Reference Wetland Hydrologic Regime Monitoring

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3 INTRODUCTION

3.1 Background

Wetlands are known to provide a great deal of important functions from species diversity and recreational benefits to flood attenuation and water quality improvement. The Wisconsin DNR estimated a loss of 47% of the states ten million acres of wetland (WDNR, 1978-9). As Wisconsin continues to develop its economy, the loss of wetlands continues. Wetland compensatory mitigation and voluntary restoration programs seek to offset the losses that occur during economic development through restoration, enhancement, and creation of wetlands.

A primary driving factor in wetland functions is hydrology. The Army Corps of Engineers (USACE) has provided target hydrology and performance standards for compensatory mitigation sites. The performance standards set by the USACE offer guidance for ideal hydrology of wetlands in both Minnesota and Wisconsin. The USACE report encourages using a site near the planned restoration as a hydrologic reference (USACE, 20019). Due to the nature of these mitigation banking projects it is not always feasible to find a neighboring wetland that has an undisturbed hydrology. In these cases, a regional standard is the next best alternative. However, regional standards do not exist for any wetland types in the state of Wisconsin.

3.2 Project Objectives

The goal of this study was to inform wetland compensatory mitigation performance standards on the hydrologic regimes of commonly restored wetlands in the Southern portion of Wisconsin*. This may* guide better practices when assessing wetland restoration projects where a local reference wetland is not available. The study collected groundwater level data from wetlands that had been selected for their reference-quality vegetation. The study also assessed each site's floristic quality and evaluated species composition to see what relationships exist between hydrology regimes and plant species assemblages.

3.3 Description of Need/Background

The state of Wisconsin and the Interagency Review Team have often utilized basic wetland compensatory mitigation hydrology performance standards that were informed primarily by the most basic expectations of meeting wetland hydrology definitions as defined by Federal agencies and by regional expertise of what optimum hydrologic regimes are – for sedge meadow and wet to wet-mesic prairie wetland communities that has been defined as having water within 12 inches of the soil surface for 28 consecutive days or two 14-day periods during the growing season during normal or wetter-than normal hydrological conditions (USACE, 2019). This standard does set the expectation that all wetland mitigation credits meet minimum wetland definitions but does not reflect the hydrological nuance or variety of Wisconsin's wetland communities' natural hydrologic regimes.

Wisconsin wetlands are varied in their structure as well as their hydrological regimes. A wet-mesic prairie will have a different 'normal' hydroperiod from a southern sedge meadow and that will have a different hydroperiod from other wetland communities. Wet Prairies tend to form on mineral soils that undergo soil saturation for long periods of time (usually around 7-30 days), while sedge meadows tend to form on mineral or organic soils that undergo saturation or ponding for very long periods of time (usually over 30 days) (Schoeneberger, *et.al*., 2012). And therefore, it cannot be expected that wetland mitigation sites restored to wet-mesic prairie will succeed if it is expected to have the same optimum hydroperiod as a southern sedge meadow. Without a thorough understanding of regional, community-specific reference hydroperiods, it is difficult to better inform wetland restoration expectations.

With this effort it was proposed to test out methods for studying wetland reference hydrology by studying two natural wetland communities in south-central Wisconsin – Southern Sedge Meadows and Wet-Mesic Prairies. We hope that this study will demonstrate the complexity of hydrologic regimes and show the need for more detailed study of all of Wisconsin's wetland community types.

3.4 Study Design Background

Since the primary goal was to better inform wetland mitigation efforts, two commonly-restored wetland community types in south-central Wisconsin – Southern Sedge Meadows and Wet-Mesic Prairies - were selected. These communities are often proposed for restoration on mitigation sites as they are herbaceous communities requiring fewer monitoring years (WNDR, 2013) and tend to have readily available native seed sources. Consequently, these two communities were selected due to their being commonly restored wetland types at mitigation sites, and because of their common occurrence near Madison.

In addition to the factors described above, site selection was also dictated by this study's' materials budget. Each well was estimated to cost about $600 (logger cost + groundwater well materials). In addition, it was determined that around 10 replicates were needed of each community. The budget allowed for 21 sites with the understanding that some of the wells could be damaged due to frost-heaving, vandalism, or other unforeseen events.

Wetland mitigation credits are frequently purchased in watersheds with high development pressure that have few reference-quality wetlands due to urbanization and agricultural land uses. Consequently, it is not always feasible to monitor reference hydrology prior to establishing wetland mitigation banks. The hope is that this study can inform mitigation performance standards and/or provide helpful information to restorationists wanting to restore these two native wetland communities.

4 METHODS

The Wisconsin DNR Wetland Monitoring Program has monitored and assessed wetland conditions and functions in partnership with other programs and external groups. This project was a collaboration of efforts between the Wetland Monitoring Program and the DNR Wetland Compensatory Mitigation team. While wetland vegetation monitoring has a longer history in the program, wetland hydrologic monitoring does not have as much history. As one component of wetland compensatory mitigation, wetland restoration experts are required to monitor the restored wetland hydrology by utilizing sub-surface hydrology wells in both the restored wetlands and in nearby reference hydrology wells. But in many situations, a suitable reference wetland is not available. This project hopes to create a portrait of the vegetation and hydrologic conditions of reference sedge meadows and wet-mesic prairies, two of the most commonly restored wetland communities. The work completed under this grant followed the protocols and best-management practices developed within the grant's Quality Assurance Project Plan (WDNR, 2020a).

4.1 Experimental Design

4.1.1 Site Selection

A total of twenty-one sites were selected, consisting of eleven southern sedge meadows and ten wet-mesic prairies. After discussions with DNR's wetland compensatory mitigation staff, it was determined that these two communities are the most frequently proposed for restoration on mitigation sites. The southern portion of the state experiences some of the highest levels of impacts and often has the fewest opportunities for closely situated reference wetlands upon which to base hydrology performance standards. Sites were selected from all the known reference-quality southern sedge meadow and wet-mesic prairie communities in this region of the state with the assistance of Natural Heritage Conservancy (NHC) members Ryan O'Connor and Thomas Meyer. Sites were selected based on their proximity to Madison, which is located within Wisconsin's southernmost Omernik ecoregions: The Southeast Till Plains and the Driftless Area, as well as their high-quality vegetation survey records.

Table 1. Hydrology well location information

Site Name	Community Type	Well location
Lewiston Marsh	Southern Sedge Meadow	***SITE DROPPED DUE TO WELL DISLODGING***
Erickson SSM	Southern Sedge Meadow	42.7080883, -89.8798642
Dorne Creek Fishery Area	Southern Sedge meadow	43.1406813, -89.4594581
Lulu Lake SNA	Southern Sedge Meadow	42.8315780, -88.458883
Dodge Branch Wetlands (Sylvan Road Conservation Area)	Southern Sedge Meadow	42.89103, -89.98911
Bear Creek Meadow SNA (Bear Creek Fishery Area)	Southern Sedge Meadow	43.280804, -90.209861
Puchyan Prairie SNA	Wet-mesic Prairie	43.8902450, -89.0225732
White River Marsh SNA	Southern Sedge Meadow	43.92089, -89.07886
White River Prairie/Tamaracks SNA	Wet-mesic Prairie	43.9508787, -89.1310675
Loews Lake	Southern Sedge Meadow	43.2154550, -88.3126716
Scuppernong Prairie SNA	Wet-mesic Prairie	42.8988999, -88.5011347
Kettle Moraine Low Prairie SNA	Wet-mesic Prairie	42.9098600, -88.4892300
Bluff Creek SNA	Southern Sedge Meadow	42.7964357, -88.6915239
Young Prairie SNA	Southern Sedge Meadow	42.83987, -88.63317
Faville Prairie SNA	Wet-mesic Prairie	43.1464240, -88.878546
Snapper Prairie SNA	Wet-mesic Prairie	***SITE DROPPED DUE TO MANAGEMENT CONFLICT***
Lower Mud Lake SSM	Southern Sedge Meadow	42.99981, -89.28212
Blue Mounds Creek Bottoms	Wet-mesic Prairie	43.182314, -89.897221
Weister Creek	Southern Sedge Meadow	43.627867, -90.635992
Turtle Creek SSM	Southern Sedge Meadow	42.61478, -88.78194
Swan Lake SNA	Southern Sedge Meadow	43.5400455, -89.4272649

4.1.2 Site Location

The location of each well, wetland community type, name of the site, and information specific to each site (land manager, management practices, additional information) have been stored in a geodatabase for this project (see Figure 1).

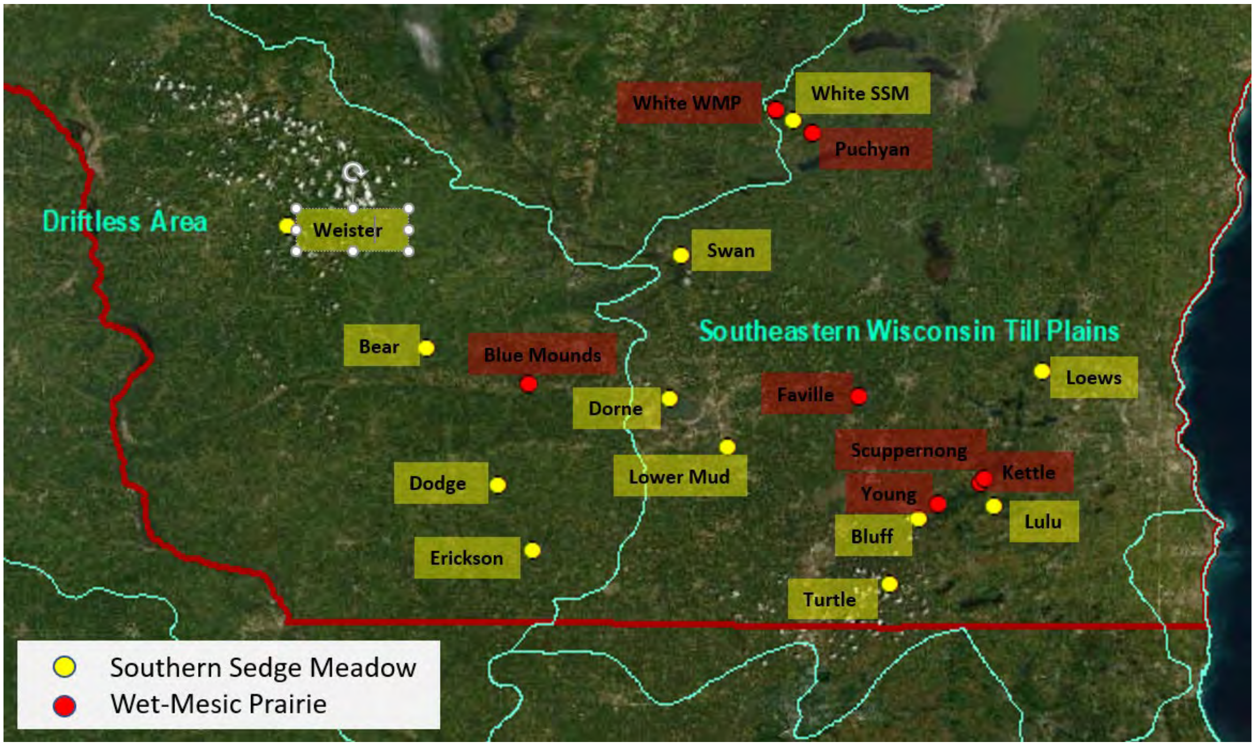

Figure 1. Well Site Locations

4.1.3 Determination of Growing Season

Growing season dates were based on a 30-year average (1989 – 2019) of the median dates (50% probability) of 28F air temperatures in spring and fall as report in the WETS tables provided by the USDA-NRCS. Table 2 shows a calculation of a handful of those dates for the counties where sites are located. Based on this data the target start date for monitoring was the first week of April with set up staged from the southernmost stations to the northern most stations. Removal of data loggers was done in the reverse fashion starting with the northernmost stations in Mid-October and working towards the southernmost stations. The target dates as listed below were used for rough planning purposes; actual deployment dates were based on actual climatic conditions in the early spring and fall. For example, if the ground was still frozen hard at the median start date, loggers were not be deployed at that time; deployment waited until conditions were suitable (unfrozen). For the sites listed below with insufficient information, the median start and end of growing season was inferred from neighboring sites/counties.

Table 2. Anticipated Growing Season by County (1990 - 2019)

County /Station	Start to Growing Season	End to Growing Season
Columbia (Station: Arlington Univ Farm, WI)	April 24	October 10
Dane (Station: Arboretum Univ WI)	April 27	October 13
Green Lake (INSUFFICIENT DATA)	N/A	N/A
Iowa (Station: Dodgeville, WI)	April 21	October 14
Jefferson (Station: Fort Atkinson, WI)	April 16	October 19
Kenosha (Station: Kenosha, WI)	April 5	November 5
Lafayette (INSUFFICIENT DATA)	N/A	N/A
Richland (INSUFFICIENT DATA)	N/A	N/A
Rock (Station: Afton, WI)	April 16	October 20
Vernon (Genoa Dam, WI	April 7	October 25
Washington (Hartford, WI)	April 25	October 15
Waukesha (Oconomowoc, WI)	April 19	October 19

*Data found using http://agacis.rcc-acis.org/

**Deployment of hydrology well data loggers were delayed for the year of 2020 because of travel restrictions tied to the COVID-19 pandemic. Loggers were deployed during the summer when travel restrictions had been modified to allow for safe field work.

4.2 Sampling Method Requirements

4.2.1 Floristic Quality Assessment

Floristic quality and assessment area flora assemblages was determined using the Timed-Meander Sampling Protocol for Wetland Floristic Quality Assessment (Bernthal, 2003; WDNR, 2003). All data collected here was added to the FQA database, consistent with previous projects. Community type designations were made by the lead wetland ecologist conducting the floristic surveys and utilized the Wisconsin DNR's Key to Wetland Natural Communities (WDNR, 2020b).

Link to methods of timed meander survey:
https://dnr.wi.gov/topic/Wetlands/documents/TimedMeanderSamplingProtocol.pdf

4.2.2 Soil Pit Characterization

At each site, soil pits were excavated to determine the soil profile and hydrology characteristics such as soil types, root presence, redoximorphic features, and soil color (USACE, 2005). The pit locations were determined by the surveyor and were chosen based upon the location that best represented typical site characteristics such as wetness, vegetation, topography, and centrality. In the event of microtopography such as tussocks or hummock/hollow landscapes, soil pits were dug in depressional features to remain consistent across all sites. The soil profile was characterized following the form provided in the 2005, US Army Corps of Engineers, *Technical Standard for Water-Table Monitoring of Potential Wetland Sites*.

4.2.3 On-Site Well Point Selection and Installation

Installation of the monitoring well was within ten feet of the soil pit. In sedge meadow communities, wells were installed in depressional features (hollows) between hummocks when present, to remain consistent with the soil pit characterization and to be more resilient to frost/heave effects. The design of the wells followed the instruction of the 2005, US Army Corps of Engineers, *Technical Standard for Water-Table Monitoring of Potential Wetland Sites*. The wells for this project had a two-inch diameter to be compatible with the data logging device used. Wells were installed by excavating with a four-inch diameter hand auger to a depth informed by the soil pit. Ideally wells would reach a depth of two feet below the surface. However, an impermeable clay layer was often met before this depth and the well had to be adjusted to a shallower depth. PVC was measured and cut on site using a notched bucket and hand saw to match the necessary depth.

The bottom one-two inches of each well pit were filled with sand. The well casing were then placed into the pit and packed along the sides with sand to within two inches of the surface. The remainder of the pits were filled with bentonite pellets and wetted. Measures taken to protect the wells included marking the well locations with pink flagging and using steel rubbish bins (trash cans) to cover wells located in areas that were slated for prescribed burns.

4.2.4 Hydrologic Regime Sampling

Water level data was collected using the HOBO MX2001-04 Water Level Logger, a vented water level measuring device that corrects for barometric pressure and has Bluetooth capabilities. Data was collected with a handheld tablet using the HOBOware application which is compatible with the logger. The MX2001-04 logger has a typical error of 0.3 cm and maximum error of 0.6 cm. As is recommended by the USACE (Eggers, 2019), the device was deployed and collected data four times per day during the growing season (April-October). The exact date that the logger devices were deployed was dependent on the start of the growing season. Per U.S. Army Corps of Engineering guidance (Eggers, 2019), wells should be deployed at least 5-7 days prior to the average start of the growing season (based on the median date of 28F air temperatures as reported in WETS tables). This was not possible during the first year of data collection (2020) because of COVID protocol. Data was downloaded, and the logger assessed for damage three times each season.

4.3 Quality Control Requirements

4.3.1 Process for Addressing Deviations

Deviations made to the methods of sample collection, data analysis, or the QAPP itself were addressed by the principal investigator as well as the project manager. Deviations were reviewed to determine their effect on data quality and the project timeline. Corrective actions were taken to mitigate negative results. All deviations were documented and included in a deviation report.

Ground water sampling could be made invalid or lost if level loggers are damaged, stolen, or malfunction. Well casings could be disturbed by animal activity, frost heave, fire, weather disturbances, or vandalism. To address these concerns level loggers were tested before deployment for damage. Additionally, wells were inspected for damage at the time of logger deployment. Conditions of the wells were documented if a disturbance had been found. When possible, corrective action took place to address the disturbance. Each site was visited and assessed two more times during the growing season (a total of three site visits). Since the loggers were checked and data downloaded multiple times in a season, this gave field staff the opportunity to correct or fix problems that arose throughout the growing season. This reduced the chances of losing an entire seasons' worth of data.

4.4 Equipment Inspection, Maintenance and Disinfection Requirements

Equipment, boots and clothing were cleaned between sites to prevent introduction of invasive species propagules following DNR Manual Code (https://dnr.wi.gov/topic/Invasives/disinfection.html). HOBO logger devices were tested and calibrated before deployment. When visiting sites, the data collected by loggers were reviewed to assure the device was operating properly and the well was inspected for any visible disturbance. Any visible damage to the monitoring well housing was fixed on-site if possible. When damage was too extensive, a discussion took place between project leads and land managers to correct the problem.

4.5 Analytical Requirements

Water level data collected at each site was placed in reference to antecedent precipitation to determine whether data being collected was in a wetter, normal, or drier than normal year. This was achieved by utilizing the USACE antecedent precipitation tool to plot the 30 years average range of precipitation and 30-day rolling totals. This was then viewed in relation to water level data. All data downloaded from the water level loggers was reviewed by the Project Manager to verify the legitimacy of such data.

5 RESULTS

5.1 Problems Encountered

Over the duration of this study several problems were encountered that lead to complications with data collection or data loss. Major hinderances in data collection can be most attributed to the delayed start of field operations brought on by policy for COVID19. Pandemic shut-downs, travel limitations, and work-from-home requirements started in March 2020, right before logger launch was supposed to start in early spring of 2020. These limitations were not eased until June of 2020, at which point the loggers were launched immediately.

The study also began later than anticipated due to staffing changes which resulted in delays associated with site identification, landowner communications, well construction, and ordering of equipment.

Additional problems included frost heaving dislodging the well at Lewiston (subsequently, this site had to be dropped), burn damage warping the well for Bluff Creek, and a software malfunction that resulted in the loss of 3 months of data for Weister Creek in 2020.

A final problem encountered involved HOBO loggers recording water level values in the 33' range above ground level which is clearly an error. This issue appeared to occur for sites in which a reference water level was not able to be set during deployment because of lack of water within the well on site. The reference water level had to be updated after the field season.

5.2 Hydrograph Trends

Hydrology data was collected for each site from mid-summer 2020 through fall of 2020 and again from early spring of 2021 through fall of 2021. Data presented in this report only goes through mid-summer of 2021 although loggers continued to gather data after the summer of 2021 (see section 7.3 for more information on study continuation). Figures 2, 3, 4, and 5 below show hydrographs of all sites plotted alongside their community type for each growing season (2020 and 2021). Water levels may appear as non-fluctuating at their minimum when either no water is present (water level is below the bottom of the installed well), or water has pooled at the base of the well casing and should be considered as null data. Individual hydrographs for each site during the 2020 and 2021 season can be viewed in Appendix A: Final Hydrographs.

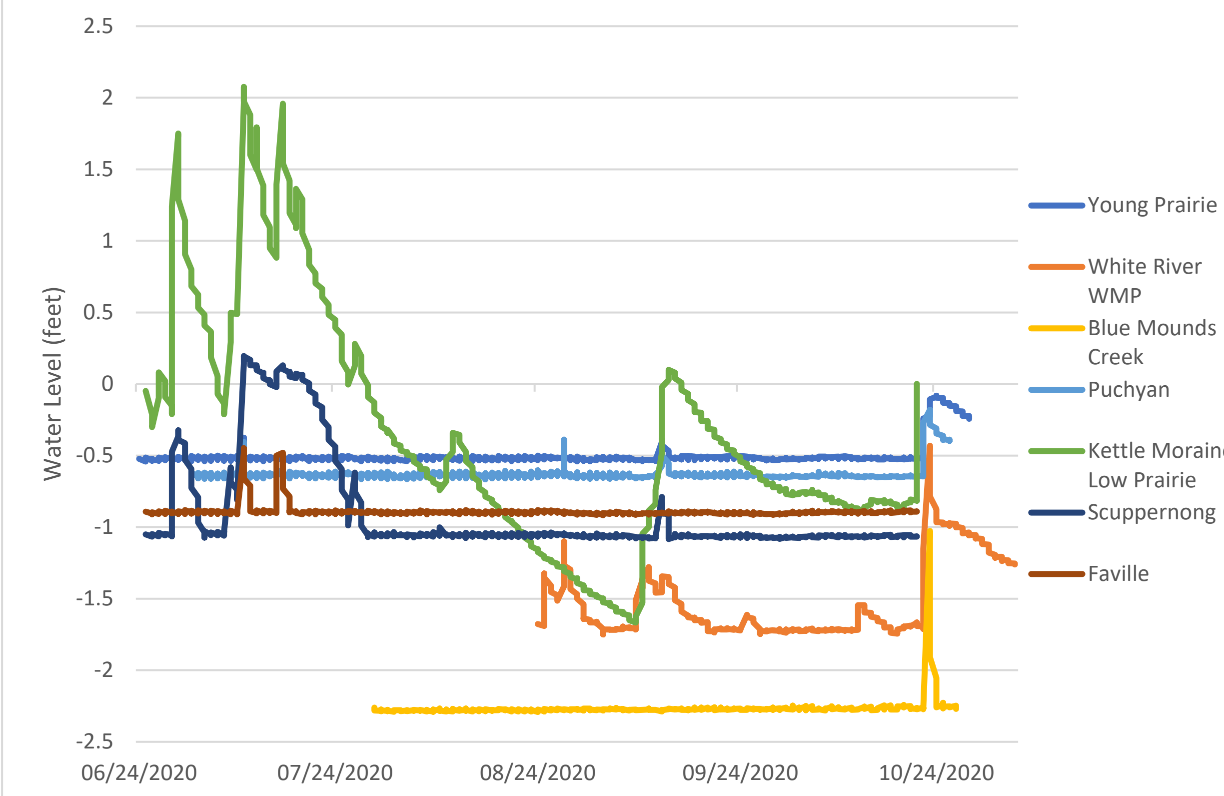

Figure 2. Wet-Mesic Prairies Hydrographs from 2020

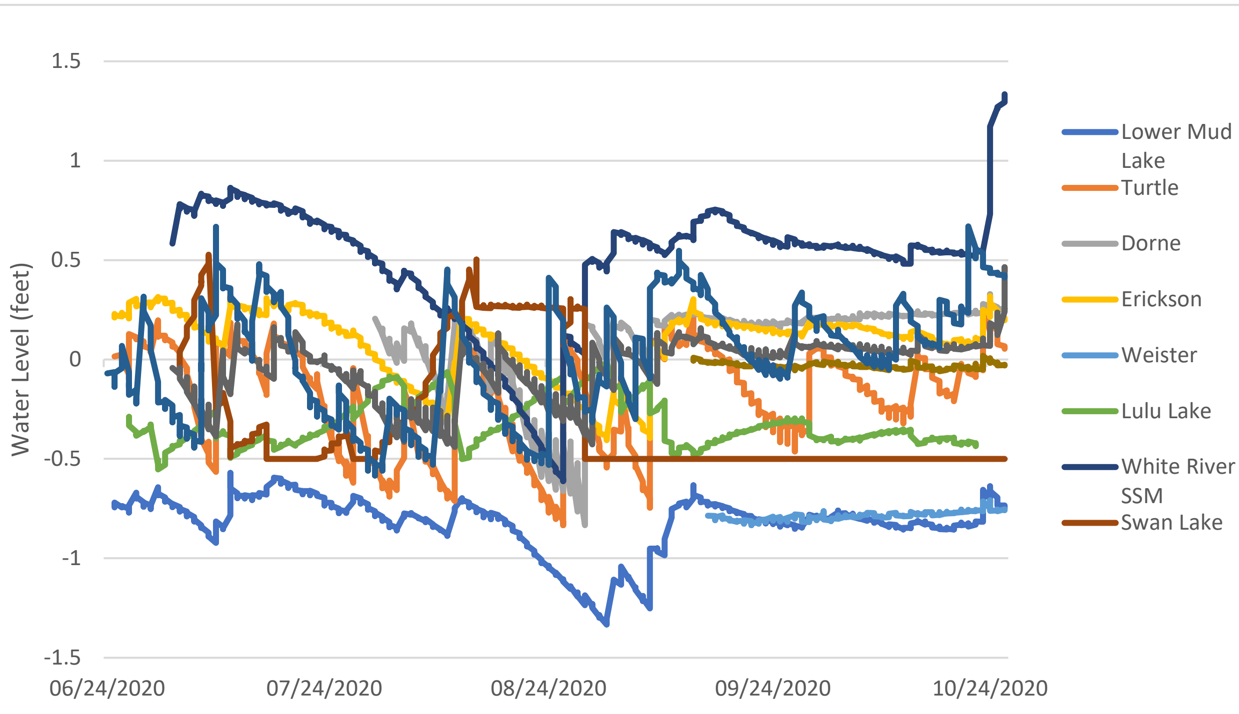

Figure 3. Sedge Meadow Hydrographs from 2020

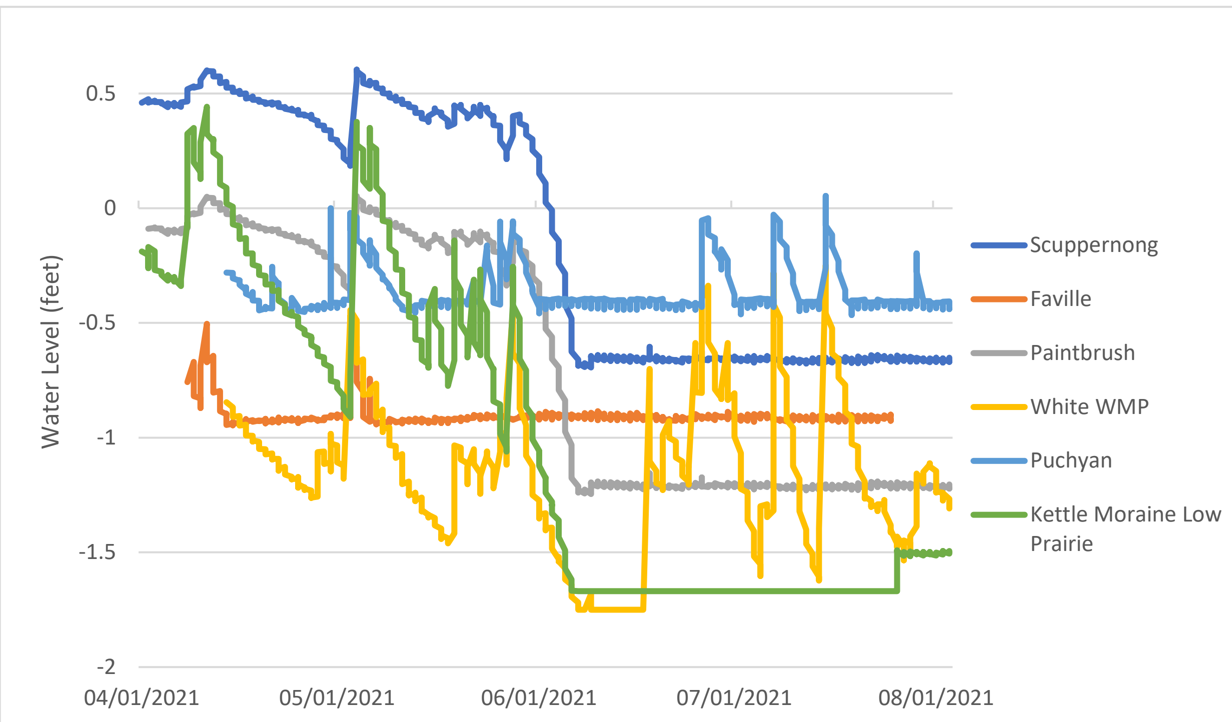

Figure 4. Wet-Mesic Prairie Hydrographs from 2021

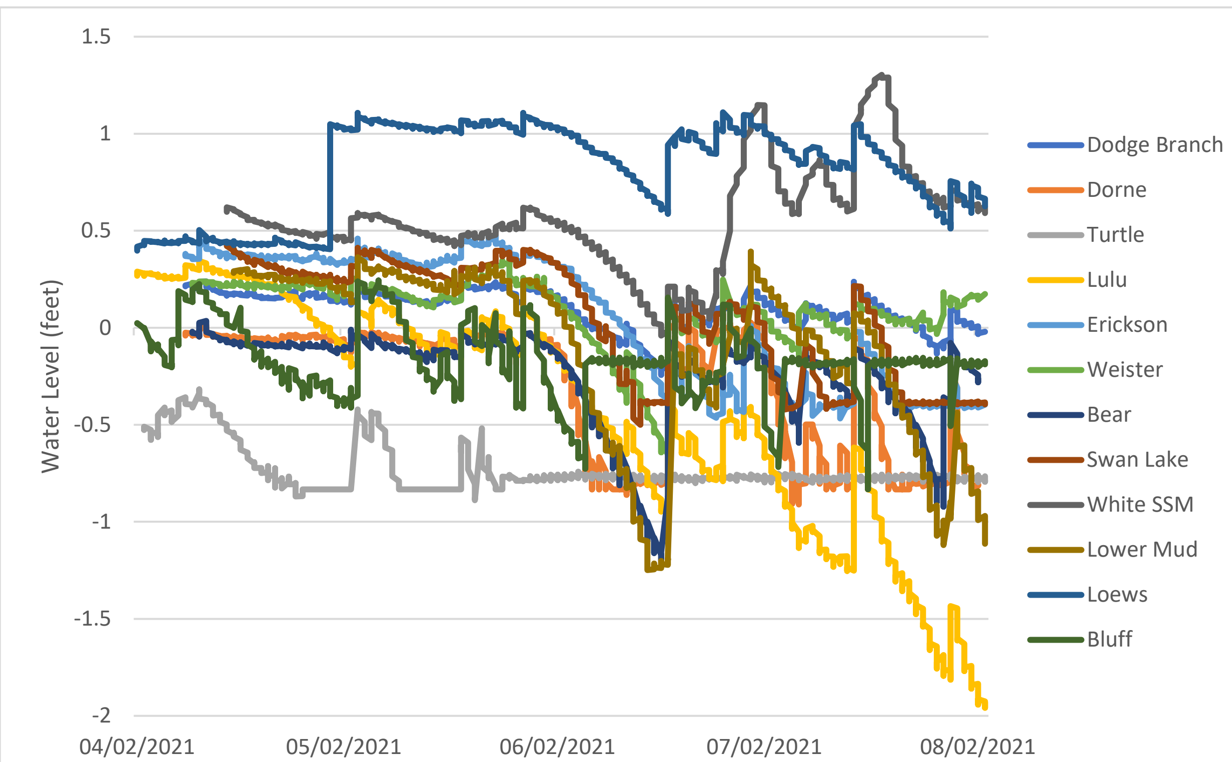

Figure 5. Sedge Meadow Hydrographs from 2021

5.3 Wetland Target Hyrologic Performance Standards

USACE defines many wetland compensatory mitigation sedge meadow and wet-mesic prairie restoration sites as meeting hydrologic performance standards if the wetland has a water table within 12 inches of the soil surface for a minimum of 28 consecutive days or two periods of at least 14 days each (USACE, 2019). The data from each of the reference sites was assessed to determine if each site would meet these minimum standards. Usually, this standard is met in the spring, so it is not surprising that some of the drier sites did not meet standards in 2020 when data was only collected for summer and fall. Table 3 shows which sites met this minimum standard and which dates of each year the standard was met through.

Table 3: Target Hydrologic Performance Standards Results

Site Name	Meets USACE Standards 2020	Duration	Meets USACE Standards 2021	Duration
WMP's				
Young Prairie	NA	NA	NA	NA
White River WMP	No	-	No	-
Blue Mounds Creek Bottom	No	-	No	-
Puchyan Prairie	NA	NA	NA	NA
Kettle Moraine Low Prairie	Yes	6/25 - 8/21	No	-
Scuppernong Prairie	No	7/8 - 7/28	Yes	4/1 -6/8
Faville Prairie	NA	NA	NA	NA
SSM's				
Turtle Creek	Yes	6/24 - 10/28	No	4/2 - 4/23
Dorne Creek	Yes	7/30 - 10/28	Yes	4/8 - 8/2
Dodge Branch	Yes	6/24 - 10/28	Yes	4/8 - 8/2
Erickson	Yes	6/24 - 10/28	Yes	4/8 - 8/2
Weister Creek#	NA	NA	Yes	4/9 - 8/2
Lulu Lake	Yes	6/25 - 10/20	Yes	4/1 - 6/17
White River SSM	Yes	7/2 - 10/26	Yes	4/14 - 8/6
Swan Lake	Yes	7/2 - 8/28, 9/14 - 10/23	Yes	4/14 - 6/14
Lower Mud Lake	No	-	Yes	4/14 - 6/15, 6/18 - 7/22
Bear Creek Meadow	Yes	7/1 - 10/27	Yes	4/14 - 6/15, 6/18 - 7/28
Loews Lake	Yes	9/11 - 10/29	Yes	4/1 - 8/3
Bluff Creek%	NA	NA	Yes	4/2 - 6/4

Logger issues resulted in lost data in 2020.

% Prescribed burn resulted in well malfunctions in 2020.

* Sites marked as NA for “Meets USACE STANDARDS” did not have wells installed to a depth of greater than 12 inches below surface and therefore can’t be confirmed as failing to meet target hydrology standards.

In 2020 data collection began near the end of June to the beginning of July. During this season one of the seven wet-mesic prairies met target hydrology standards with another site, Scuppernong, being close with 20 consecutive days with a water table within 12 inches of the soil surface. Nine of the twelve sedge meadows also met USACE standards. See Section 7 of this report for recommended modifications to fix this issue.

During the 2021 season one of seven wet-mesic prairies met USACE standards. Eleven of the twelve sedge meadows also met USACE standards. The site at Turtle Creek was short of meeting standards, having saturation within 12 inches of the surface for 21 consecutive days.

5.4 Soils Information

Soils listed in Table 4 below are the dominant soil type in which the wells were installed. All sedge meadows besides Swan Lake (sandy loam) and Bluff Creek (silty loam) were classified as muck soil type. The wet-mesic prairie communities ranged from sands to clays. Full soil data from soil pit excavations can be found in Appendix B: Site Summary Data.

Table 4: Site Dominant Soil Type

Site Name	Community Type	Soil Type
Puchyan Prairie SNA	WMP	Clay
White River Prairie	WMP	Sandy Loam
Scuppernong Prairie	WMP	Clay Loam
Kettle Moraine Low Prairie SNA	WMP	Mucky Clay
Young Prairie SNA	WMP	Sandy Clay Loam
Faville Prairie SNA	WMP	Sandy Clay
Blue Mounds Creek Bottoms	WMP	Sand
Bluff Creek SNA	SSM	Silt Loam
Erickson SSM	SSM	Muck
Dorne Creek Fishery Area	SSM	Muck
Lulu Lake SNA	SSM	Muck
Dodge Branch Wetlands (Sylvan Road Conservation Area)	SSM	Mucky Mineral
Bear Creek Meadow SNA (Bear Creek Fishery Area)	SSM	Muck
White River Marsh SNA	SSM	Muck
Loews Lake	SSM	Muck
Lower Mud Lake	SSM	Muck
Weister Creek	SSM	Muck
Turtle Creek SSM	SSM	Muck
Swan Lake SNA	SSM	Sandy Loam

5.5 Floristic Quality Community Trends

There were a couple community trends that were observed in the floristic data: the inclusion of certain species of high importance value, the coverage of sedge species, species richness, and weighted wetland indicator score. These floristic condition metrics, when taken with the hydrological data, further clarify the conditions between southern sedge meadow and wet-mesic prairie communities.

5.5.1 Prairie Community Indicators

According to a draft species lists document (Noll and Kron, 2020), wet-mesic prairie communities in the southeast till plains Omernik Level 3 Ecoregion have two species with an Importance Value of ten – *Andropogon gerardii* and *Sporobolus heterolepis*. Table 5 shows that all wet-mesic prairie communities always included one or both of these indicator species whereas none of the sedge meadow communities had either of these indicator species.

Table 5. Combined Absolute Coverage of Wet Mesic Prairie High Importance Value Species

Site	Community Type	Coverage of ANDGER or SPOHET
Weister Creek	SSM	0
Turtle Creek	SSM	0
Erickson	SSM	0
White River Marsh	SSM	0
Swan Lake	SSM	0
Dorne Creek	SSM	0
Bear Creek Meadow	SSM	0
Loews Lake	SSM	0
Dodge Branch	SSM	0
Lower Mud Lake	SSM	0
Lulu Lake	SSM	0
Bluff Creek	SSM	0
White River Prairie	WMP	3
Puchyan Prairie	WMP	8
Faville Prairie	WMP	36
Blue Mounds Creek	WMP	45
Young Prairie	WMP	45
Kettle Moraine	WMP	55
Scuppernong Prairie	WMP	90

5.5.2 Carex Coverage

Another trend we observed was that of all the communities we surveyed the coverage of Carex species was a decent indicator of community type – with higher coverages tending to sedge meadows with an average absolute cover of 82.25% and wet-mesic prairies having an average absolute coverage of Carices of 29.43%. Only Puchyan Prairie and White River Prairie had higher coverages of 89% and 66% absolute cover of Carex species – the highest of the wet prairies.

5.5.3 Species Richness

It is well documented that Wisconsin's native prairies have very high diversity of species and we found this in these 19 wetlands. The sedge meadows, on average, were made up of 51.8 species (49.92 native species) and wet-mesic prairies were made up of 97.29 species on average (90.29 native species). Prairies on average were made up of almost double the native species. Table 6 shows that for the most part, there was a clear break in total species richness between community types for the exception of Blue Mounds WMP which had the lowest species richness.

Table 6. Total and Native Species Richness of Southern Sedge Meadows and Wet-Mesic Prairies

Site	Community Type	Total Spp Richness	Native Spp Richness
Erickson	SSM	33	33
Bluff Creek	SSM	36	36
White River Marsh	SSM	40	39
Lower Mud Lake	SSM	43	40
Swan Lake	SSM	46	44
Dorne Creek	SSM	47	45
Weister Creek	SSM	50	49
Lulu Lake	SSM	54	52
Bear Creek Meadow	SSM	59	59
Loews Lake	SSM	69	66
Turtle Creek	SSM	71	64
Blue Mounds	WMP	72	65
Dodge Branch	SSM	74	72
White River Prairie	WMP	86	84
Scuppernong	WMP	97	89
Puchyan Prairie	WMP	97	87
Kettle Moraine	WMP	100	93
Faville Prairie	WMP	114	108
Young Prairie	WMP	115	106

5.5.4 Weighted Wetland Indicator Score

Using wetland indicator values and relative percent cover, we created a weighted wetland indicator score to assess the "wetness" of the species. We assigned any species that is an obligate species a score of -2, facultative-wet species a -1, facultative species 0, a facultative-upland species was assigned a score of 1, and obligate upland species are given a 2. We then multiplied the indicator score by the relative cover with the community.

As we predicted, we found that wet-mesic prairies had a cumulative weighted wetland indicator score of much higher than sedge meadows showing that the species of the prairie communities trended to drier and sedge meadows trended wetter (Table 7).

Table 7. Weighted wetland indicator scores by community type

Site	Community Type	Weighted Wetland Indicator Score
Erickson	SSM	-1.91
White River Marsh	SSM	-1.90
Weister Creek	SSM	-1.85
Lulu Lake	SSM	-1.79
Swan Lake	SSM	-1.78
Bluff Creek	SSM	-1.76
Dodge Branch	SSM	-1.76
Lower Mud Lake	SSM	-1.76
Dorne Creek	SSM	-1.71
Loews Lake	SSM	-1.64
Bear Creek Meadow	SSM	-1.42
Turtle Creek	SSM	-1.23
Puchyan Prairie	WMP	-0.88
White River Prairie	WMP	-0.59
Blue Mounds	WMP	-0.01
Faville Prairie	WMP	0.05
Kettle Moraine	WMP	0.06
Young Prairie	WMP	0.12
Scuppernong	WMP	0.18

5.6 Mitigation Bank Data

When it became apparent that the DNR would not be able to gather as much hydrologic data as originally proposed, it was determined that another route to gain additional information would be to request hydrologic data from southern mitigation sites that had wet mesic prairie and southern sedge meadow wetland communities. The DNR sent out multiple requests to all wetland mitigation bank owners in Wisconsin requesting voluntary submittal of raw hydrology data from either restored or reference sites. Unfortunately, only 2 sites offered up raw data – which proved to be not enough data to make any noteworthy conclusions from. An example hydrograph of data submitted from a mitigation bank is shown in Figure 6 from the Barnes Prairie Mitigation Bank. The logger data shown here is from a wet to wet-mesic prairies re-establishment area prior to the construction work being completed. This sort of data collected from before restoration, during restoration, and after restoration when paired with the reference wetland information collected through this grant could help us better understand restoration successes, complications, trends, etc.

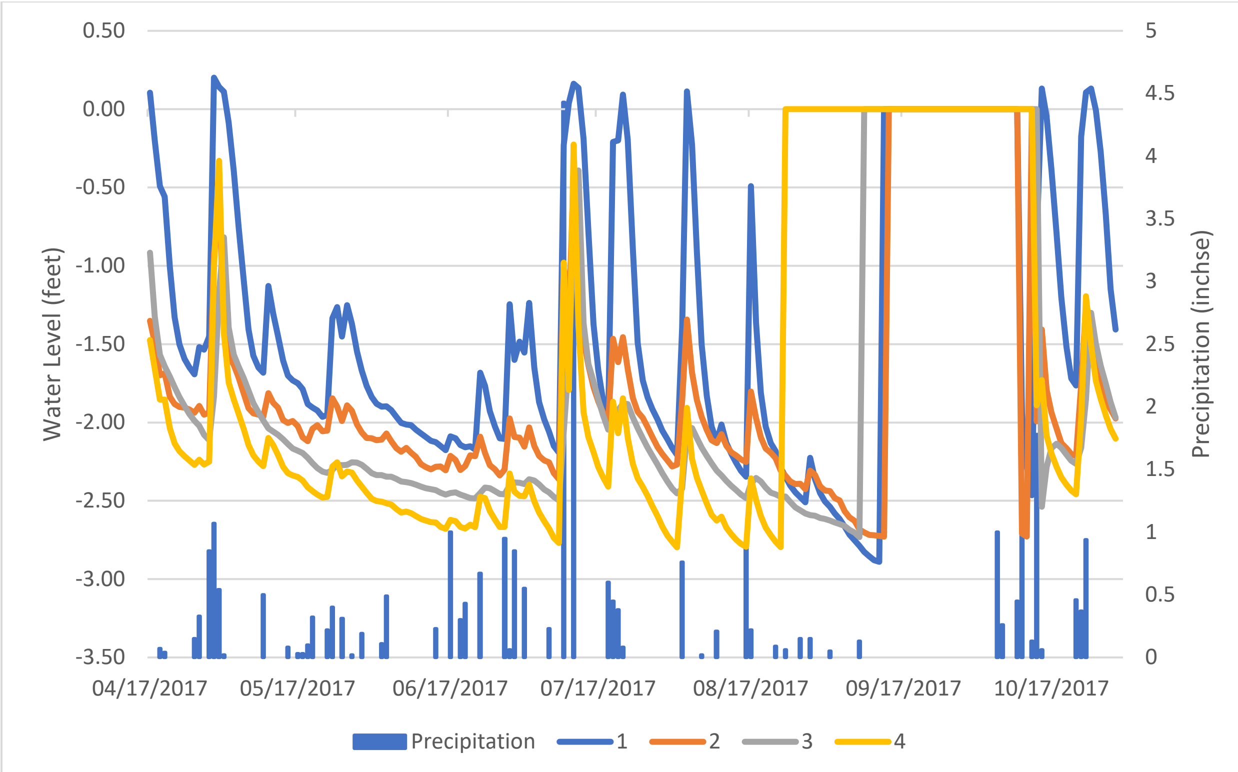

Figure 6. Barnes Prairie Mitigation Bank Hydrograph from 2017.
Data taken from 4 hydrology wells placed in a community proposed for wet to wet-mesic prairie re-establishment once the bank is approved. Data shows monitoring well information prior to restoration efforts.

In the future, the intent is to gather raw hydrology data from mitigation sites so that it can better inform restoration practices. Currently, this data is presented to regulatory agencies in summary form only but if the DNR could gather raw data from both the restored wetlands as well as reference wetlands utilized by mitigation practitioners, the agency could greatly expand the replicates of hydrology well locations.

5.7 Precipitation Trends

During the 2020 growing season there was a significant amount of precipitation with most sites having normal to wetter than normal precipitation, experiencing mild to extreme wetness. In 2021 sites had normal to drier than normal precipitation experiencing mild to moderate drought conditions.

6 Conclusions

6.1 Hydrologic Regime

Several trends appeared consistent over multiple sites when it comes to water table fluctuations. All sites had a rise in water level starting in May of 2021 followed by increased drawdown starting towards the end of May or start of June. Unfortunately, this was not an observable trend in 2020 as data collection was delayed until end of June for that season. A second spike in water level is observable in the sedges on June 18, 2021 (Figure 5). It is possible the wet-mesic prairies (Figure 4) also experienced this uptick but were only captured for White WMP because of the depth at which the wells were installed.

There appears to be different rates in which drawdown occurs in the two community types. Water table behavior was difficult to capture specifically for wet-mesic prairies during the 2020 growing season. 5 of the 7 sites had no water present at the beginning of data capture with a water table lower than the installation of the wells. Sedge meadows displayed drawdowns of 0.5 feet to 1 foot over 3-6 weeks. Wet-mesic prairies would achieve a similar drawdown over 1-2 weeks.

Water tables at the beginning of the 2021 growing season were on average higher in sedge meadow and lower in wet-mesic prairies. Sedge meadow recorded water levels near or above the surface between (0.5 feet below the soil surface to 0.5 feet above the soil surface) at the start of April. Wet-mesic prairies recorded water levels between -1.0 foot below the soil surface and 0.5 feet above the soil surface, with two sites' (Kettle Low Prairie and Blue Mounds) water table sitting below the maximum depth of the well unable to be recorded.

6.2 Wetland Indicator Scores Relationship with Hydrology

Trends related to wetland indicator score are not inherently noticeable provided the current dataset. The "drier" sedge meadows, Bear Creek Meadow (-1.42) and Turtle Creek (-1.23), behaved similar to the other sedge meadows with water levels remaining near the surface for most of the growing season. Turtle Creek had the highest weighted wetland indicator scores for sedge meadows which indicates it was on the drier end of sedge meadows (fewer obligate species) and was the only site during 2021 to fail to meet hydrology standards, falling short of the 28 days by one week (Appendix A).

When viewing wetland indicator scores in relation to the wet-mesic prairie hydrographs, no correlation was identified. The two "wetter" wet-mesic prairies, Puchyan Prairie (weighted wetland indicator score of -0.88) and White River WMP (weighted wetland indicator score of -0.59), with the lowest wetland indicator scores failed to meet U.S. Army Corp of Engineers basic hydrology standards. By contrast, Kettle Moraine Low Prairie (0.06) was the only WMP that met Corps of Engineers standards in 2020 and has the third highest weighted wetland indicator score (Table 7). Additionally, Scuppernong (weighted wetland indicator score of 0.18) was the only WMP to meet Corps standards in 2021 and has the highest wetland indicator score indicating it was one of the driest prairie sites (Appendix A).

6.3 Soils Relationship to Drawdown Rate

As expected, drawdown rate appears more rapid in sandy and loamy soils when compared to muck soils. White River SSM, a muck soil site, had a drawdown of 0.5 feet in 18 days. Lower Mud Lake, another muck soil site has a drawdown of 1 foot in 24 days. For comparison, Scuppernong Prairie, a clayey loam site had the same drawdown of 1 foot in 8 days. Young Prairie, a sandy clay loam site, had a similar drawdown of 1 foot in 8 days.

6.4 Reference Sites and Performance Standards

It is important to note that of the sites where the well was able to be installed deep enough, only two of the WMP sites met standard hydrology performance expectations of having water within 12" of the soil surface for a period of 28 consecutive days or two 14-day periods. Improvements should be made to future well design protocols to capture more/deeper data. For example, Blue Mounds WMP was experiencing normal to wetter-than-normal conditions in 2020 and normal or slightly drier-than-normal in 2021 and didn't meet minimum standards in either year. That said, it is interesting that many of the state's high-quality reference WMPs did not meet the standards during the monitoring period of this study.

Sedge meadows communities, which tend to be wetter than WMP communities, in this study did mostly meet the basic hydrology standard (9 of 11 meeting it is 2020 and 10 of 11 meeting the standard in 2021). Even though SSM communities are typically wetter, there were still two sites that didn't meet the standard in one of the years, suggesting that these standards are typically sufficient for this community type but are not foolproof. It is yet to be determined if these sites would meet minimum hydrologic expectations in future years which is why the Department is hoping to continue monitoring these communities past the duration of this grant effort.

7 RECOMMENDATIONS

7.1 Implications for Wetland Mitigation Practices

The intent of this effort was to understand wetland communities but also to assist in wetland compensatory mitigation. With additional years of data to add to this dataset, the DNR could assist wetland bankers and mitigation managers. Often, the USACE and Interagency Review Team require or prefer that bank sites have a hydrologic reference site that represents what natural hydrologic regimes are for the same community and landscape position. In more urban settings where it is difficult to find a nearby reference wetland that has undisturbed hydrology, it can be hard to meet this regulatory requirement. Having established reference wetlands with a long-term hydrologic dataset can be used as a substitute when a bank-specific reference site is not feasible.

Another possibility for this dataset is to further fine-tune wetland mitigation performance standards. The standards currently used for Minnesota and Wisconsin mitigation sites are generalized to a suite of wetland communities (e.g. fresh (wet) meadows, sedge meadows, hardwood swamps, shrub-carrs, alder thickets, open bogs, and coniferous bogs with organic soils have the same performance standard) (USACE, 2019). With more community-specific and regionally-specific datasets, regulatory agencies will be better equipped to prescribe or suggest more appropriate hydrologic regimes. This would be possible if the DNR is able to extend the length of this study and add additional community types and ecoregions to include most of the commonly-restored wetland community types (see Future Study Recommendations, below).

7.2 Ways to Improve Wetland Hydrology Understanding

As the importance of wetland hydrology on the functioning and quality of wetland communities becomes more apparent, it has become clear that we need to expand our understanding of subsurface hydrology. This report will provide some suggestions on how the DNR and our partners can work together to expand wetland hydrology datasets in order to expand our understanding of wetland functions.

7.2.1 Mitigation Data

One way to increase the dataset is to gather and compile the data that is already being collected – such as compiling the raw hydrology data collected from wetland mitigation sites. As part of almost every wetland mitigation site, there are pre- and post-restoration hydrologic data collected in addition to reference wells installed for mitigation sites. This is a wealth of data that could possibly be harvested and used to better inform wetland restoration practices.

Another possibility is to find a way to incentivize bankers to gather hydrology data even past the required 1 to 3 years post-restoration, once a mitigation site meets hydrology performance standards. Since the subsurface hydrology wells were already installed, it wouldn't require any additional infrastructure other than to utilize the loggers for longer than current practice of 1 to 3 years. A more extensive dataset of wetland restoration sites would allow ecologists to analyze the response of hydrology to various restoration techniques, soil types, precipitation events, etc. Further by comparing restoration sites hydrologic regimes to reference wetland hydrologic regimes, we can further understand what level of hydrologic response is reasonable to expect from mitigation sites and how to better match up restoration sites with appropriate restoration communities.

Finally, as Wisconsin and the Midwest further experience the impacts of global climate change, it will become increasingly important to understand regional wetland hydrology changes and the response of wetland conditions to changing hydrologic levels. Having long-term hydrology monitoring sites at reference wetlands will help agencies understand what should be expected from mitigation sites.

7.2.2 Central Data Collection

In order to capitalize on the data collected through this study as well as the other proposed datasets mentioned here, the DNR needs to develop a way to capture, store, and query this data. As part of a separate effort, the DNR is in the process of developing a new wetland database. Whether this database or another is needed is yet to be determined.

Another database that could potentially gather this data would be a USACE-based platform that is focused primarily on wetland mitigation sites. One way or another, these hydrology datasets need to be captured and utilized in a more efficient way.

7.2.3 Plant Assemblages Data Analysis

One interesting finding from this study is the close relationship between hydrologic regimes and plant assemblages within a given wetland community type. Additional data analysis should be conducted to better understand these relationships and if/how they could be utilized to inform wetland restoration success measures. This could include the use of species of high importance value, species from the most appropriate wetland indicator category, or species richness of a given wetland community type.

For example, sedge meadows on average were made up of 52 species whereas prairie communities in this study had an average of 97 species. A natural next step from this study would be to query the FQA database of reference-quality wetlands to assess if there is a significant difference in species richness across additional regions and community types. Since species richness is often included as a performance standard, it makes sense to further evaluate this relationship so that restoration sites can be designed to better-mimic their reference-quality community assemblages.

7.3 Future Study Recommendations

Through the process of this grant, many lessons were learned - both about reference wetland hydrology and about the process of gathering wetland hydrology data and its complications. Additionally, this project experienced delays due to the Covid-19 pandemic.

7.3.1 Suggested Changes to Well Design/Installation/Monitoring

With interest in continuing wetland hydrology monitoring, the following suggestions are made to improve future studies. A deeper installation of wells should be used when possible. This will help ensure the capture of data as the water table drops. Issues can occur in clay rich soils where it is difficult to get enough drainage at the base of the well. There is also difficulty when encountering perched layers. In these situations, a piezometer can be installed alongside the shallow well to allow for an understanding of how the water table is behaving beneath the perched layer. An additional recommendation would be to visit sites after a rain event has occurred to take manual recordings of the water level to proof the data collected by automatic loggers. It is also encouraged to place protective casing for all wells (a metal trash bin in this study's case) on sites that are actively managed. This can relieve the complications of wells becoming damaged during management activities.

7.3.2 Additional Reference Hydrology Sites

It was determined that this type of data collection is integral to understanding the functionality of these wetland communities. Expansion of this effort will add understanding about additional wetland communities, how the same community varies by landscape position or ecoregion, and how reference wetlands compare to restored or degraded wetlands of the same community type.

Southern sedge meadow and wet-mesic prairie communities in Southern Wisconsin were prioritized since these are the regions and community types that experience the most mitigation/restoration. If and when the DNR continues to broaden this effort, the types of communities and ecoregions added would be common wetland community types such as emergent marsh, southern hardwood swamp, shrub-carr, floodplain forest, and/or alder thicket. If funding becomes available to expand beyond that, DNR suggests targeting all of the reference communities that have developed provisional benchmarks developed to-date (Hlina, et. al., 2015; Marti and Bernthal, 2019).

7.3.3 Study Modifications

Through observations in this project, sedge meadow communities were found to have similar hydrographs and responses to precipitation events. Due to issues installing the wet-mesic prairie wells too shallow, it was more difficult to compare those hydrographs. All said, the DNR feels that a replicate of around 10 reference wetlands provides a good model, especially if funding is limited. Additional replicates are always preferable, but with limited budgets and the need to expand, ten replicates appear to be sufficient when installed at an appropriate depth and at a representative location.

7.3.4 Continuation of this Study

Due to Covid-19 pandemic delays, this study was only able to gather just more than one full growing season's worth of data. As of the writing of this report, the plan is to continue gathering hydrologic data at as many of the original 19 sites as possible. Land managers will be contacted about their willingness and interest in gathering additional data starting in 2022. Longer-term data sets will give a much stronger picture of how each wetland and wetland community responds to wetter-than-normal, normal, or drier-than-normal conditions. With this information it will be possible to do a more thorough statistical analysis of the data. The plan would be to install the loggers at these sites for 5-10 years.

This additional data would further allow the Department and the U.S. Army Corps of Engineers to better assess whether wetland mitigation hydrology standards are sufficient or may need to be modified to better represent reference site conditions.

One challenge with this plan is to determine who will be responsible for launching the loggers in the spring, performing well maintenance, downloading data periodically, and pulling the loggers out in the fall. The wetland monitoring team will work with DNR regional staff to identify staff who are willing and interested in assisting to gather long-term data sets.

8 References

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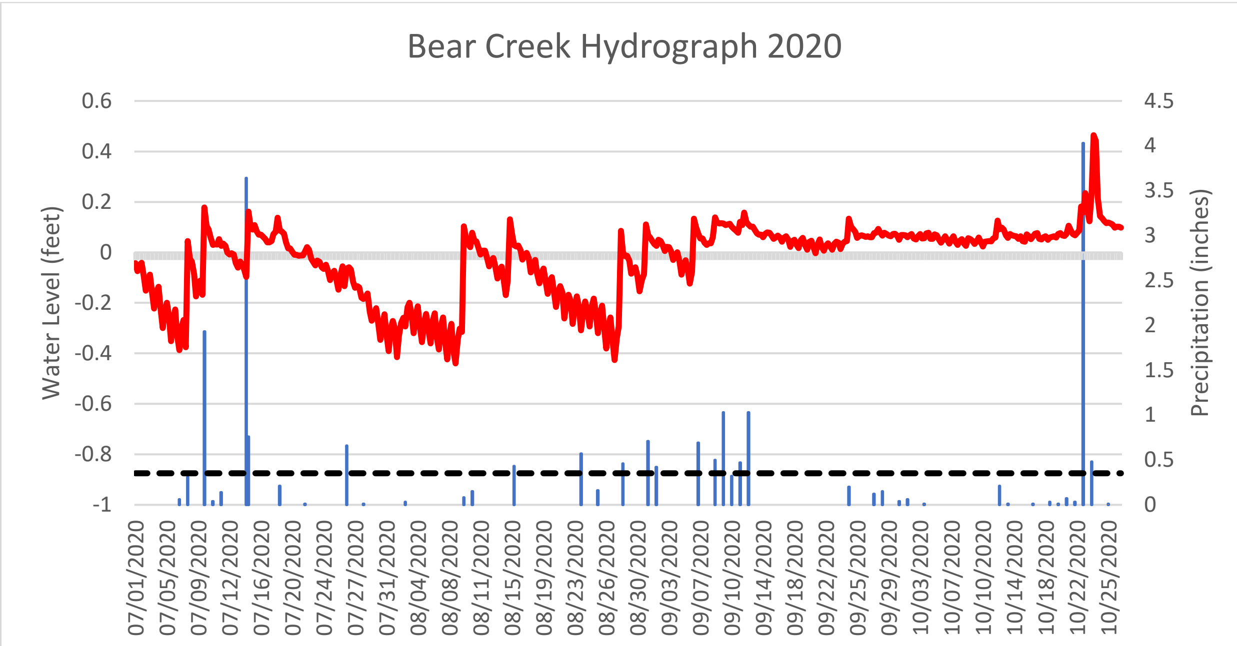
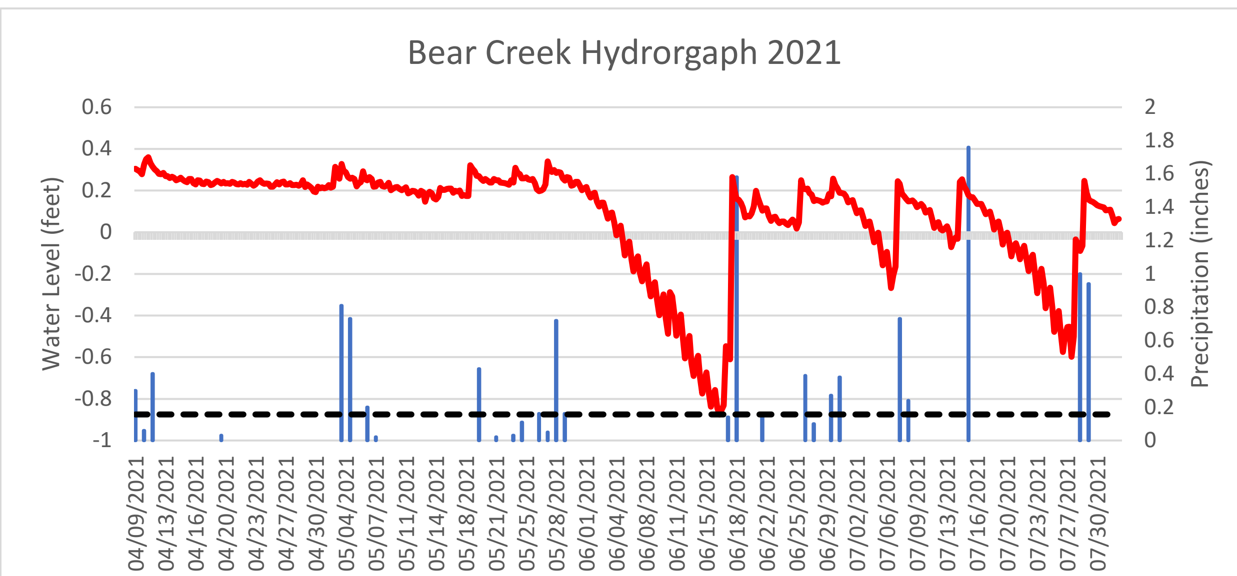
9 APPENDICES

Appendix A: Final Hydrographs
Appendix B: Site Summary Data
Appendix C: Site Photos
Appendix D: Summary Vegetation Data
Appendix E: Antecedent Precipitation Data

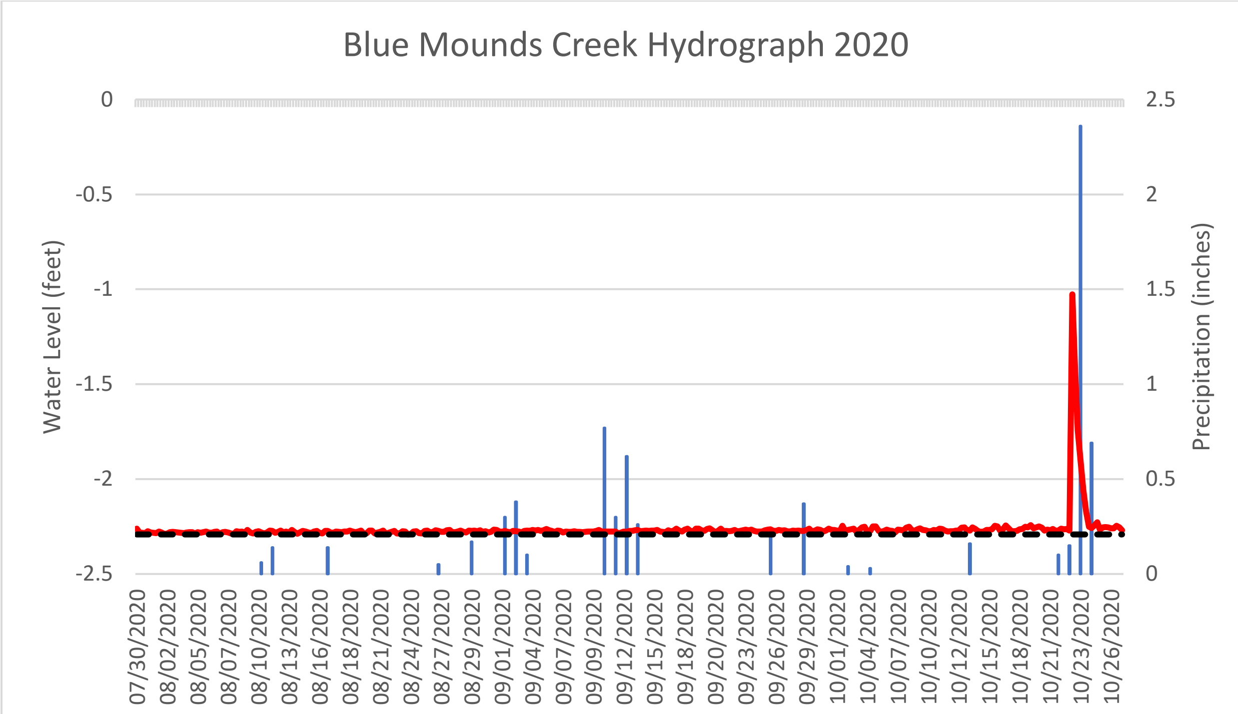
Appendix A. Final Hydrographs

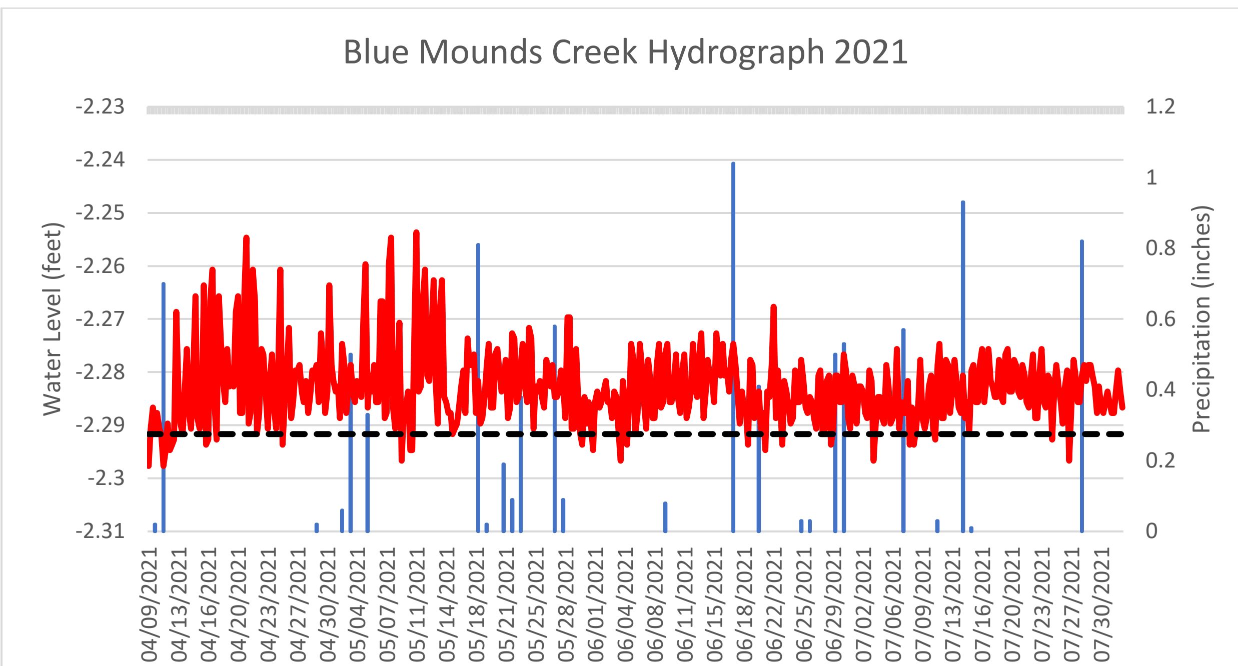
Bear Creek SSM



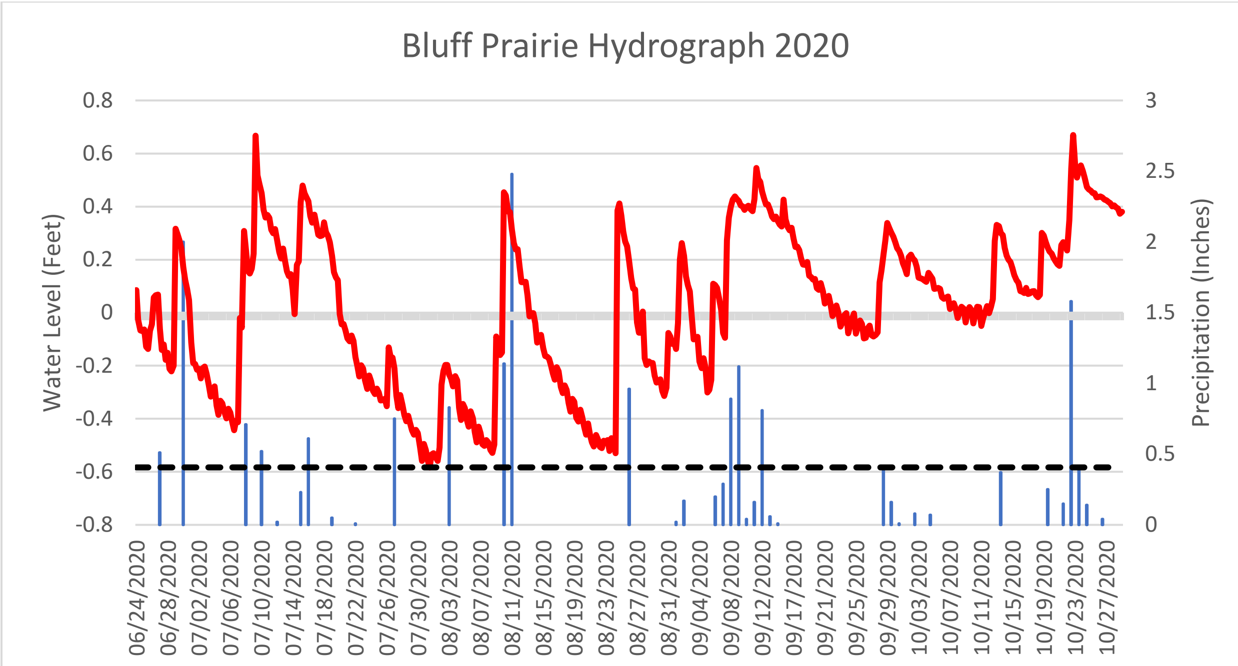


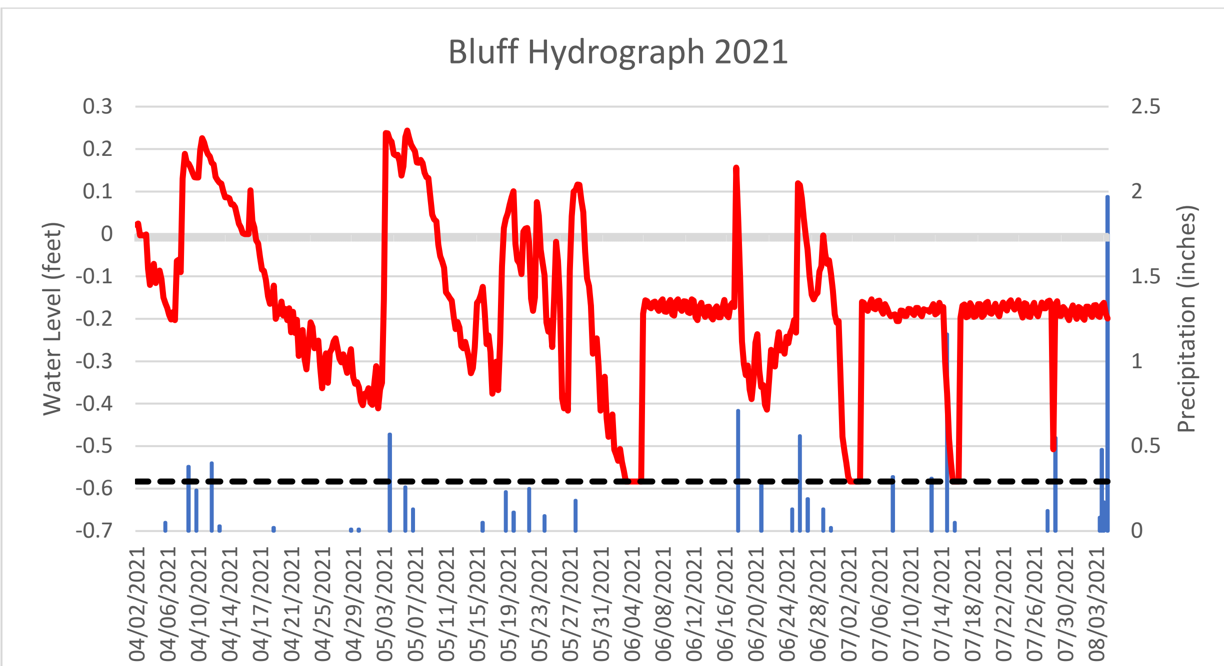
Blue Mounds Creek Bottom WMP



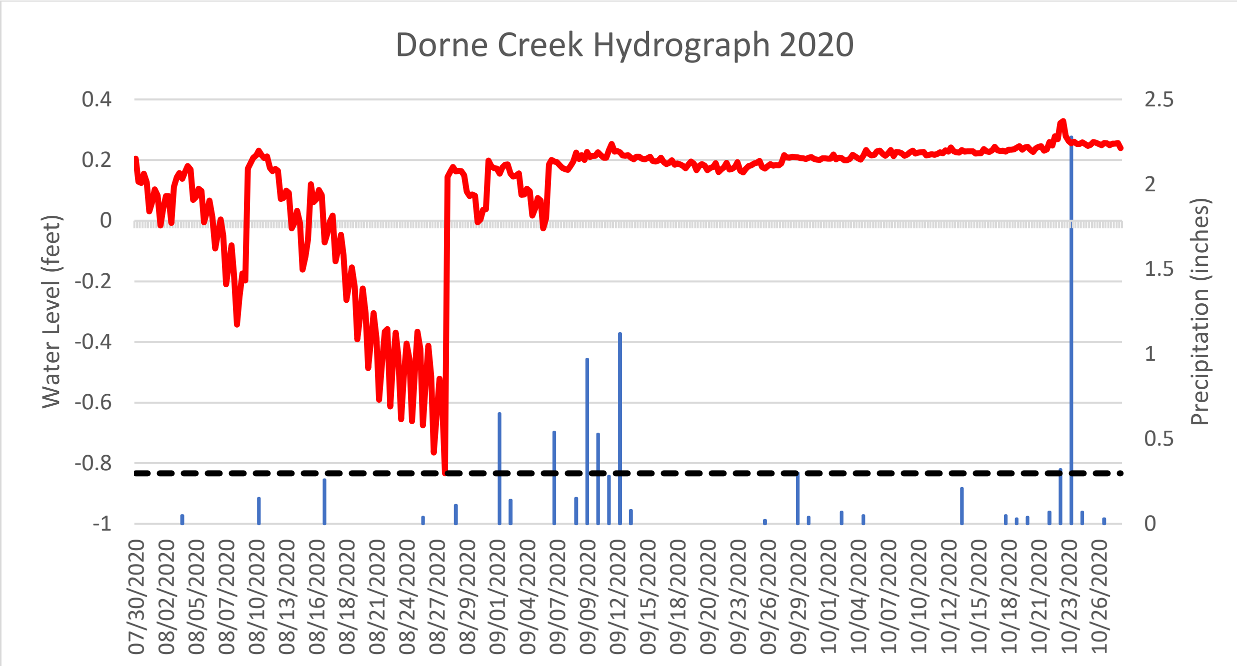


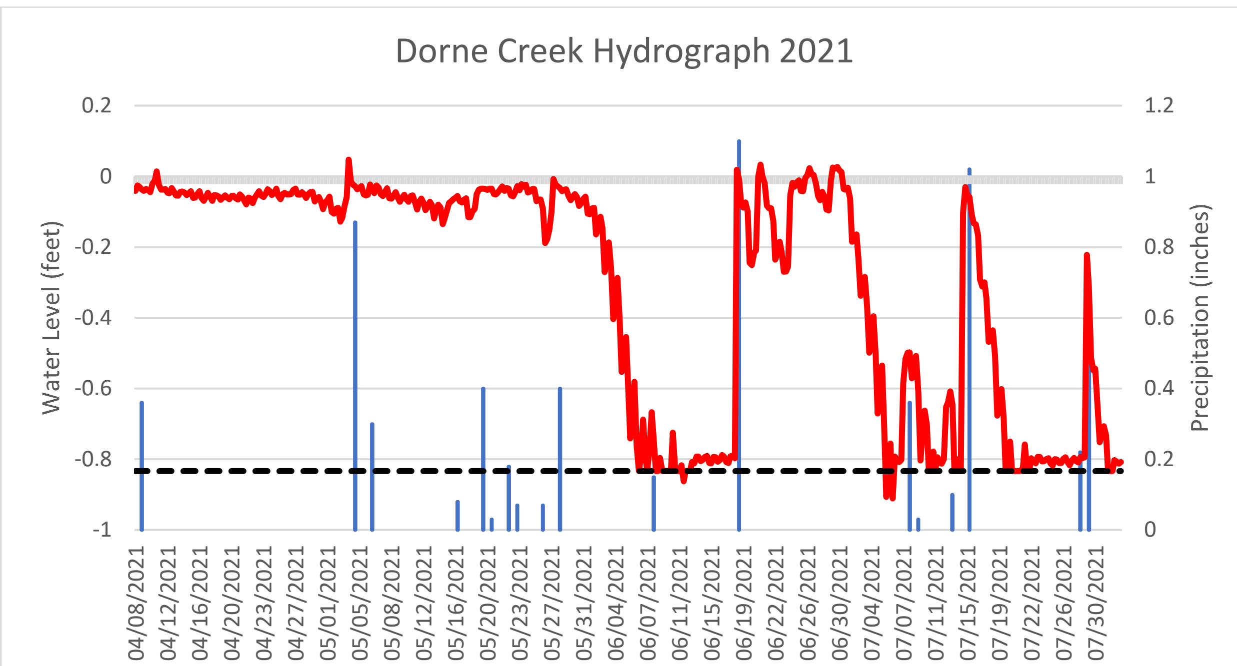
Bluff Creek SSM



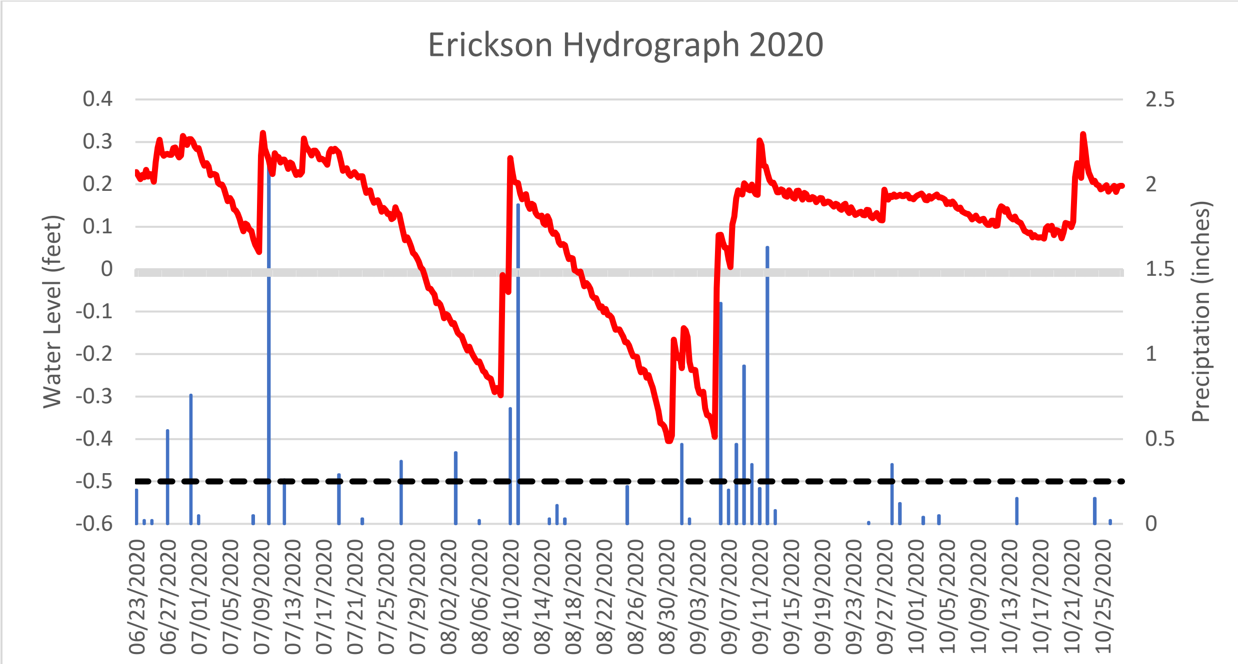


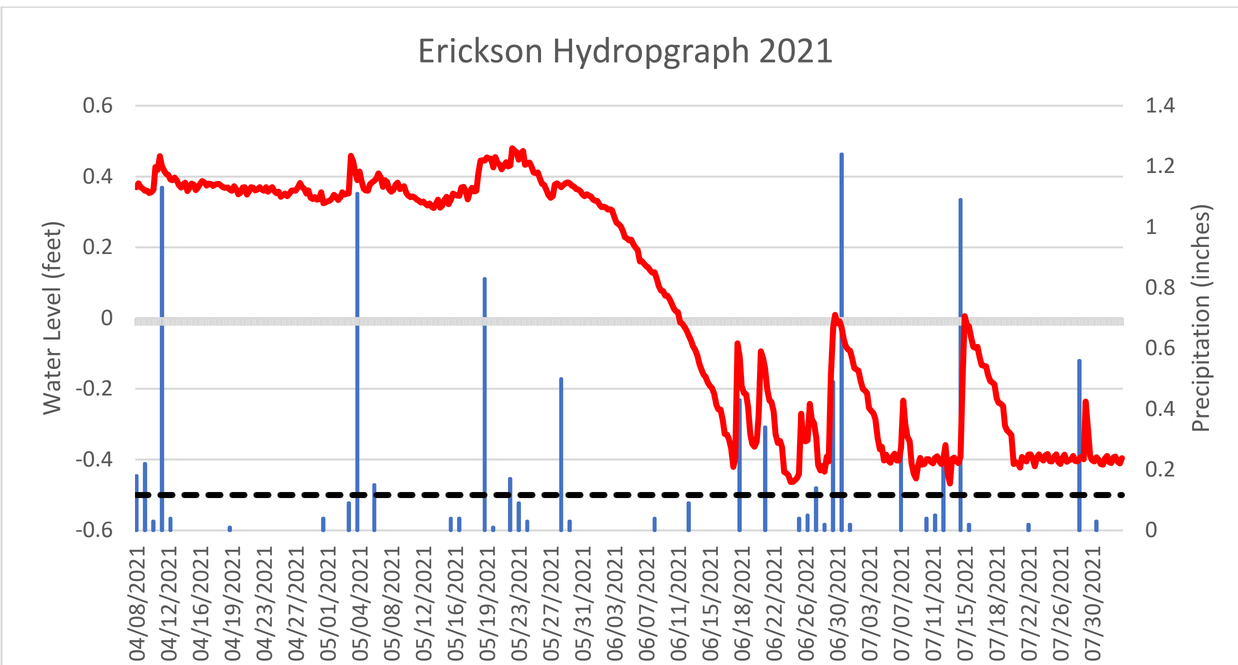
Dorne Creek SSM



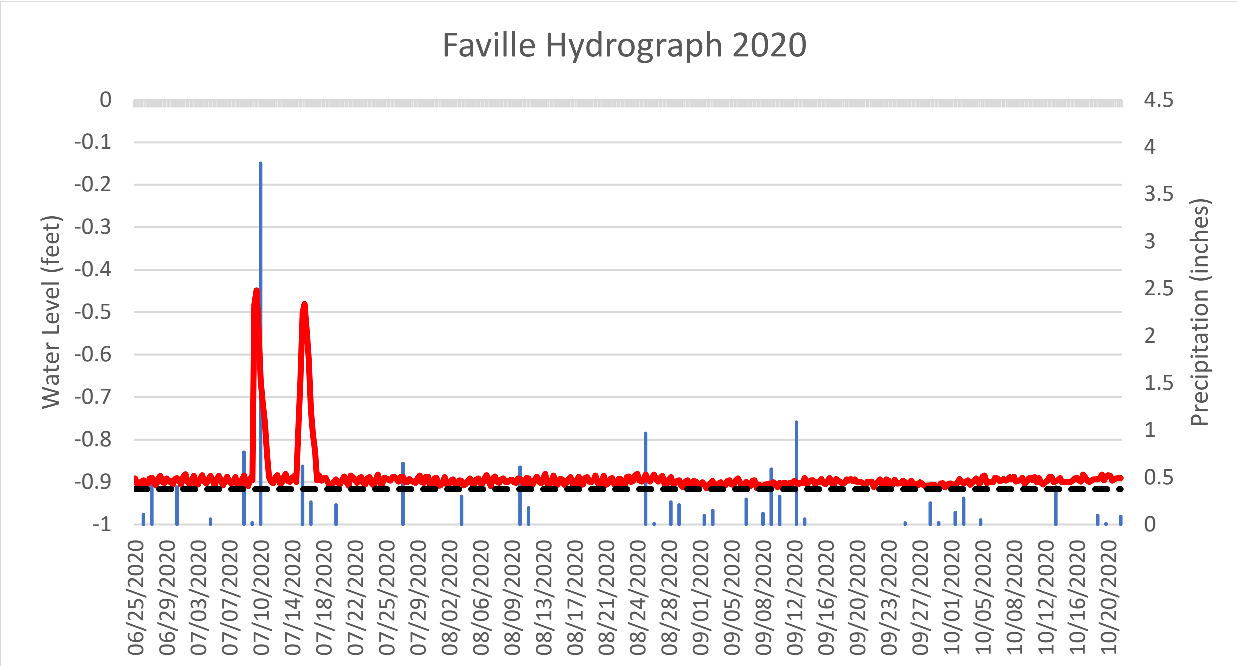


Erickson SSM





Faville WMP


Faville Hydrograph 2020
Water Level (feet)
Precipitation (inches)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
06/25/2020
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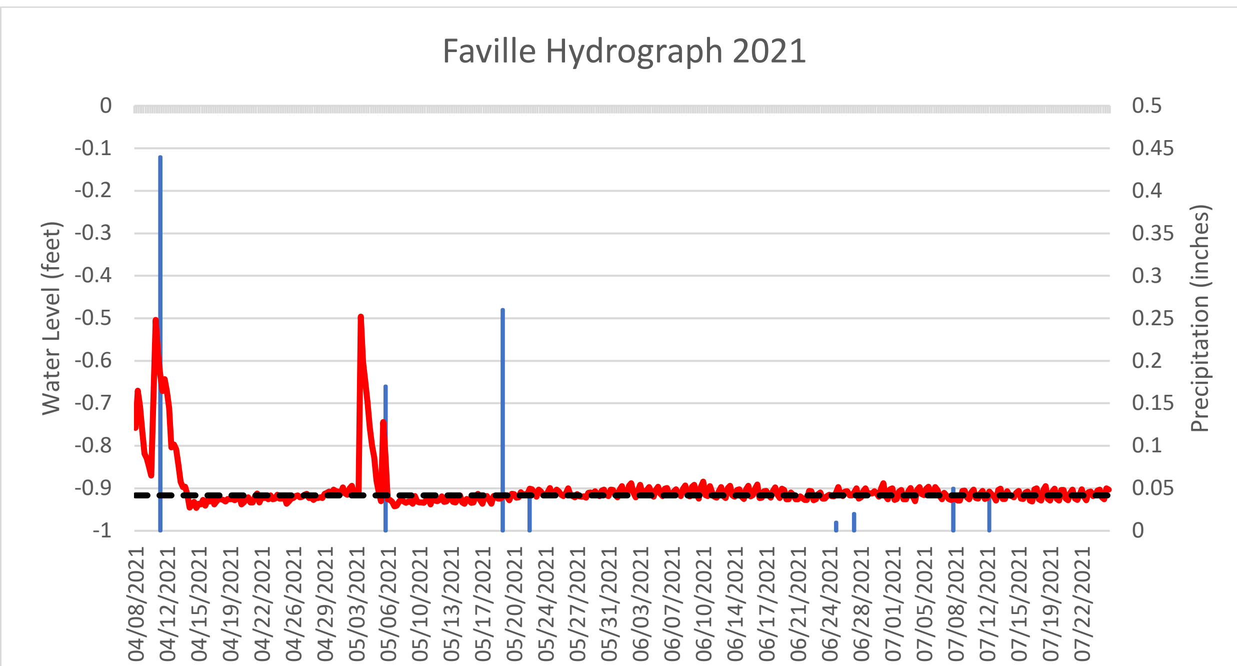
Faville Hydrograph 2021
Water Level (feet)
Precipitation (inches)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
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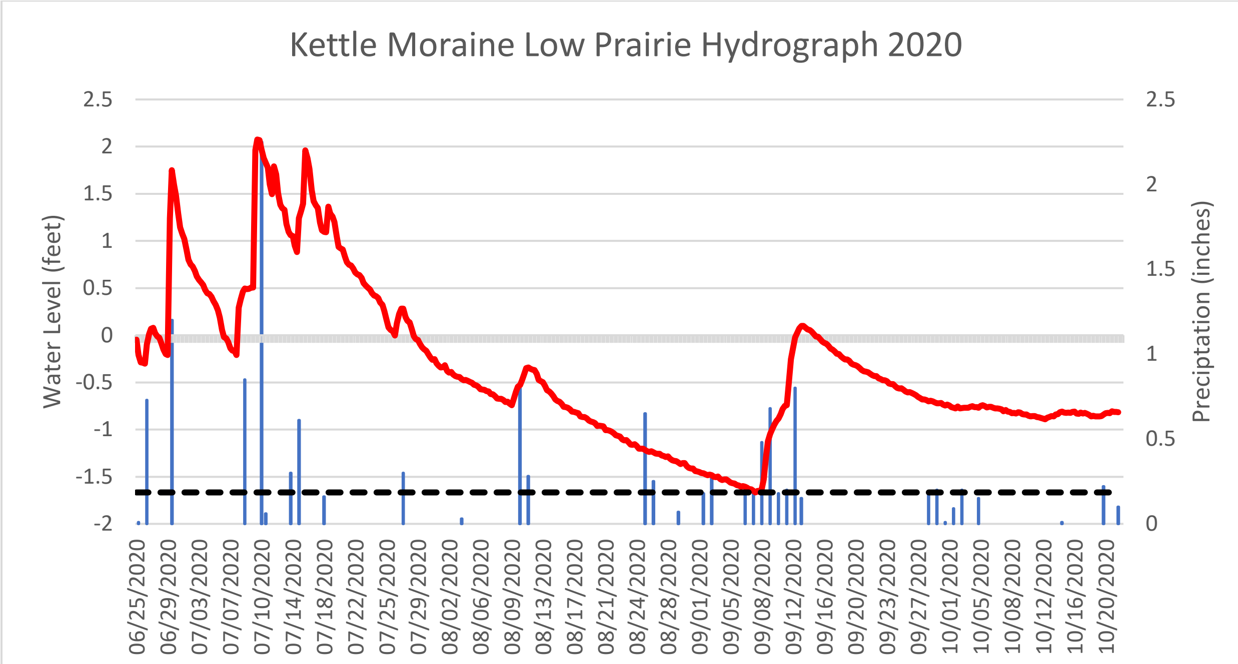
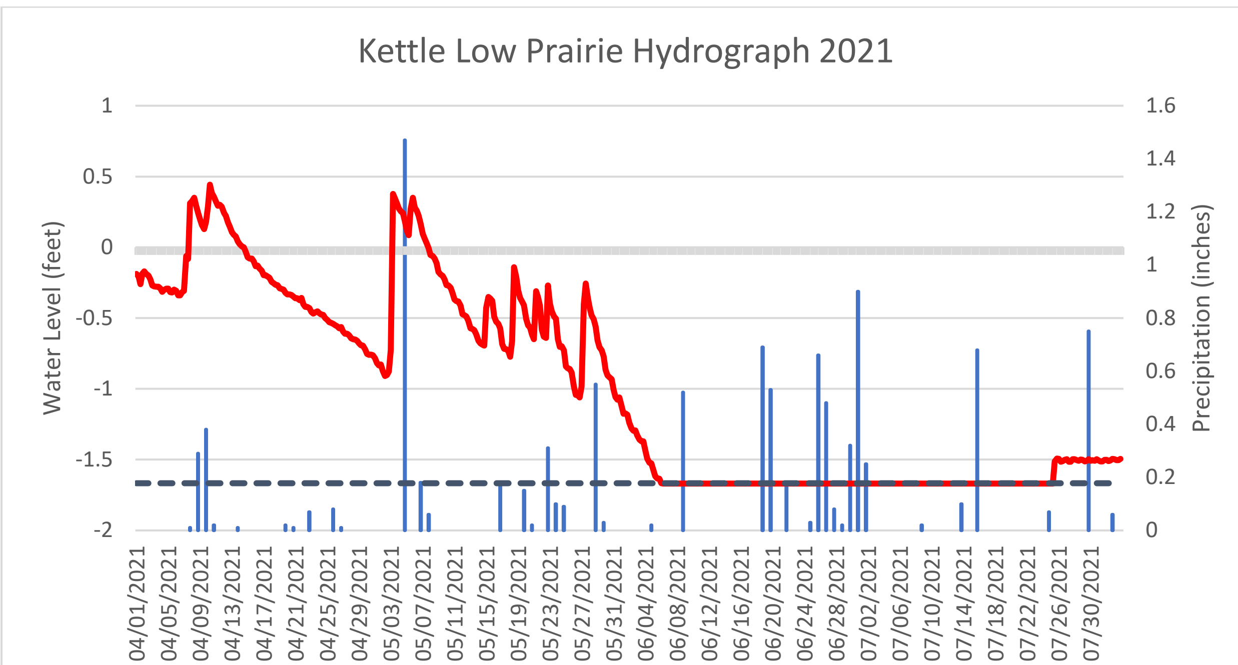
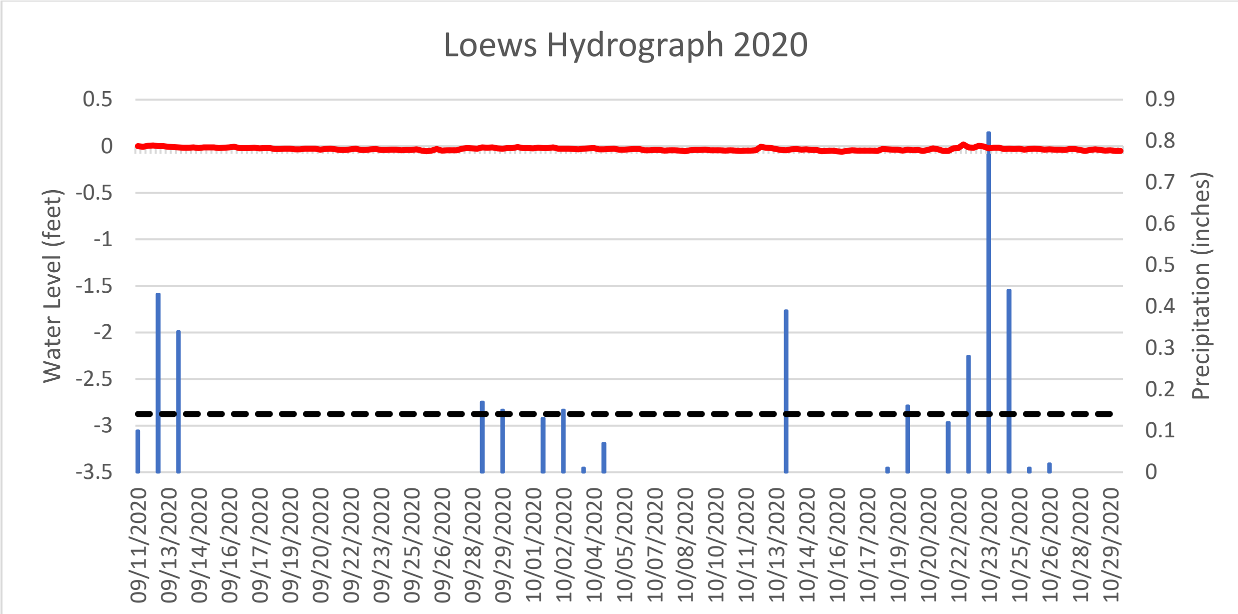
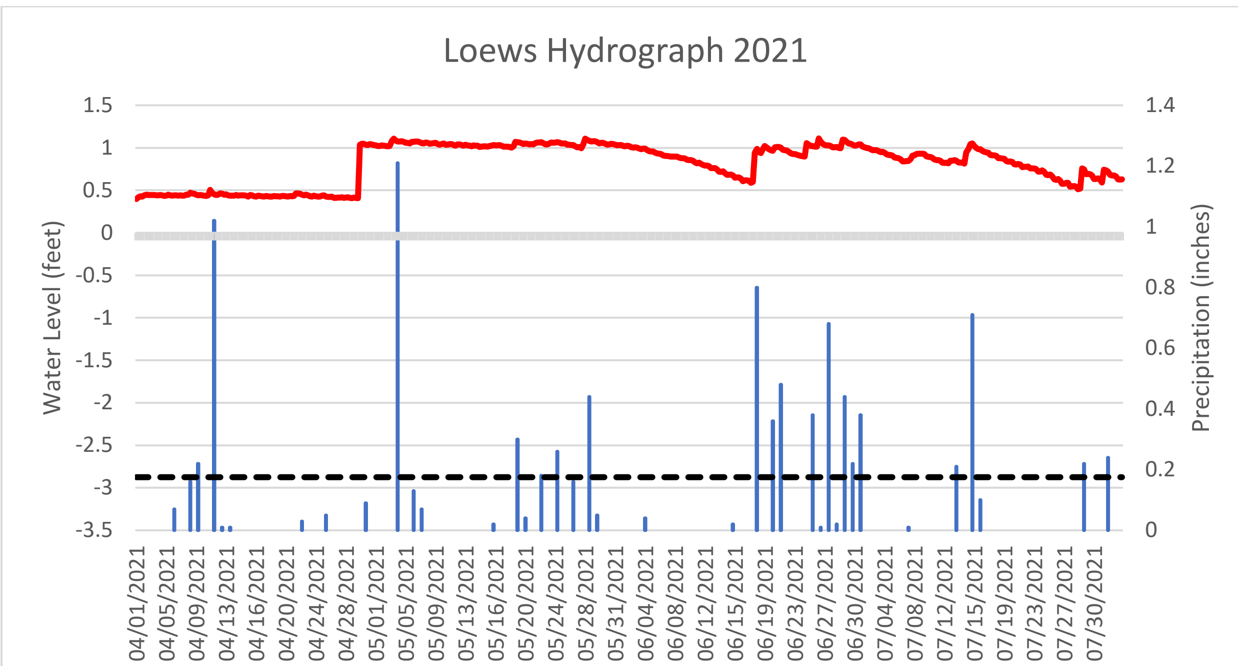
Kettle Moraine Low Prairie WMP



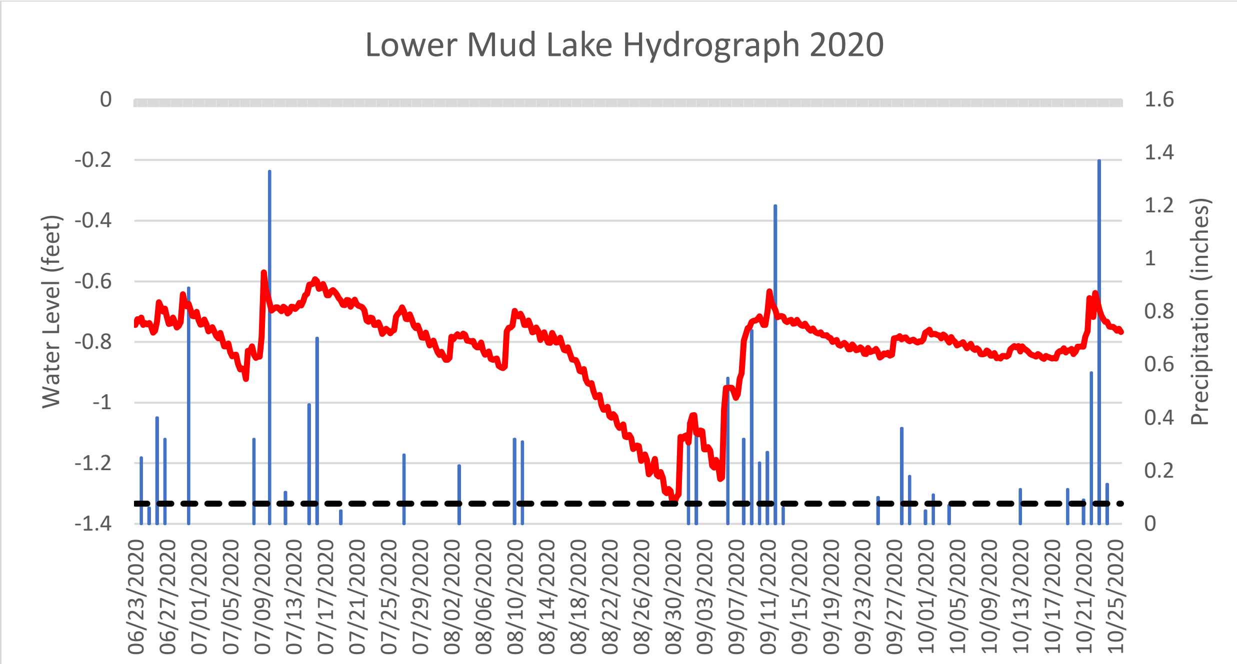


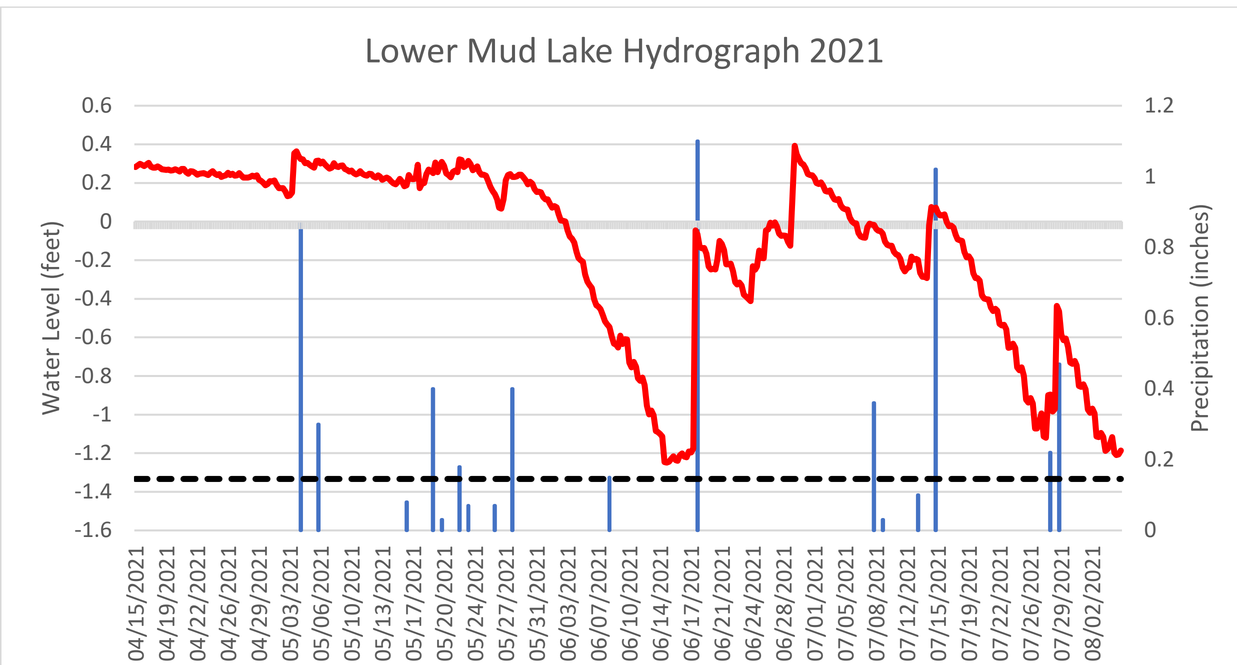
Loews Lake SSM



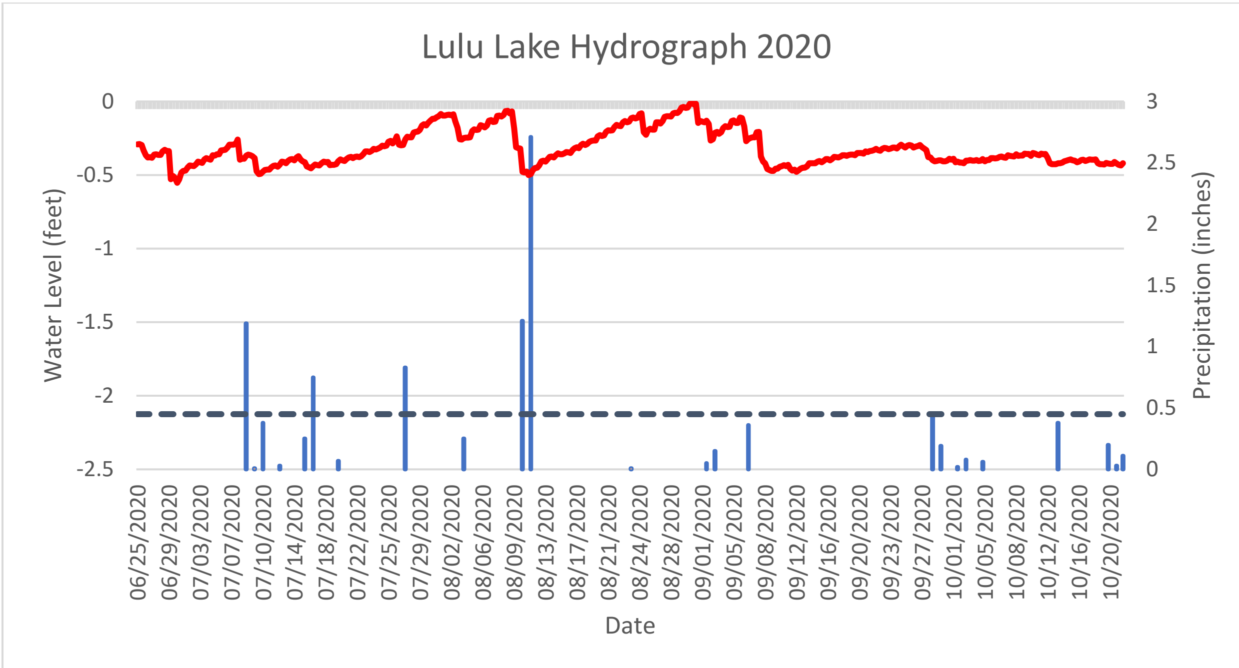


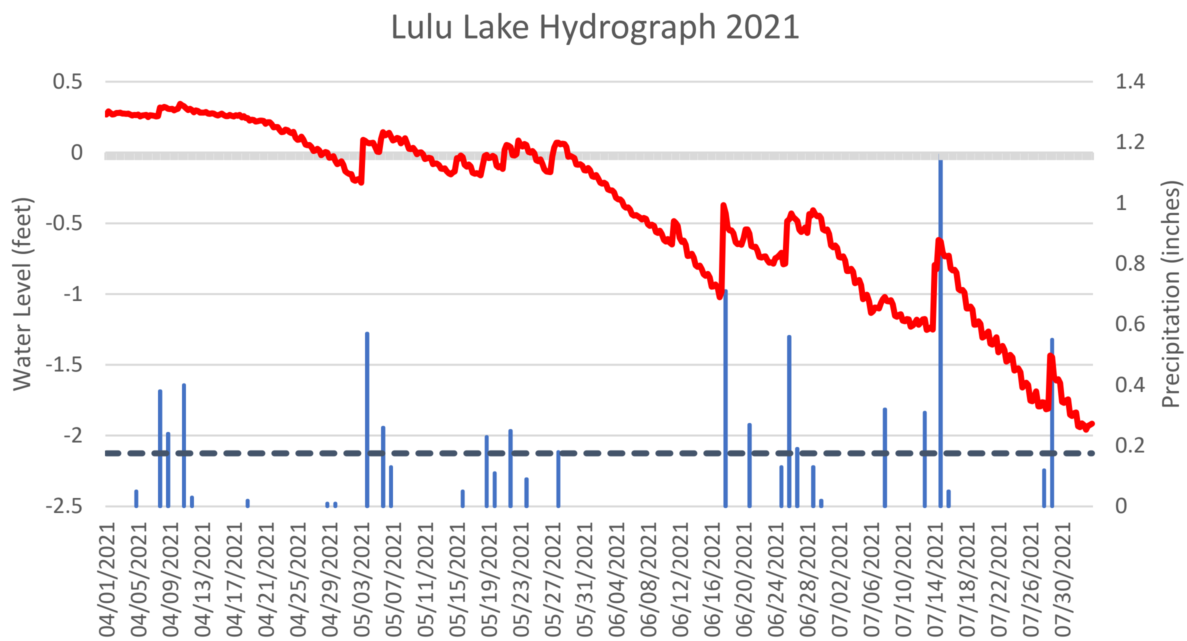
Lower Mud Lake SSM



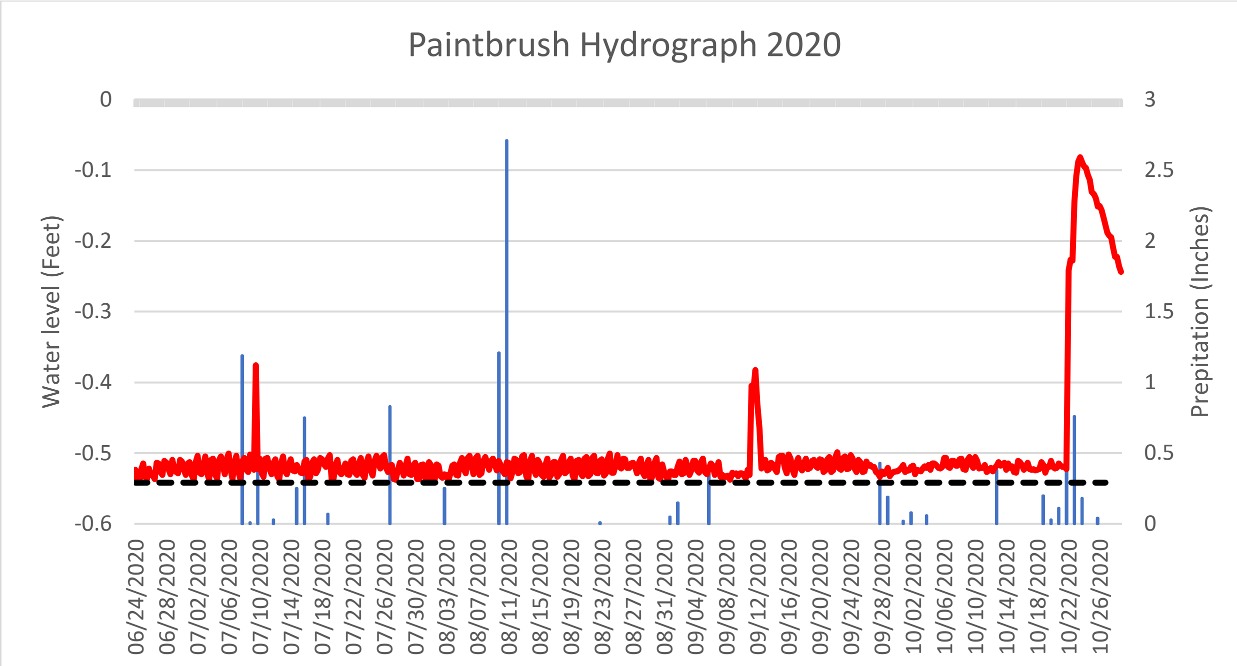


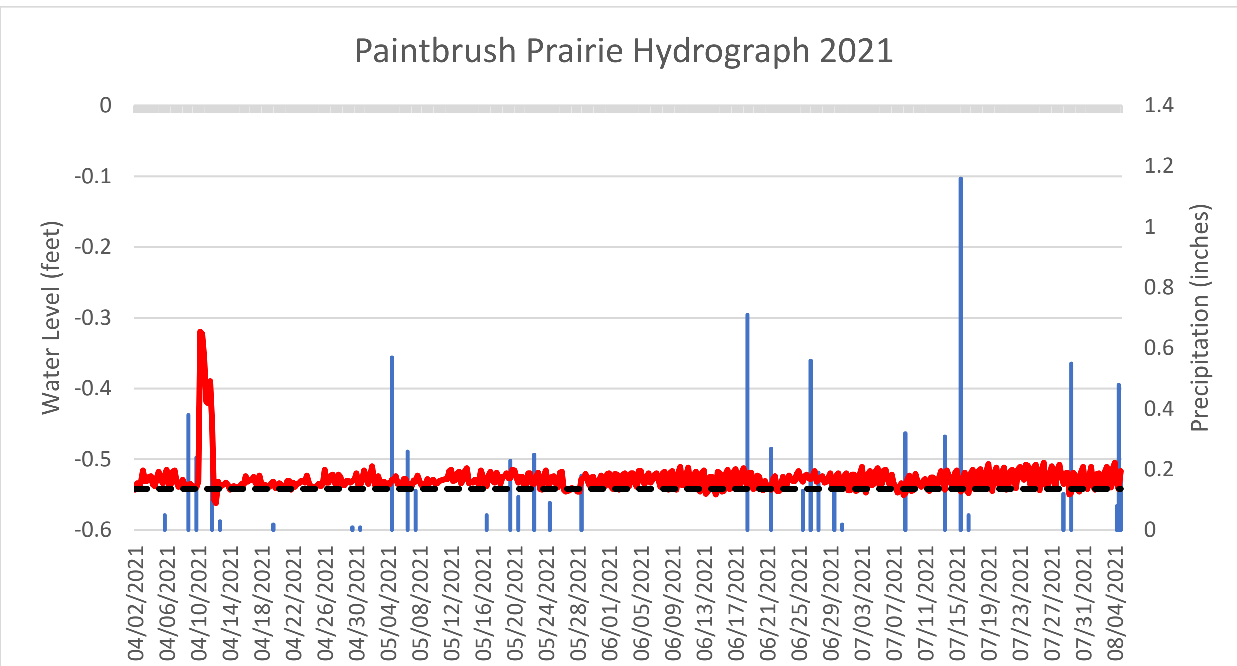
Lulu Lake SSM



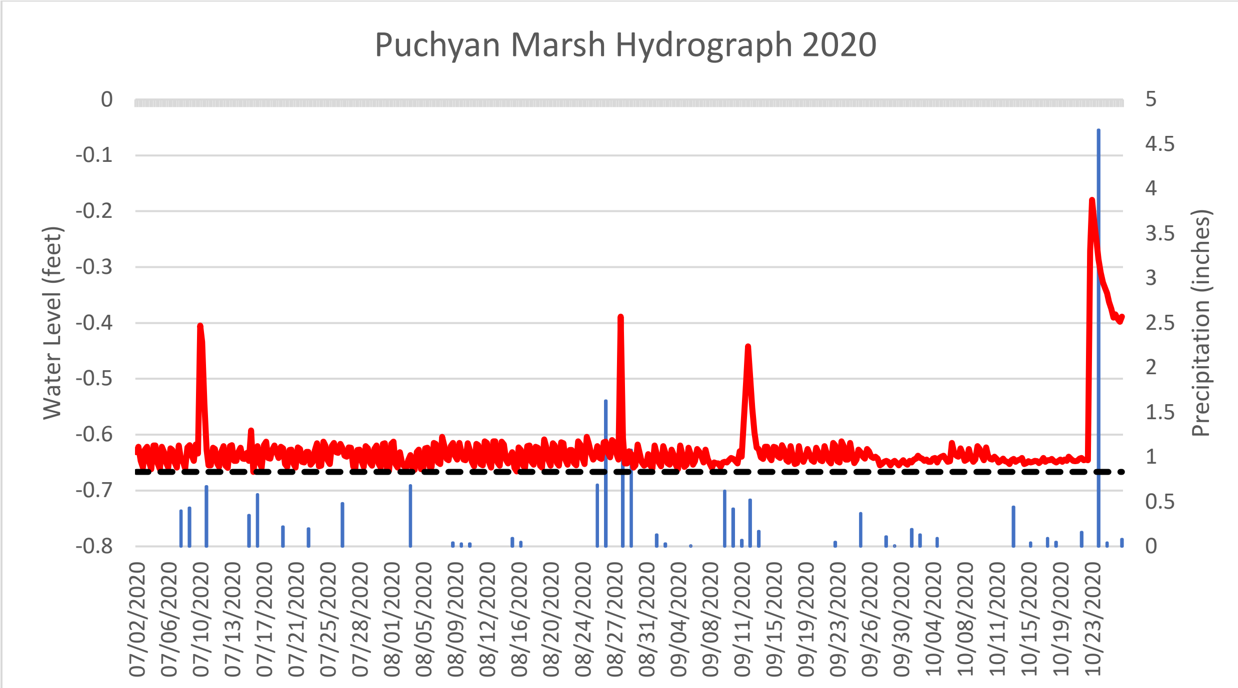


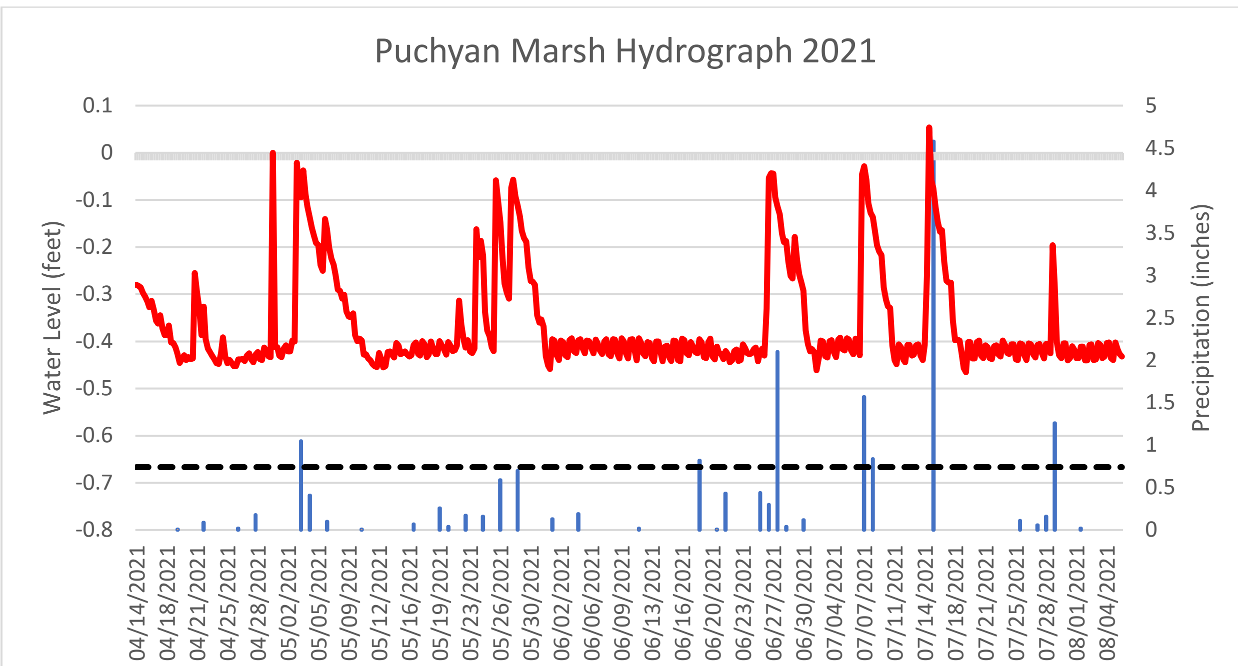
Paintbrush Prairie (Young) WMP



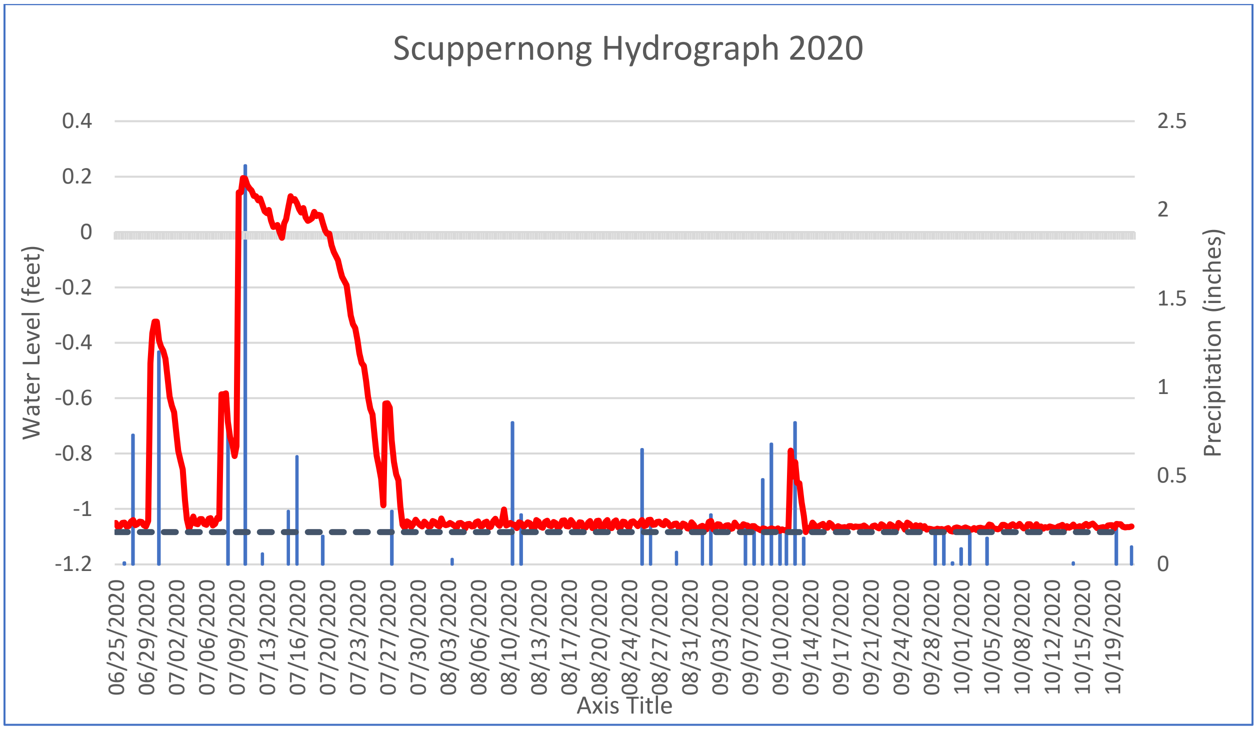


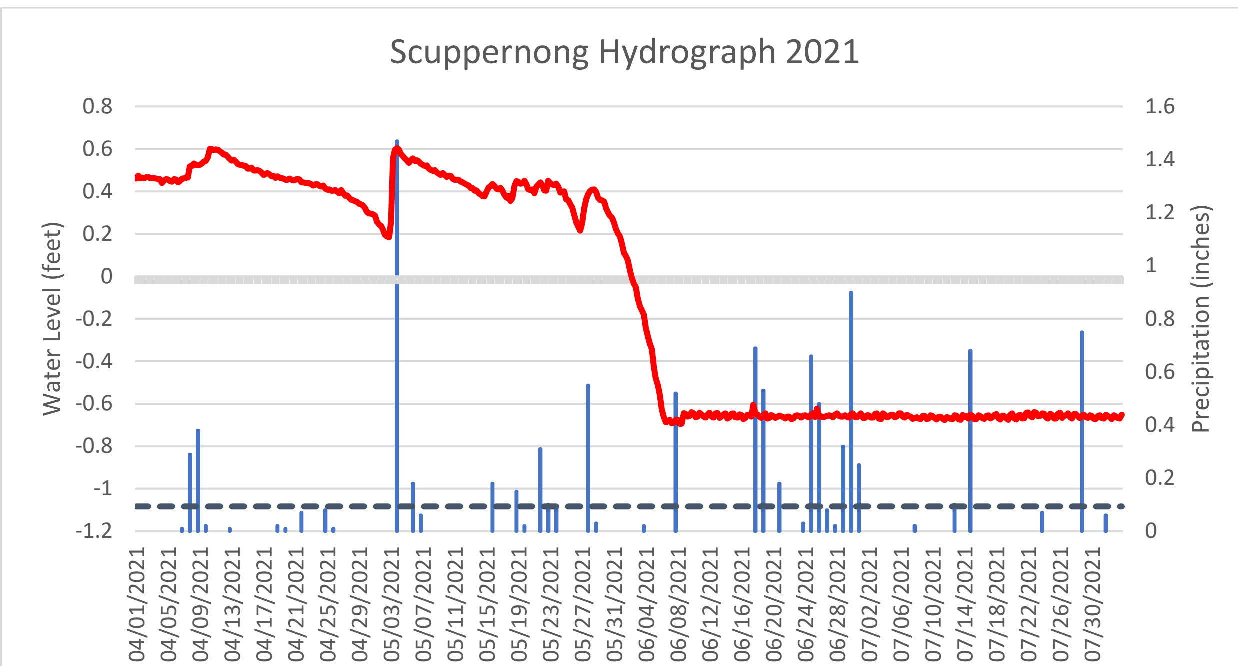
Puchyan Marsh WMP



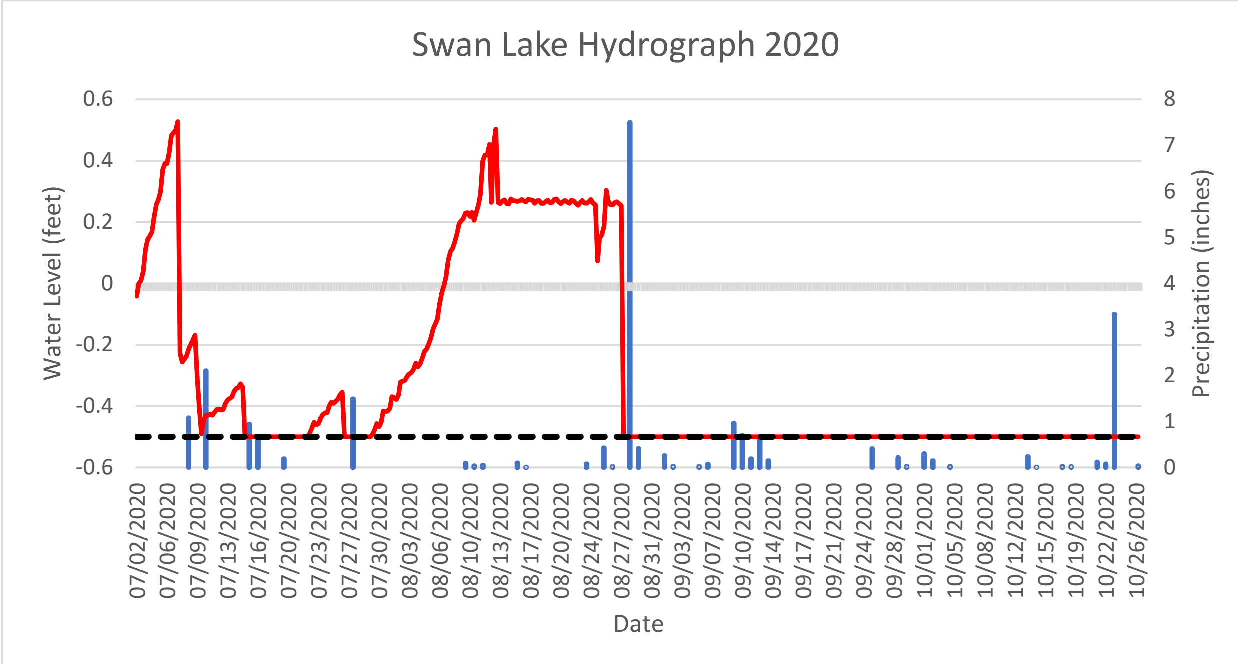


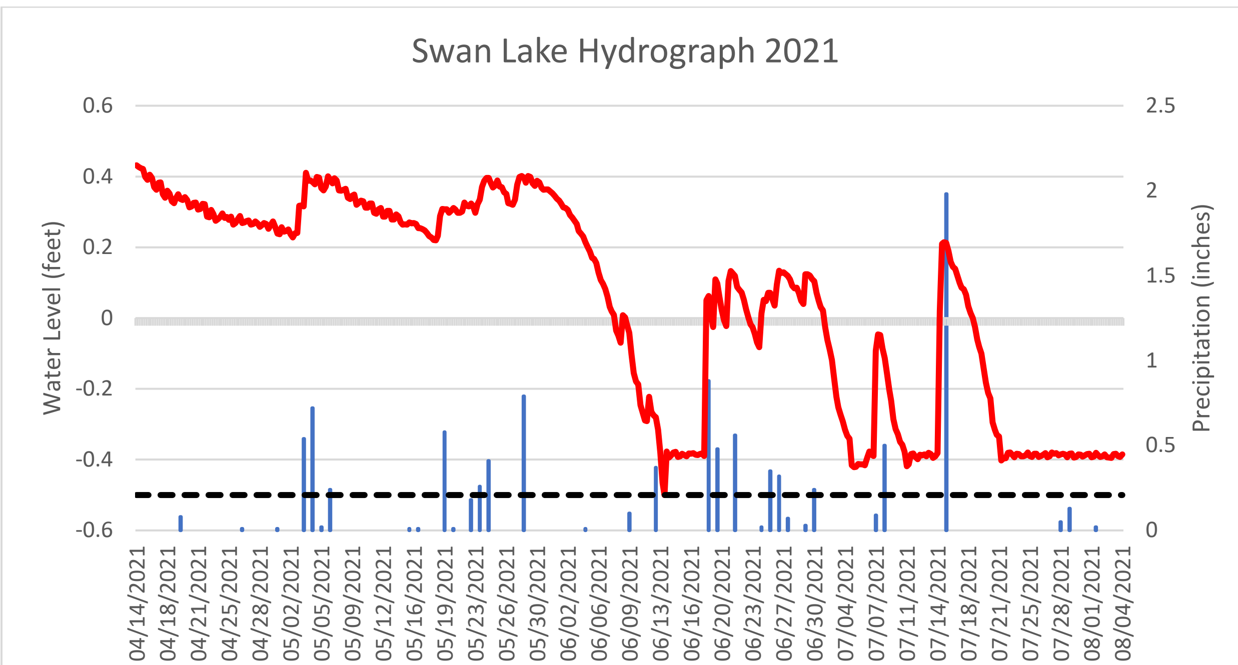
Scuppernong Prairie WMP



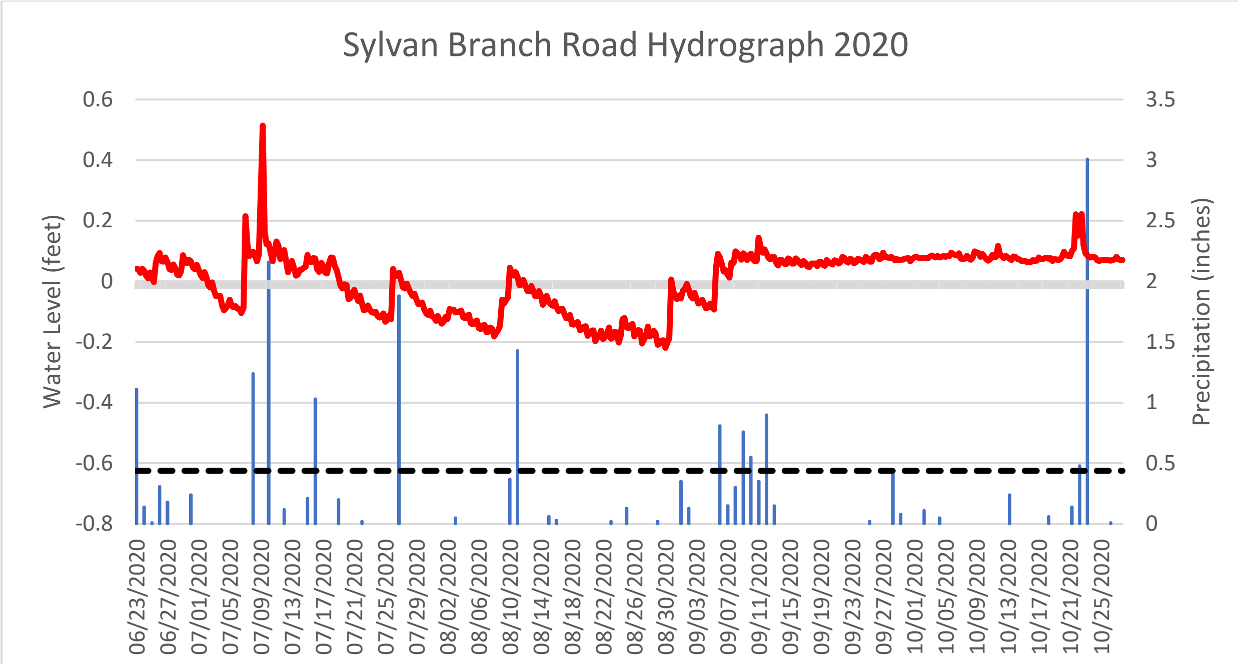


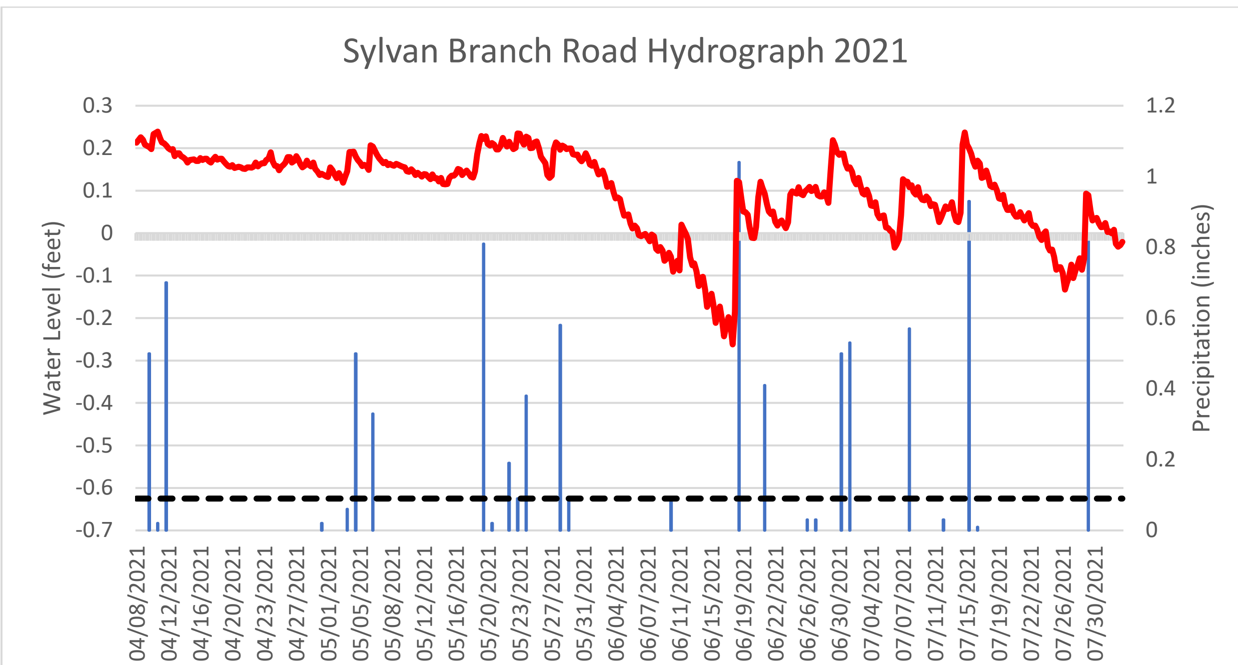
Swan Lake SSM



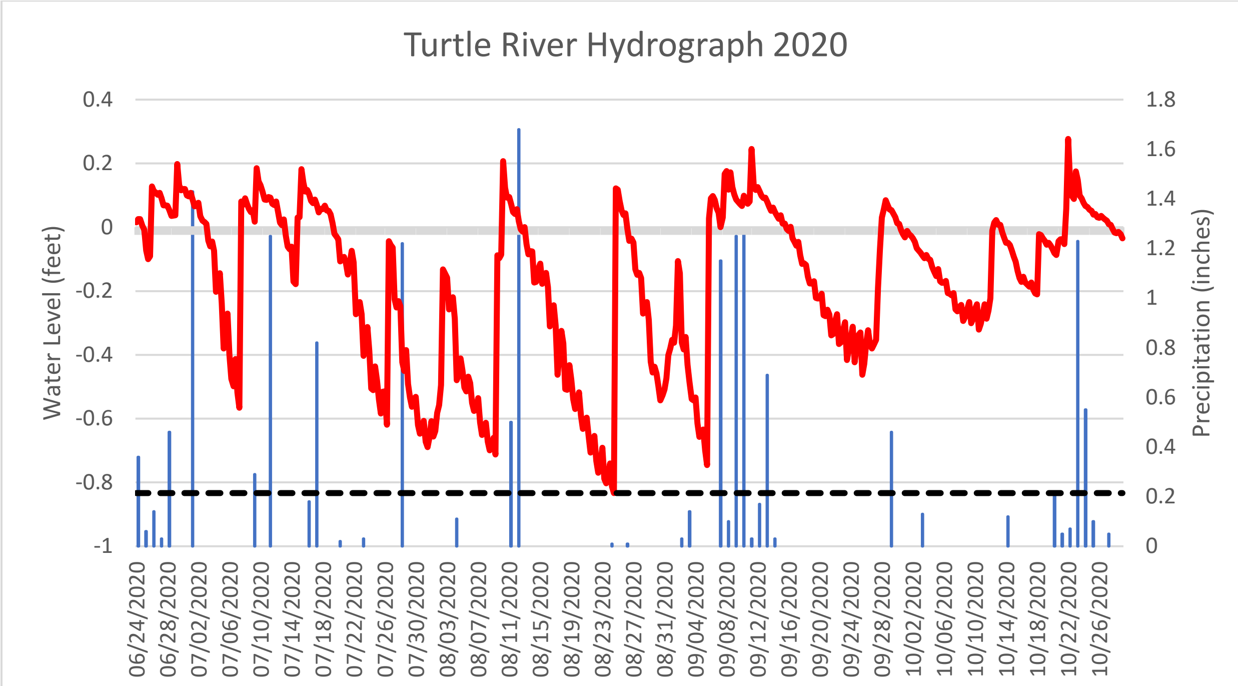


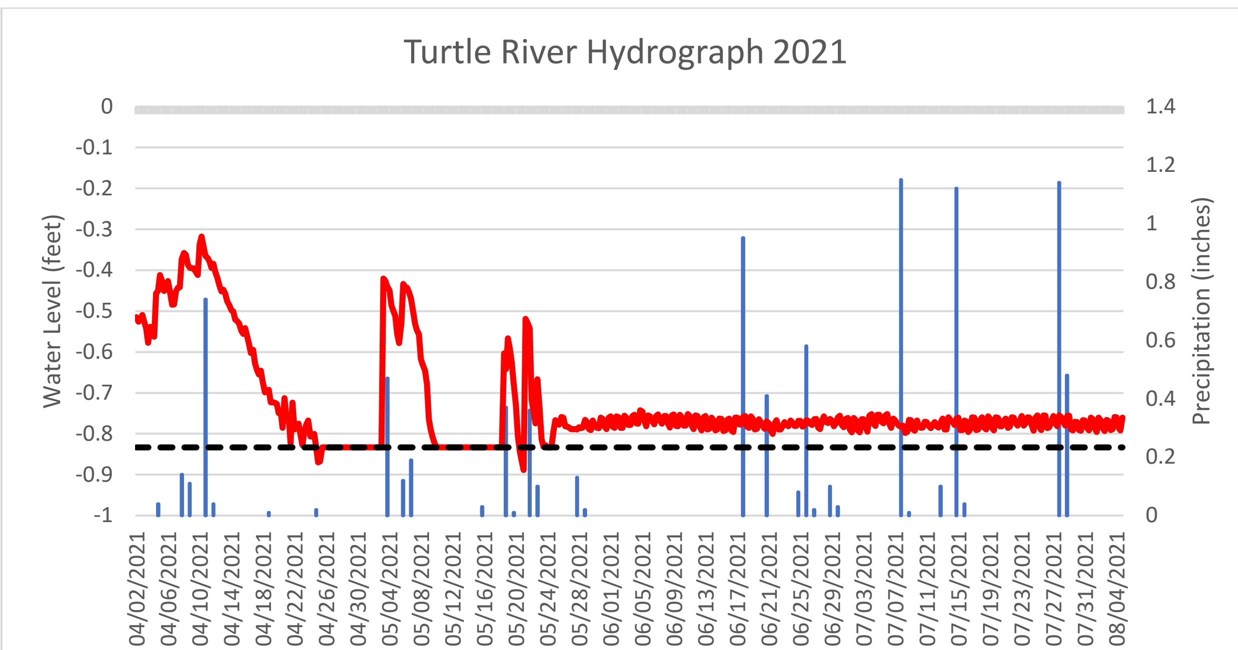
Sylvan Road SSM



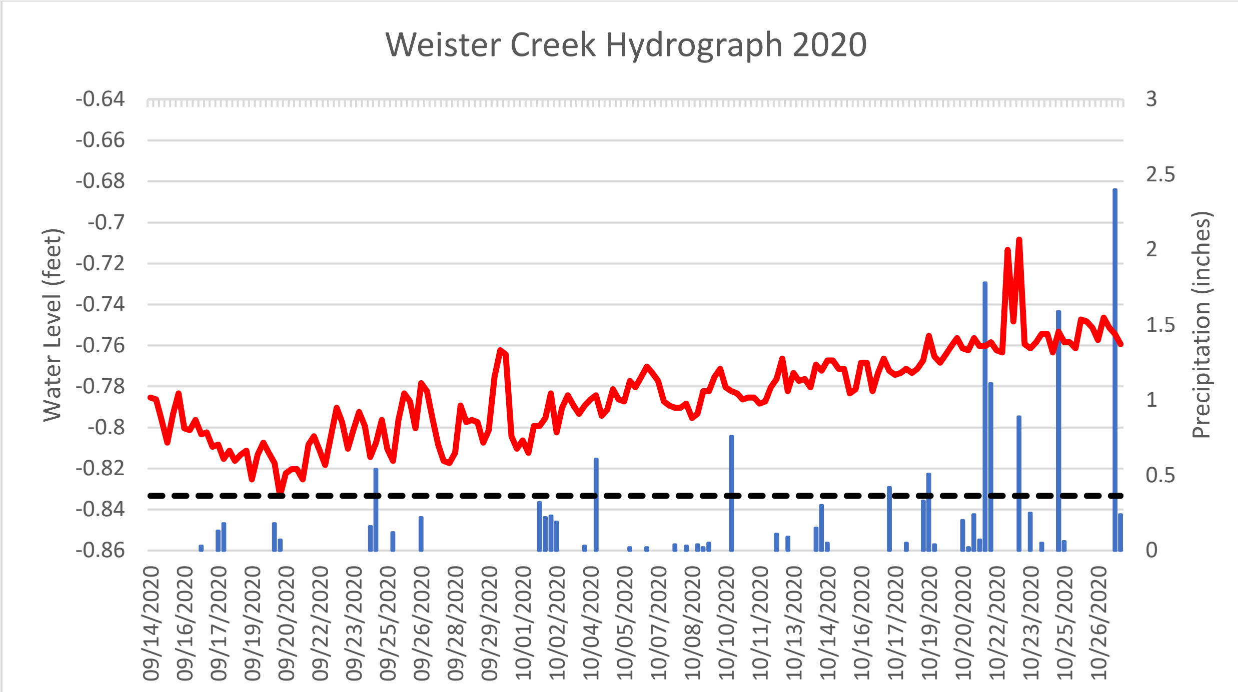


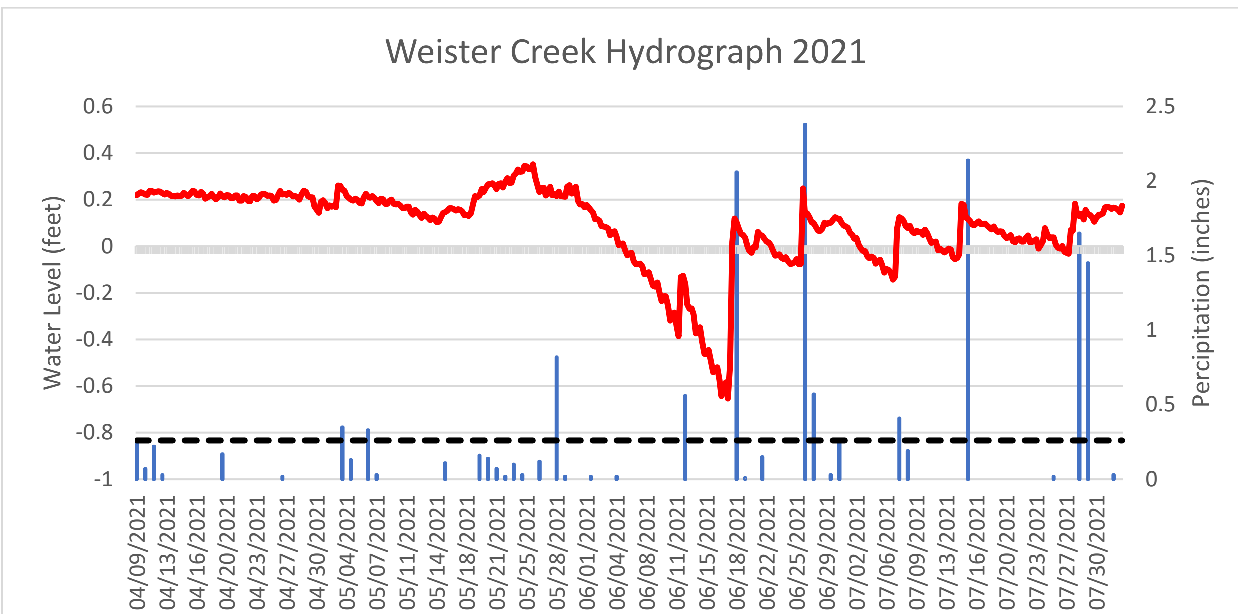
Turtle Creek SSM



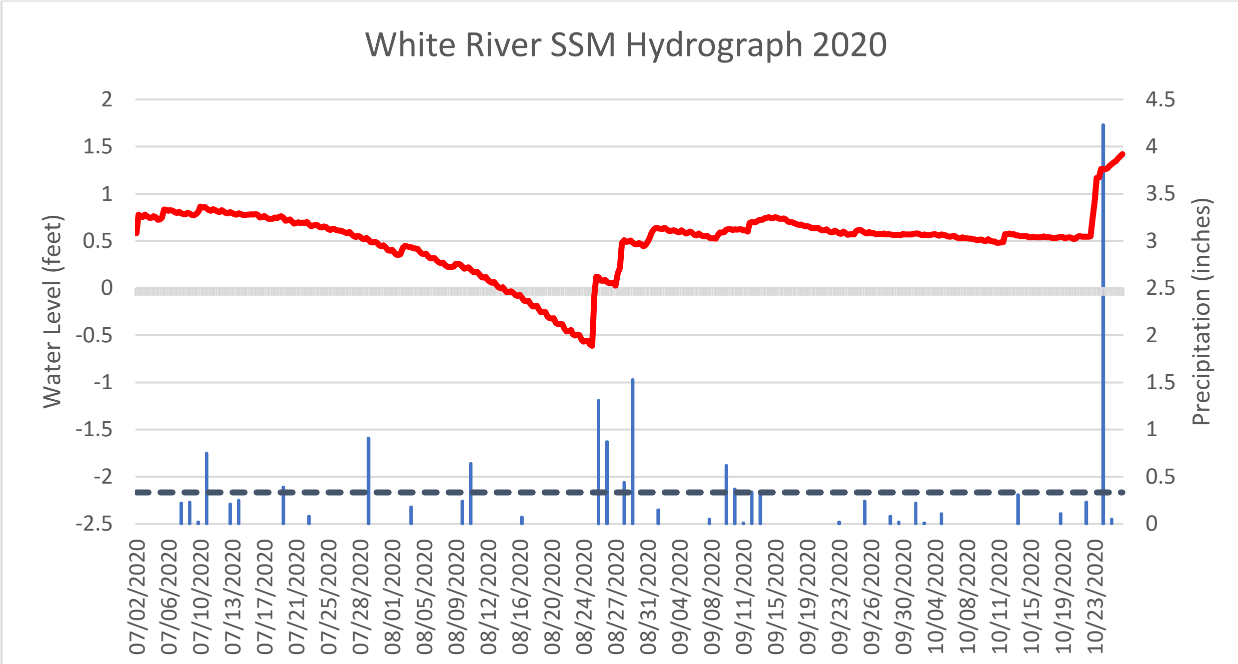


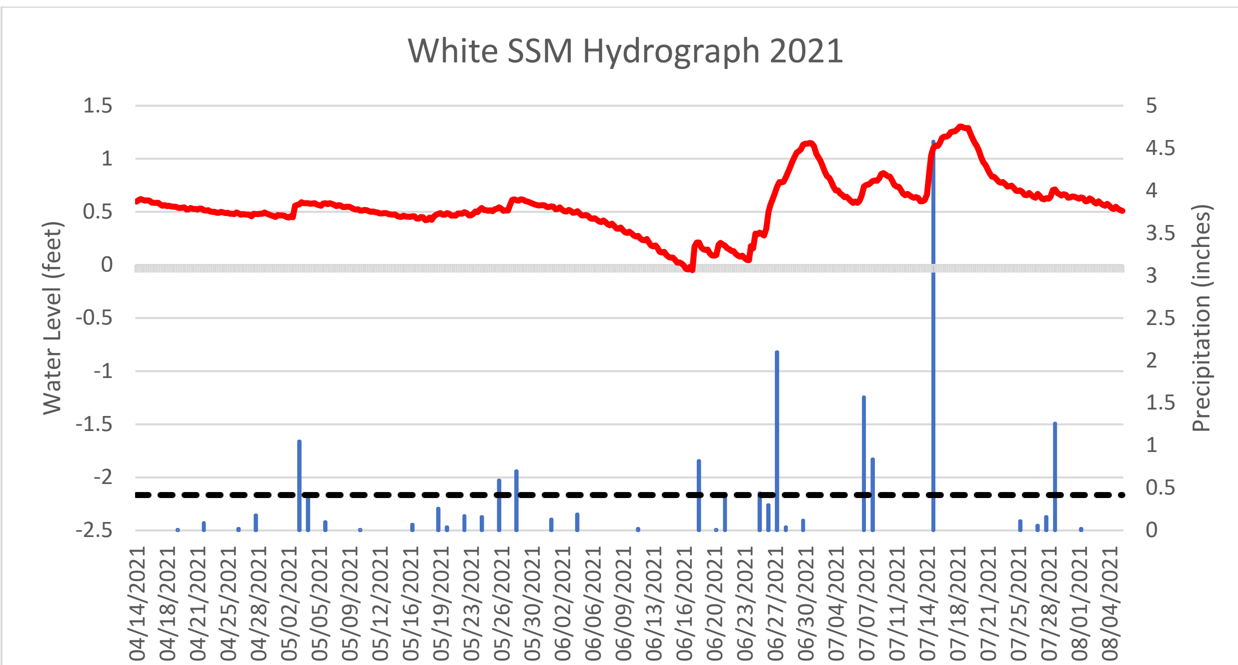
Weister Creek SSM



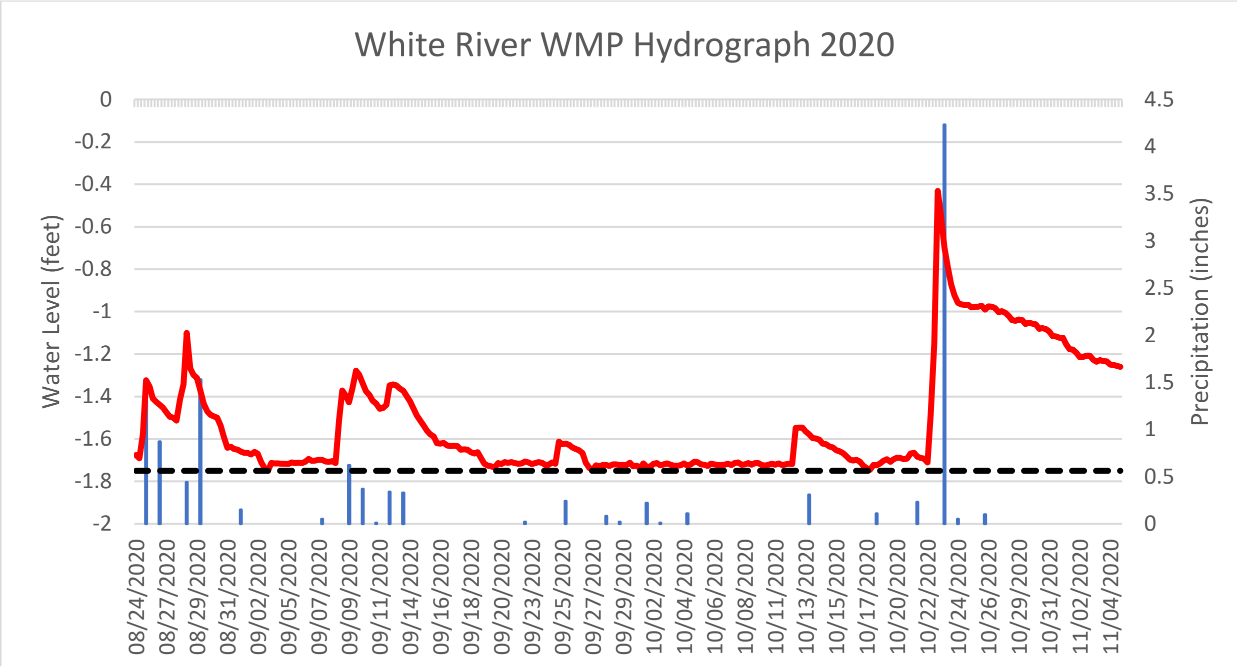


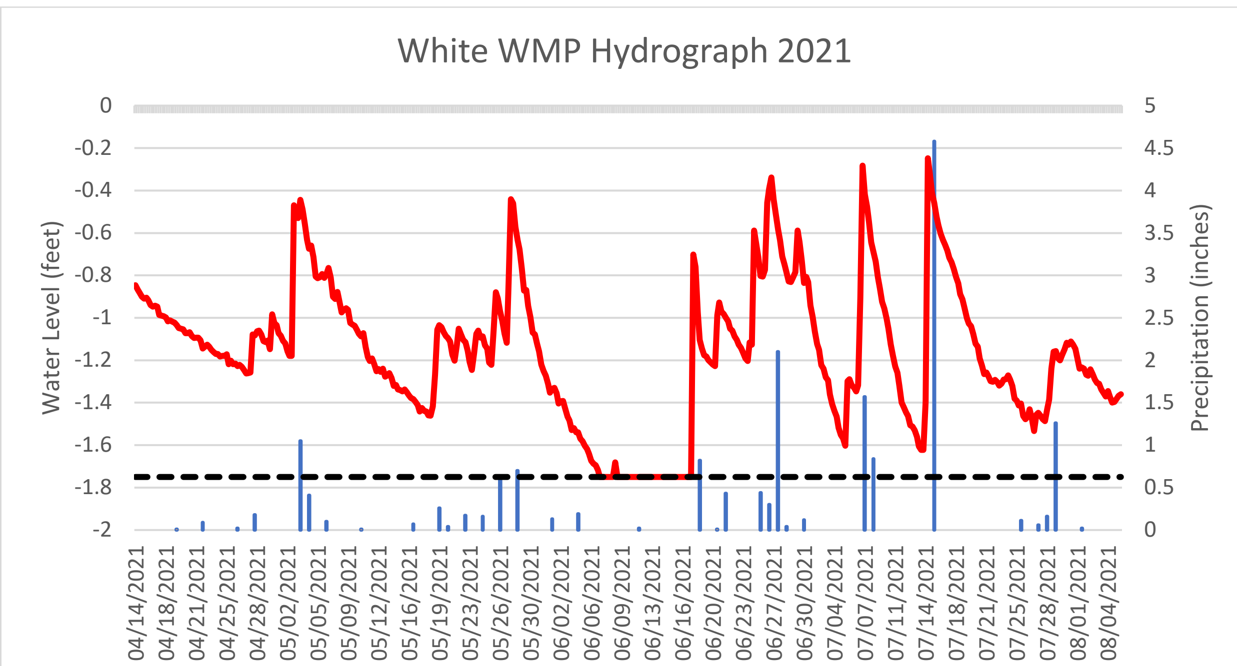
White River SSM





White River WMP





Appendix B: Site Summary Data

Project Name: Wetland Hydrology Monitoring FY18	**Location: Bear Creek SNA**
Date of Installation: 10/10/2019	**Personnel: W. Kolb, M. Smale**
Depth of Well: 10.5 inches	**Community Type: Southern Sedge Meadow**

Horizon Depth (cm)	**Texture**	**Matrix Color (Munsell moist)**	**Redoximorphic Features**		**Induration (none, weak, strong)**	**Roots**
			Color	**Abundance**		
32	MK	10YR2/1	N/A	N/A	none	45%VF
43	SC	2.5Y5/1	7.5YR4/6	3%	none	4%VF
64+	C	10YR4/1	5YR4/4	8%	none	2%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: Blue Mounds Creek Bottoms
Date of Installation: 10/10/2019	Personnel: W. Kolb, M. Zoellner
Depth of Well: 27.5 inches	Community Type: Wet-Mesic Prairie

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
32	MK	10YR2/1	N/A	N/A	none	45%VF
43	SC	2.5Y5/1	7.5YR4/6	3%	none	4%VF
64+	C	10YR4/1	5YR4/4	8%	none	2%VF

Project Name: Wetland Hydrology Monitoring FY18	**Location: Bluff Creek**
Date of Installation:10/03/19	**Personnel: W. Kolb, J. Homer**
Depth of Well: 7 inches	**Community Type: Southern Sedge Meadow**

Horizon Depth (cm)	**Texture**	**Matrix Color (Munsell moist)**	**Redoximorphic Features**		**Induration (none, weak, strong)**	**Roots**
			Color	**Abundance**		
9	SiL	10YR2/1	N/A	N/A	none	25%VF
55	C	10YR3/1	N/A	N/A	none	1%VF

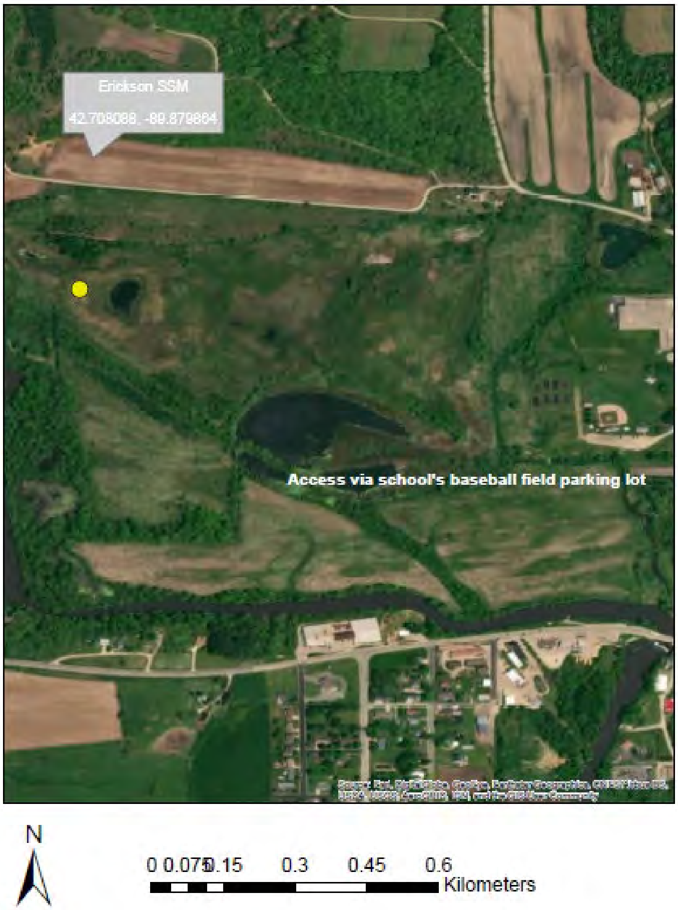
Project Name: Wetland Hydrology Monitoring FY18	Location: Dodge Branch
Date of Installation: 10/22/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 7.5 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
9	MK	2.5Y2.5/1	N/A	N/A	none	25%VF
22	MK	2.5Y3/1	N/A	N/A	none	5%VF
70+	C	10YR2/1	10YR4/6	1%	none	1%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: Dorne Creek
Date of Installation: 10/14/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 10 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
20	MK	10YR2/2	N/A	N/A	none	30%VF
53+	C	2.5/N	N/A	N/A	none	20%VF

Project Name: Wetland Hydrology Monitoring FY18	**Location: Erickson**
Date of Installation: 10/24/2019	**Personnel: W. Kolb, J. Homer**
Depth of Well: 6 inches	**Community Type: Southern Sedge Meadow**



Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
15	MK	10YR2/1	N/A	N/A	none	30%VF
29	MKC	10YR2/1	N/A	N/A	none	8%VF
73+	C	2.5Y2.5/1	10YR4/6	3%	none	0%

Project Name: Wetland Hydrology Monitoring FY18	**Location: Faville Prairie**
Date of Installation: 10/01/2019	**Personnel: W. Kolb, M. Zoellner**
Depth of Well: 11 inches	**Community Type: Wet-Mesic Prairie**

Horizon Depth (cm)	**Texture**	**Matrix Color (Munsell moist)**	**Redoximorphic Features**		**Induration (none, weak, strong)**	**Roots**
			Color	**Abundance**		
29	SC	10YR2/1	N/A	N/A	none	3%VF
43+	C	10YR3/1	10YR6/1	3%	none	1%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: Kettle Moraine Low Prairie
Date of Installation: 10/03/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 20 inches	Community Type: Wet-Mesic Prairie

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
10	MK Clay	10YR2/1	N/A	N/A	none	30%VF
29	MK Clay	10YR2/1	N/A	N/A	none	3%VF
49	SCL	2.5Y3/1	N/A	N/A	none	2%VF
70+	SC	2.5Y6/6	N/A	N/A	none	1%F

Project Name: Wetland Hydrology Monitoring FY18	Location: Loews Lake
Date of Installation: 10/09/2019	**Personnel: W. Kolb, M. Zoellner**
Depth of Well: 34.5 inches	**Community Type: Southern Sedge Meadow**

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
38	MK	10YR2/1	N/A	N/A	none	35%VF
52	MK	10YR2/1	N/A	N/A	none	1%VF
73+	MK	10YR2/1	N/A	N/A	none	5%VF

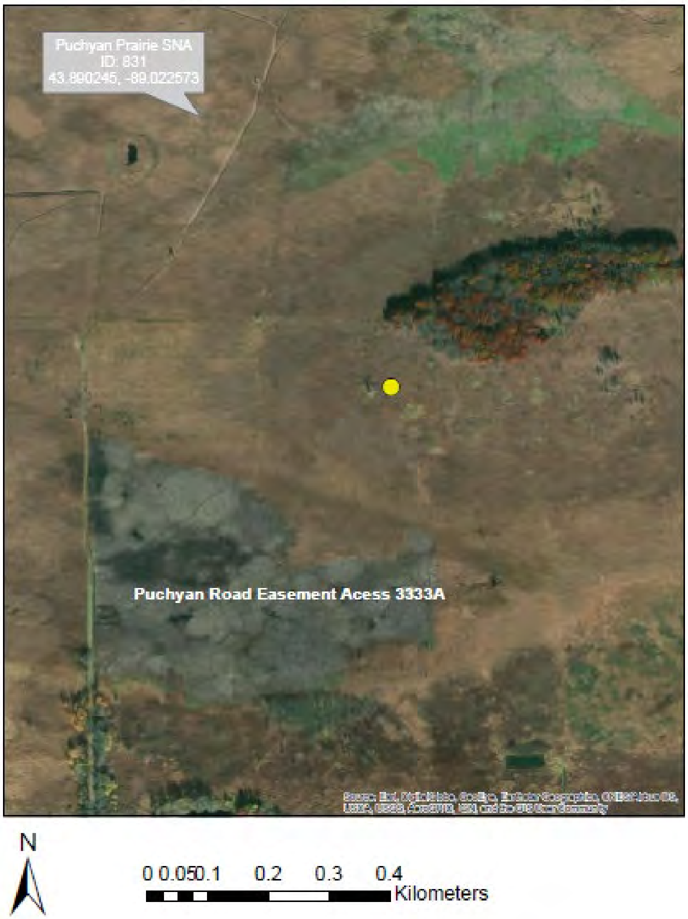
Project Name: Wetland Hydrology Monitoring FY18	**Location: Lower Mud Lake**
Date of Installation: 10/07/2019	**Personnel: W. Kolb, J. Homer**
Depth of Well: 16 inches	**Community Type: Southern Sedge Meadow**

Horizon Depth (cm)	**Texture**	**Matrix Color (Munsell moist)**	**Redoximorphic Features**		**Induration (none, weak, strong)**	**Roots**
			Color	**Abundance**		
43	MK	10YR2/1	N/A	N/A	none	25%VF
61+	MK	10YR2/1	N/A	N/A	none	17%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: Lulu Lake SNA
Date of Installation: 10/24/2019	Personnel: W. Kolb, M. Zoellner
Depth of Well: 25.5 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
9	MK	10YR2/1	N/A	N/A	none	60%VF
66+	MK	10YR2/1	N/A	N/A	none	0%

Project Name: Wetland Hydrology Monitoring FY18	**Location: Puchyan Prairie SNA**
Date of Installation: 10/23/2019	**Personnel: W. Kolb, M. Zoellner**
Depth of Well: 8 inches	**Community Type: Wet-Mesic Prairie**



Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
28	CL	10YR2/1	N/A	N/A	none	9%VF
40	C	2.5Y4/2	10YR5/3	20%	none	2%VF
67+	C	2.5Y6/1	7.5YR6/4	4%	none	1%VF

Project Name: Wetland Hydrology Monitoring FY18	**Location: Scuppernong Prairie SNA**
Date of Installation: 10/07/2019	**Personnel: W. Kolb, J. Homer**
Depth of Well: 13 inches	**Community Type: Wet-Mesic Prairie**

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
20.3	CL	2.5/N	N/A	N/A	none	20%VF
45.7+	SC	2.5Y5/3	10YR5/8	30%	none	0%

Project Name: Wetland Hydrology Monitoring FY18	Location: Swan Lake
Date of Installation: 10/23/2019	Personnel: W. Kolb, M. Zoellner
Depth of Well: 6 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
6	SL	10YR2/1	N/A	N/A	none	20%VF
18	SCL	10YR2/1	N/A	N/A	none	2%VF
31	SC	7.5YR3/1	N/A	N/A	none	1%F
50	SC	10YR4/2	7.5YR4/6	25%	none	1%F
70+	SC	10YR4/6	10YR4/2	5%	none	0%

Project Name: Wetland Hydrology Monitoring FY18	Location: Turtle Creek
Date of Installation: 10/03/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 10 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
39	MK	10YR2/1	N/A	N/A	none	40%VF
62	C	2.5/N	N/A	N/A	none	5%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: Weister Creek
Date of Installation: 10/10/2019	Personnel: W. Kolb, M. Smale
Depth of Well: 10 inches	Community Type: Southern Sedge Meadow

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
5	MK	7.5YR3/2	N/A	N/A	none	60%VF
10	MK	10YR2/1	N/A	N/A	none	40%VF
23	MK	2.5Y3/1	N/A	N/A	none	15%VF
38+	C	10YR2/1	N/A	N/A	none	1%VF

Project Name: Wetland Hydrology Monitoring FY18	**Location: White River Marsh SNA**
Date of Installation: 10/09/2019	**Personnel: W. Kolb, M. Zoellner**
Depth of Well: 26 inches	**Community Type: Southern Sedge Meadow**

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
16	Peat	10YR2/2	N/A	N/A	none	75%VF
52	MK	10YR2/1	N/A	N/A	none	12%VF
72	SiCL	2.5Y2.5/1	N/A	N/A	none	2%VF
87+	SCL	10YR3/1	N/A	N/A	none	2%VF

Project Name: Wetland Hydrology Monitoring FY18	Location: White River Prairie SNA
Date of Installation: 10/15/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 21 inches	Community Type: Wet-Mesic Prairie

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
21	L	10YR2/1	N/A	N/A	none	15%F
39	SL	7.5YR2.5/1	N/A	N/A	none	2%VF
64	S	5YR3/2	N/A	N/A	none	0%
87+	S	7.5YR5/6	N/A	N/A	none	0%

Project Name: Wetland Hydrology Monitoring FY18	Location: Young Prairie
Date of Installation: 10/17/2019	Personnel: W. Kolb, J. Homer
Depth of Well: 6.5 inches	Community Type: Wet-Mesic Prairie

Horizon Depth (cm)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		
19	SL	10YR2/1	N/A	N/A	none	35%VF
35	SCL	2.5Y3/1	N/A	N/A	none	3%VF
48+	C	2.5Y5/1	10YR6/4	25%	none	0%

Appendix C: Site Photos

Bear Creek SSM

Blue Mounds Creek Bottom WMP

Bluff Creek SSM

Dorne Creek SSM

Erickson SSM

Faville WMP

Kettle Moraine Low Prairie WMP

Loews Lake SSM

Lower Mud Lake SSM

Lulu Lake SSM

Young WMP

Puchyan Marsh WMP

Scuppernong Prairie WMP

Swan Lake SSM

Sylvan Road SSM

Turtle Creek SSM

Weister Creek SSM

White River SSM

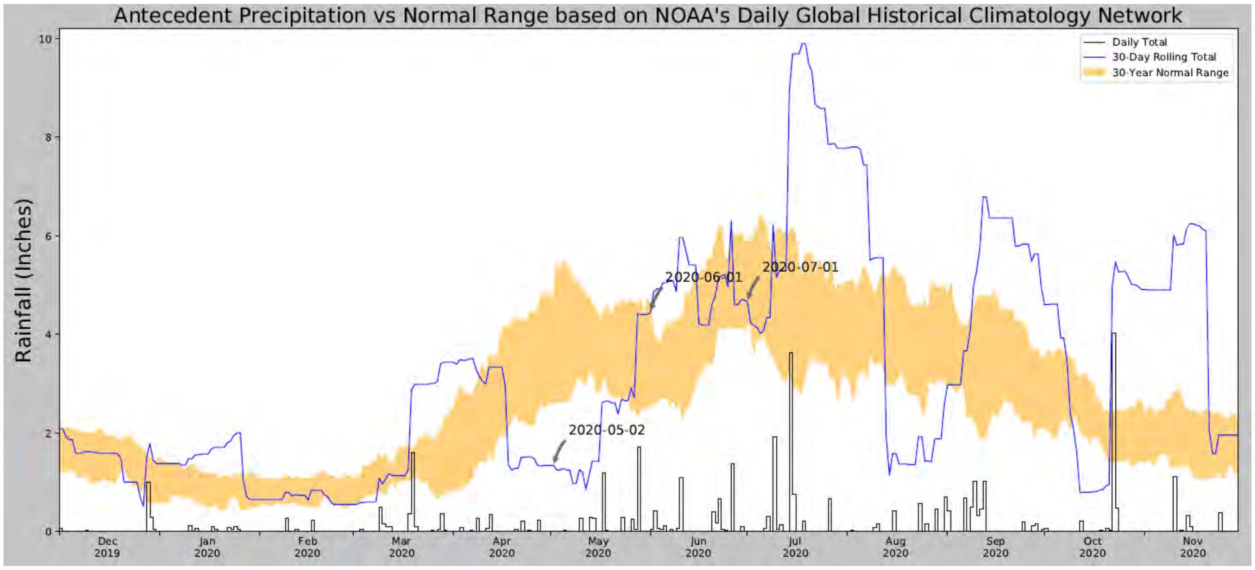
White River WMP

Appendix D: Summary Vegetation Data

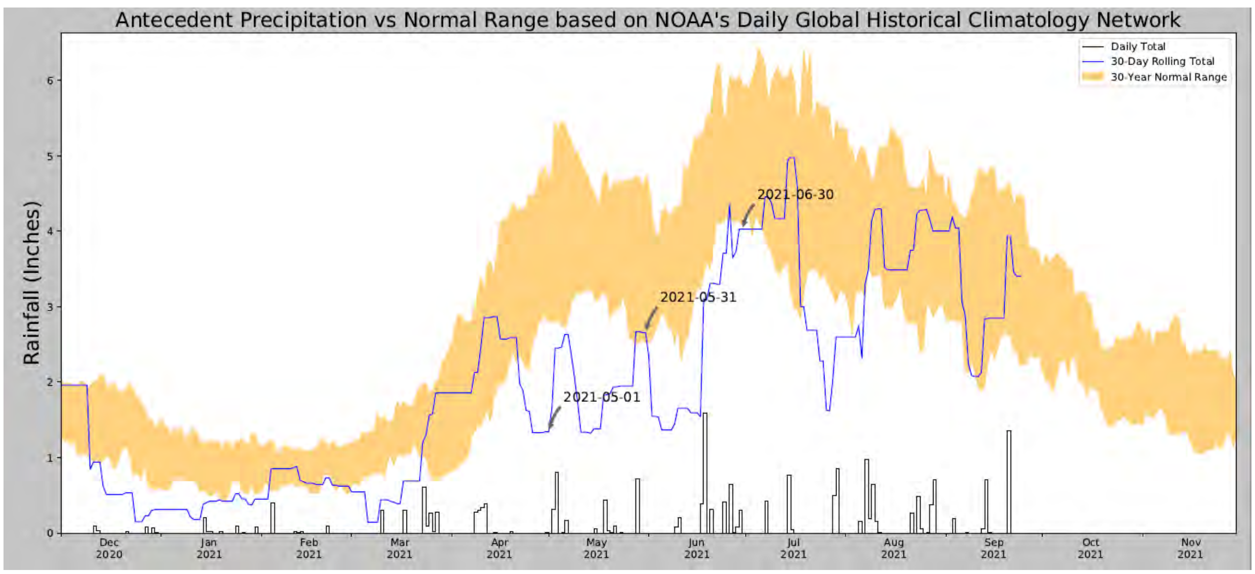
Summary of vegetation data from timed meander survey/floristic quality assessment data. Full FQA data not included here to protect confidential species information. Contact authors to inquire about access to raw data.

Site	Community Type	Sum of Absolute Cover	Absolute Cover Carices	Percent Cover Carices	Total Species Richness	Native Species Richness	Percent Native Species	Absolute Coverage of CARSTR and CARLAC	Absolute Coverage of ANDGER and SPOHET	Weighted Wetland Indicator Score
Erickson	SSM	117	64	54.70	33	33	100.00	45	0	-1.9145
White River Marsh	SSM	152	95	62.50	40	39	97.50	60	0	-1.9013
Weister Creek	SSM	218	71	32.57	50	49	98.00	4	0	-1.8532
Lulu Lake	SSM	149	89	59.73	54	52	96.30	85	0	-1.7919
Swan Lake	SSM	142	91	64.08	46	44	95.65	65	0	-1.7817
Bluff Creek	SSM	240	91	37.92	36	36	100.00	90	0	-1.7625
Dodge Branch	SSM	201	97	48.26	74	72	97.30	70	0	-1.7612
Lower Mud Lake	SSM	142	82	57.75	43	40	93.02	77	0	-1.7606
Dorne Creek	SSM	157	68	43.31	47	45	95.74	66	0	-1.7134
Loews Lake	SSM	185	81	43.78	69	66	95.65	70	0	-1.6378
Bear Creek Meadow	SSM	158	72	45.57	59	59	100.00	70	0	-1.4177
Turtle Creek	SSM	182	86	47.25	71	64	90.14	15	0	-1.2308
Puchyan Prairie	WMP	194	89	45.88	97	87	89.69	50	8	-0.8763
White River Prairie	WMP	191	66	34.55	86	84	97.67	30	3	-0.5916
Blue Mounds	WMP	238	3	1.26	72	65	90.28	0	45	-0.0084
Faville Prairie	WMP	173	10	5.78	114	108	94.74	3	36	0.0520
Kettle Moraine	WMP	265	8	3.02	100	93	93.00	5	55	0.0566
Young Prairie	WMP	180	10	5.56	115	106	92.17	5	45	0.1167
Scuppernong	WMP	265	20	7.55	97	89	91.75	20	90	0.1849

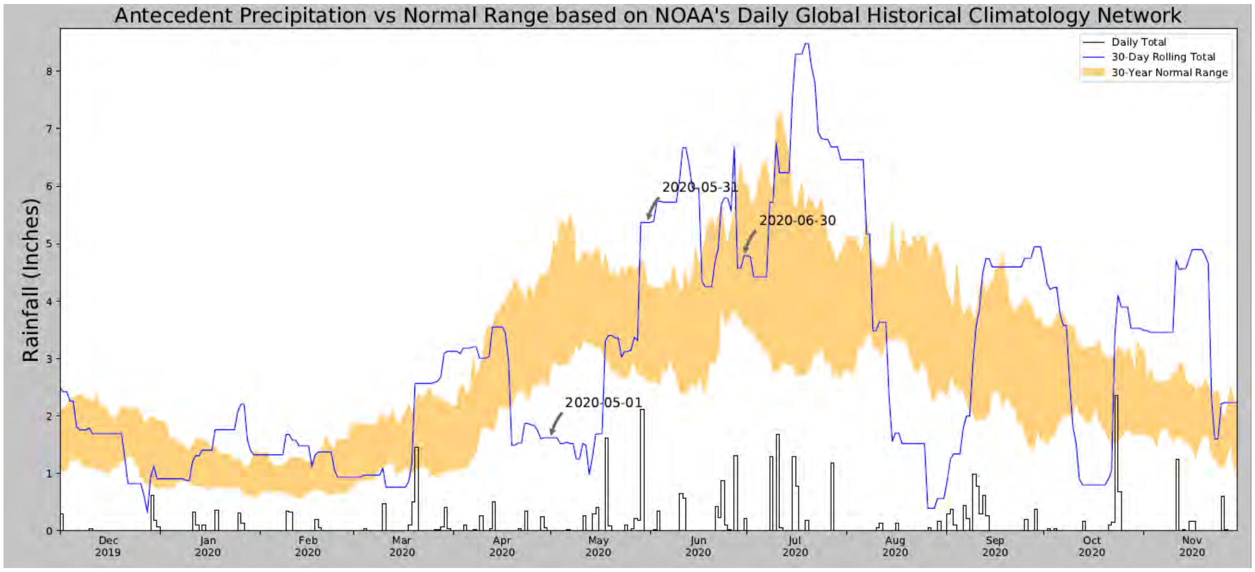
Appendix E: Antecedent Precipitation Data



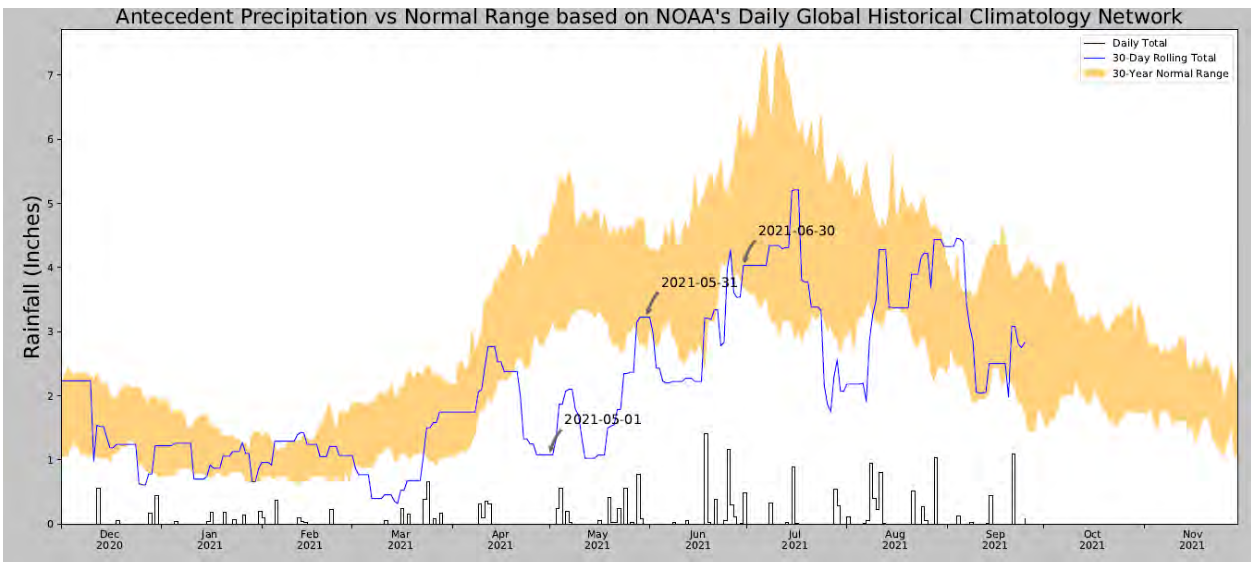
1a. Bear Creek 2020: Site was normal to wetter than normal, experiencing extreme wetness.



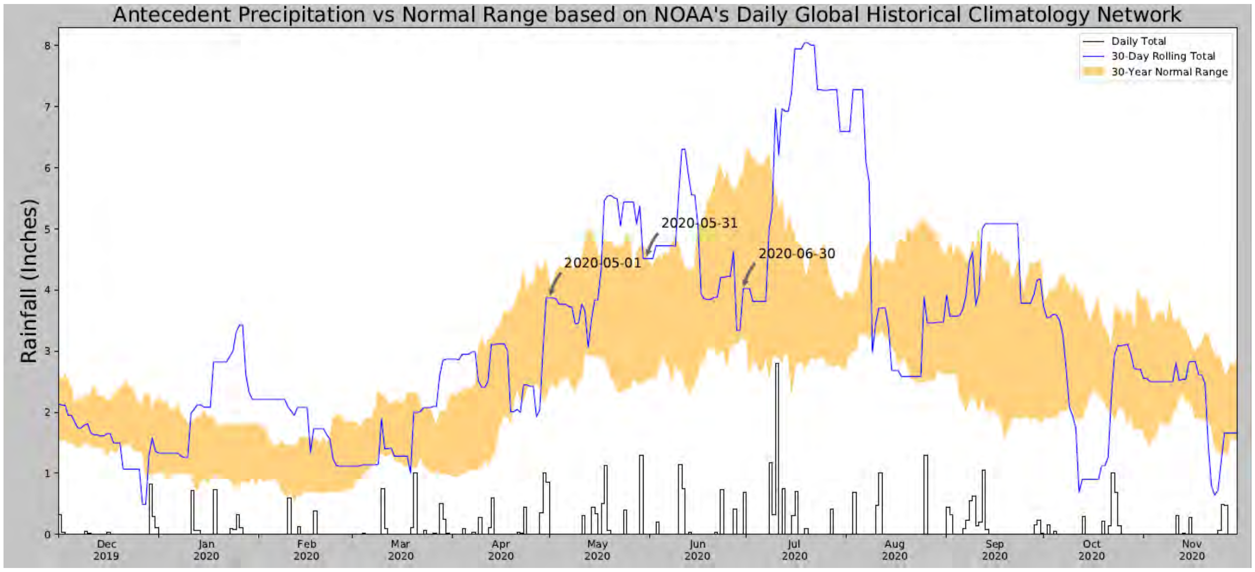
1b. Bear Creek 2021: Site was dry for most of growing season trending towards normal at end of season.



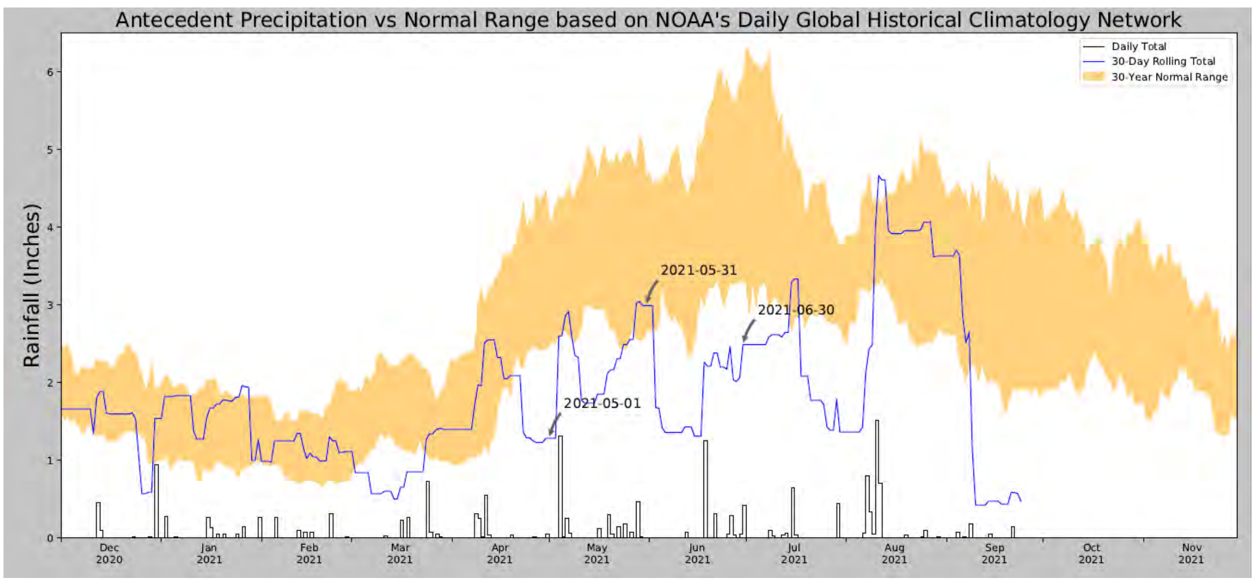
2a. Blue Mounds 2020: Site was normal to wetter than normal, experiencing extreme wetness.



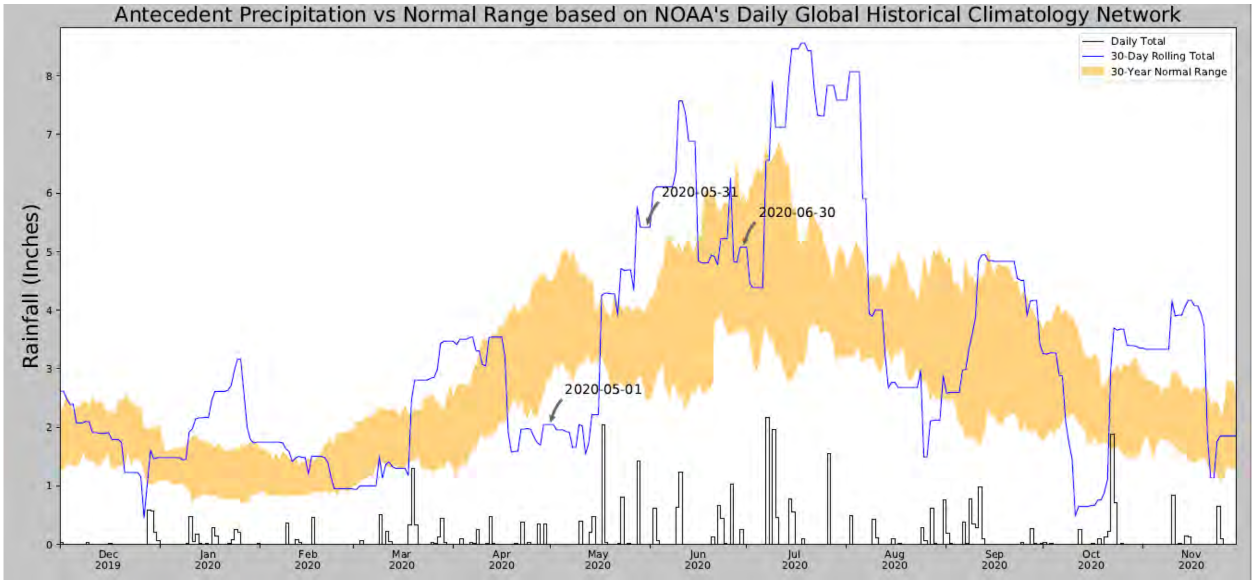
2b. Blue Mounds 2021: Site was drier than normal to normal, experiencing mild to incipient drought.



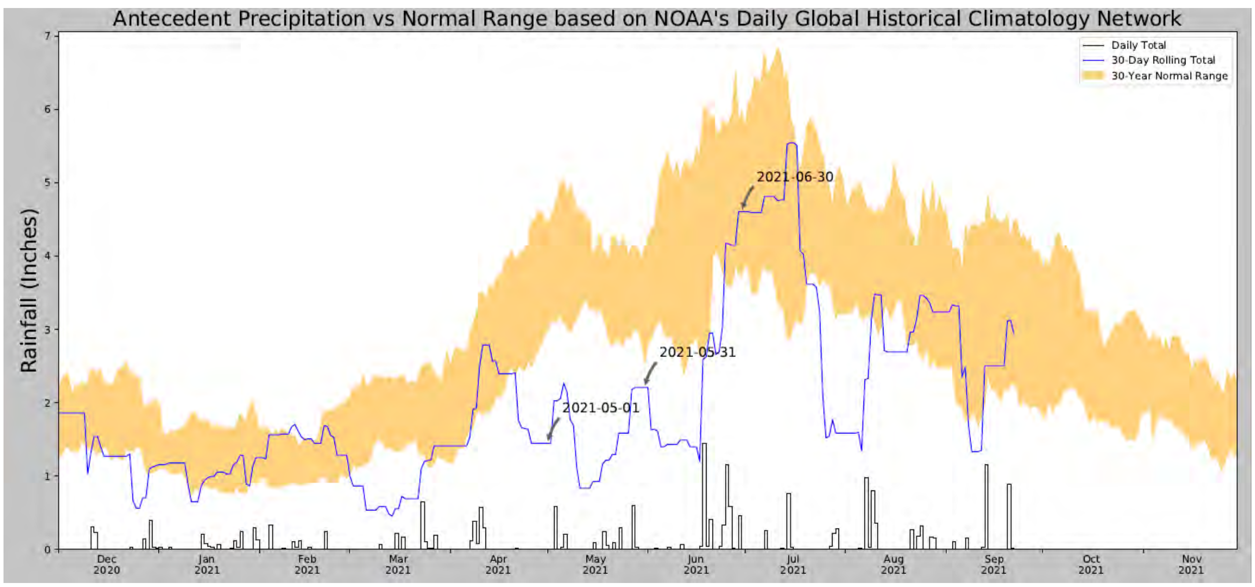
3a. Bluff Creek 2020: Site was normal to wetter than normal, experiencing extreme wetness.



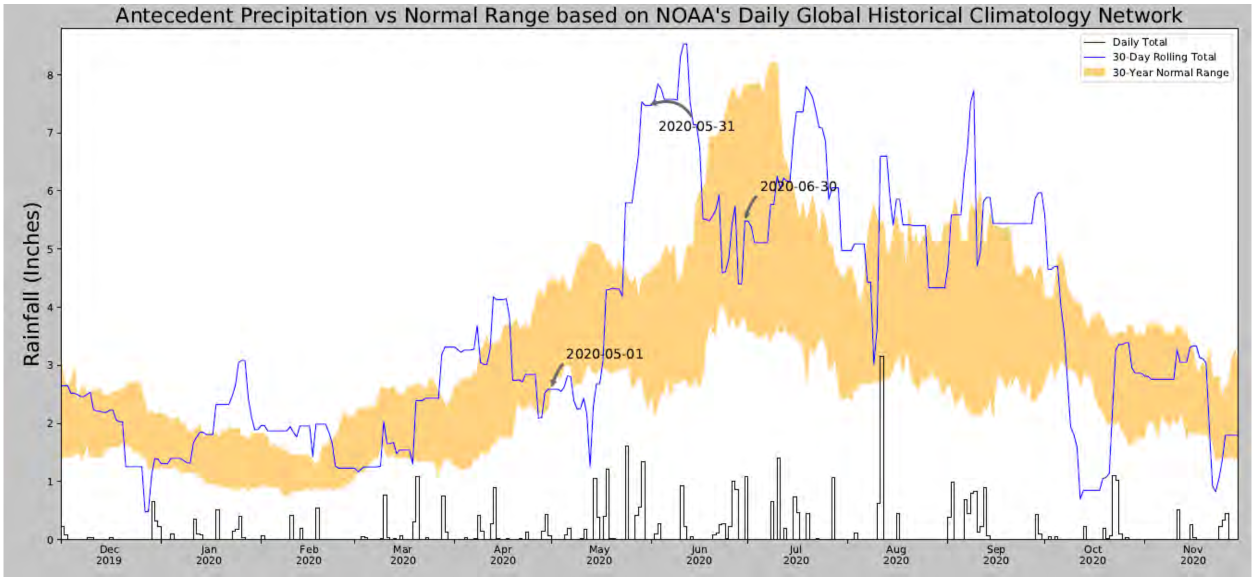
3b. Bluff Creek 2021: Site was dry for growing season, experiencing mild to moderate drought.



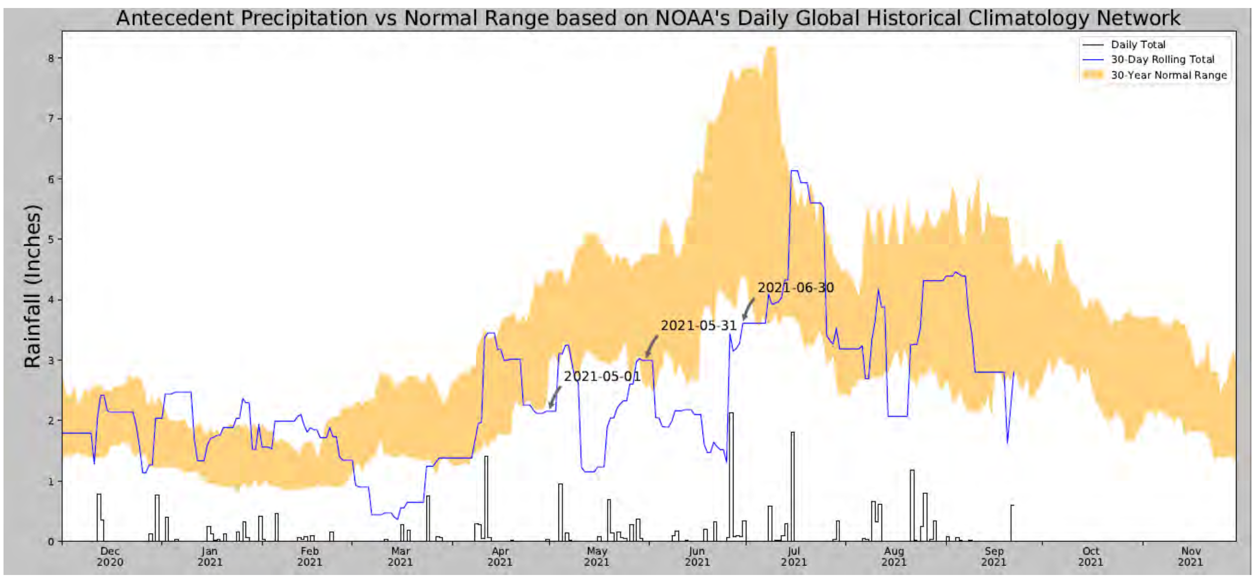
4a. Dorne Creek 2020: Site was normal to wetter than normal, experiencing extreme wetness.



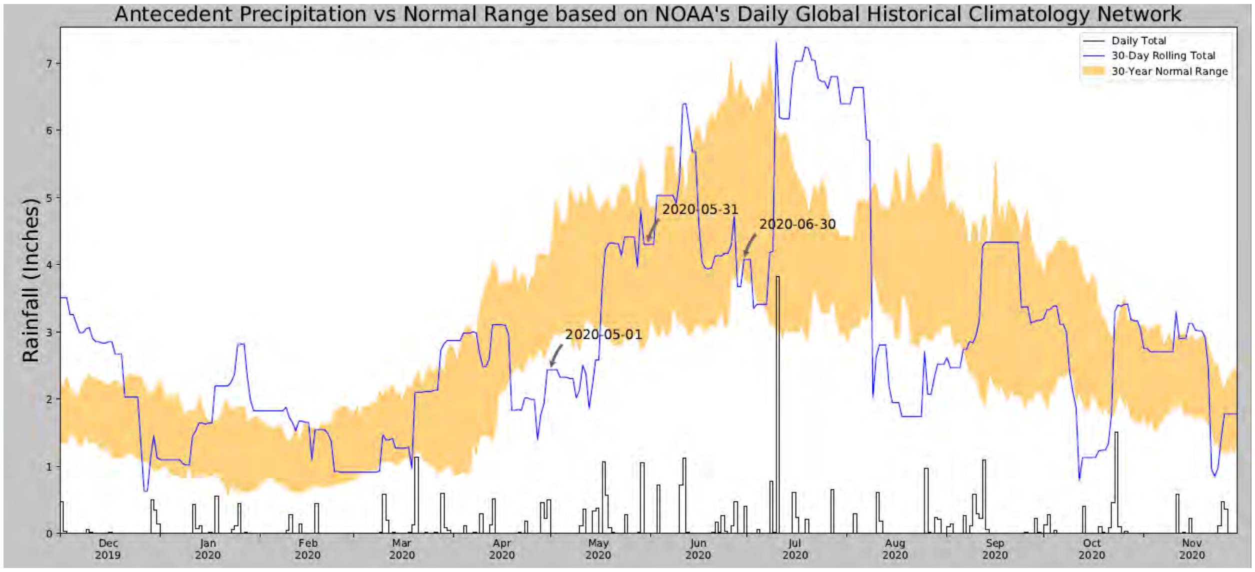
4b. Dorne Creek 2021: Site was dry at the start of the growing season trending towards normal.



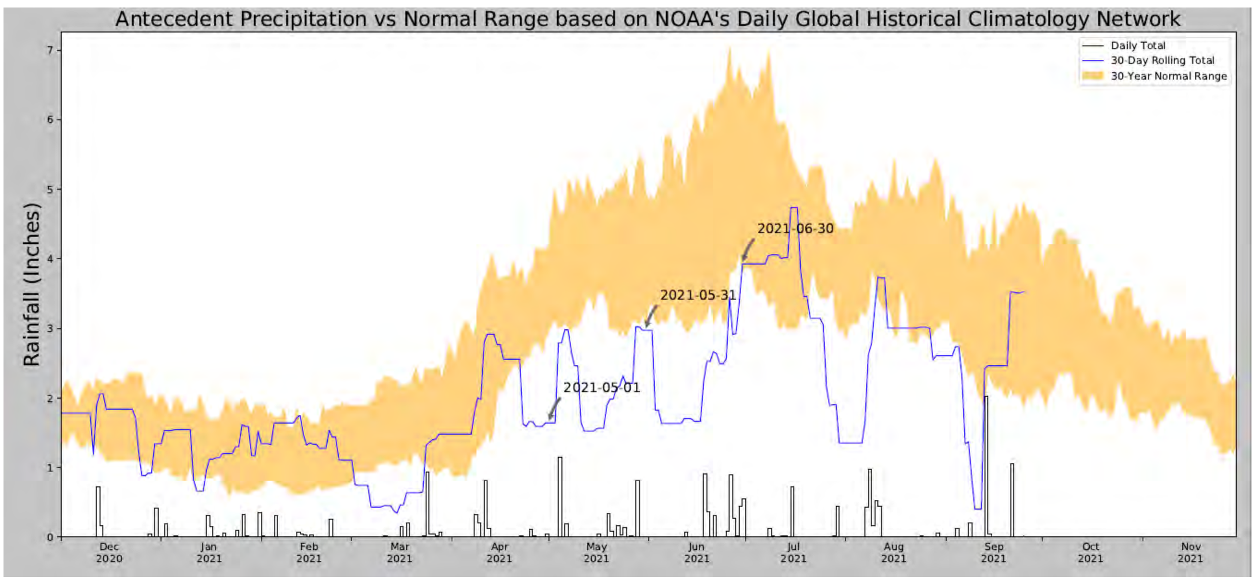
5a. Erickson 2020: Site was normal to wetter than normal, experiencing extreme wetness.



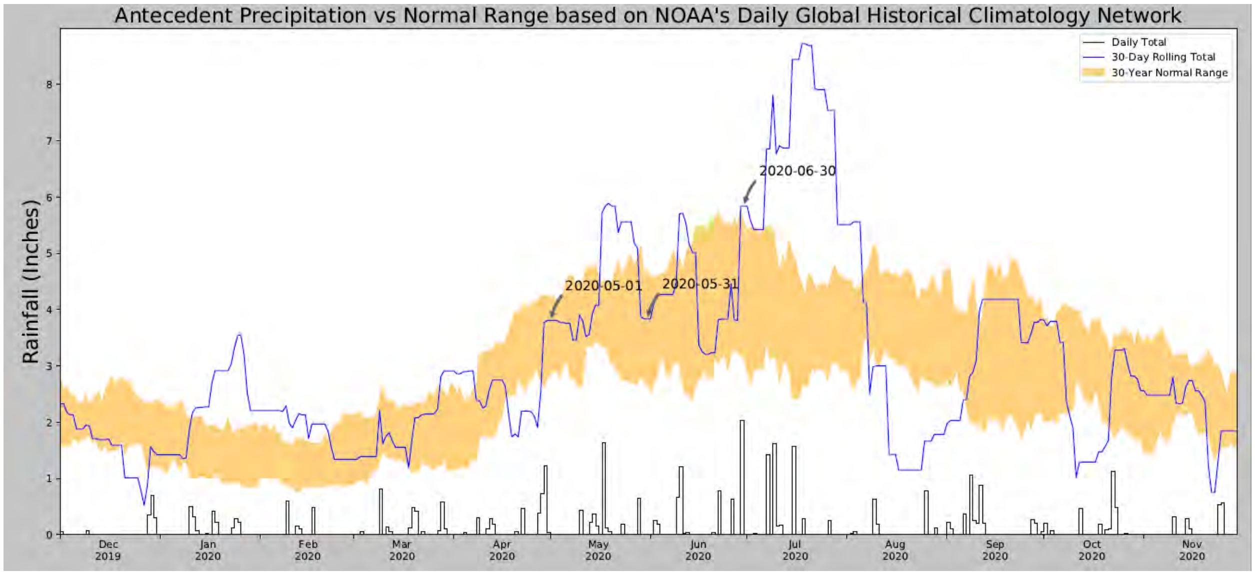
5b. Erickson 2021: Site was dry for most of growing season trending towards normal at end of season.



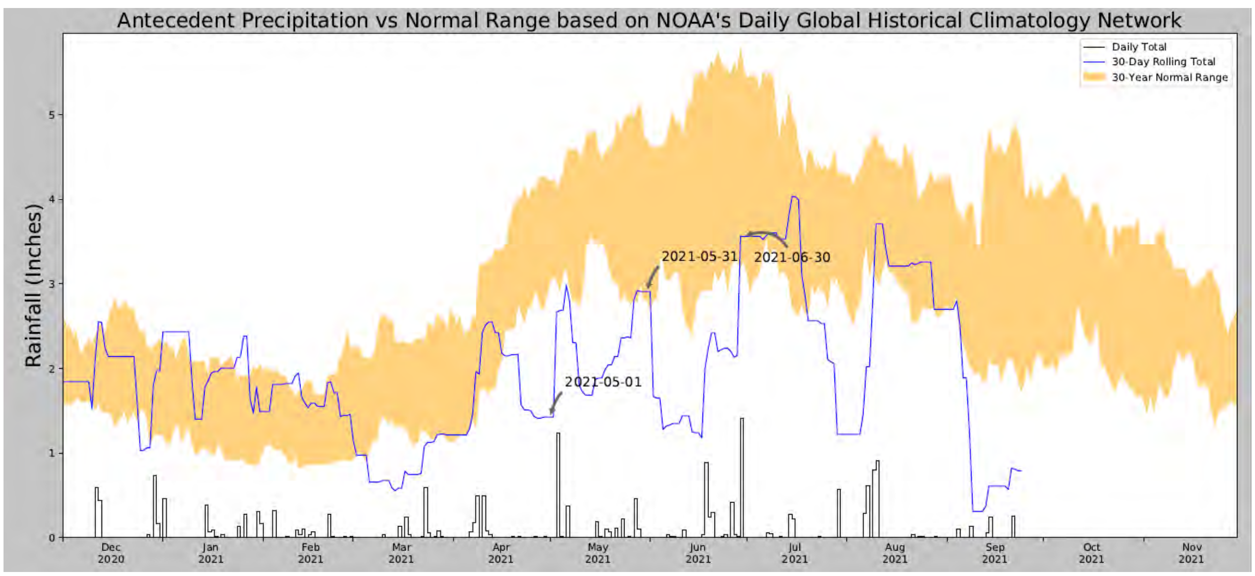
6a. Faville 2020: Site had normal levels of precipitation.



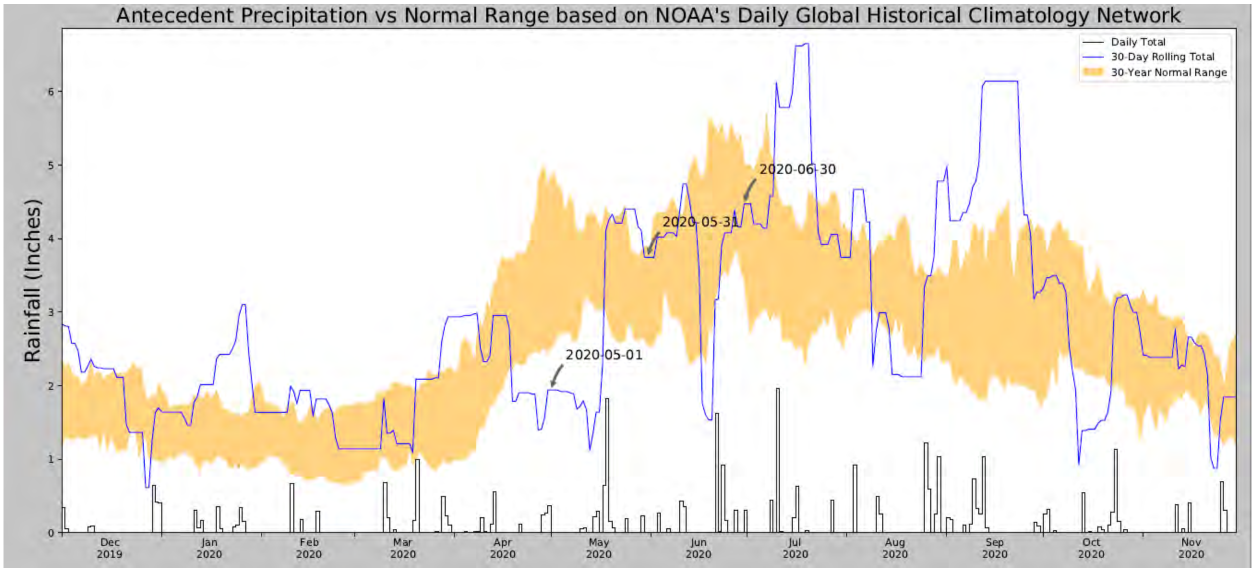
6b. Faville 2021: Site was dry for most of growing season, experiencing a mild drought.



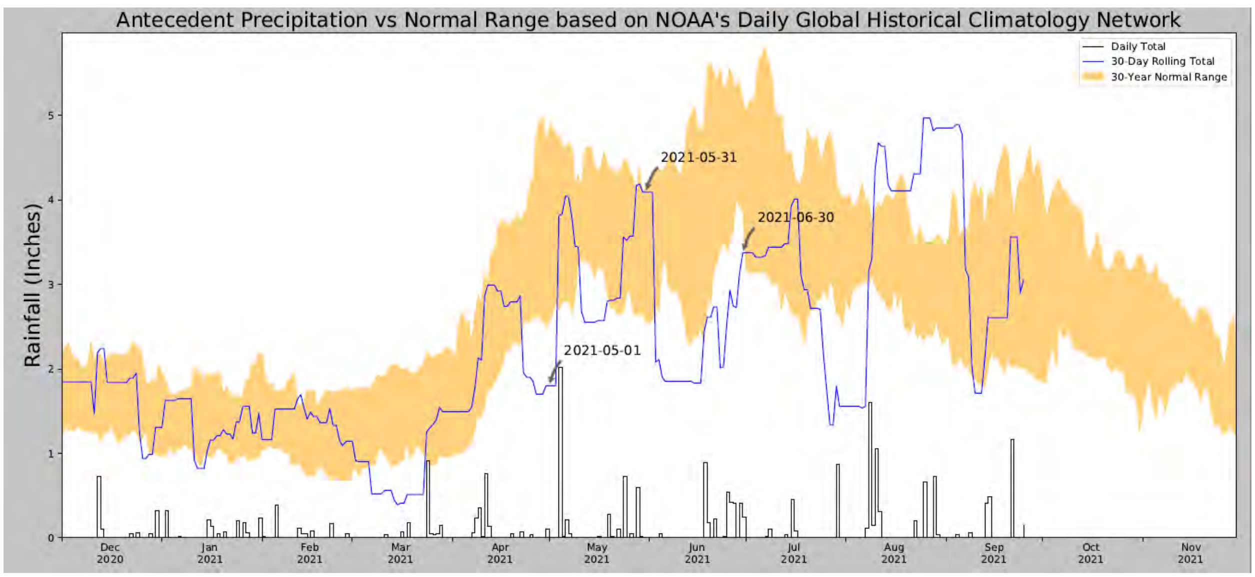
7a. Kettle Moraine 2020: Site was wetter than normal to normal conditions, experiencing extreme wetness.



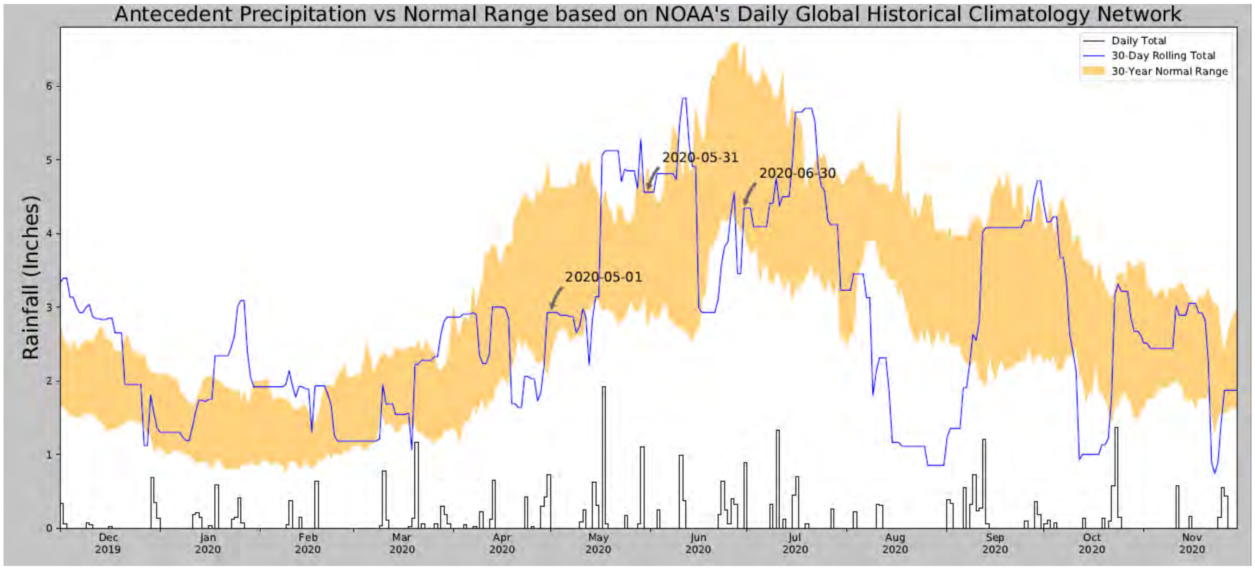
7b. Kettle Moraine Low Prairie 2021: Dry season, experiencing mild to moderate drought.



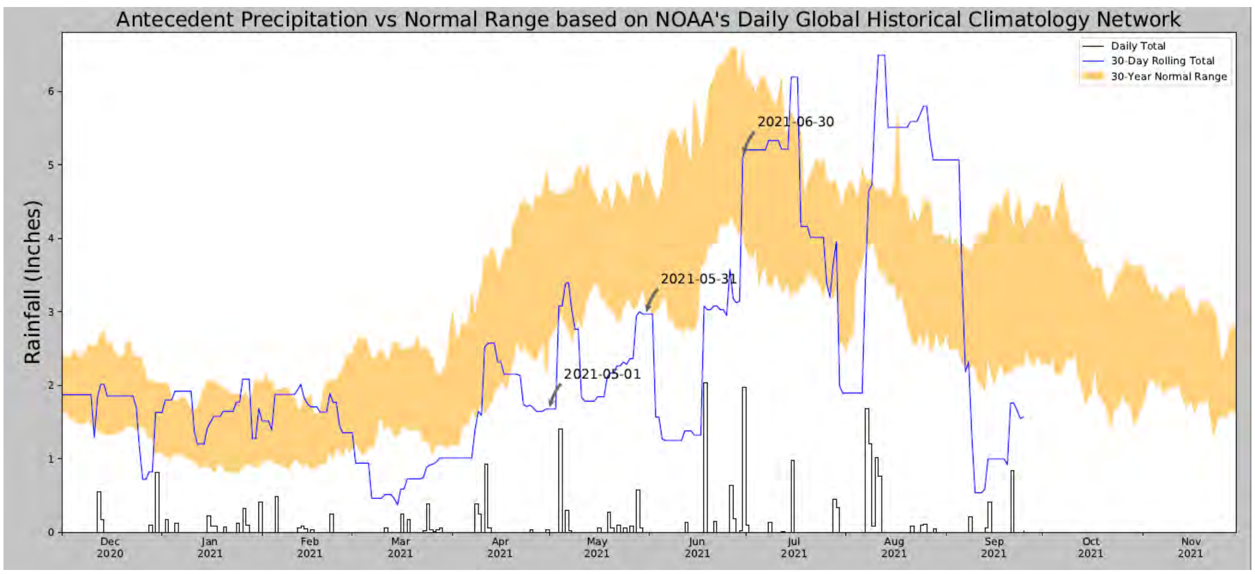
8a. Loews 2020: Site was normal to wetter than normal, experiencing extreme to severe wetness.



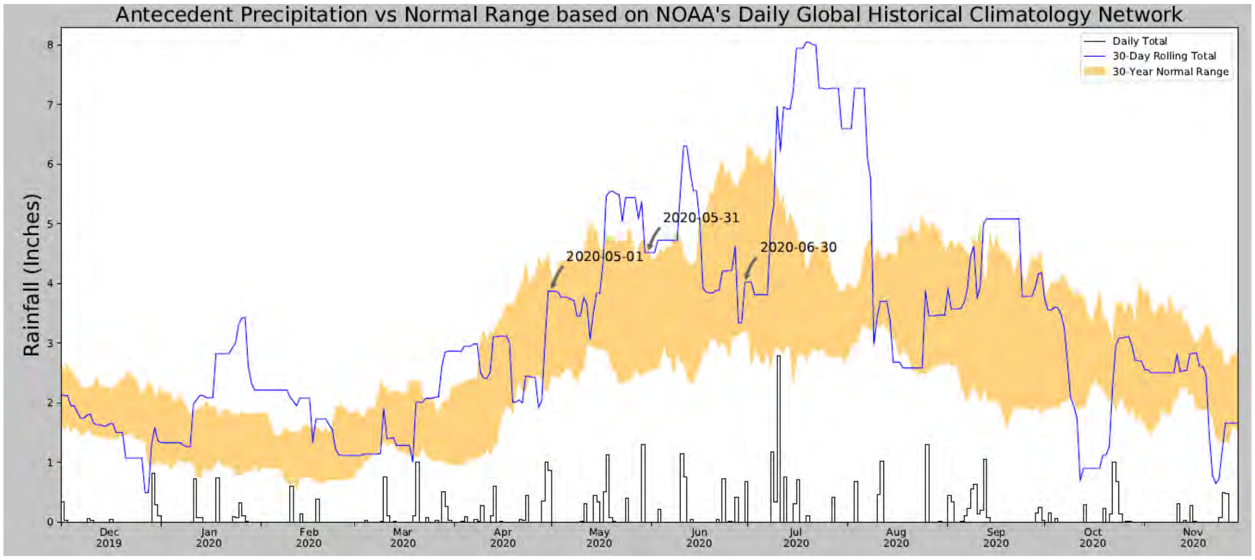
8b. Loews 2021: Site fluctuating between dry and normal conditions. Site was experiencing mild to moderate drought.



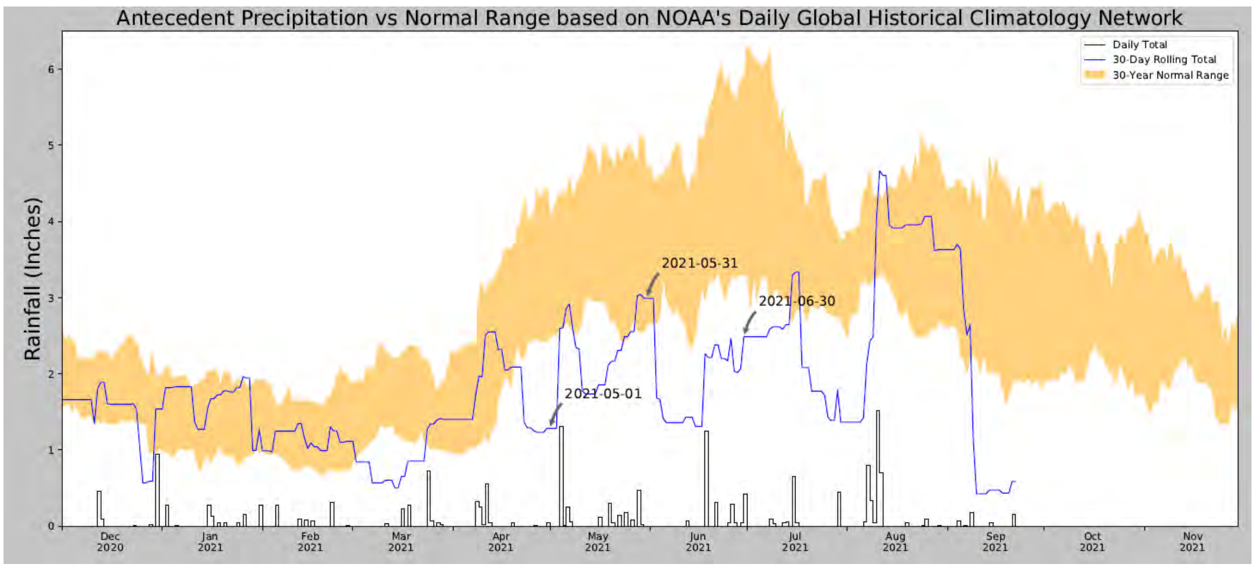
9a. Lower Mud Lake 2020: Site had mostly normal precipitation levels, experiencing extreme wetness.



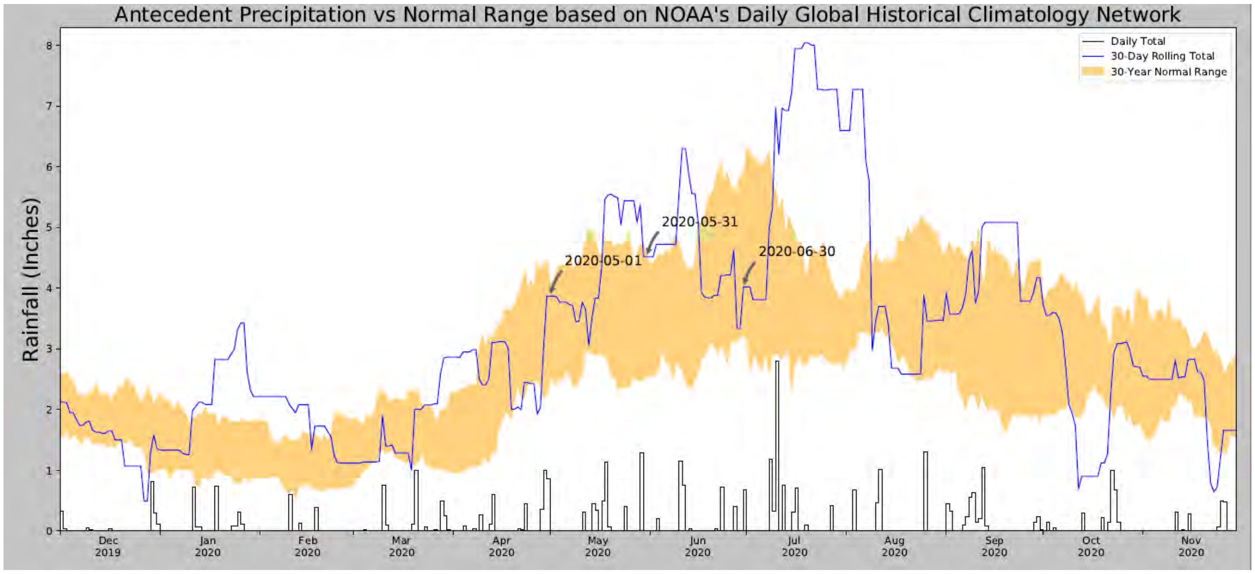
9b. Lower Mud Lake 2021: Site was predominantly dry with a few large rain events resulting in normal and wetter than normal conditions in August.



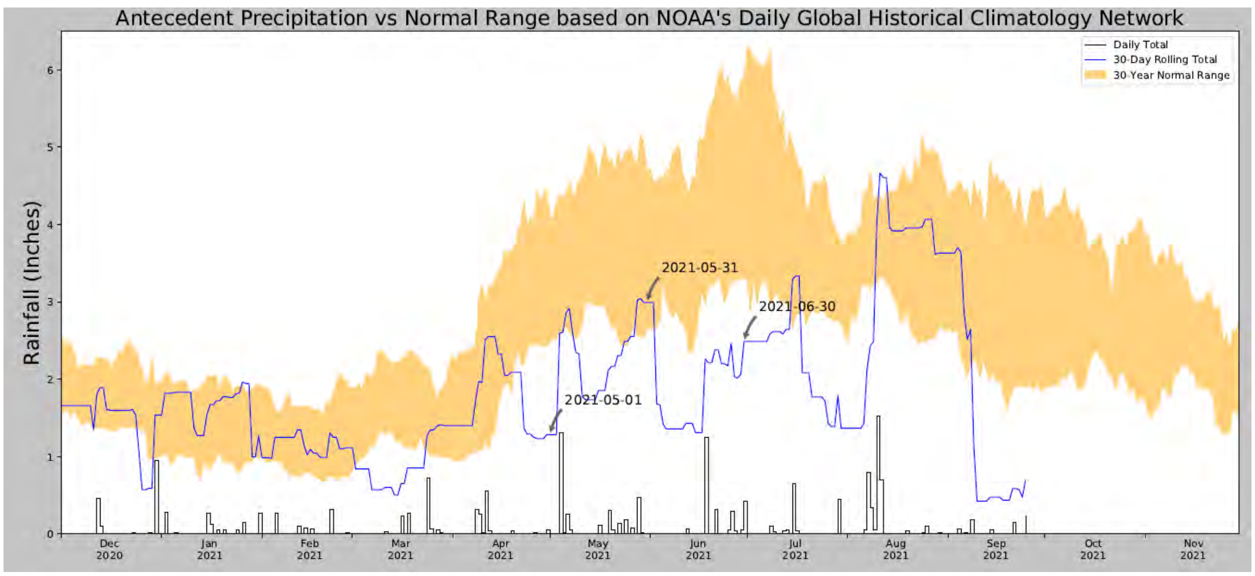
10a. Lulu Lake 2020: Site was normal to wetter than normal, experiencing extreme wetness.



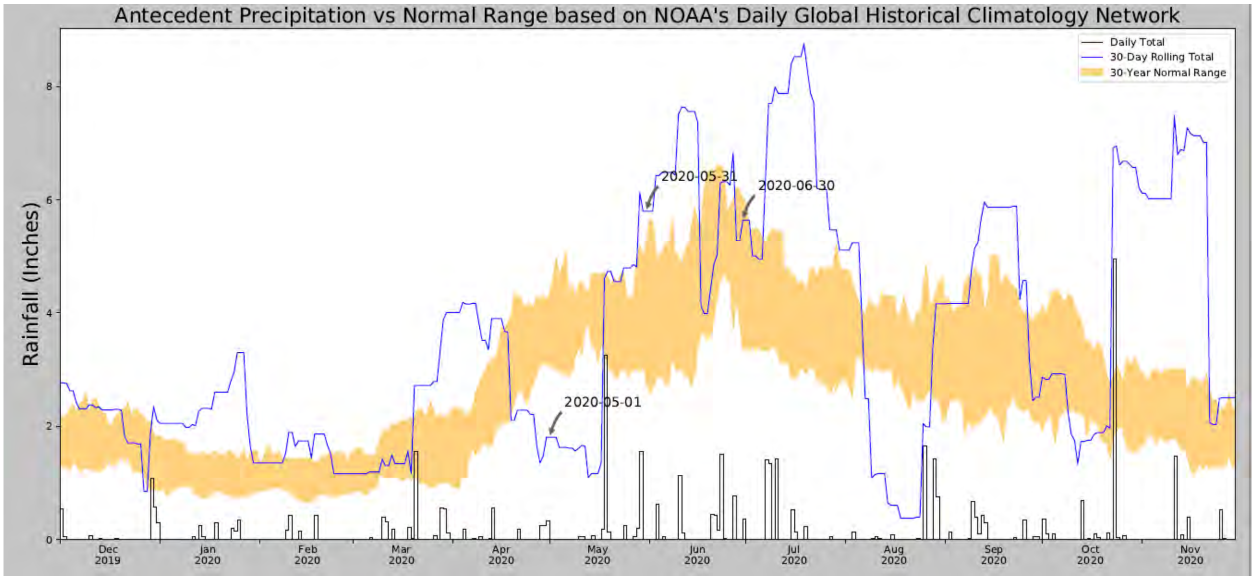
10b. Lulu Lake 2021: Site was dry, experiencing mild to moderate drought.



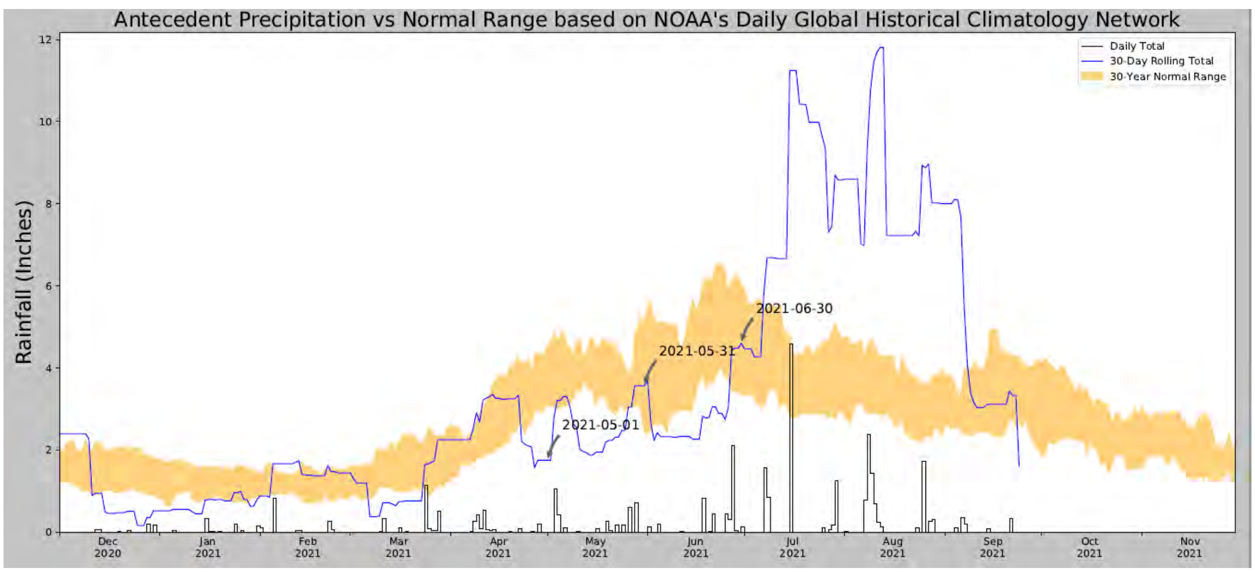
11a. Young Prairie 2020: Site was normal to wetter than normal, experiencing extreme wetness.



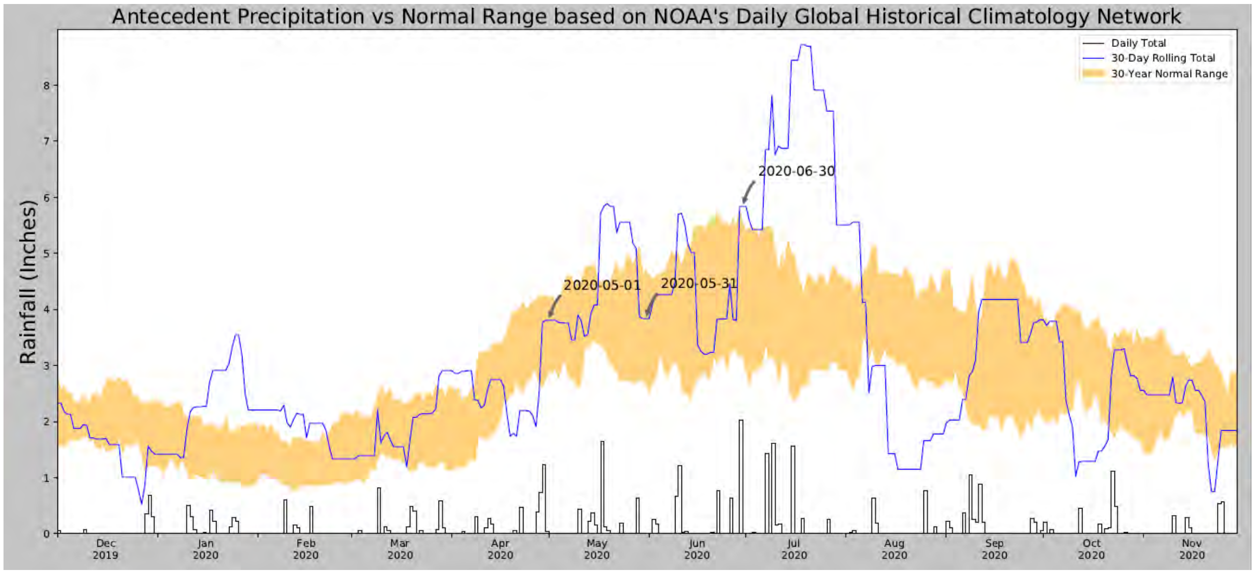
11b. Young Prairie 2021: Site was dry, experiencing mild to moderate drought.



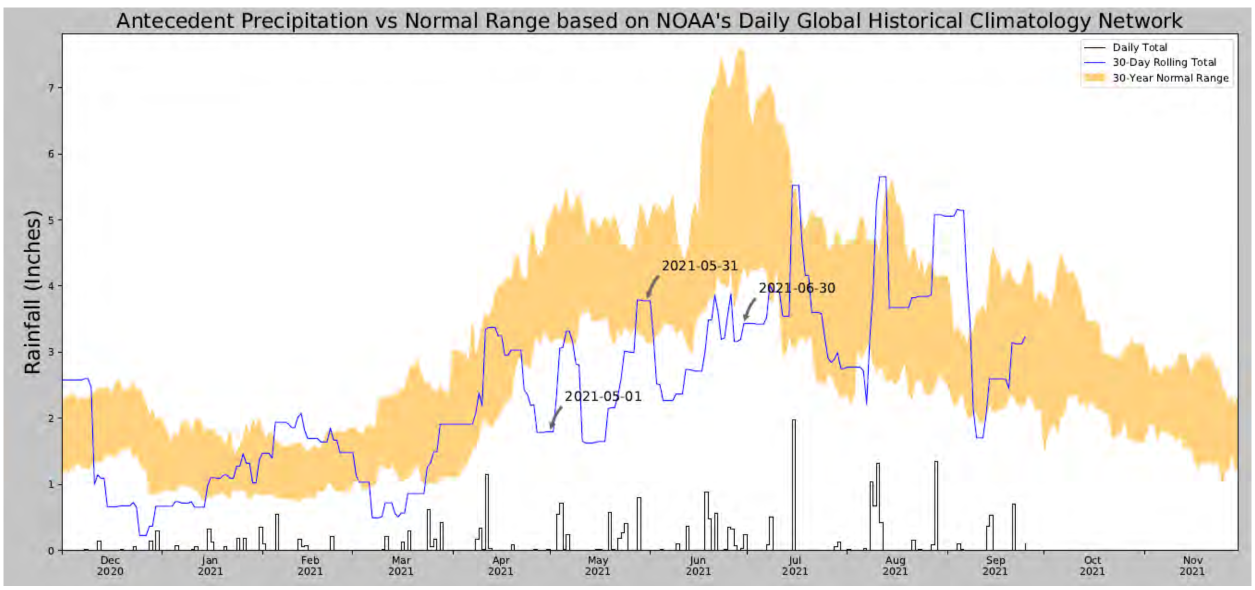
12a. Puchyan 2020: Site was normal to wetter than normal, experiencing extreme to severe wetness.



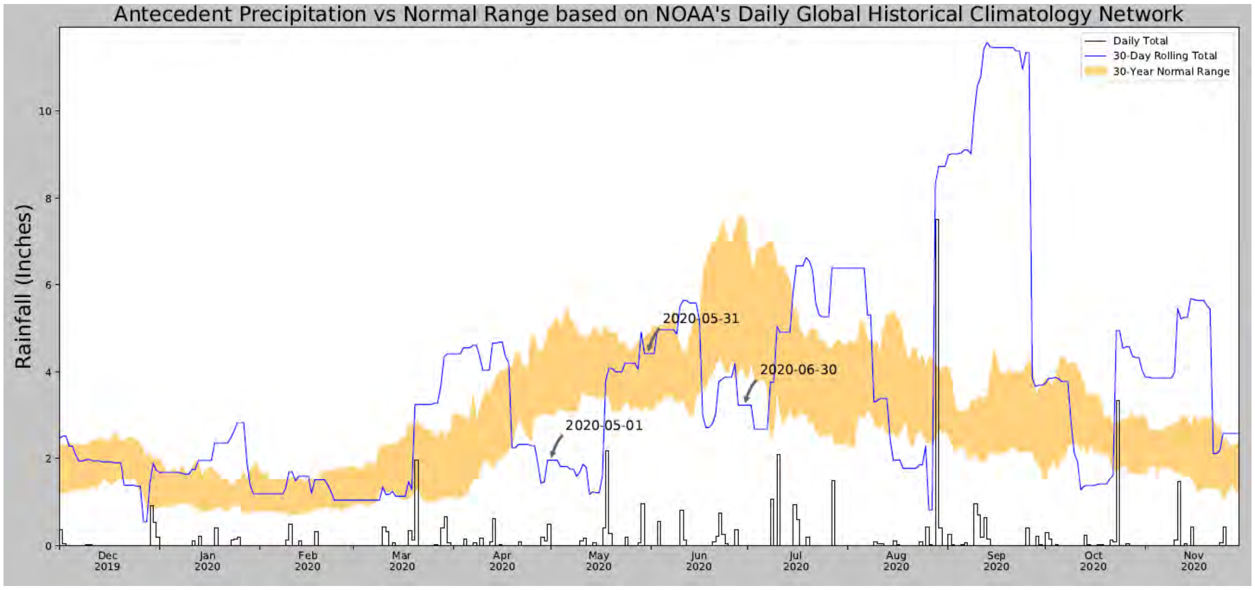
12b. Puchyan 2021: Site was drier than normal to normal at start of growing season. In July and August the site experienced extreme wetness.



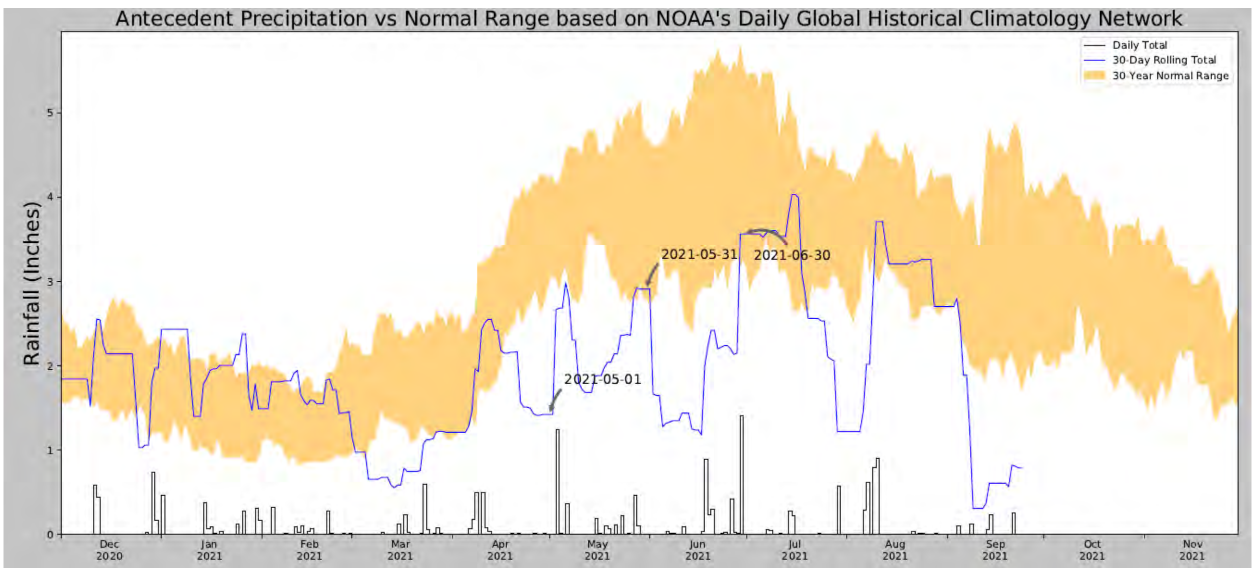
13a. Scuppernong 2020: Site was normal to wetter than normal, experiencing extreme wetness.



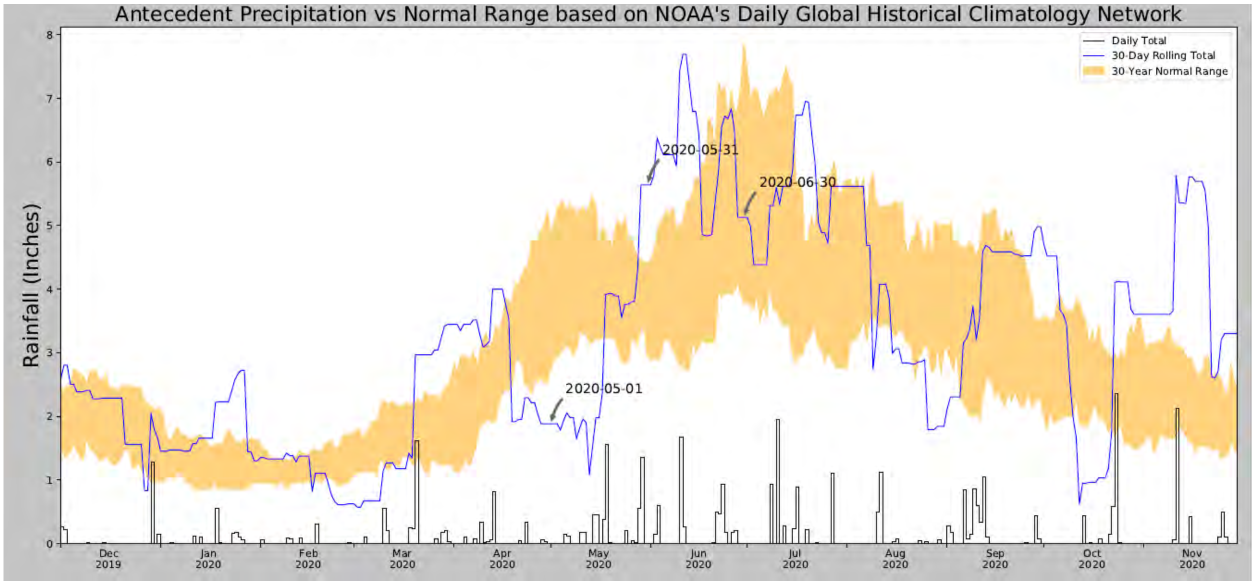
13b. Scuppernong 2021: Site was dry to normal, experiencing mild to moderate drought.



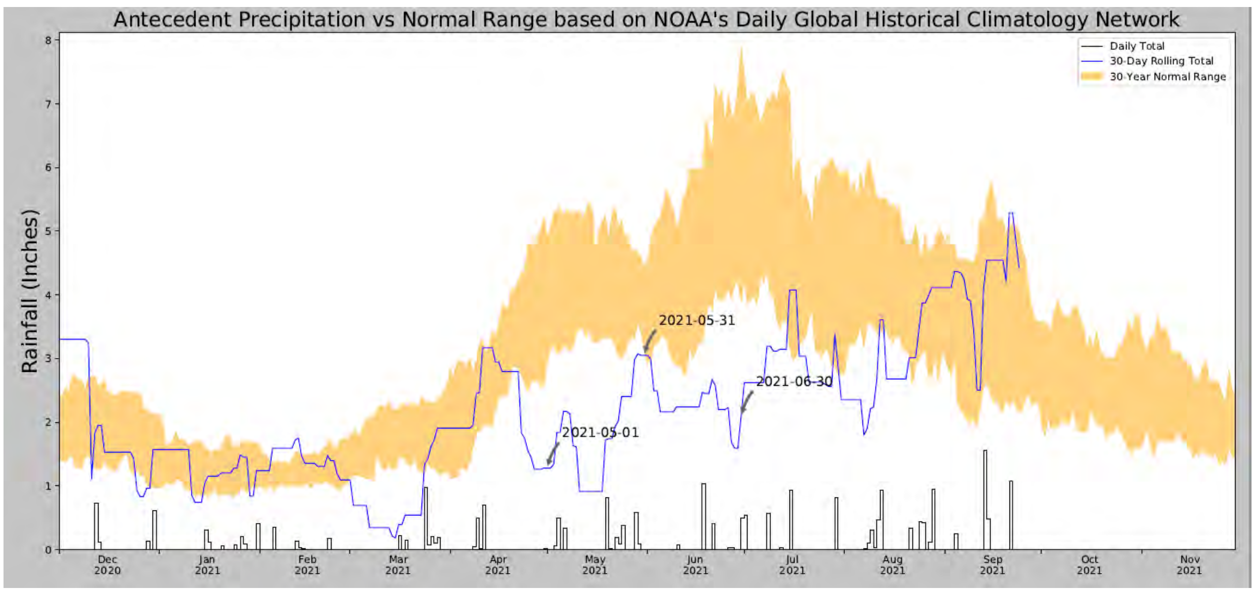
14a. Swan Lake 2020: Site had normal to wetter than normal precipitation with a drier than normal event in April. Overall site experienced extreme wetness.



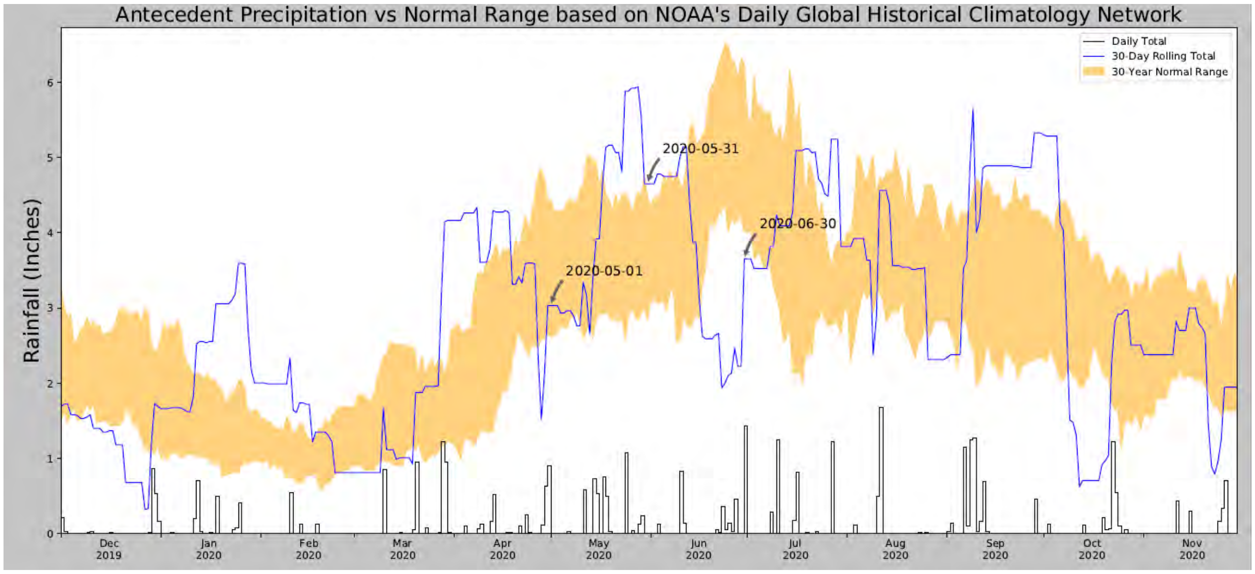
14b. Swan Lake 2021: Drier than normal to normal conditions, experiencing mild drought.



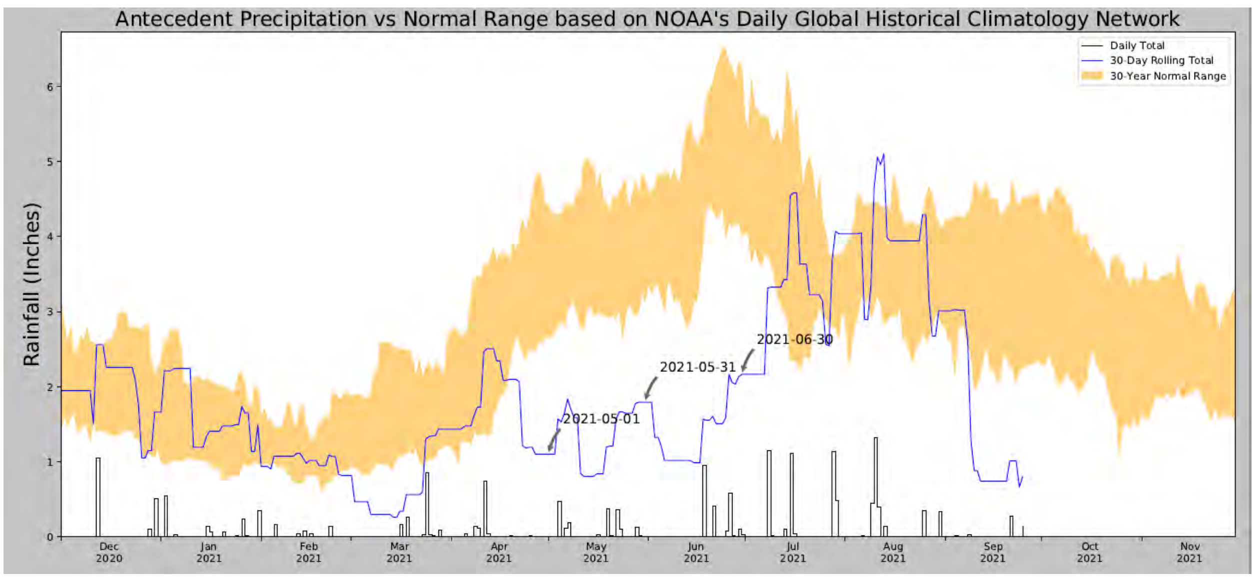
15a. Sylvan Road 2020: Site had normal precipitation, occasionally wetter than and drier than normal.



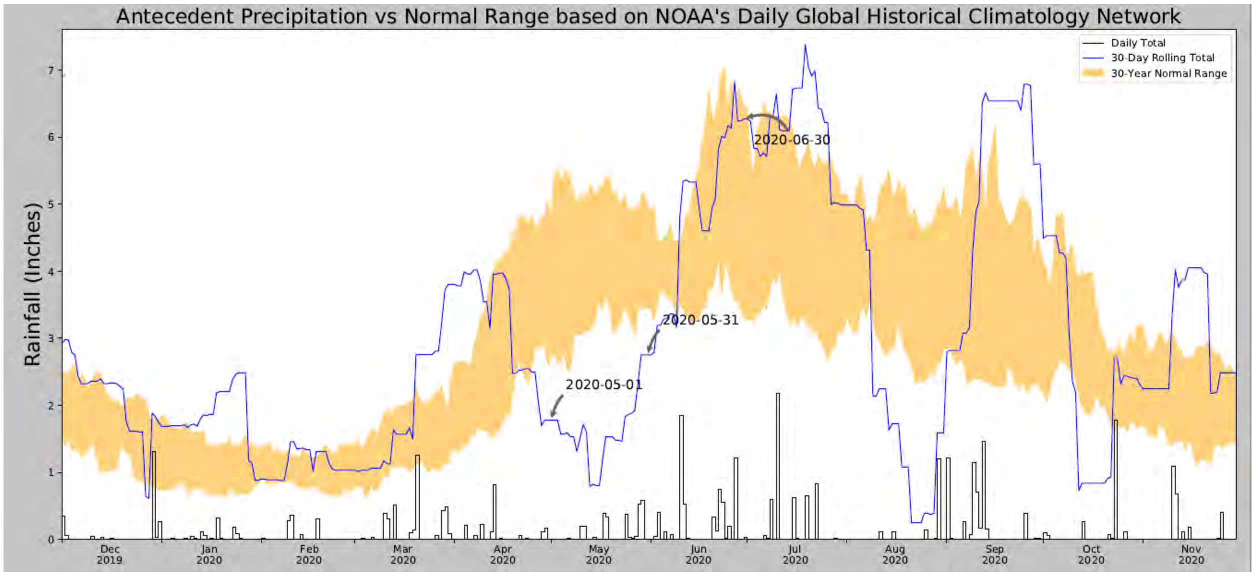
15b. Sylvan Road 2021: Site was drier trending towards normal towards end of growing season. Site was undergoing a mild drought.



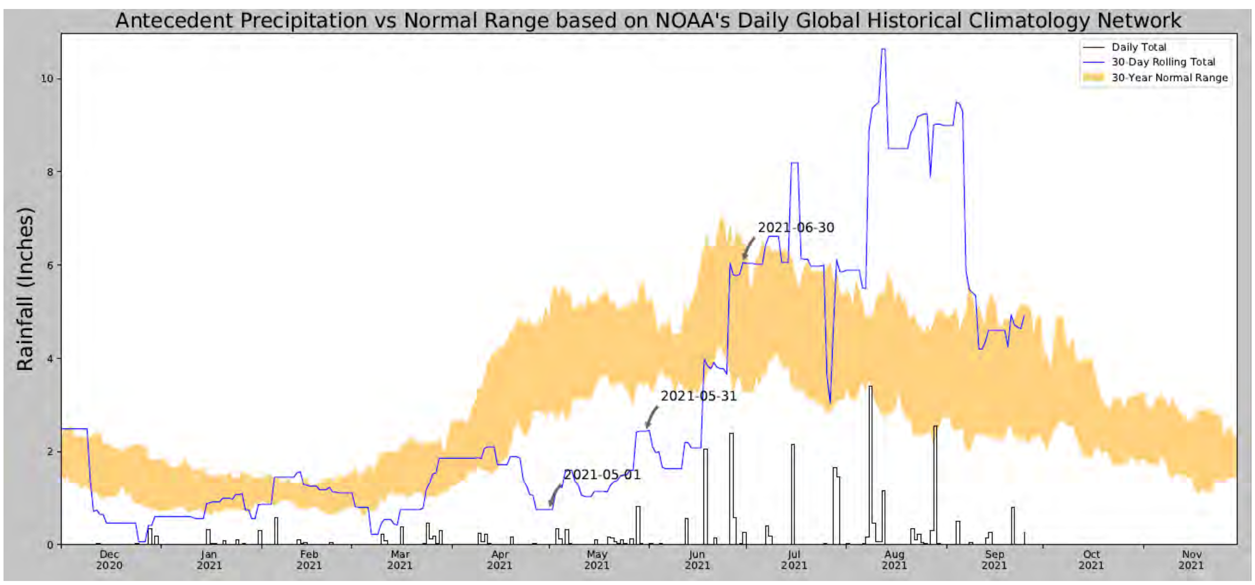
16a. Turtle 2020: Site had normal levels of precipitation, experiencing extreme wetness.



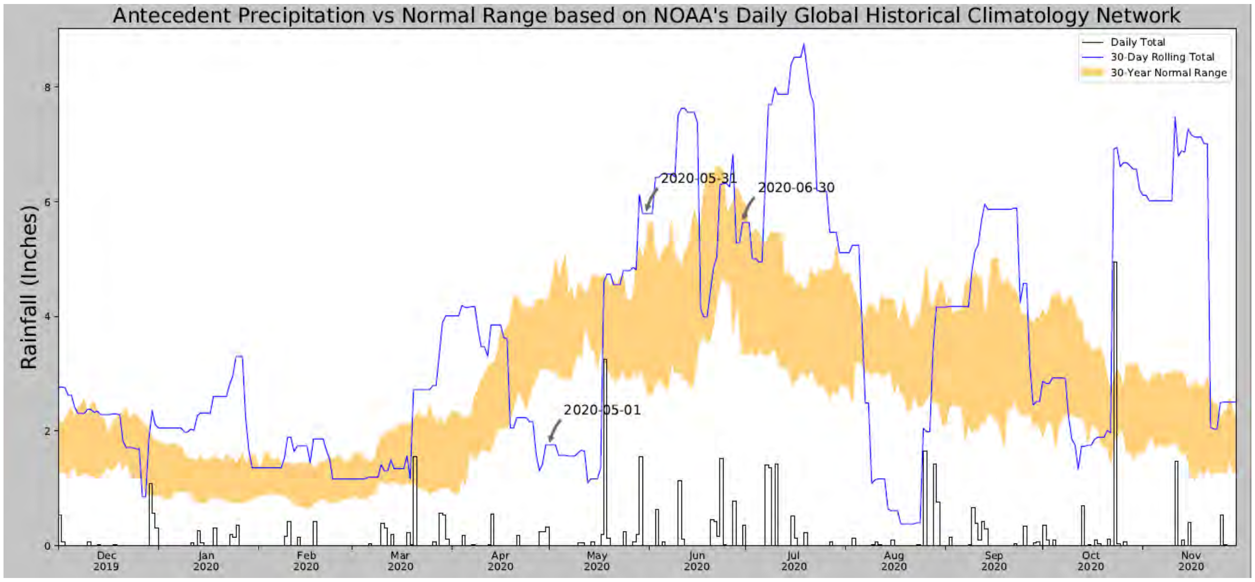
16b. Turtle Creek 2021: Site was drier than normal, experiencing mild drought.



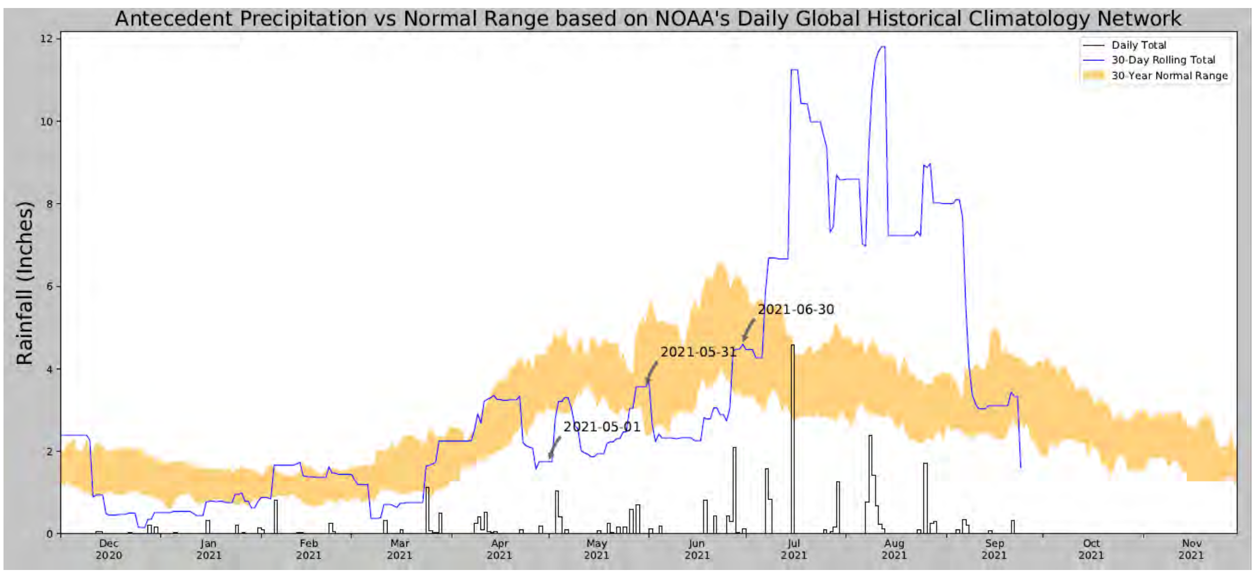
17a. Weister 2020: Site was predominantly normal, occasionally wetter or drier than normal. Site was experiencing extreme wetness.



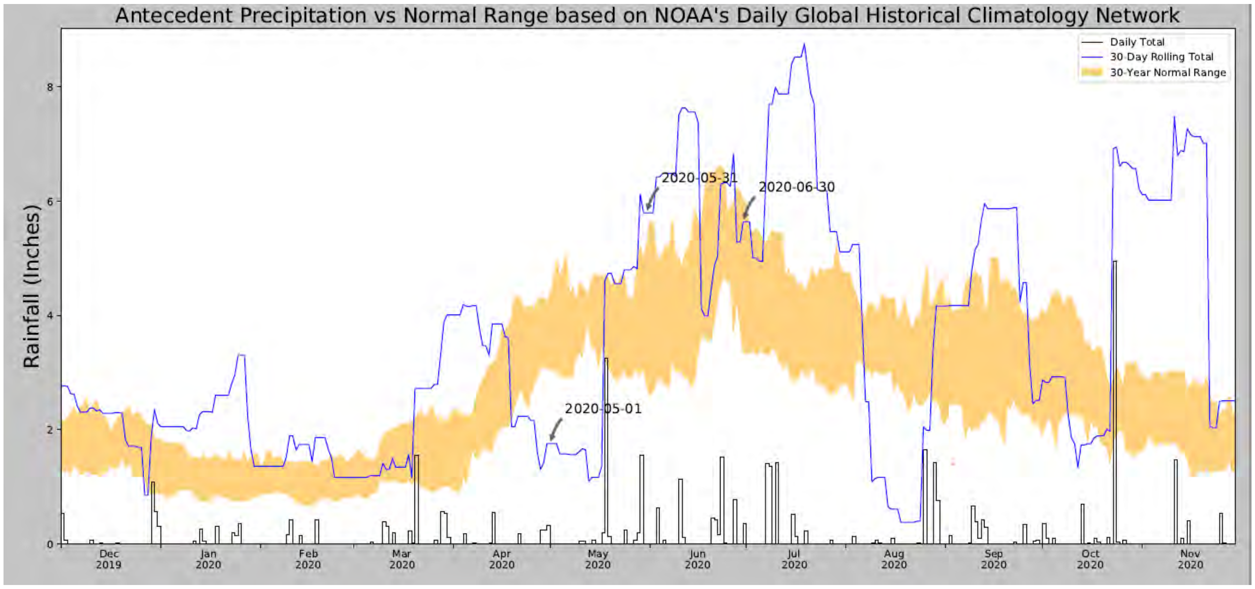
17b. Weister Creek 2021: Dry season trending towards wet season mid-July.



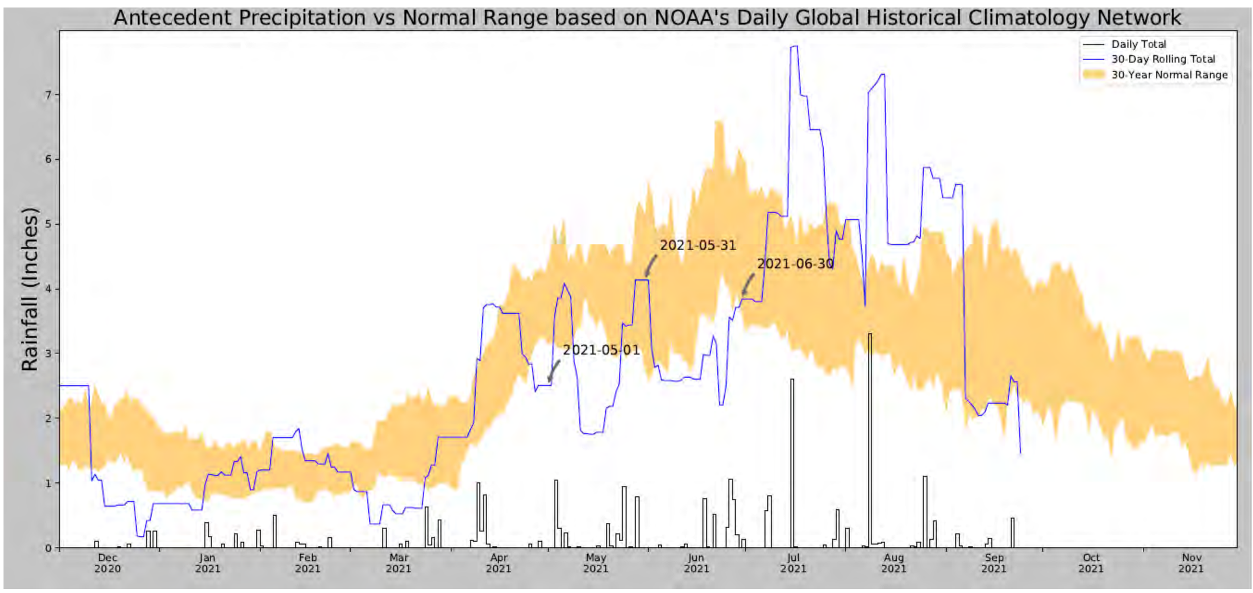
18a. White SSM 2020: Site was normal to wetter than normal, experiencing extreme wetness.



18b. White SSM 2021: Site was slightly drier than normal at start of the growing season followed by extreme wetness beginning in July.



19a. White WMP 2020: Site was normal to wetter than normal, experiencing extreme wetness.



19b. White WMP 2021; site was normal to drier than normal with occasional wetter than normal conditions. Overall site was experiencing mild dryness.