ILLINOIS STATE
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February 12, 2013

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 during the growing season, and the rate at which the aquifer recharges. This letter serves as the year end report for Year 21 which covers the time period from September 1, 2012 through August 31, 2013.

The groundwater observation well network consists of thirteen wells, MTOW-01 through MTOW-13. The observation wells are drilled wells between 2 and 6 inches in diameter. With the exception of MTOW-05 and MTOW-09, these wells are equipped with pressure transducers that electronically log the groundwater level data.

In Year 15, a new well was drilled to replace MTOW-1. This new well, named Snicarte #2, or MTOW-1A has taken the place of the original well (MTOW-01 or Snicarte #1) within the monitoring well network.

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 is maintained by a Mason County resident, Bob Ranson, hired to visit each of the sites monthly. During these visits the charts are changed, data downloaded and other routine services performed. Champaign-based ISWS personnel visit the rain gauge network to perform major maintenance and repairs as needed.

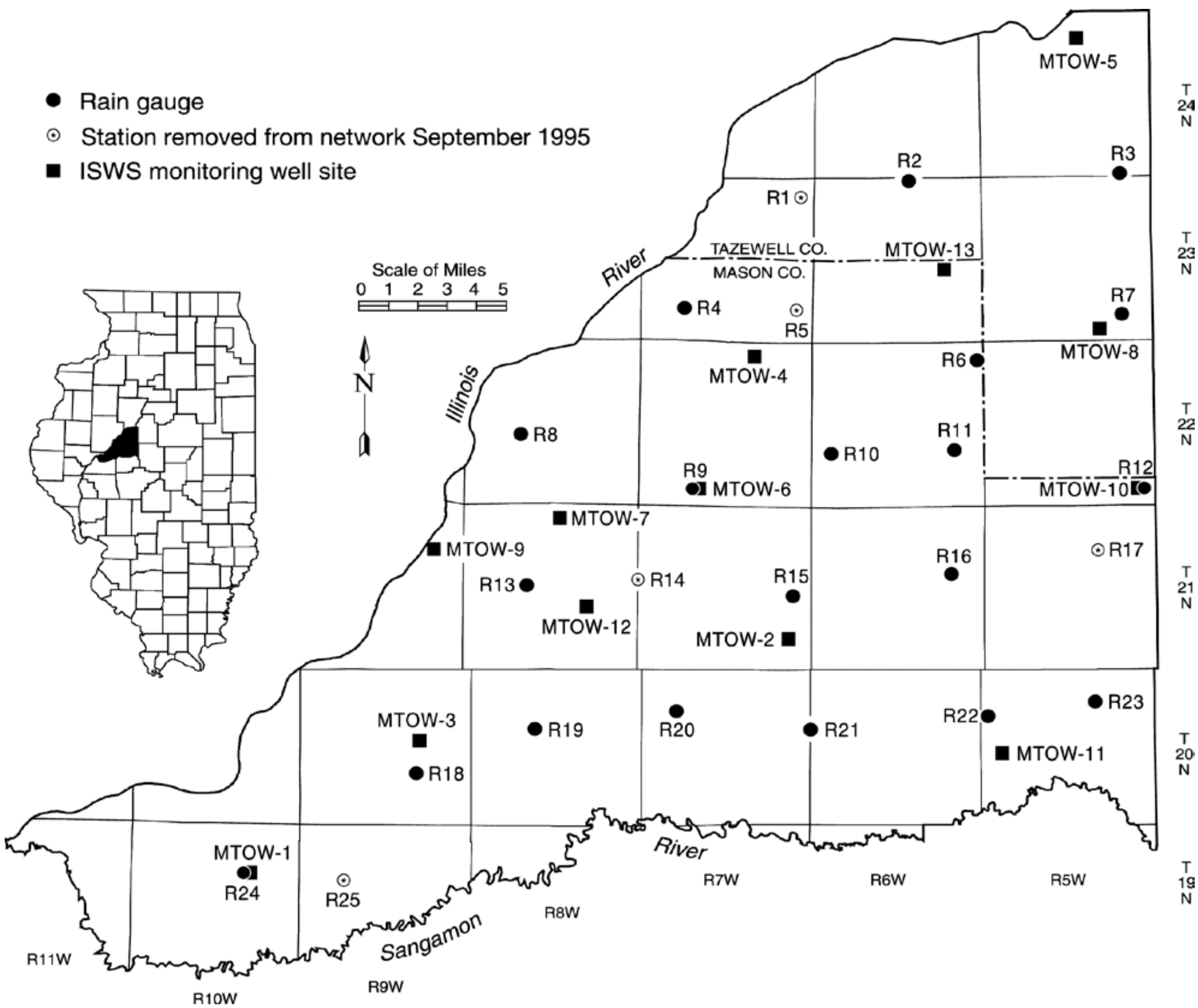

Figure 1. Configuration of the 13-site observation well and 25-site rain gauge networks.

Data reduction activities during Year Twenty One of network operation are similar to those performed during the previous twenty 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 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 levels for each well for the period of record (September 1, 2012-August 31, 2013) 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 stream gage 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 Twenty One 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 21 network precipitation of 38.35 inches was 3.67 inches above the previous 20-year's average of 34.68 inches. Overall, Year 21 was the eighth wettest in the 21 years of network operation. The summer was the second driest, second only to 2012, and spring the second wettest (1994-1995 wettest) of 21 years. Table 1 gives the monthly precipitation totals for each rain gauge within the network during Year 21.

Figure 2 presents the 21-year network average, and Figure 3 presents the annual precipitation pattern for Year 21. During Year 21, annual gauge totals varied from 31.05 inches at site 3 to 48.97 inches at site 19 (Figure 3). Eleven-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 gage exposure to the wind or by measurement errors. Gages that are overly sheltered (Site 8), or with little or no shelter from the wind (most of the gage sites) can underestimate precipitation under strong wind conditions.

October 2012, January 2013, April 2013 and May 2013 received precipitation more than 1 inch above the monthly network average during Year 21. November 2012, June 2013, July 2013 and August 2013 received precipitation that was at least 1 inch below the network average (Figures 4-9). The network received 17.20 inches less precipitation than in the wettest year (1992-1993), and 16.91 inches more than the driest year (2011-2012) of the 21 years of network observations. Although the annual total was fairly average, there were extreme differences between the spring and summer months, ranging from 5.42 inches above average in May 2013 to 3.05 inches below average in August 2013.

Table 1. Monthly Precipitation Amounts (inches), September 2012-August 2013

						Month							
Station	***Sep***	***Oct***	***Nov***	***Dec***	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Total***
2	3.55	4.48	0.82	2.05	3.59	3.04	3.01	6.19	10.42	1.89	0.49	0.03	39.56
3	2.60	4.84	0.89	1.42	3.32	1.58	1.98	5.29	7.85	0.66	0.62	0.00	31.05
4	4.75	3.86	0.82	1.58	3.20	2.22	2.44	6.21	9.53	2.24	1.45	0.00	38.30
6	2.87	5.22	1.08	1.41	4.02	1.58	2.11	4.98	9.38	3.25	1.40	0.28	37.58
7	3.04	4.98	0.95	1.27	3.02	2.14	2.14	5.17	8.87	1.73	0.57	1.69	35.57
8	3.53	3.79	0.53	1.59	2.90	2.21	2.06	4.81	10.21	2.66	0.86	0.02	35.17
9	2.71	4.98	0.87	1.80	3.74	2.42	2.76	5.35	10.74	4.17	0.90	0.02	40.46
10	3.69	4.72	0.89	1.43	3.64	2.00	2.15	5.01	8.72	3.75	1.42	0.94	38.36
11	2.91	4.59	1.00	1.52	3.57	1.66	2.39	4.55	9.43	2.63	0.50	0.15	34.90
12	3.49	4.69	0.86	1.59	2.69	2.07	2.46	6.19	8.29	5.07	1.21	0.56	39.17
13	2.65	4.60	0.76	1.92	3.20	2.56	2.58	4.97	9.99	3.98	0.31	0.03	37.55
15	3.02	4.88	0.81	1.57	4.01	2.29	2.16	5.88	9.30	2.38	2.26	0.05	38.61
16	3.01	4.45	0.85	1.74	2.66	2.10	2.03	4.71	8.35	2.46	2.09	0.02	34.47
18	3.14	6.15	0.79	2.18	3.33	3.31	3.28	6.75	11.69	4.98	3.23	0.14	48.97
19	3.11	5.36	0.94	2.05	3.32	3.07	3.33	6.09	11.47	3.66	1.55	0.07	44.02
20	3.22	5.25	0.87	1.60	3.58	2.09	2.49	5.55	10.29	2.09	0.47	0.06	37.56
21	3.11	6.01	1.02	1.67	3.13	3.12	3.21	5.31	9.04	1.08	3.16	0.02	39.88
22	3.35	5.61	0.79	1.69	2.55	1.86	2.11	4.57	7.66	2.25	2.70	0.09	35.23
23	3.74	4.55	0.90	2.21	2.69	1.91	2.90	4.04	6.55	3.38	2.35	0.03	35.25
24	2.05	5.28	0.79	2.24	2.73	2.52	2.72	5.91	12.03	3.52	5.14	0.49	45.42
Avg	3.18	4.91	0.86	1.73	3.24	2.29	2.52	5.38	9.49	2.89	1.63	0.23	38.35

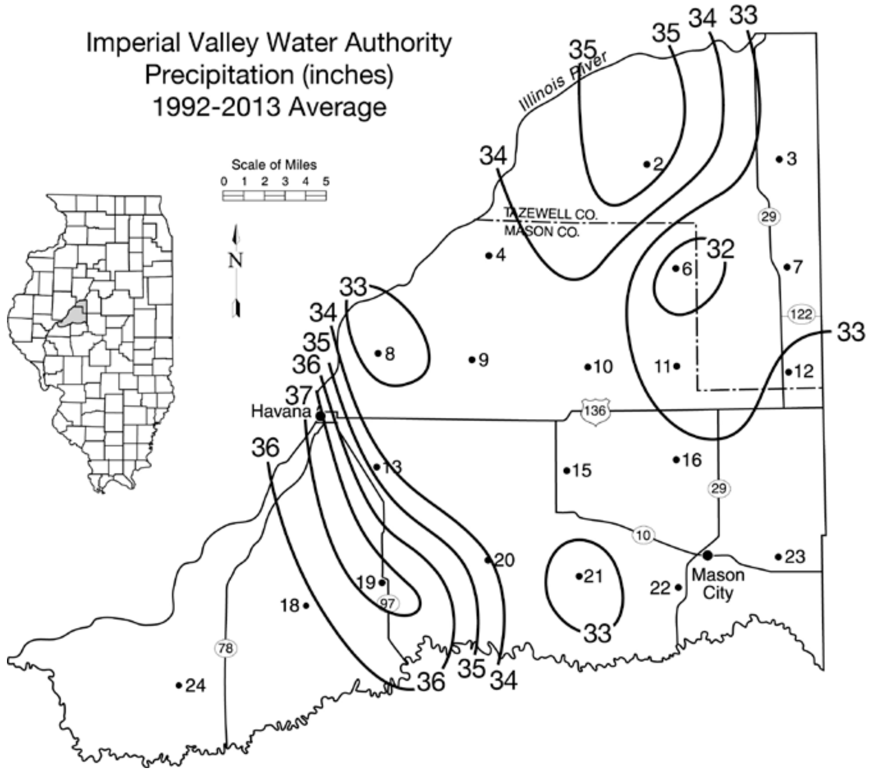

Figure 2. Network average annual precipitation (inches) for September 1993 - August 2013

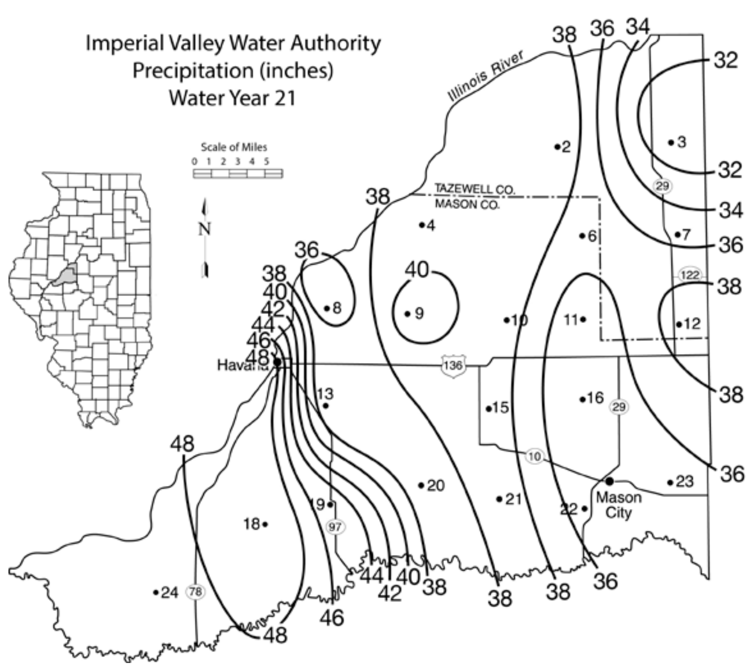

Figure 3. Total precipitation (inches) for September 2012- August 2013

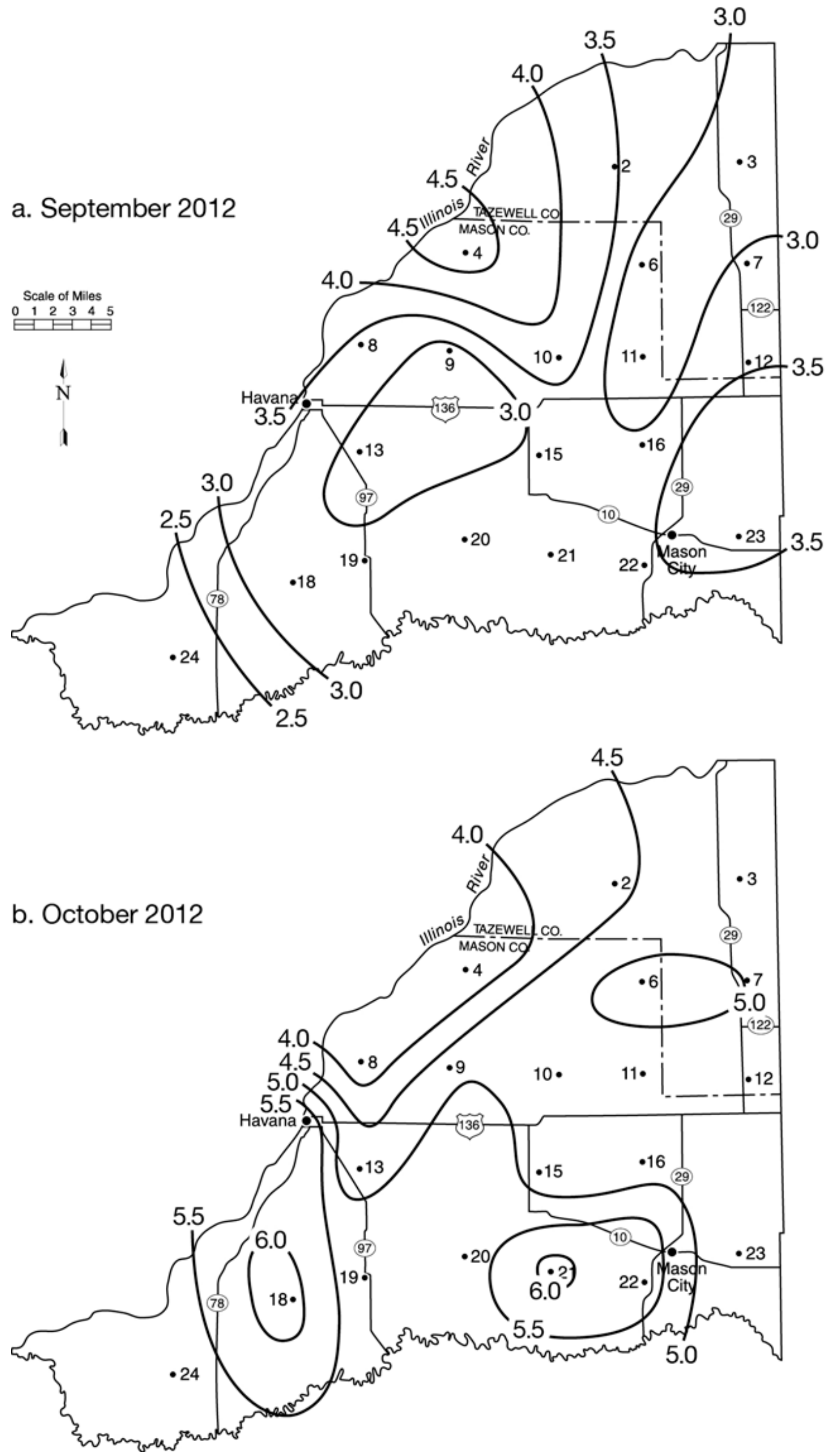

Figure 4. Precipitation (inches) for September 2012 and October 2012

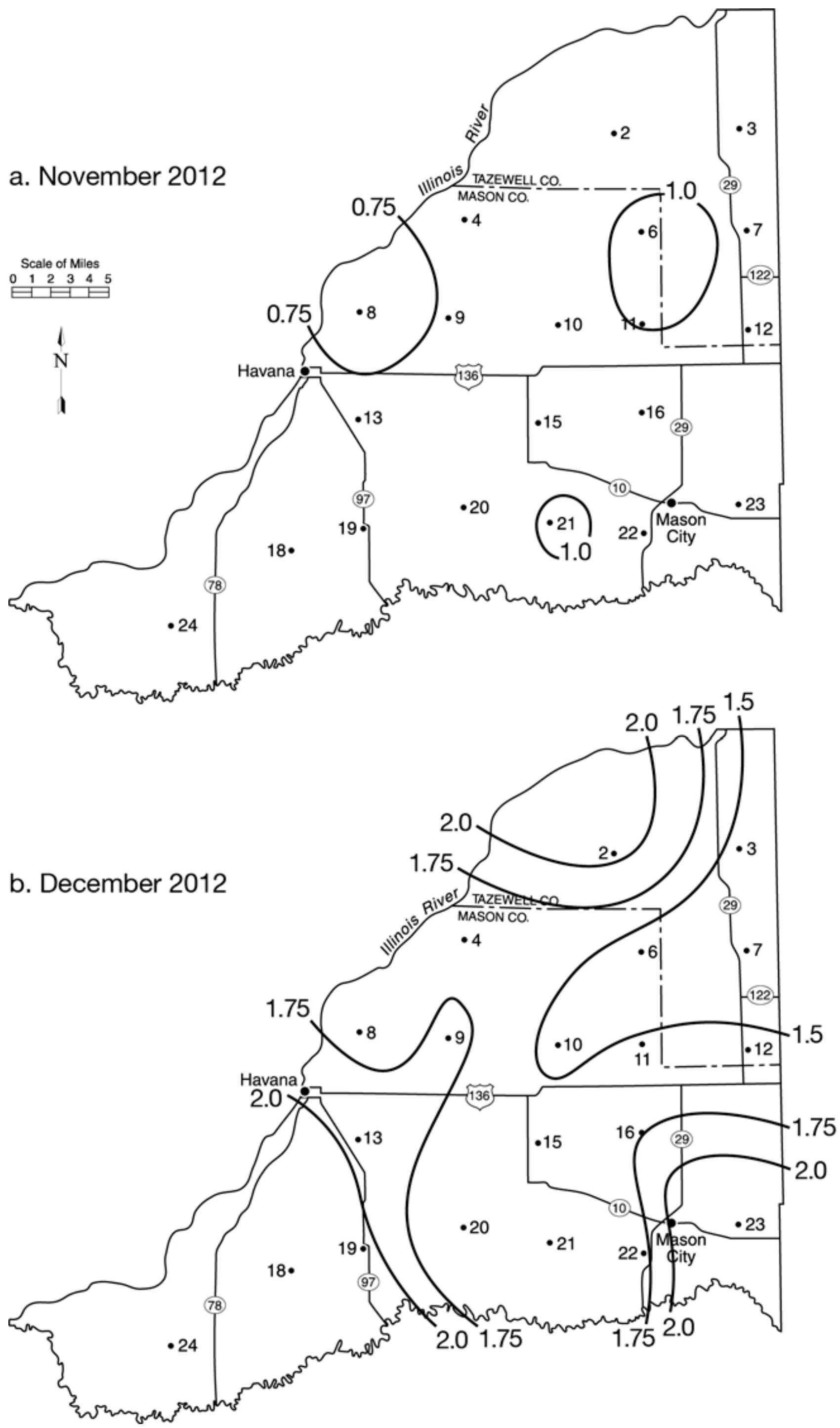

Figure 5. Precipitation (inches) for November 2012 and December 2012

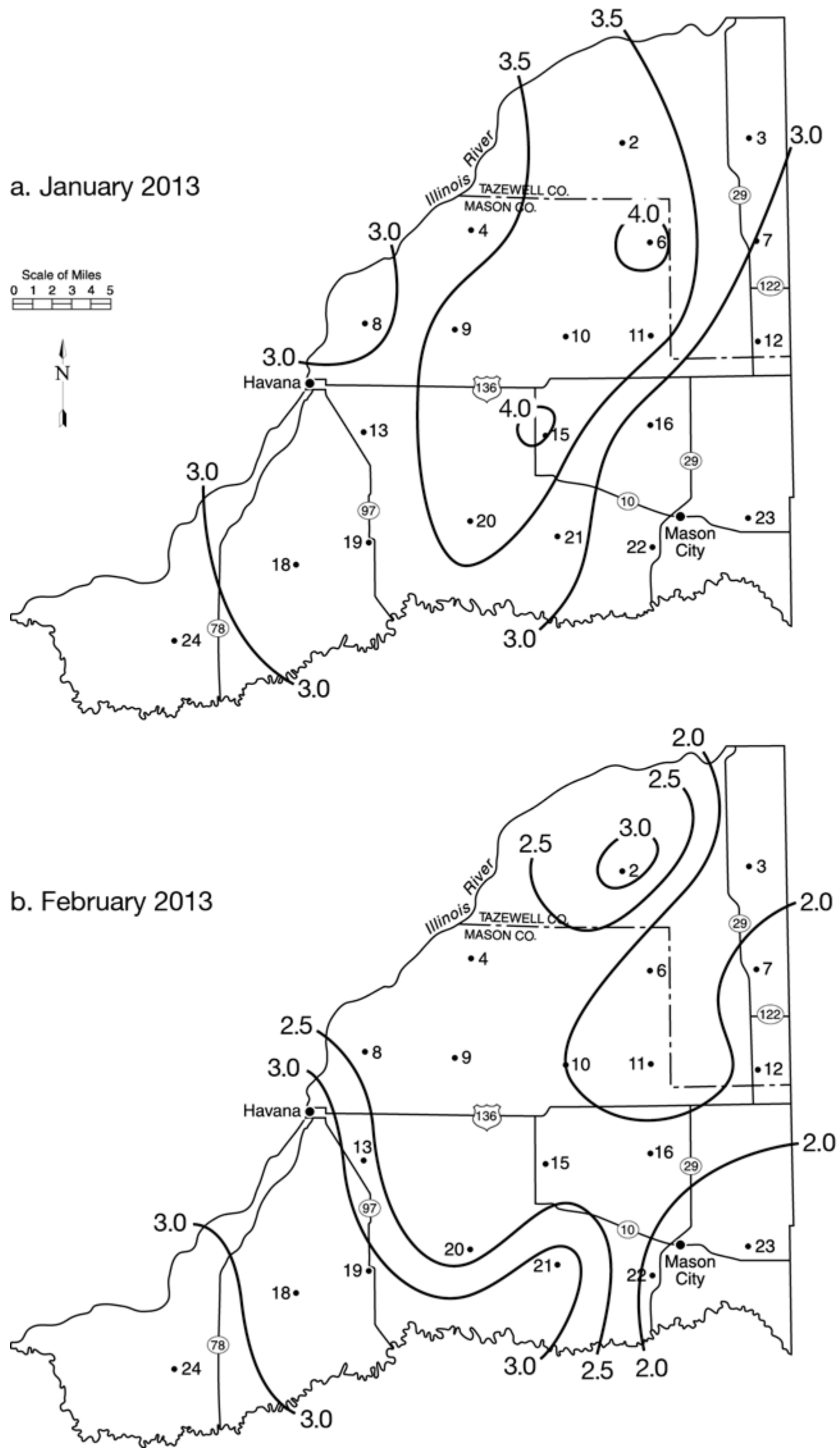

Figure 6. Precipitation (inches) for January 2013 and February 2013

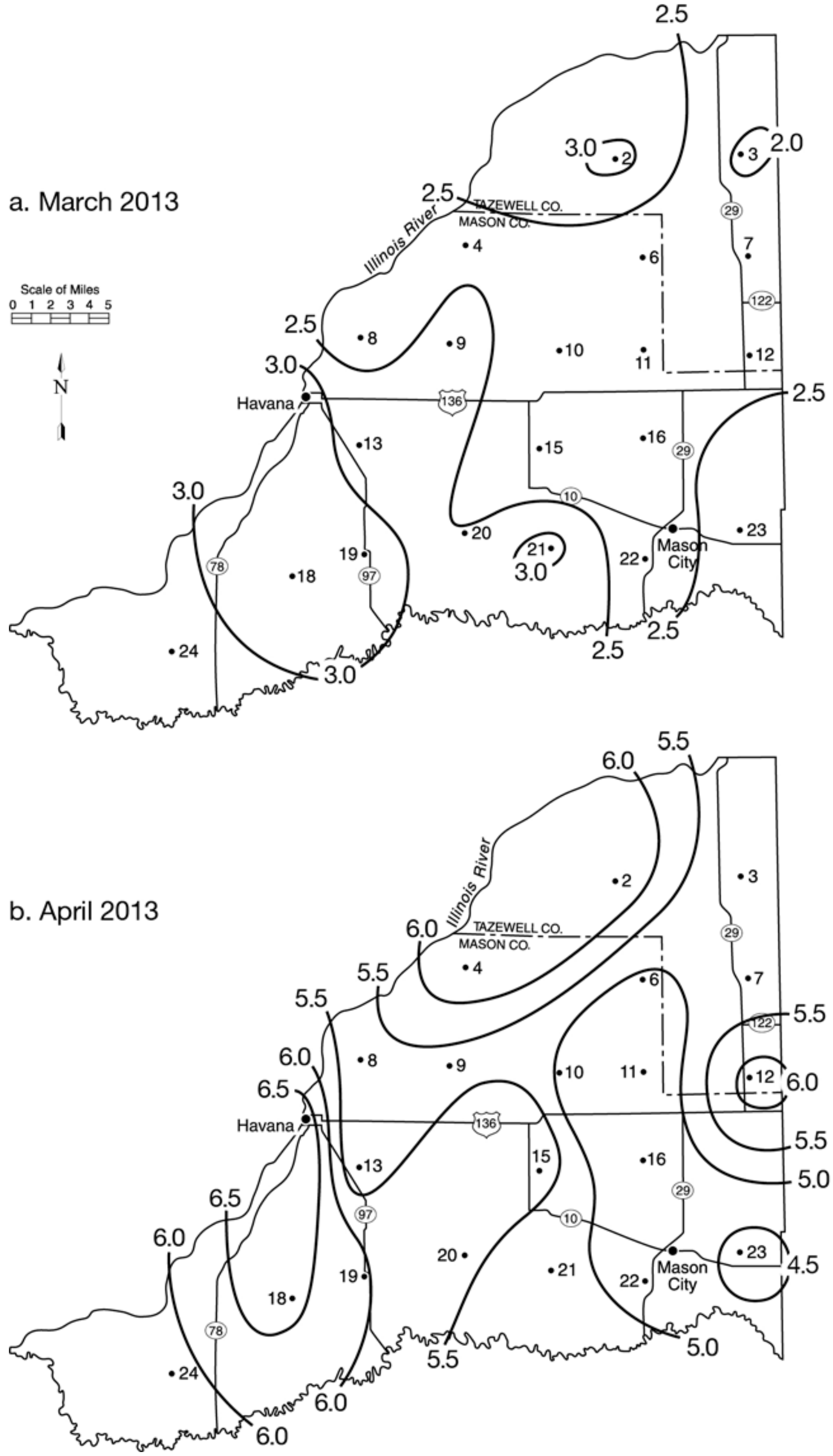

Figure 7. Precipitation (inches) for March 2013 and April 2013

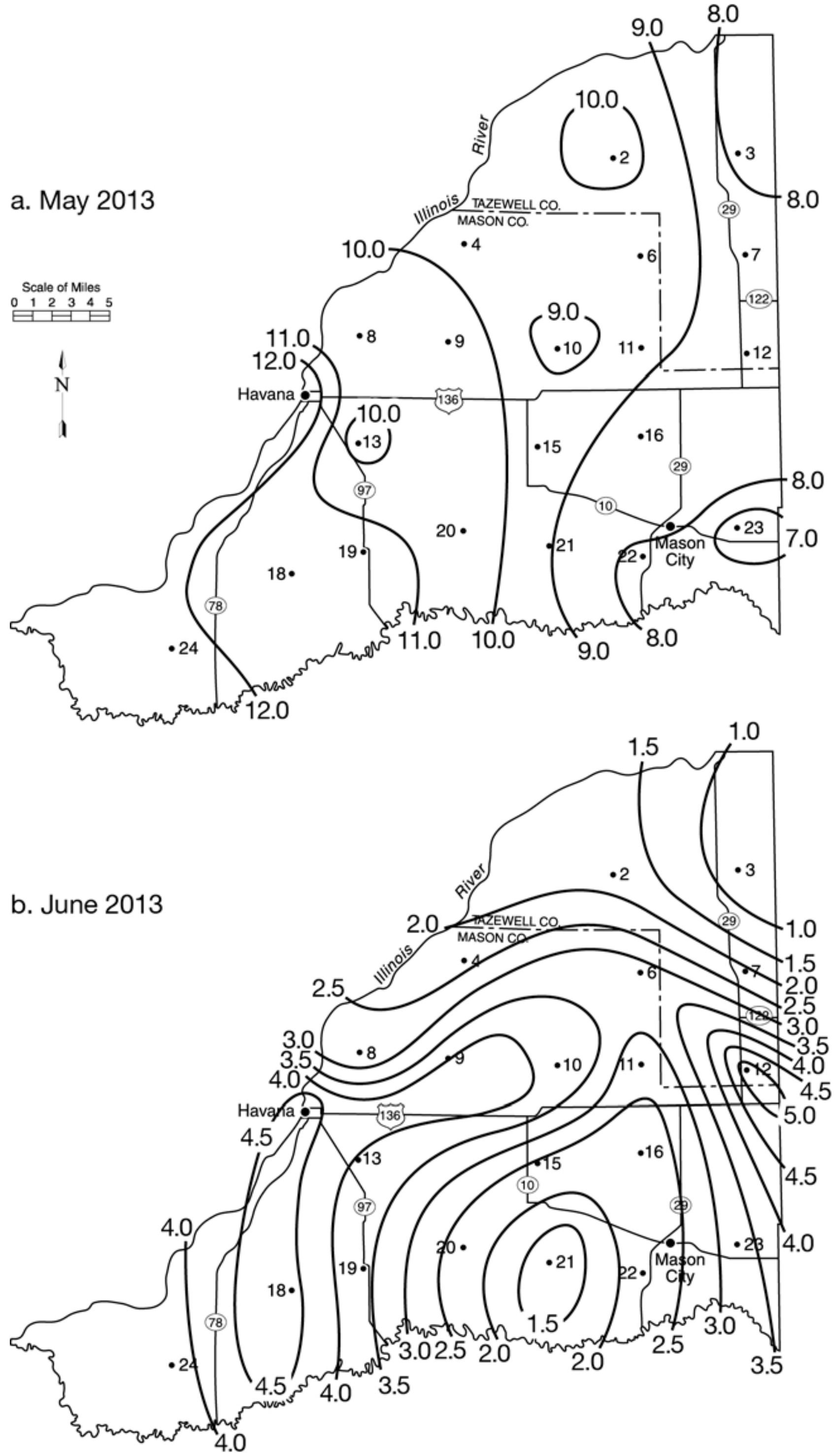

Figure 8. Precipitation (inches) for May 2013 and June 2013

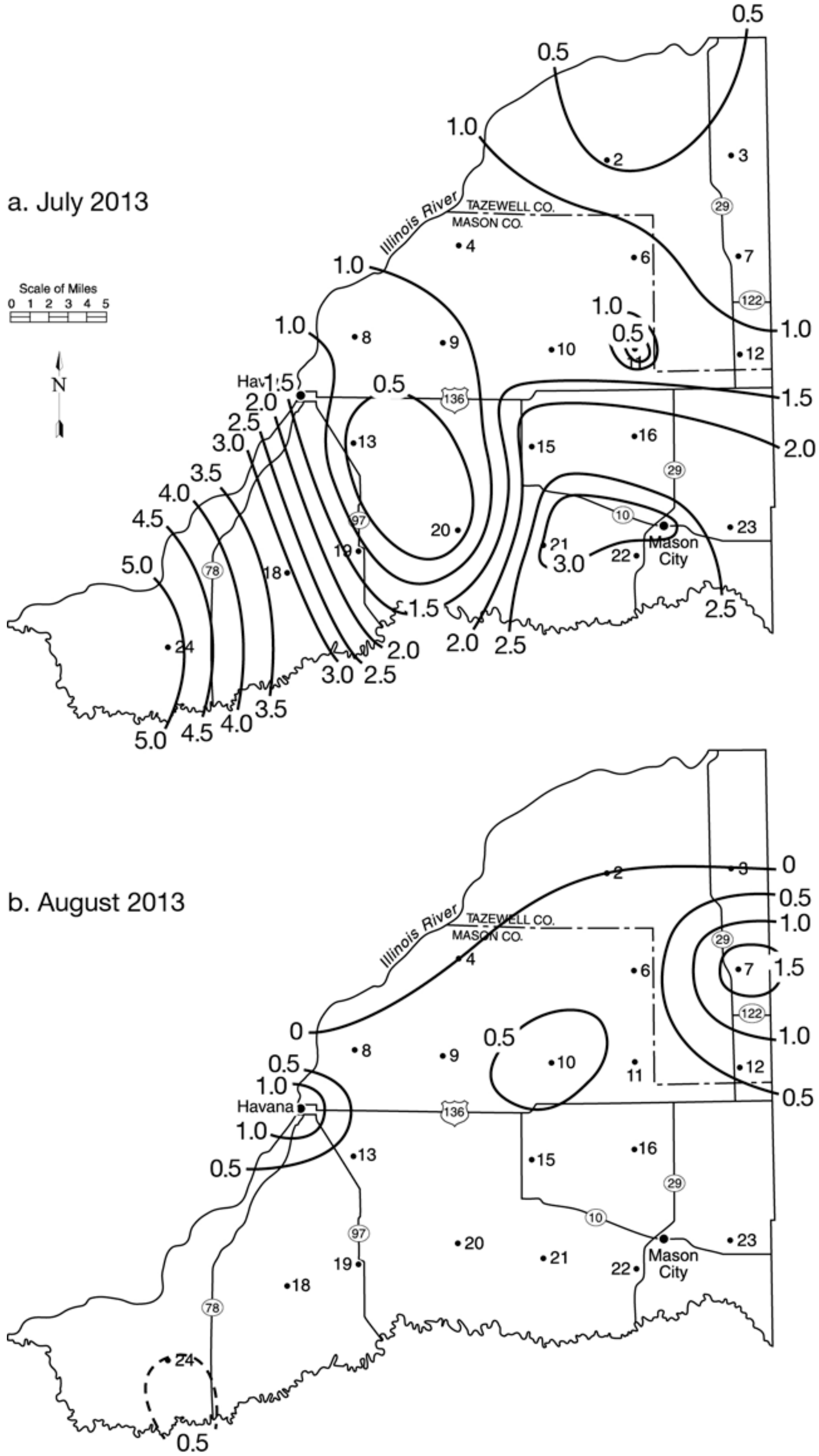

Figure 9. Precipitation (inches) for July 2013 and August 2013

Table 2. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event for Each Month and Season, 1993-2012 and 2012-2013

	1993-2012 20-yr average			*2012-2013 average*		
Period	***Precipitation***	***Events***	***Inches/event***	***Precipitation***	***Events***	***Inches/event***
Sep	2.99	7.6	0.40	3.18	9	0.35
Oct	2.57	8.7	0.30	4.91	10	0.49
Nov	2.71	9.0	0.30	0.86	8	0.11
Dec	1.92	9.5	0.20	1.73	12	0.14
Jan	1.93	9.1	0.21	3.24	6	0.54
Feb	1.73	8.2	0.21	2.29	7	0.33
Mar	2.21	8.5	0.26	2.52	9	0.28
Apr	3.52	11.2	0.32	5.38	12	0.45
May	4.07	13.5	0.30	9.49	11	0.86
Jun	4.03	12.1	0.33	2.89	10	0.29
Jul	3.72	10.7	0.35	1.63	9	0.18
Aug	3.28	11.7	0.28	0.23	6	0.04
Fall	8.27	25.2	0.33	8.95	27	0.33
Winter	5.57	26.7	0.21	7.26	25	0.29
Spring	9.80	33.1	0.30	17.39	32	0.54
Summer	11.04	34.5	0.32	4.75	25	0.19
Annual	34.68	119.5	0.29	38.35	109	0.35

The number of network precipitation periods was determined for the previous 20-year period. Mean monthly, seasonal, and annual number of precipitation events are presented for 2012-2013 (Table 2). The monthly, seasonal, and annual numbers of precipitation events averaged over the 1993-2012 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.

A total of 2,499 storm periods occurred during the 21-year observation period, resulting in an average of 119 storm events per year. During Year 21, there were 109 precipitation events. Fewer events than average occurred in November 2012, January 2013, February 2013, and May 2013 through August 2013. A greater number of events than average occurred in September, October and December 2012. The summer in particular had many fewer events than average (25 vs 34.5), and the amount of precipitation per event was much lower than average for the summer season (0.19 vs 0.32). The number of spring events was near average (32 vs 33.1), but the amount of rain per event was much higher than average (0.54 vs 0.30).

The plot of the network average monthly precipitation time series (Figure 10) beginning in September 2007 shows the monthly variation of precipitation. The continuation of a very dry period when only six months had precipitation of greater than 3.0 inches that began in February 2005 through May 2008 is evident. June 2008 through June 2011 was wetter, with 15 months receiving 4.5 inches of precipitation or greater. 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, 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.

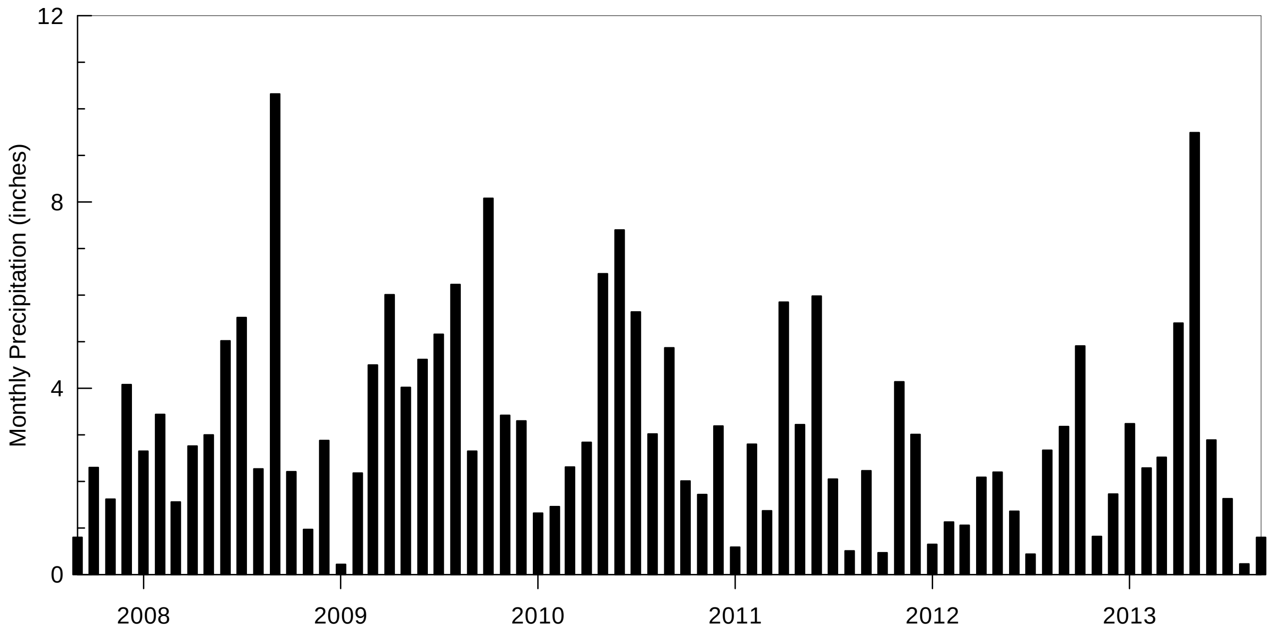

Figure 10. Network average monthly precipitation (inches), September 2007 - August 2013

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 gage and are based upon the gage total storm precipitation and the total storm duration for the gages with precipitation.

In the first 21-years of network operation, 95 of 2,499 storm events produced maximum precipitation at one or more gages with a recurrence frequency greater than one year: 50-yr (1 storm), 10-year (6 storms), 5-year (12 storms), 2-year (38 storms), and 1-year events (38 storms). The 50-year storm occurred on 13 September 1993, and the 10-year storms on 16 May 1995, 8 May 1996, 19 July 1997, 30-31 March 2007, and 11-14 September 2008. An average of 119 rain events and 5 heavy rain events occurred per year.

In Year 21, six of the 109 network storm periods exceeded the 1-year or greater recurrence frequency. Year 21 had a below average number of storm periods but an average number of heavy rainfall events. Four of these events exceeded the 1-year recurrence frequency and two storm events exceeded the 5-year recurrence frequency. No 2-year, 10-year, or 50-year events occurred.

Groundwater Levels

The long-term hydrograph at MTOW-01A (Snicarte) in Figure 11 provides a 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. Based on the data available, these annual fluctuations often appear to be superimposed on longer term trends, perhaps 10 years or more.

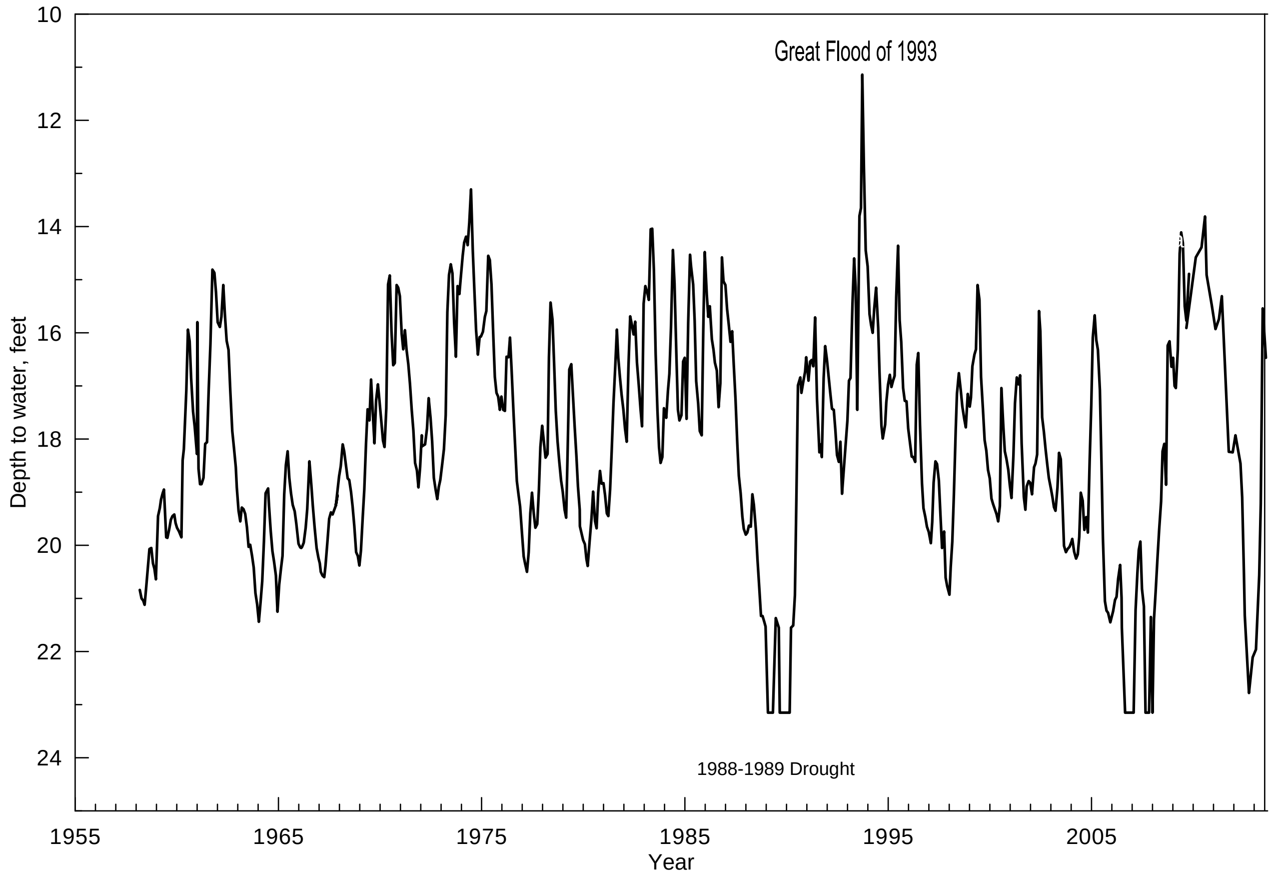

Figure 11. Groundwater levels at the Snicarte wells, 1958-2013

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 around 8 feet and peaked at approximately 11 feet below land surface in September 1993.

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 (72 billion gallons) were 164 percent of average since 1995 and we saw similar 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 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 elevated groundwater levels to record highs in several of the network wells.

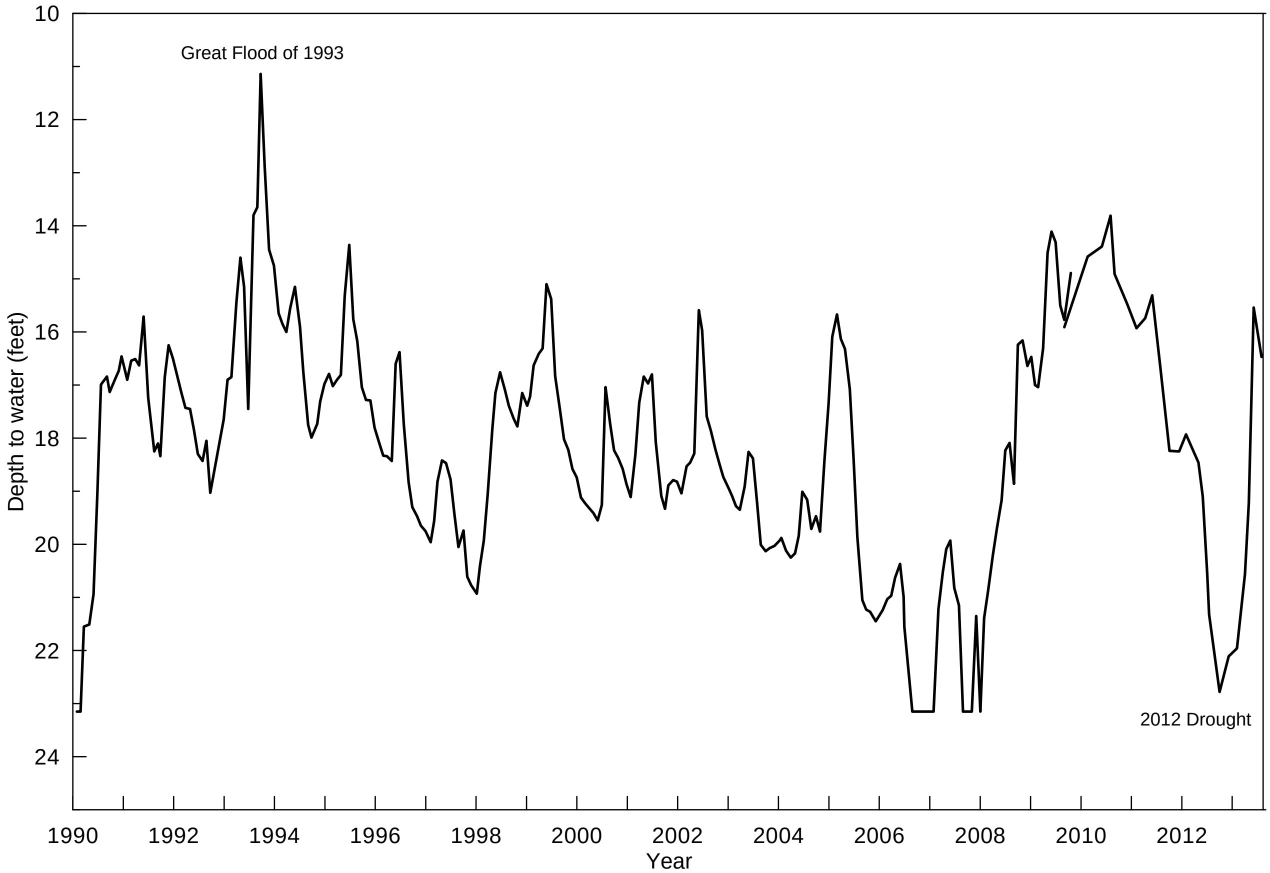

Figure 12. Groundwater levels at MTOW-01(Snicarte, IL) 1990-2013

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. 2013 saw groundwater levels recover during the first part of the year because of heavy spring rainfall, and then decline as precipitation amounts fell below average and irrigation increased.

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)

Previous reports have shown hydrographs indicating recharge events in the aquifer occurring within a few days after a rainfall event. In other words, recharge occurs on a scale of days after a precipitation event, and so historical monthly measurements missed many such events. Based on these results, the IVWA purchased ten In-Situ data loggers that were installed in wells between December 30, 2004 and August 2005.

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, 2012 to August 31, 2013 and contain all groundwater elevation data and daily precipitation totals for nearby rain gauges. Looking at the Figure 15, the rainfall/recharge relationship is evident as groundwater levels rise dramatically during periods of heavy precipitation and drop when there is a lack of precipitation. Pumpage in the summer of 2013 also caused groundwater elevations to drop.

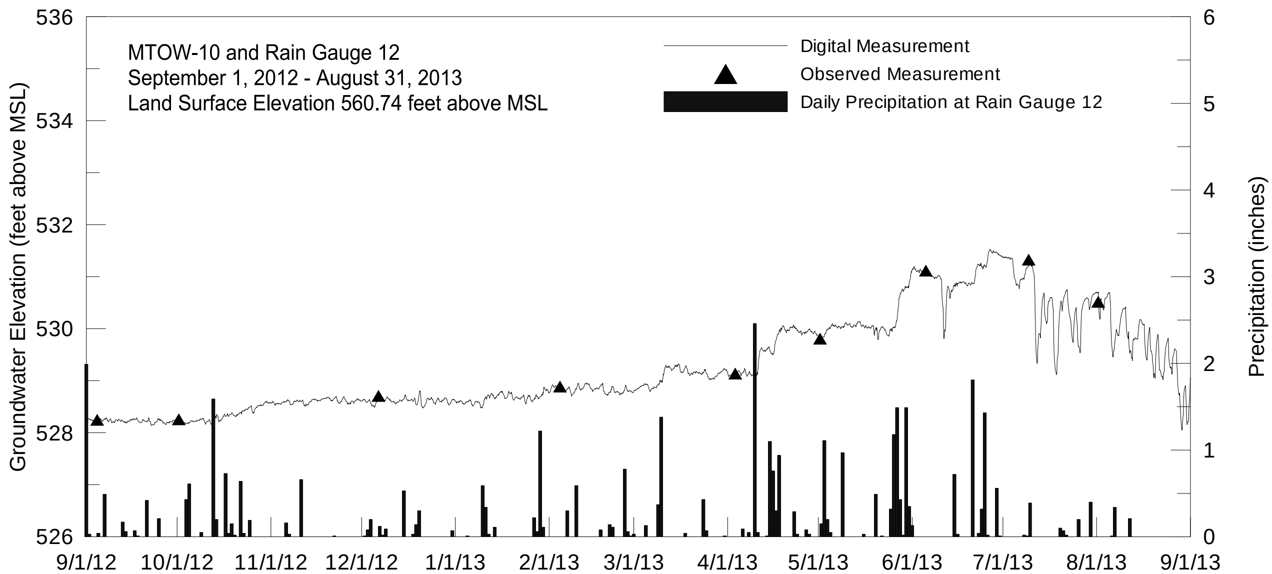

Figure 15. Year 21 Groundwater depth and precipitation for MTOW-10

Figure 16 shows the entire period of record for MTOW-02, located within the village limits of Easton, IL. It is interesting to note the lowest water levels on record occur on 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 during 2009-2011. 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.

Figure 17, 18 and 19 are hydrographs showing groundwater elevation and precipitation data for a portion of Year 21. The hydrographs start June 1, 2013 and go to the end of the project year which ends August 31, 2013. The hydrographs illustrate the effects of irrigation pumpage resulting in the lowering of groundwater levels

Figure 20 and 21 are aerial photo graphs showing the locations of MTOW-10 and MTOW-12 with the surrounding irrigation pivots. MTOW-10 at San Jose, IL, has three irrigation pivots in close proximity. Assuming the well is in the center of the pivot, the two closest wells are 1450 and 1800 feet away. Figure 17(MTOW-10) seems to indicate that two or more irrigation wells may be influencing water levels. The downward spikes in water level seem to be of different sizes and irregularly shaped, indicating multiple wells. It seems likely the drawdowns come from irrigation and not the Village of San Jose well as the village wells are a greater distance away. The downward spikes in water levels occur every few days during irrigation season and are much more pronounced than during the non-irrigation times of the year (Figure 15).

Figure 21 is an aerial view near MTOW-12 (Hahn Farm) and the nearby irrigation pivots. The two closet irrigation center pivots are 1120 and 2519 feet away. The Hahn well appears to only be influenced by the closer of the two irrigation wells. MTOW-06 at the State Tree Nursery shows the same trends in Figure 18.

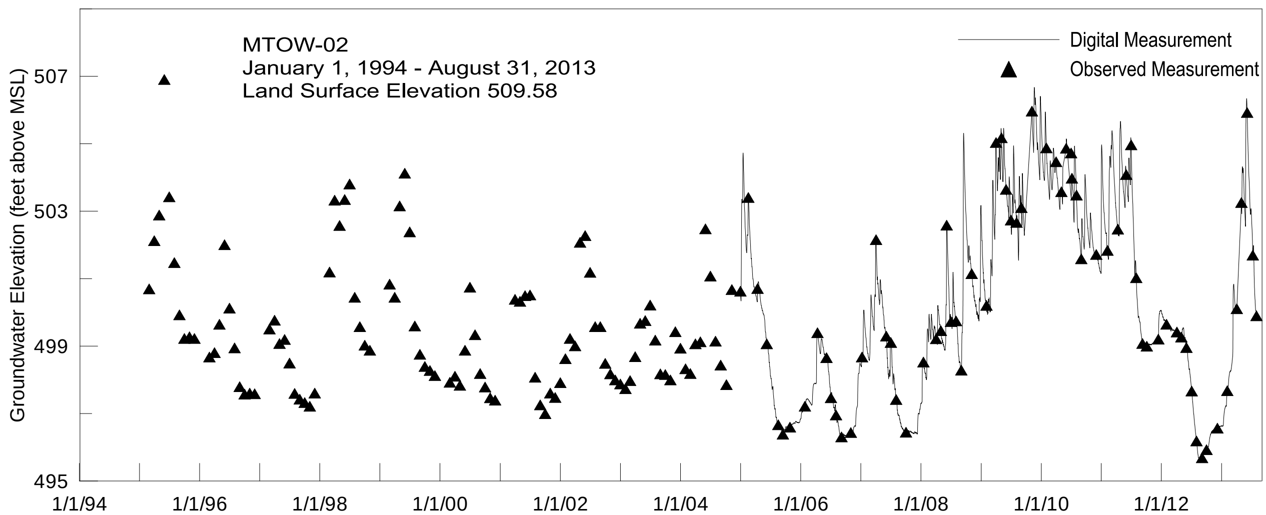

Figure 16. Groundwater elevations at the Easton well, MTOW-02,
January 1, 1994-August 31, 2013

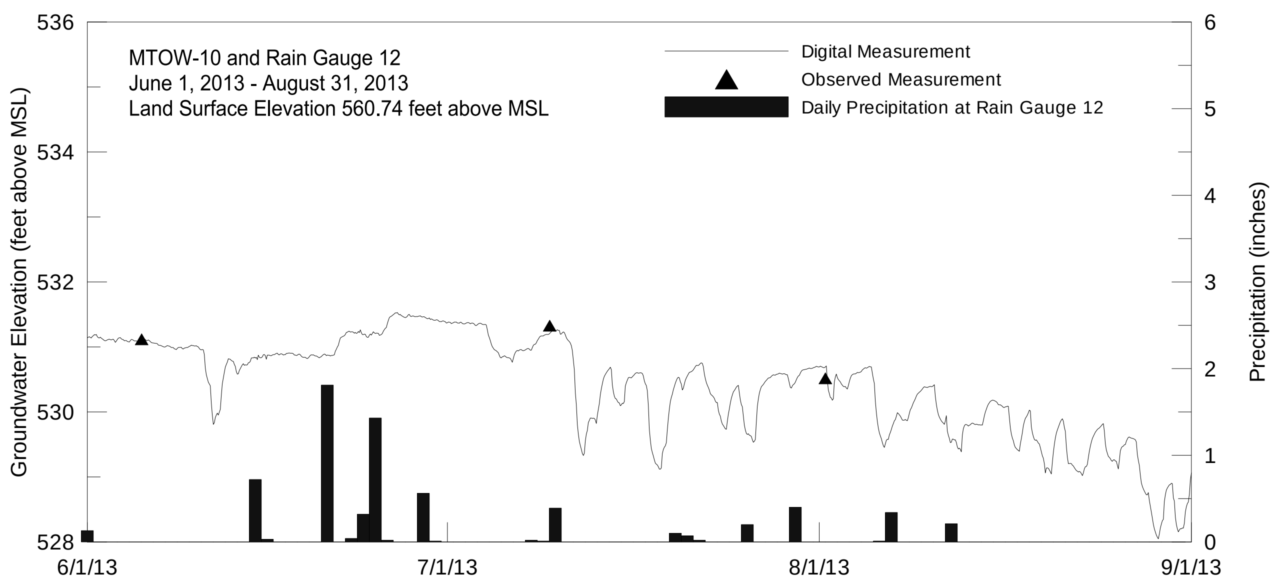

Figure 17. Groundwater elevations and precipitation at the San Jose well, MTOW-10,
June 1, 2013-August 31, 2013

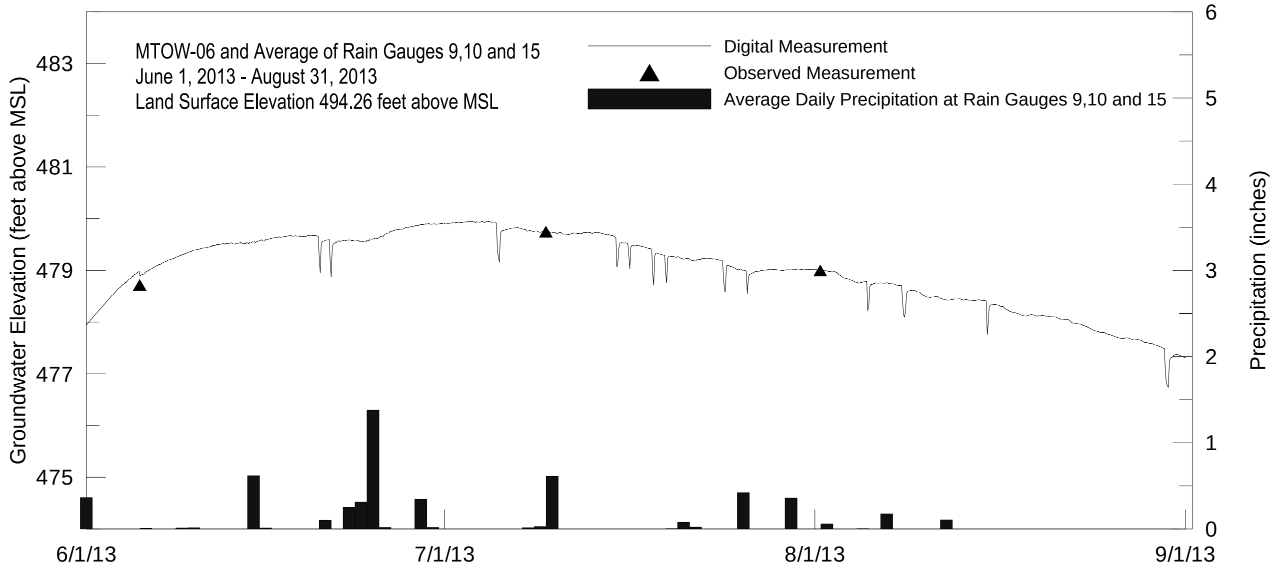

Figure 18. Groundwater elevations and precipitation at the Tree Nursery well, MTOW-06, June 1, 2013-August 31, 2013

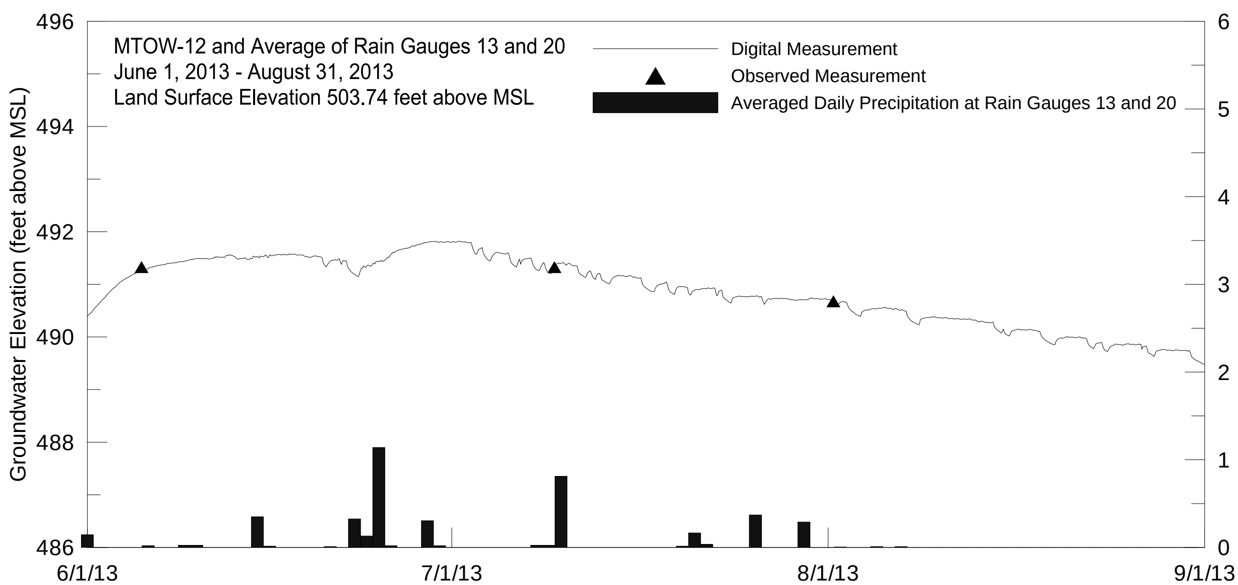

Figure 19. Groundwater elevations and precipitation at the Hahn Farm well, MTOW-12, June 1, 2013-August 31, 2013

Figure 20. Aerial view of MTOW-10 and irrigation pivots

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.

Figure 21. Aerial view of MTOW-12 and irrigation pivots

Irrigation Water Use

The total irrigation pumpage in 2013 was approximately 71 billion gallons (bg), which is the third highest irrigation amount for the observation period, less than the approximately 72 bg pumped in 2005 and the 98 bg pumped in 2012. For Year 21, the lower than normal precipitation during August and September affected irrigation practices significantly. Irrigation in June, like that in 2011, was the lowest June pumpage for the period of study and July was the second lowest. August had the second highest amount of irrigation and September the highest for the period of study. It should be noted the IVWA now collect data for the months of May and October. While October falls outside the time frame of the project year which ends August 31 of every year, the totals for October, which was 10 bg, will be included here, as this irrigation represents the conditions in 2013, not the following year. The totals from these months had previously been added to the June and September totals, but will no longer be. The hot and dry late summer clearly affected pumpage. 71 bg was pumped during 2013, of which 65.3 bg was pumped from August through October. This means only 5.7 bg were pumped in May, June, and July before the dry weather began. On average, May, June, and July pumpage totals about 20 bg.

The monthly and seasonal estimates of irrigation withdrawals are shown in Table 3. These data were calculated for the Imperial Valley by previously described methods. The rank from highest to lowest irrigation amounts are shown in the right hand column in Table 3. Two of the three highest irrigation withdrawals have occurred in the last 2 years. Typically, irrigation withdrawals are greatest in July and August, with September and June withdrawals being much less. That was not the case in 2013 as August and September proved to be the more heavily irrigated months. Though more irrigation systems are added each year, suggesting that irrigation pumpage should keep increasing, it is clearly apparent that the timing and amount of rainfall received during the irrigation season (rather than throughout the whole year) are primary contributing factors affecting the amount of irrigation.

The estimated monthly irrigation pumpage is displayed graphically in Figure 22 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. For example, only 30 bg were pumped in 2000 (Year Eight), even though Year Eight showed a deficit of 9.5 inches (Table 4). This was because significant precipitation fell during the summer of 2000, reducing the need for irrigation. Similarly, Year Fifteen (summer 2007) was the ninth driest of network operation, but ranked number 2 for irrigation pumpage. Irrigation during Year 21 started out as one of the lowest on record, but that quickly changed as precipitation became scarce.

The abundant rainfall early in Year 19 both decreased the amount of water withdrawn for irrigation and resulted in higher groundwater levels throughout the study area. However, the severe drought conditions since have seen record amounts of pumpage due to irrigation. During 2011, 2012 and 2013 irrigation seasons, a total of 221 bg of water was pumped, by far more than any other 3 year period. Table 4 also shows that for 9 of the last 11 years and for 14 of the 21 years on record, rainfall has been below the 30-year (1981-2010) historical average of 38.38 inches (average of Havana and Mason City).

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			13
1996		2.0	20	18	12		52			5
1997		2.6	19	14	2.0		38			13
1998		2.1	7.8	13	6.9		30	1622	.018	16
1999		2.8	18	12	6.0		39	1771	.022	12
2000		6.4	6.0	12	5.6		30	1799	.017	16
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	11
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	15
2009		1.6	9.3	12.1	2.9		26	2054	.013	19
2010		1.8	2.4	11.7	10.6		27	2077	.013	18
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	5.0	26.4	28.9	10.0	71	2293	.045	3
Average	0.1	4.8	14.8	17.5	9.2	5.7	47.1			

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.

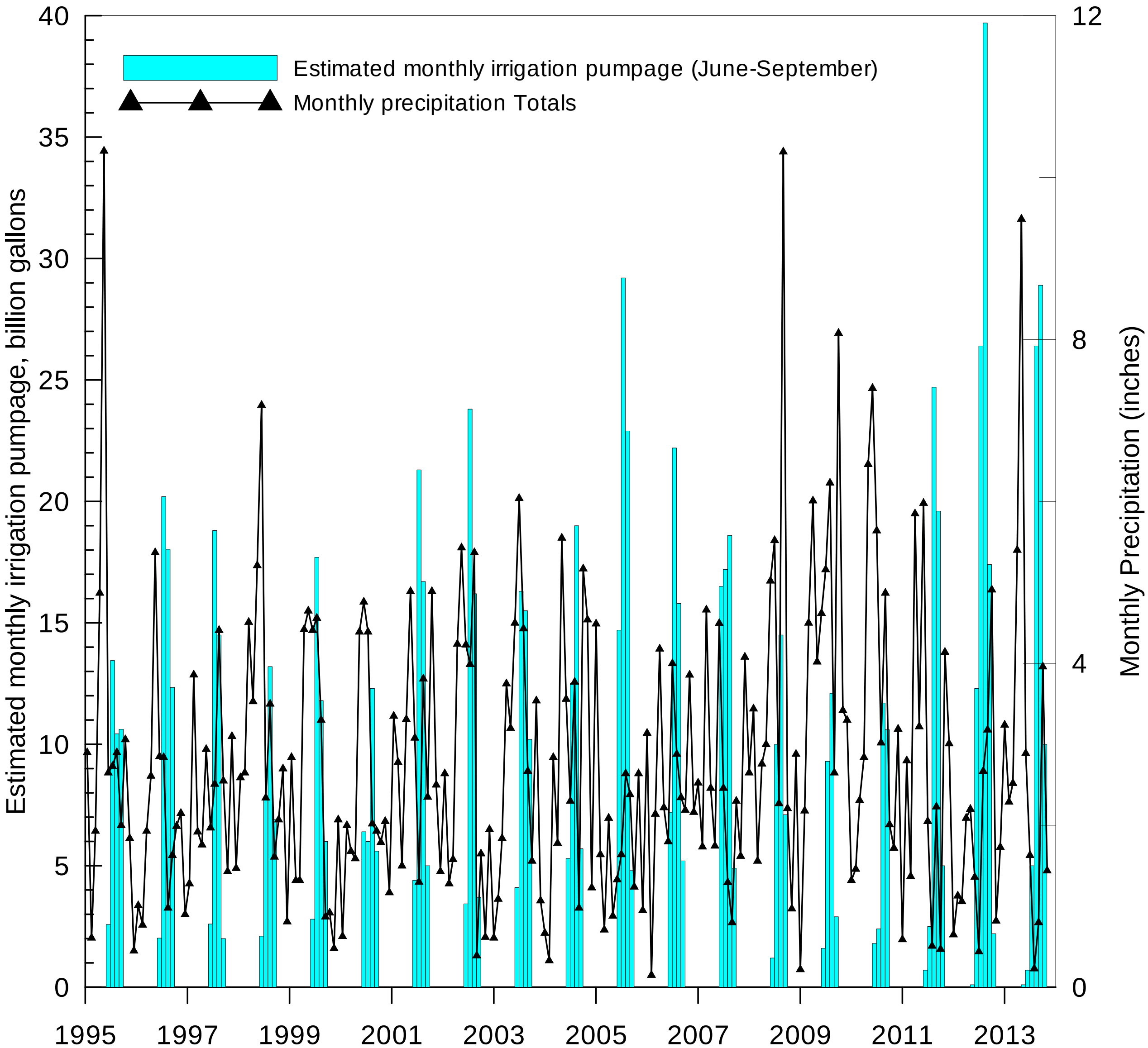

Figure 22. Estimated irrigation pumpage and average monthly precipitation, Imperial Valley

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.	*Irrigation*
1992 - 1993	**55.55**	**+17.17**	**+17.17**	**1**	**-**
1993 - 1994	**40.21**	**+1.83**	**+19.00**	**4**	**-**
1994 - 1995	**39.42**	**+1.04**	**+20.04**	**7**	**13**
1995 - 1996	**25.70**	**-12.68**	**+7.36**	**20**	**5**
1996 - 1997	**27.31**	**-11.07**	**-3.71**	**18**	**13**
1997 - 1998	**40.06**	**+1.68**	**-2.03**	**5**	**16**
1998 - 1999	**34.02**	**-4.36**	**-6.39**	**11**	**12**
1999 - 2000	**25.81**	**-12.57**	**-18.96**	**19**	**16**
2000 - 2001	**30.97**	**-7.41**	**-26.37**	**13**	**8**
2001 - 2002	**39.91**	**+1.53**	**-24.84**	**6**	**8**
2002 - 2003	**30.06**	**-8.32**	**-33.16**	**14**	**10**
2003 - 2004	**29.64**	**-8.74**	**-41.90**	**15**	**11**
2004 - 2005	**27.34**	**-11.04**	**-52.94**	**17**	**2**
2005 - 2006	**27.74**	**-10.64**	**-63.58**	**16**	**7**
2006 - 2007	**31.94**	**-6.44**	**-70.02**	**12**	**4**
2007 - 2008	**35.02**	**-3.36**	**-73.38**	**9**	**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**	**10**	**5**
2011 - 2012	**21.44**	**-16.94**	**-74.04**	**21**	**1**
2012 - 2013	**38.35**	**-0.03**	**-74.07**	**8**	**3**

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)**

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

Summary

During Year 21 of the rain gauge network operation (September 2012-August 2013), the network received an average of 38.35 inches of precipitation, 3.67 inches above the previous 20-year network average precipitation of 34.68 inches, and nearly the same as the 30-year average for the study area, 38.38 inches. Year 21 was the 8th wettest year since the deployment of the precipitation network. The summer of 2013 was the second driest summer of network operations, second only to 2012, but the spring of 2013, was the second wettest of 21 years.

Early season rainfall was such that significant irrigation use didn’t start until August. 71 bg was pumped for irrigation from the aquifer. The spring rainfalls led to significant groundwater level recovery from the lows in 2012. However, increased pumping after July led to significant decreases in the groundwater elevations at some of the observation wells.

The data collected over the last 21 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 if you have any questions or comments.

Sincerely,

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Appendix A. Hydrographs, Imperial Valley Observation Well Network

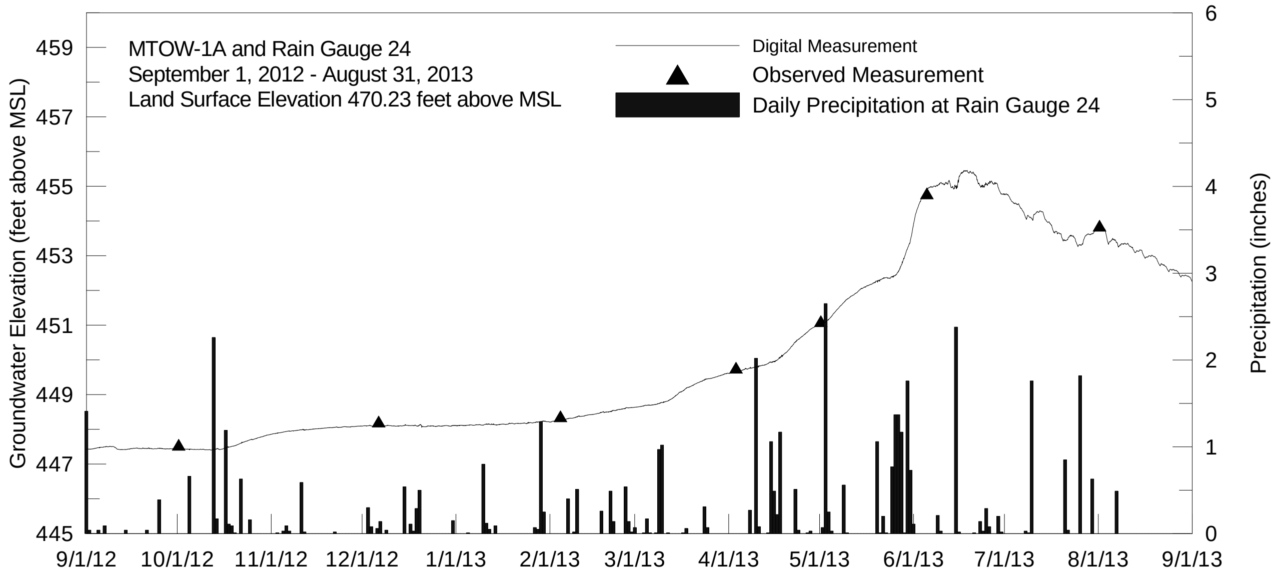

Figure A-1. Year 21 Groundwater depth and precipitation for MTOW-01

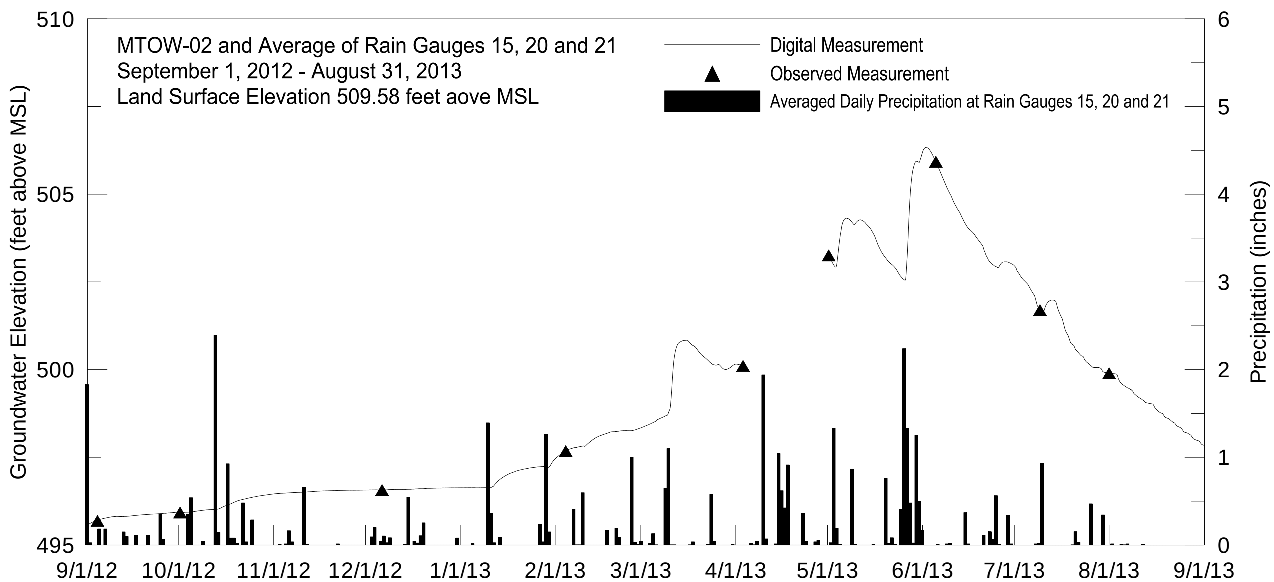

Figure A-2. Year 21 Groundwater depth and precipitation for MTOW-02

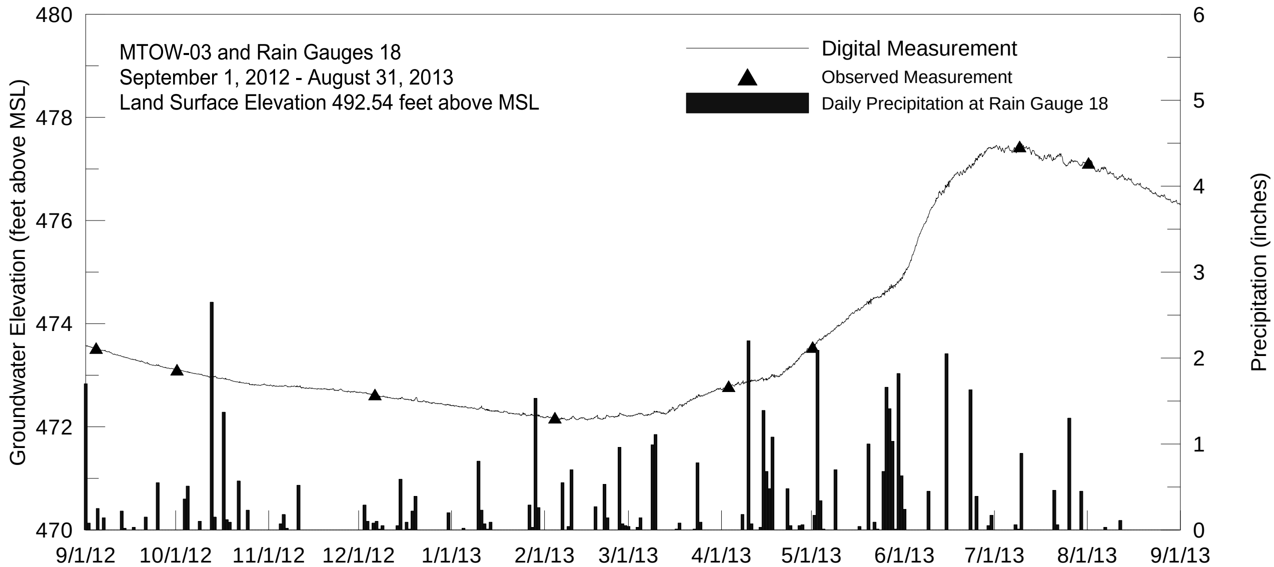

Figure A-3. Year 21 Groundwater depth and precipitation for MTOW-03

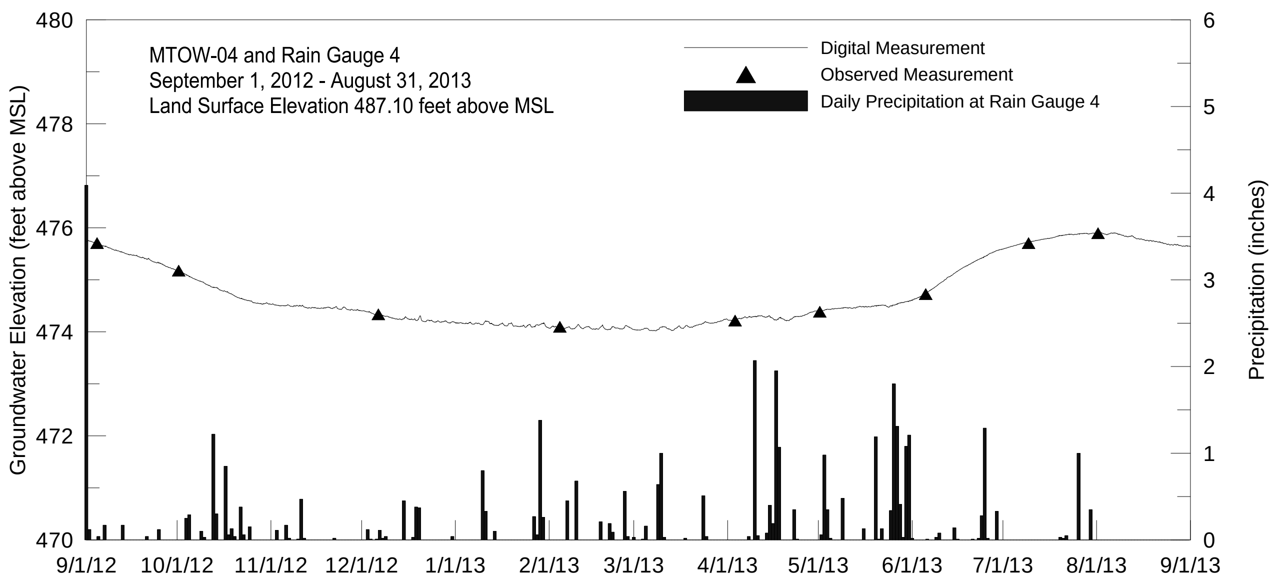

Figure A-4. Year 21 Groundwater elevation and precipitation for MTOW-04

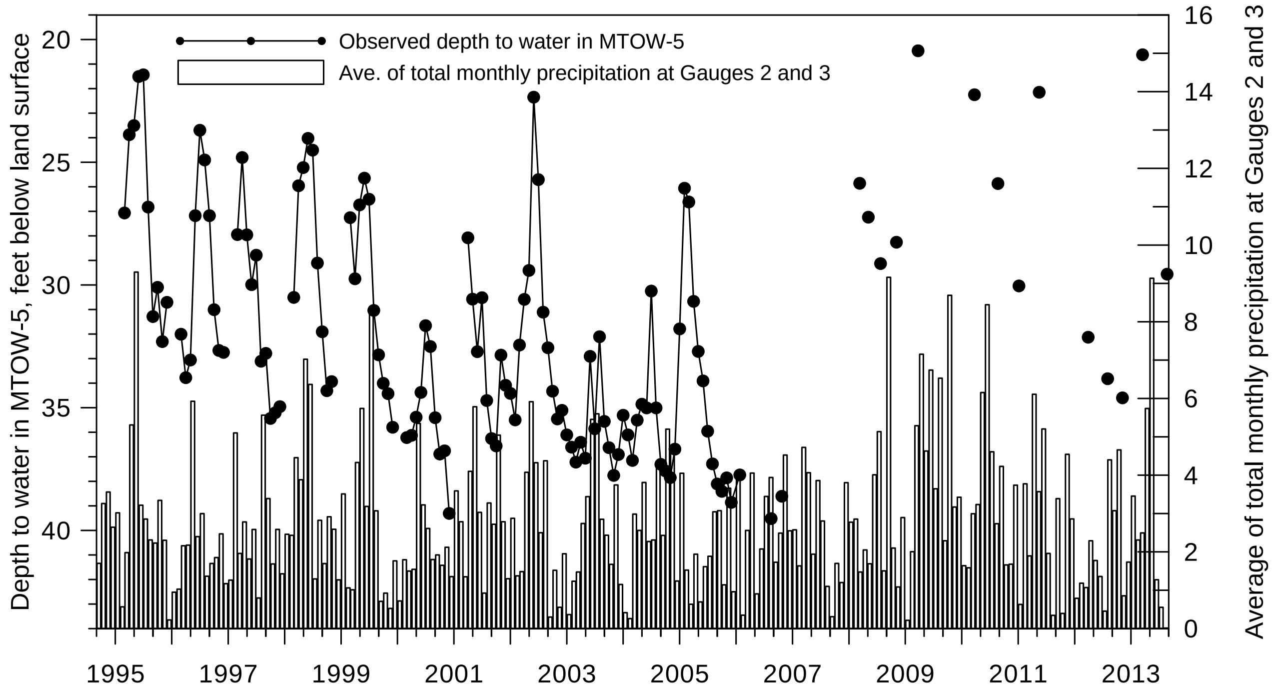

Figure A-5. Year 21 Groundwater depth and precipitation for MTOW-05 (not continuous recorder)

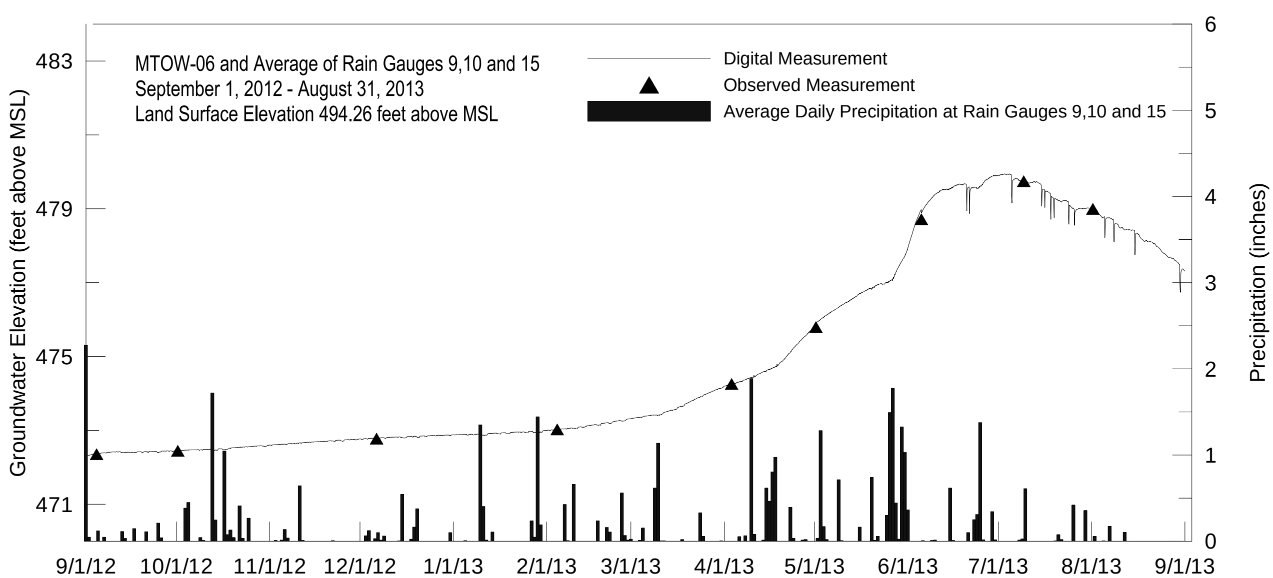

Figure A-6. Year 21 Groundwater elevation and precipitation for MTOW-06

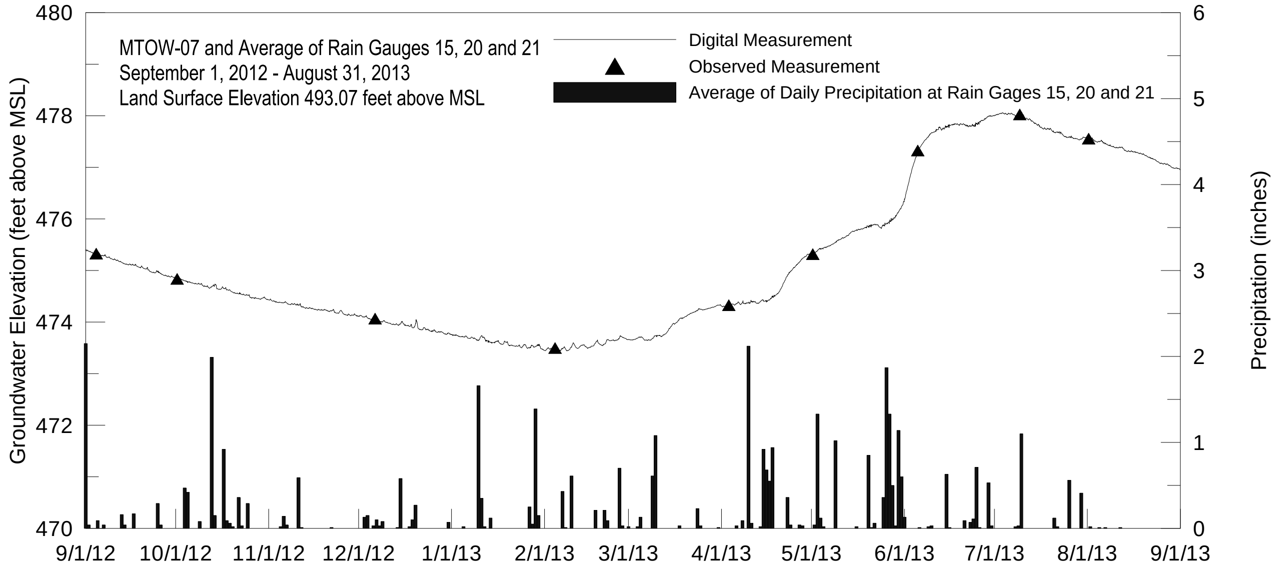

Figure A-7. Year 21 Groundwater elevation and precipitation for MTOW-07

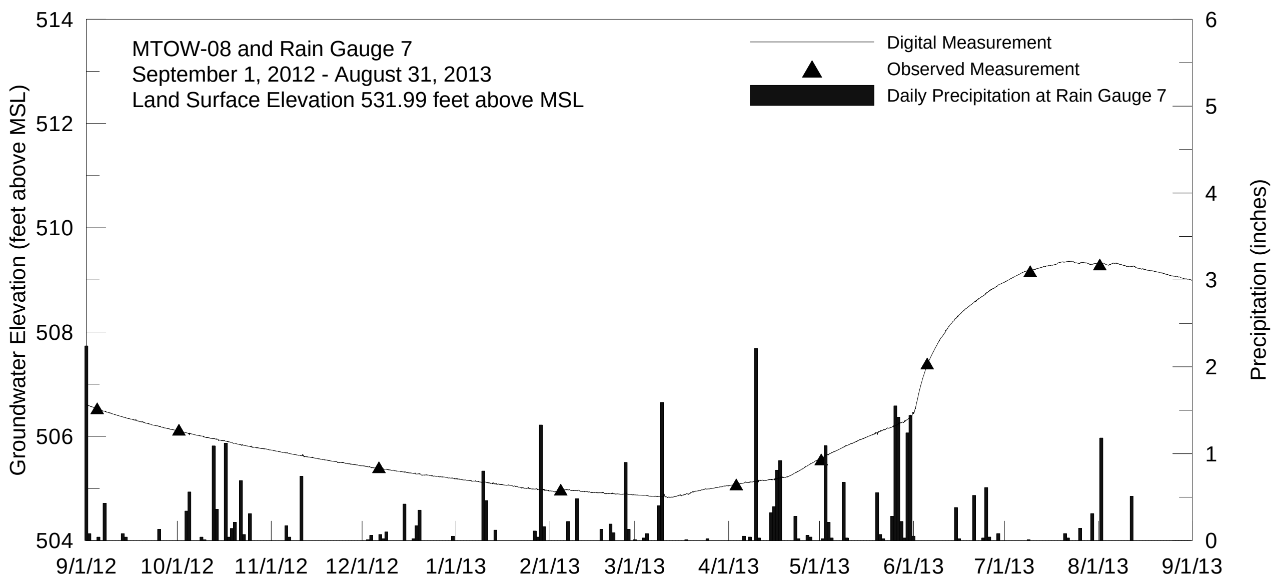

Figure A-8. Year 21 Groundwater elevation and precipitation for MTOW-08

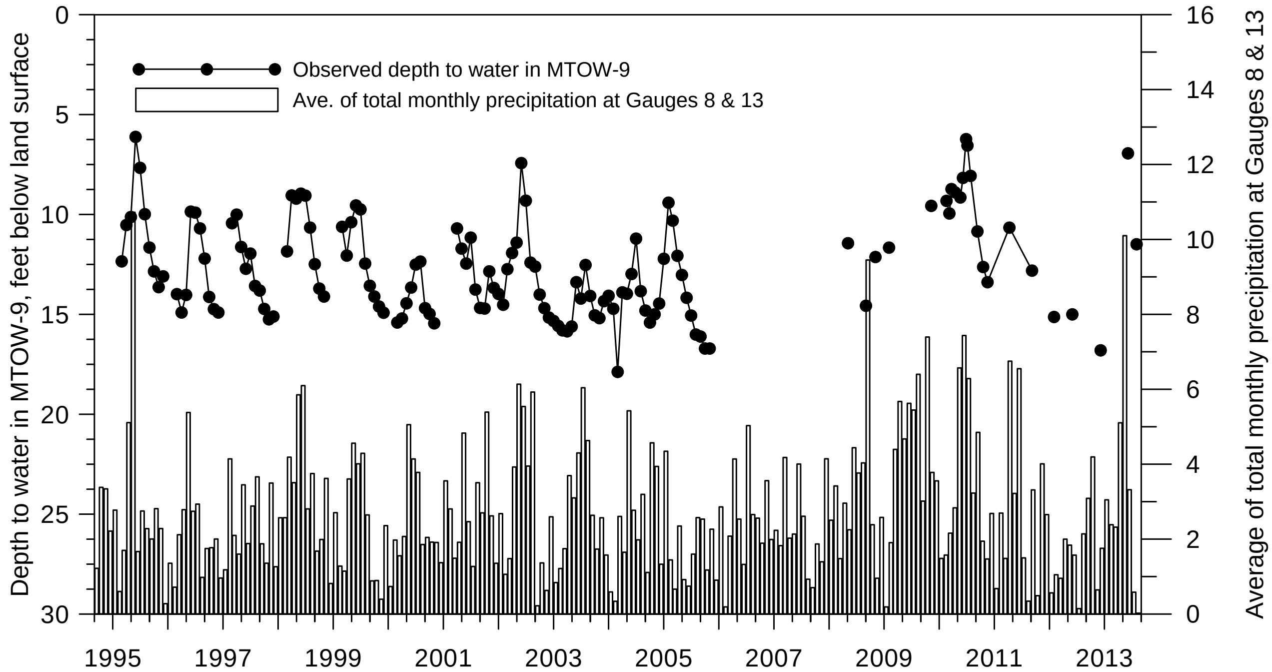

Figure A-9. Year 21 Groundwater depth and precipitation for MTOW-09 (not continuous recorder)

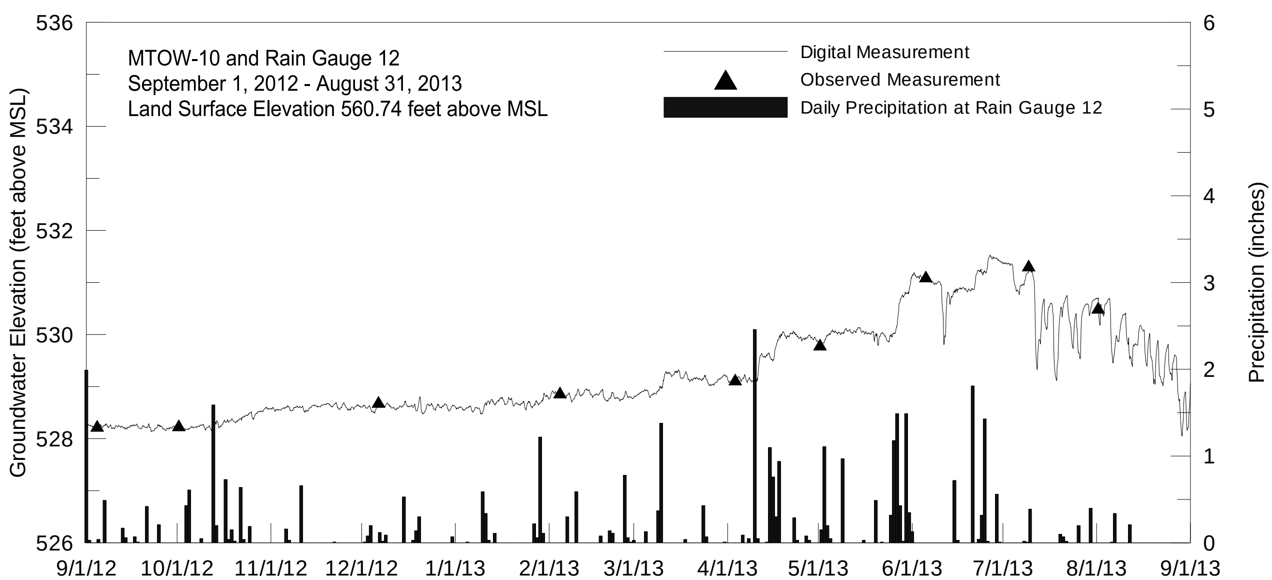

Figure A-10. Year 21 Groundwater depth and precipitation for MTOW-10

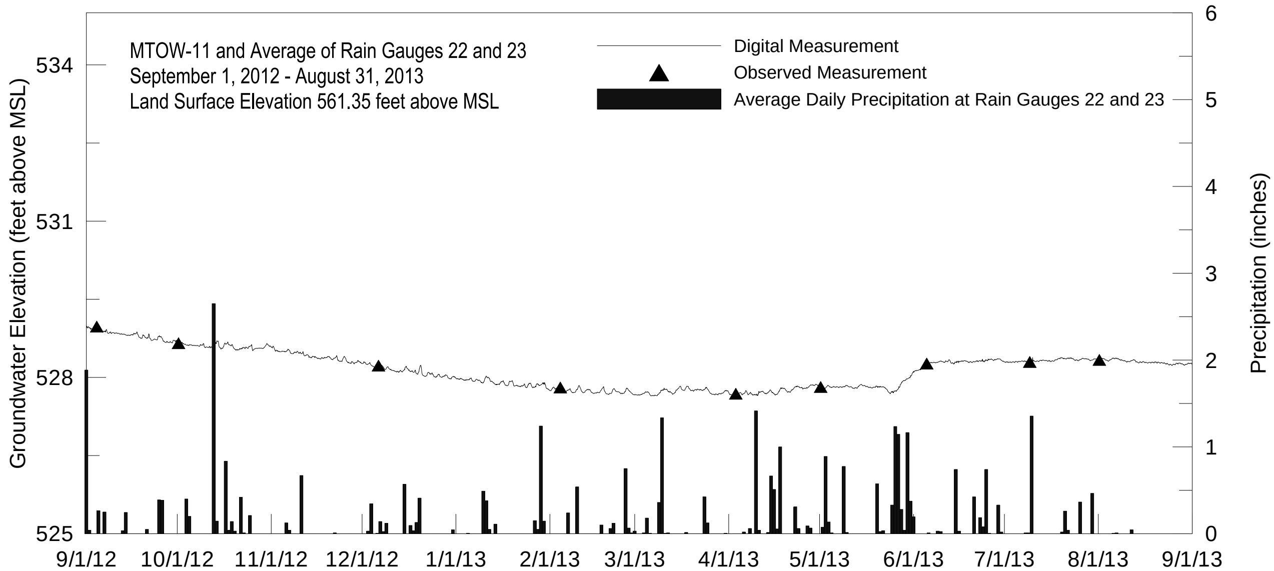

Figure A-11. Year 21 Groundwater elevation and precipitation for MTOW-11

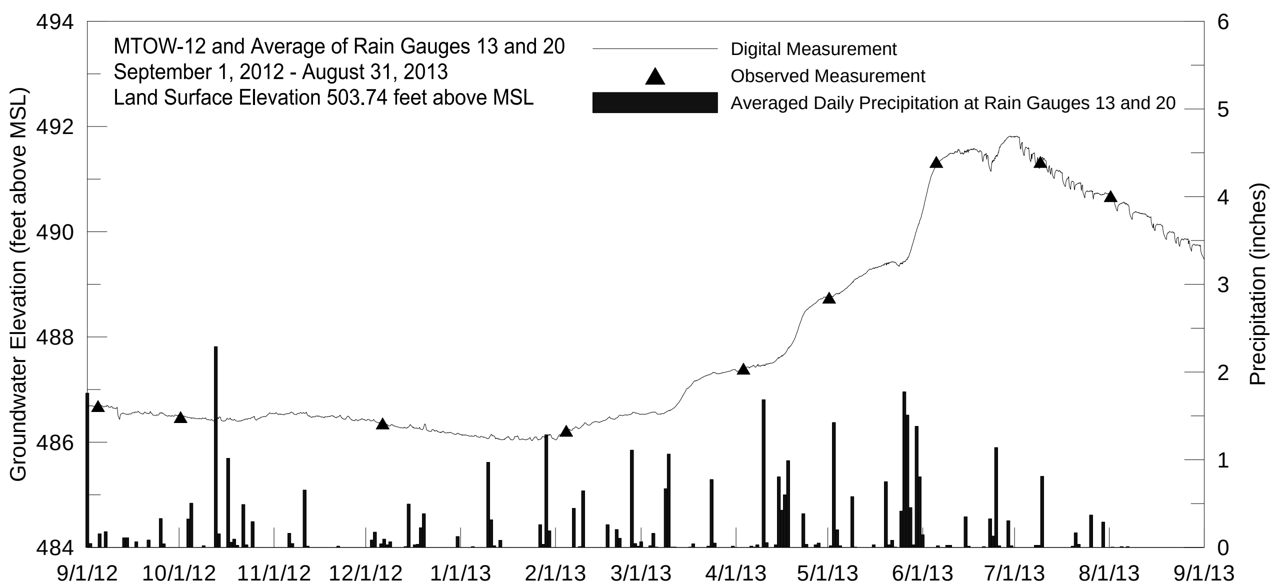

Figure A-12. Year 21 Groundwater elevation and precipitation for MTOW-12

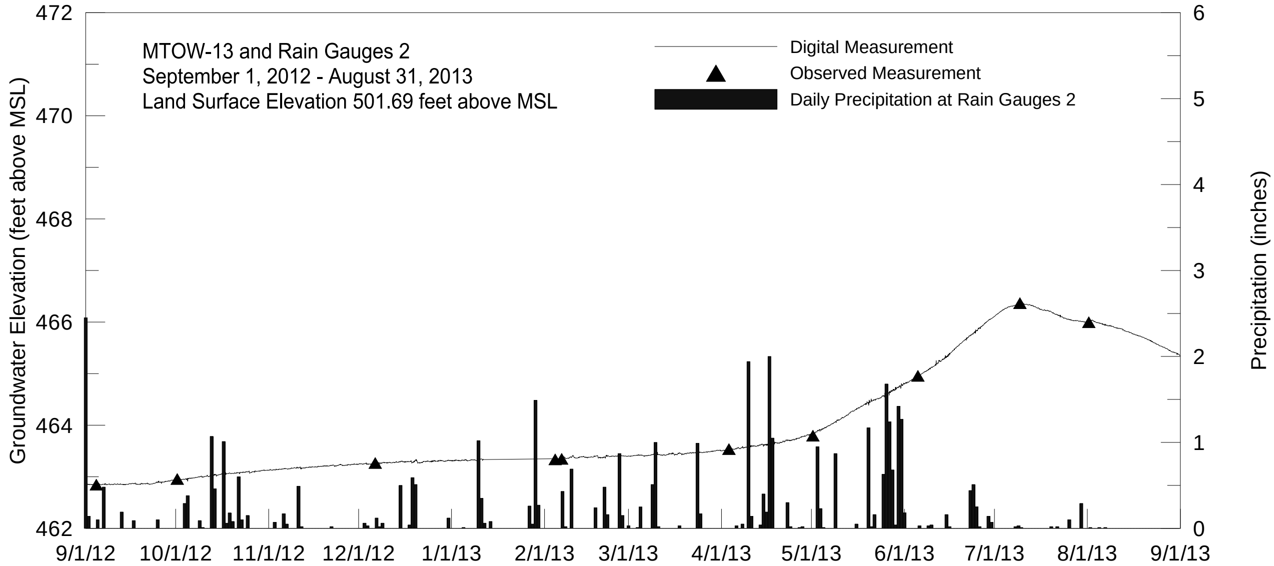

Figure A-13. Year 21 Groundwater depth and precipitation for MTOW-13