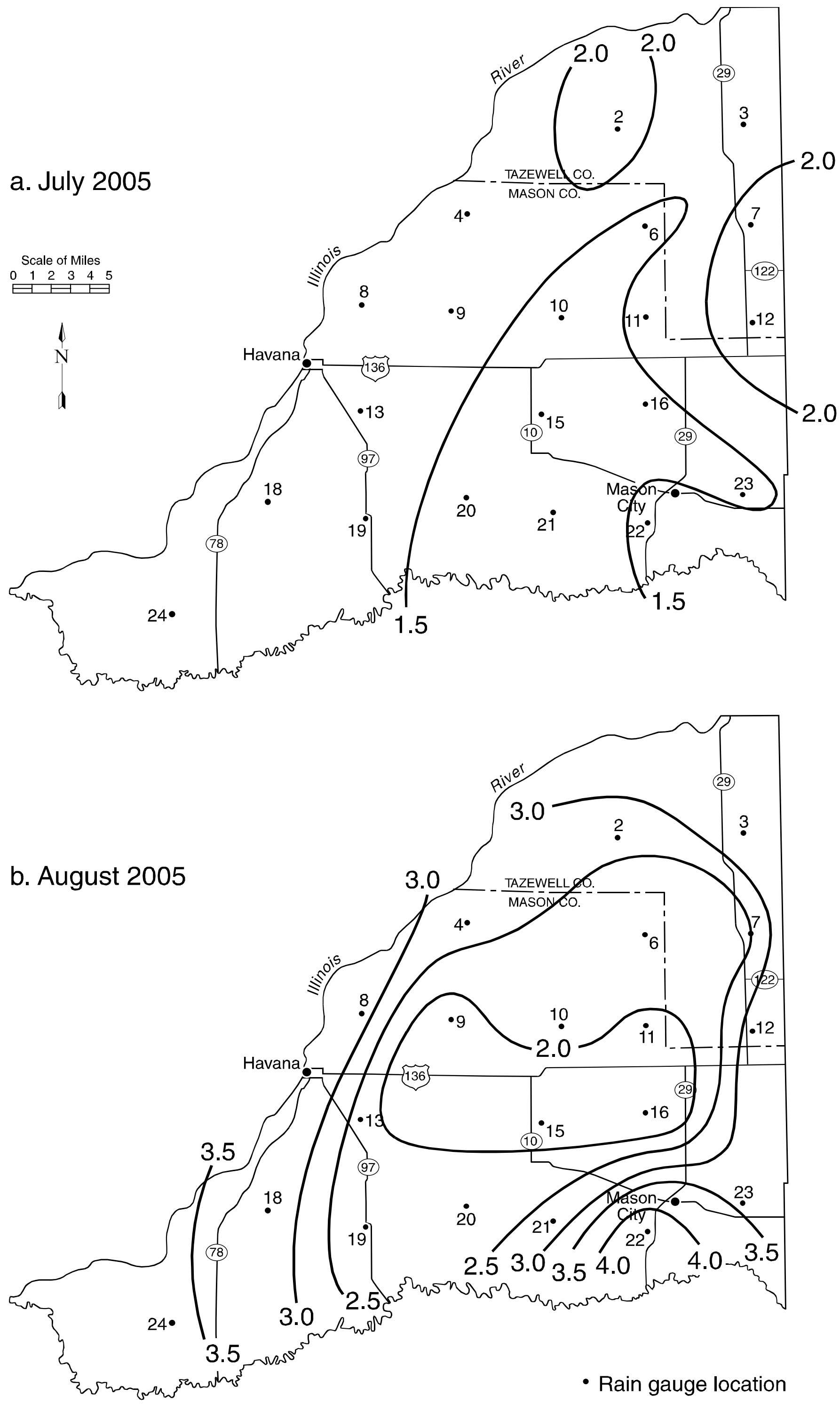


Figure 10. Precipitation (inches) for July 2005 and August 2005

Figure 3a presents the 13-year network average including all sites; Figure 3b presents the 13-year network average for all sites, excluding sites 16, 19, and 21 during the period 1997–2002, and Figure 4 presents the annual precipitation pattern for Year Thirteen. The pattern seen in the 13-year network average (Figure 3a) is still dominated by values at stations 16, 19, and 21 (Figure 4), which greatly differed from their neighbors during the period 1997–2002. The bias at sites 16, 19, and 21 were considerably smaller for Years Eleven–Thirteen, and thus the precipitation data for these three stations are included in all analyses. During Year Thirteen, annual gauge totals varied from 24.1 inches at site 16 to 31.2 inches at site 22 (Figure 4). Six-inch gradients in precipitation are not unusual events during any given year, as long as they are not replicated at the same gauges year after year.

October 2004 (Figure 5b) was the wettest month of Year Thirteen, reporting a 5.17-inch network average, followed by November 2004 (Figure 6a, 4.54 inches), and January 2005 (Figure 7a, 4.49 inches). Precipitation for those four months totaled 14.20 inches, or approximately 52 percent of the total annual precipitation. March 2005 was the driest month of the year (Figure 8a, 0.71 inches), followed by May 2005 (Figure 9a, 0.88 inches). Total average precipitation for the network in the three spring season months (March–May) was light, 3.68 inches, or about 13 percent of the yearly total.

Individually, October and November 2004 and January 2005 were wetter than the 12-year average by 1.75 inches or more (see Table 4). May, June, and July 2005 were drier than average by more than 2.0 inches, and September 2004 and March, April, and August 2005 were drier than average by more than 1.0 inch. Only December 2004 and February 2005 were within ± 0.25 inches of the 12-year average. The fall of 2004 (September–November, 10.69 inches) was the wettest season of the year, followed by winter 2004–2005 (December–February, 7.36 inches). The fall precipitation total was 3.02 inches above normal and the winter precipitation total was 2.32 inches above average. The spring total precipitation was 6.79 inches below the 12-year network spring average, and the summer total precipitation was 6.08 inches below average.

The annual precipitation total for 2004–2005 was the fourth driest of the 13 years of network operation. The network received 28.20 inches less precipitation than in the wettest year (1992–1993) and 1.65 inches more than in the driest year (1995–1996). Year Thirteen had the third wettest fall (1992 and 1993 were wetter), and the second wettest winter (1992–1993 was wetter) of the 13 years of network operation. The spring and summer of 2005 were the driest warm seasons of the 13 years of network operation.

Storm Events

The network precipitation events were examined for the 13-year period of record. Mean monthly, seasonal, and annual number of these precipitation events are presented for each year (Appendix H), and for 2004–2005 (Table 4). The monthly, seasonal, and annual number of precipitation events averaged over the 1992–2004 period also are presented (Table 4). A network storm period was defined as a precipitation event separated from preceding and succeeding events at all network stations by at least three hours. Data for the individual network storm periods also are presented (Appendix I, Tables I-2 and I-3).

During this dry Year Thirteen, there were 98 precipitation events, which tied for the second fewest number of events in 13 years of network operation. More events than average occurred in the fall, but fewer than average events were observed during the next three seasons of the year.

The majority of events occurred in the fall and winter, which is unusual. The spring and summer seasons had the fewest number of precipitation events of the past 13 years. The amount of precipitation per event also was below average in the spring and summer of 2005, about 60 percent (spring) and 72 percent (summer) of the average amount of precipitation per event.

The plot of the network average monthly precipitation time series (Figure 11) shows the monthly variation of precipitation. It is not uncommon for five to six months of the fall–winter seasons to fall below 2.75 inches of precipitation. This occurred in the five years from 1995–1996 to 1999–2000 and in the three successive years 2001–2002 to 2003–2004. It is not unusual for one or two spring and summer months to fall below 2.75 inches of precipitation in any given year. In the four summers of 1995, 1996, 1997, and 2000, three or four months during the spring–summer seasons fell below 2.75 inches. The 1996, 1997, and 2000 years were drier overall than Year Thirteen when all six spring–summer months fell below 2.75 inches of precipitation.

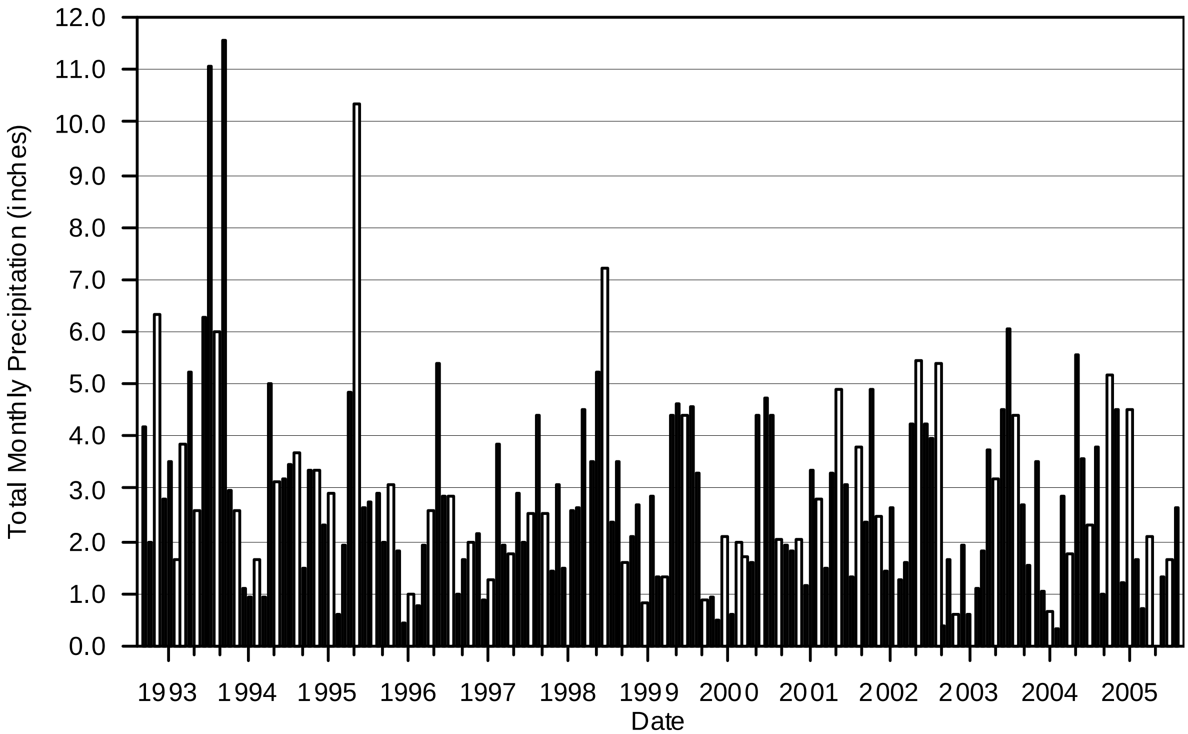


Figure 11. Network average monthly precipitation (inches), September 1992 - August 2005

A total of 1590 network storm periods have occurred during the 13-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, 110 in 2003–2004, and 98 in 2004–2005, resulting in a 13-year average of 124.3 storms per year.

Appendix I documents each network storm period for Year Thirteen 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, and the storm average is the arithmetic mean of the precipitation received at stations reporting precipitation during the storm period.

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 I for further explanation. Also included in Appendix I is a table indicating the precipitation received at each of the 20 stations for each network storm period for Year Thirteen (Table I-3). Sites that exceed the one-year or more recurrence frequency are indicated in bold type (Table I-3). Previous years of network storm periods can be found in Scott et al. (2002), Wehrmann et al. (2004, 2005), and Wilson et al. (2008).

In the first 12 years of operation, 61 of the 1492 storm periods produced maximum precipitation at one or more stations with a recurrence frequency greater than one year: 50-year (1 storm), 10-year (3 storms), 5-year (8 storms), 2-year (31 storms), and greater than 1-year but less than 2-year (18 storms). The 50-year storm (storm 153) occurred on September 13, 1993, and the 10-year storms 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 months (May–September).

Nine storms had a recurrence interval exceeding the 1-year or greater recurrence frequency in 1992–1993, five in 1993–1994, six in 1994–1995, one in 1995–1996, three in 1996–1997, four in 1997–1998, four in 1998–1999, five in 1999–2000, four in 2000–2001, eight in 2001–2002, seven in 2002–2003, and five in 2003–2004.

In Year Thirteen, only one of the 98 network storm periods exceeded the 1-year recurrence frequency. Year Thirteen also had a below average number of network storm periods and a below average number of heavy rainfall periods. No events exceeded the 5-year or more recurrence frequency. The Year Thirteen heavy rain event was a 2-year event that occurred on September 15–16, 2004 (storm 1495).

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 mean monthly Illinois River stage during Year Thirteen occurred in January and February 2005. For three straight months the Illinois River had a mean stage of more than 440 feet msl. River stage had exceeded 440 feet msl only one month since 2002. Because of the extended, elevated river stage, groundwater levels in MTOW-5 and -9 show strong recovery during those three months (Dec. 2004–Feb. 2005).

Most of the study area had fairly consistent average to above average rainfall from February 2004 through January 2005. In that span, there were at least five months with 4 inches of rain at nearly every gauge. The aquifer responded accordingly and groundwater levels rose in all the observation wells through March 2005, except for those close to the Illinois River, which began declining in February. Beginning in March, however, precipitation amounts decreased significantly. The following months were below the 12-year average for the study area and water levels declined through August 2005; some wells were at or near the lowest point they have been since the project began (see the graphs in Appendix A).

As witnessed in Year Thirteen, and 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. Significant precipitation in Fall 2004 through January 2005 resulted in aquifer recharge, and conversely, the lack of precipitation from March 2005 through August 2005 limited recharge to the aquifer and groundwater levels declined.

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 1 foot to more than 6 feet have been observed. Based on available data, these annual fluctuations often appear to be superimposed on longer-term trends, perhaps of 10 years or more. For the 47-year record, both the record low and high have been observed within the past 15 years. A detailed look at water levels since 1990 is shown in Figure 13. 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 45-year history that MTOW-1 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 showed an almost linear decline until 1998, when water levels again rose dramatically, recovering to peak levels similar to those observed in 1994 and 1995. In 2005 this well was close to being dry; the August 31, 2005 water level measurement (September reading) was 39.90 feet below land surface.

Irrigation Test Site Measurements

The data for wells 3 and 6 are shown in Figure 14 along with the stage in Crane Creek and precipitation from gauge 20. The data show each summer's effects from irrigation pumpage at the site. Figure 14 graphically represents the significance of the dry summer in 2005 as well as the significance of heavy rainfall that occurred in May and June of 2004. The number of irrigation pumpage cycles completed at the site in 2005 can be counted on the figure. The dry summer required more frequent irrigation than in 2004 or 2003.

Figure 15 shows discharge versus time for the upstream and downstream portion of Crane Creek. Fewer measurements (12) were taken during the summer of 2005 because it appeared that the values from 2004 provided better representation of creek conditions. The readings continued to show that the downstream discharge was higher than the upstream discharge, indicating the groundwater system was contributing to the stream. Development of the groundwater model at the site will help to quantify the loss of groundwater to the stream at the site. The results of the model can then be evaluated against the field data and should correlate with what we have seen with our discharge measurements.

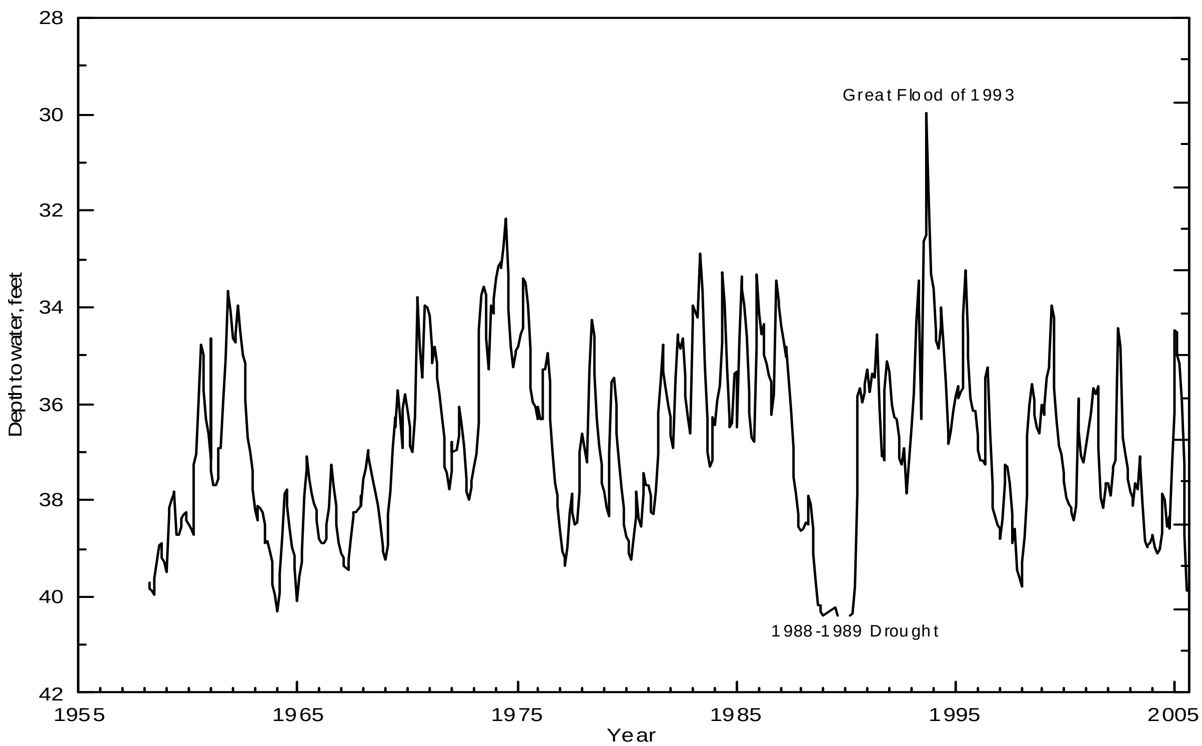


Figure 12. Groundwater levels at the Snicarte well, MTOW-1, 1958-2005

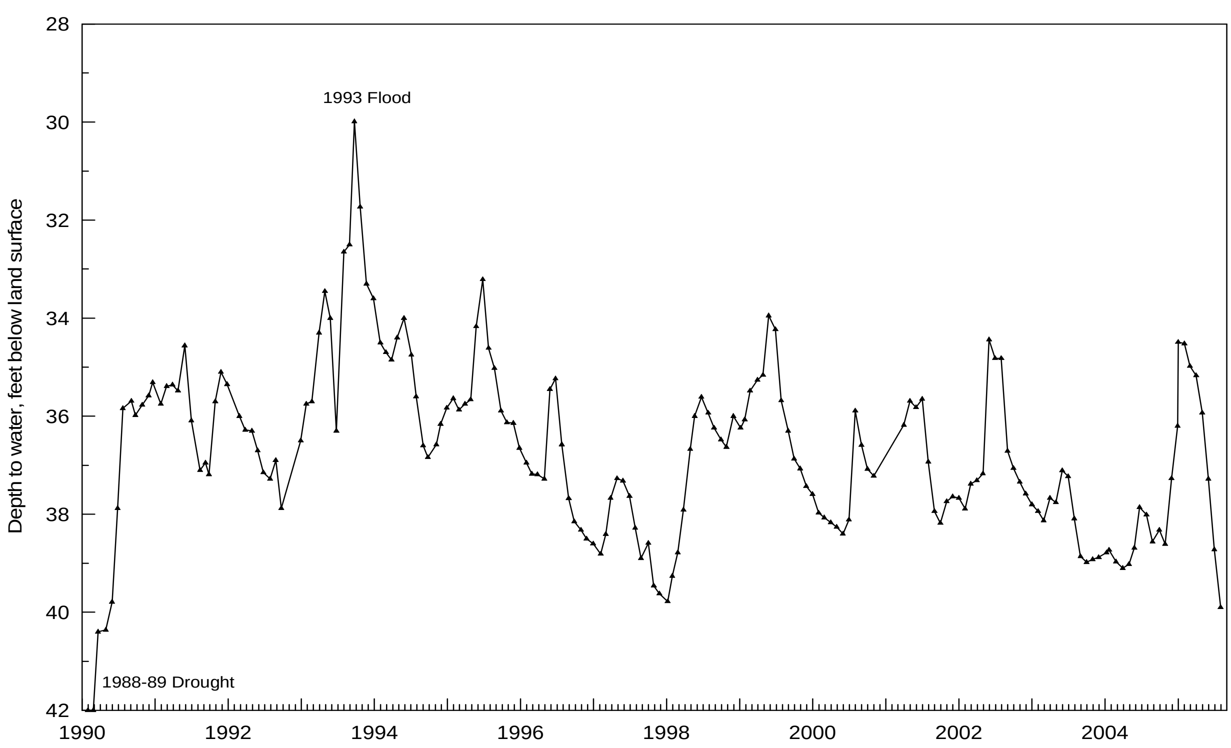


Figure 13. Groundwater levels at the Snicarte well, MTOW-1, 1990-2005

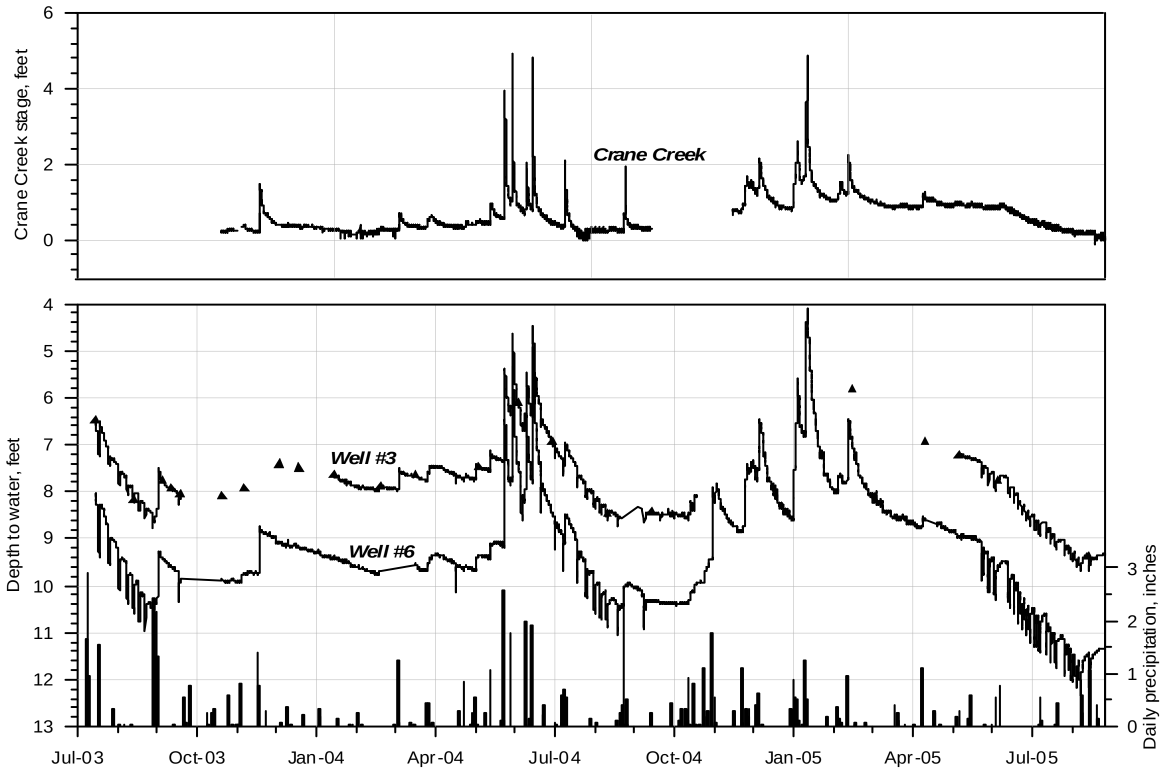


Figure 14. Groundwater level (Wells 3 & 6), Crane Creek stage elevation, and precipitation (Gauge 20) at the irrigation test site. Triangles are manual readings.

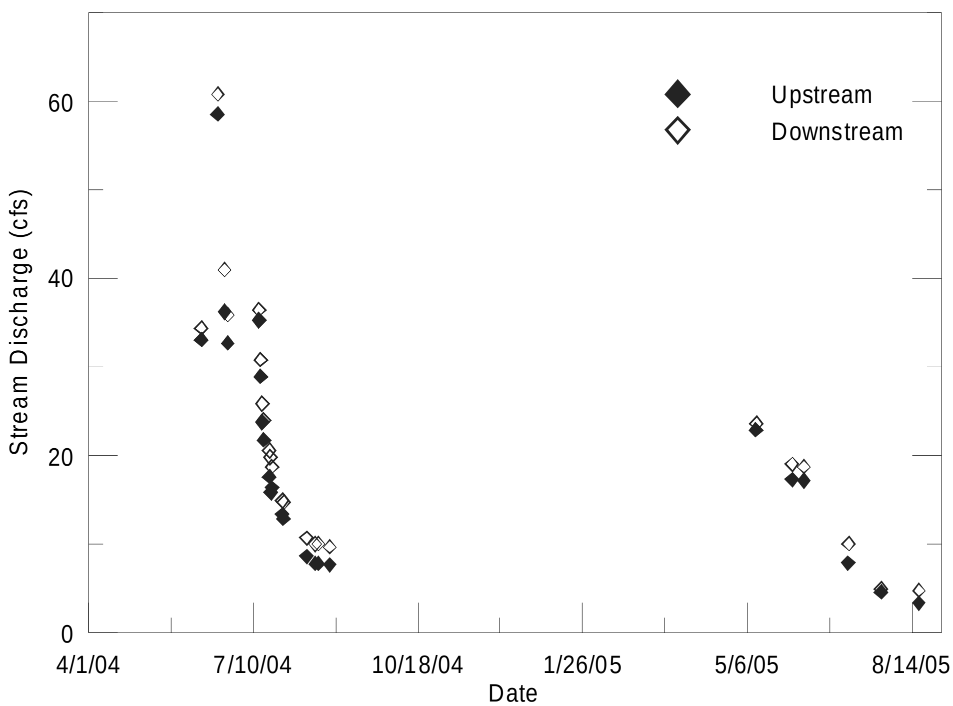


Figure 15. Discharge measurements in Crane Creek at the irrigation test site

Continuous Measurements

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 one to three days of the rainfall event and typically lasts three to five days after the rainfall event has ended. This analysis confirms that aquifer response to rainfall can happen quickly, as expected, given the permeable surface soils typical of the area. Further, duration of the recharge events vary based on the magnitude of the rainfall event. 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.

In response to this finding, transducers were placed in the Green Valley (MTOW-8) and Route 136 Rest Area (MTOW-7) observation wells during Year Twelve to begin collecting continuous water-level data. The data indicated that indeed recharge was evident two to three days after significant rainfall events at these wells.

Based on the success of these results, the IVWA purchased four In-Situ Mini-troll data loggers and installed them in four wells on December 30, 2004. The wells outfitted with digital recorders are Easton (MTOW-2), Wildlife Refuge (MTOW-3), Rest Area (MTOW-7), and the Talbott Tree Farm (MTOW-13). Figures 16–19 illustrate the water-level data collected for these four wells during Year Thirteen. Six more data loggers were purchased at the end of Year Thirteen to place in six additional network wells.

These water-level measurements from the short period of record do not show the recharge events as clearly as have been evident on past datasets. This is likely because Year Thirteen was an unusually dry year, with only one storm greater than a 1-year recurrence interval, that being a 2-year storm. It is anticipated that as more data are collected and more severe storm events occur, recharge events will be evident on the water level hydrographs. For this year, however, only the Easton well showed recharge events that can be correlated to precipitation events. Figures 20 and 21 show the effects of precipitation on water levels for January and April of 2005.

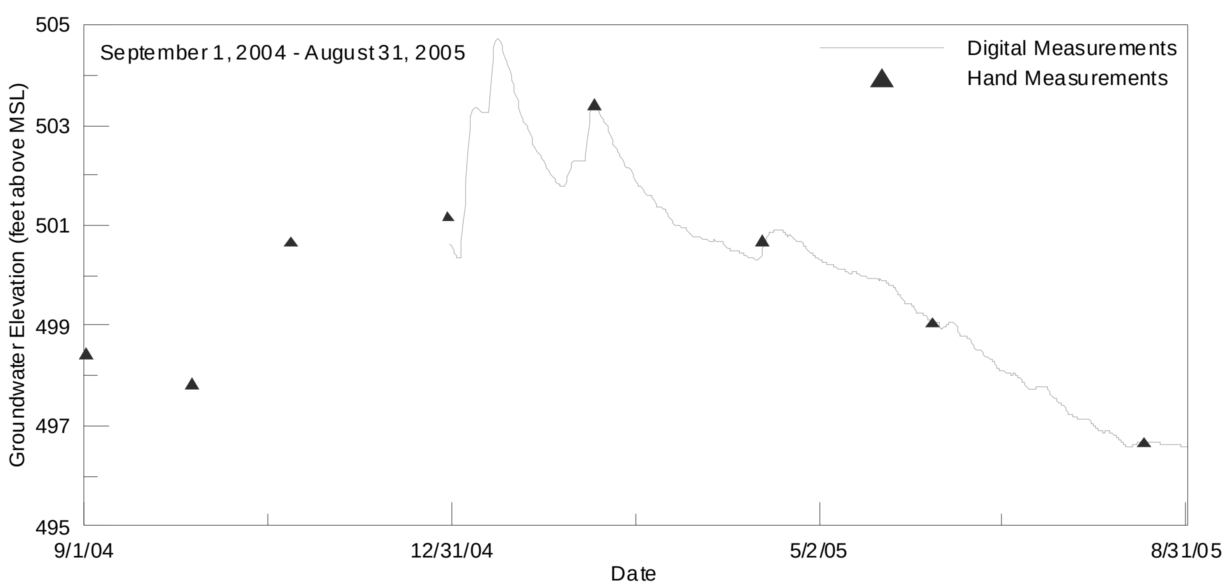


Figure 16. Digital water level data for the Easton well (MTOW-2)

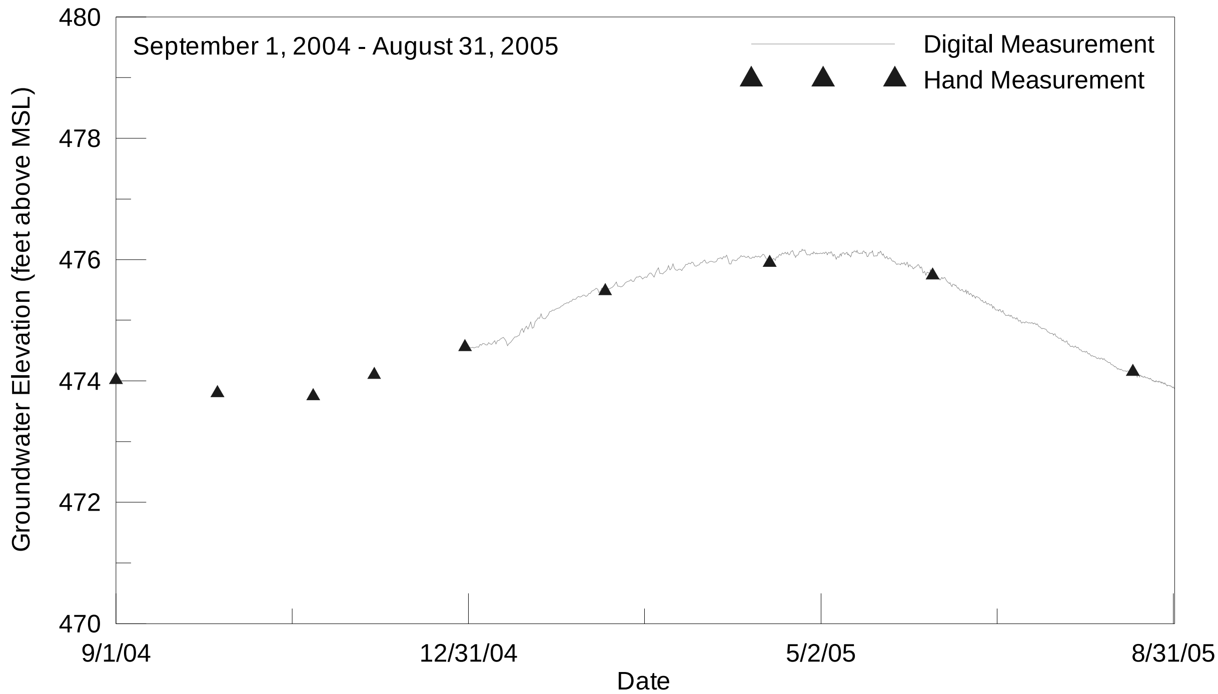


Figure 17. Digital water level data for the Wildlife Refuge (MTOW-3)

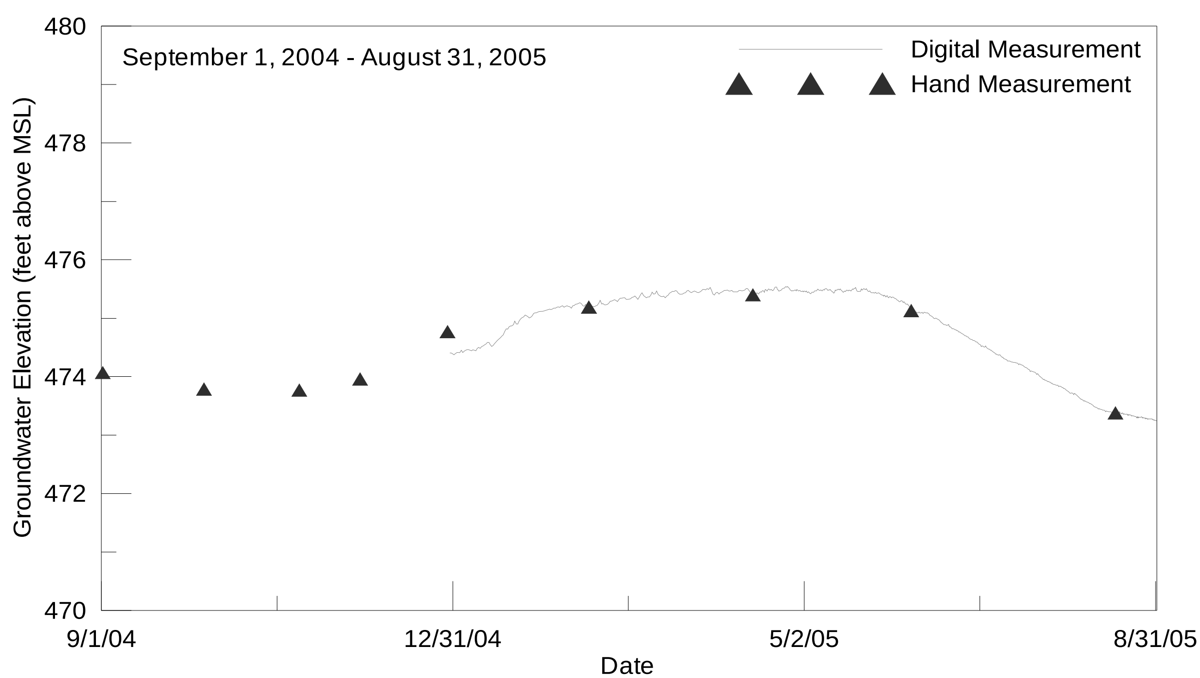


Figure 18. Digital water level data for the Rest Area (MTOW-7)

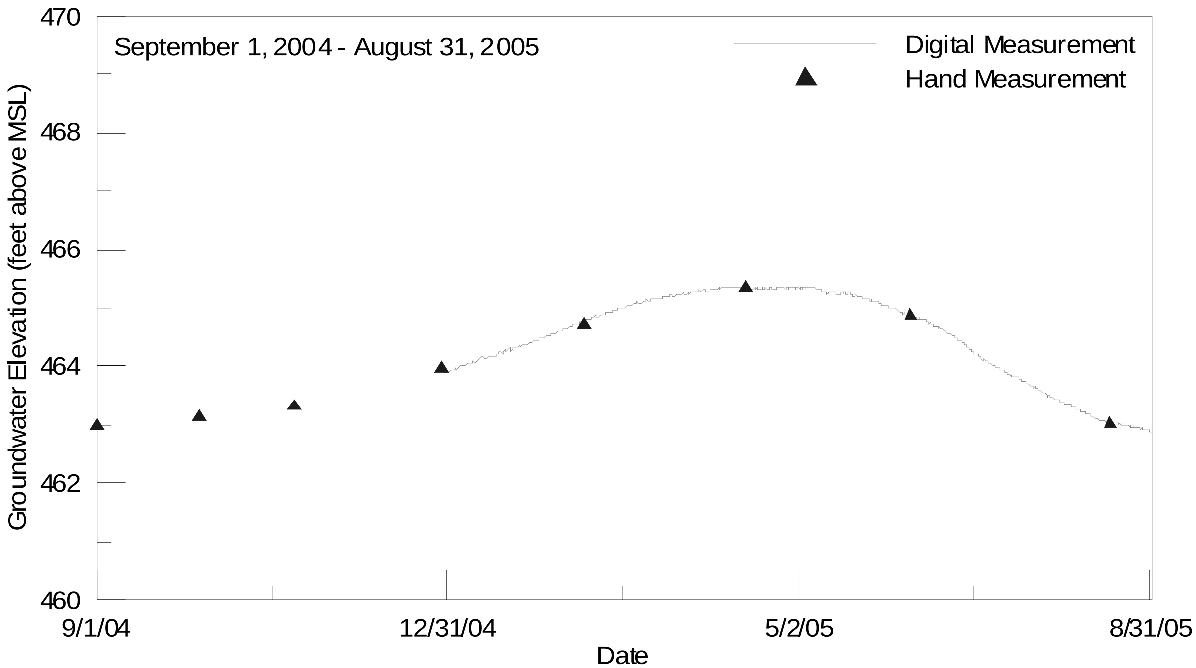


Figure 19. Digital water level data for the Talbott Tree Farm network well (MTOW-13)

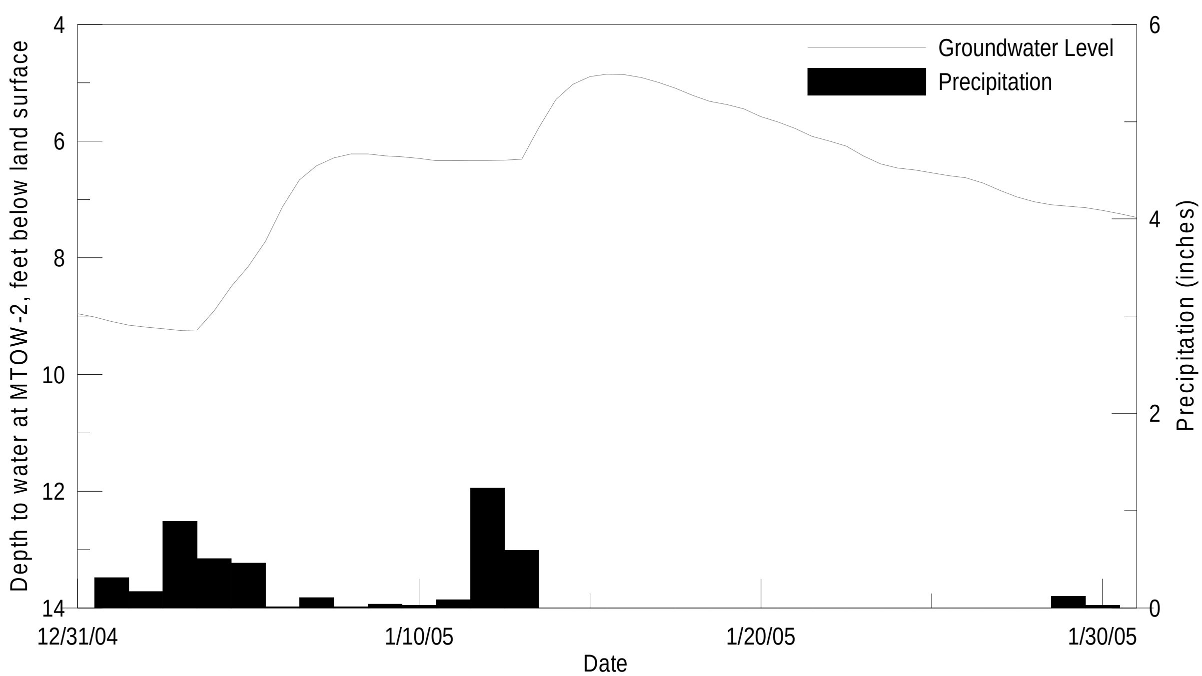


Figure 20. Groundwater elevations and precipitation at the Easton network well (MTOW-2) for a January 2005 recharge event

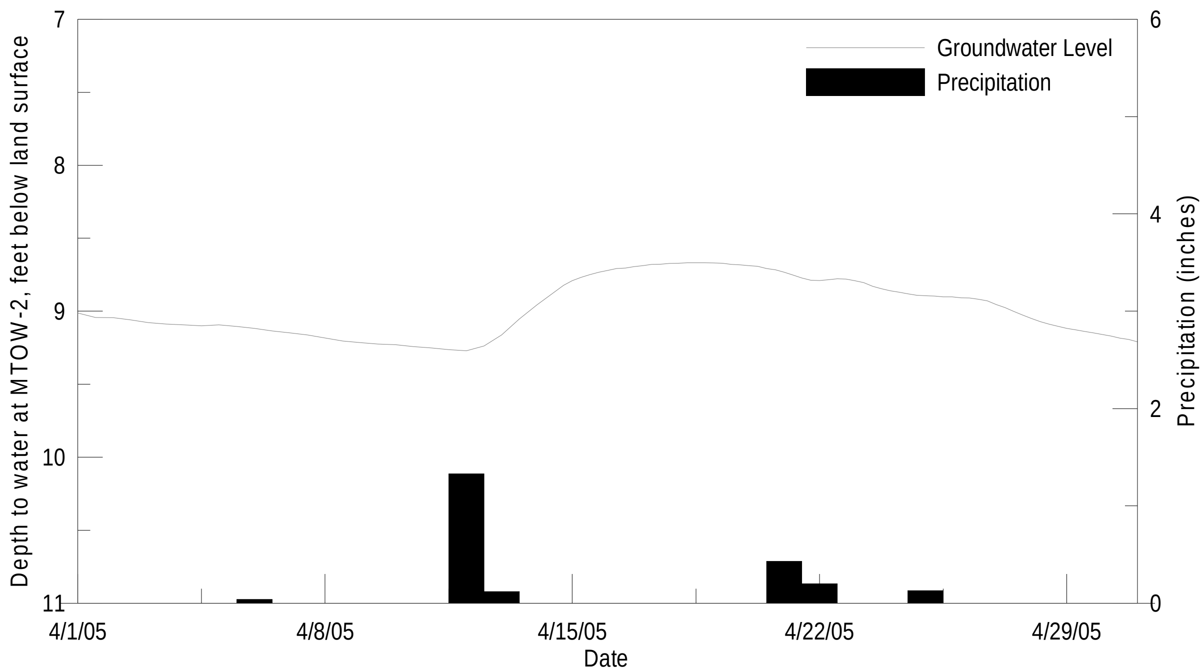


Figure 21. Groundwater elevations and precipitation at the Easton network well (MTOW-2) for an April 2005 recharge event

Irrigation Water Use

Low precipitation during the growing season affected irrigation demand dramatically during Year Thirteen. Since 1995 the average irrigation withdrawals were 41 billion gallons (bg) a year, ranging from 30 to 50 bg. In 2005, however, the total irrigation pumpage was approximately 72 bg. This is 70 percent above average for the previous 10 years and 20 bg more than in any other year.

Monthly and seasonal estimates of irrigation withdrawals are shown in Table 5. These data were calculated for the Imperial Valley by previously described methods. Total annual irrigation withdrawals, from highest to lowest, are as follows: 2005; 1996; 2001 and 2002 (equal); 2003; 2004; 1999; 1997 and 1995 (equal); and 1998 and 2000 (equal). Though more irrigation systems are added each year, this year (2005) showed that rainfall during the irrigation season is the primary factor in determining the amount of irrigation that takes place. Note also that even though there are more systems operating, the production from each system, 0.037 billion gallons, was much higher than any previous year. The greatest average irrigation withdrawals typically occur in July and August, and the least occur in September and June.

The estimated monthly irrigation pumpage also is displayed graphically in Figure 22 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 (Year Eight), even though Year Eight showed a precipitation deficit of 9.5 inches (Table 6). This was because significant precipitation fell during the summer of 2000, reducing the need for irrigation. Year Thirteen was the fourth driest of network operation, 7.55 inches lower than the network 12-year average precipitation (Table 4), but because the irrigation season was dry, it had the highest irrigation pumpage recorded for the study area.

Table 5. Estimated Monthly Irrigation Withdrawals (billion gallons), Number of Irrigation Systems, Withdrawal per System, and Withdrawal Rank

Year	*June*	*July*	*August*	*September*	*Total*	*# Systems*	*BG/system*	*Rank*
1995	2.6	14	10	11	38			8
1996	2.0	20	18	12	52			2
1997	2.6	19	14	2.0	38			8
1998	2.1	7.8	13	6.9	30	1622	.018	10
1999	2.8	18	12	6.0	39	1771	.022	7
2000	6.4	6.0	12	5.6	30	1799	.017	10
2001	4.4	21	17	5.0	47	1818	.026	3
2002	3.4	24	16	3.7	47	1839	.026	3
2003	4.1	16	15	10	46	1867	.025	5
2004	5.3	12	19	5.7	42	1889	.022	6
2005	15	29	23	4.8	72	1909	.037	1
Average	4.6	17	16	6.6	44			

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 6. 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	8
1995 - 1996	25.70	-11.06	+13.84	13	2
1996 - 1997	27.31	-9.45	+4.39	11	8
1997 - 1998	40.06	+3.30	+7.69	3	10
1998 - 1999	34.02	-2.74	+4.95	6	7
1999 - 2000	25.81	-10.95	-6.00	12	10
2000 - 2001	30.97	-5.79	-11.79	7	3
2001 - 2002	39.91	+3.15	-8.64	4	3
2002 - 2003	30.06	-6.70	-15.34	8	5
2003 - 2004	29.64	-7.12	-22.46	9	6
2004 - 2005	27.34	-9.42	-31.88	10	1

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.

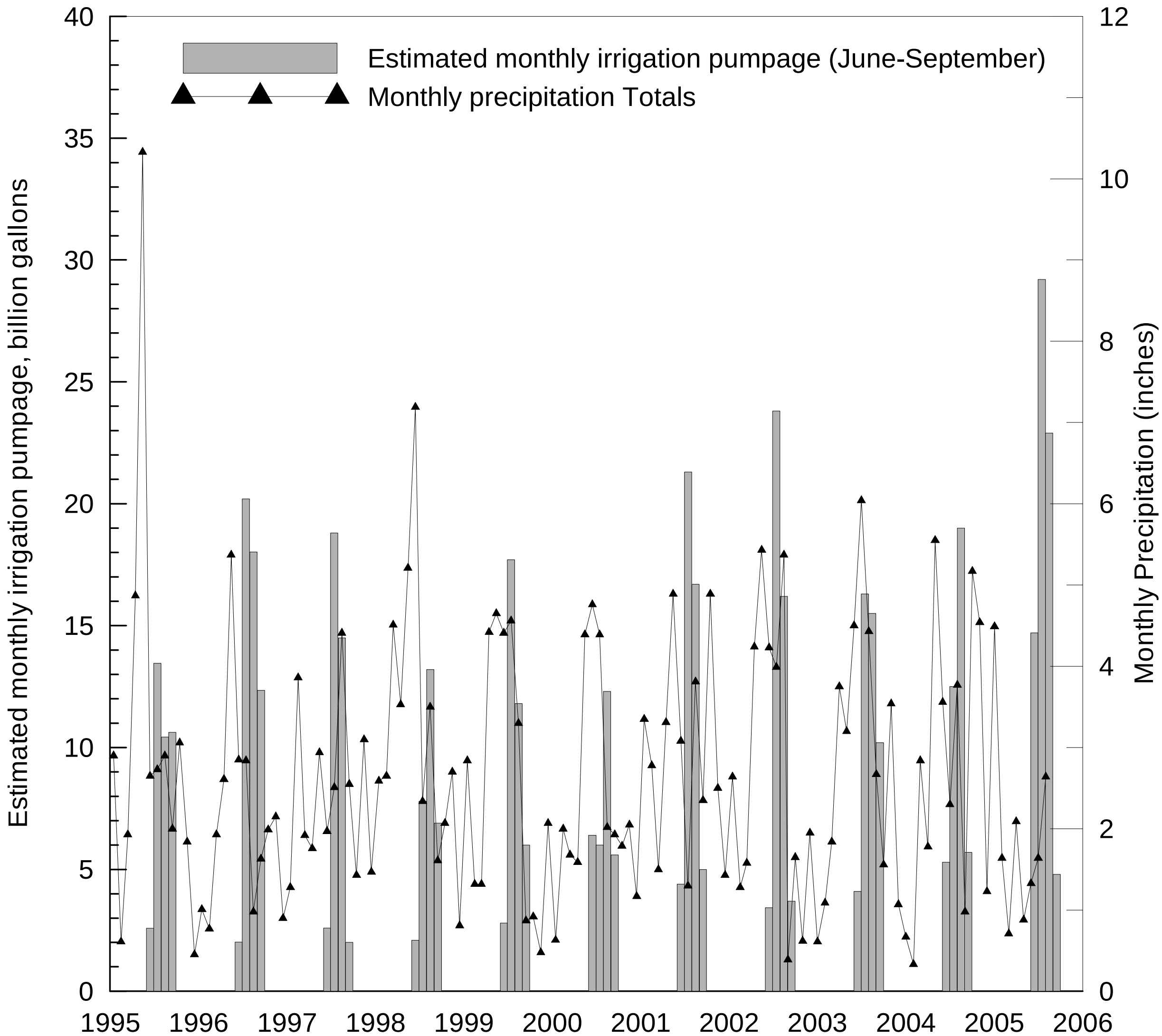


Figure 22. Estimated irrigation pumpage and average monthly precipitation, Imperial Valley

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

Table 6 shows that for seven of the past nine years, rainfall has been 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 287 more systems in 2005 than in 1998, the increase in the number of irrigation systems also must play a role in how much water is being applied within the IVWA. The increase has been steady over the past few years, averaging about 20 new systems a year. Obviously, 2005 was an unusually dry year and required additional irrigation to meet crop needs. This year highlights the importance of the timing of rainfall on the need for irrigation.

Summary

In Year Thirteen of rain gauge network operation in the Imperial Valley (September 2004–August 2005), the network received an average of 27.34 inches of precipitation, 7.55 inches less than the network 12-year average precipitation of 34.89 inches. This occurred despite above average precipitation in the fall of 2004 and in the winter of 2004–2005 months. The shortfall was due to below average rain in the spring and summer of 2005. Year Thirteen had the third wettest fall and second wettest winter, but the driest spring and summer of network operation. Only one month during the year (November 2004) had more than 5 inches of precipitation, and nine months had less than 2.75 inches of precipitation. It was also observed that the precipitation events during the spring and summer were less intense than normal, and only one heavy precipitation episode occurred during Year Thirteen (September 15–16, 2004).

Groundwater levels typically tend to peak in most wells in the Imperial Valley during the spring and early summer, but then decline in late summer and fall as precipitation evaporates, is transpired back into the atmosphere by growing crops, and as a result of seasonal irrigation withdrawals. In Year Twelve, some wells declined throughout the entire year, with only a slight recovery in May 2004. For those wells, the highest water levels for the year were in September 2004. Therefore, the wetter-than-average Fall in 2004 brought about a marked increase in groundwater levels as the aquifer recovered from the previous dry weather. After February 2005, when rainfall amounts again fell significantly below average, groundwater levels declined to some of the lowest levels recorded during the study. The water level in the Snicarte well (MTOW-1), for example, was very close to the bottom of the well, a level previously seen only during the drought in 1988.

With an additional year of data gathered at the irrigation test site, a better understanding of the relationship among precipitation, pumpage, stream flow in Crane Creek, and groundwater levels has been developed. It was observed that groundwater levels remained above the level of Crane Creek, even during periods of irrigation, which indicate that the groundwater system is discharging to the stream even during the summer irrigation season. Water levels on both sides of Crane Creek decline when the irrigation system is operating, which reduces groundwater discharge to the stream, but do not fall below the stream to cause a reversal of flow.

Four pressure transducers installed at the Easton (MTOW-2), Wildlife Refuge (MTOW-3), Rest Area (MTOW-7), and Talbott Tree Farm (MTOW-13) network wells showed mixed results during Year Thirteen because no significant rainfall occurred after they were installed. The Easton well did provide evidence that recharge is occurring over a fairly short time period (several days or less after a significant precipitation event). As indicated in previous reports, initial observations are that distance from a river, creek, or stream and depth to water influence the timing and magnitude of the recharge event.

Year Thirteen, the fourth driest year of network operation, also had the greatest irrigation withdrawal season by about 40 percent. This increase in pumpage was due to the extremely dry conditions that occurred during the 2005 growing season. This year highlighted the importance of precipitation timing on the amount of irrigation needed to sustain crops through the growing season.

References

Calsyn, D.E. 1995. *Soil Survey of Mason County, Illinois*. Illinois Agricultural Experiment Station Soil Report 146, U.S. Department of Agriculture, Natural Resources Conservation Service and University of Illinois, Urbana, IL.

Clark, G.R. 1994. *Mouth of the Mahomet Regional Groundwater Model, Imperial Valley Region of Mason, Tazewell, and Logan Counties, Illinois.* Illinois Department of Transportation, Division of Water Resources, Springfield, IL.

Hollinger, S.E. 1997. *Continued Operation of a Raingage Network for the Imperial Valley Water Authority, Year Four: September 1995–August 1996.* Illinois State Water Survey Contract Report 615, Champaign, IL.

Hollinger, S.E., and R.A. Peppler. 1996. *Continued Operation of a Raingage Network for the Imperial Valley Water Authority, Year Three: September 1994–August 1995.* Illinois State Water Survey Contract Report 597, Champaign, IL.

Hollinger, S.E., and R.W. Scott. 1998. *Continued Operation of a Raingage Network for the Imperial Valley Water Authority, Year Five: September 1996–August 1997.* Illinois State Water Survey Contract Report 625, Champaign, IL.

Hollinger, S.E., H.A. Wehrmann, R.D. Olson, and R.W. Scott. 2000. *Operation of Rain Gauge and Ground-water Monitoring Networks for the Imperial Valley Water Authority, Year Seven: September 1998–August 1999.* Illinois State Water Survey Contract Report 2000-12, Champaign, IL.

Hollinger, S.E., H.A. Wehrmann, R.D. Olson, R.W. Scott, and R. Xia. 1999. *Operation of Rain Gauge and Ground-Water Monitoring Networks for the Imperial Valley Water Authority, Year Six: September 1997–August 1998.* Illinois State Water Survey Contract Report 646, Champaign, IL.

Huff, F.A. 1970. Sampling errors in measurement of mean precipitation. *Journal of Applied Meteorology* **9**:35–44.

Huff, F.A., and J.R. Angel. 1989. *Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois.* Illinois State Water Survey Bulletin 70, Champaign, IL.

Panno, S.V., K.C. Hackley, K. Cartwright, and C.L. Liu. 1994. Hydrochemistry of the Mahomet Bedrock Valley Aquifer, east-central Illinois: Indicators of recharge and ground-water flow. *Ground Water* **32**: 591–604.

Peppler, R.A., and S.E. Hollinger. 1994. *Installation and Operation of a Raingauge Network for the Imperial Valley Water Authority, Year One: September 1992–August 1993.* Illinois State Water Survey Contract Report 575, Champaign, IL.

Peppler, R.A., and S.E. Hollinger. 1995. *Continued Operation of a Raingage Network for the Imperial Valley Water Authority, Year Two: September 1993–August 1994.* Illinois State Water Survey Contract Report 583, Champaign, IL.

Sanderson, E.W., and A.G. Buck. 1995. *Reconnaissance Study of Ground-Water Levels in the Havana Lowlands Area.* Illinois State Water Survey Contract Report 582, Champaign, IL.

Scott, R.W., H.A. Wehrmann, and S.E. Hollinger. 2001. *Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority, Year Eight: September 1999–August 2000.* Illinois State Water Survey Contract Report 2001-15, Champaign, IL.

Scott, R.W., H.A. Wehrmann, and S.E. Hollinger. 2002. *Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority, Year Nine: September 2000–August 2001.* Illinois State Water Survey Contract Report 2002-07, Champaign, IL.

Walker, W.H., R.E. Bergstrom, and W.C. Walton. 1965. *Preliminary Report on the Ground-Water Resources of the Havana Lowlands Region in West-Central Illinois.* Illinois State Water Survey and Illinois State Geological Survey Cooperative Ground-Water Report 3, Champaign, IL.

Wehrmann, H.A., N.E. Westcott, and R.W. Scott. 2004. *Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority, Year Ten: September 2001–August 2002.* Illinois State Water Survey Contract Report 2004-01, Champaign, IL.

Wehrmann, H.A., S. D. Wilson, and N.E. Westcott. 2005. *Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority, Year Eleven: September 2002–August 2003.* Illinois State Water Survey Contract Report 2005-06, Champaign, IL.

Wilson, S.D., H.A. Wehrmann, K.L. Rennels, and N.E. Westcott. 2008. *Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority, Year Twelve: September 2003–August 2004.* Illinois State Water Survey Contract Report 2008-12, Champaign, IL.

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. The hydrographs maintain a common y-axis range (25 feet).

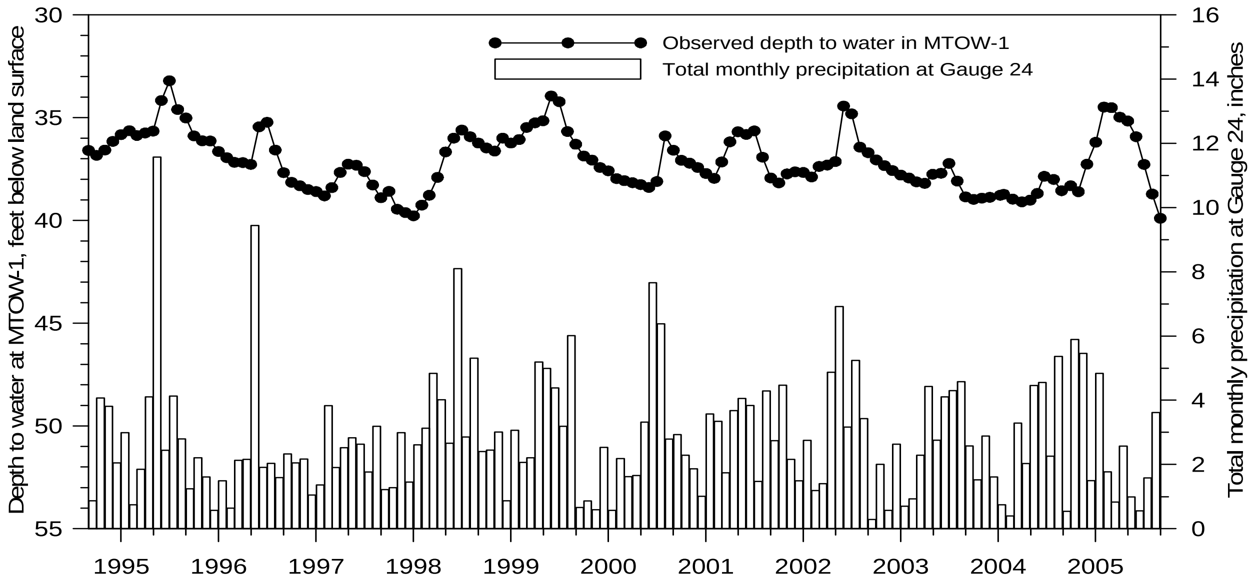


Figure A-1. Groundwater depth and precipitation for MTOW-1

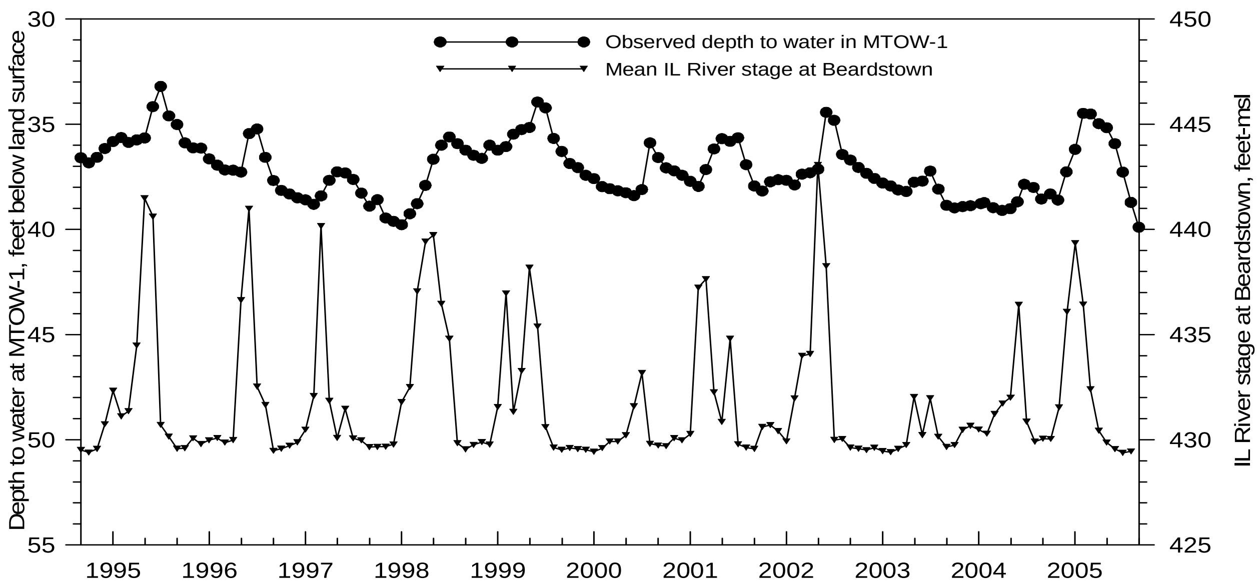


Figure A-2. Groundwater depth and Illinois River stage for MTOW-1

Appendix A. (continued)

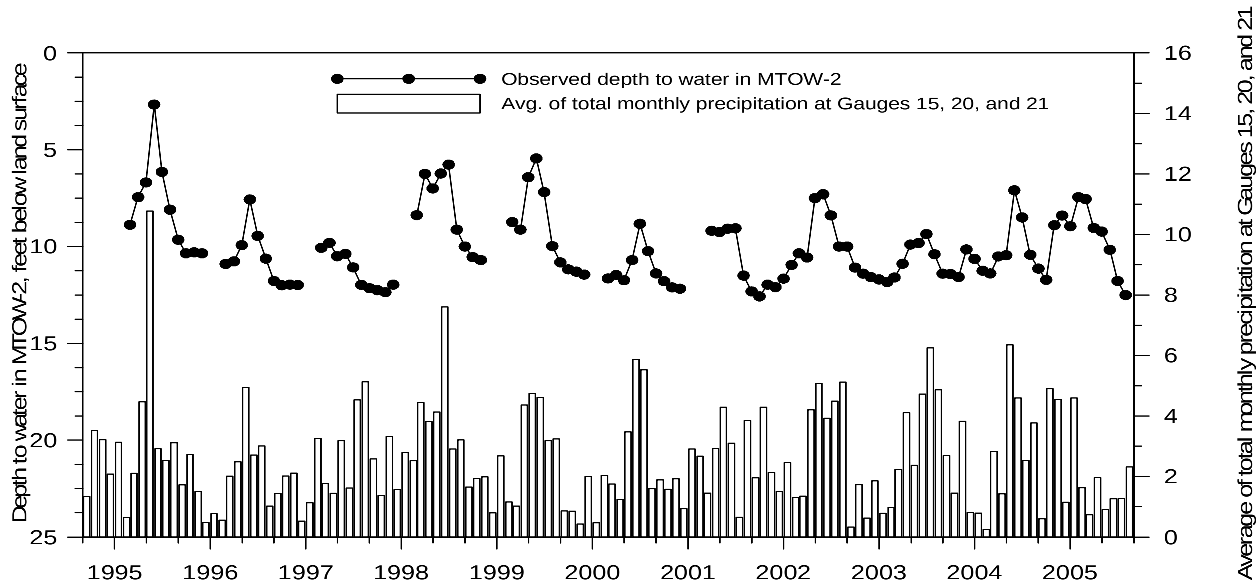


Figure A-3. Groundwater depth and precipitation for MTOW-2

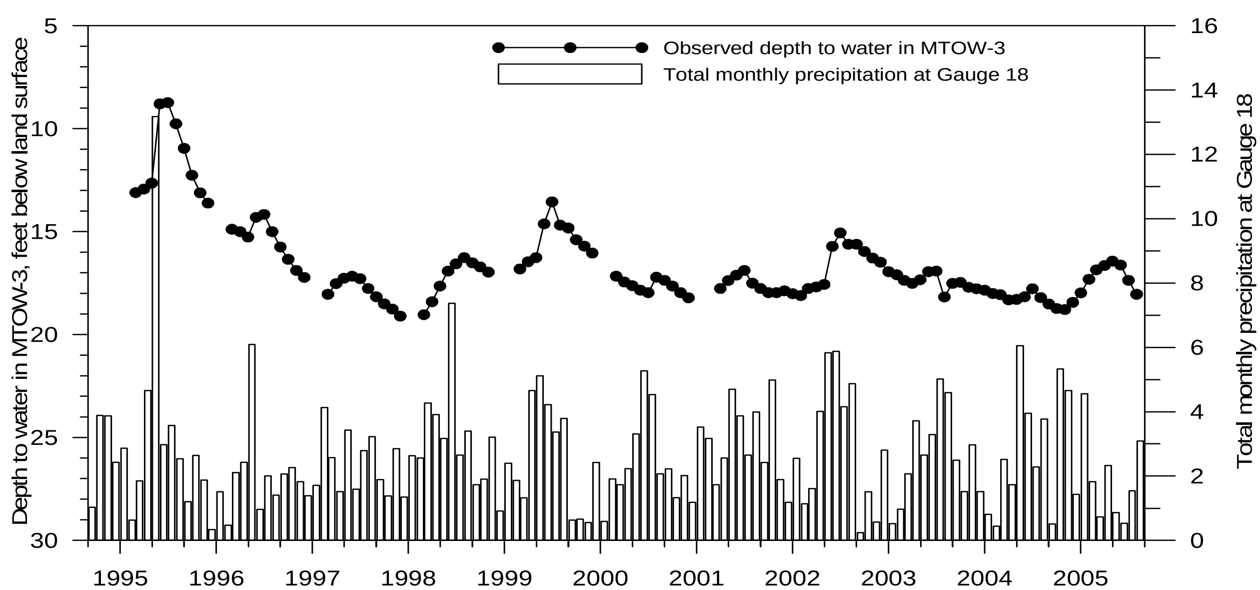


Figure A-4. Groundwater depth and precipitation for MTOW-3

Appendix A. (continued)

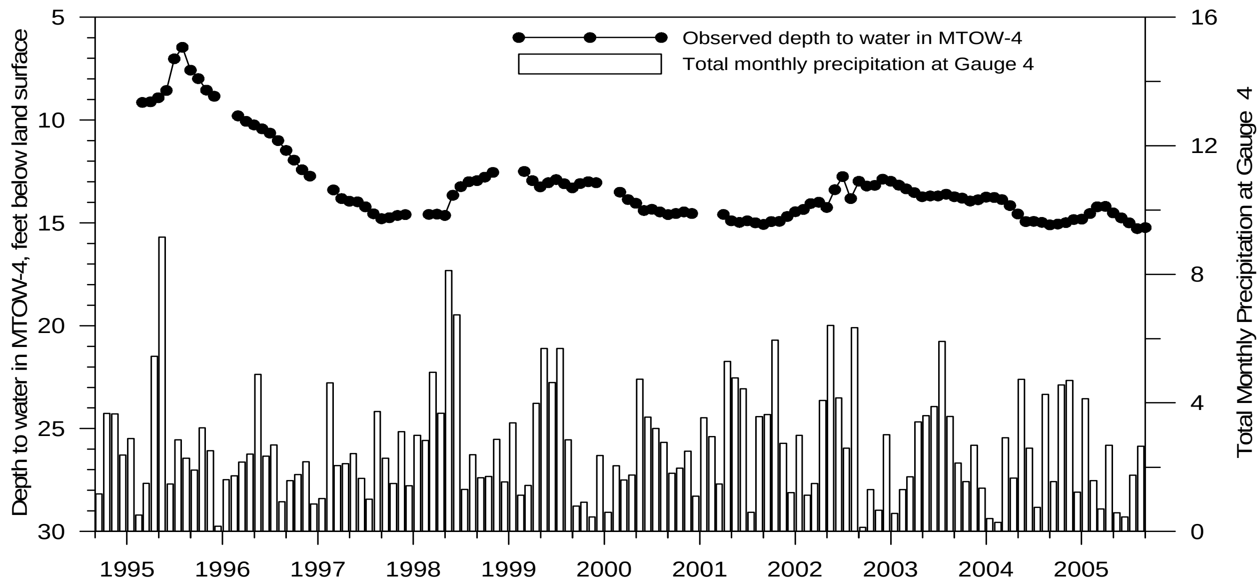


Figure A-5. Groundwater depth and precipitation for MTOW-4

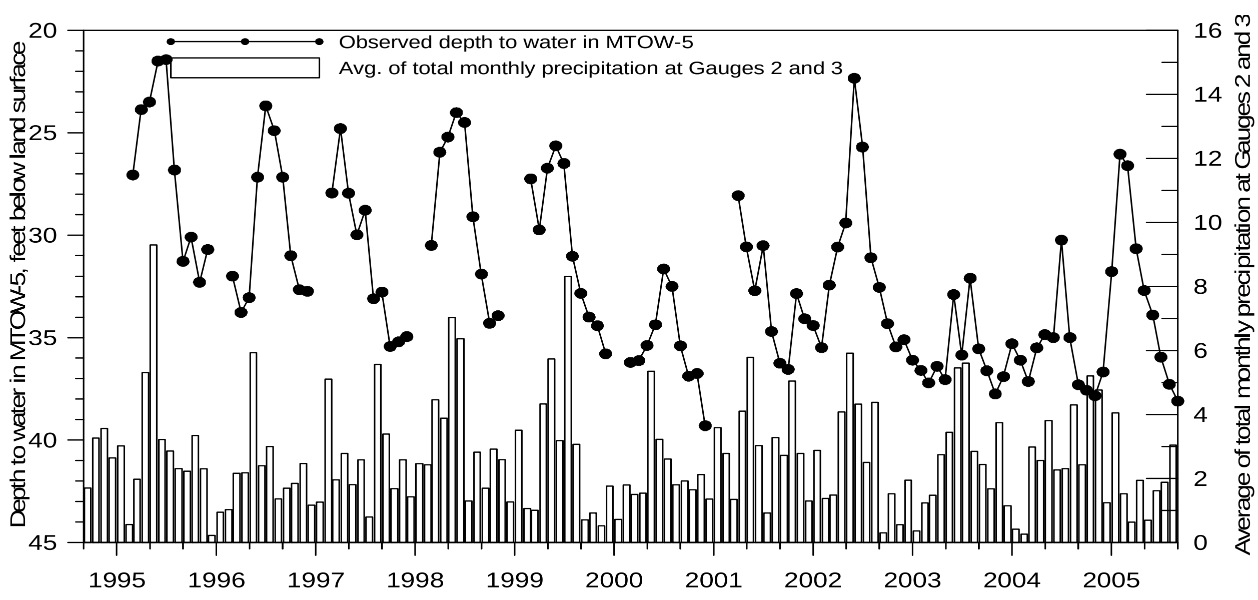


Figure A-6. Groundwater depth and precipitation for MTOW-5

Appendix A. (continued)

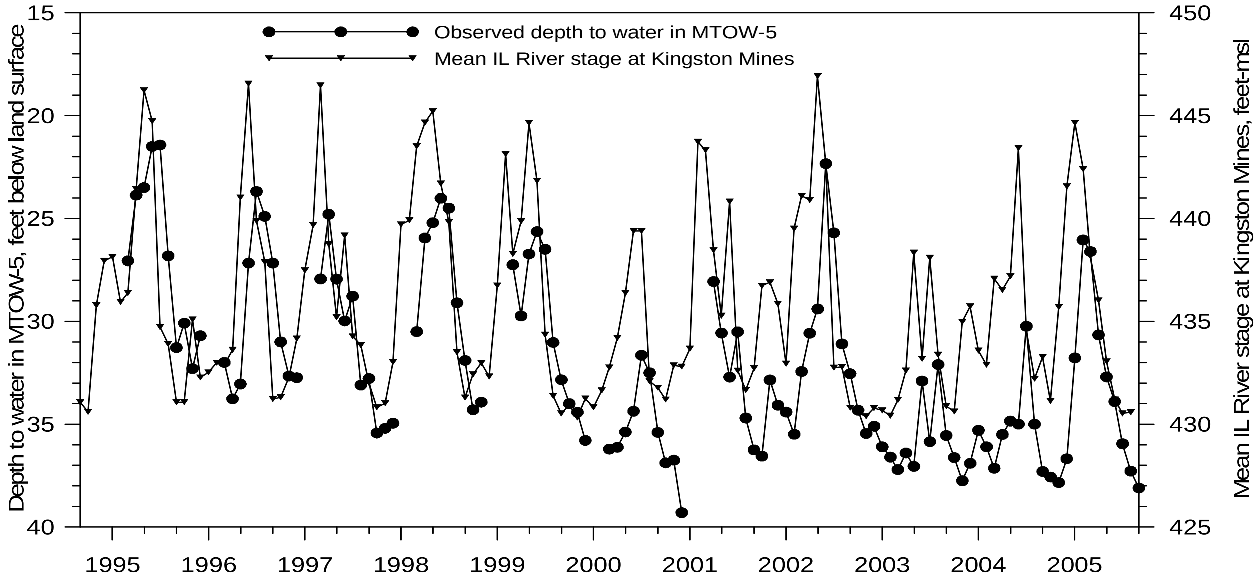


Figure A-7. Groundwater depth and Illinois River stage for MTOW-5

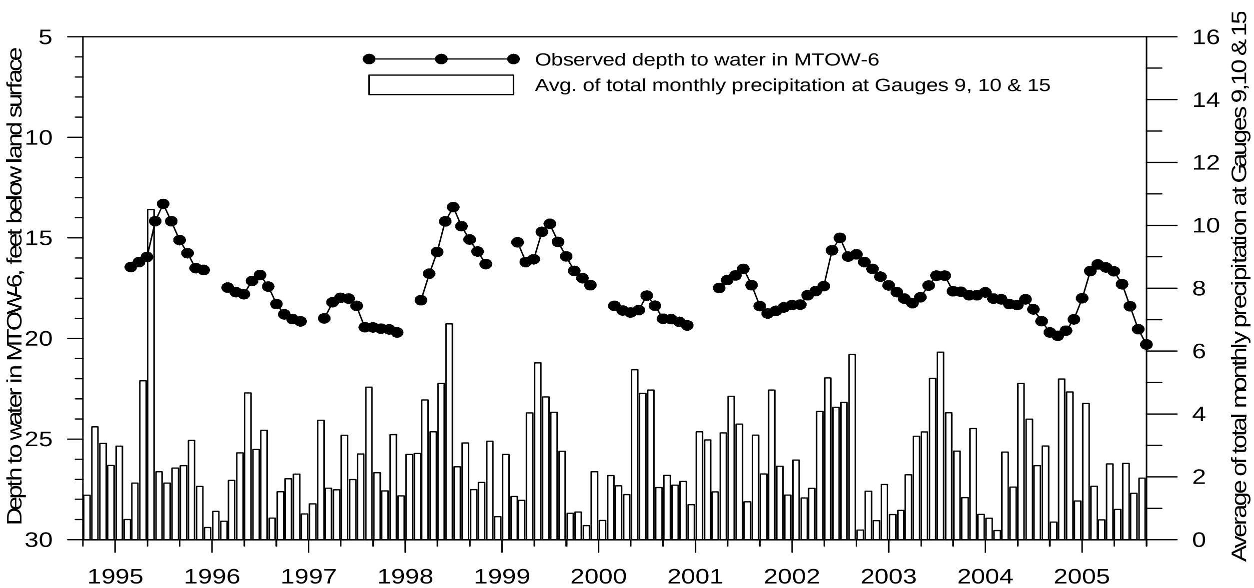


Figure A-8. Groundwater depth and precipitation for MTOW-6

Appendix A. (continued)

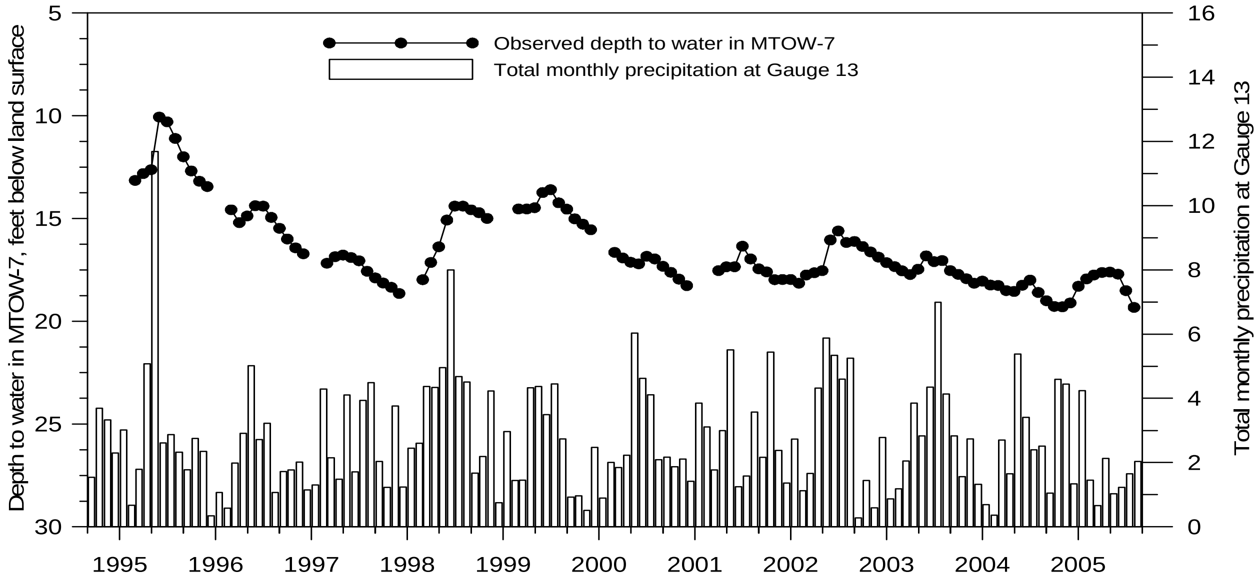


Figure A-9. Groundwater depth and precipitation for MTOW-7

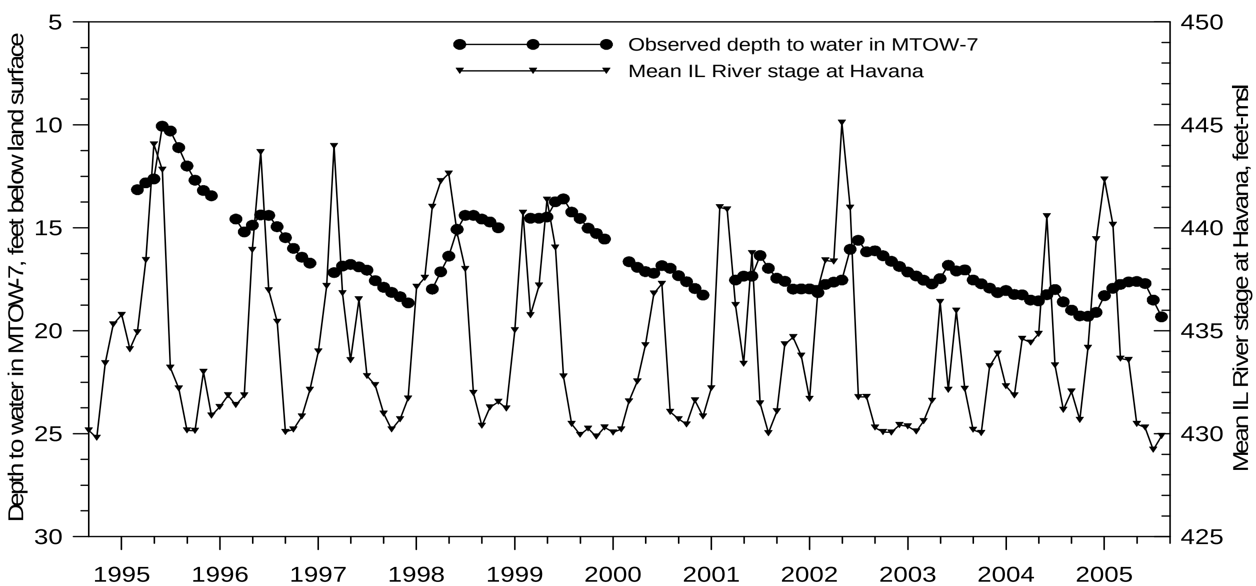


Figure A-10. Groundwater depth and Illinois River stage for MTOW-7

Appendix A. (continued)

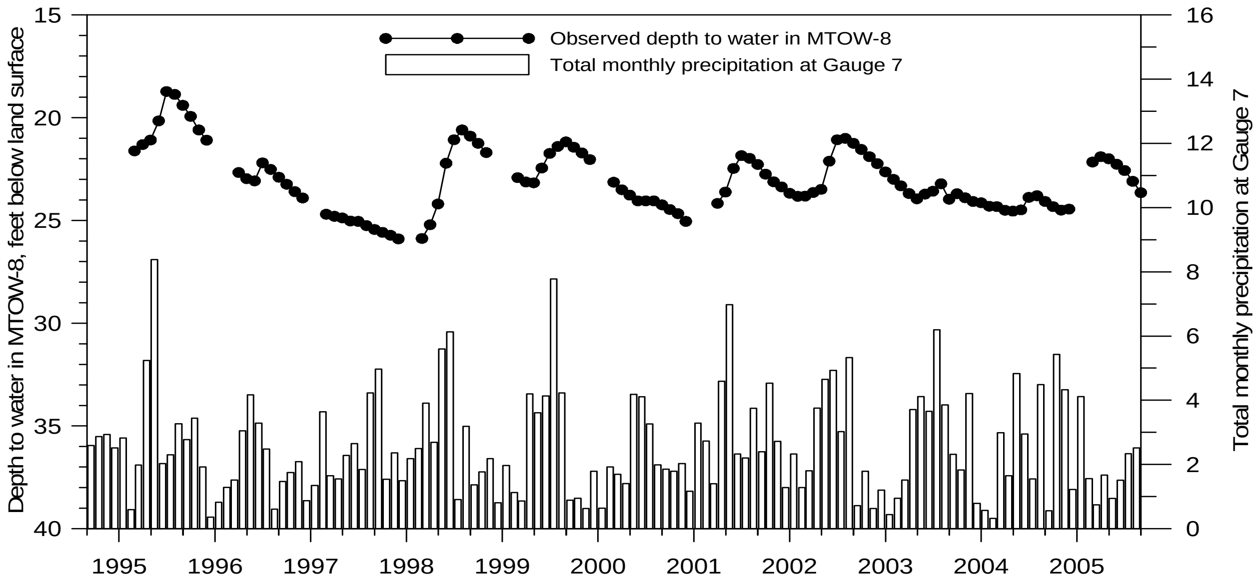


Figure A-11. Groundwater depth and precipitation for MTOW-8

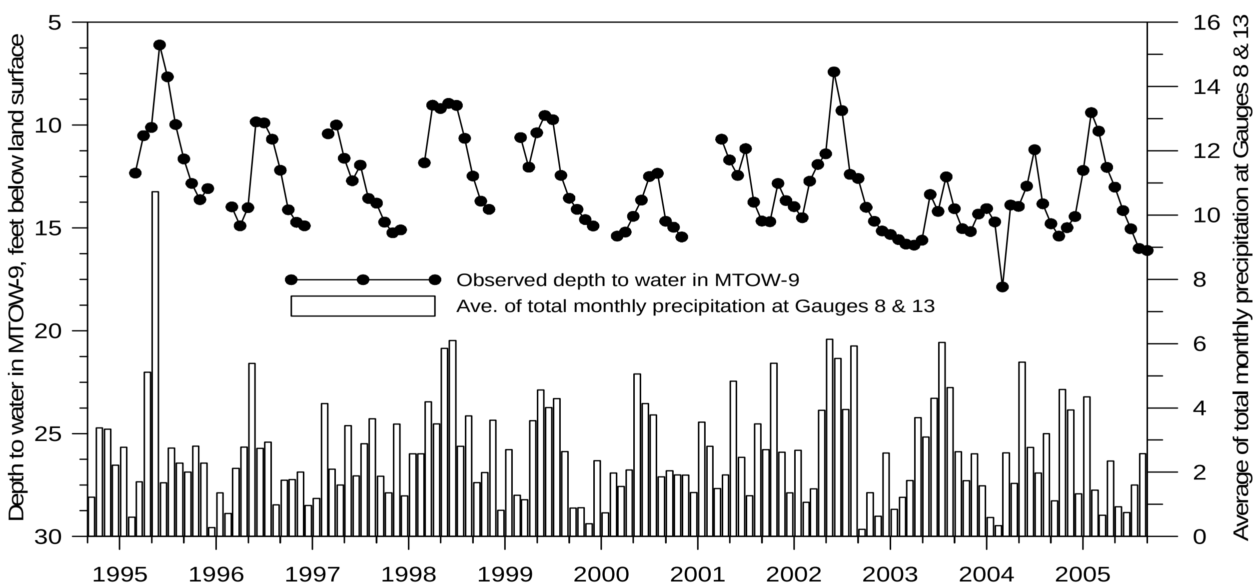


Figure A-12. Groundwater depth and precipitation for MTOW-9

Appendix A. (continued)

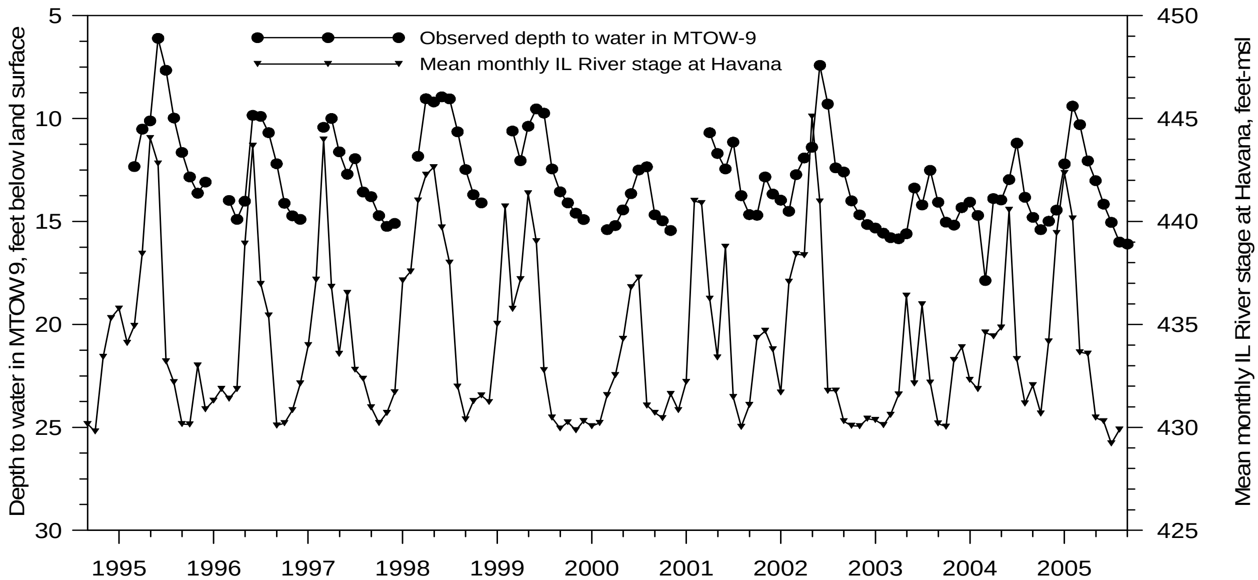


Figure A-13. Groundwater depth and Illinois River stage for MTOW-9

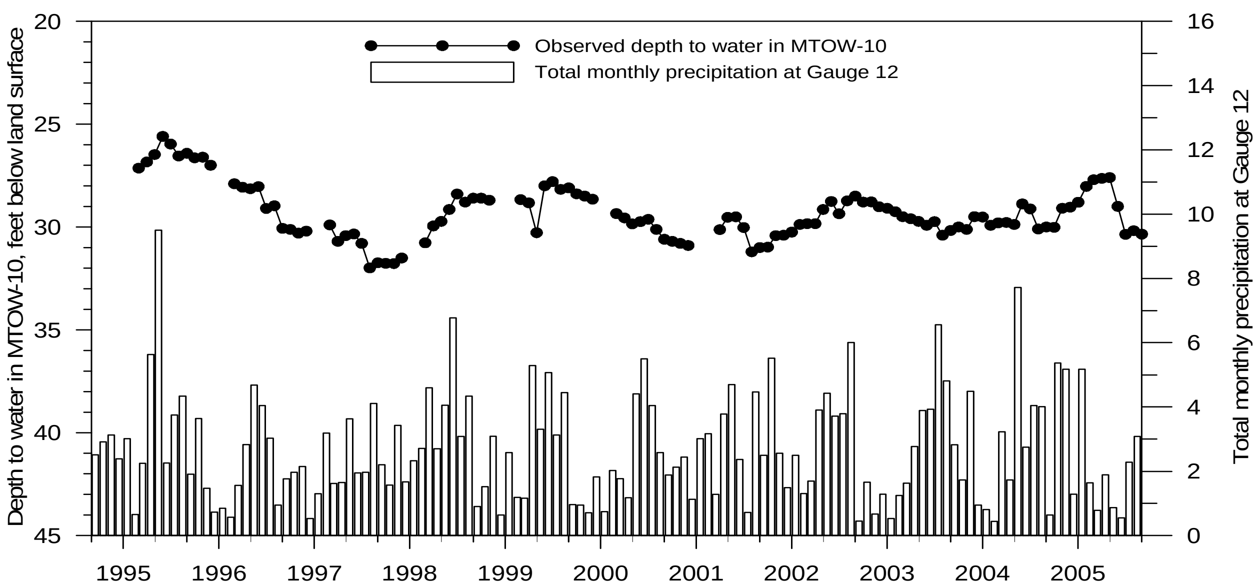


Figure A-14. Groundwater depth and precipitation for MTOW-10

Appendix A. (continued)

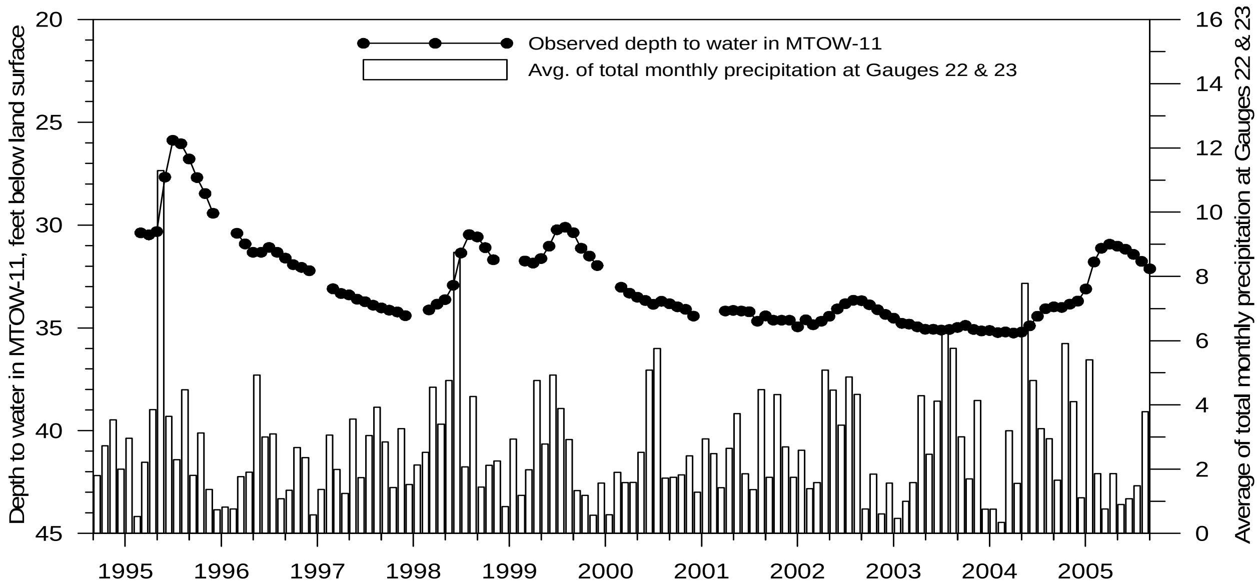


Figure A-15. Groundwater depth and precipitation for MTOW-11

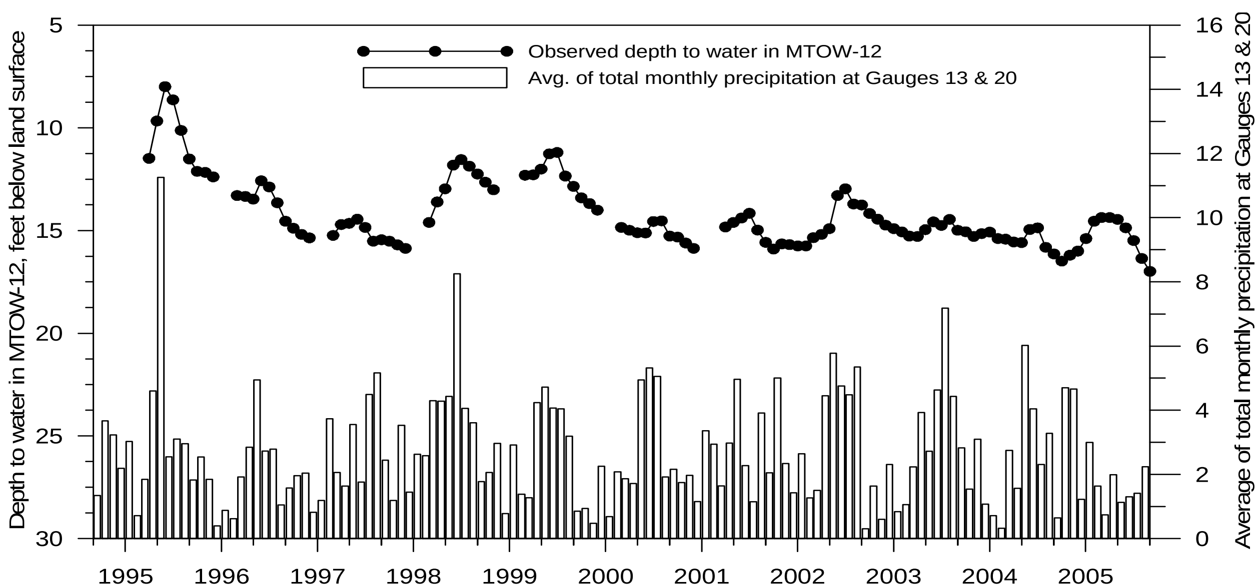


Figure A-16. Groundwater depth and precipitation for MTOW-12

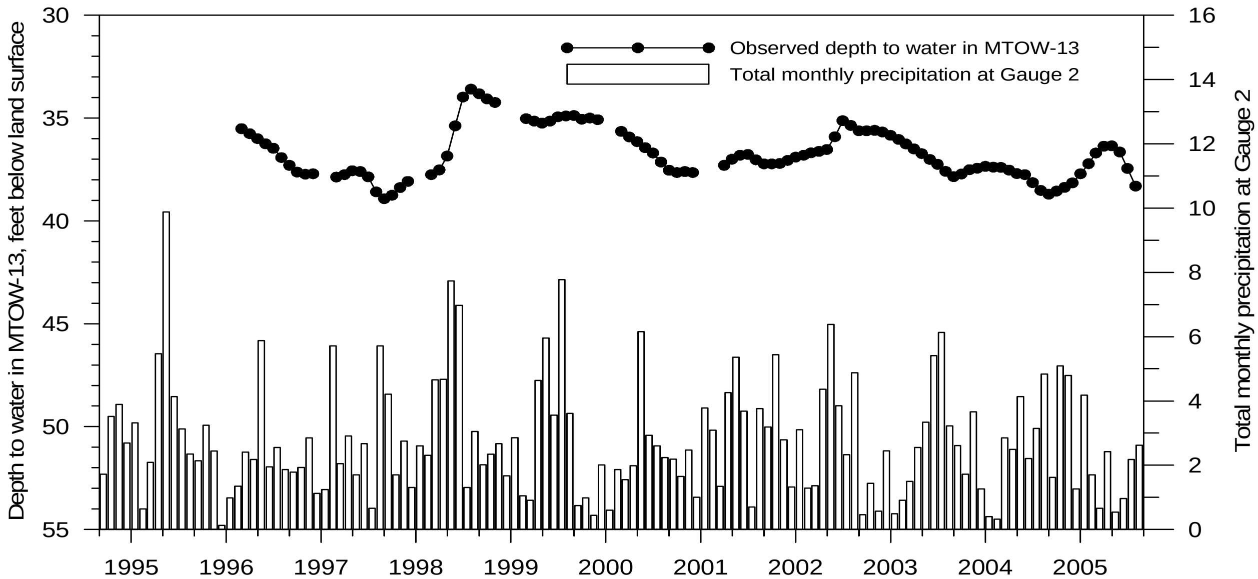


Figure A-17. Groundwater depth and precipitation for MTOW-13

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

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

Date	*Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells*												
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	*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*
	Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells												
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	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
	Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells												
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**
2-01-2004	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
9-01-2004	38.58	11.14	18.52	*15.10*	37.30	19.70	19.00	24.08	14.80	30.00	33.98	16.14	*38.70*
10-01-2004	38.98	11.72	18.74	15.06	37.57	*19.87*	19.28	24.33	15.40	30.02	34.01	*16.49*	38.55
11-01-2004	38.61	8.90	18.79	14.99	*37.84*	19.61	*19.30*	24.50	14.99	29.09	33.85	16.20	38.37
12-01-2004	n/a	8.40	18.44	14.84	36.68	19.05	19.11	24.45	14.45	29.04	**33.70**	16.00	38.15
1-01-2005	36.20	8.95	17.98	14.82	31.78	18.00	18.30	n/a	12.21	28.80	*33.11*	15.39	37.71
2-01-2005	**34.49**	**7.45**	17.32	14.55	**26.05**	16.65	17.94	n/a	**9.40**	28.03	31.80	14.55	37.22
3-01-2005	34.52	7.55	16.86	14.22	26.61	**16.32**	17.75	22.16	10.30	27.70	31.13	**14.37**	36.70
4-01-2005	34.98	9.04	16.65	**14.20**	30.66	16.47	17.63	**21.90**	12.06	27.64	**30.93**	**14.37**	36.37
5-01-2005	35.17	9.23	**16.44**	14.52	32.70	16.66	**17.61**	22.00	13.02	**27.60**	31.03	14.46	**36.35**
6-01-2005	35.93	10.17	16.63	14.76	33.90	17.30	17.71	22.27	14.16	29.00	31.18	14.87	36.65
7-01-2005	37.28	11.78	17.37	15.00	35.95	18.40	18.51	22.57	15.05	*30.36*	31.43	15.49	37.45
8-01-2005	*38.72*	*12.51*	*18.05*	*15.28*	*37.28*	*19.54*	*19.33*	*23.10*	*16.00*	30.18	31.77	*16.36*	*38.31*

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, 2005. 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 an 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 miles 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 miles 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 miles 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 disengage the tongue-and-groove assembly.
b) Carefully lift the bucket off 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 ensures 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.
f) 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@illinois.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, 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.
d) 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 e-mail her at nan@illinois.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, 2004–2005

Appendix E. Documentation, Imperial Valley Rain Gauge Network Maintenance, 2004–2005

This appendix documents major maintenance work carried out at sites in the Imperial Valley rain gauge network from September 1, 2004 through August 31, 2005.

1. Replaced gauge shelter at site 21 on 10-15-2004.

2. Winterized, including changing clock batteries, removing evaporation shield, and adding anti-freeze to all gauges on 11-2/3-2004.

3. Replaced data logger in gauge at site 23 on 11-9-2004.

4. Replaced batteries in all data loggers on 12-27-2004.

5. Replaced the top of the gauge at site 4 on 1-12-2005.

6. Repaired data logger wiring at site 12 on 3-2-2005.

7. Replaced data logger at site 24 on 3-2-2005.

8. Replaced data logger at site 24 on 3-24-2005.

9. Replaced data logger at site 8 and calibrated gauge on 6-3-2005.

10. Replaced electric clock at site 24 on 8-1-2005.

Appendix F. Hydrographs, Transducer Data at the Test Site

Appendix F. Hydrographs, Transducer Data at the Test Site

This appendix shows hydrographs of groundwater levels in each of the wells in place at the test site. The data are not continuous on each hydrograph due to removal of the transducers at various wells at various intervals.

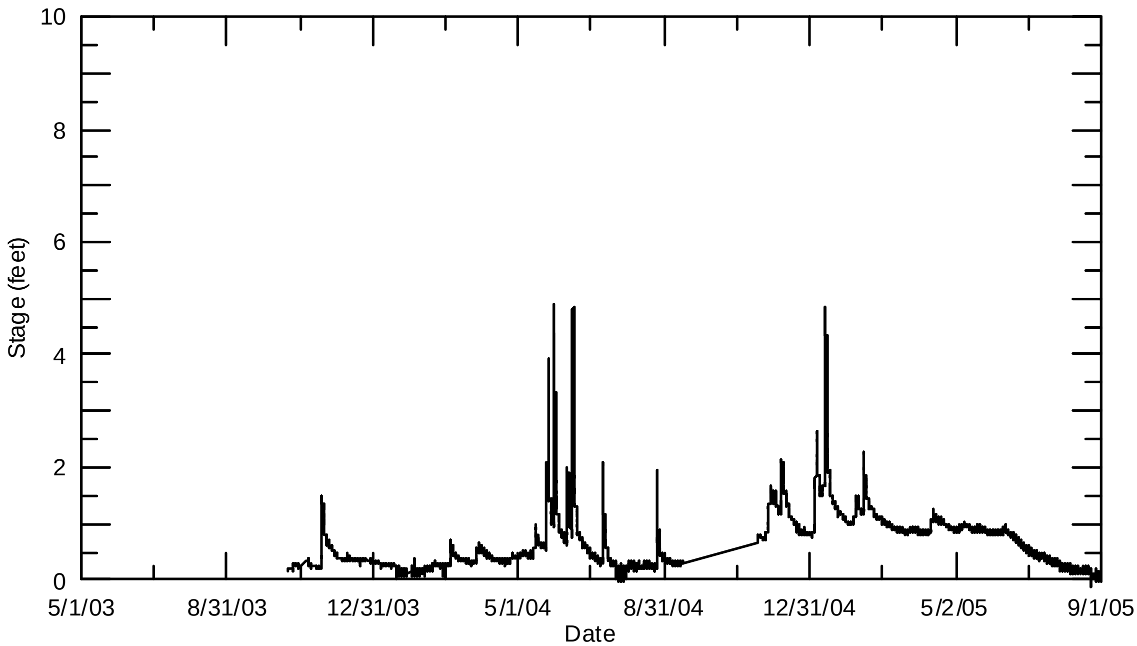


Figure F-1. Stage in Crane Creek at the downstream bridge

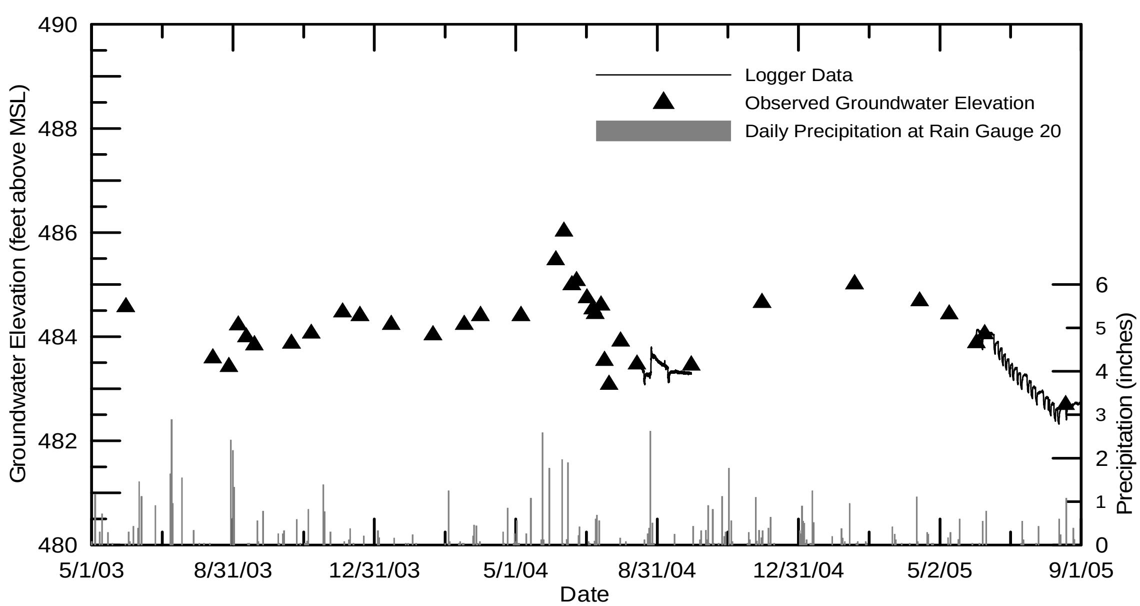


Figure F-2. Water level elevation in Well 1 at the test site

Appendix F. (Continued)

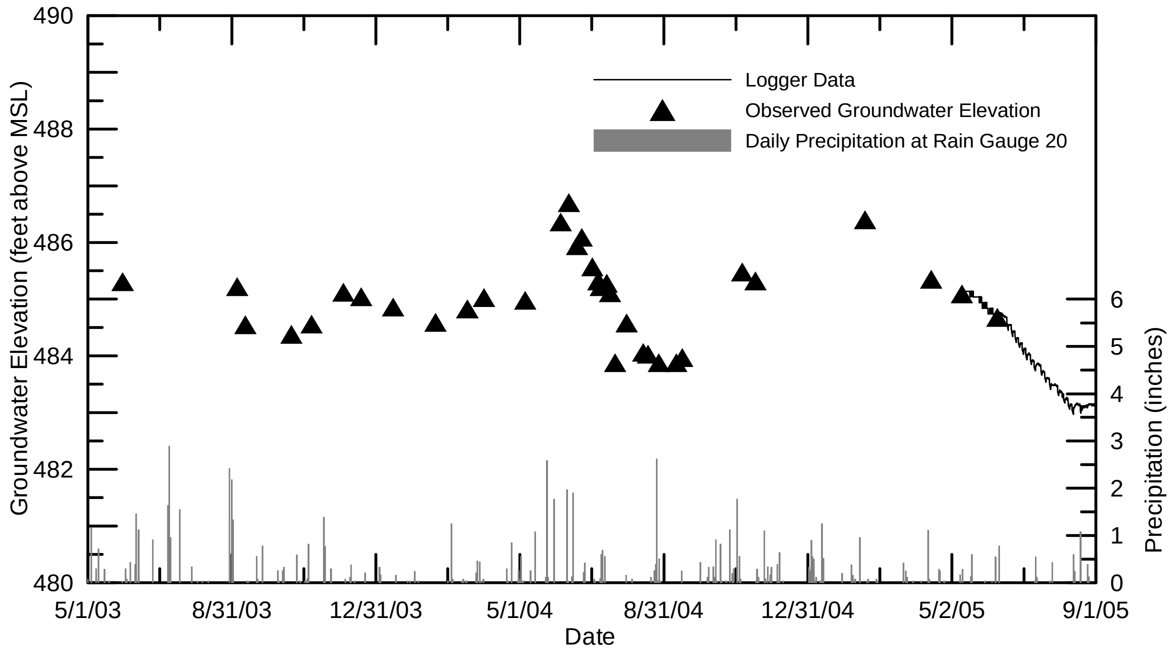


Figure F-3. Water level elevation in Well 2 at the test site

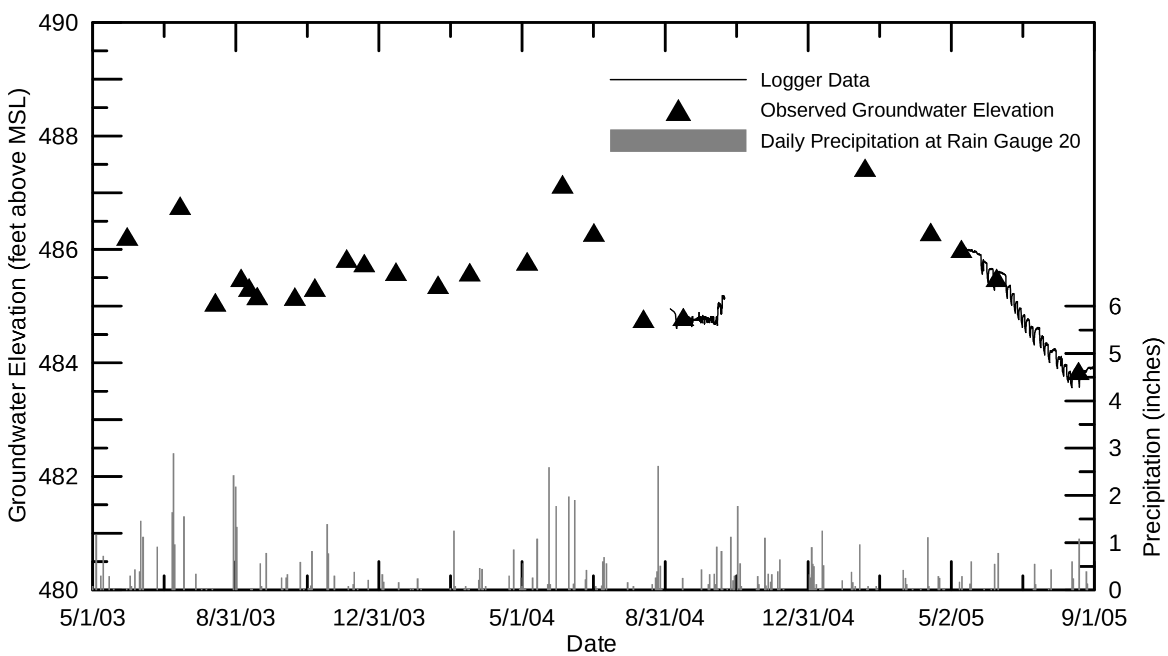


Figure F-4. Water level elevation in Well 3 at the test site

Appendix F. (Continued)

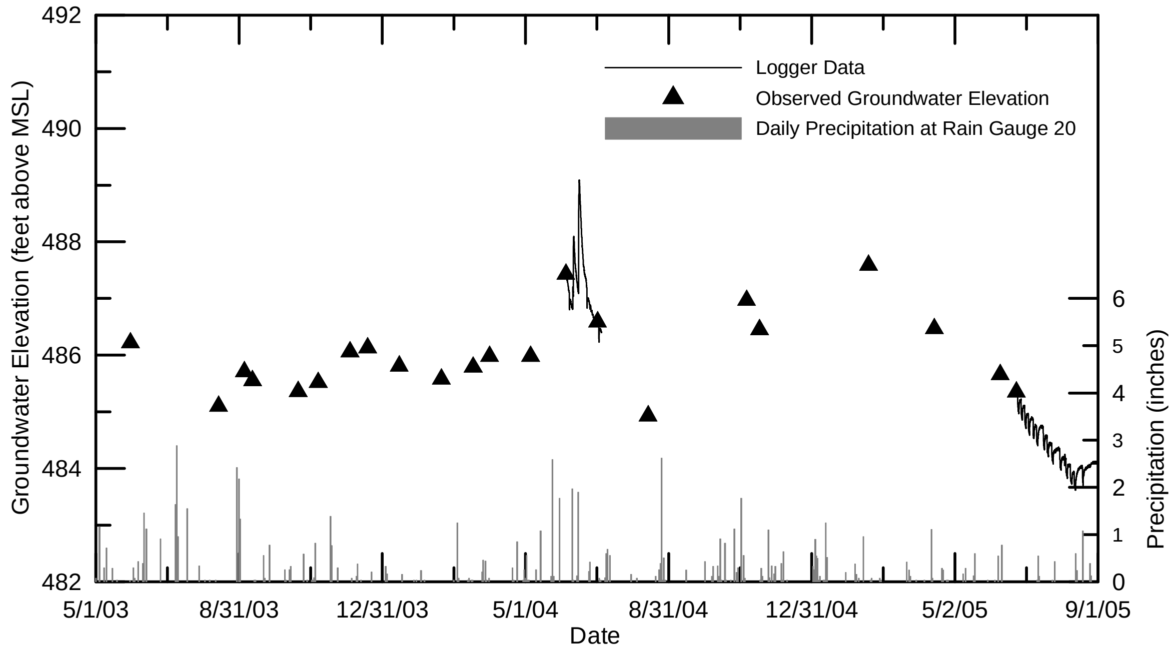


Figure F-5. Water level elevation in Well 4 at the test site

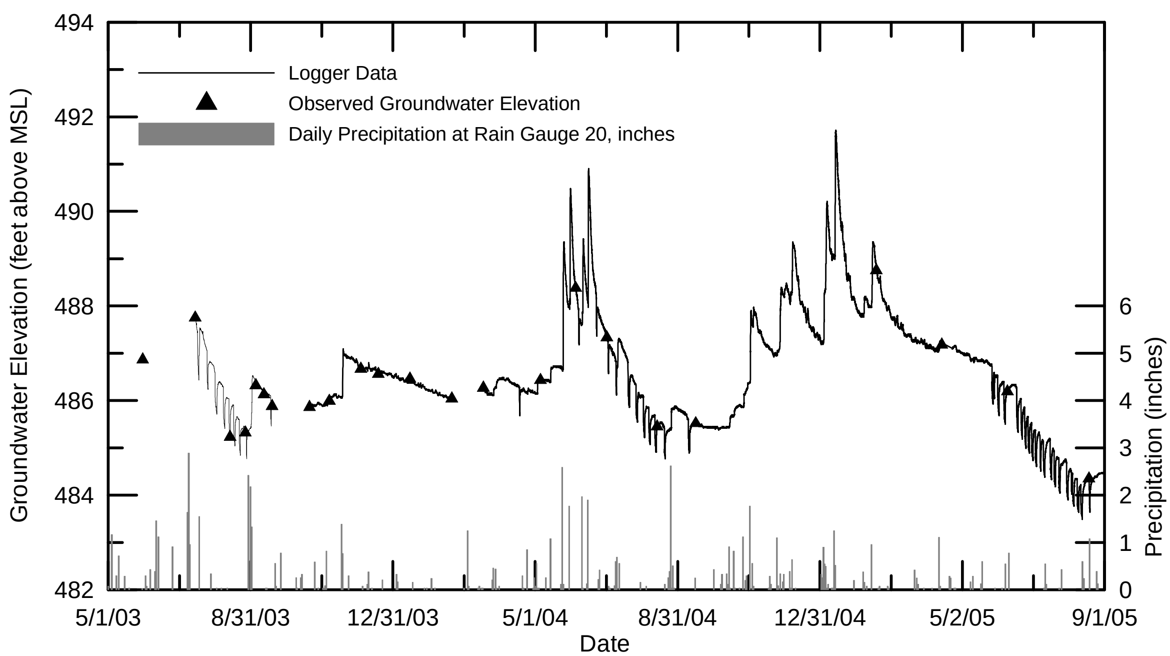


Figure F-6. Water level elevation in Well 5 at the test site

Appendix F. (Continued)

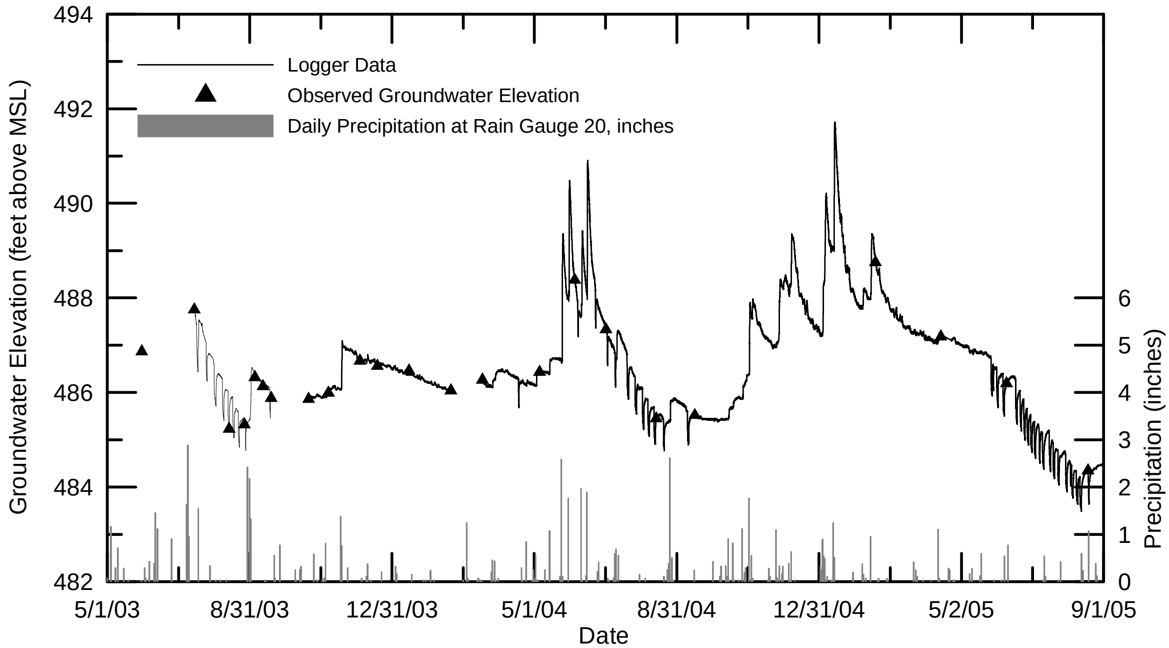


Figure F-7. Water level elevation in Well 6 at the test site

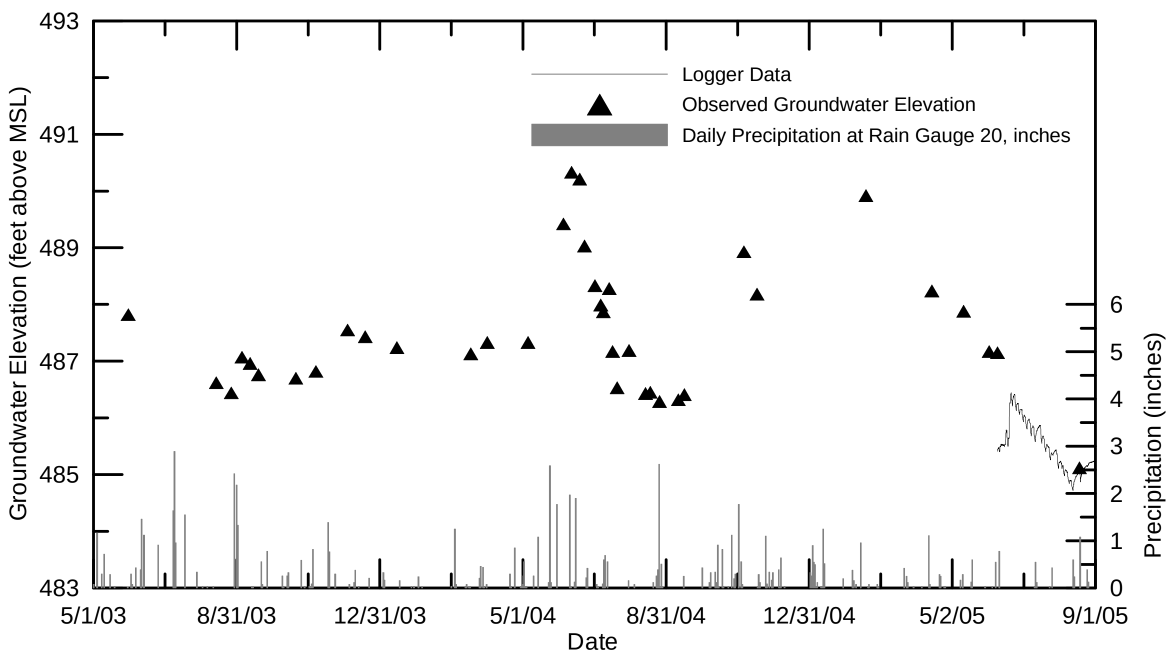


Figure F-8. Water level elevation in Well 7 at the test site

Appendix F. (Concluded)

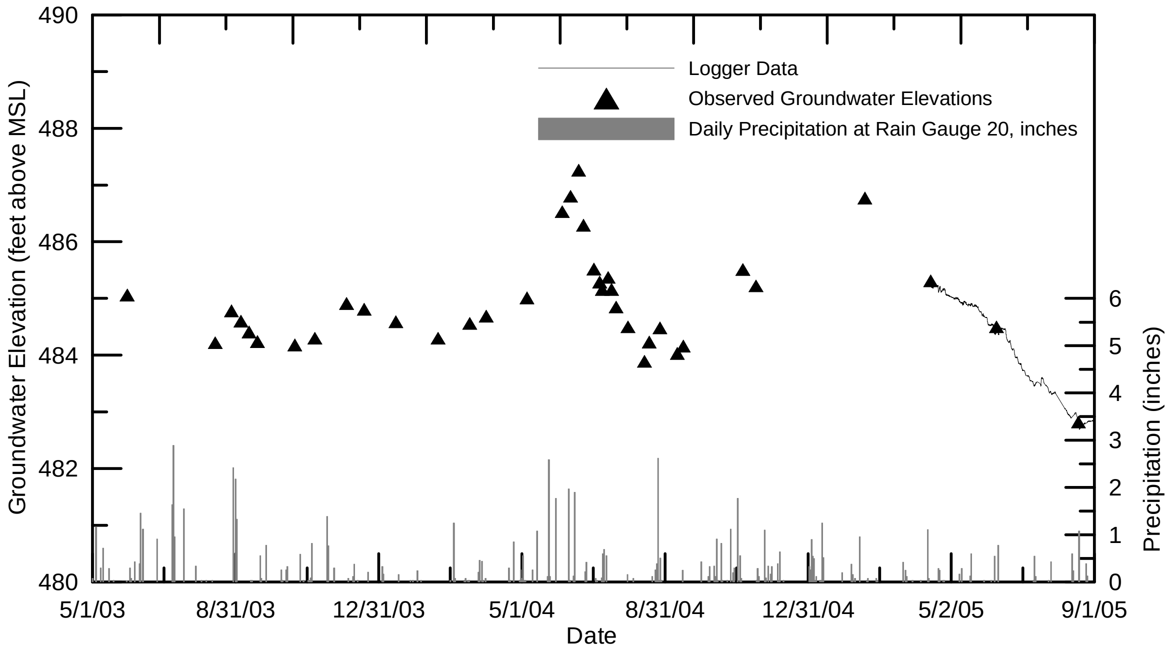


Figure F-9. Water level elevation in Well 8 at the test site

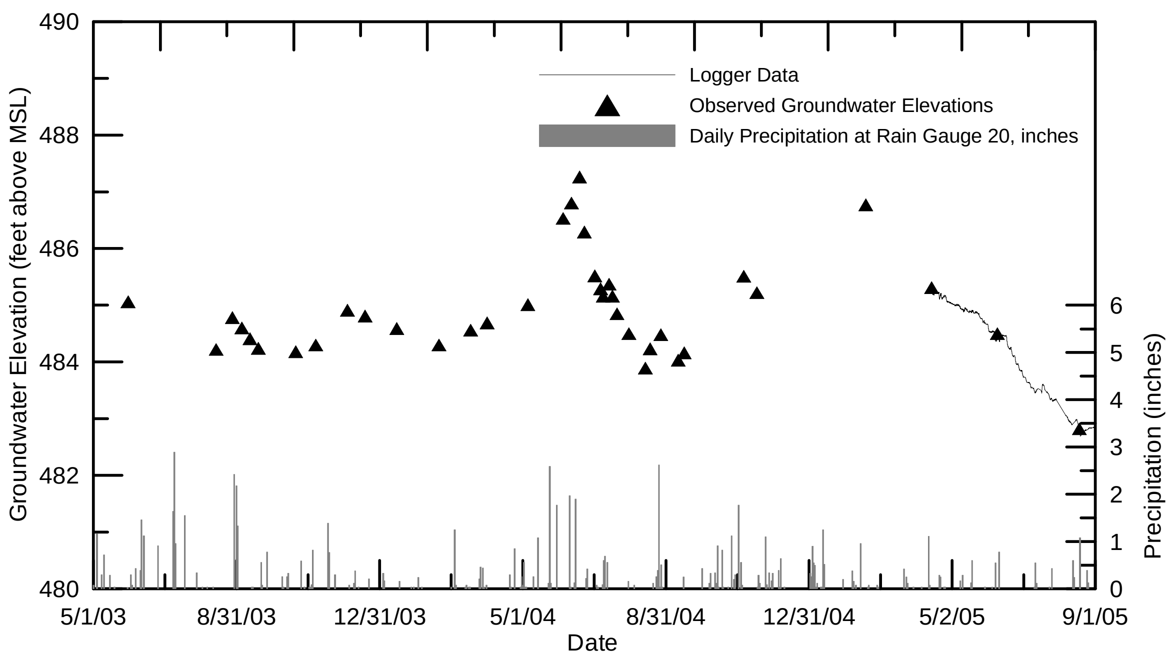


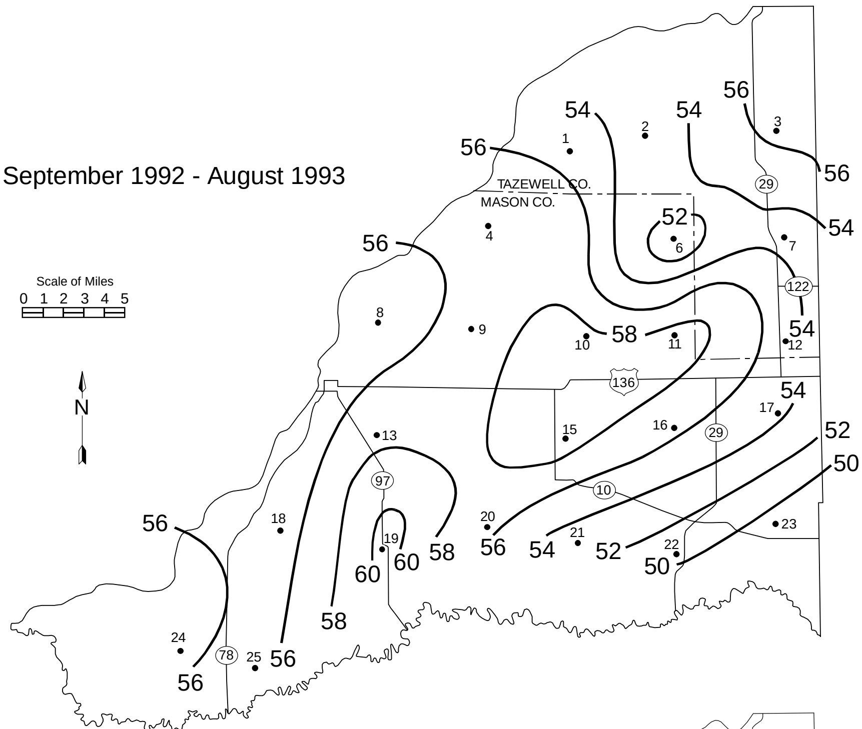
Figure F-10. Water level elevation in Well 9 at the test site

Appendix G. Annual Precipitation, Years One–Twelve

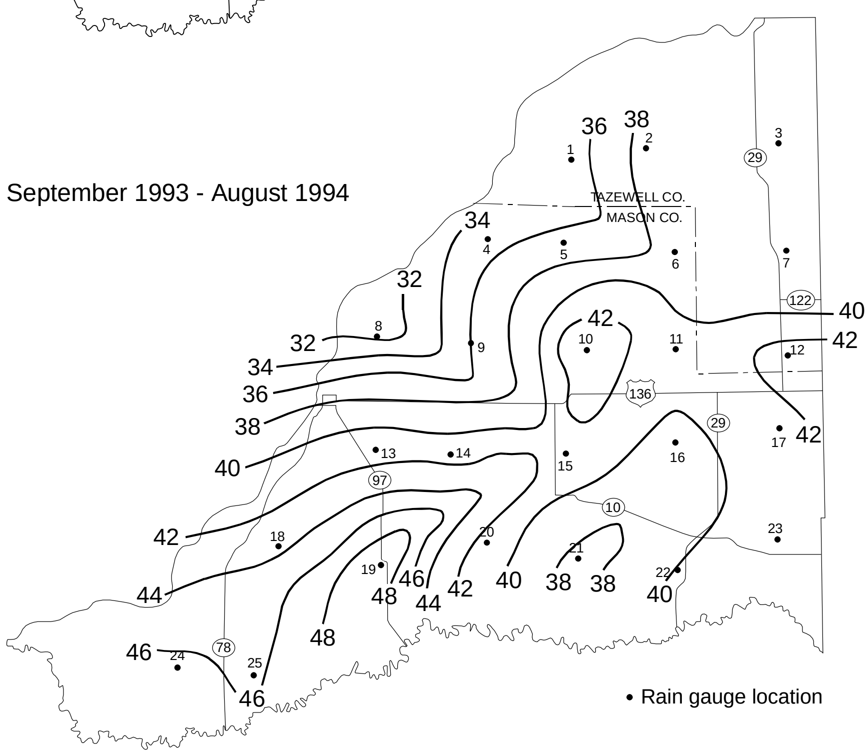
Appendix G. Annual Precipitation, Years One–Twelve

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

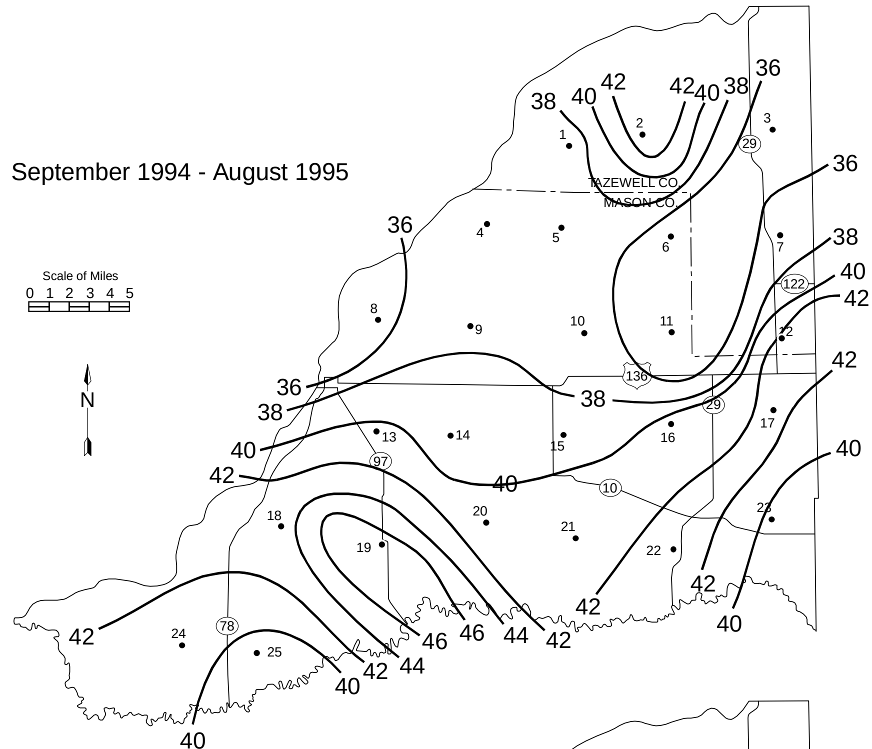
September 1992 - August 1993

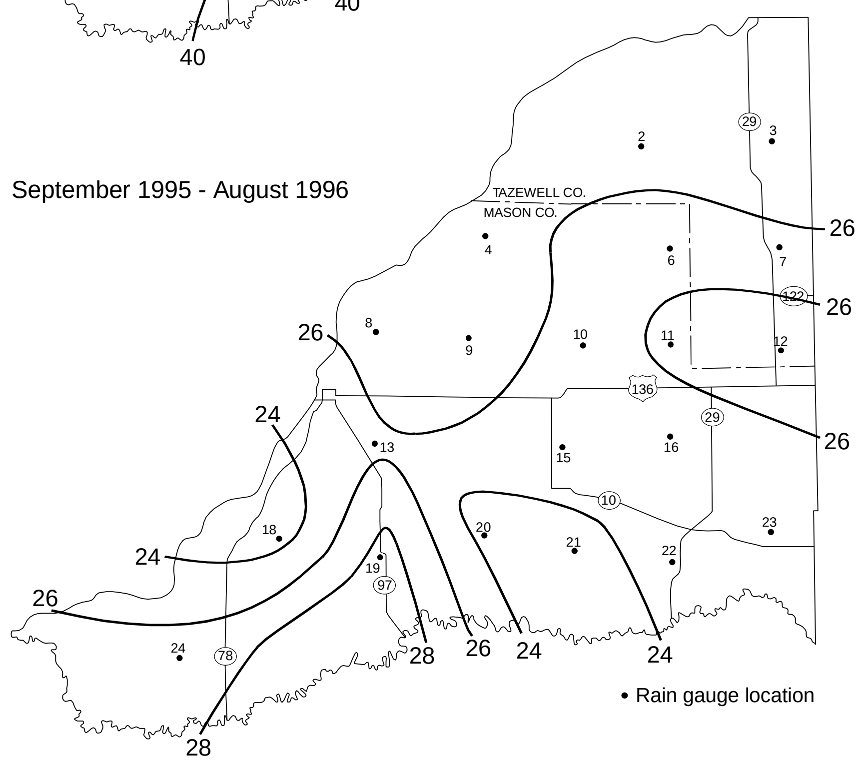


September 1993 - August 1994

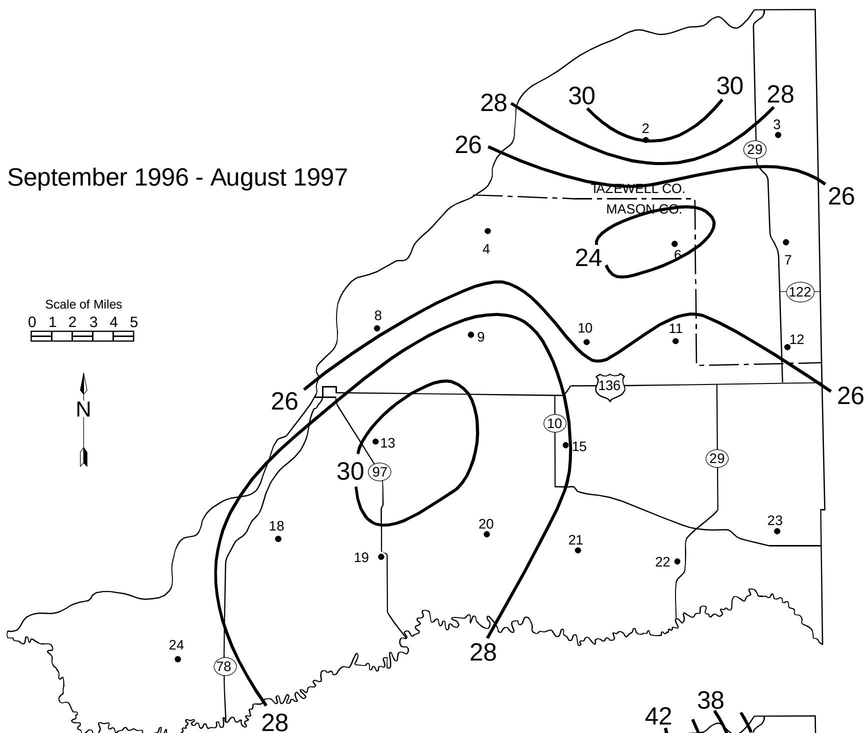


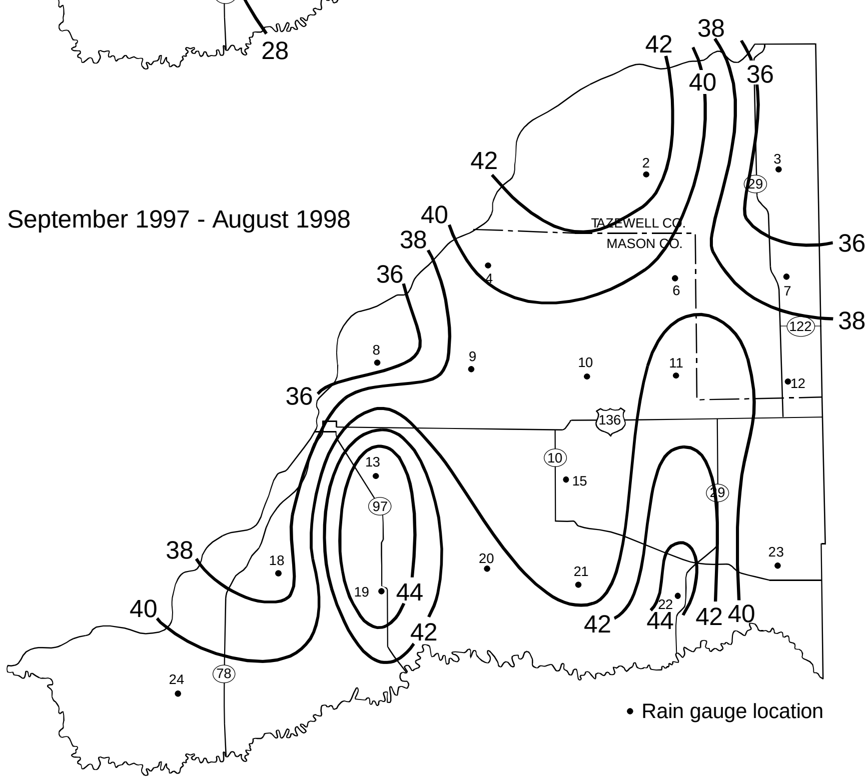
Appendix G. (continued)



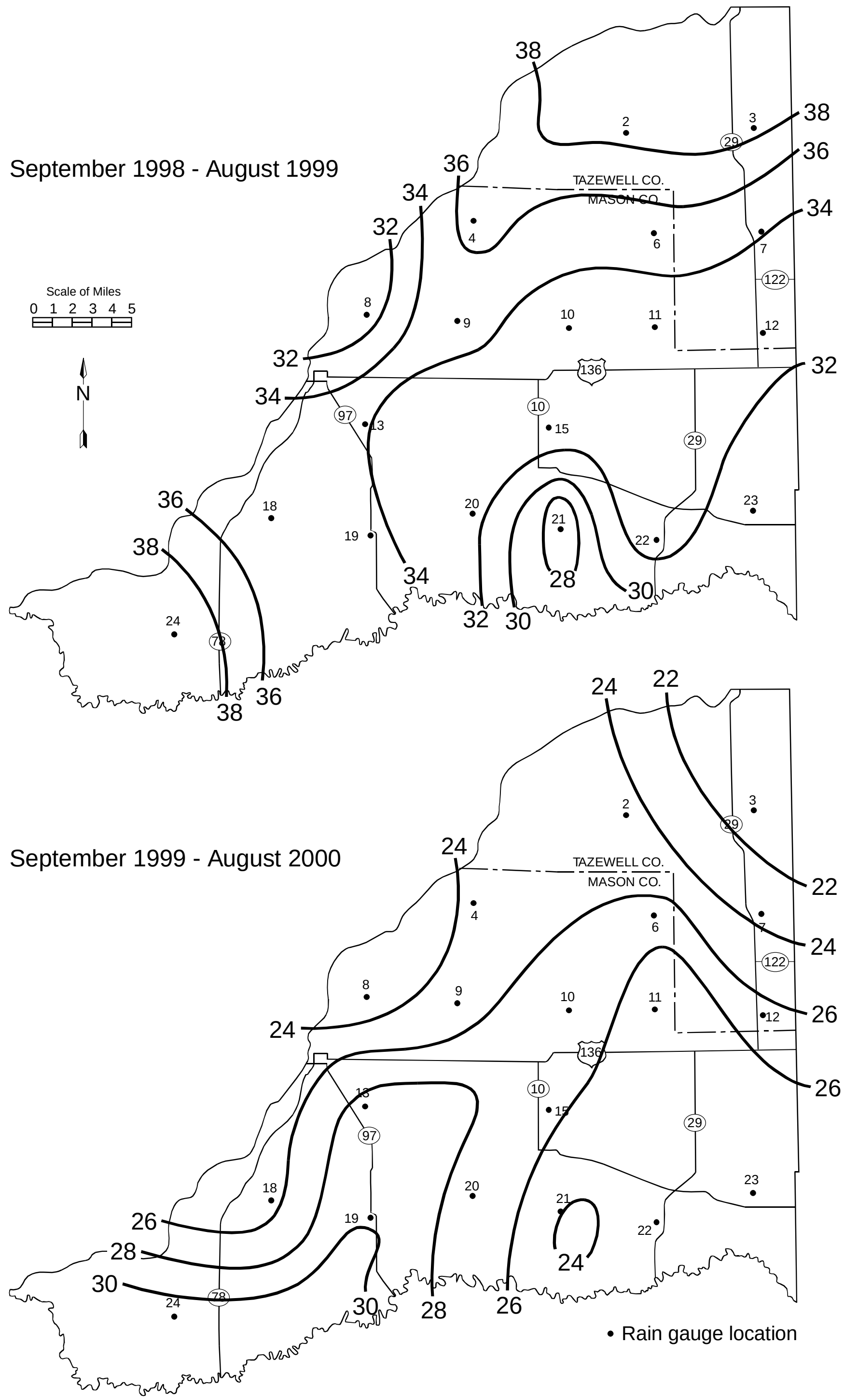


Appendix G. (continued)

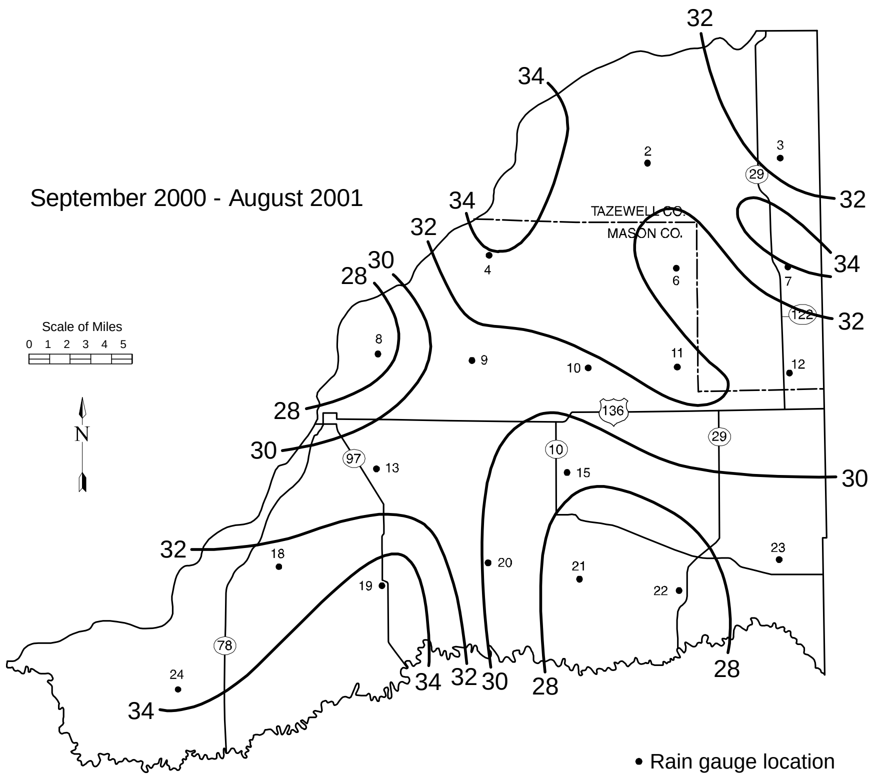


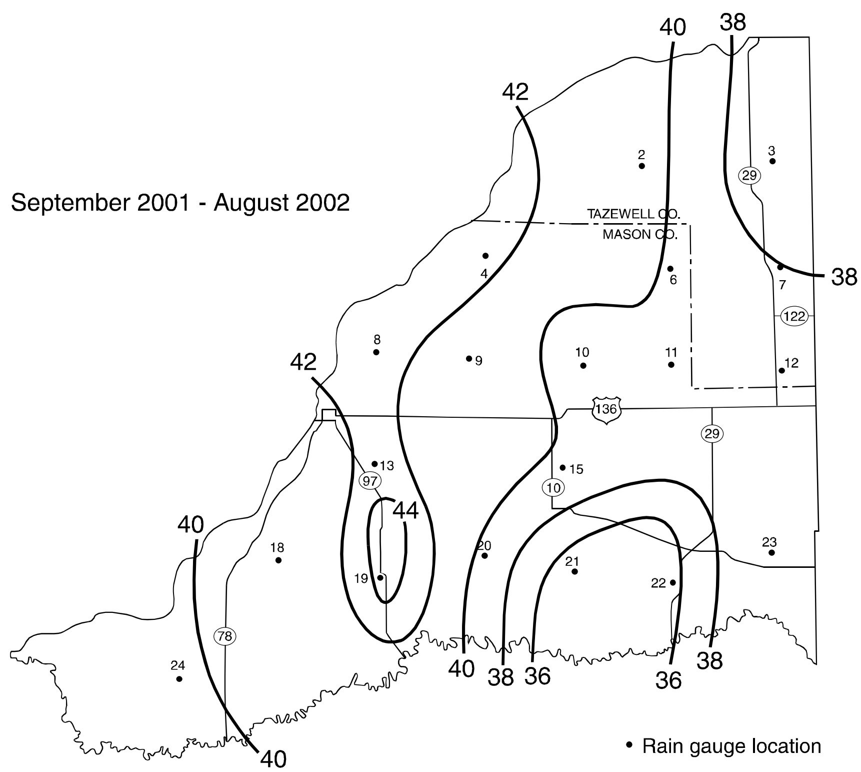


Appendix G. (continued)

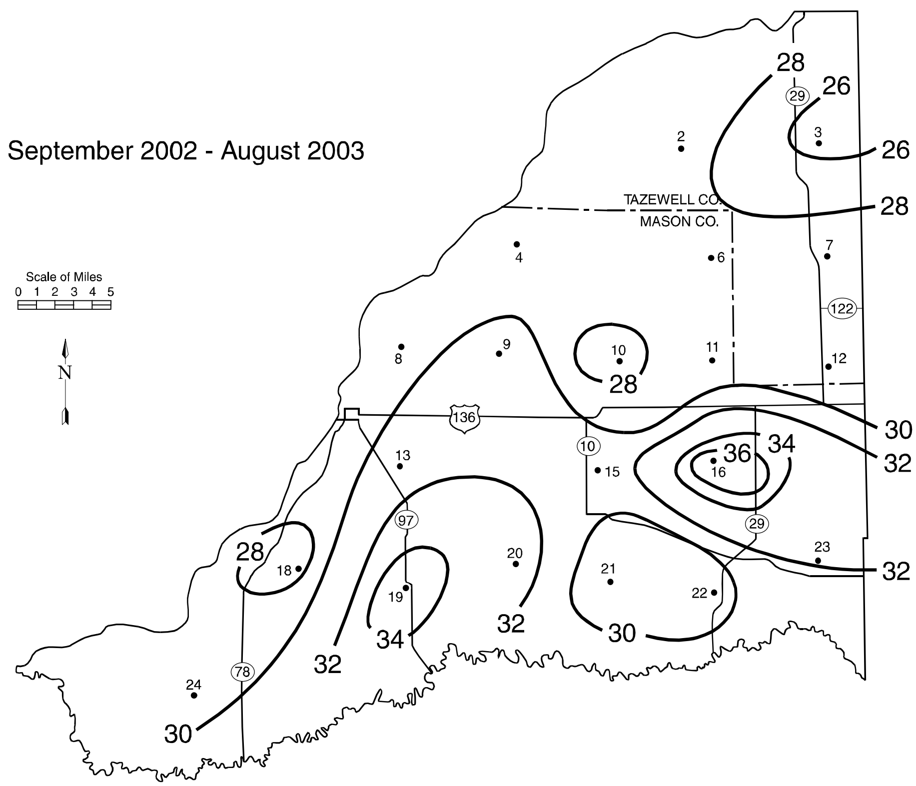


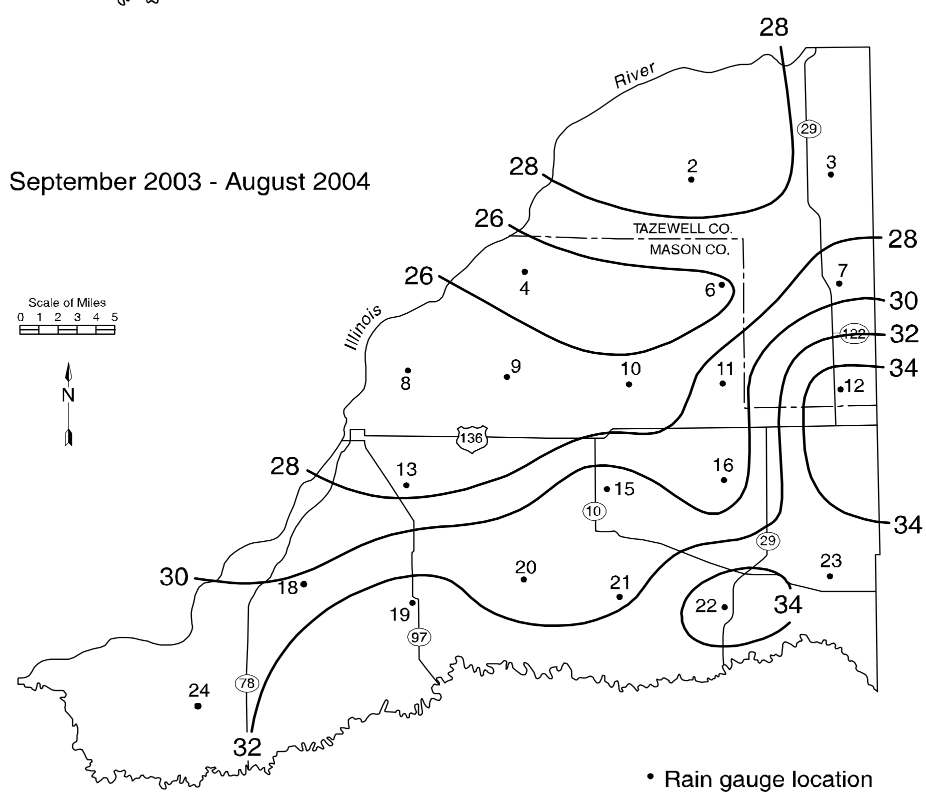
Appendix G. (continued)





Appendix G. (concluded)





Appendix H. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992–2004

Appendix H. Precipitation Events, Total Precipitation, and Precipitation per Precipitation Event by Month and Season, 1992–2004

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*	*2003-04*
September	10	8	6	6	6	6	8	8	10	7	3	7
October	10	5	7	9	11	7	11	6	10	17	8	7
November	13	7	10	3	9	8	14	17	11	12	7	9
December	9	9	8	5	5	10	6	14	21	9	2	8
January	9	8	5	8	13	12	19	11	18	4	6	8
February	5	6	3	4	8	7	17	21	8	9	5	6
March	10	6	6	7	8	8	6	9	7	12	6	12
April	11	12	19	6	11	12	18	14	14	9	6	5
May	16	7	16	25	15	16	15	16	14	13	10	16
June	13	13	15	11	14	17	12	12	11	10	11	7
July	21	9	16	10	6	15	9	11	10	10	5	14
August	21	12	18	4	15	16	9	17	14	10	11	11
Fall	33	20	23	18	26	21	33	31	31	36	18	23
Winter	23	23	16	17	26	29	42	46	47	22	13	22
Spring	37	25	41	38	34	36	39	39	35	34	22	33
Summer	55	34	49	25	35	48	30	40	35	30	27	32
Annual	148	102	129	98	121	134	144	156	148	122	80	110

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*	*2003-04*
September	4.21	11.56	1.49	2.00	1.63	2.55	1.61	0.87	1.93	2.35	0.39	2.67
October	2.00	2.97	3.34	3.06	1.99	1.43	2.07	0.92	1.79	4.89	1.65	1.56
November	6.35	2.59	3.37	1.84	2.15	3.10	2.70	0.48	2.05	2.50	0.62	3.54
December	2.82	1.11	2.29	0.45	0.90	1.47	0.81	2.07	1.17	1.43	1.95	1.07
January	3.52	0.96	2.90	1.01	1.28	2.59	2.84	0.63	3.35	2.64	0.61	0.67
February	1.64	1.64	0.61	0.77	3.86	2.65	1.32	2.00	2.78	1.28	1.09	0.33
March	3.85	0.96	1.93	1.93	1.92	4.51	1.32	1.68	1.50	1.58	1.84	2.84
April	5.25	5.03	4.87	2.61	1.76	3.53	4.42	1.59	3.31	4.24	3.75	1.78
May	2.61	3.11	10.33	5.37	2.94	5.21	4.65	4.39	4.89	5.43	3.20	5.55
June	6.27	3.19	2.65	2.85	1.97	7.19	4.41	4.76	3.08	4.23	4.50	3.56
July	11.05	3.44	2.73	2.84	2.51	2.34	4.56	4.39	1.30	3.99	6.04	2.30
August	5.99	3.66	2.90	0.98	4.41	3.50	3.30	2.02	3.81	5.37	4.43	3.77
Fall	12.56	17.12	8.20	6.89	5.77	7.08	6.38	2.27	5.77	9.74	2.66	7.77
Winter	7.97	3.70	5.80	2.23	6.04	6.71	4.97	4.70	7.30	5.35	3.65	2.07
Spring	11.71	9.10	17.14	9.91	6.62	13.25	10.39	7.66	9.70	11.25	8.79	10.17
Summer	23.31	10.29	8.28	6.68	8.89	13.03	12.27	11.17	8.19	13.59	14.97	9.63
Annual	55.55	40.21	39.42	25.70	27.31	40.06	34.02	25.81	30.97	39.91	30.06	29.64

Appendix H. (concluded)

Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*	*2002-03*	*2003-04*
	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	0.38
October	0.20	0.59	0.48	0.34	0.18	0.2	0.19	0.15	0.18	0.29	0.27	0.22
November	0.49	0.37	0.34	0.61	0.24	0.39	0.19	0.03	0.19	0.21	0.10	0.39
December	0.31	0.12	0.29	0.09	0.18	0.15	0.14	0.15	0.06	0.16	0.65	0.13
January	0.39	0.12	0.58	0.13	0.10	0.22	0.15	0.06	0.19	0.66	0.10	0.08
February	0.33	0.27	0.20	0.19	0.48	0.38	0.08	0.10	0.35	0.14	0.14	0.06
March	0.38	0.16	0.32	0.28	0.24	0.56	0.22	0.19	0.21	0.13	0.23	0.24
April	0.48	0.42	0.26	0.43	0.16	0.29	0.25	0.11	0.24	0.47	0.42	0.36
May	0.16	0.44	0.65	0.21	0.20	0.33	0.31	0.27	0.35	0.42	0.32	0.35
June	0.48	0.25	0.18	0.26	0.14	0.42	0.37	0.40	0.28	0.42	0.45	0.51
July	0.53	0.38	0.17	0.28	0.42	0.16	0.51	0.40	0.13	0.40	1.01	0.16
August	0.29	0.31	0.16	0.25	0.29	0.22	0.37	0.12	0.27	0.54	0.74	0.34
Fall	0.38	0.86	0.36	0.38	0.22	0.34	0.19	0.07	0.19	0.27	0.15	0.34
Winter	0.35	0.16	0.36	0.13	0.23	0.23	0.12	0.10	0.16	0.24	0.28	0.09
Spring	0.32	0.36	0.42	0.26	0.19	0.37	0.27	0.20	0.28	0.33	0.40	0.31
Summer	0.42	0.30	0.17	0.27	0.25	0.27	0.41	0.28	0.23	0.45	0.55	0.30
Annual	0.38	0.39	0.31	0.26	0.23	0.30	0.24	0.17	0.21	0.33	0.38	0.27

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

Appendix I. Documentation of Precipitation Events in the Imperial Valley, 2004–2005

Appendix I. Documentation of Precipitation Events in the Imperial Valley, 2004–2005

This appendix documents all storm event amounts, start times, and durations, and notes those that exceed an expected event amount (for 1-year to 100-year recurrence intervals) during the period September 1, 2004–August 31, 2005 (Table I-2). Table I-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 1- to 100-year recurrence intervals for west-central Illinois are given in Table I-1 (Huff and Angel, 1989).

To determine the return frequency of any storm in Table I-2 or I-3, obtain the storm duration from the tables, then look in the left-hand column of Table I-1 to locate the storm duration that equals or just exceeds the storm duration in Table I-2 or I-3. If the precipitation for the event at any gauge in Table I-2 or I-3 exceeds the amount in Table I-1, obtain the return frequency by looking at the heading of the right-hand column that the precipitation amount exceeds. For example, Table I-3 indicates storm number 1495 has a duration of nine hours. This storm duration falls between the 6- and 12-hour storm duration in Table I-1. Assume a 12-hour storm duration. Table I-3 indicates the gauge at site 3 recorded precipitation equal to 3.24 inches. Therefore, site 3 exceeded the two-year return frequency amount (2.62 inches) for a 12-hour storm.

Table I-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 I-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 I-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2004–2005

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-04				
1493	14	1200	3	5	0.05	0.21	0.49	13	
1494	15	700	3	2	0.00	0.04	0.04	10	
1495	15	1900	9	20	0.91	0.91	**3.24**	3	**2-yr, 24-hr**
1496	16	700	3	6	0.01	0.04	0.04	6	
					October-04				
1497	1	1900	7	20	0.36	0.36	0.51	24	
1498	7	2100	21	20	0.58	0.58	0.95	7	
1499	12	900	29	20	0.55	0.55	1.04	23	
1500	14	1000	19	19	0.73	0.77	1.29	10	
1501	15	900	15	5	0.04	0.15	0.52	23	
1502	18	400	28	20	0.82	0.82	1.21	24	
1503	19	1200	2	3	0.01	0.04	0.04	10	
1504	20	700	8	8	0.02	0.04	0.05	12	
1505	22	2100	1	2	0.00	0.02	0.04	8	
1506	23	100	11	20	0.12	0.12	0.29	9	
1507	26	1000	14	20	1.23	1.23	1.47	23	
1508	27	600	9	8	0.02	0.05	0.14	3	
1509	28	400	12	20	0.18	0.18	0.30	7	
1510	28	2100	5	5	0.01	0.04	0.04	6	
1511	29	500	6	9	0.02	0.04	0.05	3	
1512	29	1700	14	20	0.49	0.49	1.00	18	
					November-04				
1513	1	100	28	20	1.60	1.60	2.12	24	
1514	3	1700	20	20	0.66	0.66	0.95	3	
1515	17	500	11	8	0.02	0.04	0.05	3	
1516	18	600	35	20	0.47	0.47	0.76	16	
1517	24	100	22	20	0.69	0.69	1.31	24	
1518	25	900	5	20	0.25	0.25	0.52	19	
1519	27	400	16	20	0.38	0.38	0.59	7	
1520	29	800	9	20	0.14	0.14	0.25	24	
1521	30	500	19	20	0.34	0.34	0.43	12	
					December-04				
1522	1	800	7	13	0.04	0.06	0.13	11	
1523	5	2000	19	20	0.41	0.41	0.67	24	
1524	6	2300	15	20	0.75	0.75	0.85	7	
1525	10	800	2	3	0.01	0.04	0.04	18	
1526	10	2000	6	8	0.02	0.05	0.08	19	
					January-05				
1527	1	400	32	20	0.48	0.48	0.85	8	
1528	2	2400	17	20	1.01	1.01	1.24	19	
1529	4	1700	36	20	0.97	0.97	1.41	19	
1530	7	1200	5	6	0.01	0.04	0.05	3	
1531	7	2000	5	20	0.10	0.10	0.15	3	

Table I-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2004–2005

1532	8	800	7	11	0.03	0.06	0.12	2
1533	9	1000	3	8	0.02	0.06	0.12	21
1534	10	2100	22	20	0.09	0.09	0.19	12
1535	11	2200	31	20	1.50	1.50	2.50	22
1536	13	800	10	20	0.12	0.12	0.24	21
1537	29	600	16	18	0.12	0.13	0.24	24
1538	30	300	9	14	0.03	0.04	0.05	12
				February-05				
1539	6	700	22	20	0.34	0.34	0.39	19
1540	7	800	19	20	0.14	0.14	0.25	23
1541	8	600	8	6	0.01	0.03	0.04	4
1542	8	1800	29	20	0.08	0.08	0.16	24
1543	13	300	27	20	0.84	0.84	1.20	19
1544	19	2300	24	19	0.09	0.10	0.20	23
1545	27	1500	23	20	0.13	0.13	0.20	18
				March-05				
1546	22	1300	25	20	0.41	0.41	0.55	24
1547	24	700	5	7	0.02	0.05	0.09	11
1548	24	1500	22	20	0.28	0.28	0.38	22
1549	30	1600	1	6	0.01	0.03	0.04	3
				April-05				
1550	6	1200	4	9	0.03	0.06	0.20	24
1551	11	2400	34	20	1.12	1.12	1.67	24
1552	21	1700	11	20	0.68	0.68	1.47	2
1553	22	700	14	20	0.13	0.13	0.29	24
1554	23	100	10	13	0.04	0.06	0.12	18
1555	25	2100	5	15	0.07	0.09	0.17	7
1556	26	600	5	8	0.02	0.04	0.04	4
1557	26	1400	5	6	0.01	0.05	0.08	19
				May-05				
1558	1	800	2	3	0.01	0.04	0.04	9
1559	9	100	4	20	0.15	0.15	0.30	7
1560	9	800	4	5	0.01	0.04	0.04	7
1561	11	1900	21	20	0.34	0.34	0.66	24
1562	18	2300	11	20	0.25	0.25	0.43	20
1563	19	1900	18	16	0.11	0.14	0.39	13
1564	29	1200	2	3	0.01	0.04	0.08	19
1565	30	300	1	2	0.00	0.04	0.04	18
1566	30	800	3	2	0.00	0.04	0.04	2
				June-05				
1567	4	900	4	7	0.03	0.09	0.17	10
1568	5	500	9	8	0.02	0.06	0.13	11
1569	8	1400	6	20	0.60	0.60	1.92	9
1570	8	2400	10	16	0.11	0.13	0.53	3
1571	11	1300	4	15	0.54	0.72	1.67	9
1572	13	2400	2	3	0.02	0.15	0.18	12
1573	14	600	1	3	0.01	0.04	0.04	2
1574	23	700	1	1	0.00	0.04	0.04	18

Table I-2. Documentation, Heavy Storm Amounts in the Imperial Valley, 2004–2005

				July-05				
1575	4	1200	11	8	0.07	0.17	0.41	2
1576	11	2300	23	20	0.68	0.68	1.09	7
1577	13	200	16	19	0.16	0.17	0.42	24
1578	24	2200	5	3	0.02	0.13	0.32	12
1579	26	1600	11	20	0.71	0.71	1.00	7
				August-05				
1580	4	600	6	3	0.04	0.26	0.43	7
1581	4	1700	18	13	0.26	0.40	0.90	22
1582	12	100	7	3	0.01	0.08	0.13	22
1583	12	1300	4	5	0.04	0.15	0.21	24
1584	12	2100	18	20	0.50	0.50	1.05	24
1585	13	1800	30	20	0.65	0.65	1.30	3
1586	18	2300	13	17	0.40	0.47	0.90	22
1587	19	2000	15	20	0.51	0.51	1.03	21
1588	21	2300	3	5	0.02	0.08	0.13	6
1589	25	1000	14	18	0.18	0.20	0.46	24
1590	26	500	15	14	0.04	0.05	0.13	20

Table I-3. Precipitation (inches) Received at Each Station from Each Storm Period during the 2004–2005 Observation Period

Storm	*Date*	*Hour*	*Duration*	*Rain gauge site number* 2	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*15*	*16*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
1493	9142004	1200	3	0.08	0.00	0.04	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
1494	9152004	700	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1495	9152004	1900	9	1.54	**3.24**	1.51	0.51	0.56	1.17	0.41	0.34	0.47	0.64	0.48	0.47	0.82	0.51	0.34	0.25	1.08	1.67	1.60	0.50
1496	9162004	700	3	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
1497	10012004	1900	7	0.29	0.14	0.21	0.34	0.35	0.30	0.41	0.34	0.34	0.49	0.48	0.35	0.30	0.46	0.42	0.43	0.35	0.30	0.37	0.51
1498	10072004	2100	21	0.45	0.60	0.41	0.60	0.95	0.50	0.49	0.50	0.90	0.69	0.42	0.71	0.42	0.45	0.43	0.45	0.67	0.68	0.71	0.62
1499	10122004	900	29	0.75	0.55	0.41	0.62	0.59	0.33	0.28	0.65	0.88	0.69	0.12	0.49	0.92	0.21	0.33	0.46	0.58	0.78	1.04	0.24
1500	10142004	1000	19	0.54	0.60	0.58	0.53	0.58	0.63	1.11	1.29	0.62	0.62	0.90	0.97	0.61	1.09	0.92	0.95	0.83	0.63	0.00	0.70
1501	10152004	900	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.09	0.00	0.04	0.00	0.04	0.00	0.52	0.00
1502	10182004	400	28	0.80	1.07	0.80	0.73	0.77	0.65	0.68	0.70	0.69	0.96	0.62	0.82	0.81	0.67	1.14	0.86	0.64	0.85	0.86	1.21
1503	10192004	1200	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00
1504	10202004	700	8	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04
1505	10222004	2100	1	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1506	10232004	100	11	0.12	0.15	0.16	0.12	0.12	0.04	0.29	0.08	0.16	0.09	0.08	0.04	0.12	0.04	0.22	0.04	0.08	0.08	0.21	0.16
1507	10262004	1000	14	1.30	1.34	1.22	1.17	1.34	1.47	1.18	1.01	0.99	1.32	1.32	1.08	0.95	1.25	1.33	1.12	1.01	1.43	1.47	1.37
1508	10272004	600	9	0.00	0.14	0.04	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.01	0.00
1509	10282004	400	12	0.25	0.09	0.13	0.26	0.30	0.12	0.21	0.24	0.17	0.23	0.04	0.08	0.12	0.08	0.12	0.20	0.29	0.21	0.25	0.29
1510	10282004	2100	5	0.00	0.00	0.00	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	0.04	0.00	0.00
1511	10292004	500	6	0.00	0.05	0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.05	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.05	0.04
1512	10292004	1700	14	0.55	0.58	0.55	0.34	0.35	0.47	0.51	0.37	0.43	0.18	0.57	0.30	0.30	1.00	0.42	0.30	0.52	0.73	0.52	0.71
1513	11012004	100	28	1.75	1.40	1.58	1.59	1.32	1.29	1.72	1.64	1.41	1.64	1.88	1.77	1.33	1.88	1.93	1.77	1.14	1.32	1.42	2.12
1514	11032004	1700	20	0.71	0.95	0.71	0.77	0.90	0.34	0.66	0.67	0.69	0.91	0.43	0.56	0.64	0.50	0.55	0.64	0.59	0.76	0.62	0.56
1515	11172004	500	11	0.04	0.05	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.04	0.00
1516	11182004	600	35	0.49	0.37	0.44	0.54	0.46	0.58	0.57	0.53	0.68	0.60	0.46	0.50	0.76	0.40	0.33	0.41	0.24	0.41	0.32	0.40
1517	11242004	100	22	0.62	0.56	0.79	0.46	0.45	0.50	0.84	0.50	0.58	0.70	0.72	0.86	0.42	0.73	1.02	1.10	0.71	0.41	0.49	1.31
1518	11252004	900	5	0.29	0.40	0.38	0.13	0.17	0.12	0.42	0.17	0.31	0.28	0.30	0.30	0.13	0.38	0.52	0.09	0.17	0.08	0.17	0.25
1519	11272004	400	16	0.41	0.57	0.28	0.45	0.59	0.20	0.37	0.36	0.49	0.48	0.20	0.41	0.33	0.20	0.28	0.34	0.44	0.46	0.54	0.25
1520	11292004	800	9	0.16	0.09	0.12	0.12	0.08	0.12	0.08	0.04	0.08	0.14	0.16	0.16	0.12	0.16	0.21	0.17	0.12	0.21	0.21	0.25

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

Table I-3. (continued)

1521	11302004	500	19	0.32	0.34	0.36	0.25	0.36	0.29	0.32	0.28	0.32	0.43	0.29	0.37	0.32	0.37	0.38	0.33	0.36	0.33	0.41	0.28
1522	12012004	800	7	0.04	0.09	0.00	0.08	0.04	0.00	0.08	0.04	0.13	0.05	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.08	0.00	0.04
1523	12052004	2000	19	0.50	0.32	0.46	0.33	0.33	0.52	0.38	0.39	0.21	0.42	0.48	0.38	0.25	0.56	0.52	0.43	0.34	0.30	0.33	0.67
1524	12062004	2300	15	0.72	0.81	0.76	0.76	0.85	0.80	0.76	0.84	0.73	0.82	0.78	0.78	0.68	0.75	0.73	0.64	0.76	0.76	0.67	0.67
1525	12102004	800	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	0.04	0.00	0.00	0.00	0.00	0.04	0.04
1526	12102004	2000	6	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.08	0.04	0.04	0.04	0.00	0.08
1527	1012005	400	32	0.58	0.41	0.71	0.63	0.38	0.85	0.45	0.45	0.38	0.57	0.46	0.45	0.34	0.46	0.37	0.46	0.37	0.36	0.50	0.41
1528	1022005	2400	17	1.17	1.09	1.03	0.85	0.90	1.07	0.96	0.96	0.98	1.14	1.00	0.93	0.84	0.91	1.24	1.03	0.88	1.02	1.14	1.05
1529	1042005	1700	36	0.77	0.71	0.78	0.87	0.95	0.92	1.03	0.92	0.80	1.17	0.96	1.04	0.87	1.08	1.41	1.09	0.82	1.00	1.07	1.19
1530	1072005	1200	5	0.04	0.05	0.00	0.04	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1531	1072005	2000	5	0.08	0.15	0.08	0.12	0.08	0.08	0.12	0.08	0.08	0.09	0.13	0.12	0.12	0.08	0.13	0.12	0.08	0.08	0.12	0.08
1532	1082005	800	7	0.12	0.09	0.04	0.00	0.04	0.00	0.00	0.08	0.04	0.10	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.04	0.00
1533	1092005	1000	3	0.00	0.05	0.08	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.08	0.00	0.04	0.00	0.12	0.04	0.00	0.00
1534	1102005	2100	22	0.12	0.14	0.08	0.16	0.12	0.04	0.12	0.08	0.08	0.19	0.08	0.13	0.08	0.08	0.04	0.08	0.04	0.08	0.08	0.04
1535	1112005	2200	31	1.10	1.05	1.09	1.21	1.37	1.17	1.33	1.32	1.40	1.62	1.29	1.54	1.52	1.51	1.52	1.69	1.89	2.50	2.18	1.67
1536	1132005	800	10	0.08	0.09	0.08	0.08	0.12	0.08	0.16	0.16	0.12	0.10	0.08	0.12	0.16	0.20	0.16	0.08	0.24	0.12	0.12	0.12
1537	1292005	600	16	0.08	0.05	0.16	0.12	0.08	0.20	0.12	0.08	0.00	0.15	0.16	0.12	0.00	0.16	0.12	0.20	0.04	0.08	0.20	0.24
1538	1302005	300	9	0.04	0.04	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.04
1539	2062005	700	22	0.37	0.28	0.29	0.33	0.34	0.29	0.37	0.37	0.37	0.36	0.29	0.38	0.37	0.38	0.39	0.38	0.29	0.38	0.34	0.33
1540	2072005	800	19	0.12	0.14	0.12	0.16	0.12	0.08	0.12	0.12	0.12	0.13	0.12	0.12	0.08	0.17	0.17	0.16	0.16	0.17	0.25	0.12
1541	2082005	600	8	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.02
1542	2082005	1800	29	0.04	0.05	0.04	0.04	0.08	0.12	0.08	0.08	0.08	0.10	0.12	0.08	0.04	0.12	0.12	0.08	0.08	0.08	0.08	0.16
1543	2132005	300	27	0.93	0.69	0.89	0.79	0.82	0.79	1.00	0.86	0.62	0.75	0.76	0.80	0.74	0.83	1.20	0.96	0.71	0.92	0.87	0.90
1544	2192005	2300	24	0.12	0.05	0.12	0.12	0.08	0.04	0.16	0.08	0.04	0.14	0.04	0.08	0.08	0.12	0.08	0.12	0.00	0.12	0.20	0.08
1545	2272005	1500	23	0.12	0.14	0.08	0.12	0.12	0.12	0.16	0.08	0.12	0.13	0.12	0.16	0.12	0.20	0.16	0.12	0.16	0.16	0.12	0.16
1546	3222005	1300	25	0.45	0.33	0.45	0.29	0.47	0.49	0.37	0.29	0.34	0.42	0.41	0.41	0.45	0.41	0.50	0.42	0.33	0.33	0.41	0.55
1547	3242005	700	5	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.00	0.09	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.00	0.00
1548	3242005	1500	22	0.21	0.24	0.21	0.20	0.25	0.18	0.20	0.25	0.25	0.34	0.25	0.33	0.37	0.28	0.33	0.37	0.32	0.38	0.32	0.28
1549	3302005	1600	1	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00

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

Table I-3. (continued)

1550	4062005	1200	4	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.20
1551	4112005	2400	34	0.70	0.46	1.23	0.63	0.55	1.29	1.21	1.50	1.09	0.97	1.05	1.45	1.02	1.26	1.19	1.19	1.29	1.64	1.05	1.67
1552	4212005	1700	11	1.47	0.72	1.00	0.98	0.78	1.04	0.87	0.79	0.60	0.59	0.71	0.51	0.78	0.71	0.26	0.37	0.38	0.39	0.41	0.17
1553	4222005	700	14	0.17	0.13	0.13	0.13	0.09	0.08	0.12	0.17	0.12	0.15	0.21	0.12	0.13	0.12	0.16	0.17	0.08	0.04	0.04	0.29
1554	4232005	100	10	0.00	0.05	0.04	0.00	0.04	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.12	0.08	0.00	0.04	0.04	0.04	0.12
1555	4252005	2100	5	0.08	0.10	0.16	0.13	0.17	0.08	0.09	0.12	0.04	0.10	0.04	0.13	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.08
1556	4262005	600	5	0.00	0.00	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04
1557	4262005	1400	5	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.08	0.04	0.00	0.00	0.00	0.00
1558	5012005	800	2	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1559	5092005	100	4	0.21	0.22	0.12	0.04	0.30	0.11	0.16	0.17	0.09	0.23	0.09	0.17	0.09	0.12	0.13	0.13	0.17	0.13	0.21	0.04
1560	5092005	800	4	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	0.04	0.04	0.00	0.04	0.04	0.00
1561	5112005	1900	21	0.12	0.32	0.25	0.43	0.17	0.36	0.62	0.29	0.17	0.32	0.30	0.30	0.43	0.37	0.39	0.29	0.38	0.34	0.34	0.66
1562	5182005	2300	11	0.04	0.18	0.08	0.38	0.34	0.32	0.34	0.37	0.39	0.32	0.25	0.21	0.21	0.25	0.17	0.43	0.12	0.12	0.21	0.21
1563	5192005	1900	18	0.13	0.13	0.13	0.00	0.09	0.01	0.00	0.16	0.04	0.00	0.39	0.00	0.04	0.08	0.21	0.30	0.12	0.30	0.08	0.04
1564	5292005	1200	2	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04	0.00	0.00	0.00	0.00
1565	5302005	300	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00
1566	5302005	800	3	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1567	6042005	900	4	0.04	0.00	0.00	0.00	0.00	0.00	0.08	0.17	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.08	0.00	0.00	0.09
1568	6052005	500	9	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.13	0.00	0.08	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.08	0.00
1569	6082005	1400	6	0.63	0.72	0.08	1.25	0.56	0.09	1.92	0.71	0.73	0.19	1.11	0.34	0.60	0.33	0.65	0.51	0.25	0.86	0.25	0.26
1570	6082005	2400	10	0.04	0.53	0.08	0.00	0.04	0.17	0.00	0.38	0.00	0.18	0.04	0.17	0.00	0.08	0.04	0.04	0.04	0.04	0.04	0.21
1571	6112005	1300	4	0.17	1.02	0.25	1.16	0.70	0.00	1.67	1.01	0.87	0.00	0.00	0.78	0.61	0.00	0.21	0.78	0.68	0.81	0.09	0.00
1572	6132005	2400	2	0.00	0.00	0.00	0.09	0.17	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1573	6142005	600	1	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1574	6232005	700	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1575	7042005	1200	11	0.41	0.00	0.04	0.00	0.00	0.04	0.17	0.00	0.00	0.00	0.13	0.00	0.00	0.21	0.30	0.00	0.00	0.00	0.00	0.08
1576	7112005	2300	23	0.78	0.68	0.66	0.50	1.09	0.64	0.59	0.47	0.67	0.99	0.64	0.54	0.67	0.54	0.75	0.59	0.72	0.71	0.69	0.62
1577	7132005	200	16	0.12	0.18	0.08	0.17	0.25	0.09	0.33	0.16	0.25	0.14	0.04	0.12	0.25	0.08	0.08	0.12	0.21	0.21	0.00	0.42
1578	7242005	2200	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00

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

Table I-3. (concluded)

1579	7262005	1600	11	0.87	0.73	0.97	0.78	1.00	0.78	0.76	0.67	0.77	0.83	0.84	0.60	0.51	0.71	0.61	0.43	0.43	0.61	0.75	0.46
1580	8042005	600	6	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.22	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1581	8042005	1700	18	0.46	0.82	0.28	0.00	0.30	0.21	0.00	0.00	0.00	0.10	0.04	0.00	0.00	0.67	0.04	0.00	0.21	0.90	0.88	0.29
1582	8122005	100	7	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	0.13	0.04	0.08
1583	8122005	1300	4	0.00	0.09	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	0.17	0.13	0.13	0.21
1584	8122005	2100	18	0.34	0.36	0.33	0.30	0.21	0.97	0.38	0.25	0.43	0.22	0.84	0.35	0.34	0.97	0.57	0.56	0.43	0.52	0.55	1.05
1585	8132005	1800	30	1.16	1.30	1.25	0.94	1.07	1.08	0.63	0.68	0.50	0.84	0.47	0.37	0.33	0.37	0.45	0.28	0.33	0.29	0.28	0.41
1586	8182005	2300	13	0.00	0.00	0.04	0.00	0.13	0.21	0.34	0.76	0.70	0.86	0.31	0.38	0.56	0.58	0.43	0.34	0.30	0.90	0.50	0.58
1587	8192005	2000	15	0.58	0.90	0.55	0.56	0.34	0.48	0.34	0.34	0.17	0.64	0.09	0.39	0.48	0.21	0.30	0.74	1.03	0.90	0.63	0.50
1588	8212005	2300	3	0.00	0.00	0.08	0.13	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
1589	8252005	1000	14	0.04	0.00	0.12	0.08	0.00	0.16	0.13	0.16	0.13	0.10	0.21	0.17	0.08	0.25	0.35	0.39	0.17	0.43	0.21	0.46
1590	8262005	500	15	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.04	0.05	0.08	0.00	0.00	0.04	0.04	0.13	0.04	0.04	0.04	0.04

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