ILLINOIS STATE
WATER SURVEY
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October 12, 2016

Mr. Jeff Smith, Chairman
Imperial Valley Water Authority
25865 E. County Road 1000 N
Easton, IL 62633

Dear Chairman Smith:

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 and a network of groundwater observation wells since 1994. The purpose of the rain gauge and groundwater observation well networks is to collect long-term data to determine the impact of groundwater withdrawals during dry periods and the growing season, and the rate at which the aquifer recharges. This letter serves as the year end report for Year 23 which covers the time period from September 1, 2014 through August 31, 2015.

The groundwater observation well network has previously consisted of thirteen wells, MTOW-01 through MTOW-13. The network was established in 1995-96. Three new observation wells have been added to the network during 2014. MTOW-14 is located next to MTOW-11, south of Mason City, and wells MTOW-15 A & B are Northwest of Mason City near Ellsberry Lake. All of the observation wells are drilled wells between 2 and 6 inches in diameter. With the exception of MTOW-05 and MTOW-09, all wells are equipped with data loggers that electronically log the groundwater level data. The data loggers were installed in 2004 and 2005. MTOW-14 and MTOW-15 A & B will be outfitted in the future. Figure 1 shows the location of each well.

In accordance with our agreement, each well, with the exception of MTOW-05 and MTOW-09, is visited by ISWS personnel during the first few days of the month during irrigation season and approximately bi-monthly during the non-irrigated portion of the year.

A 25-site rain gauge network (Figure 1) was established in late August 1992 with approximately 5 miles between gauges. The network was reduced to 20 sites in September 1996. The rain gauge network was maintained monthly by a Mason County resident, Bob Ranson through July 2014. It is now maintained by ISWS field technician Dana Grabowski. During these visits, data are downloaded, other routine services are performed and major maintenance and repairs are completed as needed.

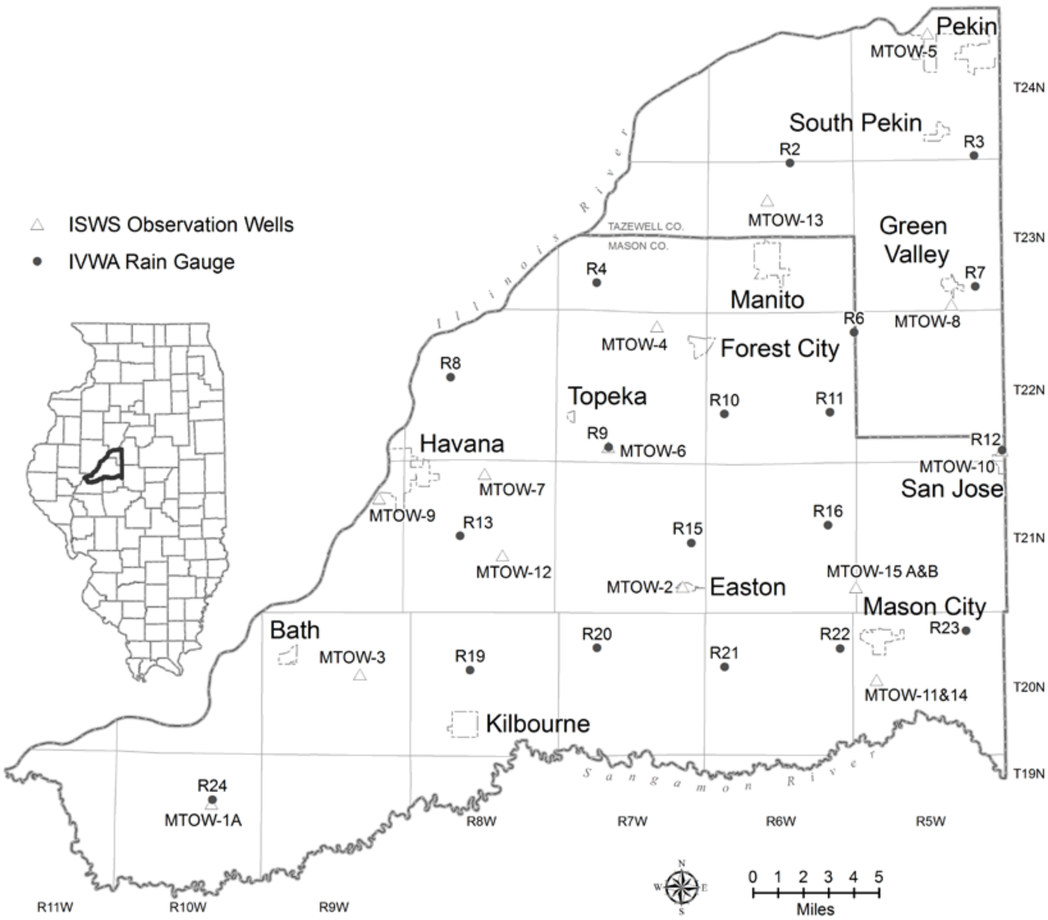


Figure 1. Configuration of the 16-site observation well and 25-site rain gauge networks.

Data reduction activities during Year 23 of network operation are similar to those performed during the previous 22 years. Each month, hourly rainfall amounts are totaled from 15-minute digital data and are placed into an array of values for the 20 gauges. This data array is used to check for spatial and temporal consistency between gages, and to divide the data into storm periods. If the digital data are missing, the hourly amounts are estimated based on an interpolation of values from the nearest surrounding gauges.

Groundwater levels for each well for the period of record (September 1, 2014-August 31, 2015) are presented in Appendix A. For MTOW-05, and -09 their entire period of record is shown because these wells do not have digital recorders and have only been measured periodically since 2005. These two wells have been shown to mimic the stage in the Illinois River. Stage data from the Illinois River can be used, if necessary to recreate groundwater levels in those regions of the study area. Each hydrograph also contains the daily precipitation for the nearest rain gauge.

Since 1995, the IVWA has estimated irrigation pumpage from wells in the Imperial Valley based on electric power consumption. Menard Electric Cooperative provides the IVWA with electric power consumption data for the irrigation services they provide during the growing season (June-September). 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 2002, the U.S. Geological Survey (USGS) updated the formula used to calculate pumpage by closely measuring the pumping rate at 77 irrigation systems serviced by Menard Electric. The updated formula provides estimates that are appreciably lower than the previous formula, by approximately 20 percent. Therefore, irrigation withdrawals for the years 1997 to the present were recalculated using the new formula, replacing earlier published estimates (reports through Year 12 use the original formula).

The Year 23 rain gauge dataset was used to produce summaries for all storm data for each station and the network; monthly, seasonal, and annual rainfall totals; analysis of the rainfall and groundwater level fluctuations; the data obtained from the long-term monitoring well network; the database showing the individual storms in the Imperial Valley region; and an updated version of the irrigation pumpage data.

Precipitation Analysis

The Year 23 network precipitation of 41.23 inches was 6.48 inches above the previous 22-year's average of 34.75 inches. Overall, Year 23 was the fourth wettest in the 23 years of network operation. Fall was the 6th wettest fall, winter the third driest winter, spring the 7th driest spring, and summer was the wettest spring of the 23 years. Table 1 gives the monthly precipitation totals for each rain gauge within the network during Year 23.

Figure 2 presents the 23-year network average, and Figure 3 presents the annual precipitation pattern for Year 23. During Year 23, annual gauge totals varied from 36.61 inches at site 8 to 46.24 inches at site 2 (Figure 3). Ten-inch differences between gauges in annual precipitation amounts are not unusual during any given year, representing natural variability. If large differences between individual gauges are repeated year after year, this would suggest possible differences caused by differences in gauge exposure to the wind or by measurement errors. Gauges that are overly sheltered or with little or no shelter from the wind (most of the gage sites) can underestimate precipitation under strong wind conditions. Note that on July 23rd 2015, Site #8 was moved to a more open location on the Forbes Biological Station property.

September 2014 received precipitation more than 3 inches above the monthly network average during Year 23, and June 2015 received more than 9 inches above the monthly network average. October 2014, February 2015, March 2015, April 2015 and August 2015 received precipitation that was at least 1 inch below the network average (Figures 4-9). The network received 14.32 inches less precipitation than in the wettest year (1992-1993), and 19.97 inches more than the driest year (2011-2012) of the 23 years of network observations. There were notable differences between seasons, with autumn 2014 and summer 2015, 2.31 and 8.80 inches above the 23 year average respectively, and winter 2014-15 and spring 2015, 2.37 and 2.27 inches below average respectively.

Table 1. Monthly Precipitation Amounts (inches), September 2013-August 2014

	Month												
Station	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	7.63	2.85	1.11	1.08	1.89	0.92	0.33	2.84	5.36	13.25	7.72	1.26	46.24
3	6.71	4.07	1.35	0.99	1.57	0.71	0.29	2.49	4.29	11.84	8.84	1.15	44.30
4	6.70	3.18	1.01	0.98	1.36	0.65	0.41	3.04	5.66	13.96	4.78	0.91	42.64
6	5.54	3.89	1.27	0.88	1.44	0.30	0.26	1.94	4.28	13.46	4.01	0.84	38.11
7	5.95	3.83	1.34	1.11	1.43	0.59	0.44	1.53	4.45	13.35	7.71	1.89	43.62
8	5.01	2.56	0.81	0.97	1.30	0.46	0.36	2.88	5.07	10.76	5.25	1.18	36.61
9	5.00	3.53	1.33	1.04	1.49	0.57	0.51	2.32	4.40	13.45	5.45	0.96	40.05
10	6.22	3.41	1.16	0.92	1.23	0.52	0.49	2.06	4.61	15.00	4.24	0.78	40.64
11	6.07	3.33	1.17	0.99	1.23	0.74	0.40	1.90	4.16	13.21	4 .48	1.10	38.78
12	6.63	2.75	1.31	1.35	1.27	0.65	0.68	1.51	4.95	13.87	5.00	1.27	41.24
13	4.18	3.06	0.98	1.15	1.30	0.56	0.43	2.69	4.93	13.15	5.31	1.00	38.74
15	4.65	3.49	1.43	1.14	1.39	0.68	0.88	2.16	5.63	14.16	5.14	1.06	41.81
16	6.32	3.17	1.21	1.29	1.38	0.54	0.72	1.81	5.92	13.89	4.76	1.19	42.20
18	6.39	3.93	1.50	1.35	1.64	1.27	1.14	2.73	5.23	13.59	4.98	1.44	45.19
19	5.73	3.31	1.32	1.27	1.54	1.03	1.05	2.20	4.91	13.45	5.46	1.34	42.61
20	6.25	2.79	1.19	1.29	1.33	0.64	0.67	1.89	4.55	12.04	4.95	1.27	38.86
21	5.46	3.01	1.39	1.44	1.43	0.68	0.99	1.94	5.38	13.34	5.44	1.29	41.79
22	6.29	2.74	1.68	1.44	1.38	0.68	1.09	1.67	4.94	13.80	5.49	1.45	42.65
23	5.89	2.34	1.35	1.27	1.20	0.53	0.80	1.34	4.24	12.68	4.24	1.10	36.98
24	8.11	3.31	1.06	1.44	1.34	0.60	0.87	2.22	4.96	10.42	4.73	2.09	41.15
Avg	6.04	3.23	1.25	1.17	1.41	0.67	0.64	2.16	4.90	13.13	5.40	1.23	41.23

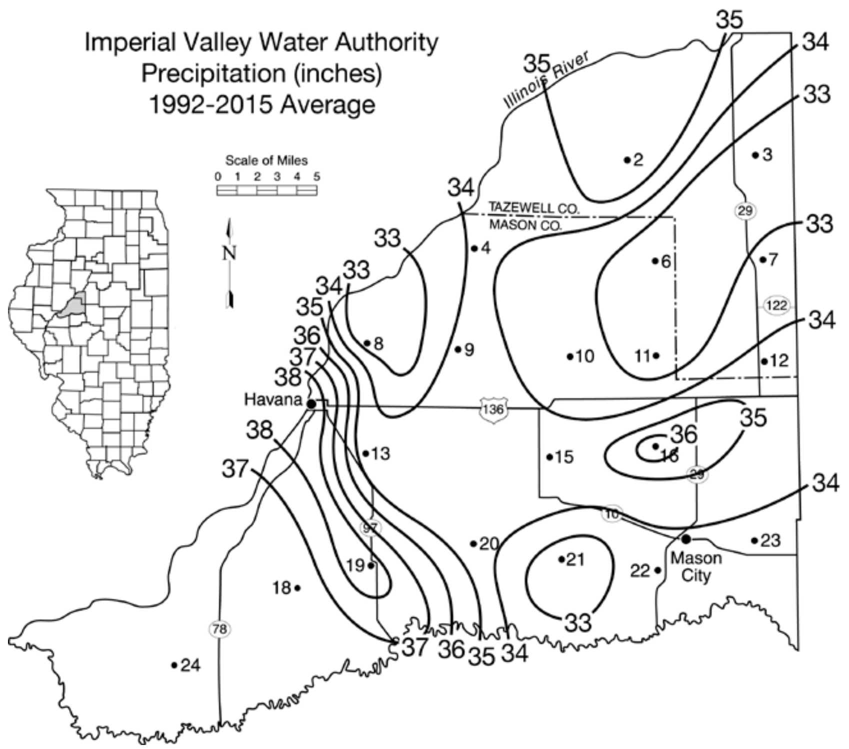


Figure 2. Network average annual precipitation (inches) for September 1993 – August 2015

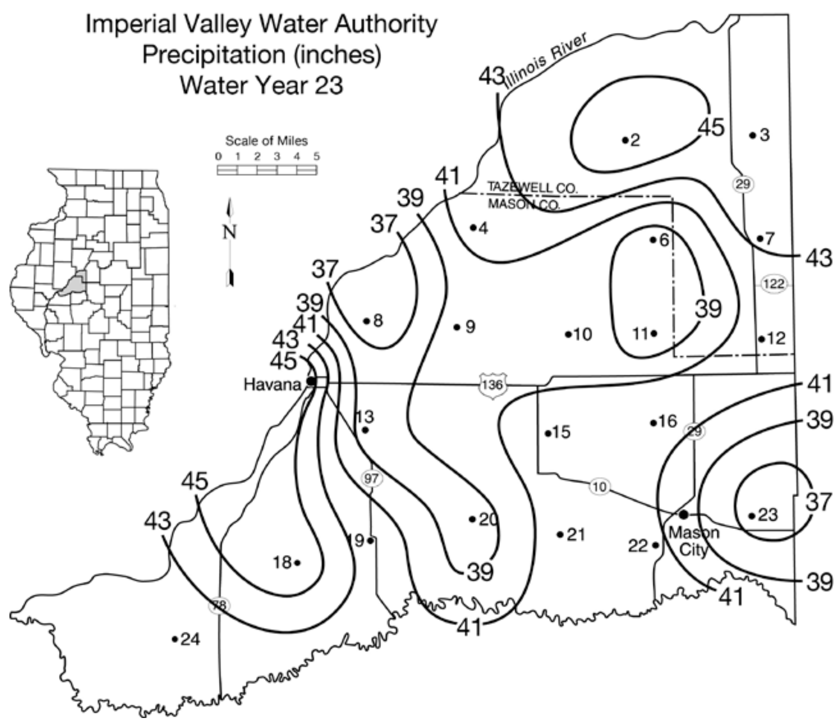


Figure 3. Total precipitation (inches) for September 2014 - August 2015

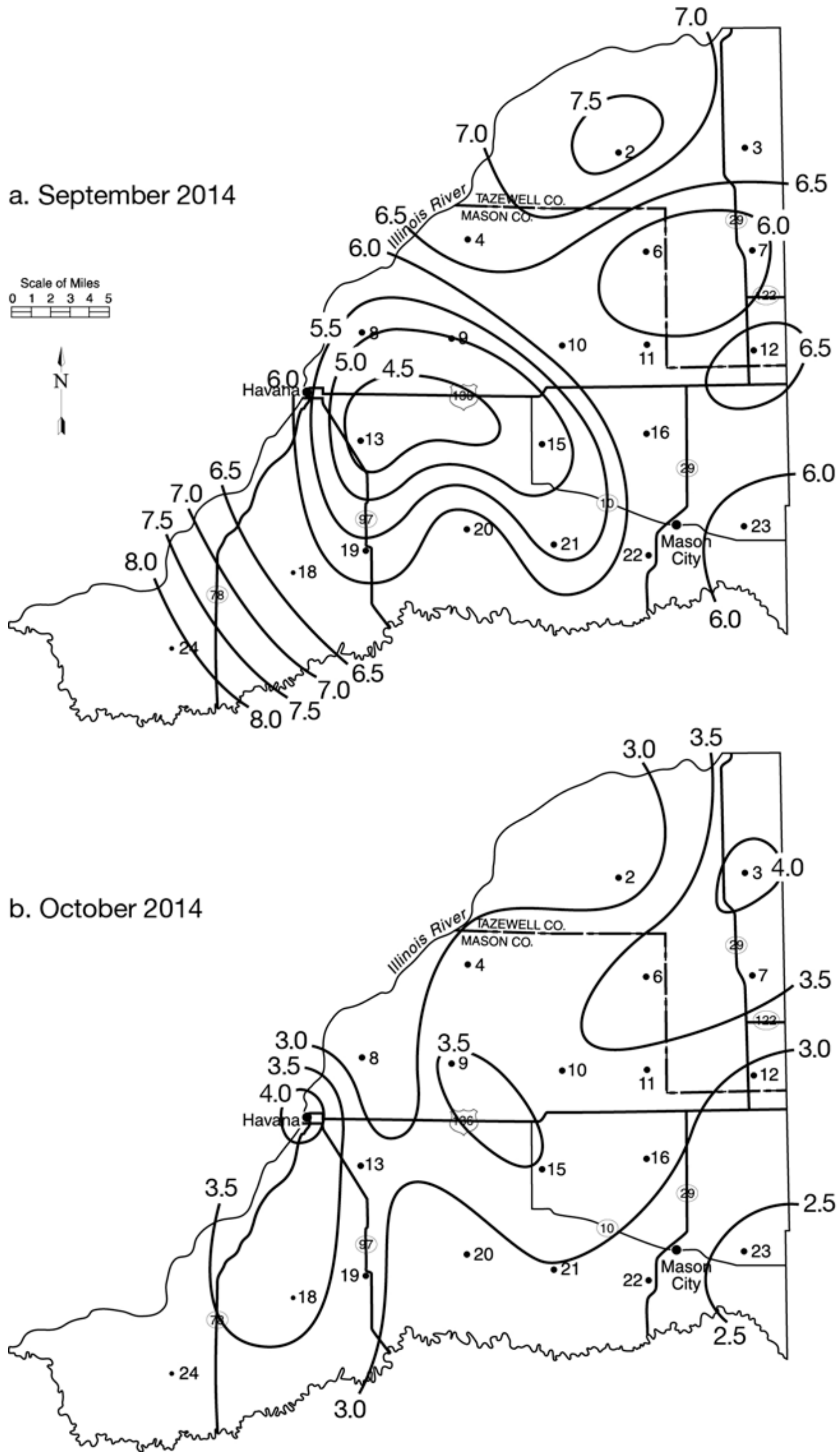


Figure 4. Precipitation (inches) for September 2014 and October 2014

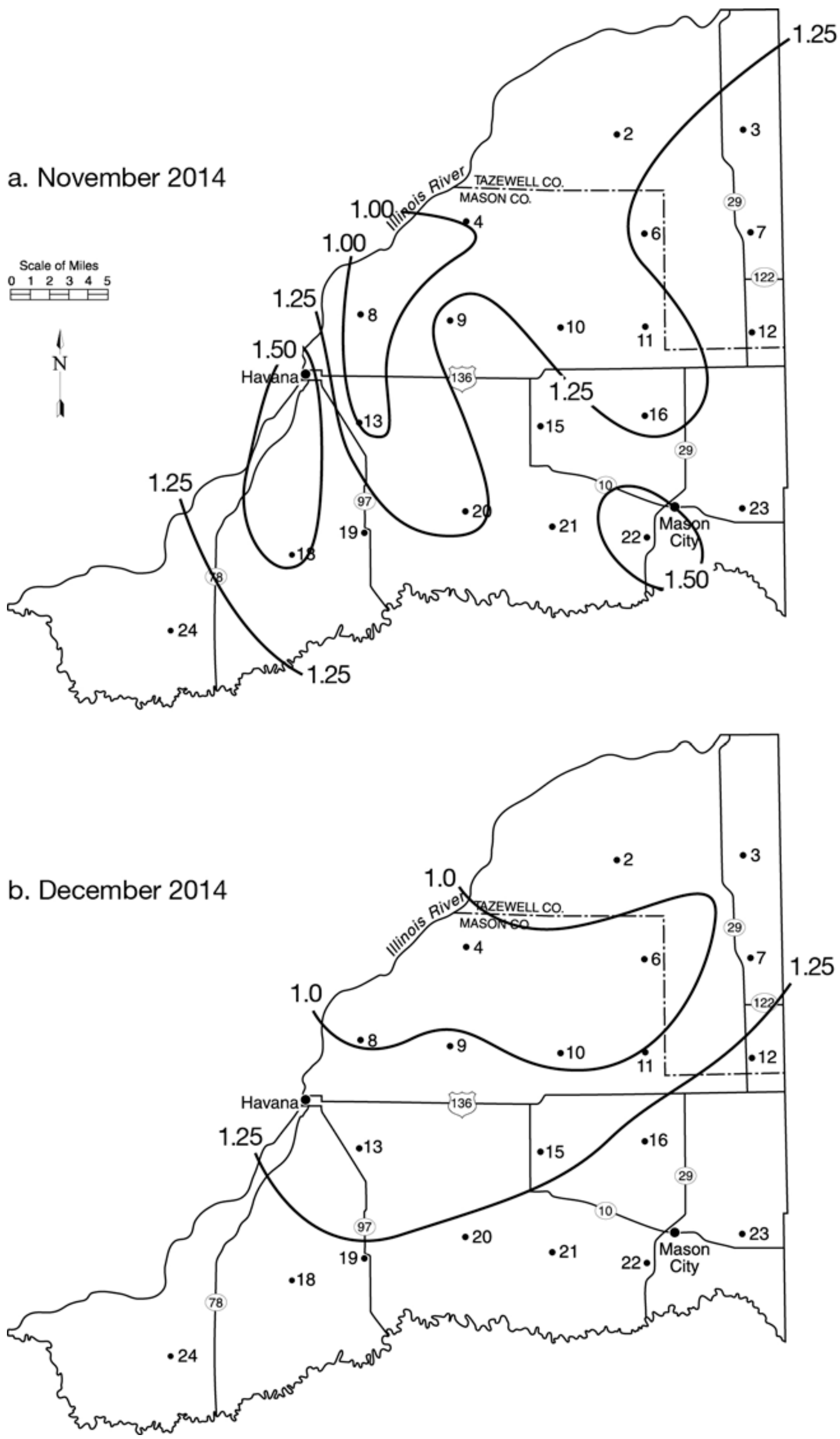


Figure 5. Precipitation (inches) for November 2014 and December 2014

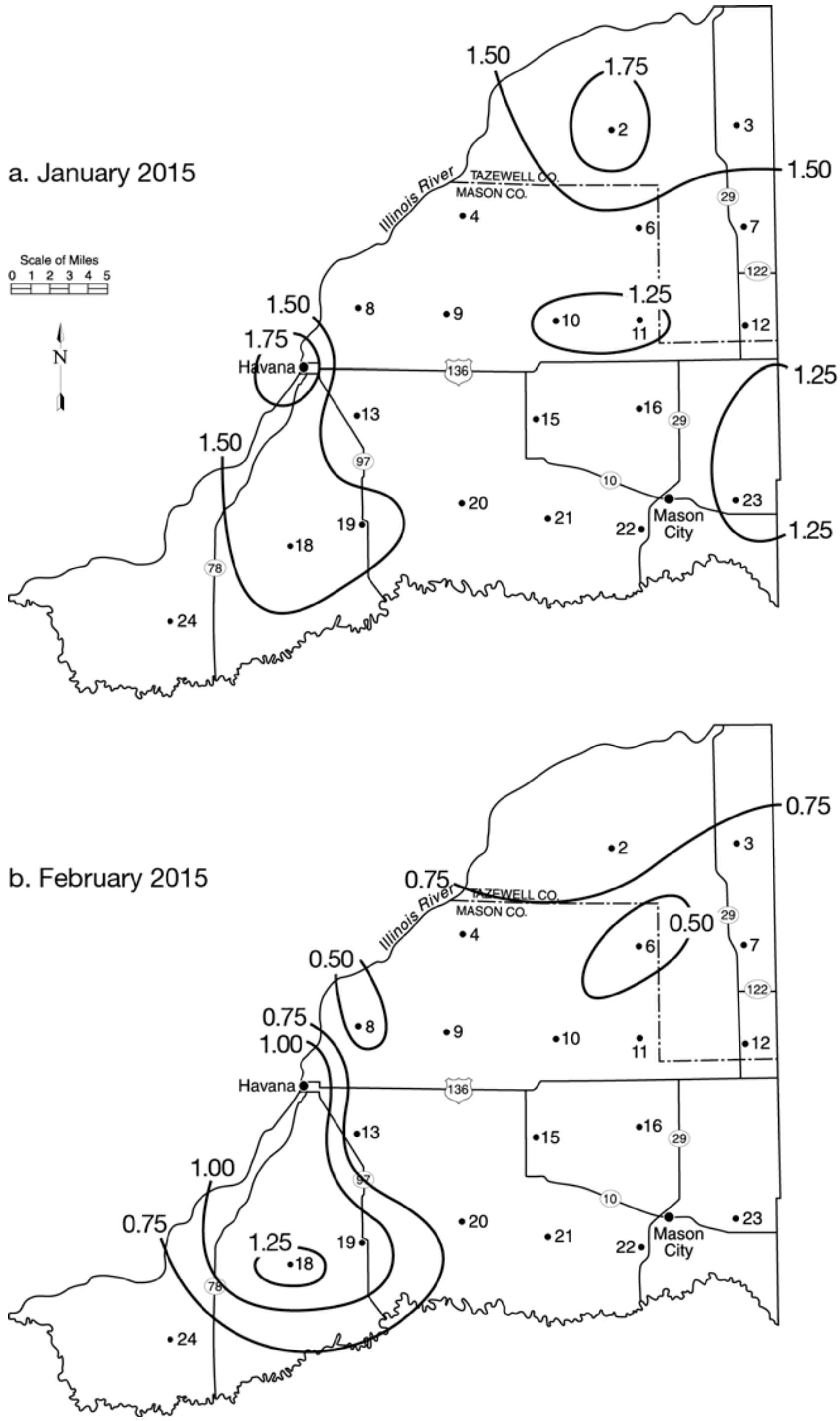


Figure 6. Precipitation (inches) for January 2015 and February 2015

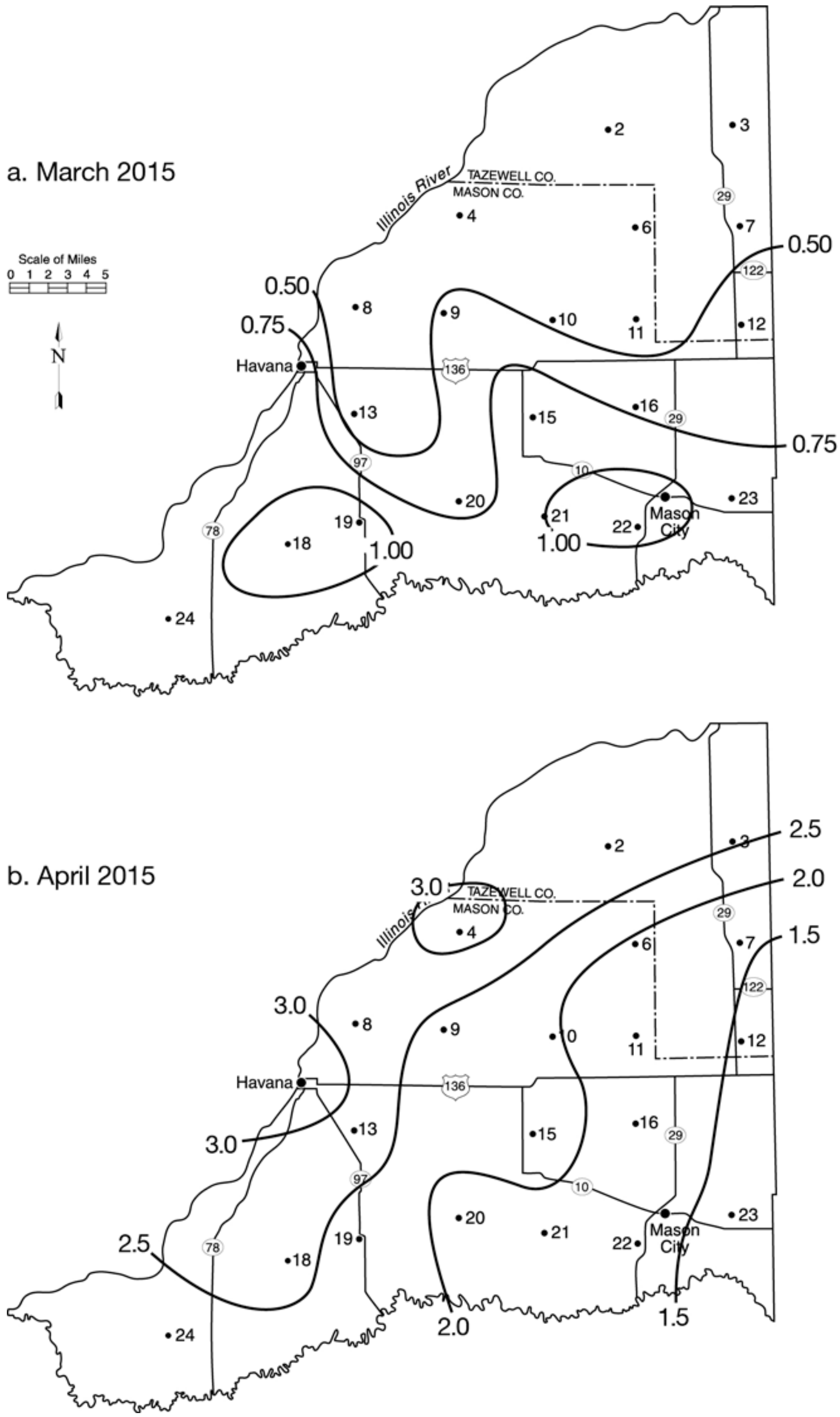
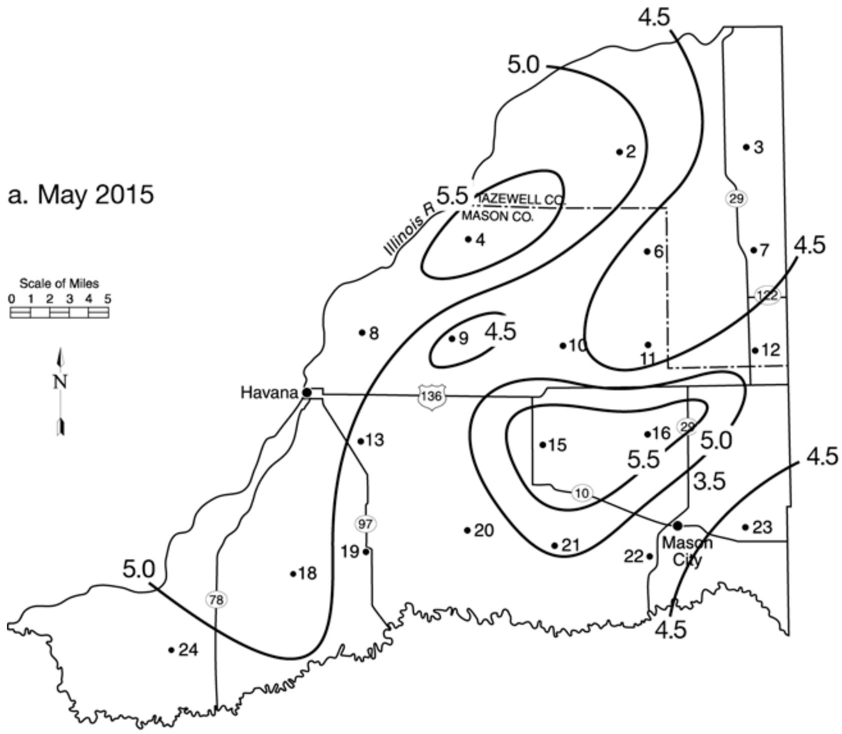


Figure 7. Precipitation (inches) for March 2015 and April 2015



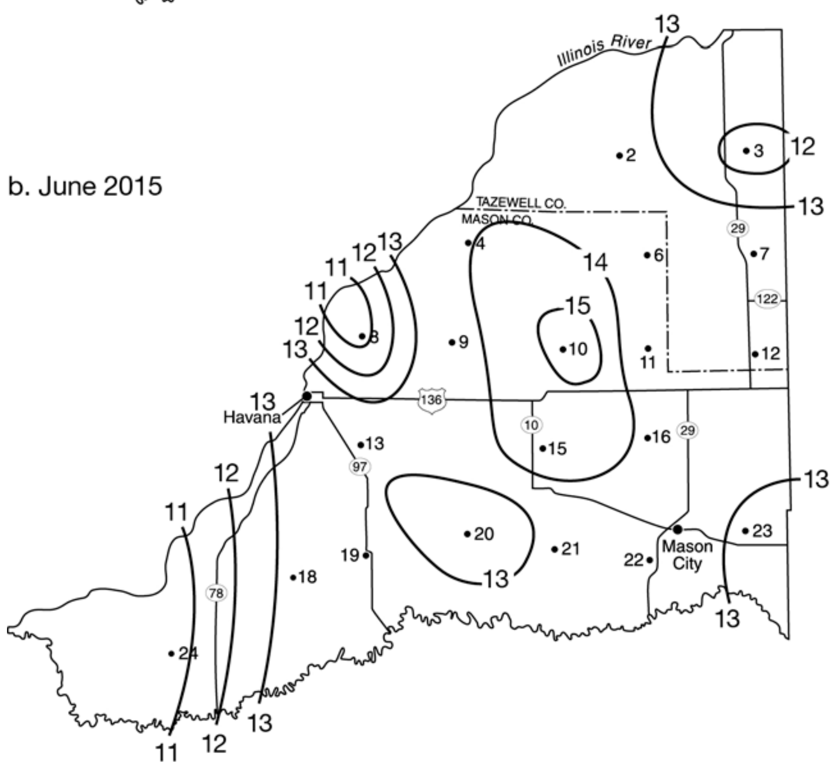


Figure 8. Precipitation (inches) for May 2015 and June 2015

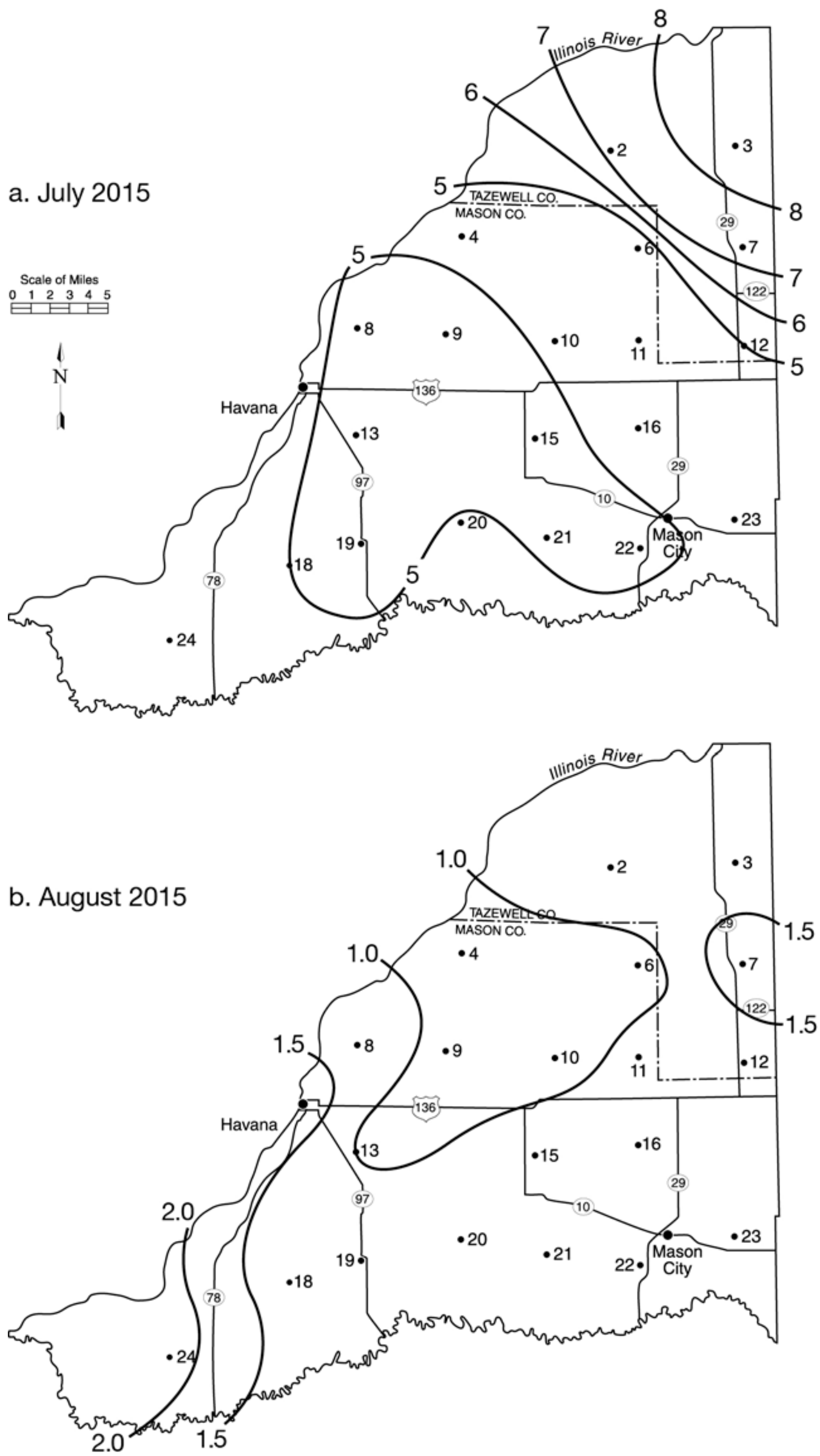


Figure 9. Precipitation (inches) for July 2015 and August 2015

Table 2. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event for Each Month and Season, 1993-2014 and 2014-2015

	1993-2014 22-yr average			*2014-2015 average*		
Period	***Precipitation***	***Events***	***Inches/event***	***Precipitation***	***Events***	***Inches/event***
Sep	2.90	7.5	0.38	6.04	5	1.21
Oct	2.74	8.7	0.32	3.23	8	0.40
Nov	2.57	8.8	0.34	1.25	8	0.16
Dec	1.88	9.6	0.23	1.17	6	0.20
Jan	1.97	9.2	0.25	1.41	9	0.16
Feb	1.77	8.2	0.24	0.67	5	0.13
Mar	2.19	8.5	0.26	0.64	7	0.09
Apr	3.56	11.2	0.34	2.16	9	0.24
May	4.23	13.0	0.33	4.90	15	0.33
Jun	4.10	12.0	0.34	13.13	15	0.88
Jul	3.62	10.5	0.36	5.40	9	0.60
Aug	3.24	11.7	0.38	1.23	6	0.21
Fall	8.21	24.7	0.33	10.52	21	0.50
Winter	5.62	27.2	0.21	3.25	20	0.16
Spring	9.97	32.6	0.31	7.70	31	0.25
Summer	10.96	33.2	0.33	19.76	30	0.66
Annual	34.75	118.9	0.29	41.23	102	0.40

The number of network precipitation periods was determined for the previous 22-year period. Mean monthly, seasonal, and annual number of precipitation events are presented for 2014-2015 (Table 2). The monthly, seasonal, and annual numbers of precipitation events averaged over the 1993-2014 period also are presented (Table 2). A network storm period is defined as a precipitation event separated from proceeding and succeeding events at all network stations by at least three hours. In September 2014, even though there were only 5 storm events, the average rainfall per event was 1.21 inches. This is well above the historic average of 0.38 inches per event. Similarly, in Year 23 there were 17 fewer events than the historic average, but the total rainfall was 6.48 inches higher than average. The historic average for the last 22 years has been 0.29 inches per event, but the average was 0.40 inches per event in Year 23.

A total of 2,721 storm periods occurred during the 23-year observation period, resulting in an average of 119 storm events per year. During Year 23, there were 102 precipitation events. Fewer events than average occurred in all seasons and individual months except May and June 2015. September 2014, October 2015, May 2015, June 2015, July 2015 were the only months with above average precipitation and of these, all but May 2015 had an average amount of precipitation per event. November 2014 through April 2015 were a total of 6.64 inches below normal. Interestingly, in Year 23, nearly have of the annual rainfall fell in two months, September 2014 and June 2015.

The plot of the network average monthly precipitation time series (Figure 10) beginning in September 2007 shows the monthly variation of precipitation. June 2008 through June 2011 was wet, with 15 months receiving 4.5 inches of precipitation or greater. Then, from July 2011 through

August 2012, only three months had more than 2.5 inches of precipitation, and six months had less than 2 inches of precipitation. The growing season of Year 21(2012-2013), experienced both above and below average precipitation periods: with two spring months totaling more than 14 inches of rain followed by three summer months totaling less than 5 inches of rain, a wet spring followed by a dry summer. In Year 22, the opposite occurred with a dry spring (5.89 inches) and a wet summer (15.58 inches**).** In Year 23 a wet fall followed the wet summer, with a dry winter and spring, and an extremely wet summer in 2015.

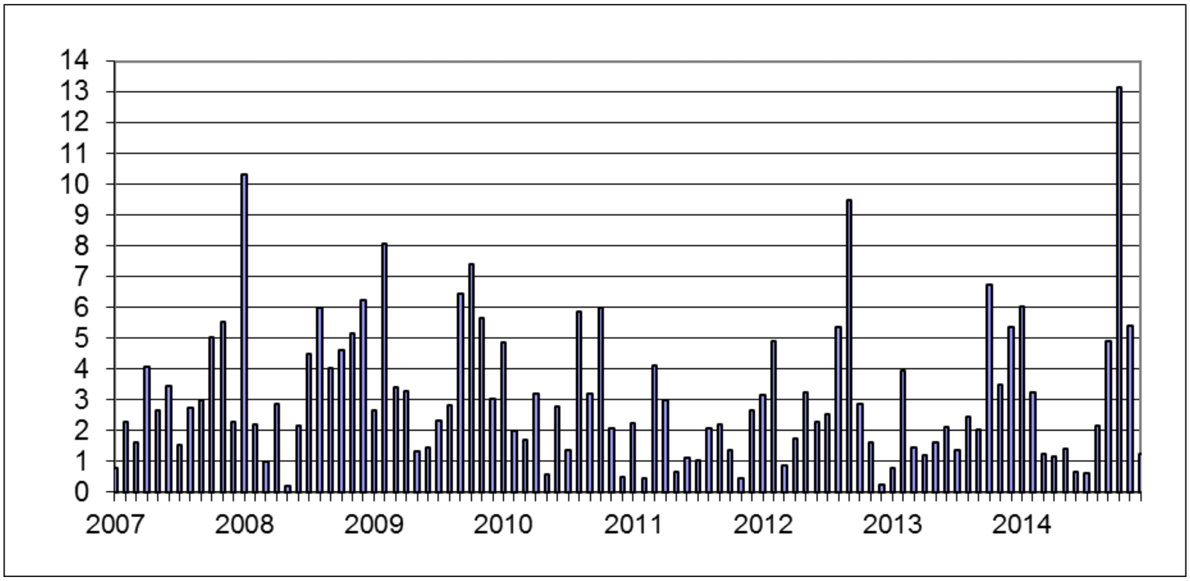


Figure 10. Network average monthly precipitation (inches), September 2007 - August 2015

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 for each gauge and are based upon the gage total storm precipitation and the total storm duration for the gauges with precipitation.

In Year 23, eight of the 102 network storm periods exceeded the 1-year recurrence frequency, for a total of 109 heavy rain events in 23 years of network operation. Of the 109 heavy storm events producing a maximum precipitation at one or more gages with a recurrence frequency greater than one year: there were: 50-yr (1 storm event), 25-yr (1 storm event), 10-year (7 storms), 5-year (13 storms), 2-year (41 storms), and 1-year (46 storm events). The 50-year storm occurred on 13 September 1993, the 25-year event on 9-10 September 2014, and the 10-year storms on: 16 May 1995, 8 May 1996, 19 July 1997, 30-31 March 2007, 11-14 September 2008, 19-20 July 2010, and 7-8 June 2015.

An average of 119 rain events and 5 heavy rain events have occurred per operation year. Year 23 had a below average number of storm periods (102) and an above average number of heavy rainfall events (8). One of the heavy rain events was in the 25-year recurrence frequency category, one in the 10-year, one in the 5-year, one in the 2-year, and four storm events were in the 1-year recurrence frequency category. No 50-year events occurred.

Groundwater Levels

The IVWA monitoring well network has consisted of thirteen monitoring wells, all but two are outfitted with data loggers that record the water level once per hour. As stated earlier, three additional well have been drilled during 2014 bringing the total number of observation wells to sixteen. The highest and lowest water levels are generally recorded at different times of the year. The highest generally occurs during the spring time and lowest during early fall. Hydrographs for each well show that water levels in the study area generally fall in late spring through the summer when discharge due to evapotranspiration and irrigation pumpage is at its greatest and precipitation is not great enough to recharge the aquifer at a rate greater than the afore mentioned factors. Recharge to the aquifer most often occur during winter and early spring times as precipitation is at its greatest and pumpage is lowest.

The long-term hydrograph at MTOW-01A (Snicarte, 1958 to present) in Figure 11 provides a historical reference for comparison with the shorter records of the other network wells. The ISWS has a record of water levels at this site since 1958. Annual fluctuations from less than a foot to more than 8 feet have been observed. A detailed look at water levels at the Snicarte site since 1990 is shown in Figure 12. 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 the well went dry, until it did so again in 2006 and 2007. During the 1993 flood, groundwater levels rose and peaked at approximately 11 feet below land surface in September 1993. The September 1993 water level of 11.14 feet below land surface is the highest water level to date for the Snicarte well.

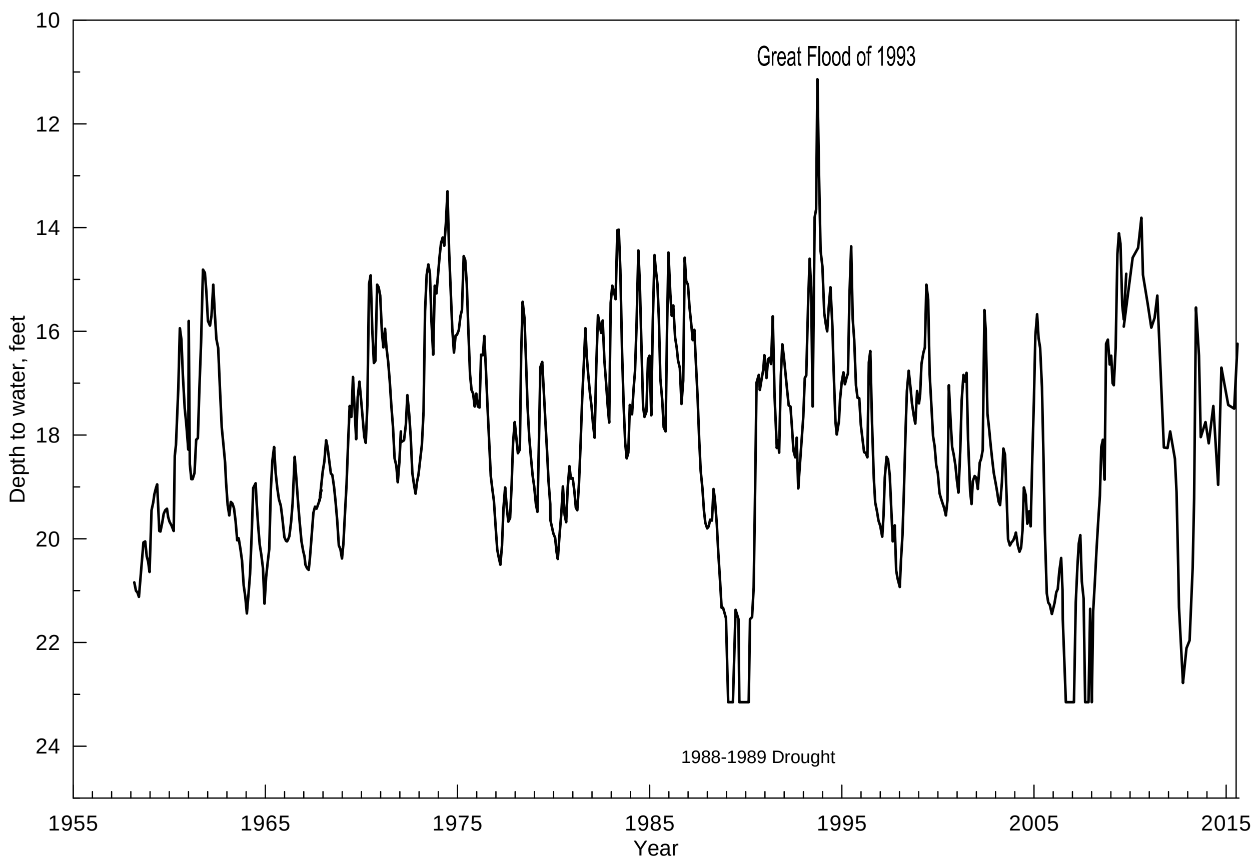


Figure 11. Groundwater levels at the Snicarte wells, 1958-2015

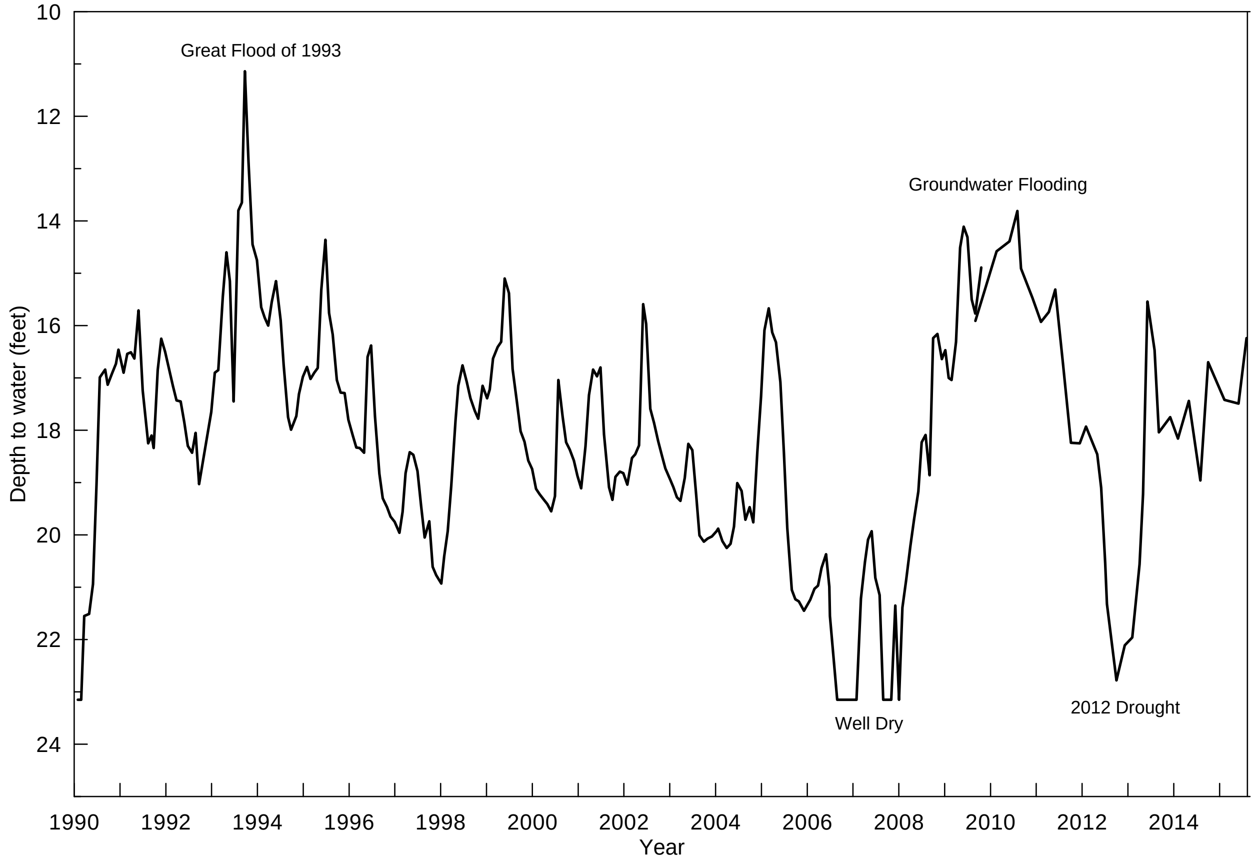


Figure 12. Groundwater levels at MTOW-01(Snicarte, IL) 1990-2013

The dramatic drop in 1988-89 shows how significantly a major drought can impact the aquifer. Though irrigation data is not available for 1988, based on data from the other parts of the state (Cravens, et al., 1989) it is likely that irrigation in 1988 was one of the highest amounts of any year. This is because summer precipitation was so low and summer temperatures were so high in 1988. Similarly, the irrigation amounts in 2005, 2006 and 20007 resulted in dramatic declines in water levels. Conversely, Year 17 (2008-2009), Year 18 (2009-2010) and most of Year 19 (2010-2011) were relatively wet years with low irrigation withdrawals, and water levels rose.

Above average precipitation in Year 17(2008-2009) elevated groundwater levels to the point of near record highs since the observation well network was established in 1995. A second year of higher than average precipitation in Year 18(2009-2010) elevated groundwater levels to record highs in several of the network wells. The above average precipitation continued until June of 2011. Because of the high precipitation totals between 2008 and 2011, the study area experienced widespread Groundwater Flooding, Figures 13 and 14 show two areas that experienced groundwater flooding. The flooding subsided during the late summer and fall of 2011.

From July 2011 until December 2012, the study area received below average precipitation. Figure 12 above shows groundwater levels declining during the drought of 2012. The groundwater levels came close to approaching the lows seen during the 1988-1989 drought and the exceptionally low groundwater levels of 2006-2008. 2015 saw groundwater levels remain steady as precipitation amounts fell above average during irrigation season.

Figure 13. Groundwater flooding near Easton (Photo courtesy of Dr. George Roadcap)

Figure 14. Groundwater flooding of Sand Lake near Havana (Photo courtesy of Dr. George Roadcap)

The hydrographs generated by the continuous water level measurements have led to an increased understanding of the relationship between rainfall, irrigation, water levels, and recharge. Appendix A shows the hydrographs for all 13 wells within the observation well network. The hydrographs run from September 1, 2014 to August 31, 2015 and contain all groundwater elevation data and daily precipitation totals for nearby rain gauges. In Figure 15, the rainfall/recharge relationship is observable as groundwater levels rise during periods of heavy precipitation. This is particularly evident after the large rainfall event in early June 2015 (4.5 inches) and the 3-4 weeks following that event. This period of higher rainfall not only created direct recharge for the aquifer, but reduced the irrigation water demand on the aquifer until mid-to-late July. Pumpage can be seen as the downward “spikes” in groundwater elevations, after July 15th, 2015.

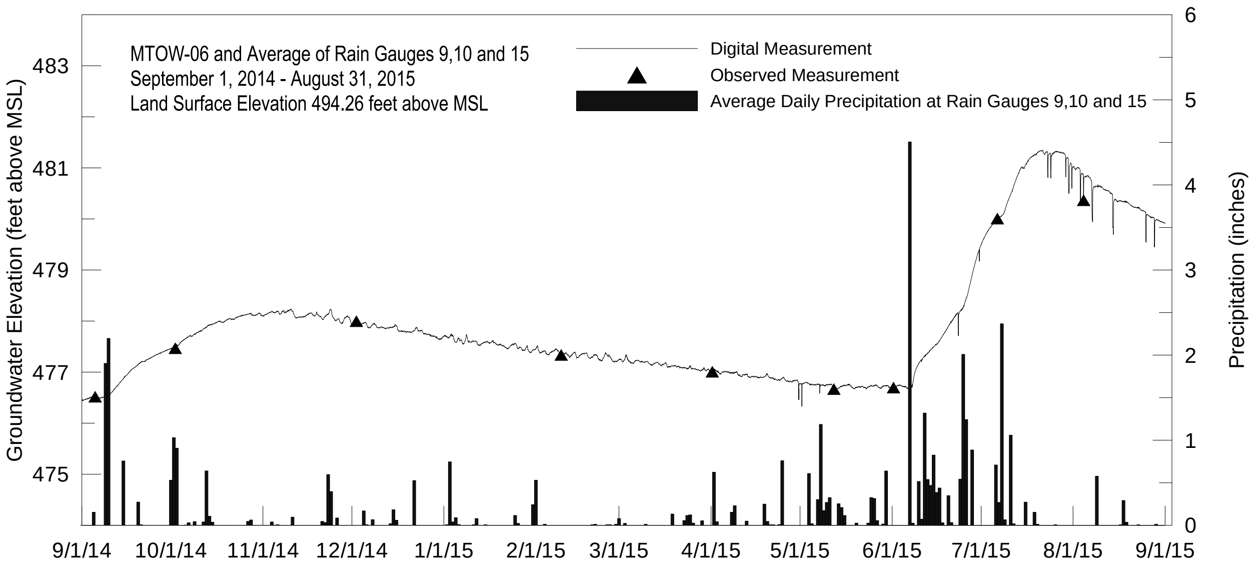


Figure 15. Groundwater elevations at the Tree Nursery Well, MTOW-06,
September 1, 2014-August 31, 2015

Figure 16 shows the entire period of record for MTOW-02, located within the village limits of Easton, IL. The lowest water levels on record occur August 25 and 26, 2012 while one of the highest water levels occur on June 2, 2013. The high and low water levels were 4.24 feet and 14.03 feet below land surface, respectively. The only higher water levels were in June of 1995 and around January 1, 2010. Having such high and low water levels in such a short time period reflects the recharge capabilities of the aquifer, particularly in the Easton region and the influence rainfall has on the aquifer when the water table is so shallow.

Figure 17, 18 and 19 are hydrographs showing groundwater elevation and precipitation data for a portion of Year 23. The hydrographs start June 1, 2015 and go to the end of the project year which ends August 31, 2015. The hydrographs illustrate the effects of abundant precipitation and increasing water levels and irrigation pumpage resulting in the lowering of groundwater levels.

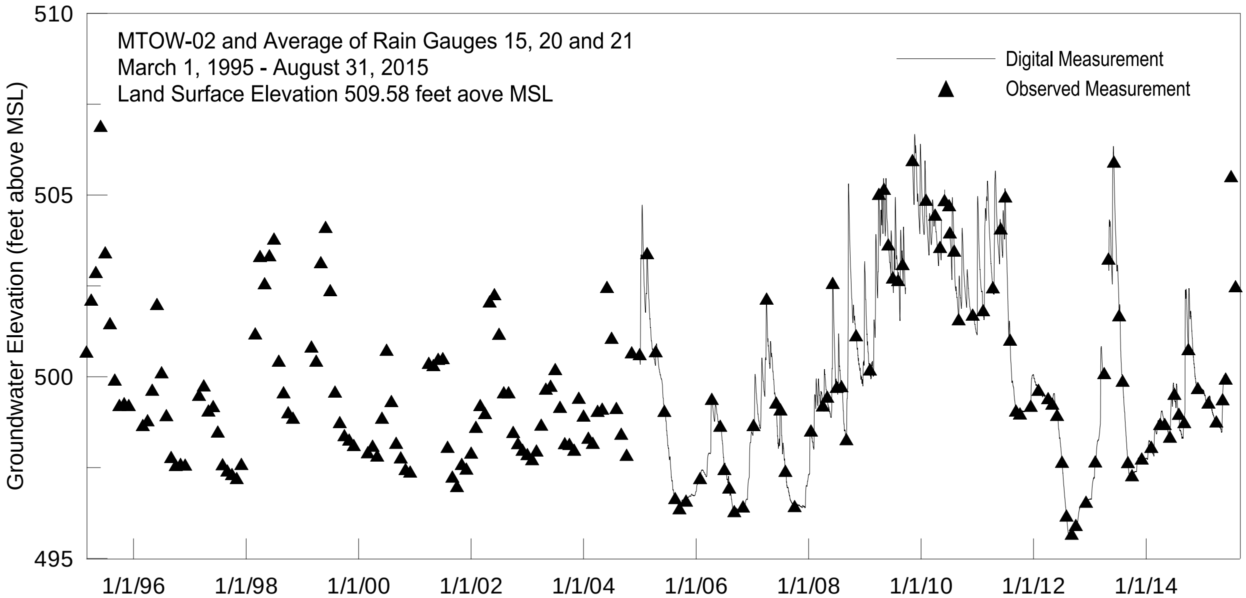


Figure 16. Groundwater elevations at the Easton well, MTOW-02,
January 1, 1995-August 31, 2015

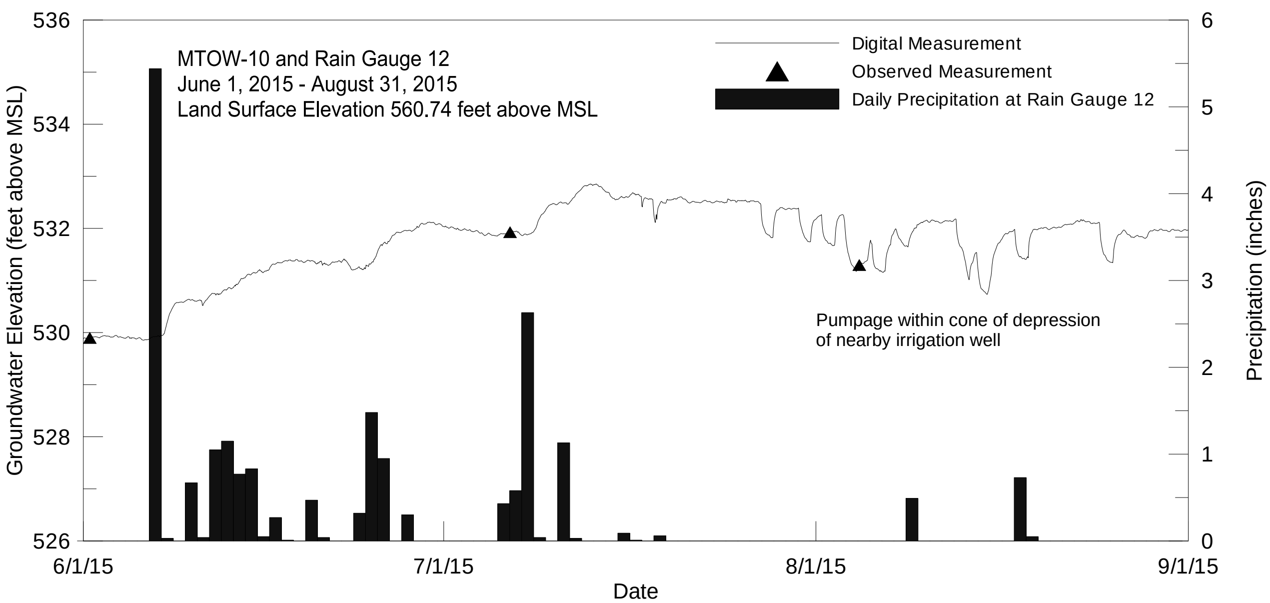


Figure 17. Groundwater elevations and precipitation at the San Jose well, MTOW-10,
June 1, 2015-August 31, 2015

Having continuous water level data allows us to better understand how rainfall affects recharge. At MTOW-10, there was 18.87 inches of rainfall between June 5th and July 18th and water levels rose 3 feet during that time. At MTOW-06 and MTOW-12, rainfall totals were 19.15 inches and 17.22 inches respectively, and water levels rose 4.8 feet and 5.2 feet. Depths to water on June 4 were 31 feet, 17.5 feet and 14.5 feet at these 3 wells. This indicates a strong correlation between depth to water and the amount of recharge for the aquifer. Where there are shallower water levels, for example near Easton, more recharge occurs for the same amount of rainfall.

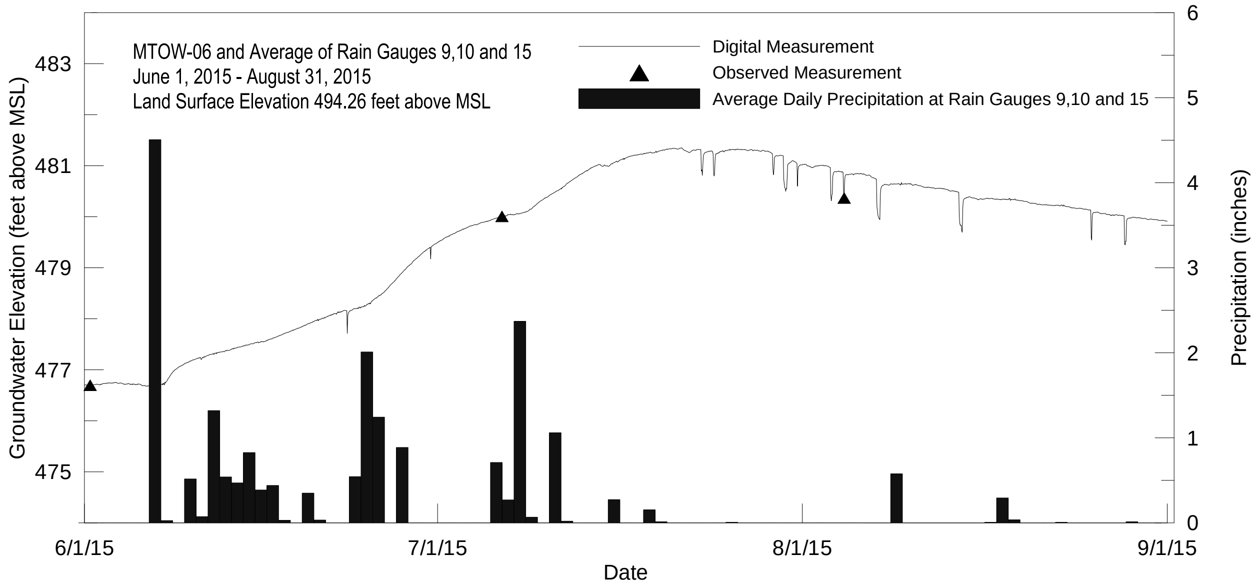


Figure 18. Groundwater elevations and precipitation at the Tree Nursery well, MTOW-06, June 1, 2015-August 31, 2015

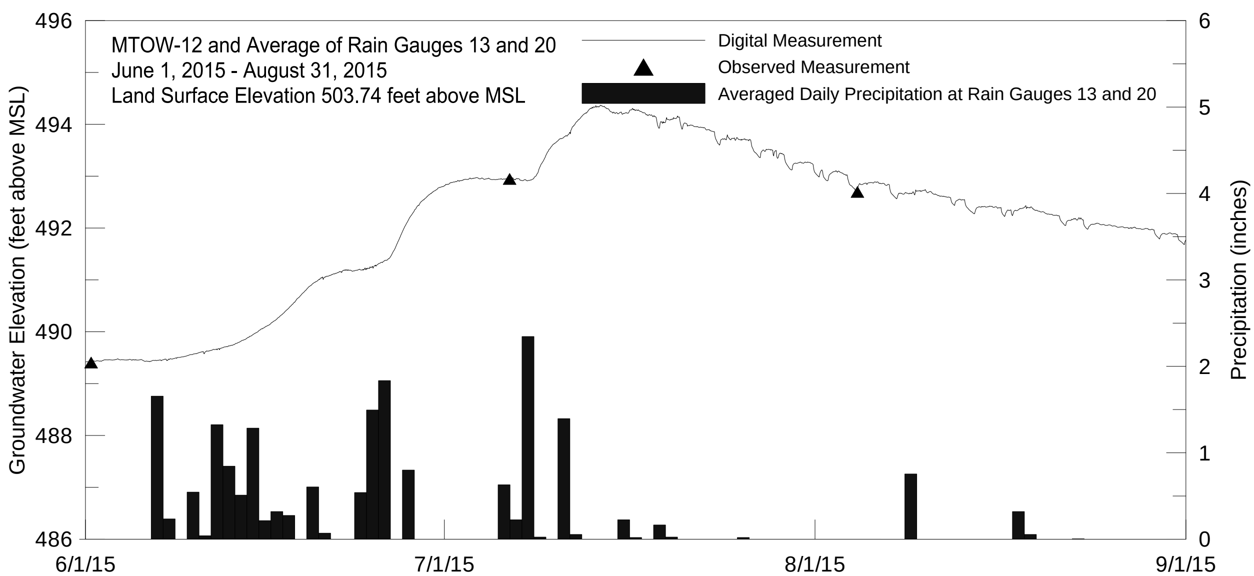


Figure 19. Groundwater elevations and precipitation at the Hahn Farm well, MTOW-12, June 1, 2015-August 31, 2015

Groundwater levels in the Pekin (MTOW-05) and Havana-IDOT (MTOW-09) wells have been found to fluctuate largely in response to river stage because of their proximity to the Illinois River. Since these two monitoring wells are so strongly influenced by the Illinois River, the wells are not outfitted with pressure transducers and are measured three to four times a year. The hydrographs for these two wells (MTOW-05 and MTOW-09) are located in Appendix A.

It is the hope of the ISWS that with three new observation wells drilled during 2014, our understanding of the aquifer will only increase as time moves forward. Appendix B has the early water level data for the 3 new wells.

Irrigation Water Use

The IVWA has provided to the ISWS a monthly estimated total pumpage of irrigation since 1997. This value is an aggregate of all irrigation which occurs over the water authority area. The water authority area includes Mason County and parts of six townships in Tazewell County. The total irrigation pumpage in 2015 was approximately 31 billion gallons (bg), which is the fifth lowest irrigation amount for the observation period. The number of irrigation systems is now at 2197. The ISWS recently (2014) developed a statewide map of irrigation based on USDA aerial photography. Based on those data, it was determined the number of systems was lower than the IVWA originally calculated. The IVWA uses new well construction reports to determine the number of irrigation systems each year, which doesn't account for wells installed to replace existing wells. This likely led to the over-counting of irrigation systems. Figure 22 shows the location of irrigation systems through 2014. For Year 23, the higher than normal precipitation during the summer affected irrigation practices. Irrigation in June, July and August was estimated at 1.6, 2.2 and 9.8 bg per month, 3.1, 11.7 and 7.2 bg less than the average. September's irrigation total was much higher at 17.0 bg, 7.8 bg higher than the monthly average of 9.2 bg. May and October were average. While September and October fall outside the time frame of the project year which ends August 31 of every year, the totals for September and October are included with the previous reporting year, as the data represents the conditions in that year, not the following year.

The monthly and seasonal estimates of irrigation withdrawals are shown in Table 3. These data were calculated by the Imperial Valley by evaluating power consumption at nearly 1100 irrigations systems in the area. The rank from highest to lowest irrigation amounts are shown in the right hand column in Table 3. Year 23 was somewhat low, ranking seventeenth overall with 31 bg pumped for the year. Typically, irrigation withdrawals are greatest in July and August, with September and June withdrawals being much lower as compared with July and August. That was not the case in 2015 as June, July and August proved to be the less heavily irrigated months due to above average precipitation, especially in June where over 13 inches of precipitation were observed over most of the study area. September's 17.0 billion gallons pumped is the fourth highest on record, though since all of the high September values have occurred since 2011, it could be that farming practices are changing in the area with more demand needed later in the summer.

The estimated monthly irrigation pumpage is displayed graphically in Figure 23 along with average monthly network precipitation. These pumpage values show a tendency for lower irrigation amounts during times of increasing precipitation and vice versa, but also show that irrigation is dependent on the timing of precipitation. Table 4 provides a comparison of rainfall and irrigation parameters showing their overall relationship. In Year 23, the timing and amount of rainfall received during the irrigation season (rather than annual precipitation) will always be the primary factors affecting the amount of irrigation.

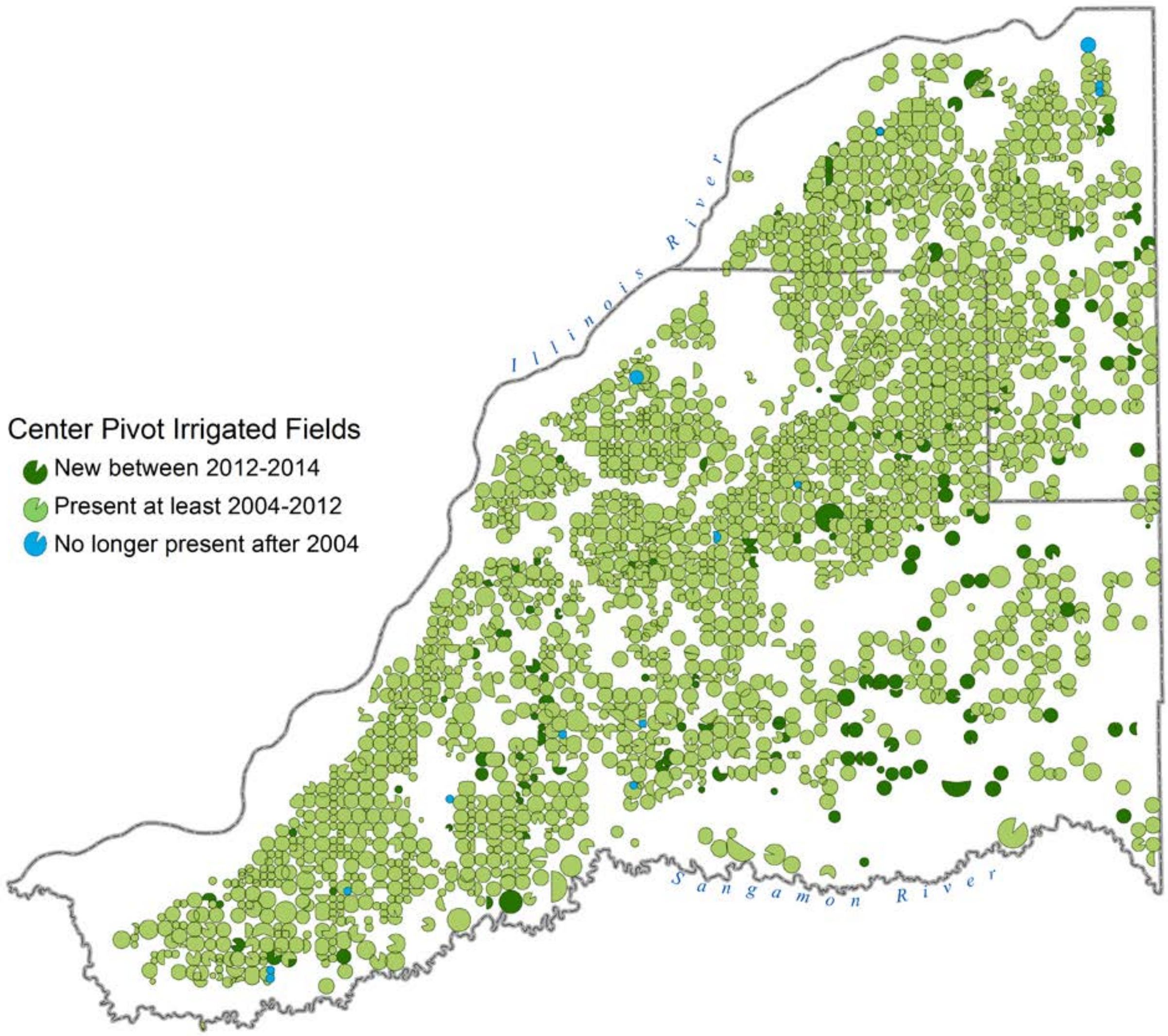


Figure 22. Location of Irrigation Systems within IVWA (2014).

Table 3. Estimated Monthly Irrigation Withdrawals (billion gallons), Number of Irrigation Systems, Withdrawal per System and Withdrawal Rank

Year	*May*	*June*	*July*	*August*	*September*	*October*	*Total #*	*Systems*	*BG/system*	*Rank*
1995		2.6	14	10	11		38			14
1996		2.0	20	18	12		52			5
1997		2.6	19	14	2.0		38			14
1998		2.1	7.8	13	6.9		30	1622	.018	18
1999		2.8	18	12	6.0		39	1771	.022	13
2000		6.4	6.0	12	5.6		30	1799	.017	18
2001		4.4	21	17	5.0		47	1818	.026	8
2002		3.4	24	16	3.7		47	1839	.026	8
2003		4.1	16	15	10		46	1867	.025	10
2004		5.3	12	19	5.7		42	1889	.022	12
2005		15	29	23	4.8		72	1909	.038	2
2006		7.2	22	16	5.2		50	1940	.026	7
2007		16	17	19	4.9		57	1971	.029	4
2008		1.2	10	14.5	7.1		33	2014	.016	16
2009		1.6	9.3	12.1	2.9		26	2054	.013	21
2010		1.8	2.4	11.7	10.6		27	2077	.013	20
2011		0.7	2.5	24.7	19.6	5.0	52	2100	.025	5
2012	0.1	12.3	26.4	39.7	17.4	2.2	98	2160	.045	1
2013	0.1	0.7	4.8	25.0	27.2	9.4	67	2293	.029	3
2014	0.1	4.7	9.2	16.3	8.2	1.1	40	2169*	.018	11
2015	0.1	1.6	2.2	9.8	17.0	0.9	31	2197	.014	17
Average	0.1	4.7	13.9	17.0	9.2	3.7	51.7		.023	

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. Also, the BG/system was rounded incorrectly for 2009 and should be .013. October data became available for 2011 and May data available for 2012. 2013 data was calculated erroneously in the previous report and has been corrected. . *Total number of system was updated during June 2014 by ISWS using aerial photography.

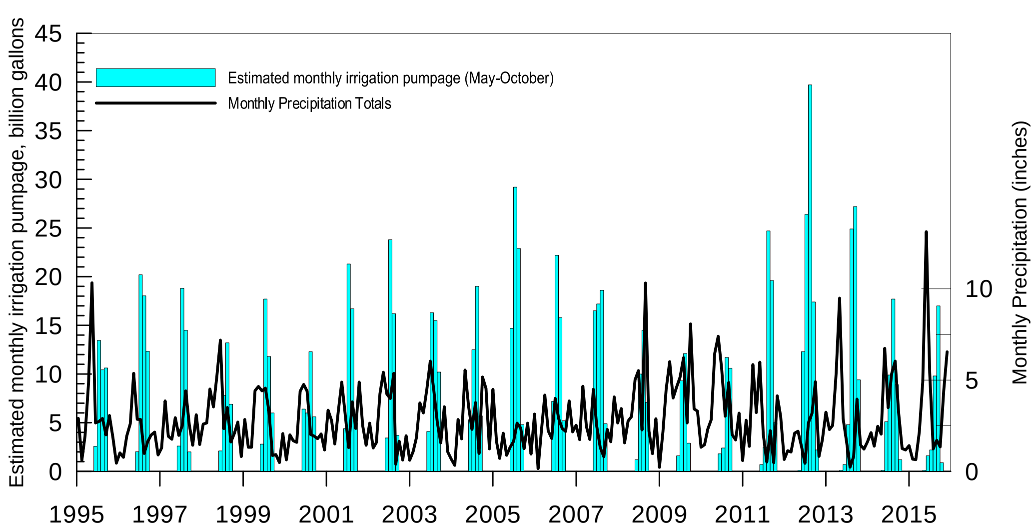


Figure 23. Estimated irrigation pumpage and average monthly precipitation, Imperial Valley

Table 4. Average Annual Precipitation, Annual Precipitation Surplus, Running Surplus, and Ranked Annual Precipitation and Irrigation, Imperial Valley Network

September-August period	*Network average precipitation (in.)*	*Annual surplus (in.)*	*Running surplus (in.)*	*Rank Precip.*	*Rank Irrigation*
1992 - 1993	**55.55**	**+17.17**	**+17.17**	**1**	**-**
1993 - 1994	**40.21**	**+1.83**	**+19.00**	**5**	**-**
1994 - 1995	**39.42**	**+1.04**	**+20.04**	**8**	**13**
1995 - 1996	**25.70**	**-12.68**	**+7.36**	**22**	**5**
1996 - 1997	**27.31**	**-11.07**	**-3.71**	**20**	**13**
1997 - 1998	**40.06**	**+1.68**	**-2.03**	**6**	**16**
1998 - 1999	**34.02**	**-4.36**	**-6.39**	**12**	**12**
1999 - 2000	**25.81**	**-12.57**	**-18.96**	**21**	**16**
2000 - 2001	**30.97**	**-7.41**	**-26.37**	**15**	**8**
2001 - 2002	**39.91**	**+1.53**	**-24.84**	**7**	**8**
2002 - 2003	**30.06**	**-8.32**	**-33.16**	**16**	**10**
2003 - 2004	**29.64**	**-8.74**	**-41.90**	**17**	**11**
2004 - 2005	**27.34**	**-11.04**	**-52.94**	**19**	**2**
2005 - 2006	**27.74**	**-10.64**	**-63.58**	**18**	**7**
2006 - 2007	**31.94**	**-6.44**	**-70.02**	**14**	**4**
2007 - 2008	**35.02**	**-3.36**	**-73.38**	**10**	**15**
2008 - 2009	**49.34**	**+10.96**	**-62.42**	**2**	**19**
2009 - 2010	**47.91**	**+9.53**	**-52.89**	**3**	**18**
2010 - 2011	**34.17**	**-4.21**	**-57.10**	**11**	**5**
2011 - 2012	**21.44**	**-16.94**	**-74.04**	**23**	**1**
2012 - 2013	**38.35**	**-0.03**	**-74.07**	**9**	**3**
2013 - 2014	**32.63**	**-5.75**	**-79.82**	**13**	**11**
2014 - 2015	**41.23**	**2.85**	**-76.97**	**4**	**17**
1981 - 2010 30-yr average	**39.80 (Havana)**				
1981 - 2010 30-yr average	**36.98 (Mason City)**				
1981 - 2010 30-yr average	**38.38 (average of Mason City and Havana used to determine surplus)**				
1993 - 2013 22-yr average	**34.75 (22-year IVWA network average)**				

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

Summary

During Year 23 of the rain gauge network operation (September 2014-August 2015), the network received an average of 41.23 inches of precipitation, 6.48 inches above the previous 22-year network average precipitation of 34.75 inches, and 2.85 inches above the 30-year average for the study area, 38.38 inches. Year 23 was the 4th wettest year since the deployment of the precipitation network. Fall was the 6th wettest fall, winter the third driest winter, spring the 7th driest spring, and summer was the wettest spring of the 23 years.

The data collected over the last 23 years as part of this project have been invaluable to the ISWS in developing a better understanding of the groundwater system in the Havana Lowlands, as well as the Mahomet Aquifer as a whole. What amazes many people who have looked at the data for the Havana Lowlands Region is the fact that water levels are basically unchanged from the

1960's even though there are now over 2000 irrigation systems in the region and in the early 1960's, there were less than 100.

The ISWS is grateful to the IVWA for their continued support of the rain gauge and observation well networks. Please contact Kevin Rennels, Steve Wilson or Nancy Westcott (Erin Bauer, after August 31, 2016) if you have any questions or comments.

Sincerely,

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Appendix A. Hydrographs, Imperial Valley Observation Well Network

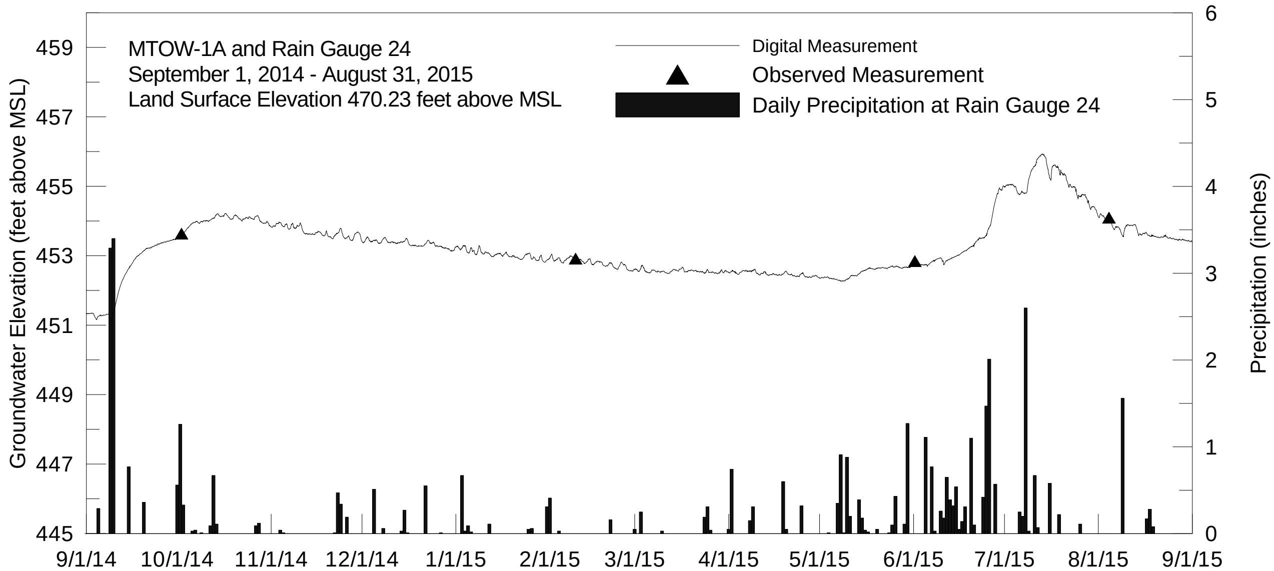

Figure A-1. Year 23 Groundwater depth and precipitation for MTOW-01A

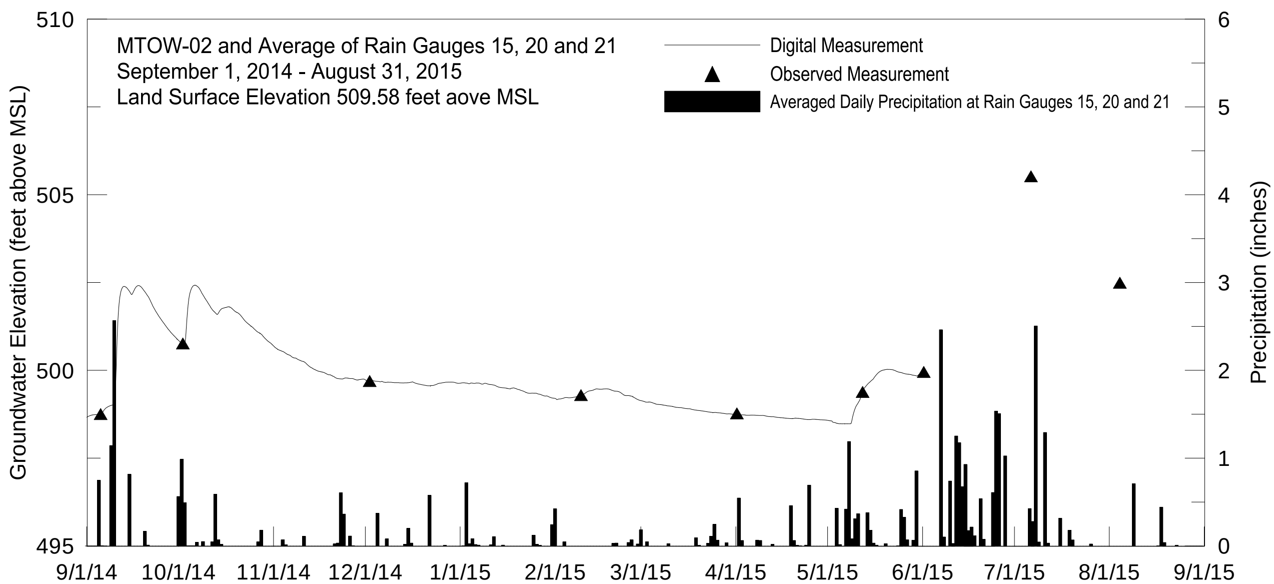

Figure A-2. Year 23 Groundwater depth and precipitation for MTOW-02

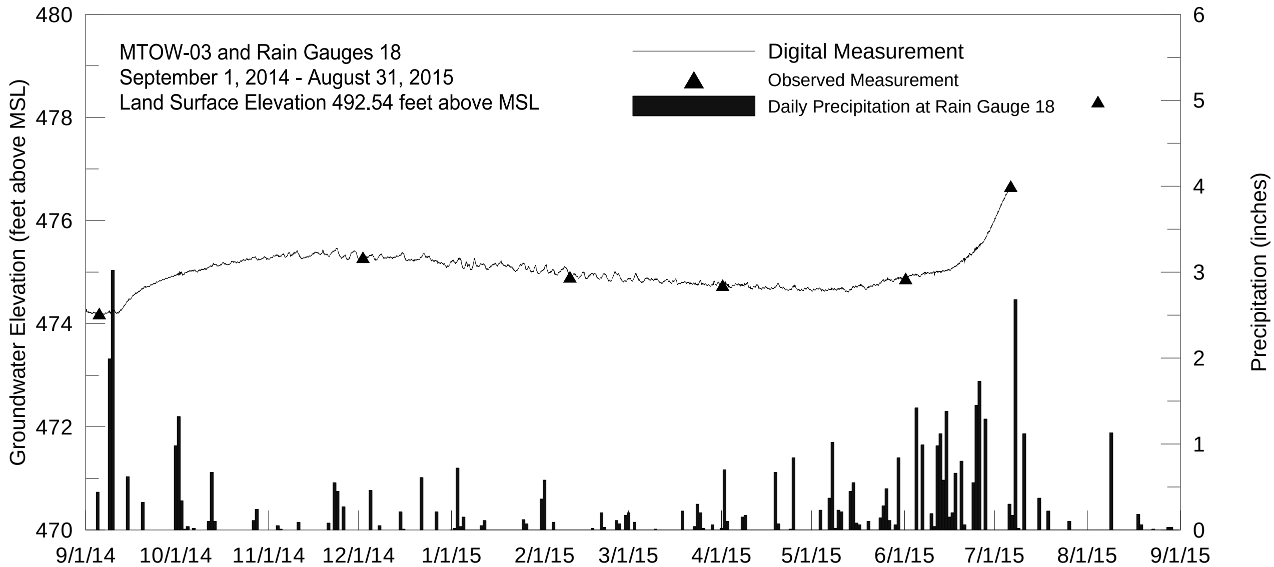

Figure A-3. Year 23 Groundwater depth and precipitation for MTOW-03

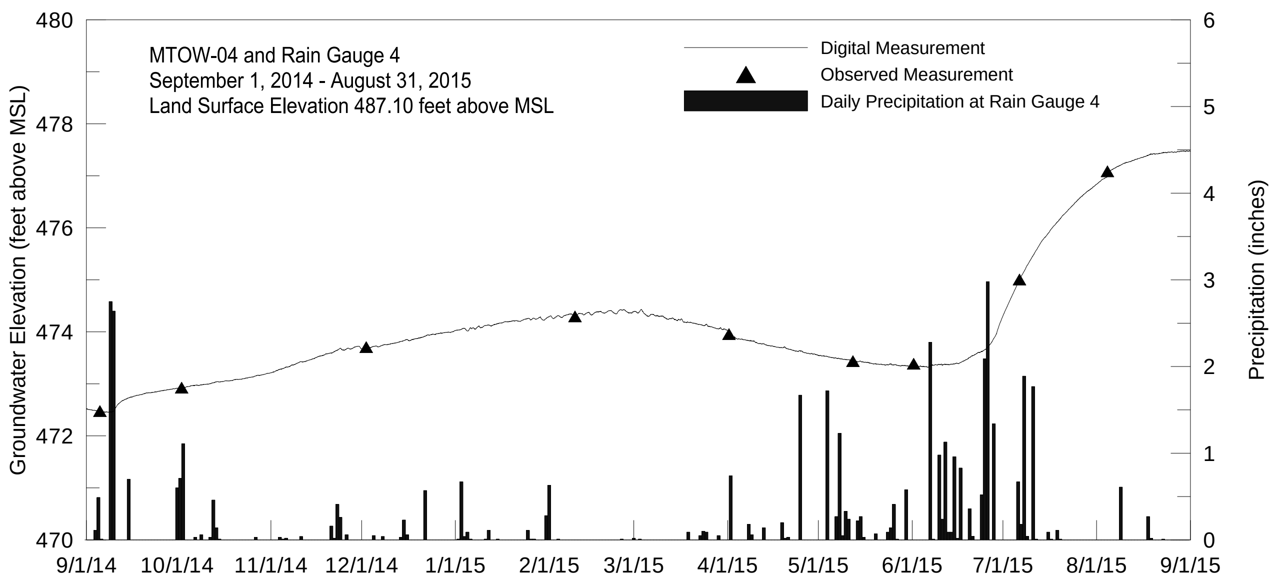

Figure A-4. Year 23 Groundwater elevation and precipitation for MTOW-04

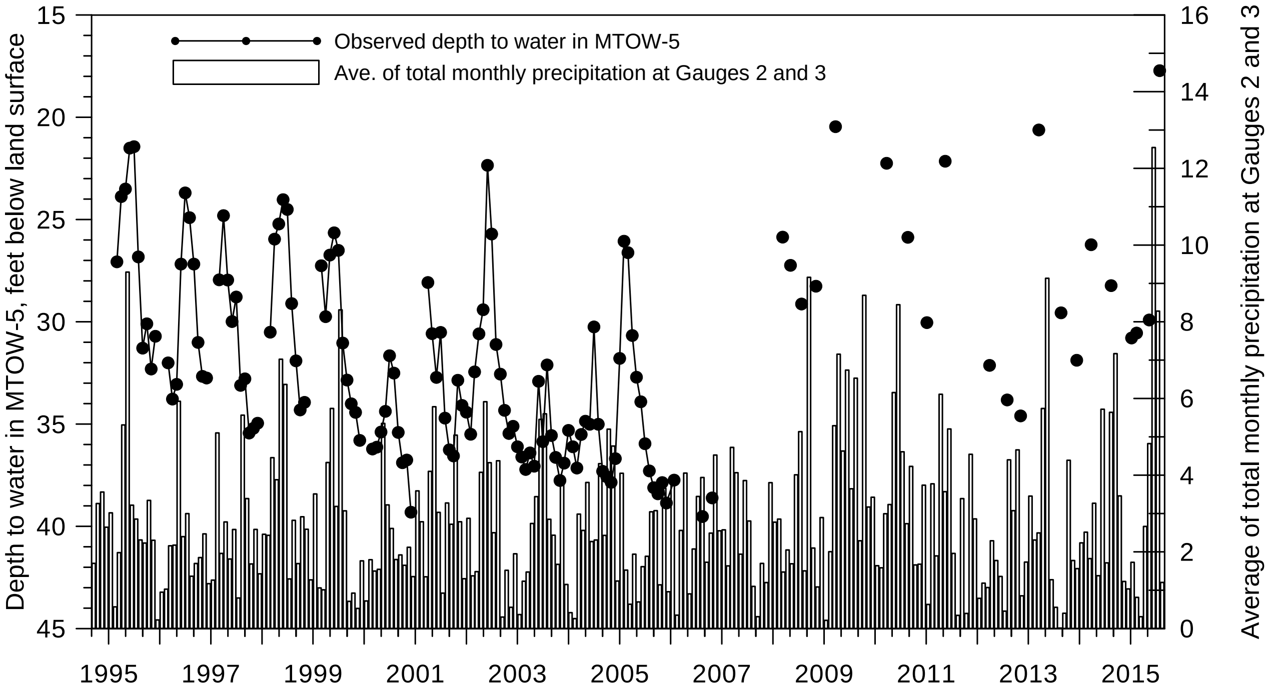

Figure A-5. Year 23 Groundwater depth and precipitation for MTOW-05 (not continuous recorder)

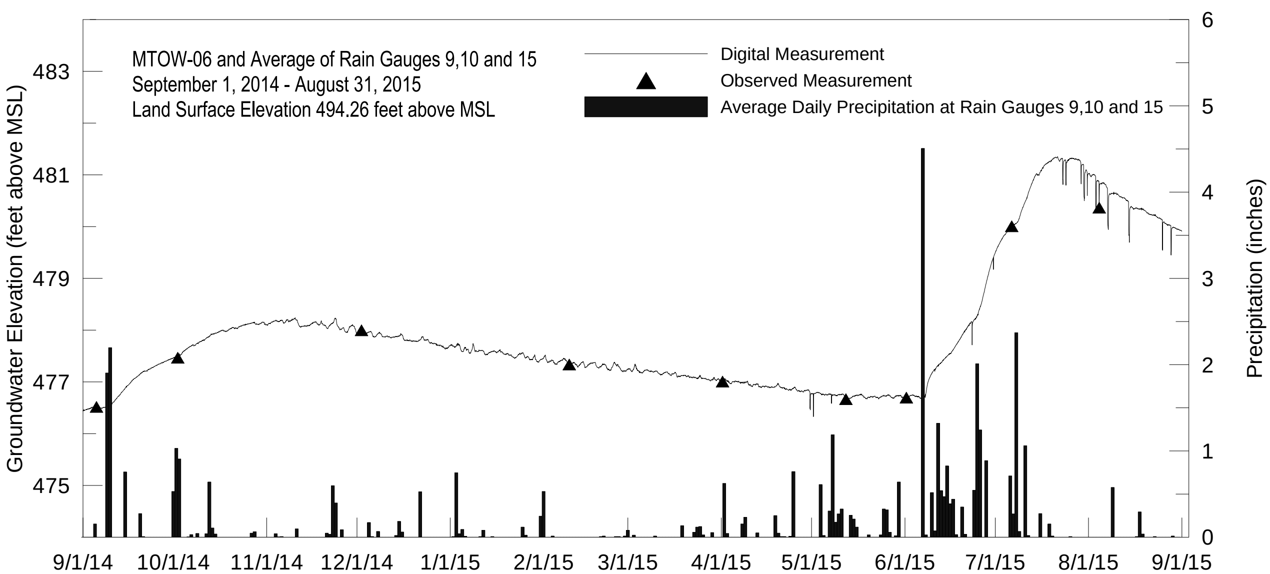

Figure A-6. Year 23 Groundwater elevation and precipitation for MTOW-06

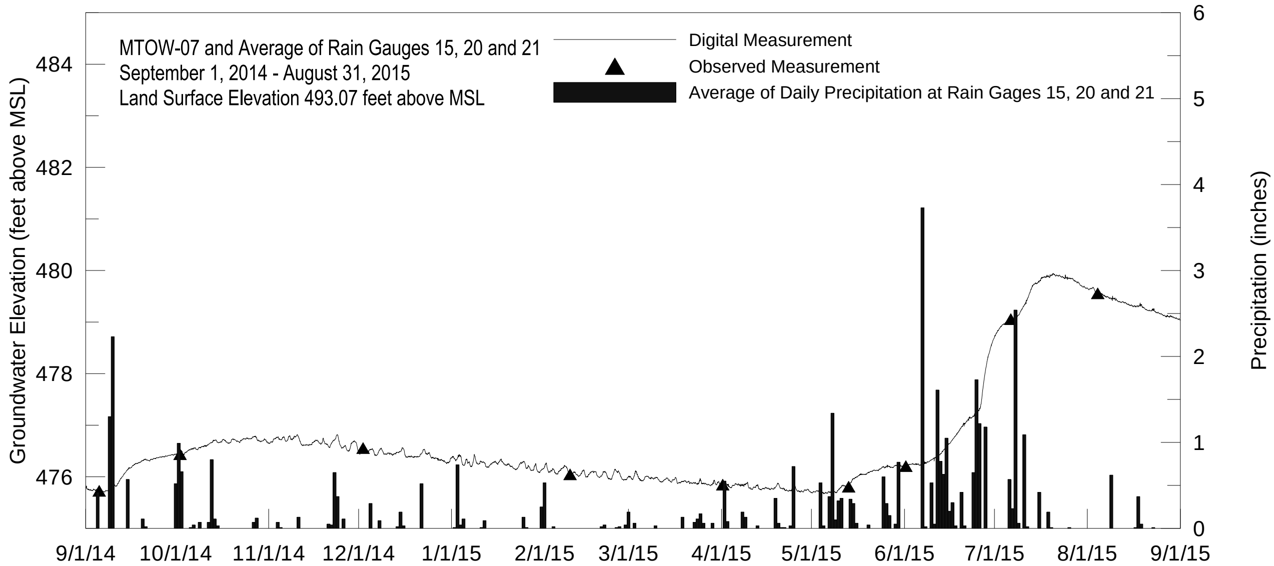

Figure A-7. Year 23 Groundwater elevation and precipitation for MTOW-07

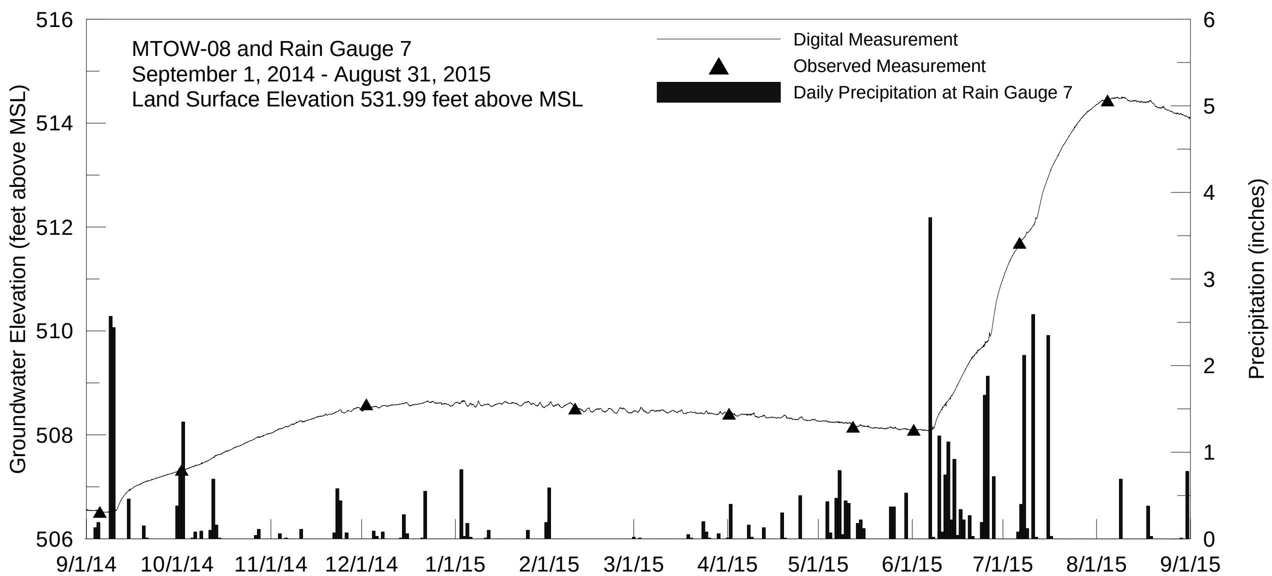

Figure A-8. Year 23 Groundwater elevation and precipitation for MTOW-08

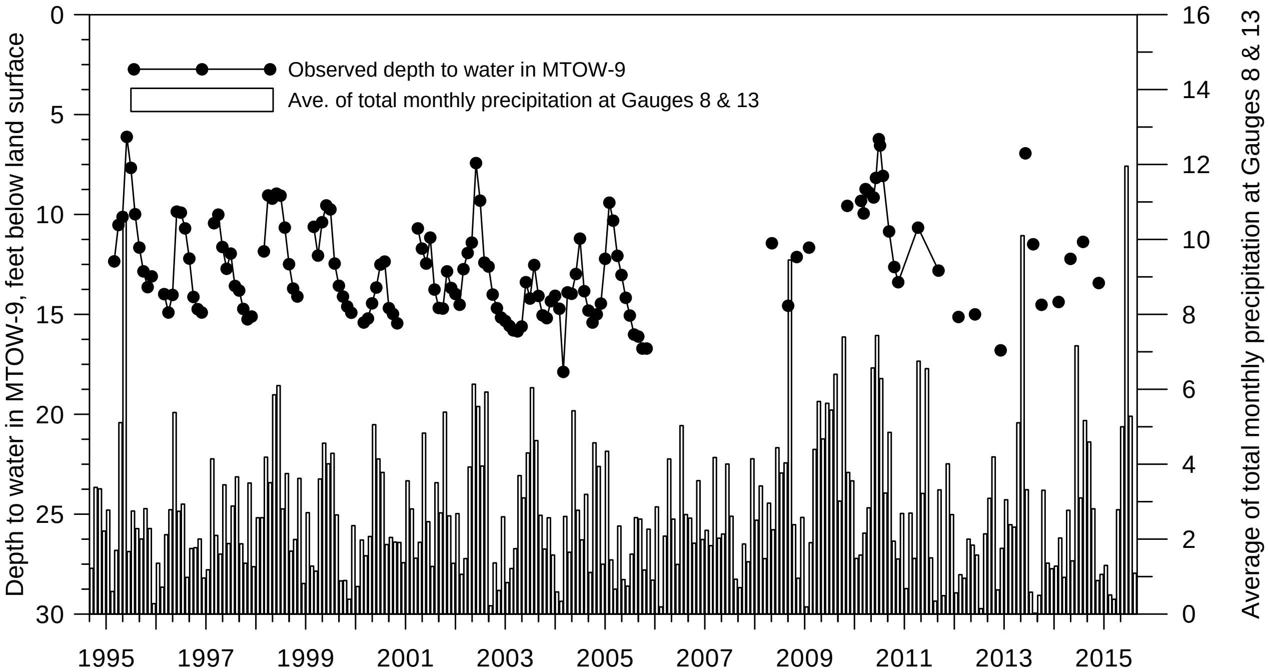

Figure A-9. Year 23 Groundwater depth and precipitation for MTOW-09 (not continuous recorder)

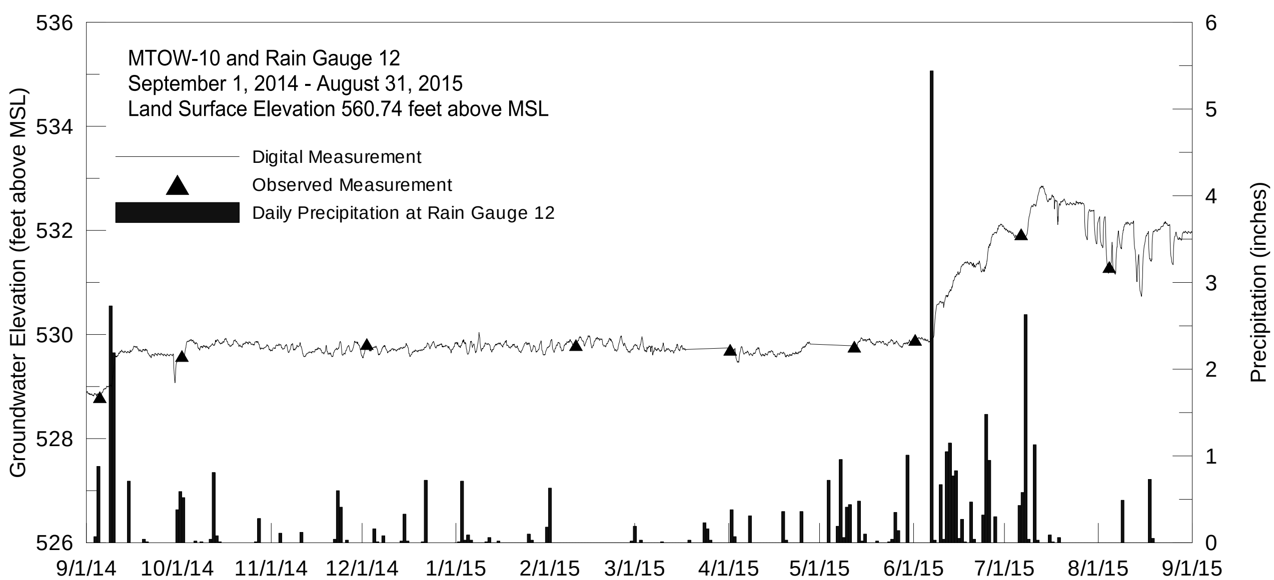

Figure A-10. Year 23 Groundwater depth and precipitation for MTOW-10

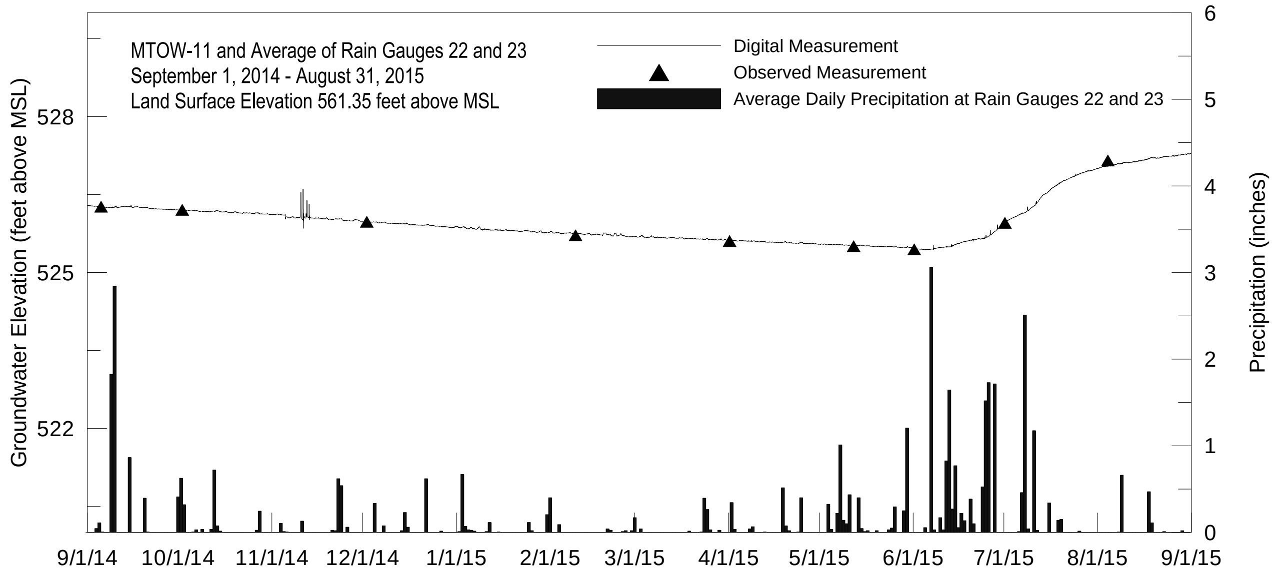

Figure A-11. Year 23 Groundwater elevation and precipitation for MTOW-11

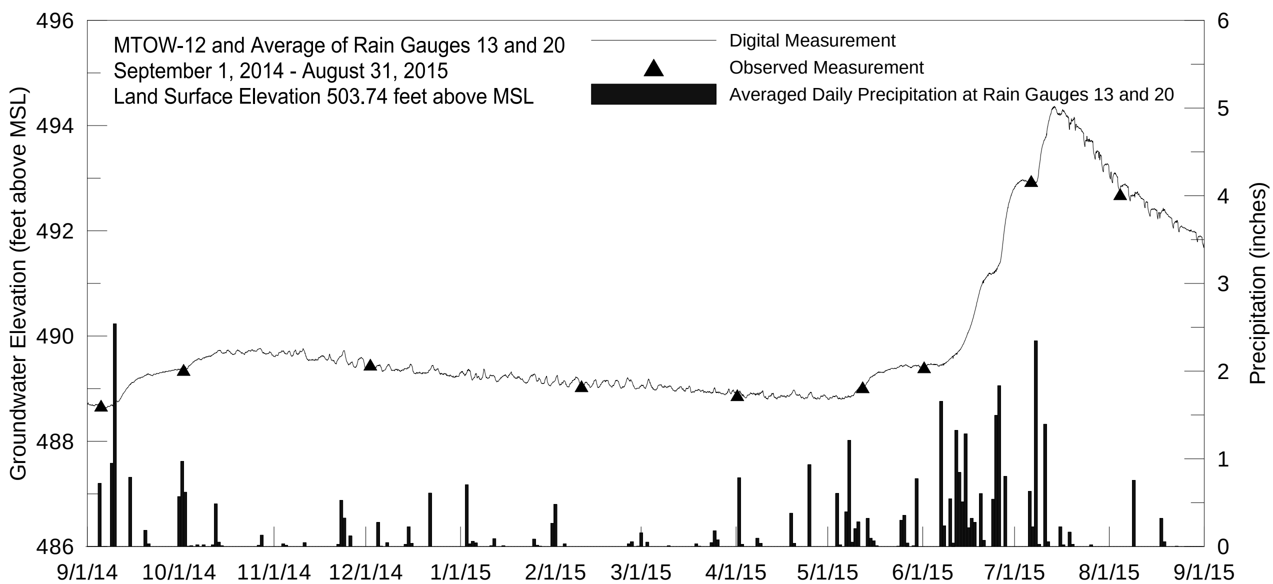

Figure A-12. Year 23 Groundwater elevation and precipitation for MTOW-12

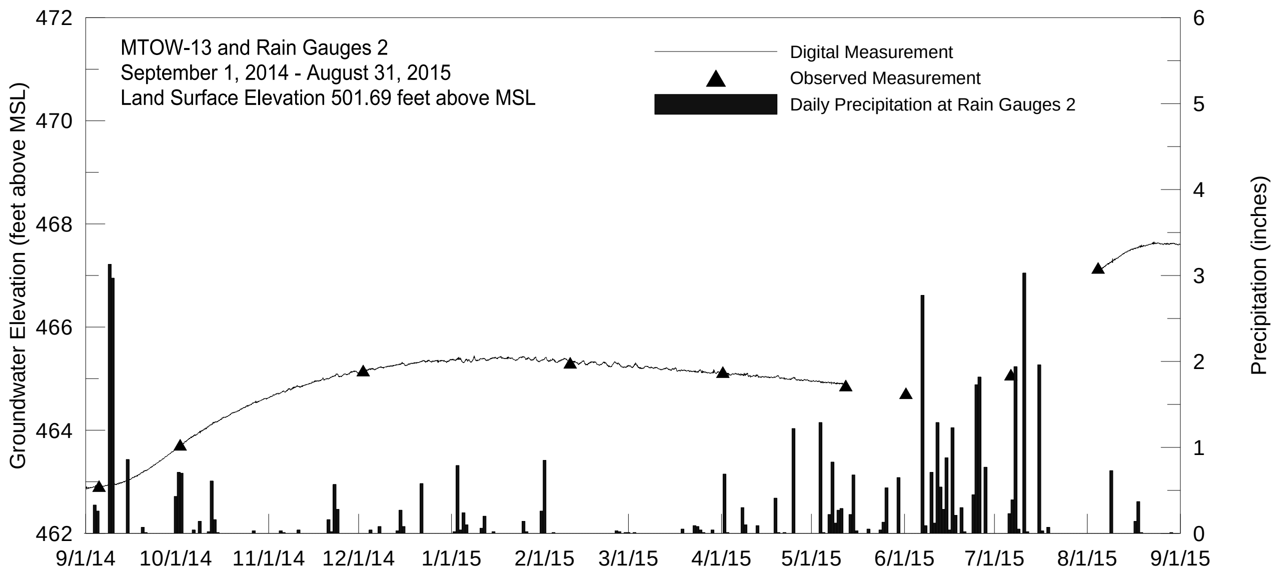

Figure A-13. Year 23 Groundwater depth and precipitation for MTOW-13

Appendix B. Depth to Water Within Newly Constructed Observation Wells at Mason City and Ellsberry Lake

Well Number	*Well Name*	*12/2/2014*	*2/9/2015*	*4/1/2015*	*5/12/2015*	*6/1/2015*	*7/6/2015*	*8/4/2015*
MTOW-14	*Mason City Deep*	*44.35*	*43.33*	*43.41*	*43.54*	*43.46*	*42.49*	*43.51*
MTOW-15A	*Ellsberry Lake Deep*	*47.67*	*49.14*	*49.36*	*49.45*	*NA*	*48.39*	*40.05*
MTOW-15B	*Ellsberry Lake Shallow*	*Dry*	*Dry*	*Dry*	*Dry*	*NA*	*Dry*	*40.35*

Note:

All depth to water measurements are from land surface and feet to water.