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April 12, 2017

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 24, project year 2016 (PY2016), which covers the time period from September 1, 2015 through August 31, 2016.

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 were 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 within the network 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.

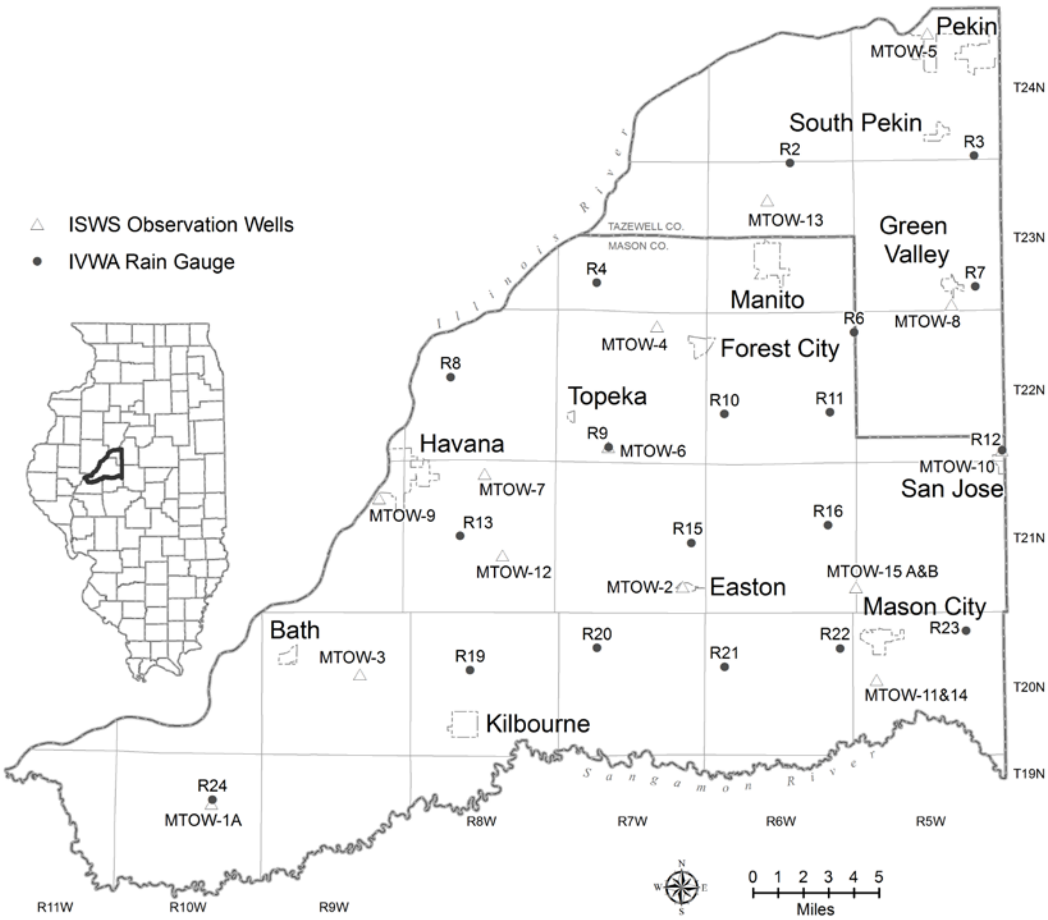


Figure 1. Configuration of the 16-Site Observation Well and 25-Site Rain Gauge Networks.

Data reduction activities during Year 24 of network operation are similar to those performed during the previous 23 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, 2015-August 31, 2016) are presented in Appendix A. For MTOW-05, and -09, 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, or average of several nearby gauges.

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 PY2016 rain gage dataset was used to produce gage and network-wide summaries of total and average precipitation at various time scales including individual storm events, monthly, seasonal, and annual time periods. Monthly and annual time scale summaries are compared with the 23-year (1993-2015) network average precipitation record.

Precipitation Analysis

The PY2016 network precipitation of 37.75 inches was slightly more than the previous 23-year annual average of 35.03 inches. Table 1 gives the monthly and annual precipitation totals for each rain gage within the network during PY2016. Gages 2 and 3 along the northern edge of the network collected the most precipitation in PY2016, 43.11 and 42.69 inches respectively. Figure 2 shows the total precipitation in PY2016**.**

Table 1. Monthly Precipitation Amounts (inches), September 2015-August 2016

	Month												
Station	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	3.40	1.91	4.77	6.78	0.72	0.72	1.54	2.03	3.66	3.67	7.53	6.38	43.11
3	4.11	1.89	4.76	6.51	0.80	0.68	2.10	2.33	3.14	2.67	7.82	5.88	42.69
4	1.92	1.44	4.32	6.54	0.45	0.38	1.96	1.80	3.92	3.75	7.27	7.57	41.32
6	1.63	0.95	4.25	6.41	0.63	0.33	1.74	1.82	3.80	2.96	6.67	4.90	36.09
7	2.07	1.66	5.22	6.36	0.76	0.51	1.74	1.03	2.78	2.10	6.98	4.54	35.75
8	1.80	1.26	3.38	6.04	0.58	0.34	2.37	2.06	4.00	3.08	5.96	6.41	37.28
9	1.21	1.36	4.97	6.22	0.80	0.57	1.90	2.55	4.42	4.06	7.38	6.84	42.28
10	0.96	1.15	4.13	6.26	0.79	0.45	1.64	2.14	2.91	3.22	6.55	6.42	36.62
11	1.02	1.43	4.37	6.28	0.72	0.75	1.64	1.72	3.55	3.00	5.43	6.00	35.91
12	1.46	1.30	4.44	6.51	0.75	0.37	1.35	1.51	3.49	3.10	4.87	7.85	37.00
13	1.03	1.33	4.23	6.39	0.71	0.38	1.43	2.32	2.91	1.81	5.96	6.75	35.25
15	0.98	1.28	4.38	6.57	0.71	0.73	1.99	1.83	2.42	2.29	4.34	7.20	34.72
16	0.89	1.26	4.02	6.32	0.56	0.38	1.50	2.00	3.10	3.32	4.53	6.94	34.82
18	2.10	1.63	5.20	7.19	0.88	0.45	2.15	1.84	3.24	1.76	5.97	5.99	38.40
19	1.45	1.35	4.63	7.04	0.96	0.62	1.86	2.27	2.97	3.54	5.81	9.56	42.06
20	0.98	0.98	4.23	6.20	0.63	0.49	1.37	1.81	2.68	3.40	4.63	7.56	34.96
21	1.43	1.26	4.30	7.15	0.71	0.60	1.73	2.32	2.44	2.96	4.41	6.25	35.56
22	1.28	1.29	4.27	7.16	0.76	0.53	1.60	2.54	2.99	2.51	5.04	7.65	37.62
23	1.63	0.92	3.86	6.12	0.87	0.30	1.27	1.71	2.91	3.05	4.56	8.11	35.31
24	2.60	1.15	4.48	6.94	0.84	0.45	1.73	2.36	3.03	1.97	6.87	5.84	38.26
Average	1.70	1.34	4.41	6.55	0.73	0.50	1.73	2.00	3.22	2.91	5.93	6.73	37.75

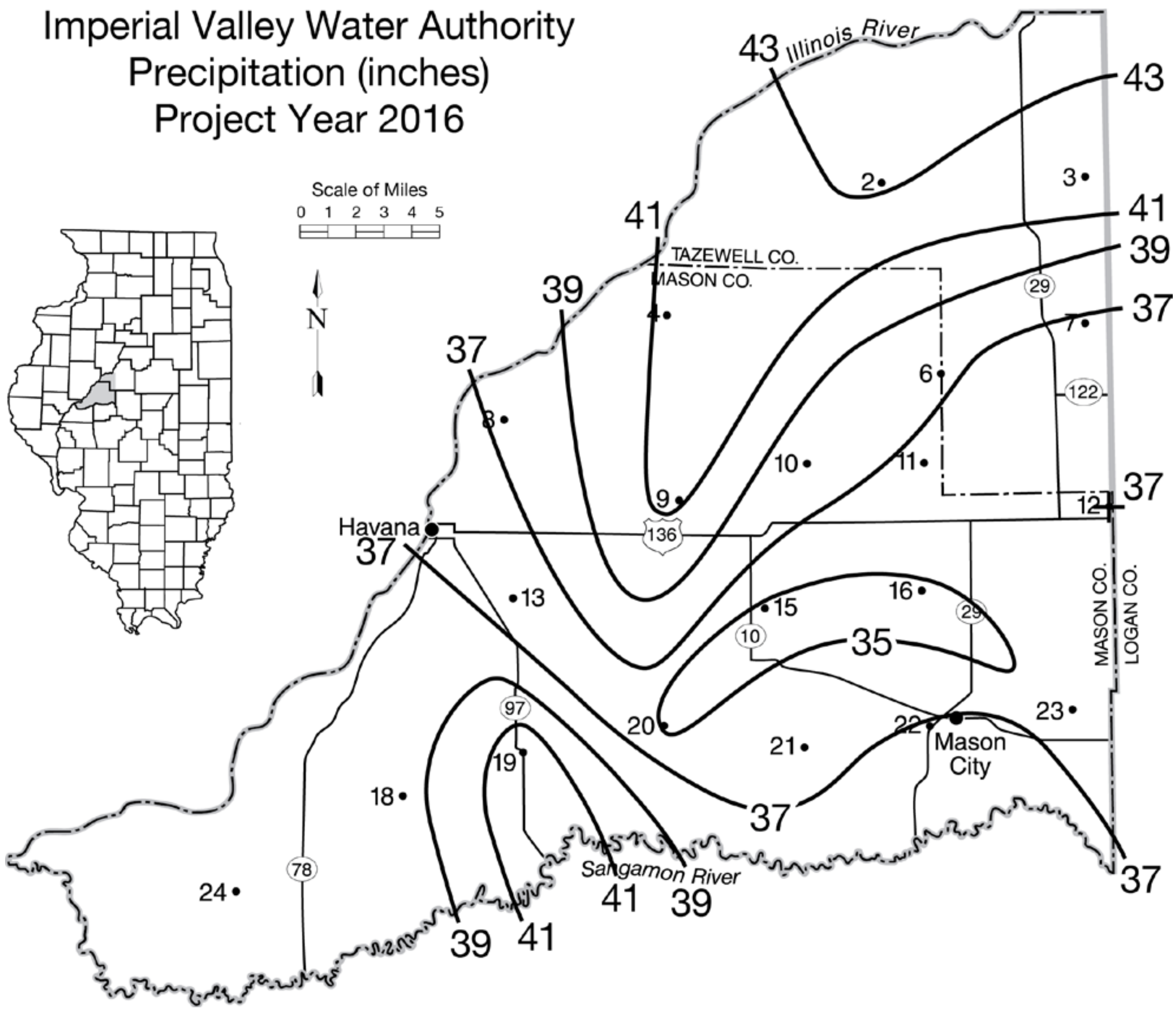


Figure 2. Total Precipitation (inches) for September 2015 - August 2016 (PY2016). Gage Locations in the Annual Precipitation Maps Have Been Updated to Reflect the Current Gage Locations.

Gages in the northern third of the network recorded the greatest precipitation. The lowest precipitation occurred in the central-southern region of the network, at gages 15, 16, and 20. Note that during PY2016, annual gage totals varied 8.39 inches, from 34.72 inches at site 15 to 43.11 inches at site 2. Ten-inch differences between gages in annual precipitation amounts are not unusual during any given year, representing natural variability. If large differences between individual gages 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 or with little or no shelter from the wind (most of the gage sites) can underestimate precipitation under strong wind conditions.

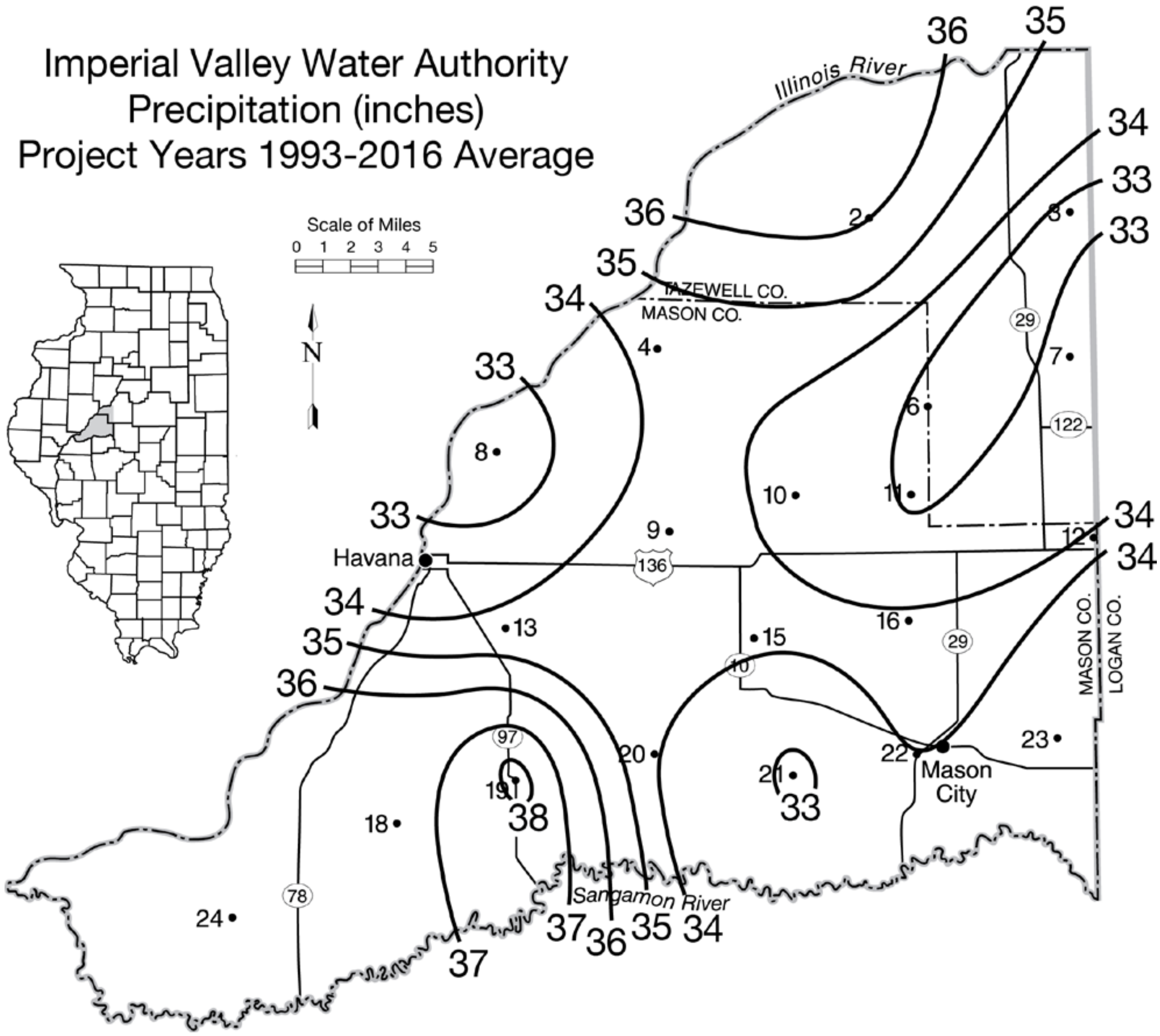


Figure 3. Network Average Annual Precipitation (inches) for September 1992 – August 2016

The distribution of the 24-year annual gage averages across the network is shown in Figure 3. The 24-year annual average for the network is 34.21 inches of precipitation. Gages 18, 19, and 24, in the southwestern third of the network and gage 2 on the north edge of the network received more than average precipitation over the last 24 years. The remaining gages, those located in the eastern two-thirds of the network received less than the 24-yr average precipitation. This broad eastern area has a regional 24-yr average of 33.6 inches.

During PY2016, the heaviest precipitation occurred during December 2015, July 2016 and August 2016. The precipitation totals for these three months accounted for 51% of the total annual rainfall. Figure 4 compares the monthly network averages for PY2016 with the 23-year monthly network averages and the 1981-2010 (30 yr) Havana, IL monthly averages. In December 2015, the network average precipitation was over 250% (4.70 inches) greater than the 23-year monthly network average. January and February 2016 each received 1.22 inches below the 23-

year average, -63% and -71% respectively. March 2016 precipitation was closest to average at -18% the 23-yr average. July and August 2016 each received about 47% more precipitation than average, 2.24 and 3.58 inches respectively. April through June 2016, September and October 2016 received precipitation that was at least 1 inch below average.

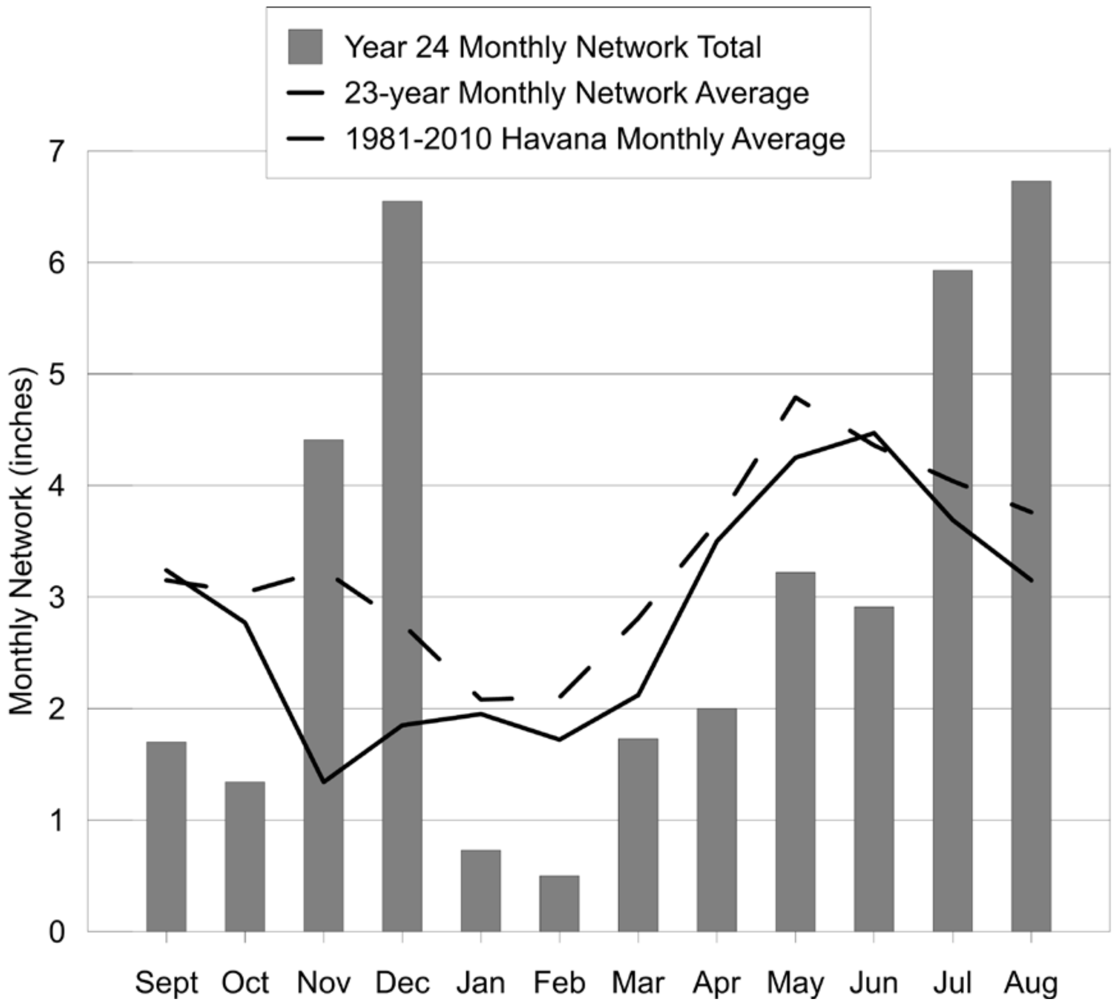


Figure 4. Monthly Comparison with 23-Year IVWA Network Average and 1981-2010 (30 Year Average) at Havana, IL Gage.

Box-whisker plots are a visual display of the quartiles and upper and lower extremes of the data, in this case, monthly precipitation. Using the monthly precipitation totals for 24 Mays from 1992-2017 for the Imperial Valley, the box-whisker plot in Figure 5 shows the maximum, median, minimum, and 1st and 3rd quartiles of each month. The May data are sorted from large to small to clearly display the median, 1st and 3rd quartiles in a list view. This presentation divides the data into quarters, not by value but by place order of the sorted set.

The **median** divides the set in half. It is the value where half the set values are above and half the numbers are below. (24 divided by 2 = 12). This is also called the **2nd quartile**.

- **1st quartile (Q1)** is the value where ¼ of the numbers are below. (24 x ¼ = 6 are below)
- **3rd quartile (Q3)** is the value where ¾ of the numbers are below. (24 x ¾ = 18 are below)
- In this report, the upper and lower caps present the minimum and maximum values.

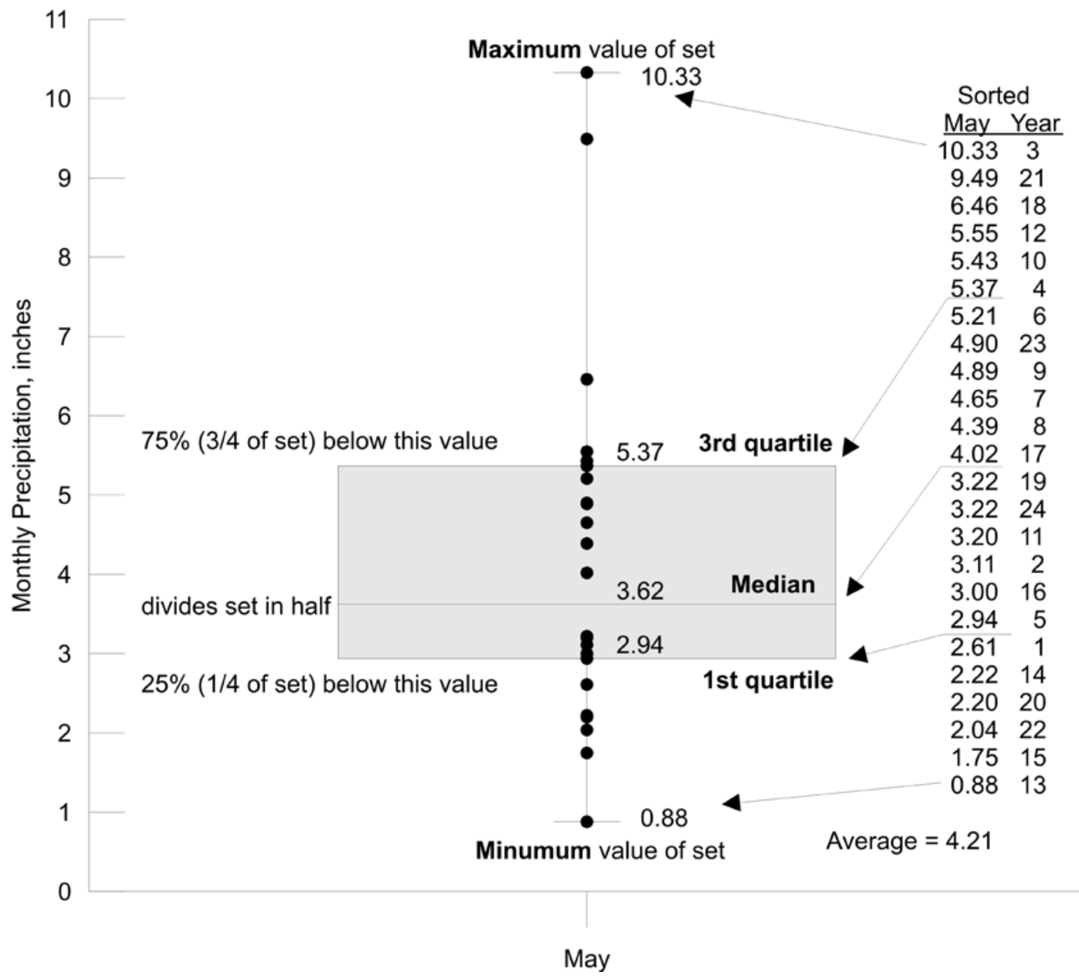


Figure 5. Features of an Example Box-Whisker Plot and Quartiles Using May Data for the Imperial Valley

This method of displaying the data provides a way of comparing and summarizing the data. The gray box (range of values between the 1st and 3rd quartiles) represents the middle 50 percent of occurrences, i.e. for 12 of 24 project years, rainfall during the month of May was between 2.94 and 5.37 inches.

Monthly network variability including minimum, maximum, medians and quartiles of the 23-year monthly precipitation data are shown in Figure 6. The monthly network precipitation for December 2015 and August 2016 were the highest ever for those months in the last 24 years. November monthly precipitation also ranked high, above the 3rd quartile. All remaining months (except March) during PY2016 had monthly precipitation well-below the median and sometimes below the 1st quartile. Only 5 months of this year had precipitation within the interquartile range (middle 50% of occurrences). Monthly network precipitation was well above the 3rd quartile for 3 of the months, and well below the 1st quartile for 8 months of the year. For the growing season of 2016, precipitation was below or near the 1st quartile (25% of occurrences) for April through June 2016 and well above the 3rd quartile (75% of occurrences) for July and August 2016.

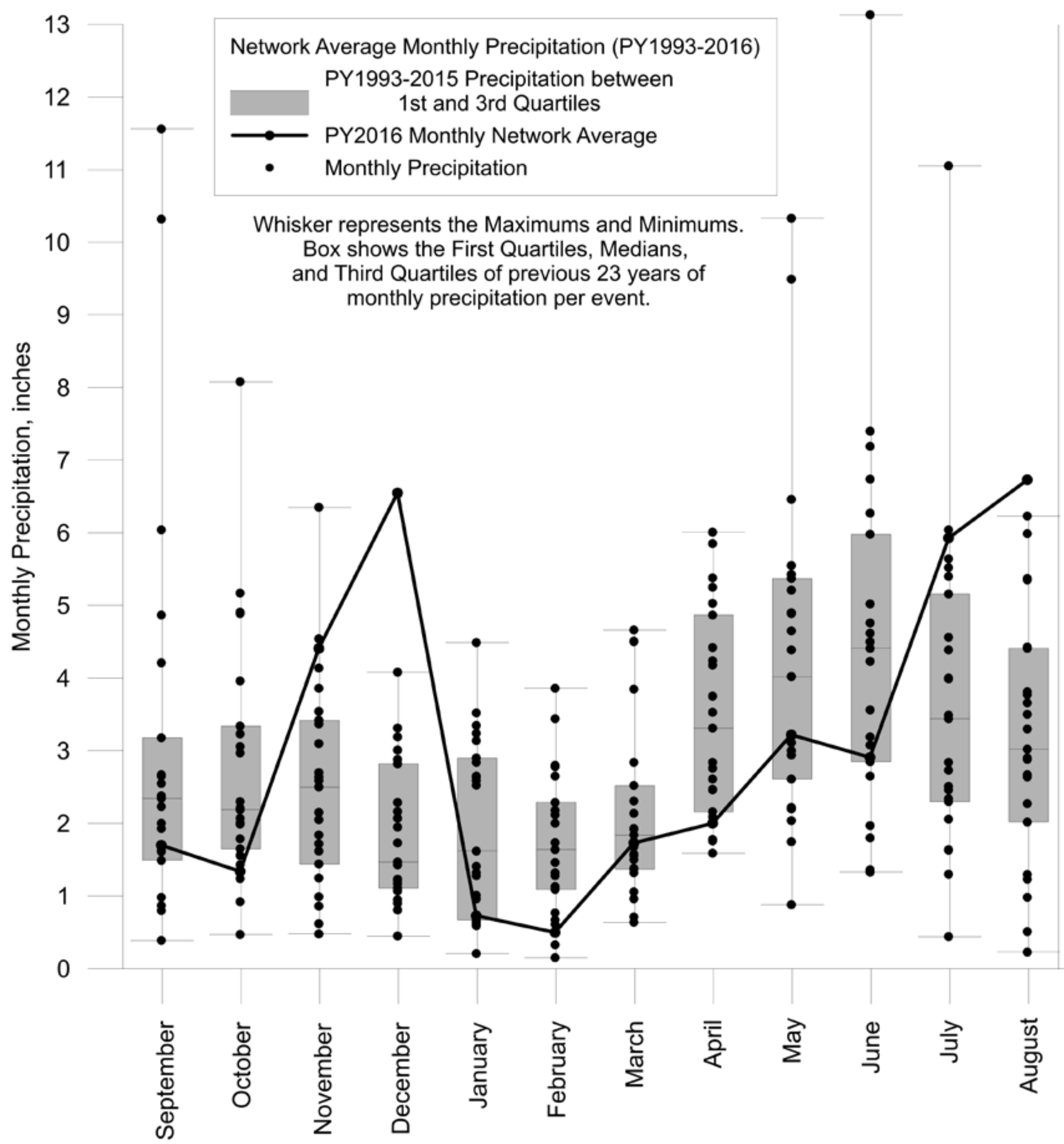


Figure 6. 23-year Monthly Average Precipitation Distribution with PY2016 Monthly Network Averages

Figure 7 presents the monthly precipitation in box-whisker plots in 8 year increments. During the first, eight-year period, September, November, May and July each had a single month of very high precipitation. The interquartile range for all of the months was about 1.5 – 3 inches, with June having the greatest range. Months with the smallest range (least total monthly precipitation variability) were October, November, February and August. The month of May had the greatest median monthly total for the last 24 years.

The middle eight years, figure 7b, had much less monthly variation of the network average than the previous eight years (1992-1999), figure 7a, or the most recent eight years (2009-2016), figure 7c. During the last eight years, the median and interquartile ranges (middle 50% of occurrences) increased compared to the last 16 years for all months except January, February and March. Monthly network precipitation maps for PY2016 are shown in Figures 8-13.

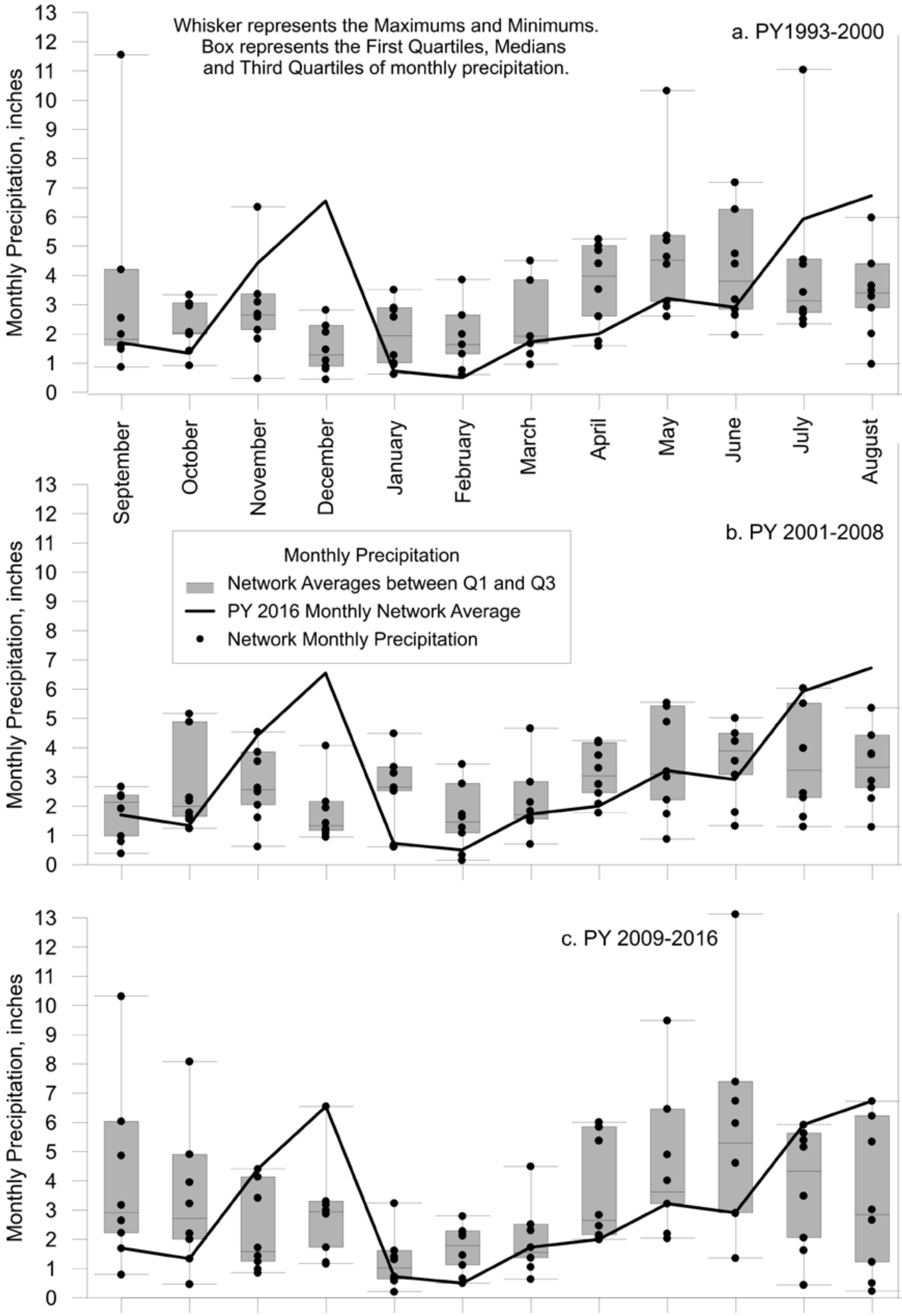


Figure 7. Monthly Box-Whisker Plots of 8 Year Time Spans.
a. PY 1993-2000, b. PY 2001-2008 and c. PY 2009-2016

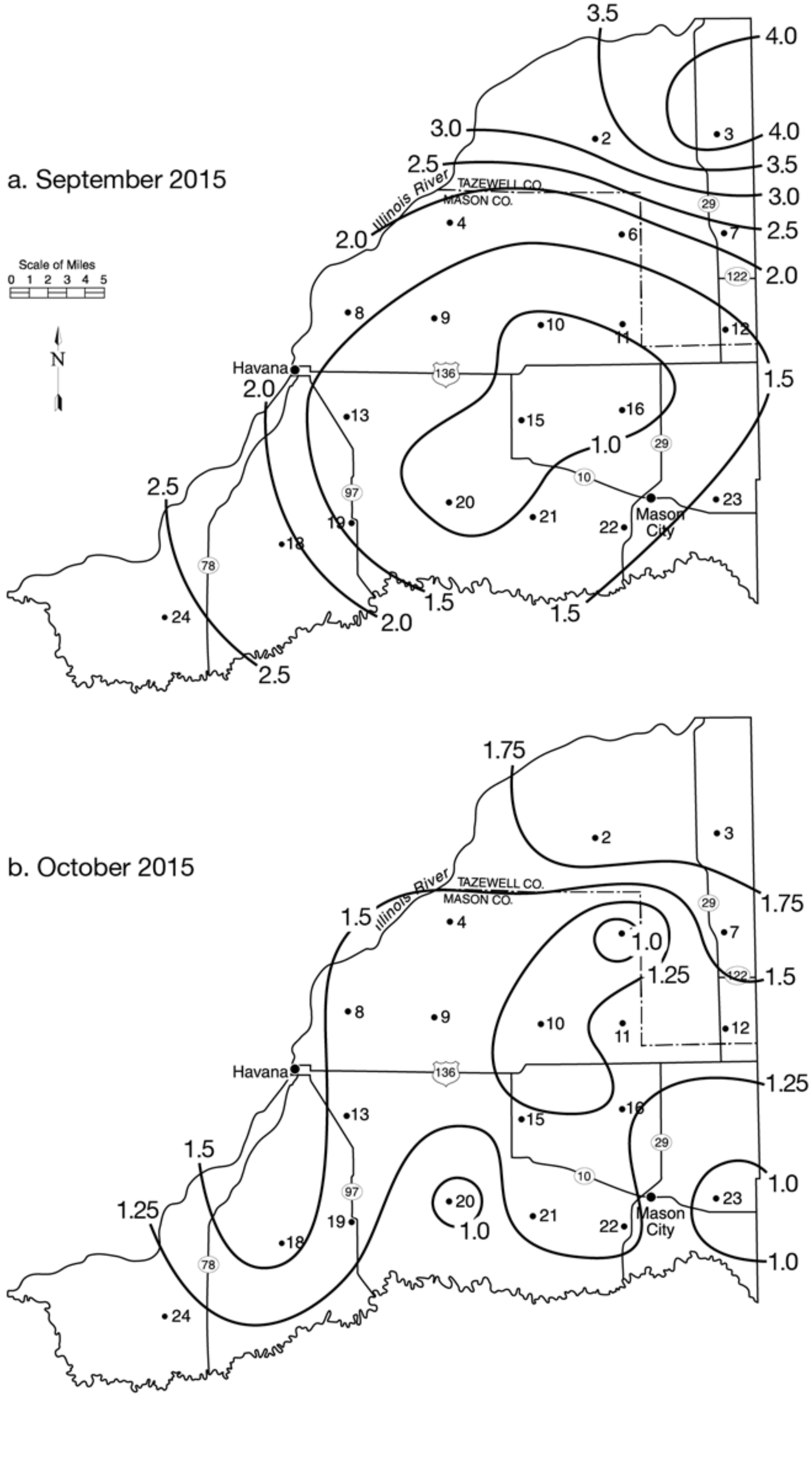


Figure 8. Precipitation (inches) for September 2015 and October 2015

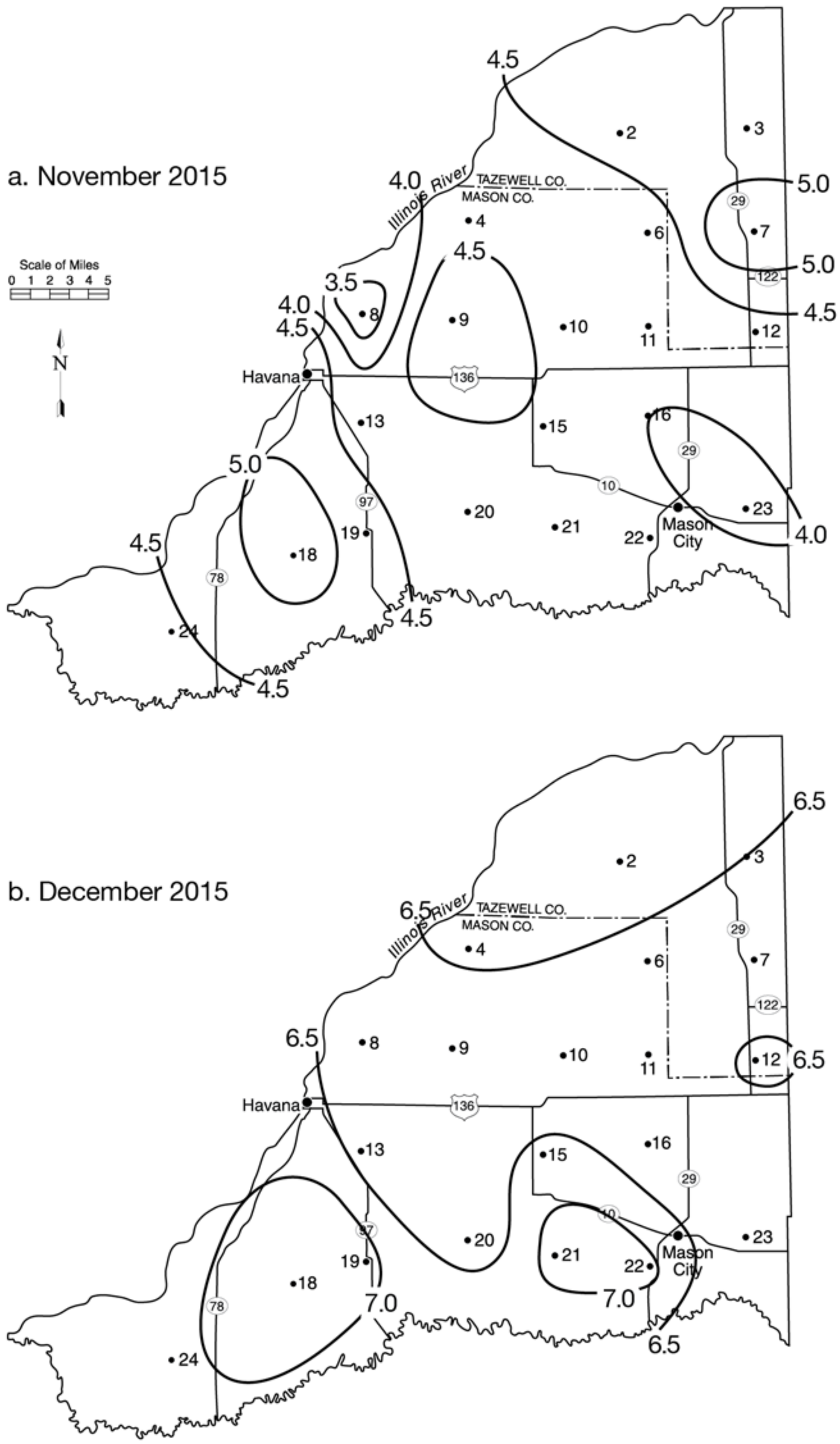
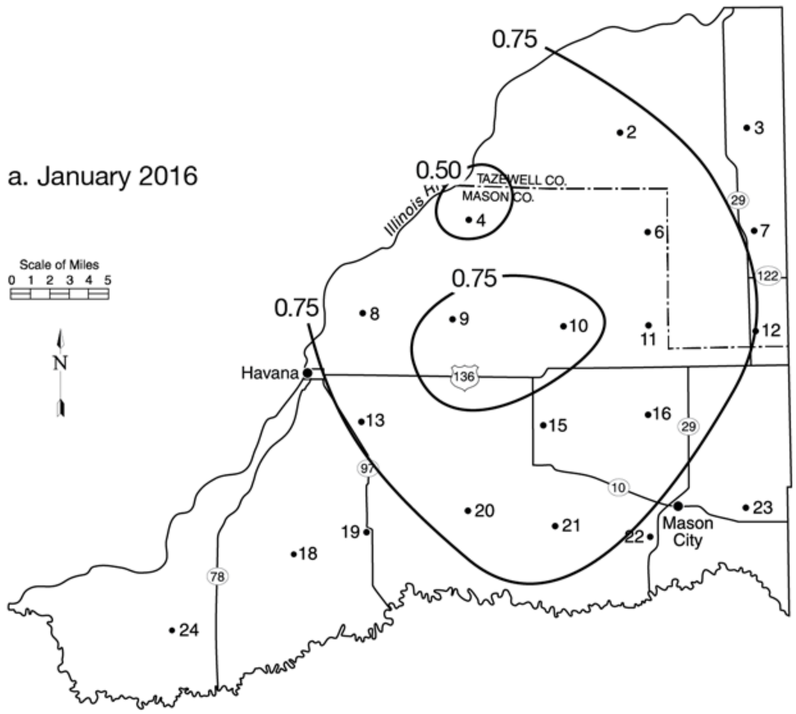


Figure 9. Precipitation (inches) for November 2015 and December 2015



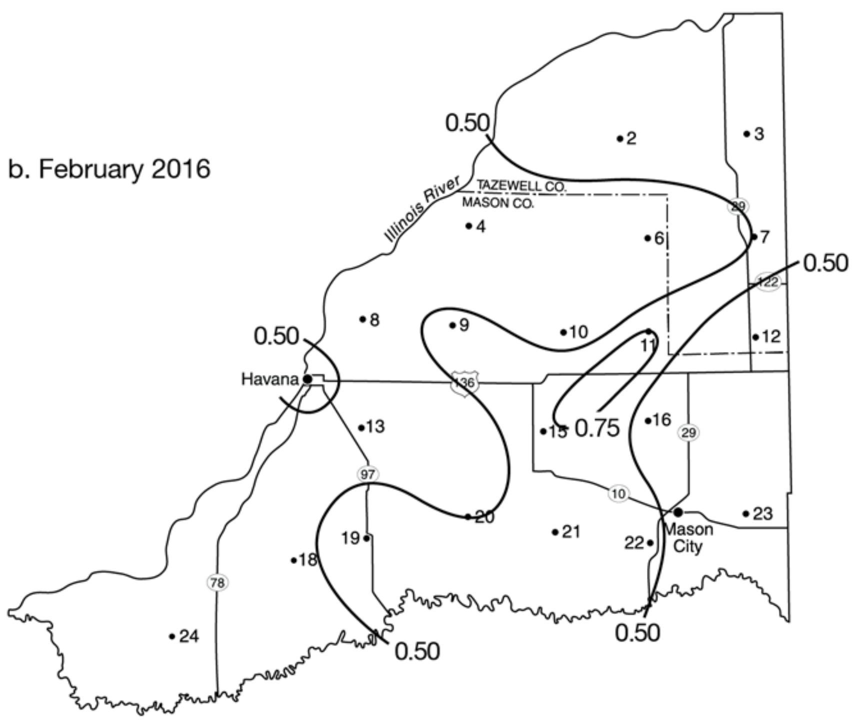


Figure 10. Precipitation (inches) for January 2016 and February 2016

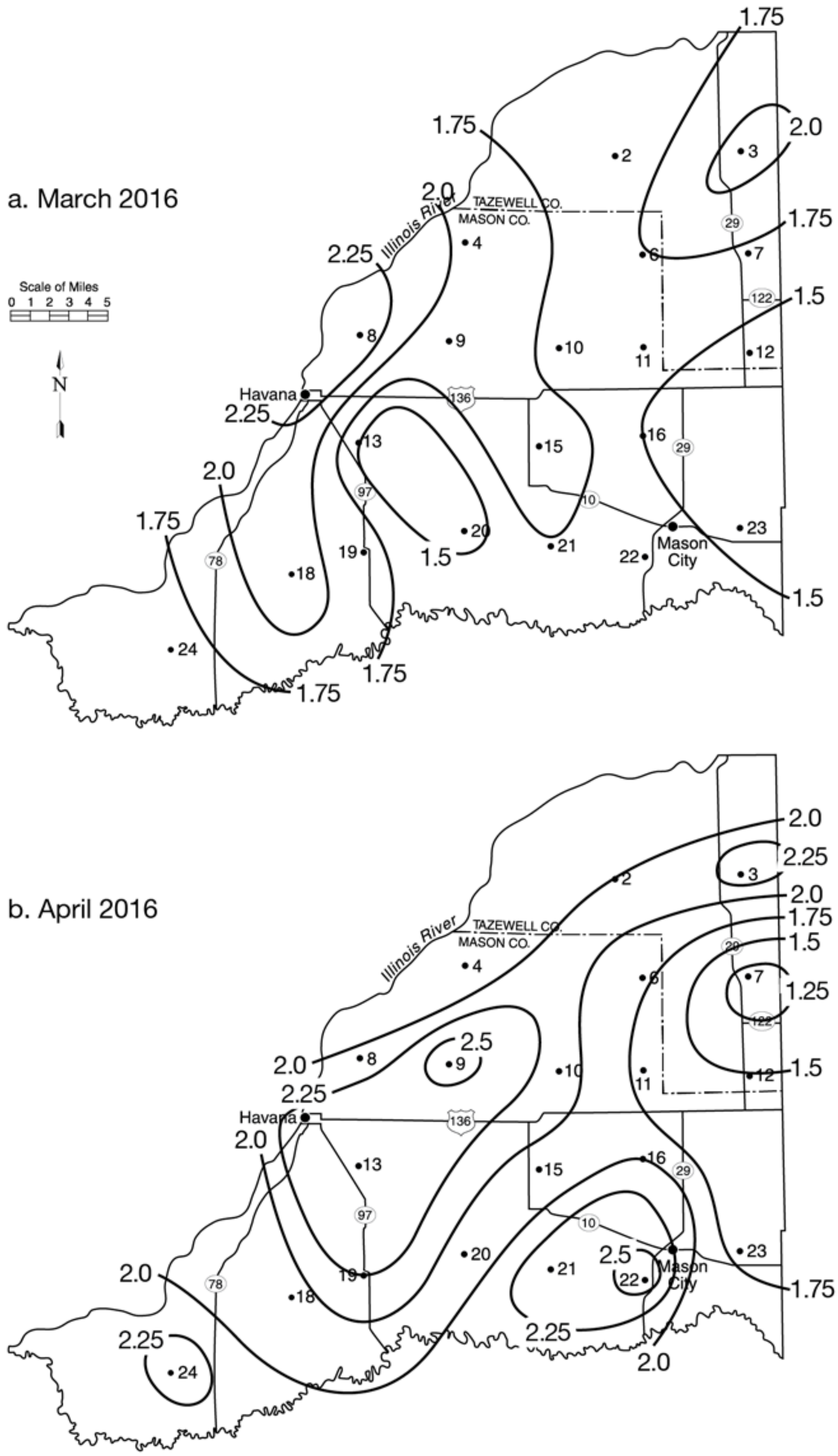


Figure 11. Precipitation (inches) for March 2016 and April 2016

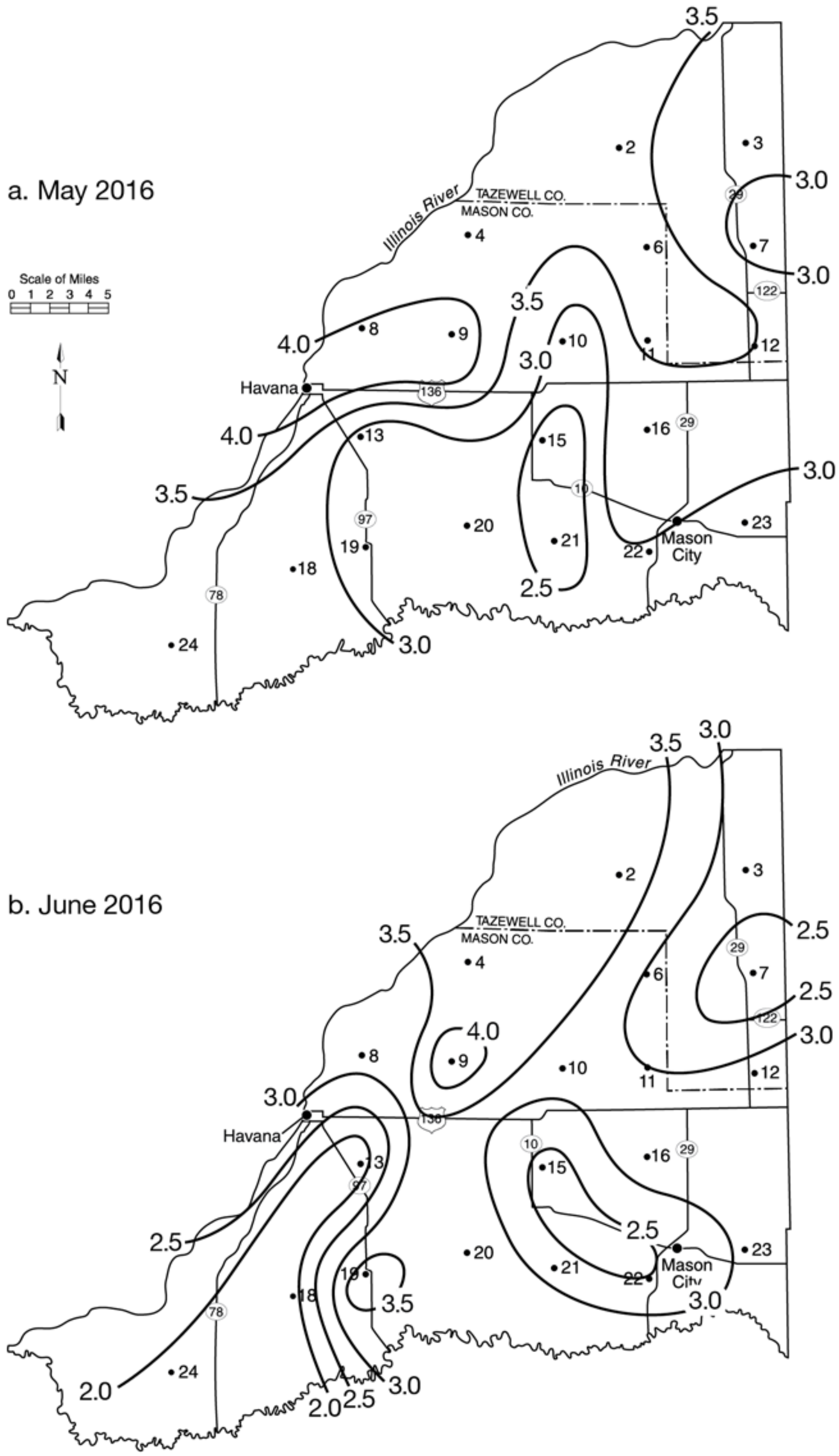


Figure 12. Precipitation (inches) for May 2016 and June 2016

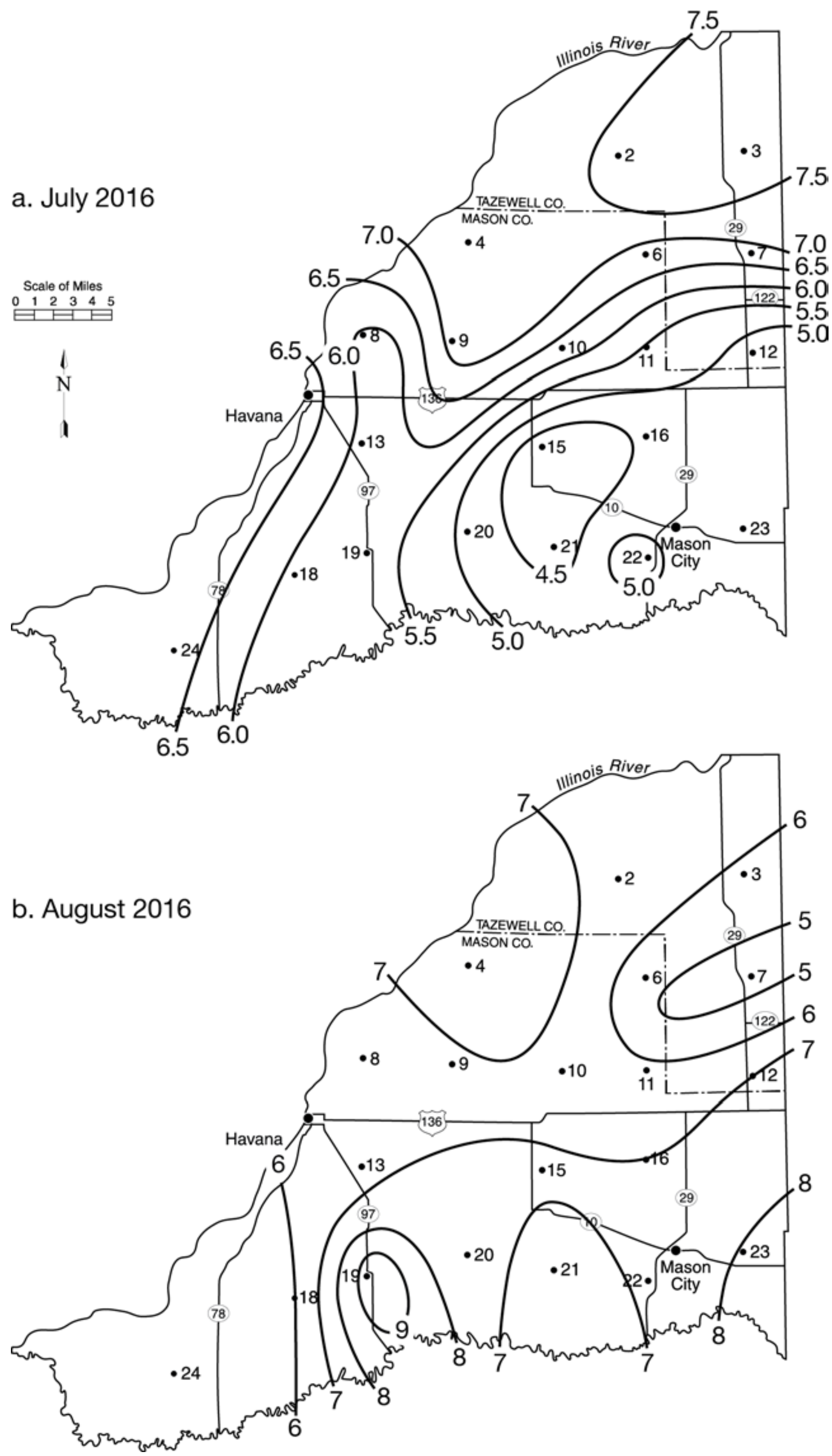


Figure 13. Precipitation (inches) for July 2016 and August 2016

Mean monthly, seasonal, and annual number of network storms (precipitation events) were determined for PY2016 and the previous 23- year period (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. The historic average for the last 23 years and the average for PY2016 was 0.30 inches per event. Note that the seasonal distribution of precipitation was noticeably different from the long term average distribution even though the annual inches/event were equal.

Table 2. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event for Each Month and Season, 1993-2015 and 2015-2016

	1993-2015 23-yr average			*2015-2016 average*		
Period	*Precipitation*	*Events*	*Inches/event*	*Precipitation*	*Events*	*Inches/event*
September	3.04	7.4	0.41	1.70	6	0.28
October	2.76	8.7	0.32	1.34	8	0.17
November	2.51	8.8	0.33	4.41	7	0.63
December	1.85	9.5	0.23	6.55	10	0.66
January	1.95	9.2	0.25	0.73	10	0.07
February	1.72	8.0	0.23	0.50	8	0.06
March	2.12	8.4	0.25	1.73	10	0.17
April	3.50	11.1	0.33	2.00	14	0.14
May	4.25	13.1	0.33	3.22	14	0.23
June	4.50	12.1	0.37	2.91	11	0.26
July	3.69	10.4	0.37	5.93	16	0.37
August	3.15	11.5	0.28	6.73	12	0.56
Fall	8.31	24.9	0.34	7.45	21	0.35
Winter	5.52	26.7	0.22	7.78	28	0.28
Spring	9.87	32.7	0.30	6.95	38	0.18
Summer	11.34	34.0	0.33	15.57	39	0.40
Annual	35.03	118.3	0.30	37.75	126	0.30

For PY2016, the winter and summer seasons had more events and inches of precipitation than the 23-year averages, while spring 2016 precipitation was low, 6.95 inches, compared to the historical average of 9.87 inches. Additionally, the number of spring events in 2016 was higher (38) than the historical average of 32.7. Summer received 15.57 inches of precipitation, 4.23 inches more than the 23-yr average of 11.34 inches.

The Imperial Valley Water Authority precipitation network has a 23-year average of 118.3 storm events per year. During PY2016, there were 126 precipitation events. Seasonally, autumn had fewer events than 23-yr average, whereas winter, spring, and summer had more. The month of July 2015 had most precipitation events in a month (16 events) during PY2016, 5.6 events more than the 23-year average. September, October, November 2015 and June 2016 had fewer events than the 23-year average, February had the same as the 23-yr average, while the rest of the months had more events than average. Interestingly, in PY2016 (September 2015-August 2016), 51% of the annual rainfall occurred during December 2015, July, and August 2016. The 23-year average accumulation during these months is only 25 % of the annual rainfall.

Figure 14 is a plot of the network average monthly precipitation beginning in September 2007 and 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 2013 experienced both above and below average precipitation periods, with two spring months (April and May 2013) totaling more than 14 inches of rain followed by three summer months totaling less than 5 inches of rain. In 2014, the opposite occurred with a dry spring (5.89 inches) and a wet summer (15.58 inches). A wet fall in 2014 was followed with a dry winter and spring in early 2015, and then an extremely wet summer in 2015.

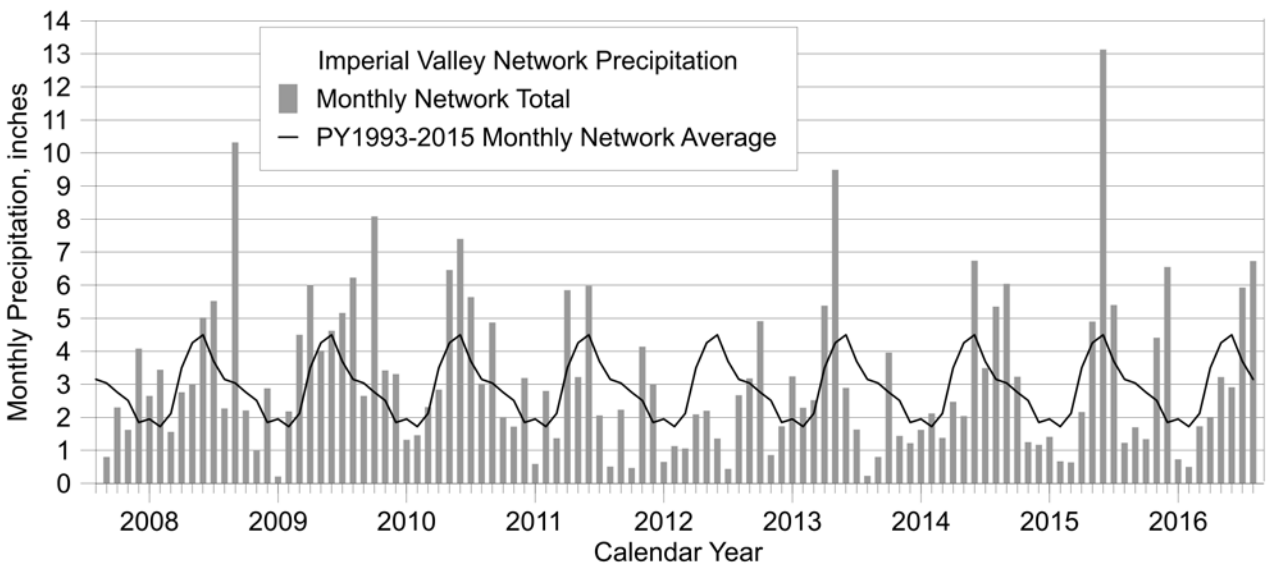


Figure 14. Network Average Monthly Precipitation (inches), January 2007 - August 2016

The PY2016 annual network average was 2.74 inches wetter (7.83%) than the 23-year annual network average. Figure 15 compares the 23-year seasonal network totals with the PY 2016 seasonal totals. Autumn was slightly wetter than the 23-year average autumn, winter was the third wettest winter, spring was the 5th driest spring, and summer was the 6th wettest summer of the last 24 years. Autumn and spring seasons received much less rain than the long term averages, while summer received much more than the average. Winter received about 2 inches more than the 23-yr network seasonal average.

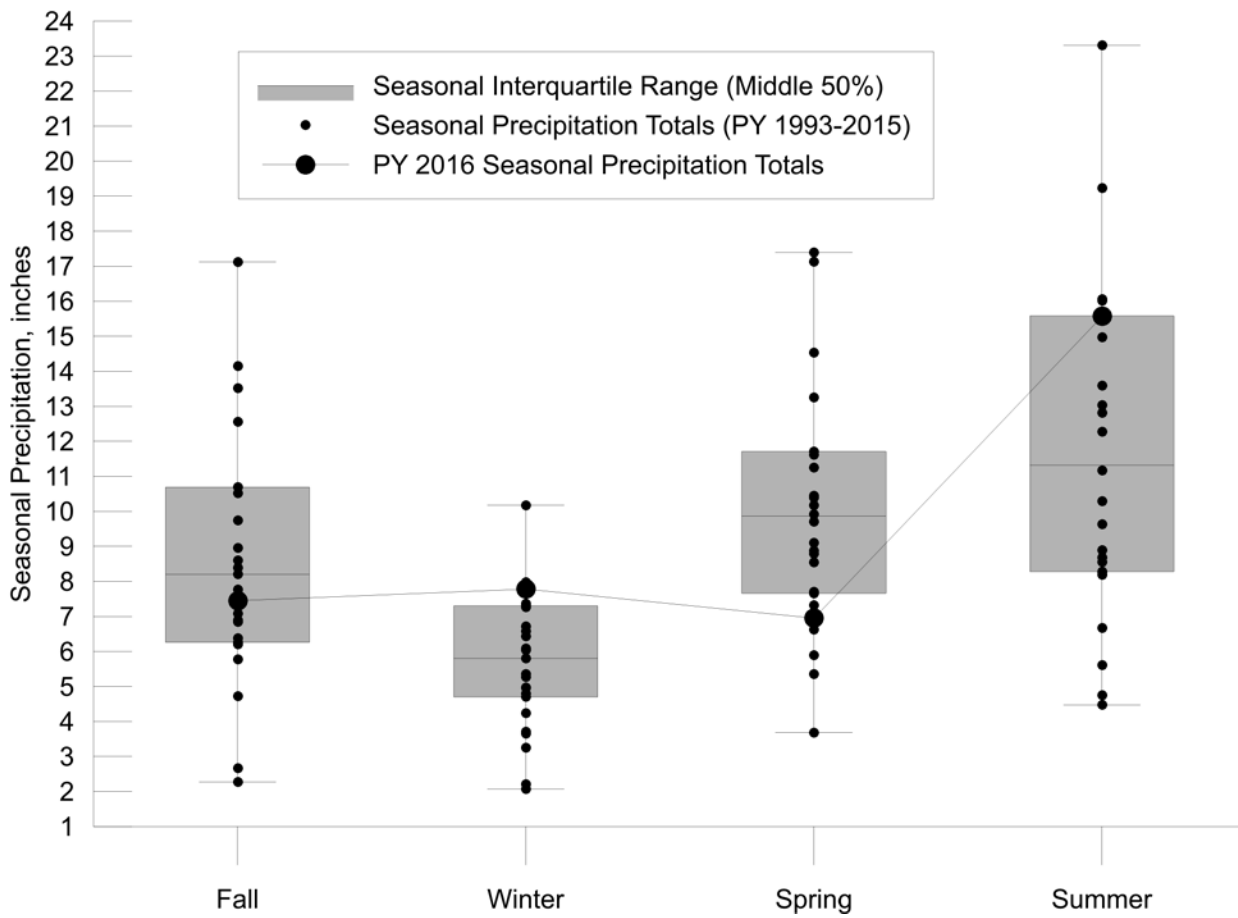


Figure 15. Seasonal Network Average Precipitation with Seasonal Totals for each Project Year. Box Plots Show the Interquartile Range (middle 50% of values, median (horizontal line within the box), Minimum, and Maximum Values.

Groundwater Levels

The IVWA monitoring well network has consisted of thirteen monitoring wells with all but two outfitted with data loggers that record the water level once per hour. As stated earlier, three additional well were drilled during 2014 bringing the total number of observation wells to sixteen. The observation well network has been in existence since 1995 and is used to monitor changes in groundwater levels in the aquifer. The new observation wells add to the understanding of the aquifer. Two wells were installed at Ellsberry Lake as a nest, meaning they are screened at different depths. The third new well was drilled and installed next to the existing well at Mason City to create a second well nest. Having a well nest allows the observance of vertical movement of groundwater from the surface to the deeper sand and gravel units of interest.

In an unconfined system, like the aquifer in the Havana lowlands, water levels typically vary by season. The highest water levels in the aquifer generally occurs during the spring 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 and withdrawals from the aquifer due to evapotranspiration and irrigation pumpage are at their greatest. Generally, precipitation is not high enough during this time to raise water levels in the aquifer. Most rainfall goes to replenish soil moisture, and make up for irrigation withdrawals. Significant recharge to the aquifer most often occurs during winter and early spring when there is little pumpage, evapotranspiration is low, and soil moisture is more likely high.

The long-term hydrograph at MTOW-01A (Snicarte, 1958 to present) in Figure 16 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 17. During the 1988-1989 drought, the water level fell to 40.5 feet below land surface in the Snicarte well. At the time, it was the only time in its 45-year history that the well had 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.

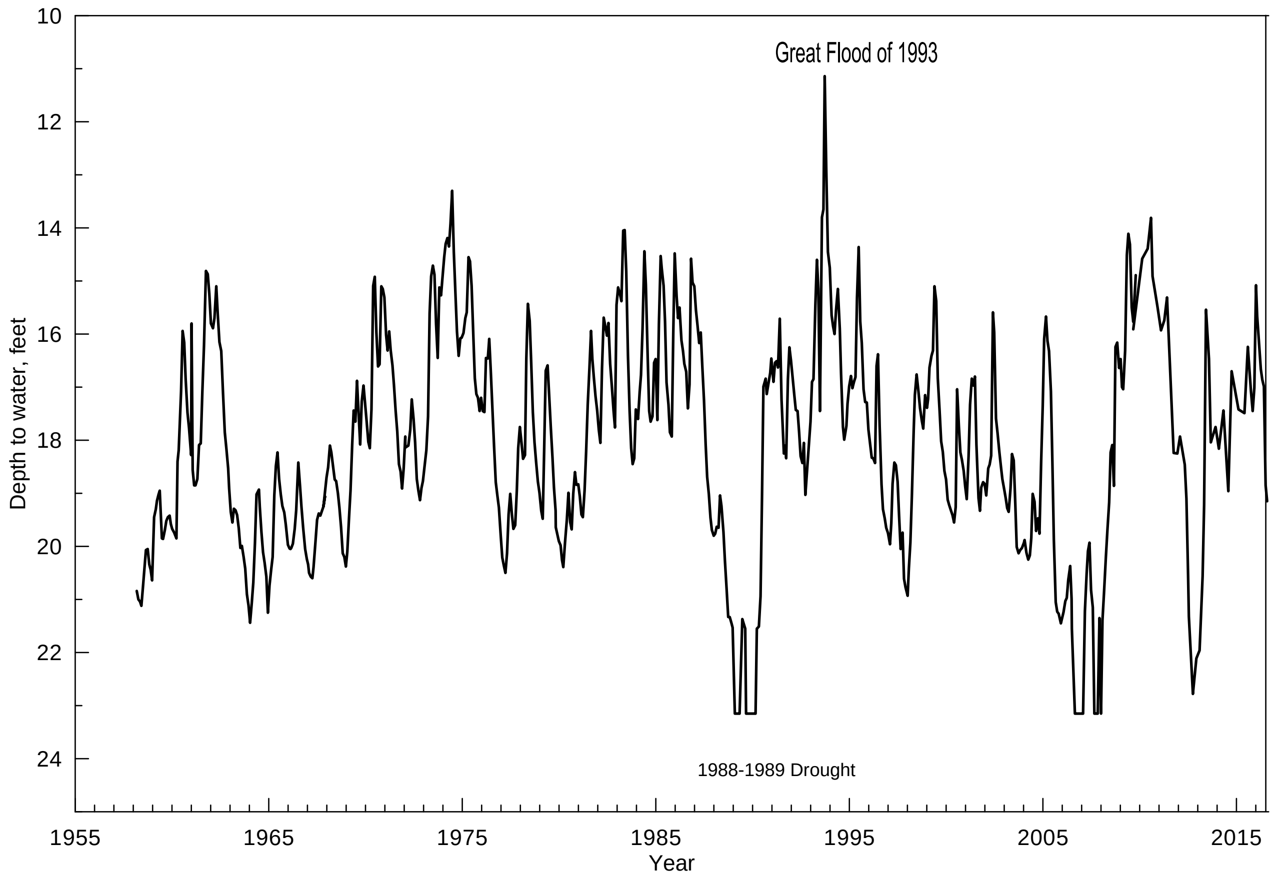


Figure 16. Groundwater Levels at the Snicarte Well, 1958-2016.

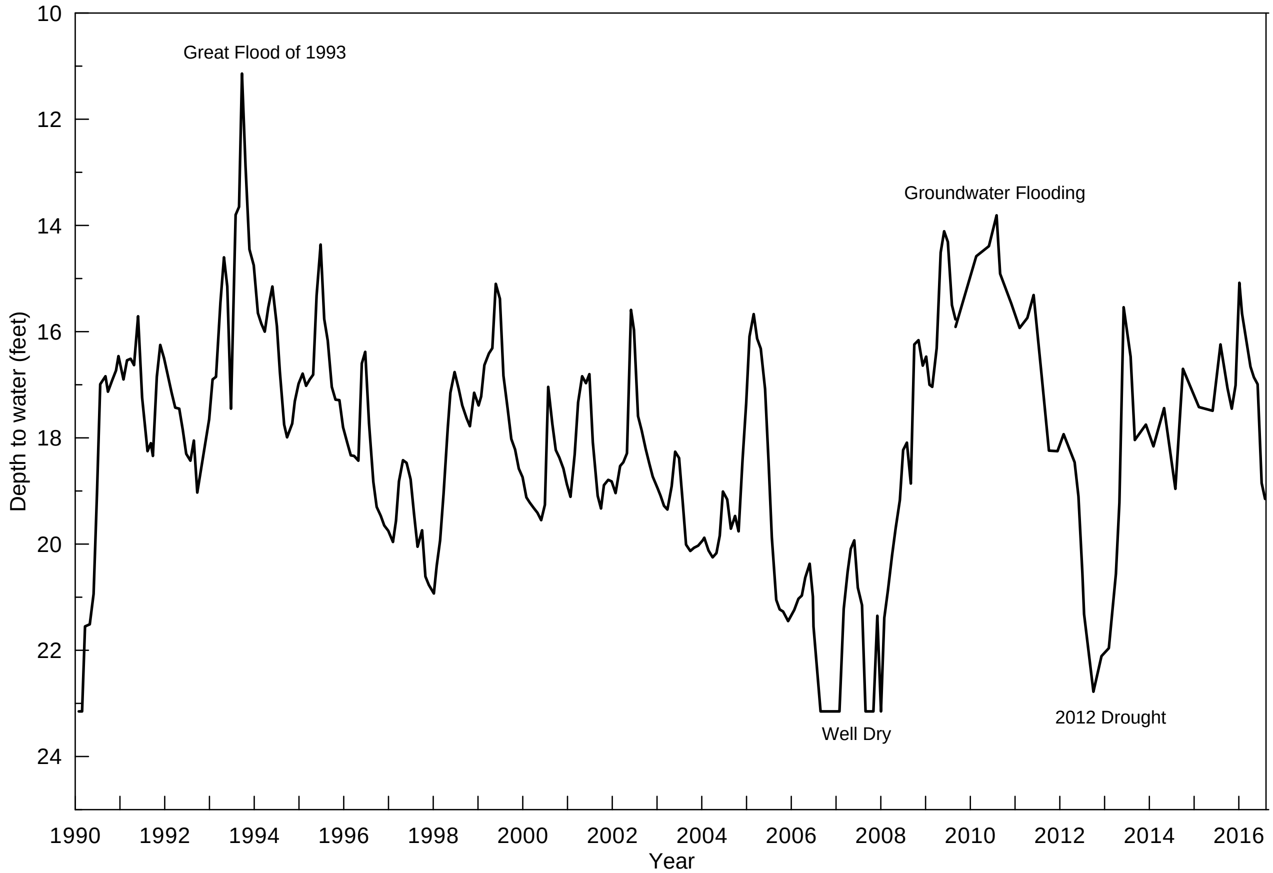


Figure 17. Groundwater Levels at the Snicarte Well, 1990-2016.

The dramatic water level 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 2007 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. 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 17 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. It is likely that because of a continued increase in the number of irrigation systems in the area, years with below average precipitation will lead to larger drops in aquifer water levels. The drops seen in 2005-2007 and in 2011-2012 suggest it won't take as significant a drought as in 1988 to cause 1988-like water level declines.

The hydrographs created from hourly water level measurements have led to an increased understanding of the relationship between rainfall, irrigation, water levels, and recharge. In Figure 18, data shown consisted of once a month measurements until 2005, when data loggers were installed to record hourly measurements. Appendix A shows the hydrographs for the 13 long-term wells within the observation well network. The hydrographs in Appendix A show water levels in each well for PY2016, from September 1, 2015 to August 31, 2016, and contain all groundwater elevation data and daily precipitation totals for nearby rain gauges.

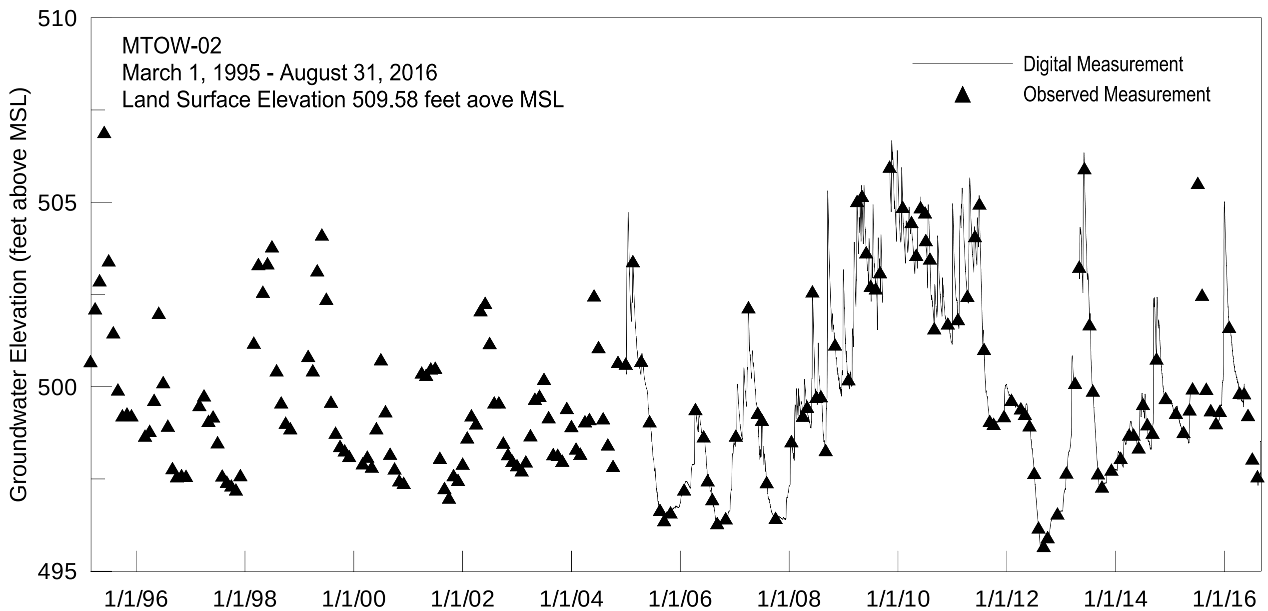


Figure 18. Groundwater Elevations at the Easton Well, MTOW-02, September 1, 1995-August 31, 2016.

Figure 18 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. It also highlights the influence rainfall has on the aquifer when the water table is so shallow and the aquifer is unconfined.

In Figures 19 and 20, the relationship between rainfall and recharge is observable as groundwater levels rise during periods of heavy precipitation. This is particularly evident after the large rainfall event in late December 2015 (around 4.0 inches over 3 days) and the 3-4 weeks following that event.

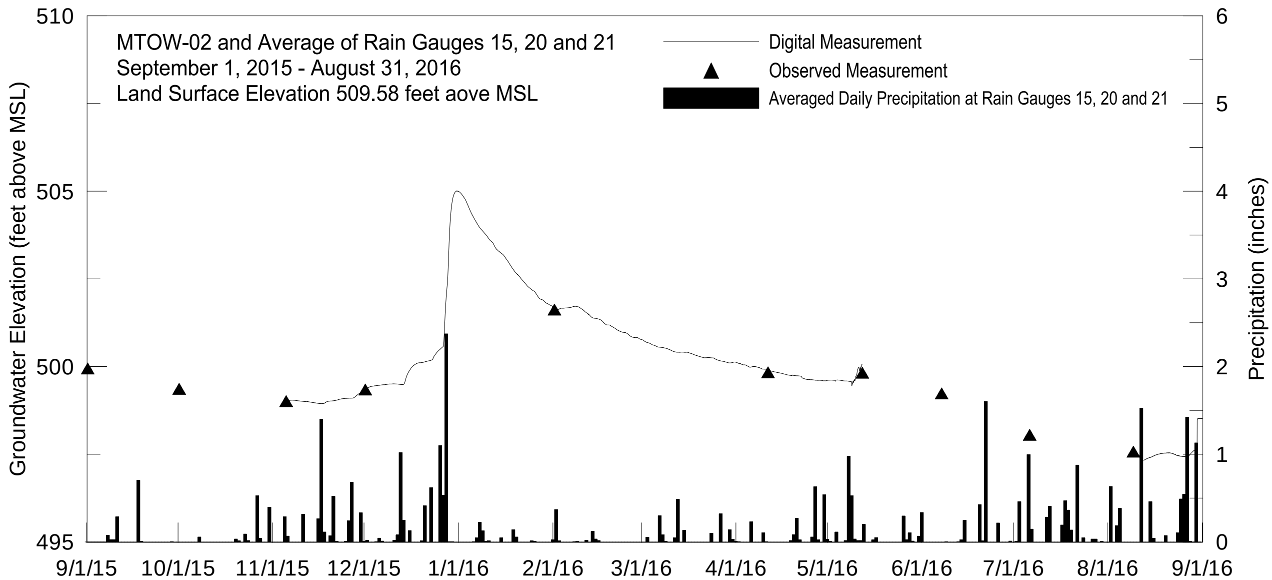


Figure 19. Groundwater Elevations at the Easton Well, MTOW-02, September 1, 2015 - August 31, 2016

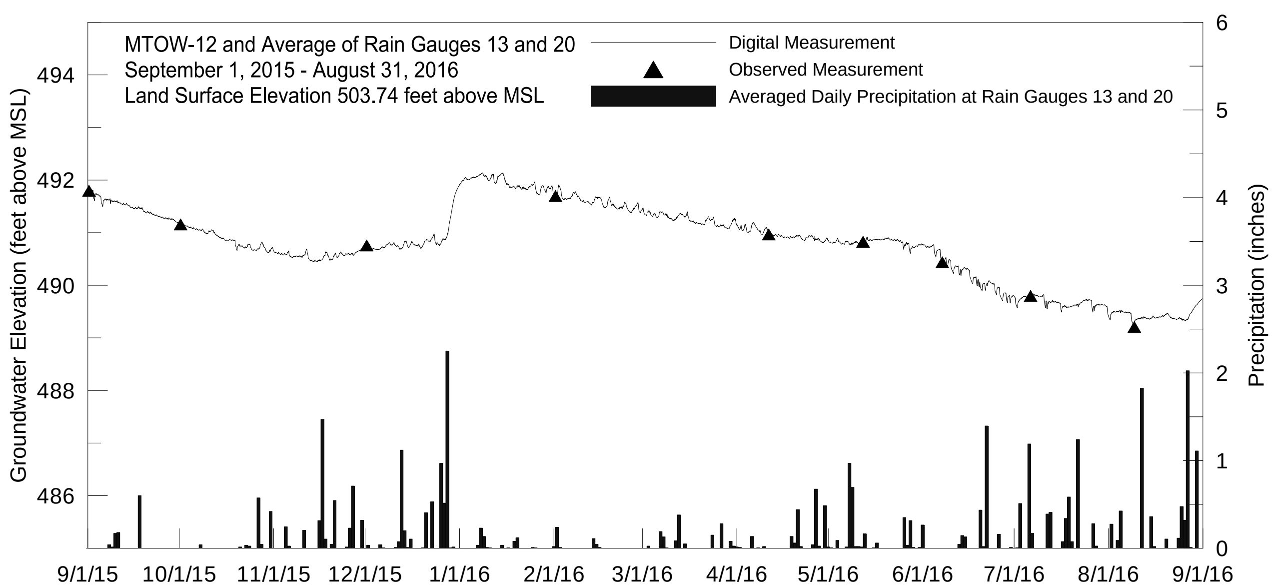


Figure 20. Groundwater Elevations and Precipitation at the Hahn Farm Well, MTOW-12, September 1, 2015-August 31, 2015

Figure 21 and 22 are hydrographs showing groundwater elevation and precipitation data during the summer of 2016. The hydrographs start June 1, 2016 and go to the end of the project year which ends August 31, 2016. The hydrographs illustrate the effects of abundant precipitation that raises water levels and irrigation pumpage resulting in the lowering of groundwater levels.

Having continuous water level data allows us to better understand how rainfall affects recharge. At MTOW-06 (Tree Nursery well) and MTOW-12 Hahn Farm well), the effect of precipitation in pumpage amounts and aquifer water level in evident. The lower than average amount of precipitation during June shows increased pumpage in Figures 21 and 22. Each "downward spike" on the hydrograph is a pumping event from a nearby irrigation pivot. July and August show a different scenario, precipitation increased and the number of pumpage events decreased.

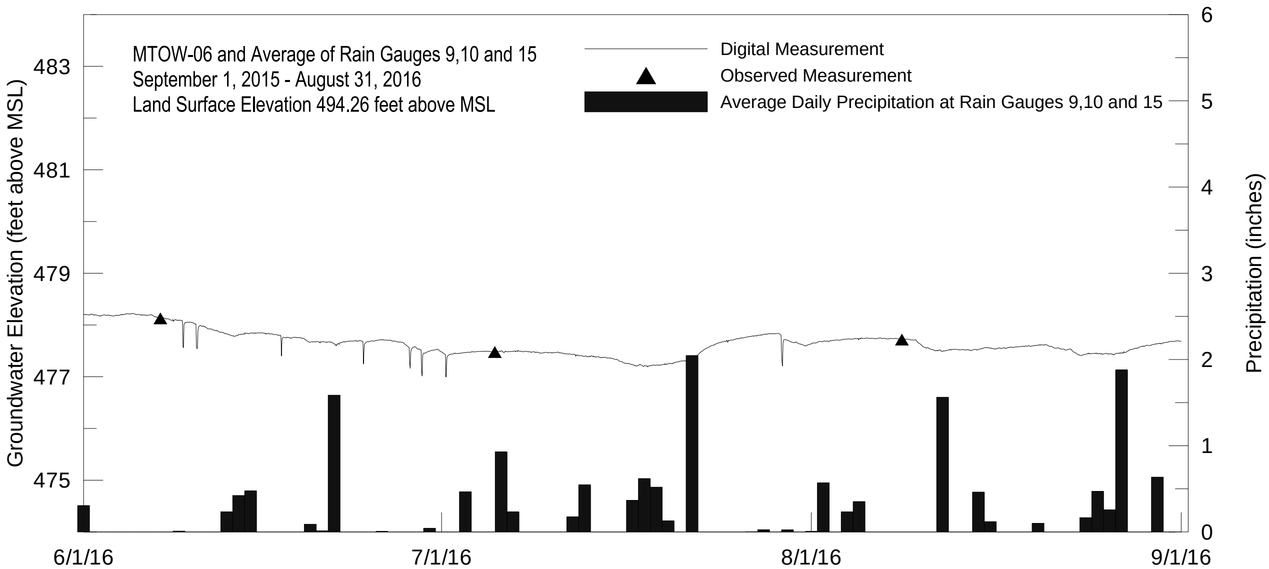


Figure 21. Groundwater Elevations and Precipitation at the Tree Nursery Well, MTOW-06, June 1, 2016-August 31, 2016.

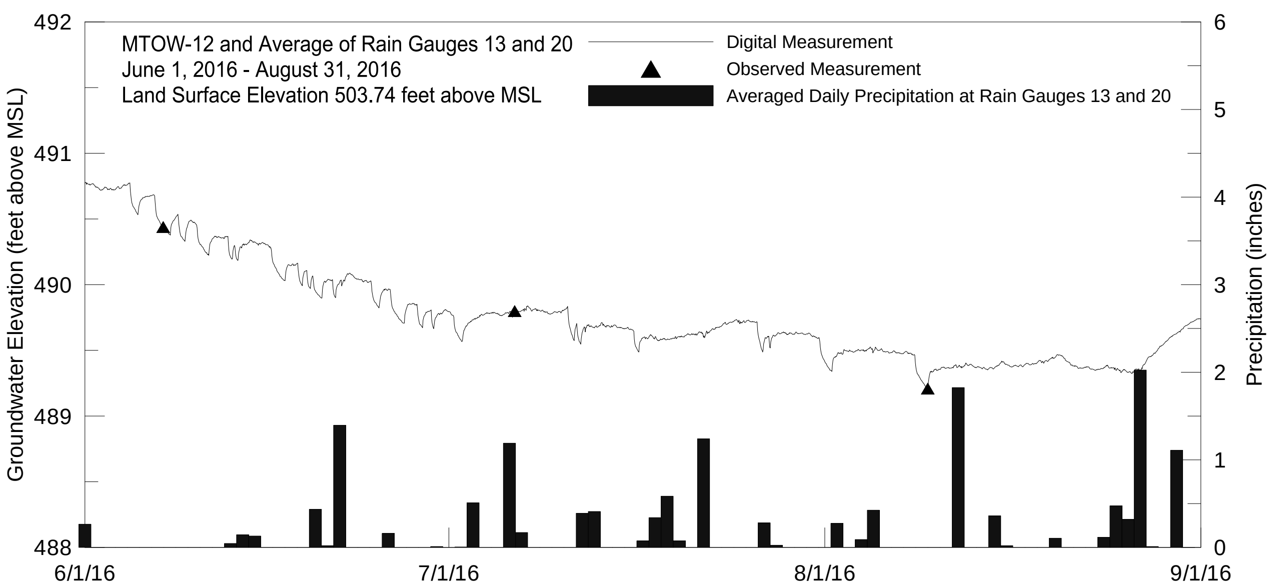


Figure 22. Groundwater Elevations and Precipitation at the Hahn Farm Well, MTOW-12, June 1, 2016-August 31, 2016.

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. Appendix B has the initial water level data for the 3 new wells installed in 2014.

Irrigation Water Use

The IVWA has provided to the ISWS a monthly estimated total pumpage of irrigation since 1997. These data aree calculated by the Imperial Valley by evaluating power consumption at nearly 1100 irrigations systems in the area supplied by the Menard Electric Cooperative. The pumpage is a monthly 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 as shown in Figure 1.

The total irrigation pumpage in 2016 was approximately 45 billion gallons (bg), which is the eleventh highest irrigation amount for the observation period. The number of irrigation systems is now at 2223. During 2014, the ISWS developed a statewide map of irrigation based on USDA aerial photography. Based on those data, it was determined the number of irrigation systems in the IVWA was lower than the IVWA was estimating. The IVWA uses new well construction reports to determine the number of irrigation systems each year, which doesn't necessarily account for wells installed to replace existing wells. This likely led to the over-counting of irrigation systems by the IVWA. Figure 23 shows the location of irrigation systems in the IVWA area in 2014.

For Year 24, the higher than normal precipitation during the spring and late summer affected irrigation practices. Irrigation in July was estimated at 23.4 billion gallons (bg), 9.5 bg more than the long term average. June, August and September's irrigation totals, however, were lower than average at 2.8 bg, 10.9 bg and 6.6 bg. The historic average for those three months is 4.7 bg, 17.0 bg and 9.2 bg.

In recent discussions with the IVWA, it has been discovered the irrigation monthly pumpage figures may be reported incorrectly, and off a month. The monthly figures reported may be for the previous month, once a final determination has been made a correction in practice and reporting will be made. The total annual pumpage data are not affected by this issue.

The monthly and seasonal estimates of irrigation withdrawals are shown in Table 3. The rank from highest to lowest irrigation amounts are shown in the right hand column in Table 3. Year 24 was in the middle, ranking eleventh overall with 45 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 2016 as June, August and September proved to be the less heavily irrigated months due to above average precipitation. July's 23.4 billion gallons pumped is the third highest on record. The August pumpage total of 10.9 bg was the third lowest on record.

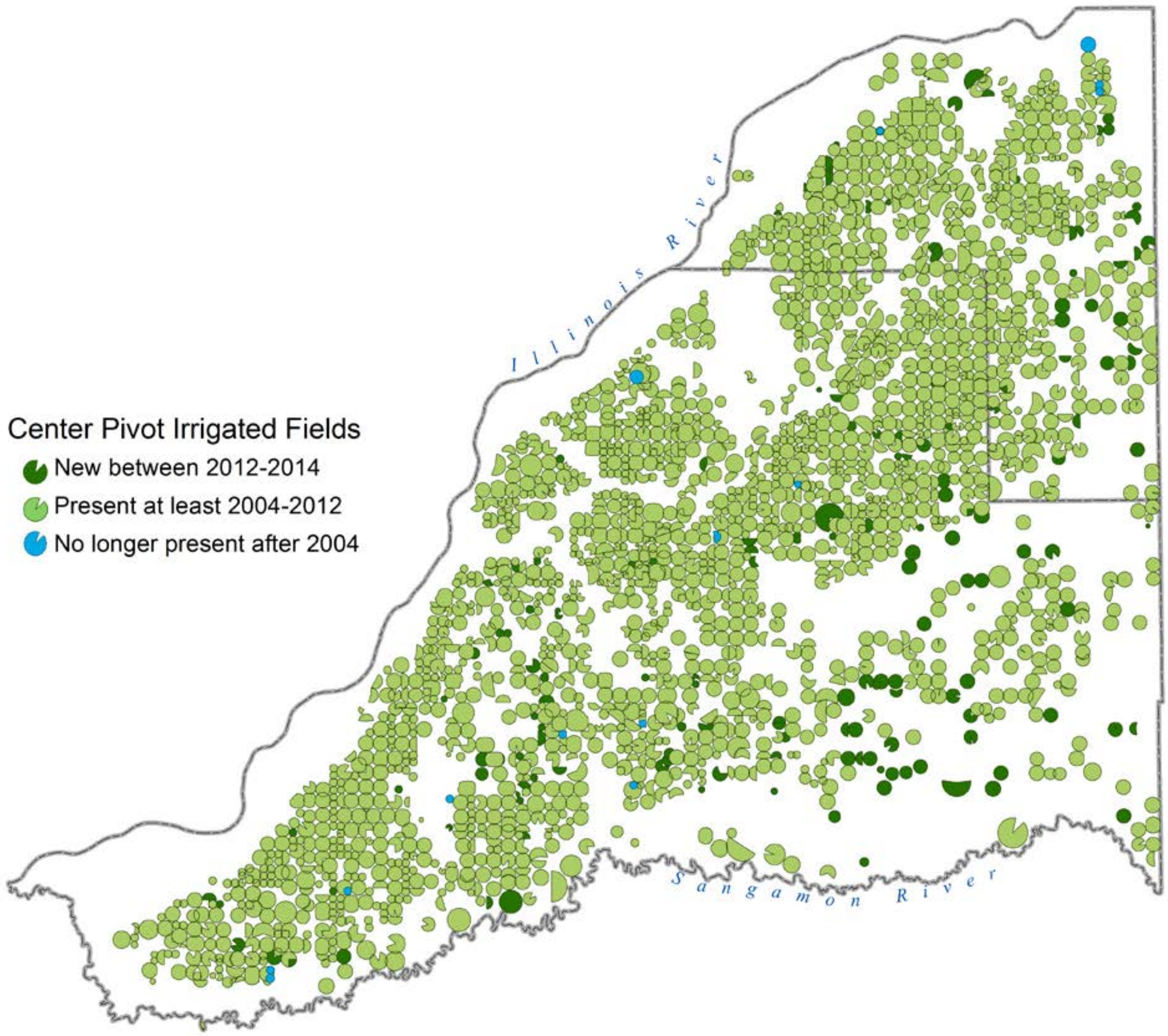


Figure 23. Location of Irrigation Systems within the IVWA (2014).

The estimated monthly irrigation pumpage is displayed graphically in Figure 24 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. The irrigation rank is from least pumpage to most so that ranks between precipitation and pumpage are comparable. This ranking makes it clear, that the timing and amount of rainfall received during the irrigation season (rather than total annual precipitation) is the primary factor affecting the amount of irrigation pumpage. The 1999-2000 project year is a great example. Even though annual precipitation was over 12 inches below normal, the 2000 growing season had the 3rd lowest total irrigation pumpage for the 22 years of record.

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			15
1996		2.0	20	18	12		52			5
1997		2.6	19	14	2.0		38			15
1998		2.1	7.8	13	6.9		30	1622	.018	19
1999		2.8	18	12	6.0		39	1771	.022	14
2000		6.4	6.0	12	5.6		30	1799	.017	19
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	17
2009		1.6	9.3	12.1	2.9		26	2054	.013	22
2010		1.8	2.4	11.7	10.6		27	2077	.013	21
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	13
2015	0.1	1.6	2.2	9.8	17.0	0.9	31	2197	.014	18
2016	0.1	2.8	23.4	10.9	6.6	1.4	45	2223	.020	11
Average	0.1	4.7	13.9	17.0	9.2	3.7	45.8		.023	

Note: Total annual withdrawal may differ from sum of monthly withdrawals due to rounding error.
*Total number of system was updated during June 2014 by ISWS using aerial photography.

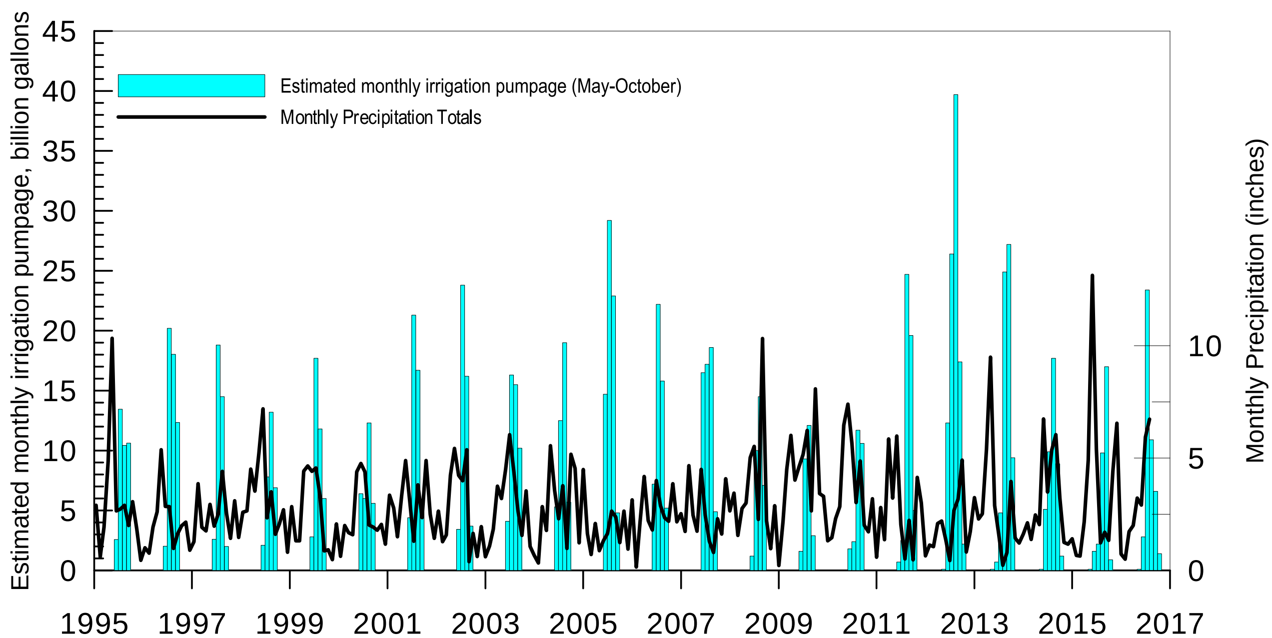


Figure 24. Estimated Irrigation Pumpage and Average Monthly Precipitation, IVWA.

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

Sept-Aug Project Year	*Network average precipitation (in.)*	*Annual surplus (in.)*	*Rank*	
			Precip.	*Irrigation**
1992 - 1993	**55.55**	**+17.17**	**1**	**-**
1993 - 1994	**40.21**	**+1.83**	**5**	**-**
1994 - 1995	**39.42**	**+1.04**	**8**	**7**
1995 - 1996	**25.70**	**-12.68**	**23**	**17**
1996 - 1997	**27.31**	**-11.07**	**21**	**7**
1997 - 1998	**40.06**	**+1.68**	**6**	**3**
1998 - 1999	**34.02**	**-4.36**	**13**	**9**
1999 - 2000	**25.81**	**-12.57**	**22**	**3**
2000 - 2001	**30.97**	**-7.41**	**16**	**14**
2001 - 2002	**39.91**	**+1.53**	**7**	**14**
2002 - 2003	**30.06**	**-8.32**	**17**	**13**
2003 - 2004	**29.64**	**-8.74**	**18**	**11**
2004 - 2005	**27.34**	**-11.04**	**20**	**21**
2005 - 2006	**27.74**	**-10.64**	**19**	**16**
2006 - 2007	**31.94**	**-6.44**	**15**	**19**
2007 - 2008	**35.02**	**-3.36**	**11**	**6**
2008 - 2009	**49.34**	**+10.96**	**2**	**1**
2009 - 2010	**47.91**	**+9.53**	**3**	**2**
2010 - 2011	**34.17**	**-4.21**	**12**	**17**
2011 - 2012	**21.44**	**-16.94**	**24**	**22**
2012 - 2013	**38.35**	**-0.03**	**9**	**20**
2013 - 2014	**32.63**	**-5.75**	**14**	**10**
2014 - 2015	**41.23**	**2.85**	**4**	**5**
2015 – 2016	**37.75**	**-0.63**	**10**	**12**

***Irrigation ranks are from lowest total pumpage to highest for comparison with precipitation.**

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	**35.03 (23-year IVWA network average)**

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

Summary

During PY2016 of the rain gauge network operation (September 2015-August 2016), the network received an average of 37.75 inches of precipitation, 2.72 inches above the previous 23-year network average precipitation of 35.03 inches, and 0.63 inches below the 30-year average for the study area, 38.38 inches. PY2016 was the 10th wettest year since the deployment of the precipitation network. Fall was near average, winter the third wettest winter, spring the 5th driest spring, and summer was the 6th wettest in the last 24 years.

The data collected over the last 24 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.

ISWS scientists are using these data in new ways. Recently developed methods for evaluating water level information using MODFLOW are leading to a better approach to understanding how irrigation, rainfall, river stage, and groundwater levels all affect each other. We hope to provide some of these results to the IVWA in the coming years as we continue to develop our understanding the groundwater resources of the area.

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

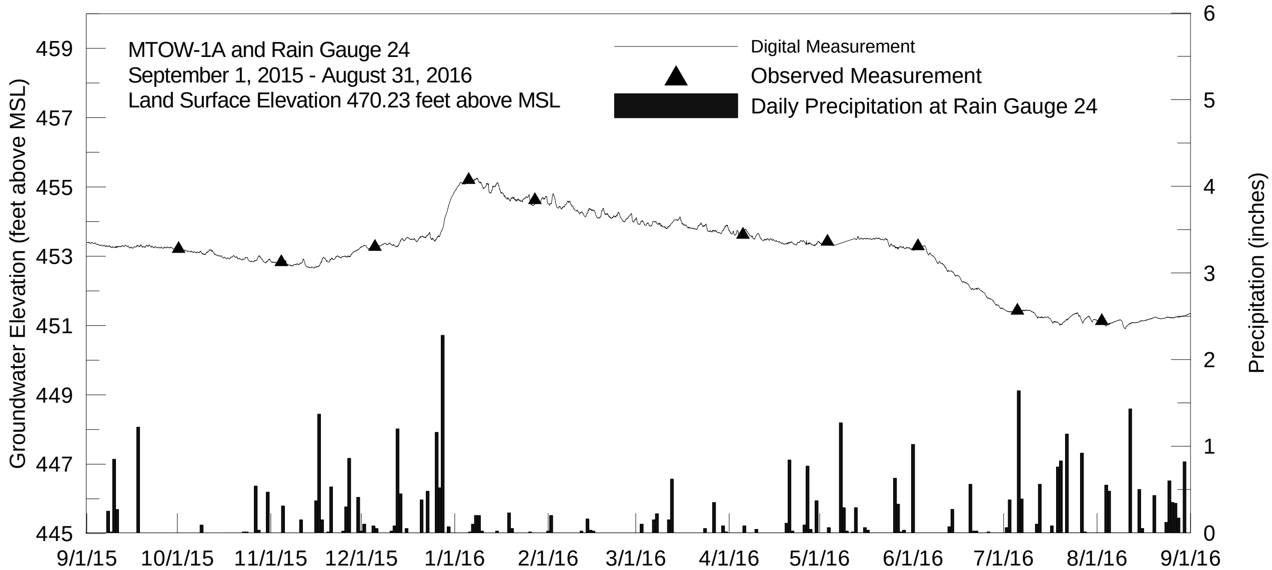

Figure A-1. Year 24 Groundwater Elevation and Precipitation for MTOW-01A

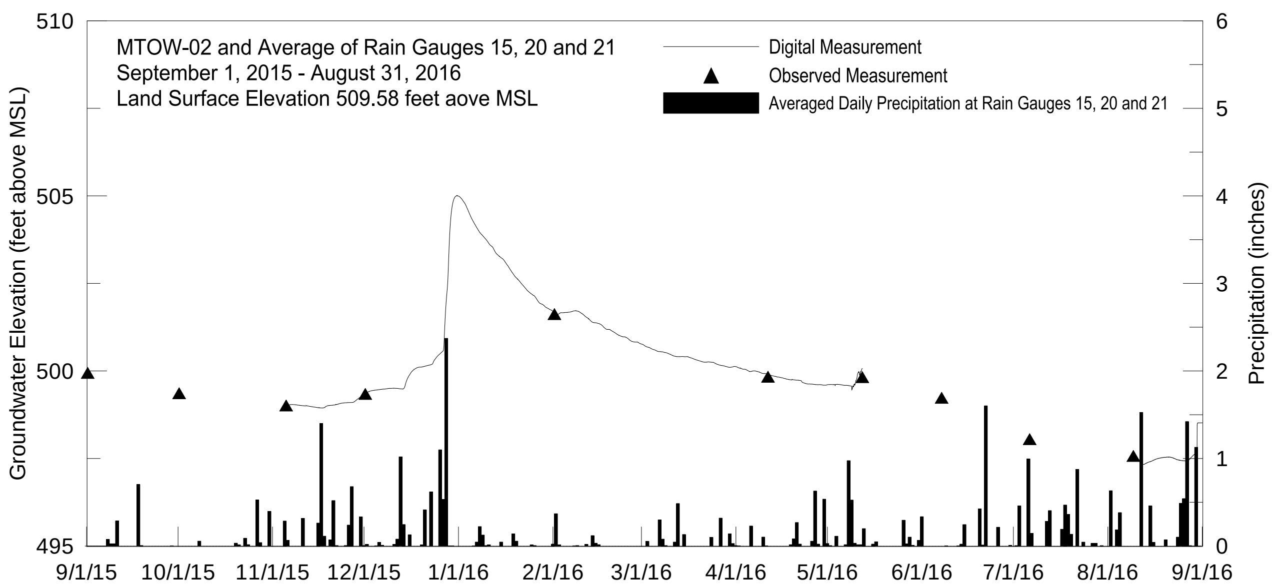

Figure A-2. Year 24 Groundwater Elevation and Precipitation for MTOW-02

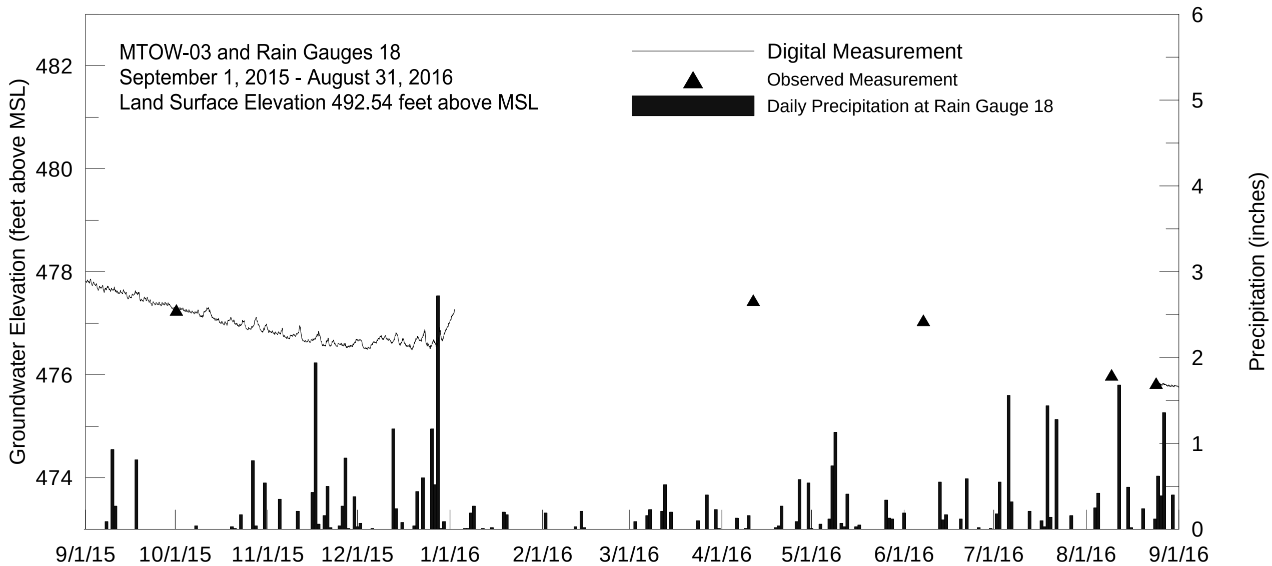

Figure A-3. Year 24 Groundwater Elevation and Precipitation for MTOW-03

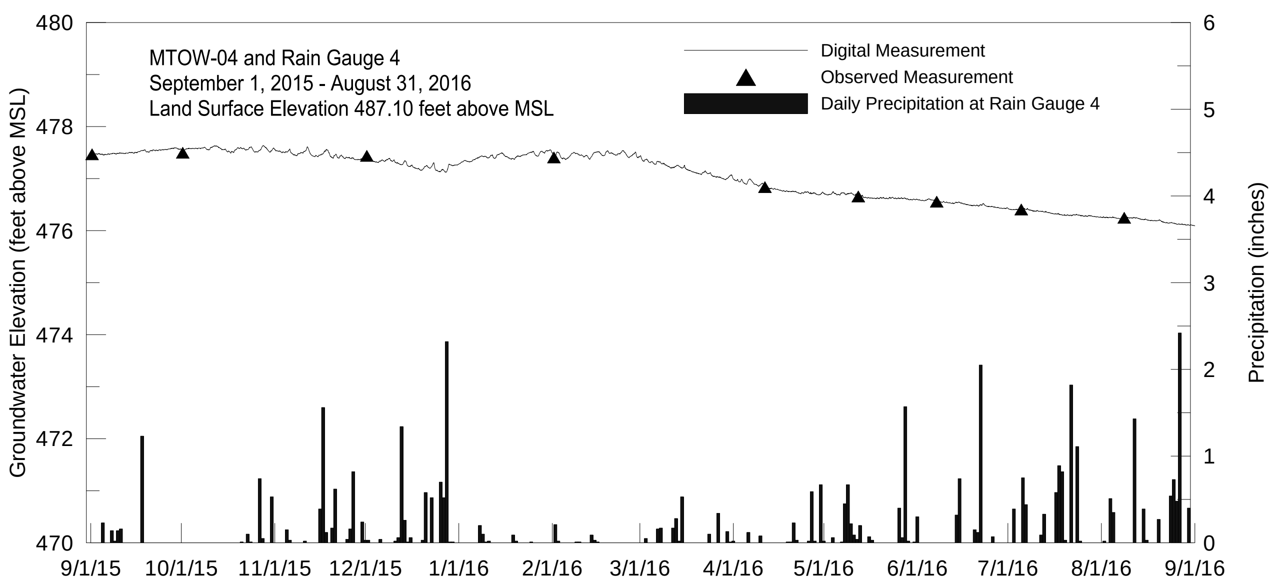

Figure A-4. Year 24 Groundwater Elevation and Precipitation for MTOW-04

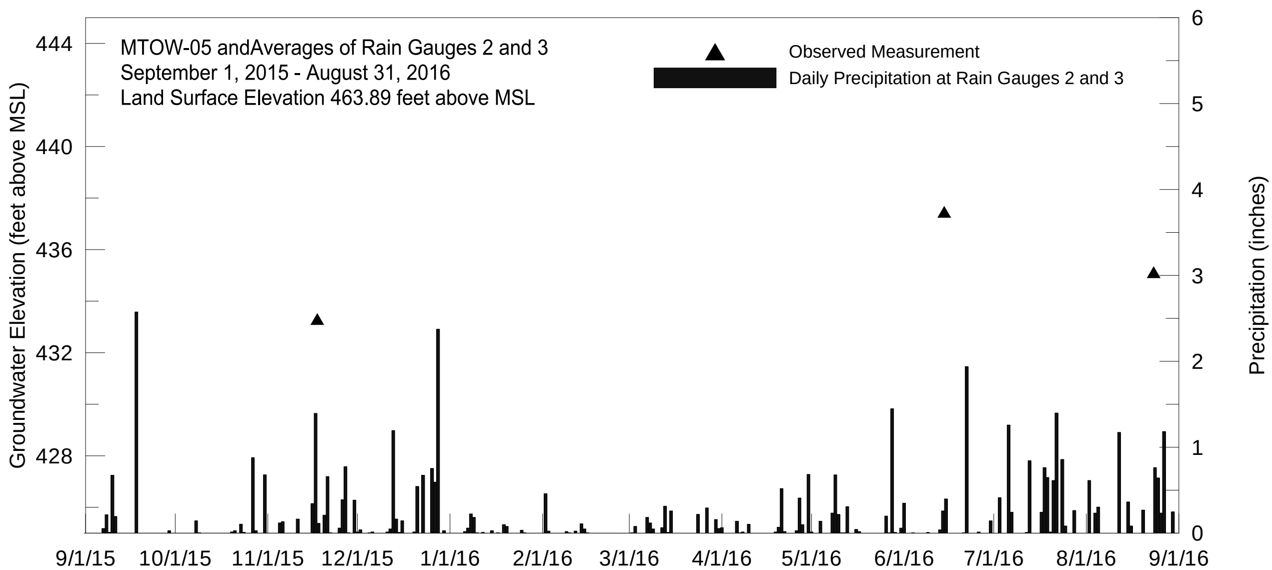

Figure A-5. Year 24 Groundwater Elevation and Precipitation for MTOW-05 (not continuous recorder)

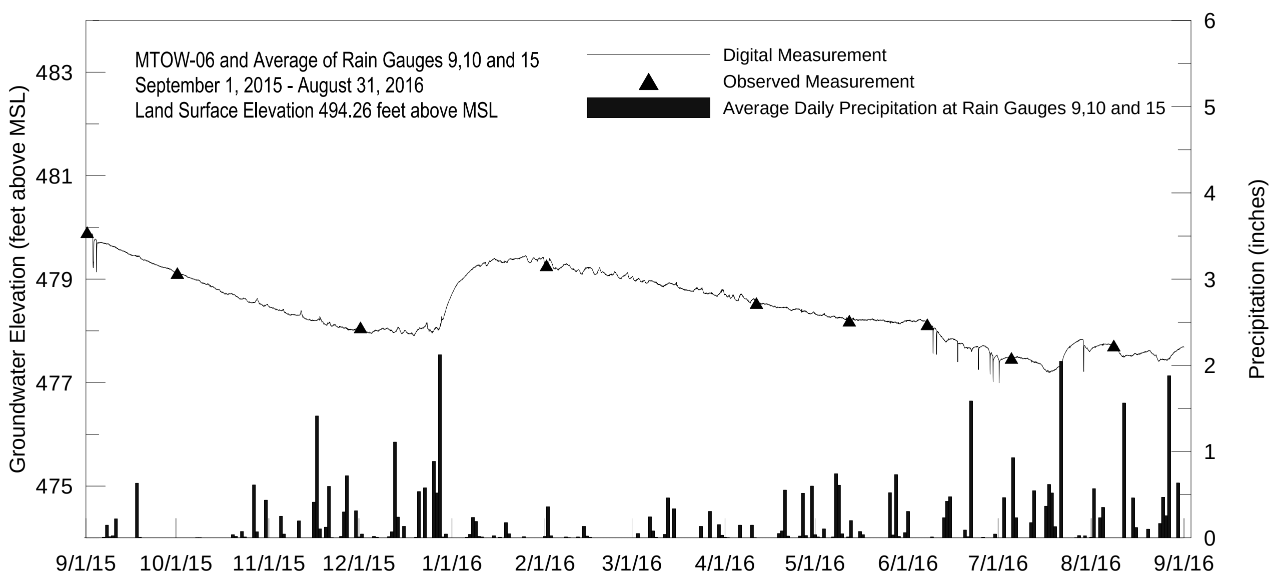

Figure A-6. Year 24 Groundwater Elevation and Precipitation for MTOW-06

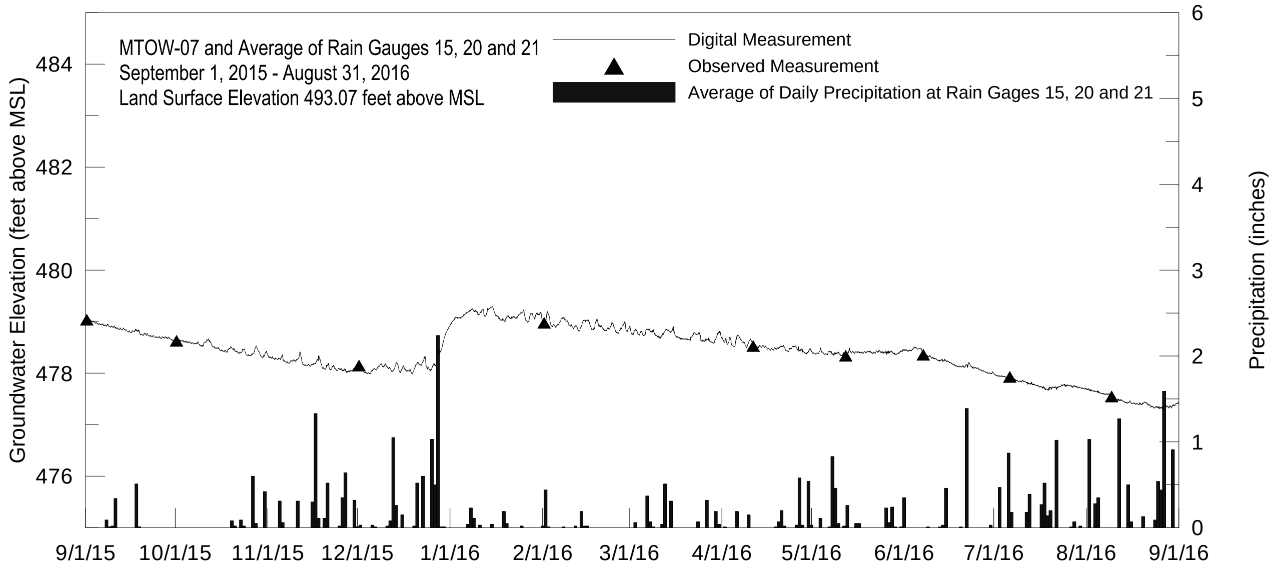

Figure A-7. Year 24 Groundwater Elevation and Precipitation for MTOW-07

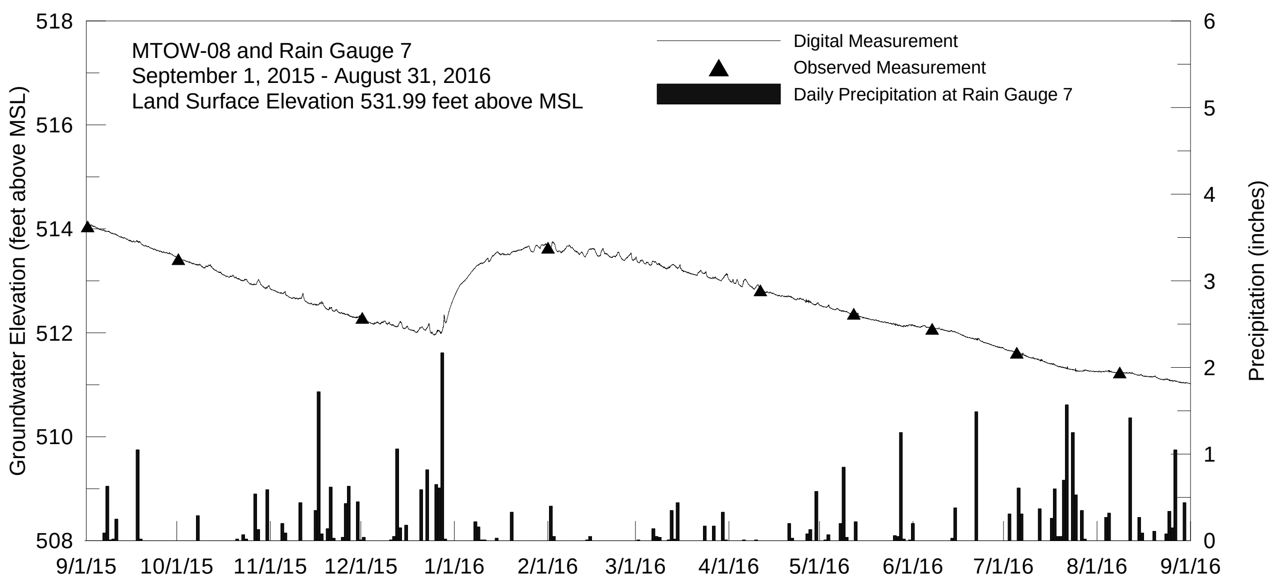

Figure A-8. Year 24 Groundwater Elevation and Precipitation for MTOW-08

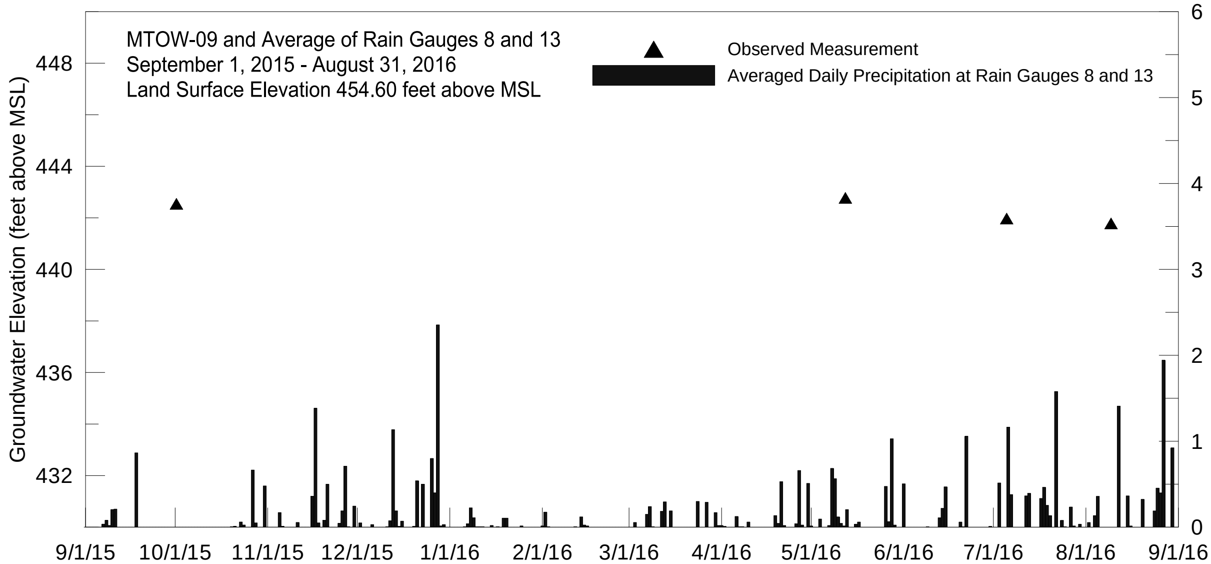

Figure A-9. Year 24 Groundwater Elevation and Precipitation for MTOW-09 (not continuous recorder)

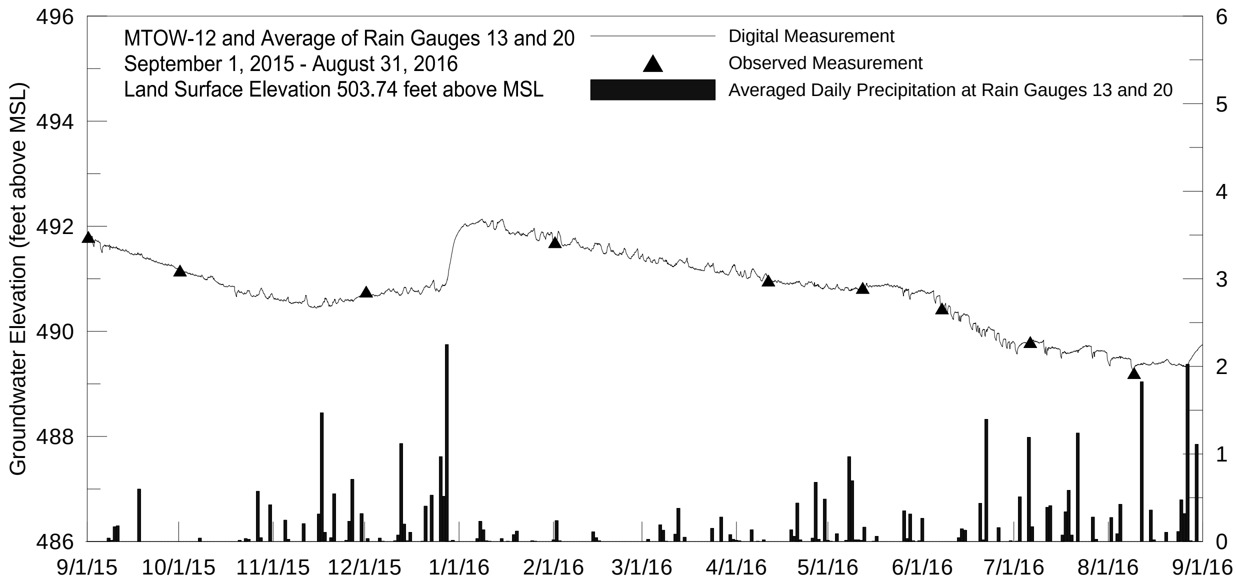

Figure A-10. Year 24 Groundwater Elevation and Precipitation for MTOW-10

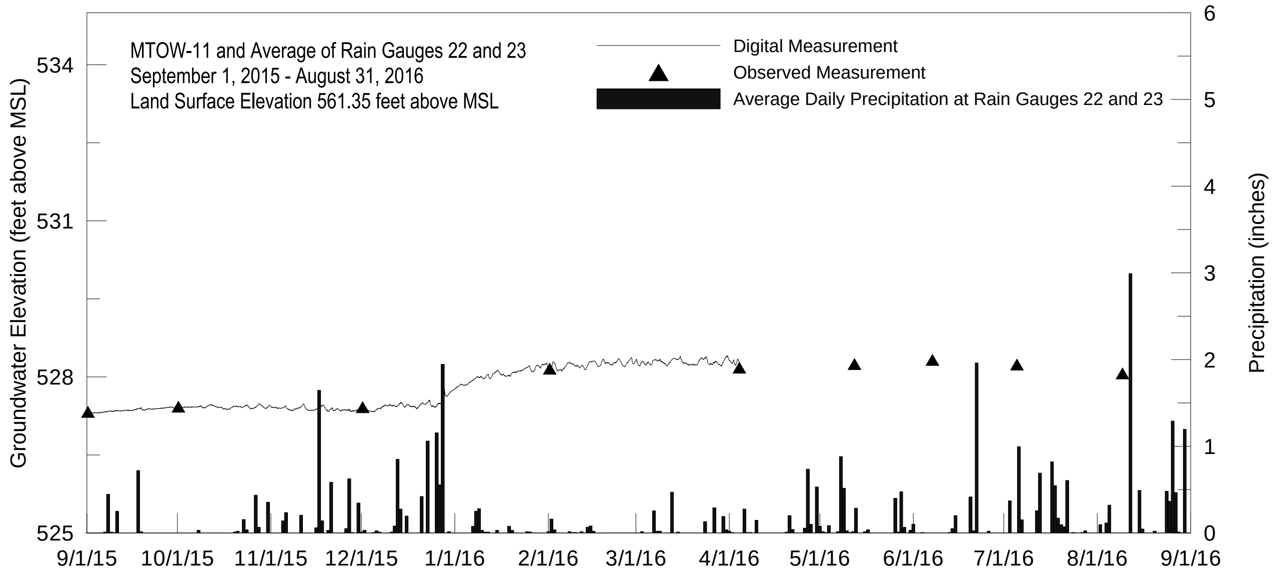

Figure A-11. Year 24 Groundwater Elevation and Precipitation for MTOW-11

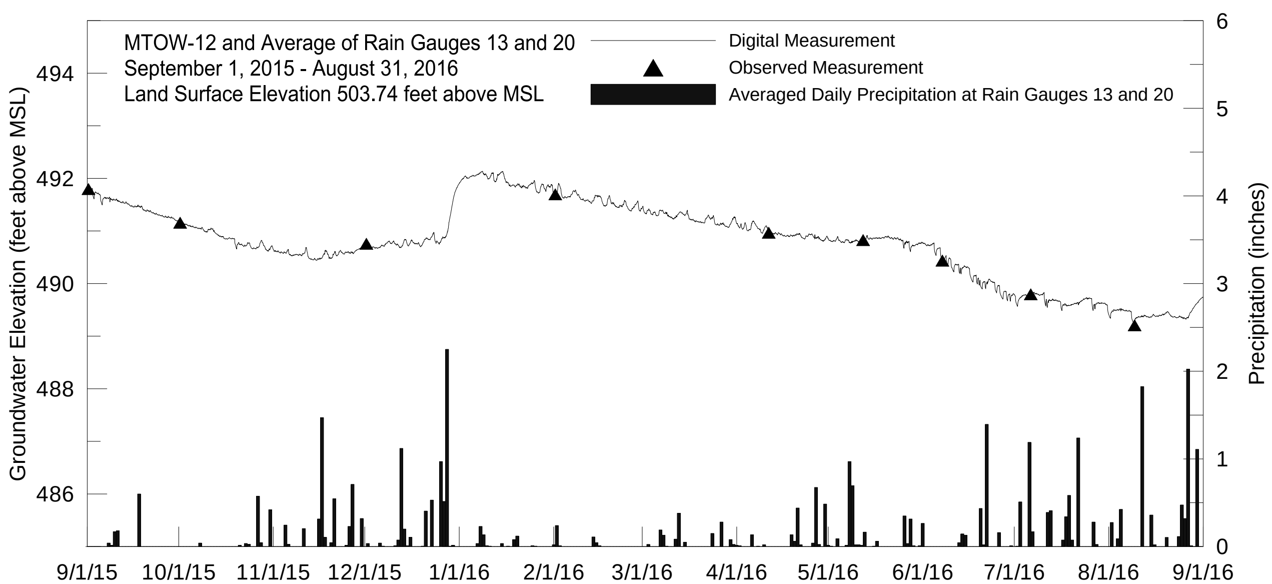

Figure A-12. Year 24 Groundwater Elevation and Precipitation for MTOW-12

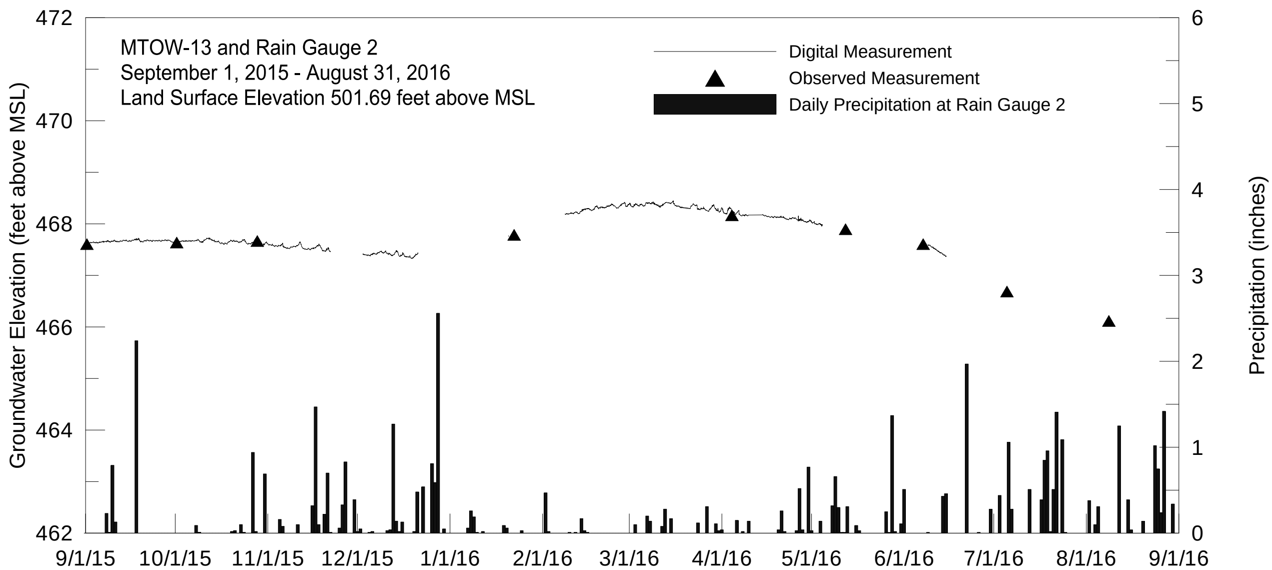

Figure A-13. Year 24 Groundwater Elevation and Precipitation for MTOW-13

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

Well Number	*Well Name*	*9/1/2015*	*10/1/2015*	*12/1/2015*	*2/1/2016*	*4/5/2016*
MTOW-14	*Mason City Deep*	*44.40*	*43.97*	*43.74*	*43.23*	*43.23*
MTOW-15A	*Ellsbury Lake Deep*	*51.41*	*49.80*	*49.30*	*48.84*	*48.71*
MTOW-15B	*Ellsbury Lake Shallow*	*42.02*	*41.79*	*41.68*	*41.63*	*41.49*
		5/12/2016	*6/7/2016*	**7***/5/2016*	*8/9/2016*	
MTOW-14	*Mason City Deep*	*43.08*	*44.08*	*44.00*	*44.12*	
MTOW-15A	*Ellsbury Lake Deep*	*48.58*	*50.04*	*50.13*	*50.28*	
MTOW-15B	*Ellsbury Lake Shallow*	*41.69*	*41.79*	*42.21*	*Well Dry*	

Note:

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