

Great West Engineering, Inc.

***Judith Basin Monitoring Stations
Annual Report, Sep. 2017 - Sep. 2018***

Central Montana Regional Water Authority

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1. INTRODUCTION

The Central Montana Regional Water Authority (CMRWA) is developing the U Bet Wellfield near Garneill for the Musselshell Judith Regional Water System (MJRWS) (see also <http://www.centralmontanawater.com>). A single well has been installed at the wellfield (CMRWA #2) and was used to verify the source capacity and to obtain water right permits (**Figure 1**). CMRWA #2 and future wells will produce groundwater from the Madison aquifer.

Further investigation and monitoring of water resources in Judith Basin (Basin) has been undertaken by the CMRWA pursuant to a Water Resources Monitoring Plan (Plan) prepared in 2014.¹ This Plan detailed several activities to gather and assess water resources data in relation to the U Bet Wellfield and for the Basin in general. In 2015, the CMRWA obtained a grant from the State of Montana² to fund the implementation of several monitoring activities from the Plan. Grant funds provide for set up of the monitoring stations and three years of monitoring (9/2016 to 9/2019).³

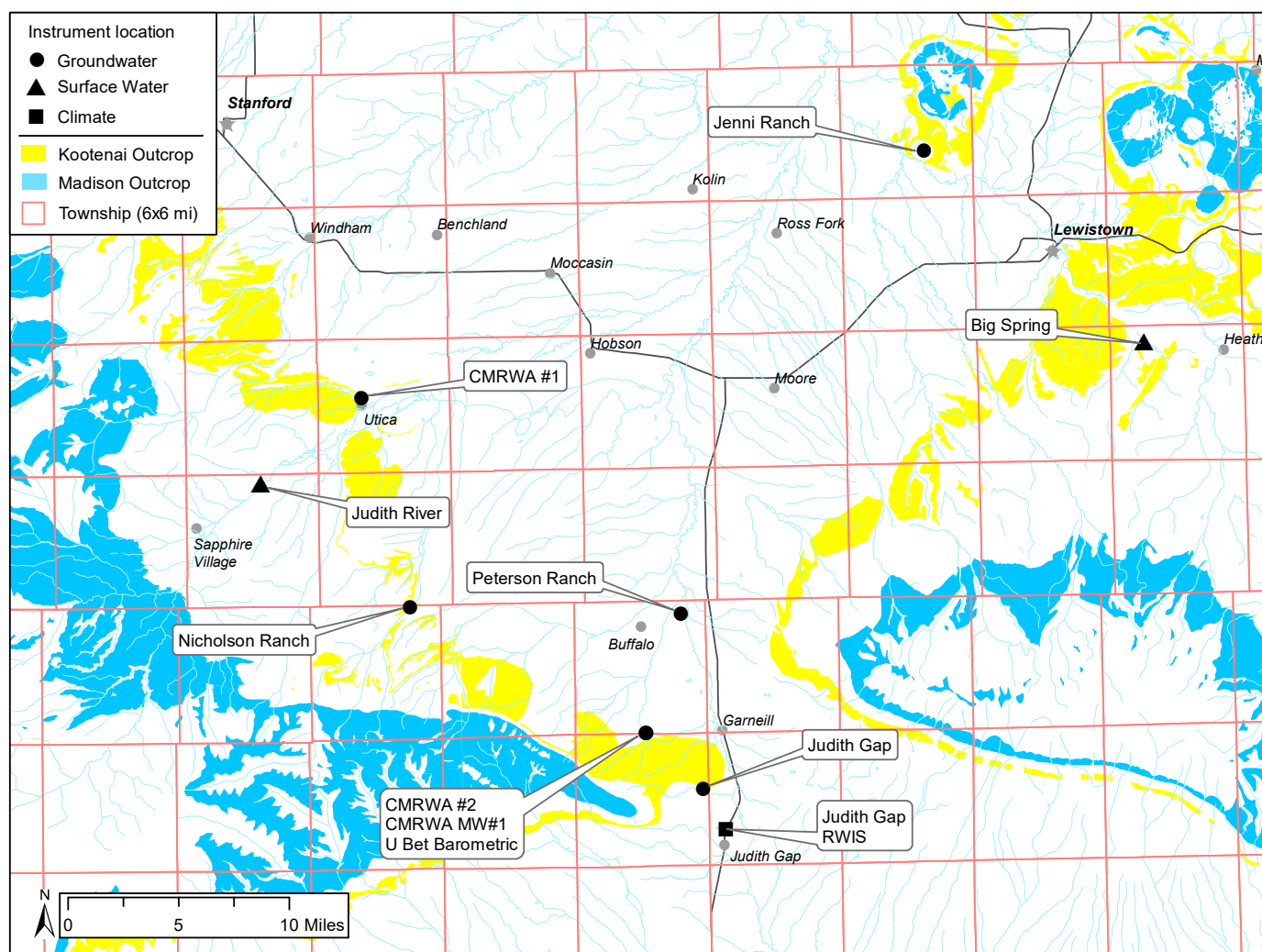


Figure 1. Location Map

1 Western Groundwater Services, LLC (2014) Water Resources Monitoring Plan, Central Montana Regional Water Authority, report to Great West Engineering, Inc., Helena, MT.

2 Grant funds are being administrated through the Department of Natural Resources and Conservation.

3 The Judith River gage was not funded from the grant. It was installed and is maintained by the U.S. Geological Survey.

This report is documenting data collected through the first two years of the grant project. The basic information for the monitoring system that was prescted in the prior report is retained for ease of reference. This report has been prepared by Western Groundwater Services, LLC working as a subconsultant to Great West Engineering, Inc. Great West Engineering, Inc. is the lead consulting engineer for CMRWA on the MJRWS project.

1.1 Hydrogeology Summary

The primary bedrock aquifer in Judith Basin is the basal sandstone of the Kootenai formation, also known as the Third Cat Creek sand.⁴ The Kootenai aquifer is developed by numerous domestic and agricultural wells. In the basin interior, many of these wells are flowing artesian and used without pumps. The Madison aquifer also occurs in Judith Basin, but at present has seen limited use, most likely because it is much deeper than the Kootenai aquifer.⁵ The Madison aquifer was 1,500 feet deeper than the Kootenai aquifer at the U Bet Wellfield and 3,000 feet deeper at Utica.

The U Bet Wellfield will produce groundwater from the Madison aquifer. There appear to be no more than three existing wells into this aquifer in Judith Basin, two of which are owned by CMRWA. The first Madison well in Judith Basin was the Hanover Well, now owned and operated by the Jenni Ranch for power generation. This well was drilled to 750 feet in 1921 and reportedly flowed at 4,500 gpm⁶, but now is estimated to yield about 1,100 gpm. The next well into the Madison was not drilled until 2005, when the CMRWA constructed their CMRWA #1 well to 3,700 feet at Utica. The third Madison well is the CMRWA #2 well constructed to 2,250 feet at the U Bet Wellfield in 2012. For economic reasons, the CMRWA is focusing on the U Bet Wellfield as the primary source to the MJRWS.

There are also several major springs in Judith Basin that discharge from the Madison aquifer. These include Big Spring (100 cubic feet per second (cfs)) and Warm Spring (150 cfs). There are at least two other Madison springs in the vicinity of Big Spring with lower but still strong flows. These include the Hatchery Spring and Lehman Spring.

2. MONITORING LOCATIONS AND SENSORS

Monitoring locations are shown on **Figure 1**. Additional information on sensors at these locations is provided in Table 1 and described in this section.

2.1 Well Sensors

As-built construction logs for the wells that are being monitored are provided in Appendix A. Wells are equipped with computer logging pressure transducers with the pressure ratings shown. These sensors are programmed to record water levels every 15-minutes. The sensors use vented cables, thereby reading gauge pressure, except for the barometric pressure sensor which uses a non-vented cable, and reads absolute pressure.

Wells that have a subsurface static water level (CMRWA #1, CMRWA #2, Nicholson Ranch) have the sensor set down the well in a 1-inch diameter PVC deployment tube. These tubes are set to the top of the pumping equipment. The setting depths are: 1) CMRWA #1 – 697 ft bgs; 2) CMRWA #2 – 372 ft bgs; and 3) Nicholson

4 There are also many wells and springs that discharge from alluvial aquifers.

5 The depth from the Kootenai to the Madison can be less on the basin margin near to the mountain ranges.

6 Feltis, R. D. (1973) Geology and Water Resources of the Eastern Part of Judith Basin, Montana, Bureau of Mines and Geology Bulletin 87, Butte, MT.

Ranch – 92 ft bgs. A barometric sensor is also located at the CMRWA #2 wellhead. This sensor measures atmospheric pressure for the purpose of determining the relation between the water level in CMRWA #2 and changes in atmospheric pressure.⁷

The Kootenai monitoring well at the U Bet Wellfield (CMRWA MW#1) has a static water level at ground surface, and is equipped with a packer set at approximately 6 ft bgs to provide frost protection of the wellhead. The sensor for this well is also set in a PVC tube to the top of the pump at a depth of 287 ft bgs. The sensor cable passes through the packer using a cable seal.

In order to access the instrument in the CMRWA MW#1 monitoring well, the mechanical packer (Well Buster™) must be removed by loosening a 1-1/2" nut using a socket ratchet tool with 6-inch extension. Once loose, the packer can be lifted from the well (15 lbs) and the sensor can be retrieved. In resetting the packer, care must be exercised to ensure that none of the pump or sensor wires move between the packer gland and the casing, as this condition will result in leaking of water past the packer—the well would not be frost free (these wires are taped to the pump column below the packer in order to ensure a proper setting of the packer). After the packer is set, it is necessary to remove water from above the packer. This can be done by air-lifting or bailing, or (preferred method) by running the well pump, in which case the water drains down through the packer in the well (drainage occurs to about 1-inch above the packer—the packer is not exposed). The 1-1/2 hp submersible pump in the well can be run using a 3.5 kW generator (1P, 240 VAC) with discharge through the hydrant adjacent to the wellhead.⁸ The pump wire has sufficient excess and is terminated with 20A/240 VAC plug for direct connection to a generator.

Sensors set onto flowing artesian wells are mounted onto fittings in the well piping at land surface.⁹ These include the sensors for Judith Gap, Peterson Ranch, and Jenni Ranch. The Judith Gap sensor is mounted onto piping that allows for discharge from the well casing. When this pump runs, drawdown occurs into the casing for some depth. This drawdown is not measured; valid readings only occur when the pump is off and the static water level has risen to elevations above the sensor. The sensor at the Peterson Ranch is mounted onto the discharge piping from the well. This well is not pumped and flows naturally for the water use by the ranch. The Jenni Ranch well is also used without a pump, and the sensor is mounted onto the outside of the well casing, about 1.5 ft bgs. This sensor was removed from the well in September 2017 for the winter in order to prevent frost damage to the instrument. It could not be reset with weather protection in 2018 and is no longer being monitored.

2.2 Judith River

The Judith River gauge (No. 06110020) was newly constructed by the U.S. Geological Survey (USGS) in 2014, and started producing data on 10/1 of that year. This gauge is located at a bridge upstream from the confluence with Carr Creek. The gauge is also maintained by the USGS and the data are directly available from the USGS stream gauging database.¹⁰

⁷ Confined aquifers will to varying degrees exhibit a rising water level in a well when atmospheric pressure declines, and vice versa.

⁸ Western Groundwater Services, LLC (2017) Kootenai Monitoring Well CMRWA MW#1 Construction Report, report to Great West Engineering, Inc., Helena, MT.

⁹ Flowing artesian wells flow naturally and hold pressure at the surface when shut-in.

¹⁰ This website is most easily access by browsing for "USGS Stream Gauge 06110020", but can also be accessed from this URL: https://waterdata.usgs.gov/mt/nwis/uv?site_no=06110020.

2.3 Big Spring

Big Spring requires multiple instruments to measure discharge. The spring discharge is directed to three locations: 1) the City of Lewistown; 2) the FWP Fish Hatchery; and 3) Big Spring Creek. Additionally, Hansen Creek discharges into Big Spring Creek immediately above the spring. In order to measure the spring flow rate, the Hansen Creek flow must be subtracted from the other discharges.

FWP measures Big Spring Creek by traditional stream gauging methods and develops stage-discharge correlations through the year. The Hatchery and Hansen Creek are measured with FWP flow meters. The City measures withdrawals from the spring also with flow meters. The instrument readings are processed by computer in the City's control building located at Big Spring. The integration of the monitoring system, which included both hardware and software improvements, was funded from the CMRWA grant. The grant is also paying for operation of the monitoring system for the three year monitoring period ending 9/2019.

2.4 Climate

Climate data for the elevation of the U Bet Wellfield and the Kootenai outcrop area in Judith Basin are being measured at the Montana Department of Transportation (MDT) Remote Weather Information Station (RWIS) at Judith Gap. This station was equipped with a new precipitation sensor from the CMRWA grant and operated and maintained by MDT. The data are accessed by direct request to MDT through their website.¹¹ Data from this site will be integrated into the water balance analysis for the Kootenai aquifer.¹²

3. DATA PLOTS FOR 2018

Data plots for the first two years of monitoring from September 2016 into October 2018 are provided in Appendix B. A summary discussion for each of the plots is provided below. Additional analysis of these data will be included in the grant project final report, to be completed in the last quarter of 2019.

3.1 CMRWA #1 (Madison)

There is a definitive seasonal pattern in the well water level with an maximum observed amplitude of about 65 feet (B-1). The water temperature exhibits a slight increasing trend over the period of monitoring and is approximately 48°F. A seasonal trend of this magnitude and the cold water temperature are unusual for a deep confined aquifer.

3.2 CMRWA #2 (Madison)

The initial data shown are reflecting the pumping test conducted during fall 2016 (B-2). During this testing, the well was pumped at 575 gpm with about 35 ft of drawdown. The water temperature increased by about 15°F due to heating from the 125 hp submersible pump motor. After the pumping test, water level data exhibit a definitive seasonal pattern and the water temperature is slightly greater than 49°F. The maximum seasonal amplitude is about 30 feet. The seasonal peaks/valleys correspond closely with CMRWA #1.

¹¹ By requesting atmospheric data in converted units for the Judith Gap RWIS, within specified dates. The public information request web page can be accessed at URL: http://www.mdt.mt.gov/mdt/information_request.shtml.

¹² Water balance analysis is also incorporating the PRISM data developed by Oregon State University (<http://prism.oregonstate.edu/>) and NRCS SNOTEL data local to the area.

Table 1. Monitoring System

Location ID	GWIC ID	Source	Latitude Longitude	Sensor Rating	Model	Mfg.
CMRWA #1	257040	Madison	46.973135 -110.092816	300 psig	Level Troll 500	In-Situ, Inc.
CMRWA #2	276994	Madison	46.751668 -109.825567	100 psig		
CMRWA Baro	NA	Atmospheric		30 psia	Level TROLL 400	
CMRW MW #1	289684	Kootenai	46.751664 -109.825252	300 psig	Level TROLL 500	
Judith Gap	132756	Kootenai	46.714447 -109.771655	100 psig		
Peterson Ranch	266587	Kootenai	46.829638 -109.790520	300 psig		
Nicholson Ranch	204169	Kootenai	46.836131 -110.048608	100 psig		
Jenni Ranch	174246	Madison	47.129547 -109.550441	100 psig		
Judith River 06110020	NA	Judith River	46.900548 -110.233129	NA	NA	USGS
Big Spring	Not yet Assigned	Madison	47.001867 -109.343260	NA	NA	NA
Judith Gap RWIS	NA	Climate	46.687538 -109.750838	NA	PWD12 (precipitation)	Vaisala

3.3 CMRWA Baro (Atmospheric)

The earlier report used these data to develop a barometric efficiency correction for CMRWA #2. In this report the sensor data are shown only in a time history plot (B-3).

3.4 CMRWA MW#1 (Kootenai)

The early data for fall 2016 are reflecting operation of the submersible pump that is set in this well (B-4). The pump is used for sampling of the groundwater, and otherwise will not be in regular use. After this time, the water level data exhibit a very slight possible seasonal fluctuation with an amplitude of one to two feet. The deflection occurring in July 2017 is most likely a response to aquifer pumping in private wells. The increasing water level occurring after April 2018 is attributable to natural aquifer recharge. Water temperature in the Kootenai aquifer is about 48.5°F, which compares closely to the Madison aquifer.

Under a normal geothermal gradient of 1.4F/100 ft, the Madison aquifer at 2240 ft, would be expected to have a water temperature of about 70F (calculated starting at the base of the Kootenai aquifer -- 700 ft). The lower temperature could occur in a fast flow system that is not equilibrating with the rock temperature. The same temperature anomaly is observed at the CMRWA #1 well.

3.5 Judith Gap (Kootenai)

The Town of Judith Gap Mauws Well is artesian but must be pumped to produce at sufficient capacity for the water system (B-5). The sensor is mounted at the wellhead and cannot read water level when this level drops below ground during a pump cycle. The thick band of data with a level of about 4635 ft reflects the normal static condition. The other points occurring mostly above but also below the band occur in relation to when the pump is shut off. They appear to document oscillation of the well water level of several tens of feet occurring over a period of at least 15- to 30-minutes at the end of each run cycle. The higher density of points above the band during summer, in 2017 and 2018, is reflecting a greater number of pump run cycles due to higher water demand. The dip in the band over these months is caused by incomplete recovery of the well between pump cycles. The increase in level in 2018 is from natural recharge, as occurred in the CMRWA MW#1 Kootenai monitoring well.

3.6 Peterson Ranch (Kootenai)

The Peterson Ranch well is a flowing artesian well operated without pumping equipment (B-6). The water level data for this well are dominated by usage of the well. The recovery levels, shown by the highest points on any given date, generally do not achieve a static water level because of the high frequency of use. The highest level observed corresponds to a pressure of 125 psig. The higher winter use of the well is likely reflecting increased livestock consumption.

3.7 Nicholson Ranch (Kootenai)

The Nicholson Ranch well has established pumping and recovery water levels through the monitoring period (B-7). This well is producing groundwater with about one to two feet of total drawdown. The static water level exhibits a seasonal pattern with a peak in May, which is slightly increased in 2018 as compared to 2017. The aquifer water temperature is about 45°F. The higher temperatures shown on the plot are a result of the pump motor heating the water.

3.8 Jenni Ranch (Madison)

The Jenni Ranch Hanover Well is not being monitored. The data collected for this well are unchanged since the prior report and are not included here.

3.9 Big Spring (Madison)

Discharge data for Big Spring (B-8) are presented as daily totals, and show a range from 84 to 99 cfs. The data appear noisy, particularly in comparison to how groundwater hydraulic head would be expected to change and influence spring discharge. As described above, the spring flow rate is derived from five measurements (Big Spring Creek, Hansen Creek, FWP Hatchery, City of Lewistown (two meters)). If Big Spring hydraulic head varied seasonally, as observed at CMRWA wells #1 and #2, a seasonal flow rate pattern would be observed; however, it would be very smooth in comparison to the measured flows.

3.10 Judith River Gauge

This gauge measures flow in the Judith River a short distance upstream from the confluence with Carr Creek (B-9). There are irrigation diversions that occur upstream from the gauge. Peak flow for the period of record was 769 cfs. The 10th to 90th percentile range is 6 to 182 cfs, and the 10% trimmed mean is 42 cfs. The baseflow occurring in late winter and early spring declines to rates 3 to 7 cfs. These low rates are outside the irrigation season and represent the natural base flow from groundwater.

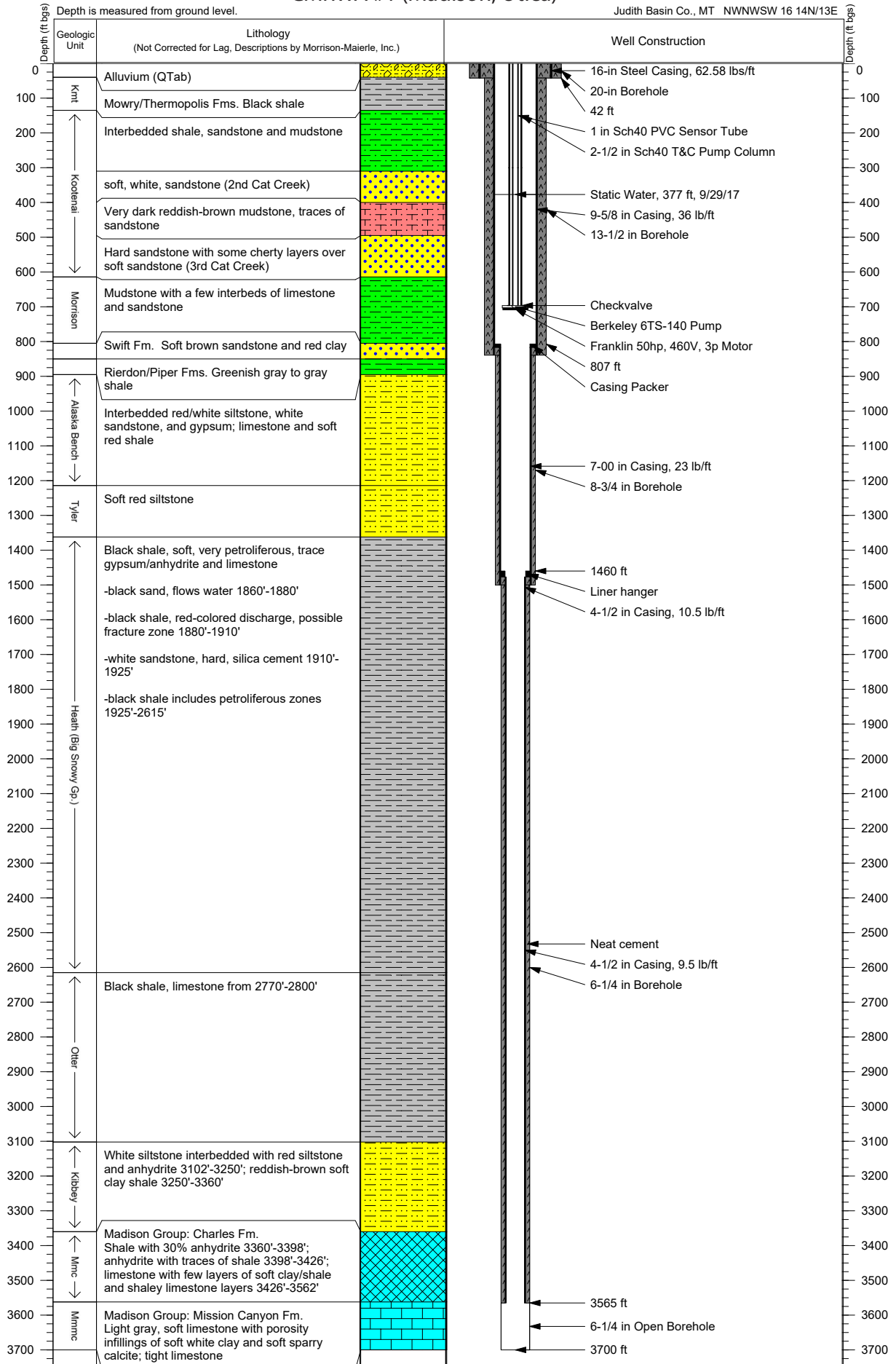
3.11 Judith Gap RWIS

Climate data for the weather station at Judith Gap provide direct measurements that will be incorporated into water balance analysis. The new precipitation sensor installed at this station was activated on February 3, 2017. This plot is showing daily and monthly totals for the precipitation and daily and monthly mean air temperature (B-10).

APPENDIX A – WELL LOGS

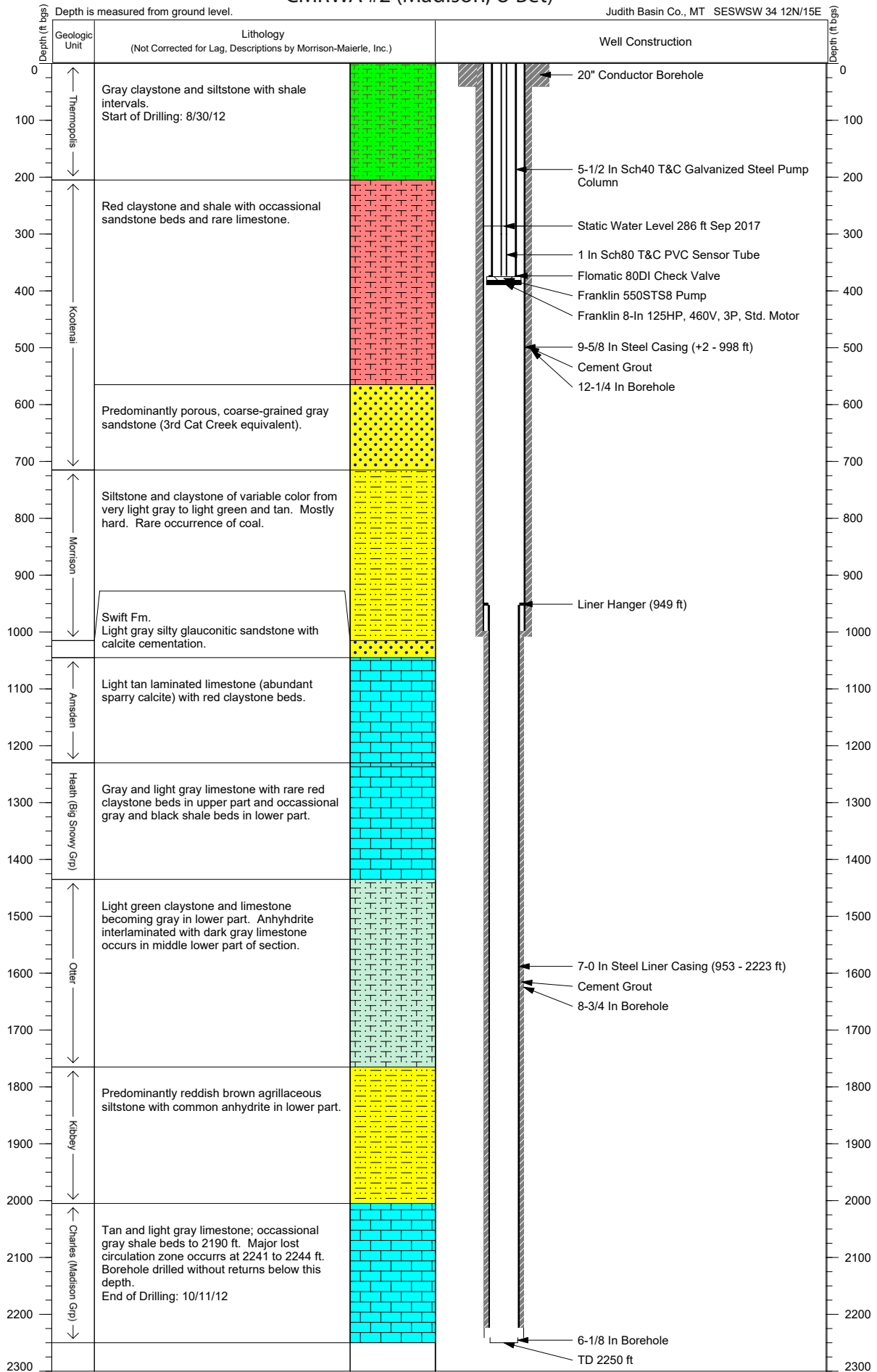
CMRWA #1 (Madison, Utica)

Judith Basin Co., MT NWNWSW 16 14N/13E



CMRWA #2 (Madison, U Bet)

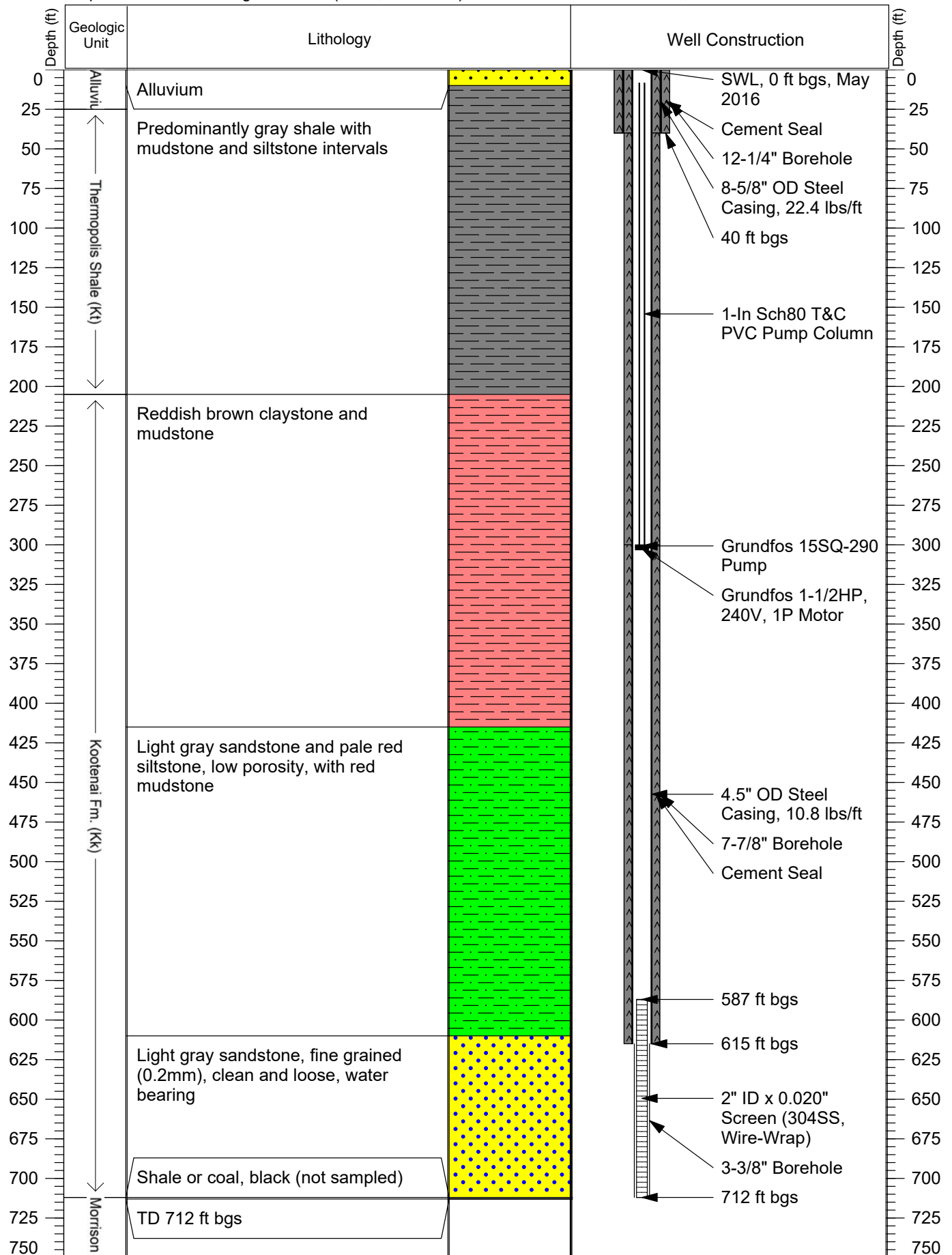
Judith Basin Co., MT SESWSW 34 12N/15E



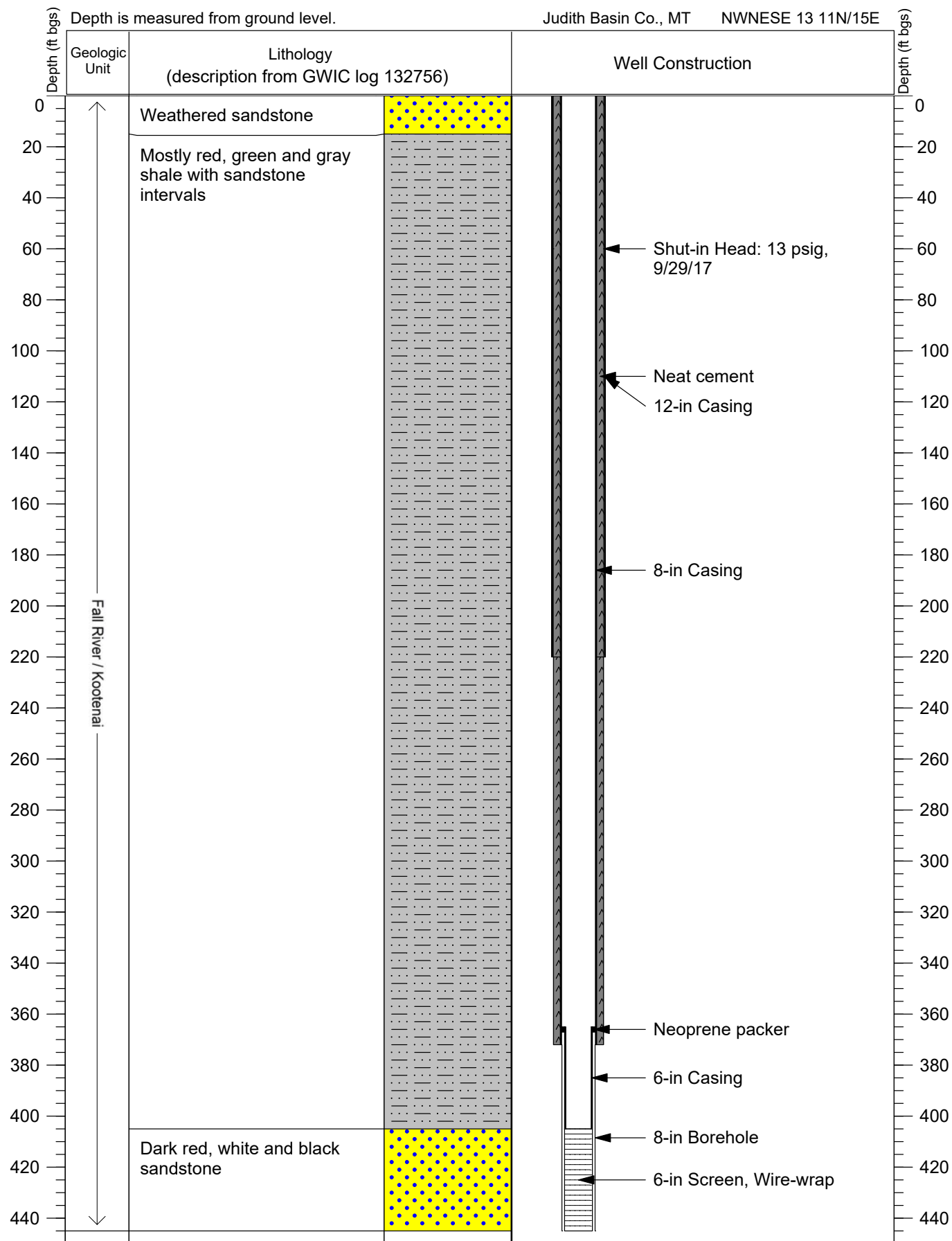
CMRWA MW#1 (Kootenai, U Bet)

Depth is measured from ground level (est. 4,698 ft MSL)

Judith Basin Co., MT SESWSW 34 12N/15E

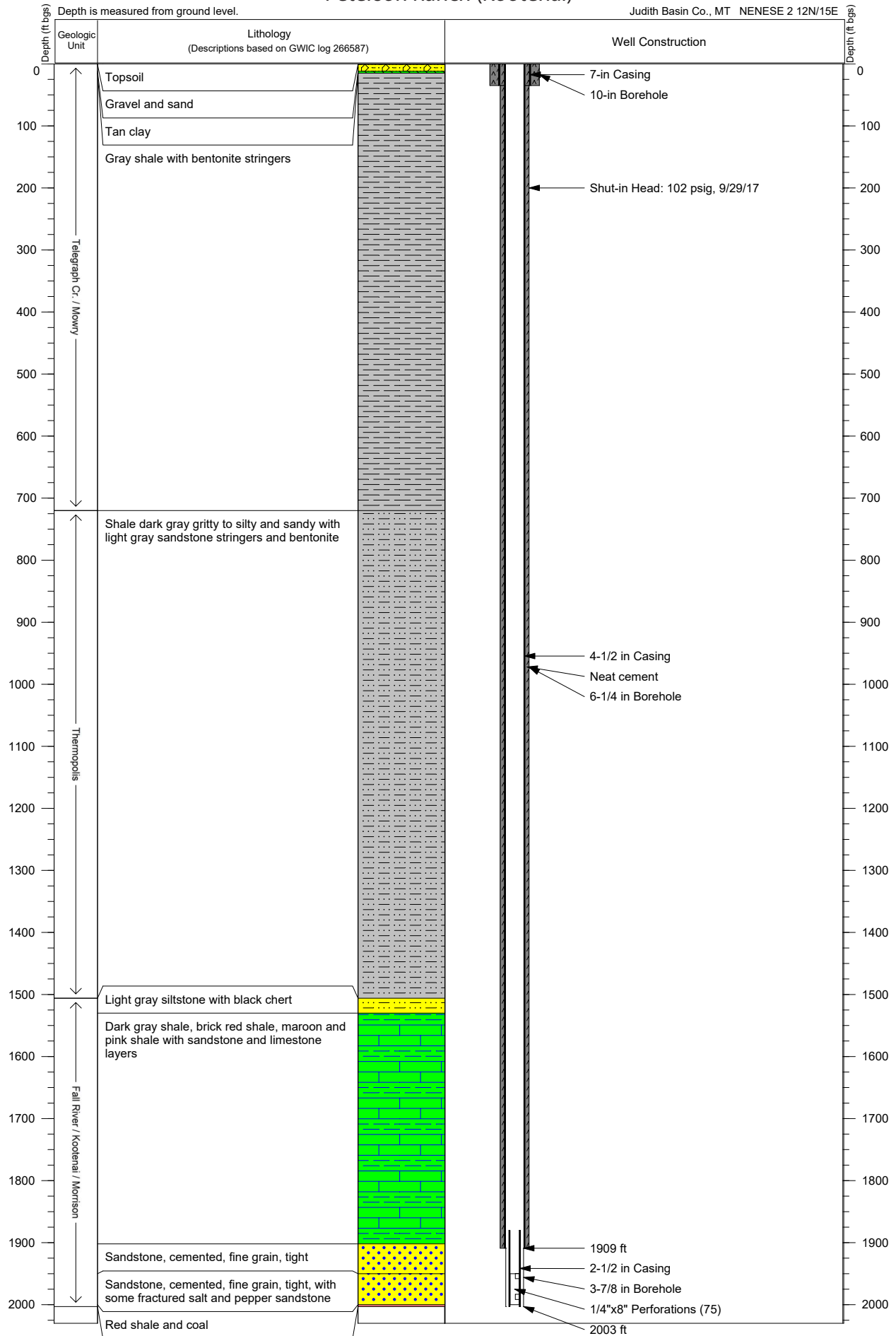


Judith Gap Mauws Well (Kootenai)

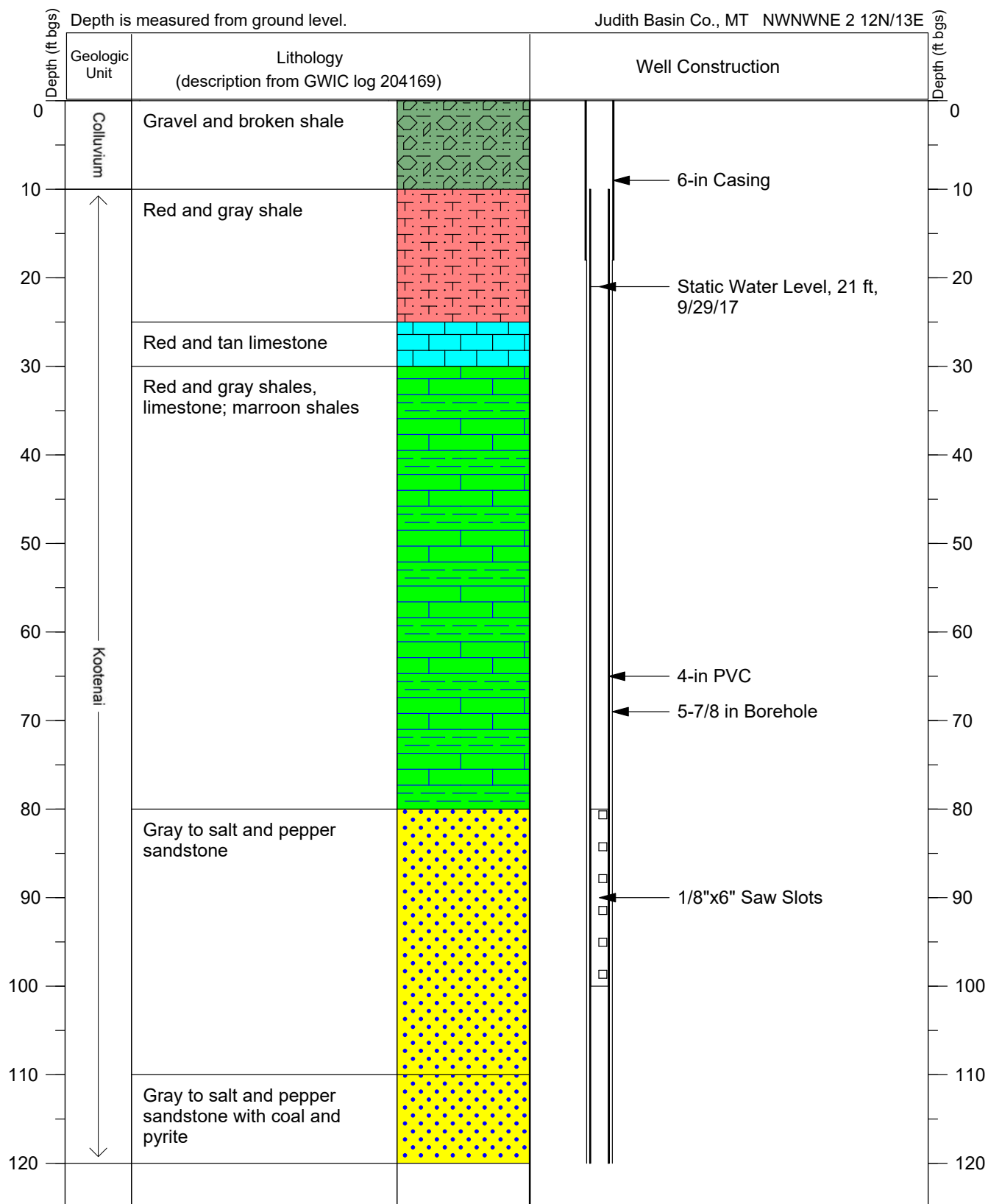


Peterson Ranch (Kootenai)

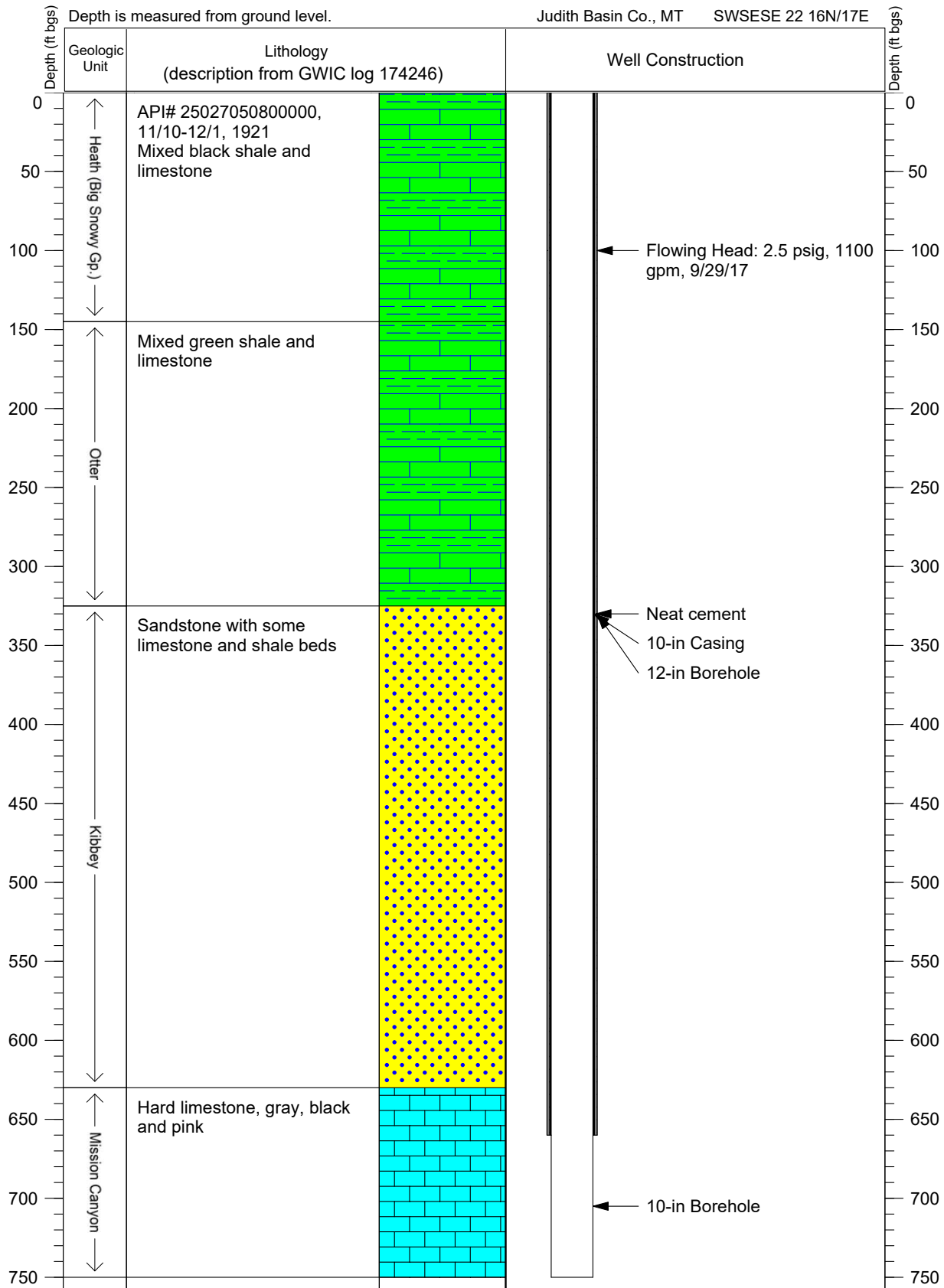
Judith Basin Co., MT NENESE 2 12N/15E



Nicholson Ranch (Kootenai)



Jenni Ranch (Madison)



APPENDIX B – DATA PLOTS

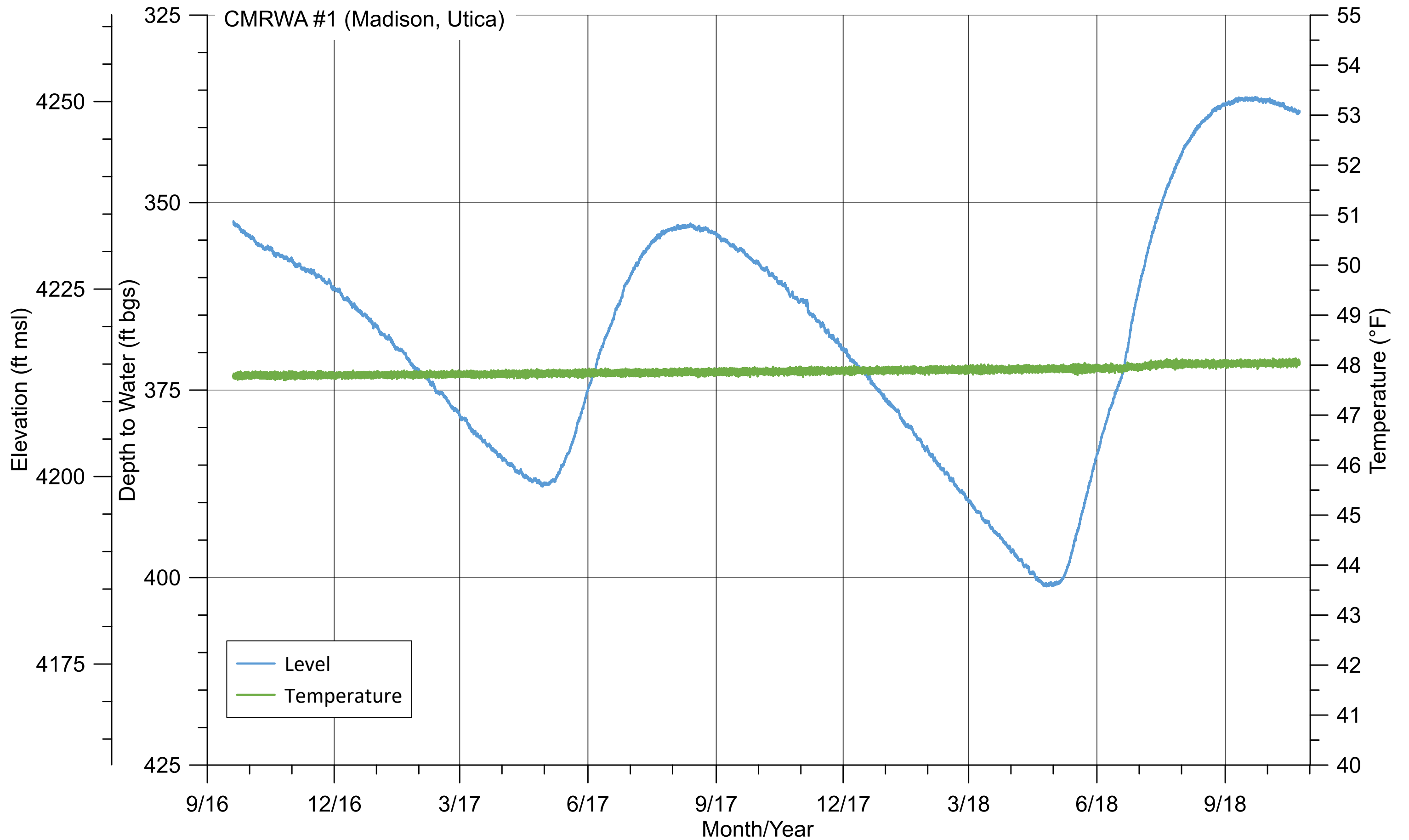


Exhibit B-1 CRMWA #1

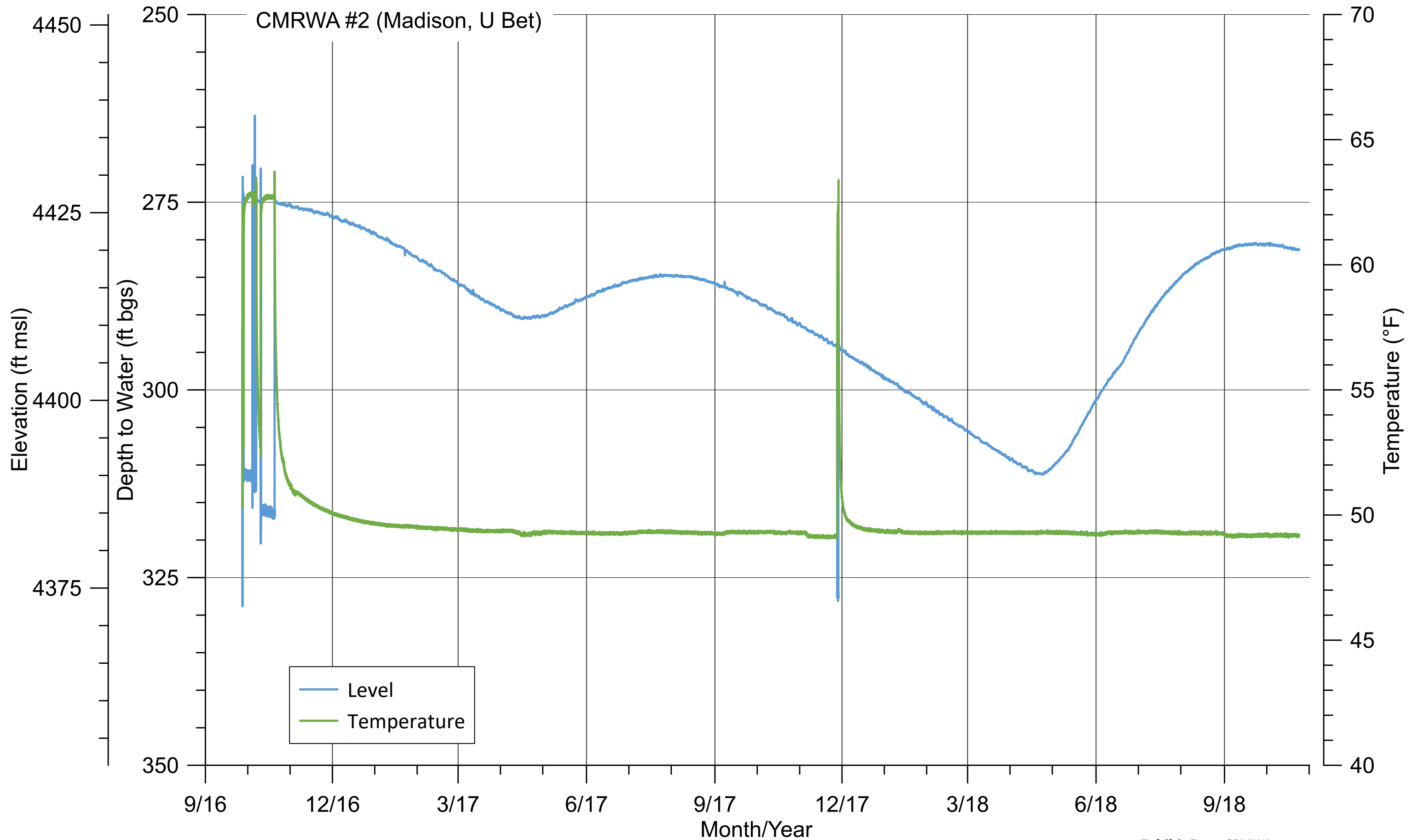


Exhibit B-2 CRMWA #2

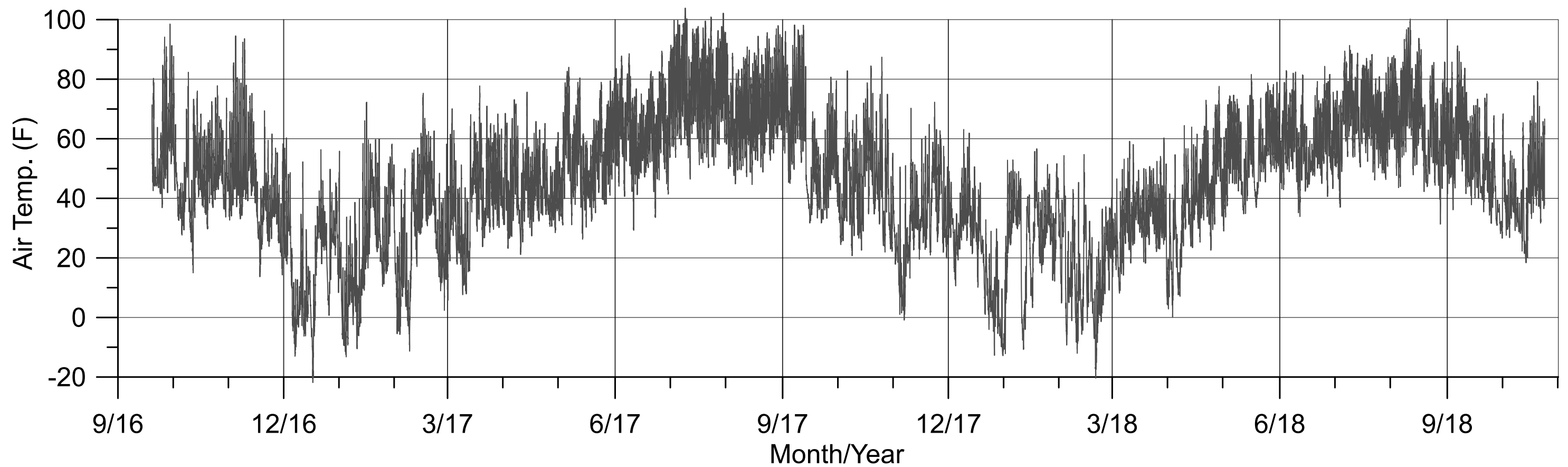
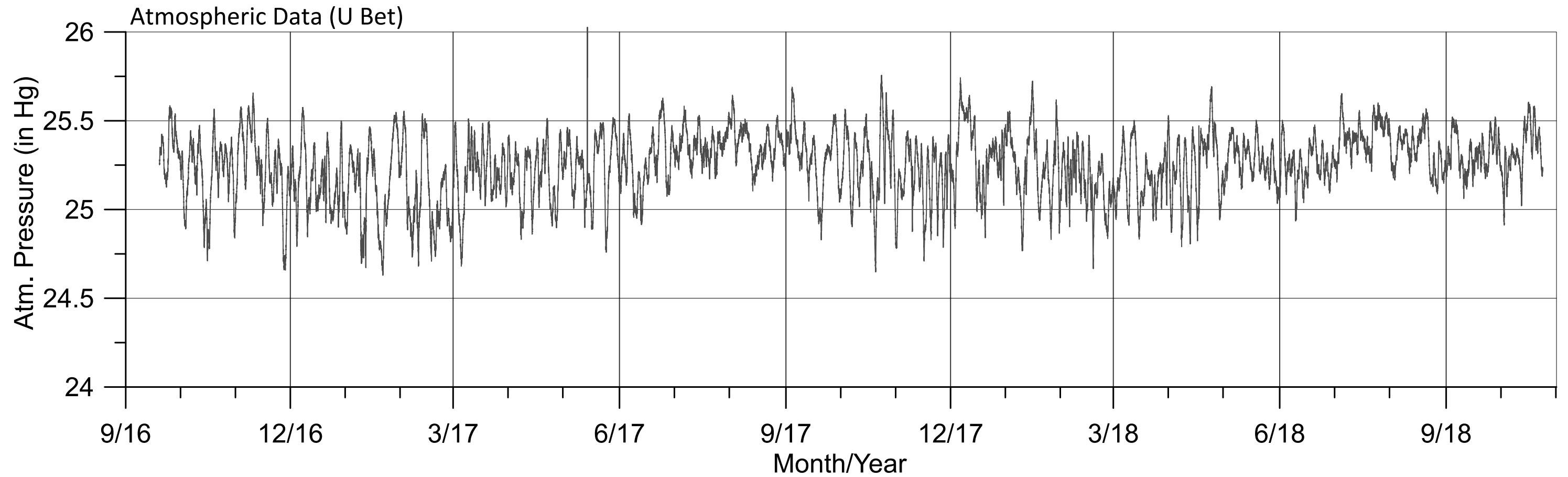


Exhibit B-3 Barometric Sensor

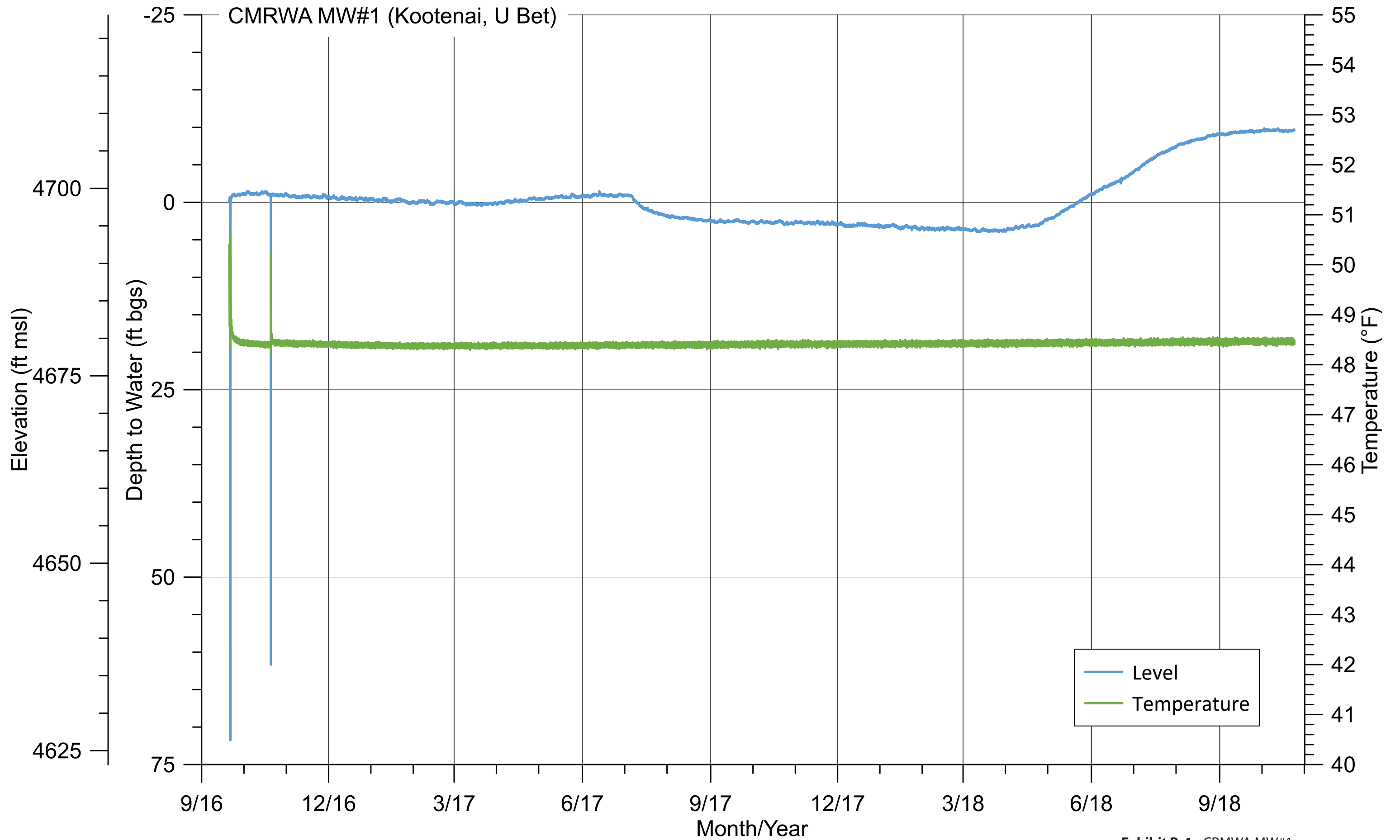


Exhibit B-4 CRMWA MW#1

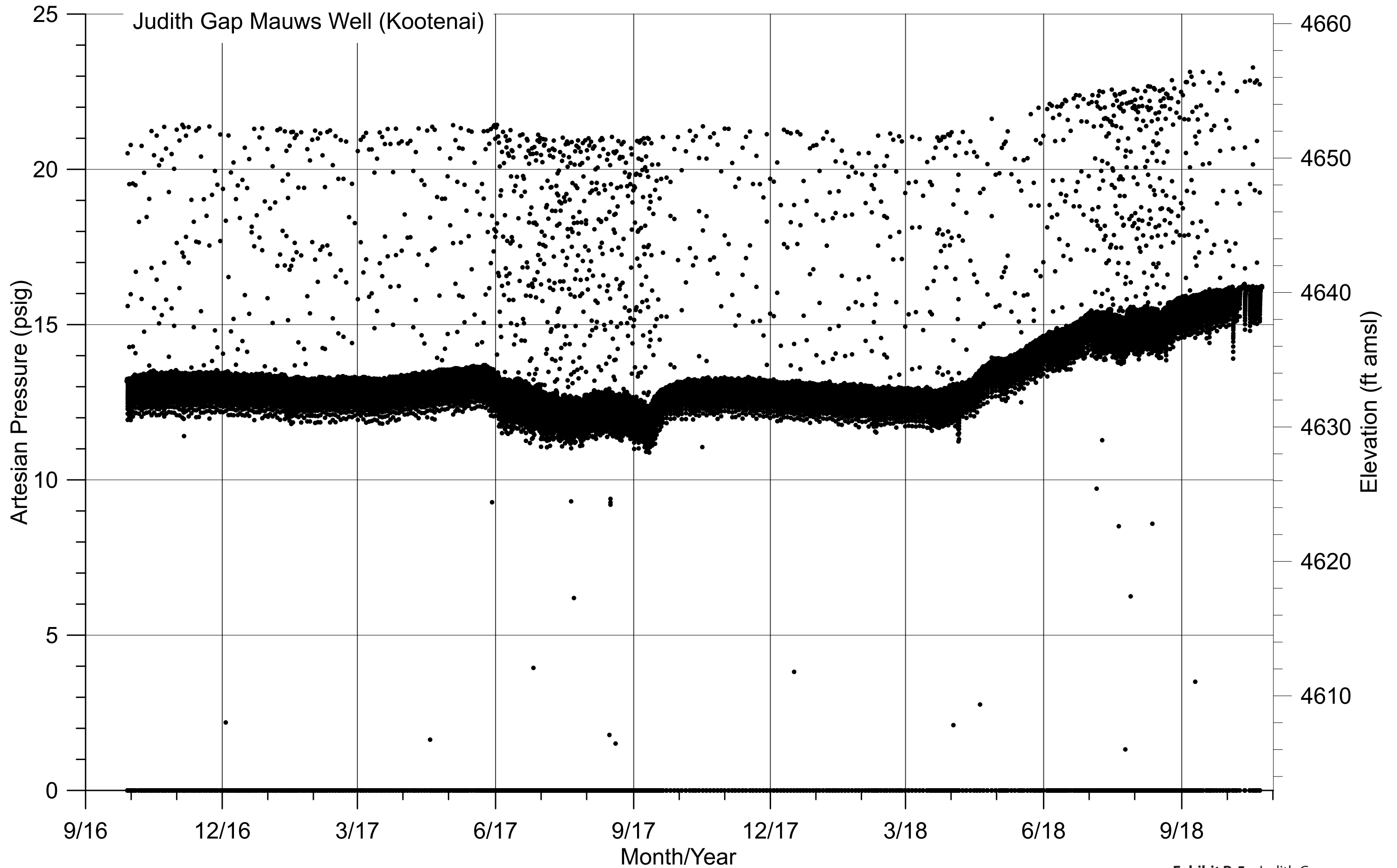


Exhibit B-5 Judith Gap

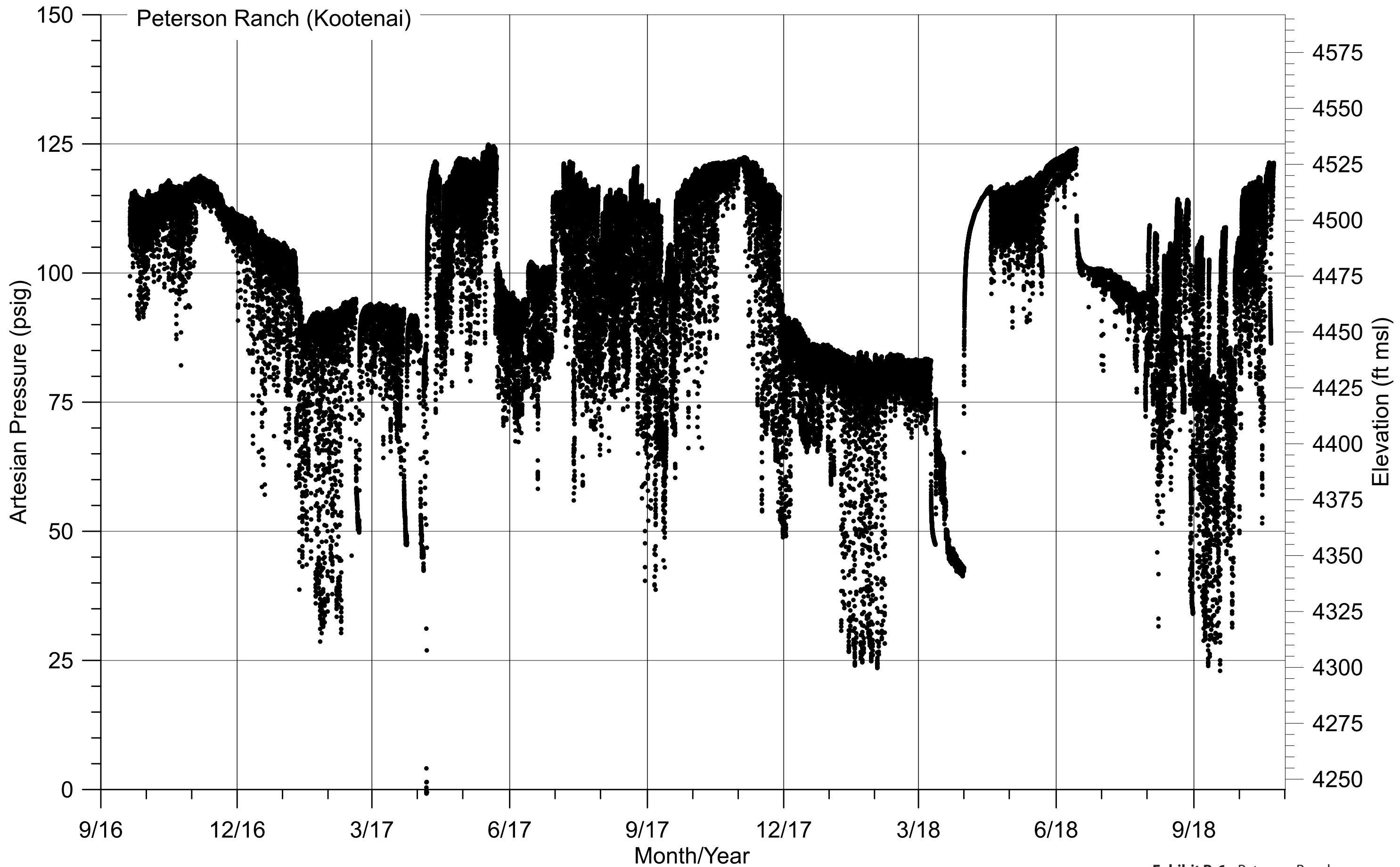


Exhibit B-6 Peterson Ranch

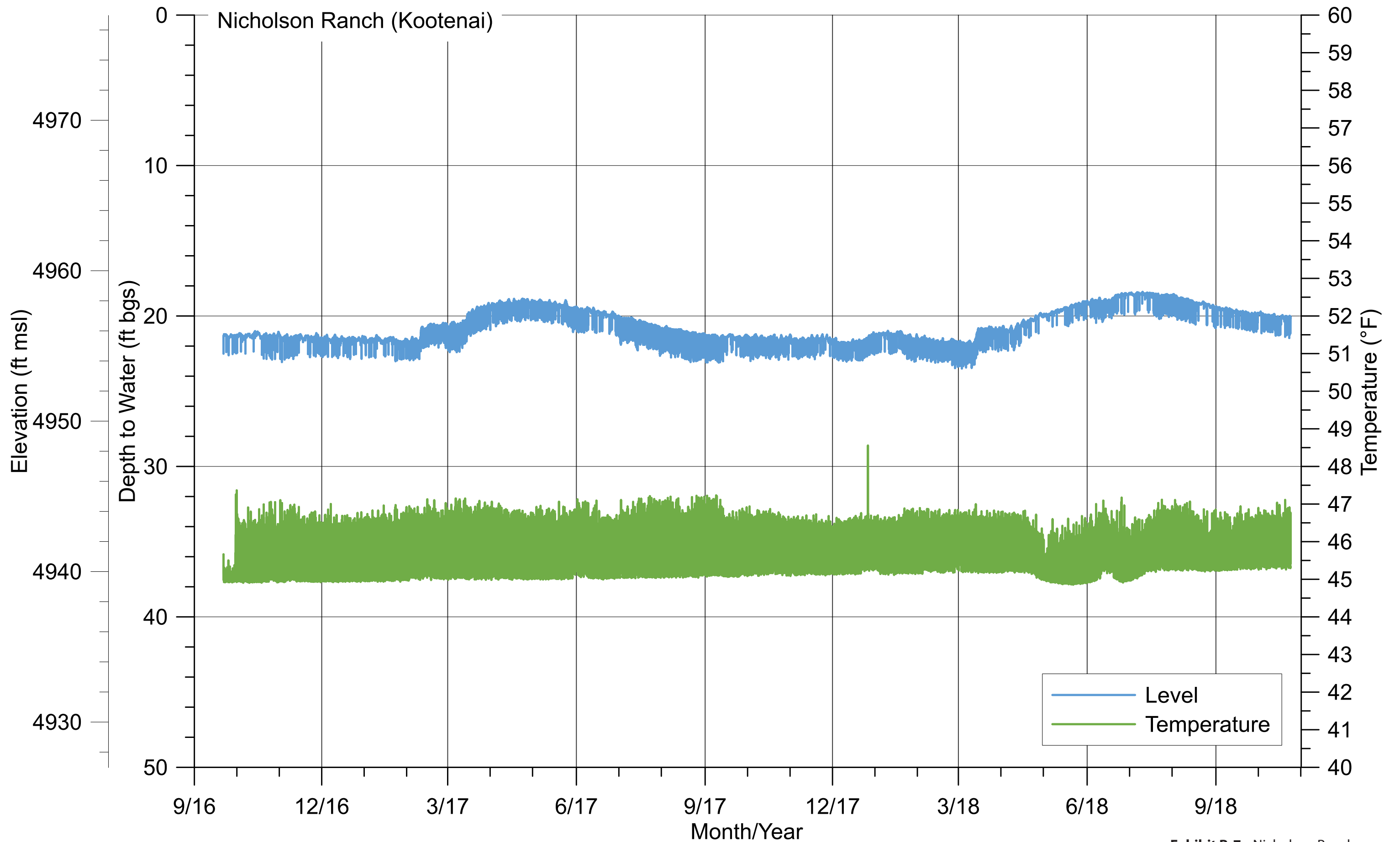


Exhibit B-7 Nicholson Ranch

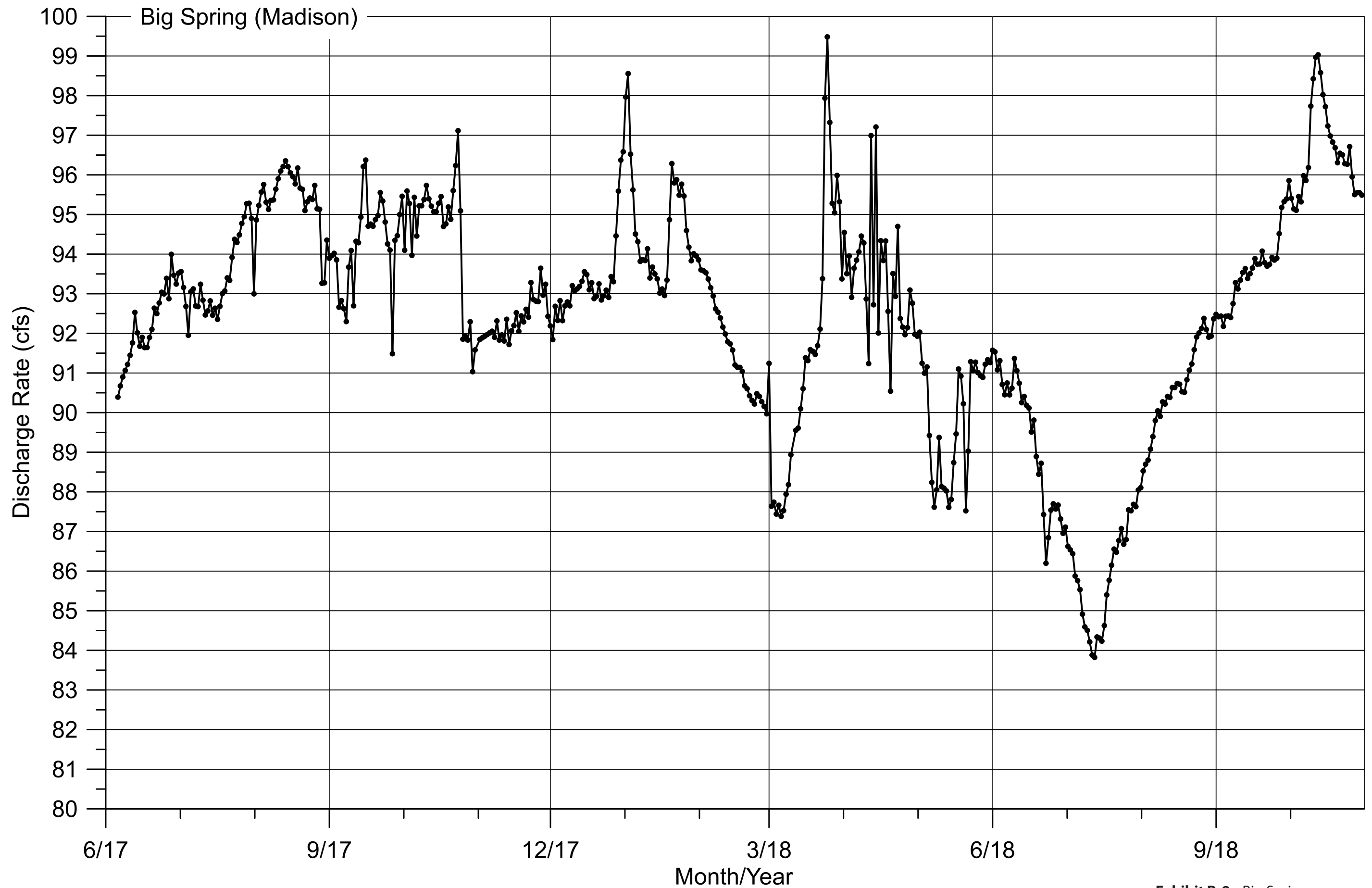


Exhibit B-8 Big Spring

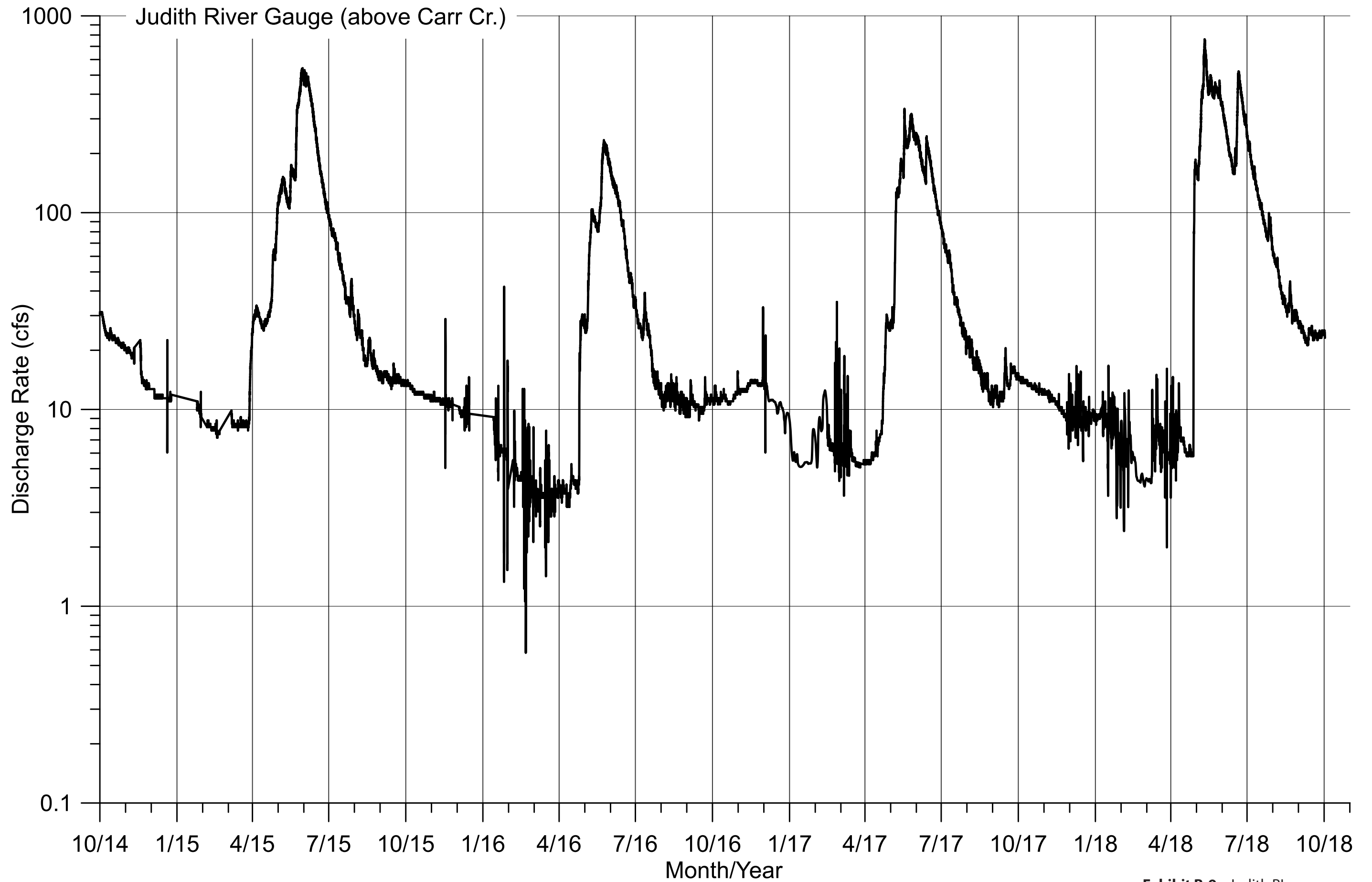


Exhibit B-9 Judith River

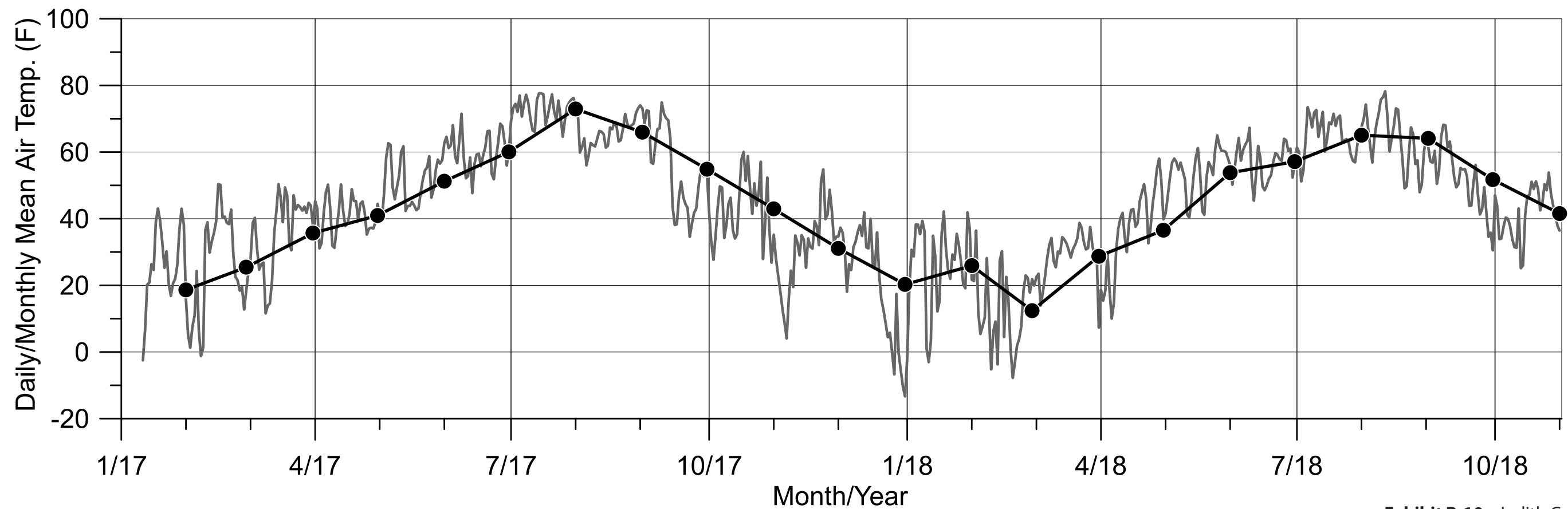
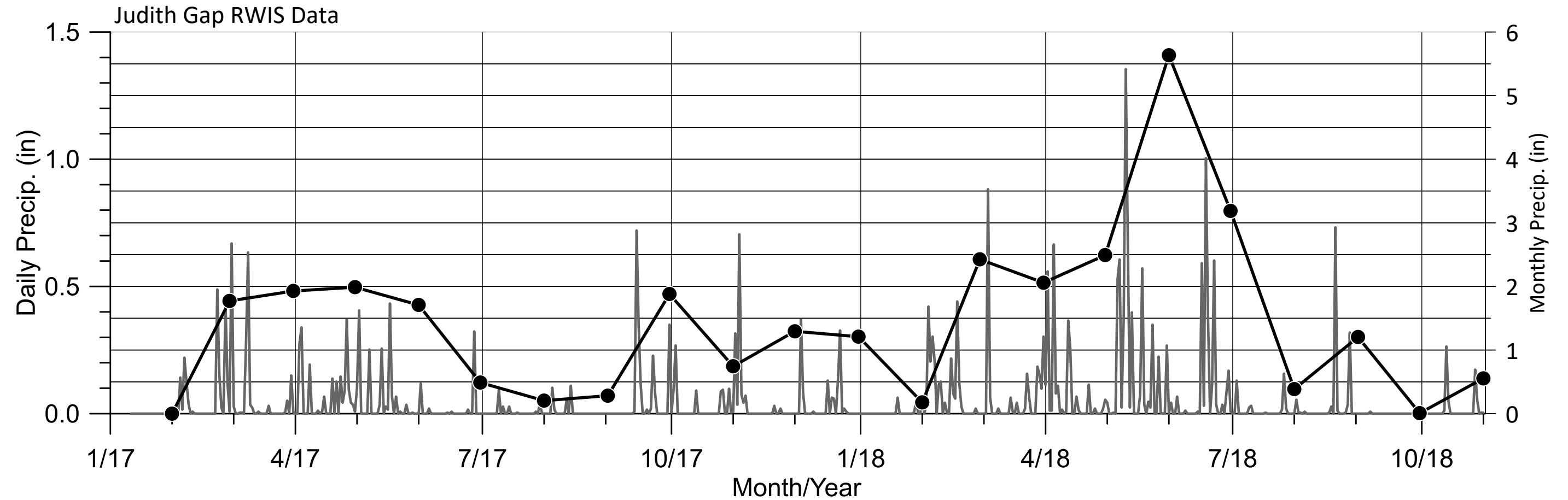


Exhibit B-10 Judith Gap RWIS