TECHNICAL MEMORANDUM

Date:	9/28/2020
To:	Brian Lockwood, PV Water
From:	Chris Hammersmark; Chris Connor
Project:	17-1003-3 – College Lake Hydrologic Monitoring for Water Year 2019
Subject:	2019 Water Year Hydrologic Monitoring Technical Memorandum

1 INTRODUCTION

cbec, inc. eco engineering (cbec) was hired by Pajaro Valley Water Management Agency (PV Water) to perform hydrologic monitoring of the College Lake system in Watsonville, California, during the 2019 water year (WY). This monitoring effort builds upon monitoring efforts that were initiated by PV Water and cbec previously (as documented in cbec, 2014), and supports the development of the College Lake Integrated Resources Management Project. The monitoring program included: 1) maintenance of several water level gages within creek channels in the College Lake area, 2) flow measurements at select monitoring sites to develop and/or validate stage-discharge rating curves to estimate hydrographs, and 3) continued monitoring of a network of piezometers in the vicinity of College Lake.

2 METHODS

Gaging was performed at seven different locations representing the main inputs and outputs to and from College Lake. Gage locations are listed in Table 1 and shown in Figure 1.

Each gaging location contains a pressure transducer that continuously measures the pressure, which is a combination of atmospheric and water pressure, occurring at the elevation of the gage. Pressure readings at each submerged gage were converted to water depth by subtracting the atmospheric pressure measured by a non-submerged barometric gage (Gage #0) located at the College Lake Pump House. Water surface elevations were surveyed at each gage location to tie each gage into to the North American Vertical Datum of 1988 (NAVD88). Surveyed elevations were corrected based on the National Geodetic Survey (NGS) benchmark GU4185 on the North-West sidewalk of the Highway 152 Bridge over Corralitos Creek. The water depth recorded by the gage at the time of the water surface elevation survey was subtracted from the surveyed water surface elevation in order to establish the elevation of the gage (i.e., pressure transducer). With the instrument elevation known, the depth time series for each location can be added to the height of instrument to provide a time series of water surface elevation at each location. Staff plates located at each submerged gaging location were read at the time of each download, to check for any potential fouling of the pressure transducers. These staff plates are also referenced to the North

American Vertical Datum of 1988 (NAVD88) allowing for the conversion of stage readings to a water surface elevation.

Discharge measurements were taken at various levels of stage to construct and/or update stage-discharge rating curves at the Casserly Creek Upstream and Casserly Creek (formerly Casserly East) gaging locations. Low and medium velocity measurements (where in-stream wading was possible) were collected using a Sontek FlowTracker acoustic Doppler velocimeter. Channels were discretized into 10 to 20 horizontal bins (depending on the channel width). Discharge was measured for each bin based on water depth and water velocities measured at 0.6 times the water depth. Discharge for each bin was then summed to produce the total discharge for the channel. Discharge measurements were not taken at the Pump House or Salsipuedes Creek gages due to bidirectional flow that occurs at these locations, precluding the development of a deterministic stage-discharge relationship.

Table 1 – Gaging locations and staff plate elevations

Gage Number	Location Name	Northing*	Easting*	Staff Plate Datum Elevation, ft**
0	Barometric Logger	1,803,304.64	6,198,178.38	NA
1	Pump House	1,803,304.64	6,198,178.38	43.17
2	Casserly Creek (Downstream)	1,808,989.26	6,197,583.86	64.18
3	Salsipuedes Creek	1,802,144.98	6,198,267.85	58.01
4	Fairgrounds Creek	1,807,671.81	6,200,153.80	84.54
5	Pinto Creek	1,802,714.37	6,196,411.50	70.55
6	Paulsen Creek	1,808,632.59	6,193,798.87	63.53
7	Casserly Creek Upstream	1,810,648.60	6,197,924.09	67.95

**Coordinates are in California State Plane Zone 3 feet. Elevations are in NAVD88 feet.*

***Elevation is referenced to 0' reading on associated staff plates*

Lake storage volume was estimated using water levels measured at the Pump House gage and a hypsometric curve (cbec, 2014) for the lake. The lake storage and gaged upstream inflows were differenced to produce an estimate for unaccounted discharge/input to College Lake using a mass balance approach.

3 Results

The monitoring period for this technical memorandum started on October 1, 2018 and continued through April 29, 2019, the date that College Lake began to be drained via pumping to support seasonal agriculture on the lake bottom. The lake area received an estimated 26.47 inches of precipitation during the 2019 water year (as recorded at City of Watsonville's Watsonville Waterworks gage; located on Freedom Blvd, near Blanca Lane). The precipitation was an estimated 118% of normal rainfall (NOAA, 2019). Table 2 provides the significant storms that occurred, with the associated lake storage and estimated Casserly Creek discharge volume. A majority of the WY 2019 precipitation (67%) occurred in January through March (17.67 inches).

Table 2 – Precipitation Events, Casserly Creek Inflow Volume and Resulting Maximum Lake Storage

Start Date	Duration (days)	Precipitation (in)	Casserly Creek Discharge Volume for Duration Shown (AF)	Maximum College Lake Storage (AF)
11/22/2018	3	2.27	30.09	129.4
11/28/2018	5	1.65	53.20	204.9
12/17/2018	1	1.59	0.74	190.7
12/25/2018	1	0.51	0.01	335.5
1/6/2019	2	1.75	183.28	543.6
1/15/2019	4	1.94	797.77	1825.2
1/30/2019	2	0.72	59.89	1536.3
2/2/2019	5	2.95	1063.56	2346.9
2/8/2019	4	1.36	484.82	2116.7
2/13/2019	6	2.68	1292.90	2791.3
3/2/2019	10	3.66	1315.25	2158.4
3/19/2019	3	0.58	84.10	1693.1
5/16/2019	2	0.52	6.03	744.1
5/19/2019	4	1.23	16.60	706.6

During the dry season, most tributary creeks (Paulsen, Fairgrounds, Pinto, Corralitos Creeks) are dry and/or are not contributing significant amounts of inflow to College Lake. However, Casserly Creek conveys small amounts of flow through the dry season. The source of this dry season flow is likely agricultural return flow or baseflow discharge. Portions of Salsipuedes Creek between the College Lake weir and the confluence with Corralitos Creek remain wet throughout the year, and the water surface elevation varies with the Reclamation District 2049 pumping activities that allow for farming in College Lake through the summer.

Discharge measurements were taken at Casserly Creek Upstream, Paulsen Creek (formerly known as Casserly Creek West), Pinto Creek, and Fairgrounds Creek sites. Due to issues with out of bank flows noted previously (cbec, 2019a), no measurements were taken at the Casserly Creek (Downstream) site.

Discharge amounts were measured on nine different dates at the Casserly Creek Upstream site with conditions ranging from low to moderate flow rates (i.e., 1 cfs to 87 cfs). In total, 12 discharge measurements were collected over the nine sampling days, including one measurement during low flow conditions in the summer. Discharges were measured on three different dates at the Paulsen Creek site (1 cfs to 6 cfs), and the Pinto Creek site (6 cfs to 19 cfs). Discharges were measured on four different dates at the Fairgrounds Creek site (2 cfs to 43 cfs). A list of all measurements collected during the 2019 WY is provided in Table 3.

Flood discharge monitoring was primarily focused on the Upstream Casserly Creek site, which has been shown in previous monitoring years to be the major source of inflow to College lake (cbec, 2019a; cbec, 2019b).

Table 3 – Discharge Measurements

Location	Date/Time	Stage (ft, NAVD88)	Flow (cfs)
Casserly Creek Upstream	11/29/18 9:35	70.91	16.7
Casserly Creek Upstream	11/29/18 11:17	70.73	13.4
Casserly Creek Upstream	1/15/19 10:13	70.93	23.8
Casserly Creek Upstream	1/15/19 14:43	71.61	73.1
Casserly Creek Upstream	1/16/19 14:58	71.31	44.8
Casserly Creek Upstream	1/16/19 16:43	71.27	44.2
Casserly Creek Upstream	3/5/19 13:38	70.32	42.5
Casserly Creek Upstream	3/7/19 8:32	70.89	86.7
Casserly Creek Upstream	3/14/19 7:57	70.11	26.7
Casserly Creek Upstream	3/18/19 8:04	69.85	16.3
Casserly Creek Upstream	4/26/19 7:53	69.35	3.8
Casserly Creek Upstream	7/19/19 10:09	69.31	1.4
Fairgrounds Creek	1/15/2019 12:23	85.75	2.0
Fairgrounds Creek	3/5/2019 11:42	85.74	2.7
Fairgrounds Creek	3/6/2019 7:39	86.92	43.2
Fairgrounds Creek	3/6/2019 11:48	86.21	9.0
Paulsen Creek	1/15/2019 11:15	65.59	6.3
Paulsen Creek	3/5/2019 9:34	65.05	1.0
Paulsen Creek	3/6/2019 10:53	65.21	3.4
Pinto Creek	1/15/2019 13:29	71.20	5.7
Pinto Creek	3/5/2019 10:33	71.14	9.5
Pinto Creek	3/6/2019 9:50	71.32	18.8

Stage at the Pump House showed a maximum lake elevation of 68.72 ft (NAVD88) on February 15, 2019 at 7:00 AM. Using this elevation, the maximum inundation extents of College Lake were estimated (Figure 2). Based on the hypsometric relationships, the maximum storage and inundation area of the lake were approximately 3,973 acre-feet (AF) and 426 acres, respectively.

3.1 Monitoring Challenges

Sediment deposition in the creek channels in the vicinity of the gages caused issues with some of the monitoring data for this period, particularly after the March downloads. It appears that sediment deposited around and accumulated within the stilling wells where the instruments are deployed. Following the March 11, 2019 download at the Paulsen Creek site, the gage was placed over a half of foot higher after downloading. Presumably it was sitting on top of sediment deposited in the pipe, rather than hanging at the correct deployment elevation. The gage at the Casserly Creek Downstream location went dry after the gage download on March 11, 2019, and the gage at Casserly Creek Upstream went dry on March 15, 2019 after the gage download. Casserly Creek was still flowing at the time, so it is hypothesized that similar to the Paulsen Creek gage, the instruments were not able to be lowered to their original elevation due to the accumulation of sediment in the stilling wells.

In addition to sediment accumulation in the channel at the Upstream Casserly Creek gage, the channel experienced a berm breach sometime between January 16, 2019 and February 28, 2019. Photos taken by Santa Cruz County staff on February 26, 2019 clearly show the breach, as well as accumulation of sediment near the staff plate (see Figure 3).

3.2 Stage-Discharge Relationships, Measured Stage and Estimated Discharge

New stage discharge relationships were developed using measurements collected in WY 2019 for all sites except for the Casserly Creek Downstream site, which was excluded due to known out of bank issues first identified in WY 2017 (cbec, 2019a). Power curves were fit to the data collected, and the curves were adjusted to minimize the root mean squared error between the measured and estimated flows.

3.2.1 Casserly Creek Upstream

Two curves were developed for the Casserly Creek Upstream site – one pre-berm breach, and one post-berm breach. Table 4 describes the two equations, and Figure 4 shows the two rating curves along with the individual discharge measurements taken. Of the 12 individual discharge measurements collected in WY 2019, 86.7 cfs was the highest measured flow rate. The higher flow measurements shown in Figure 4 were collected in February 2017.

Table 4 – Casserly Creek Upstream Stage-Discharge Equations

Condition	Period	Stage-Discharge Equation*	R^2 value
Before berm breach	Prior to 2/17/2019 0:15	$Q = 56.47(H - 70.44)^{1.29}$	0.996
After berm breach	After 2/17/2019 0:15	$Q = 34.70(H - 69.19)^{1.41}$	0.995

** where Q = flow in cfs, H = water surface elevation, feet (NAVD88). Values have been truncated.*

Figure 5 shows the measured water surface elevation at the Casserly Creek Upstream site and daily average precipitation recorded at Watsonville Waterworks. Figure 6 shows the resulting estimated discharge at the Casserly Creek Upstream site, along with daily precipitation recorded at Watsonville Waterworks and the time assumed for the berm breach.

3.2.2 Fairgrounds Creek

A new curve was developed for Fairgrounds Creek, using the four measurements collected in WY 2019, which were combined with the seven previous measurements collected in 2016. Table 5 provides the rating curve equation used, and Figure 7 shows the rating curve along with the individual discharge measurements. Figure 8 shows the measured water surface elevation at the Fairgrounds Creek site and daily average precipitation recorded at Watsonville Waterworks. Figure 9 shows the resulting estimated discharge at the Fairgrounds Creek site, along with daily precipitation recorded at Watsonville Waterworks.

3.2.3 Paulsen Creek

A new curve was developed for Paulsen Creek using the three measurements collected in WY 2019, which were combined with the seven previous measurements collected in 2016. Table 5 provides the rating curve equation used, and Figure 10 shows the rating curve along with the individual discharge

measurements taken. Figure 11 shows the measured water surface elevation at the Paulsen Creek site and daily average precipitation recorded at Watsonville Waterworks. Figure 12 shows the resulting estimated discharge at the Paulsen Creek site, along with daily precipitation recorded at Watsonville Waterworks.

Table 5 – Fairgrounds, Paulsen, and Pinto Creeks Stage-Discharge Equations

Location	Stage-Discharge Equation*	R^2 value
Fairgrounds Creek	$Q = 16.20(H - 85.32)^{2.03}$	0.984
Paulsen Creek	$Q = 2.65(H - 64.24)^{1.86}$	0.978
Pinto Creek	$Q = 7.32(H - 70.15)^{4.82}$	0.454

** where Q = flow in cfs, H = water surface elevation, feet (NAVD88). Values have been truncated.*

3.2.4 Pinto Creek

A new curve was developed for Pinto Creek, utilizing only the three discharge measurements collected in WY 2019. This was based on the determination that sediment accretion or debris accumulation had occurred in the channel reducing the conveyance. The previous measurements are provided purely for reference to illustrate this change in conveyance at intermediate flow rates. It is interesting to note that the lowest (3.9 cfs) and highest (68.8 cfs) previous flow measurements both match the new rating curve well even though they were not included in the data set used to develop the new rating curve. The low correlation coefficient (R^2) for the new rating curve is explained by the low sample size and the spread of the data. Table 5 provides the rating curve equation used, and Figure 13 shows the rating curve along with all discharge measurements for this site. Figure 14 shows the measured water surface elevation at the Pinto Creek site and daily average precipitation recorded at Watsonville Waterworks. Figure 15 shows the resulting estimated discharge at the Pinto Creek site, along with daily precipitation recorded at Watsonville Waterworks.

3.2.5 Salsipuedes Creek

A rating curve was not developed for the Salsipuedes Creek site, because of bidirectional flow and backwater resulting from Corralitos Creek. Figure 16 shows the measured water surface elevation at the Salsipuedes Creek site and daily average precipitation recorded at Watsonville Waterworks. The time that pumping was initiated in the spring is also shown. In addition, while not labelled the point that College Lake pumping was stopped in mid-November is also apparent through the reduction of water surface elevation due to reduced hydrologic inputs to this reach while College Lake began to fill.

3.2.6 Pump House

A rating curve was not developed for the Pump House site, because of bidirectional flow and backwater resulting from Corralitos Creek. Figure 17 shows the measured water surface elevation at the Salsipuedes Creek site and the estimated volume of water stored in College Lake. The time that pumping was initiated is also shown.

3.3 Water Budget for College Lake

Total storage in College Lake was estimated based on the water surface elevation recorded at the Pump House and the hypsometric curve previously developed by cbec (2014) (Figure 17). The maximum storage for the 2019 water year, approximately 3,970 AF, occurred on February 15, 2019.

Discharge volumes were computed for each gaged tributary to College Lake using the measured stage data and the corresponding stage-discharge relationships. Additional inflow to College Lake, primarily assumed to be backflow from Corralitos Creek travelling upstream through Salsipuedes Creek, was calculated via mass balance. Due to issues with the stage record at the Casserly Creek Upstream site, the water budget analysis was truncated to include only the November 16, 2018 to March 15, 2019 period where pumping did not occur and stage data (and therefore estimated discharge) exists for the largest source of water (i.e., Casserly Creek) to College Lake. As demonstrated by the stage and discharge records for the other gaging sites, this period captured all significant runoff events, although did miss low flow conditions following

The breakdown of estimated inflow to College Lake (Figure 18) showed similar trends to the previous years (cbec, 2017; cbec, 2019a; cbec 2019b). A majority of the water coming into College Lake was from Casserly Creek (74%). Other sources (i.e., upstream flow from Corralitos Creek, local runoff, and direct rainfall) accounted for the second largest amount (17%). Fairgrounds Creek accounted for 5% of the inflow, Paulsen Creek accounted for 3% of inflow, while Pinto Creek accounted for 1% of the inflow to College Lake. Pinto Creek flows were only accounted for when flow was towards College Lake (i.e., stage at Salsipuedes creek – Gage #3 – was greater than the weir elevation [60.1 ft] and greater than the stage at the Pump House – Gage #1).

4 RECOMMENDATIONS

cbec recommends that monitoring continue in the College Lake system. The monitoring infrastructure is already in place, and the data are a valuable resource for planning efforts related to the College Lake Integrated Resources Management Project.

If PV Water wishes to reduce the resources dedicated to monitoring, cbec would suggest that the gage on Pinto Creek be considered for removal. Pinto Creek only flows into College Lake during backflow events on Salsipuedes Creek and has accounted for less than 2% of total inflow to College Lake in the past four years. In addition, changes in channel geometry warrant additional measurements to solidify the rating curve, which will increase monitoring costs. However, if Pinto Creek flows are considered relevant for discharges to Salsipuedes Creek downstream of College Lake, then it is recommended that monitoring continue.

The gaging at Casserly Creek should continue, as most of the inflow to College Lake occurs on Casserly Creek. During large water years, such as those occurring in water years 2017 and 2019, special attention should be given to sedimentation occurring at the gaging site, as well as more frequent downloads to be sure that good data are being collected. If it is determined that the transducer is no longer submerged, efforts must be made to move the transducer and well pipe. Additional staff plates may be necessary in a deeper part of the channel in order to record a valid measurement.

All stilling wells should be inspected for sedimentation and should be cleaned/flushed after every download. If the pressure transducers are no longer in the low flow channel, the location of the stilling well should be moved.

Additionally, cbec recommends that monitoring be conducted concerning bank erosion and sediment aggradation in Casserly Creek. The accumulation of material in channel can lead to a loss of conveyance capacity in the channel and increased likelihood of out of bank flows. This can impact agriculture, fish passage, and vehicular accessibility via Paulsen Road.

5 REFERENCES

cbec, inc. 2014. College Lake Multi-Objective Management Project Final Report Prepared for Resource Conservation District of Santa Cruz County, with assistance from Mike Podlech and Gary Kittleson. Submitted November 14, 2014.

cbec, inc. 2017. Technical Memorandum – College Lake Hydrologic Monitoring for Water Year 2016 – Hydrologic Monitoring Results Summary. Prepared for PWMA. Santa Cruz, CA.

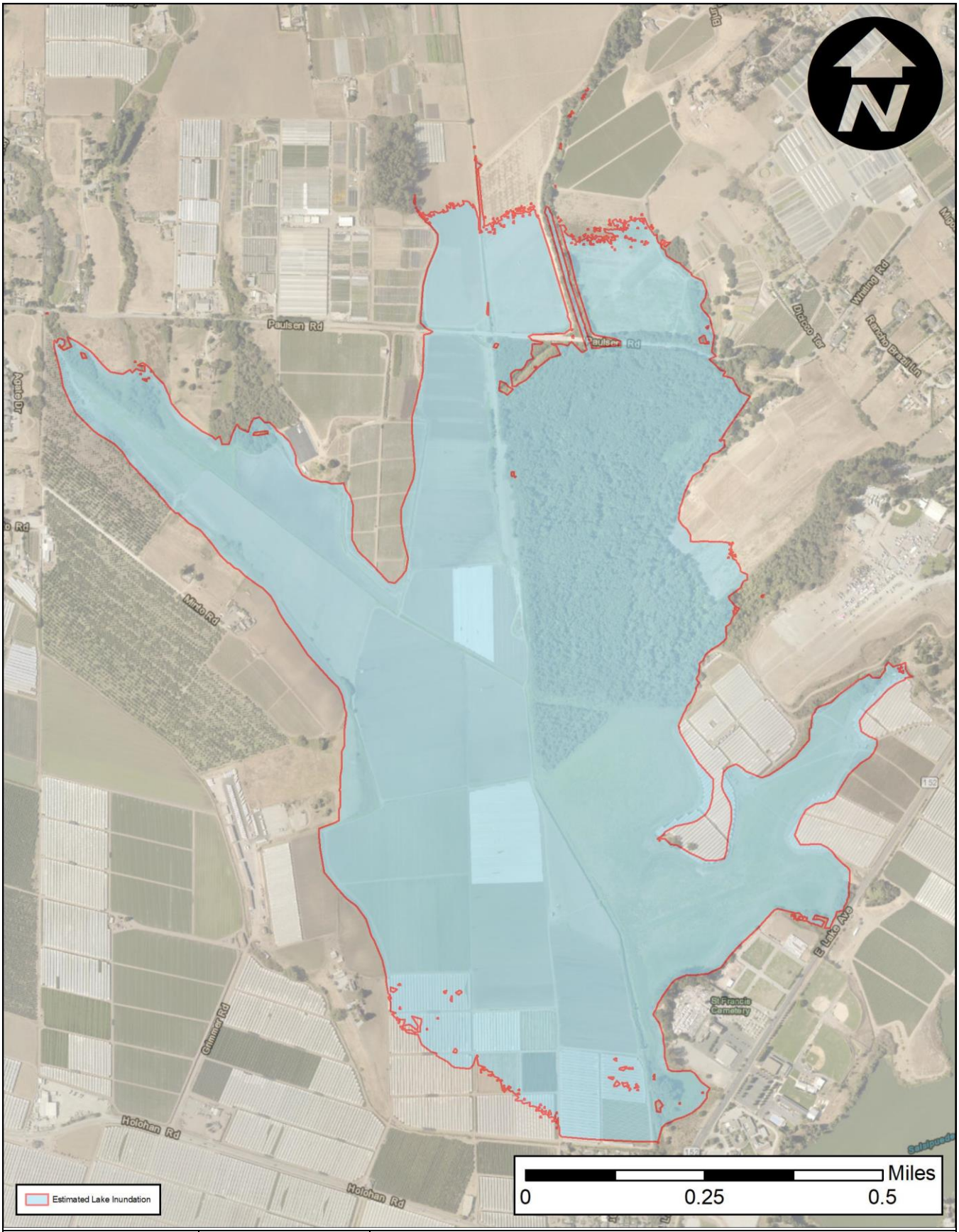
cbec, inc. 2019a. Technical Memorandum – College Lake Hydrologic Monitoring for Water Year 2017. Prepared for PVWMA. Santa Cruz, CA.

cbec, inc. 2019b. Technical Memorandum – College Lake Hydrologic Monitoring for Water Year 2018. Prepared for PVWMA. Santa Cruz, CA.

NOAA – California Nevada River Forecast Center. 2019. Monthly Precipitation Summary Water Year 2019. https://www.cnrfc.noaa.gov/monthly_precip_2019.php. Accessed February 20, 2020.

6 FIGURES

Notes:	cbec eco engineering	*College Lake Hydrologic Monitoring for Water Year 2019* **Gaging Sites**		
		Project No. 17-1003-3	Created By: CMC	**Figure 1**



Notes: Maximum water level at pump house = 68.72 ft at 2/15/2019 7:00 am.	cbec eco engineering	*College Lake Hydrologic Monitoring for Water Year 2019* **Estimated Maximum Inundation of College Lake**		
		Project No. 17-1003-3	Created By: CMC	**Figure 2**

Notes:

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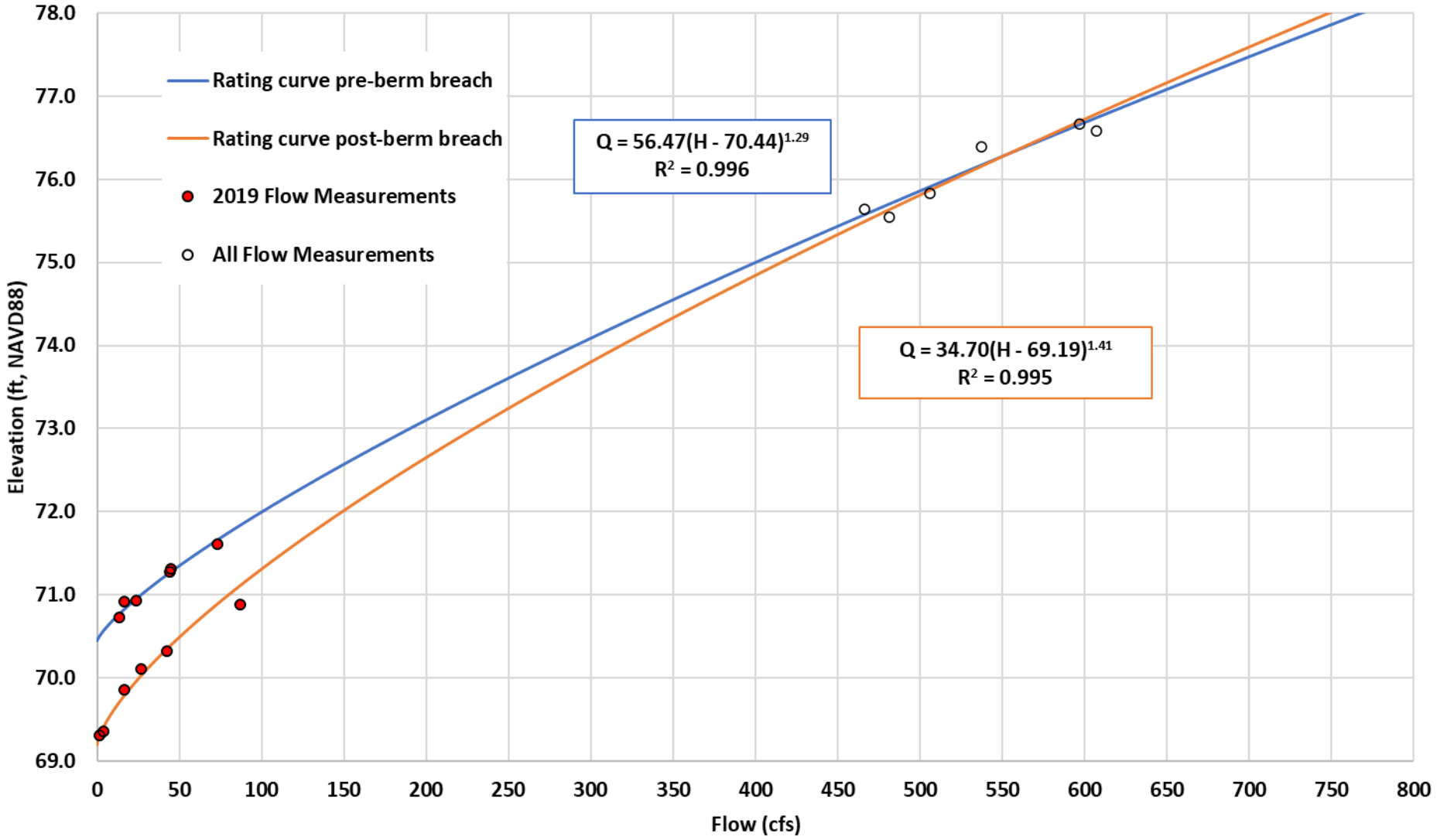
College Lake Hydrologic Monitoring for Water Year 2019

Sedimentation / Berm Failure at Casserly Creek

Project No. 17-1003-3	Created By: CMC	**Figure 3**



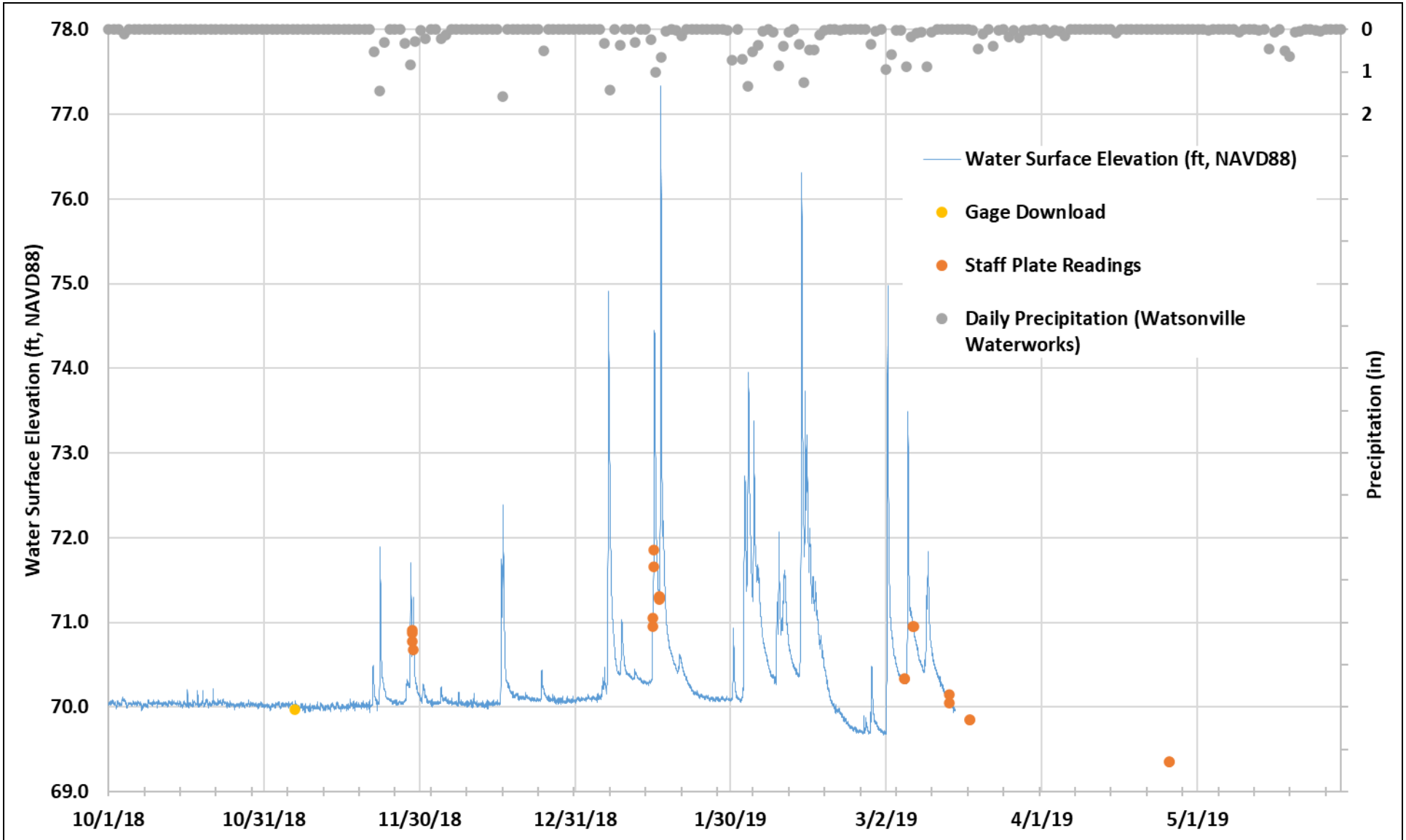
Notes:

College Lake Hydrologic Monitoring for Water Year 2019

Casserly Creek Upstream Rating Curves

Project No. 17-1003-3	Created By: CMC	**Figure 4**

9/28/2020



Notes: Data is not present after 3/15/2019 due to gage drying out.

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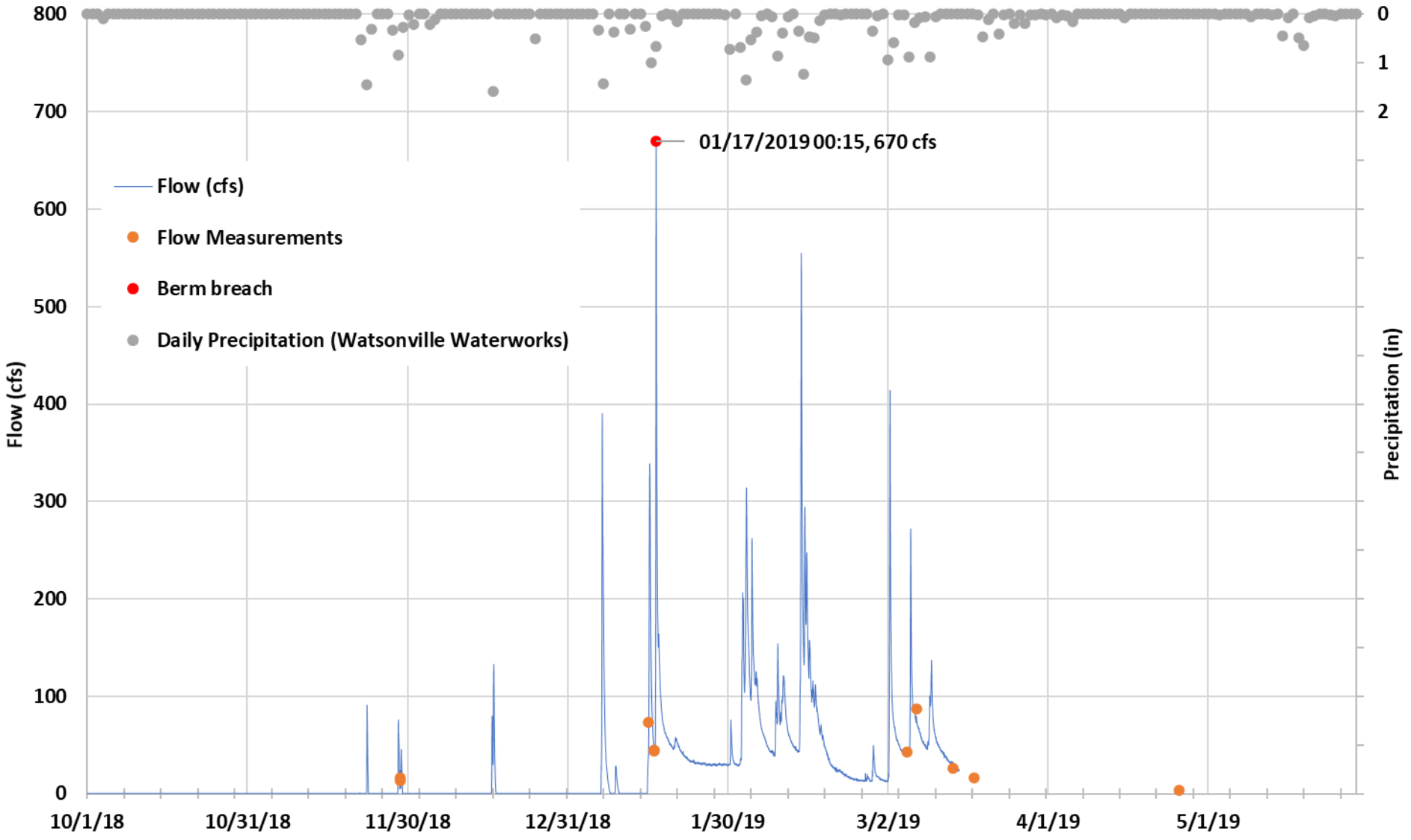
College Lake Hydrologic Monitoring for Water Year 2019

Casserly Creek Upstream Stage

Project No. 17-1003-3	Created By: CMC	**Figure 5**



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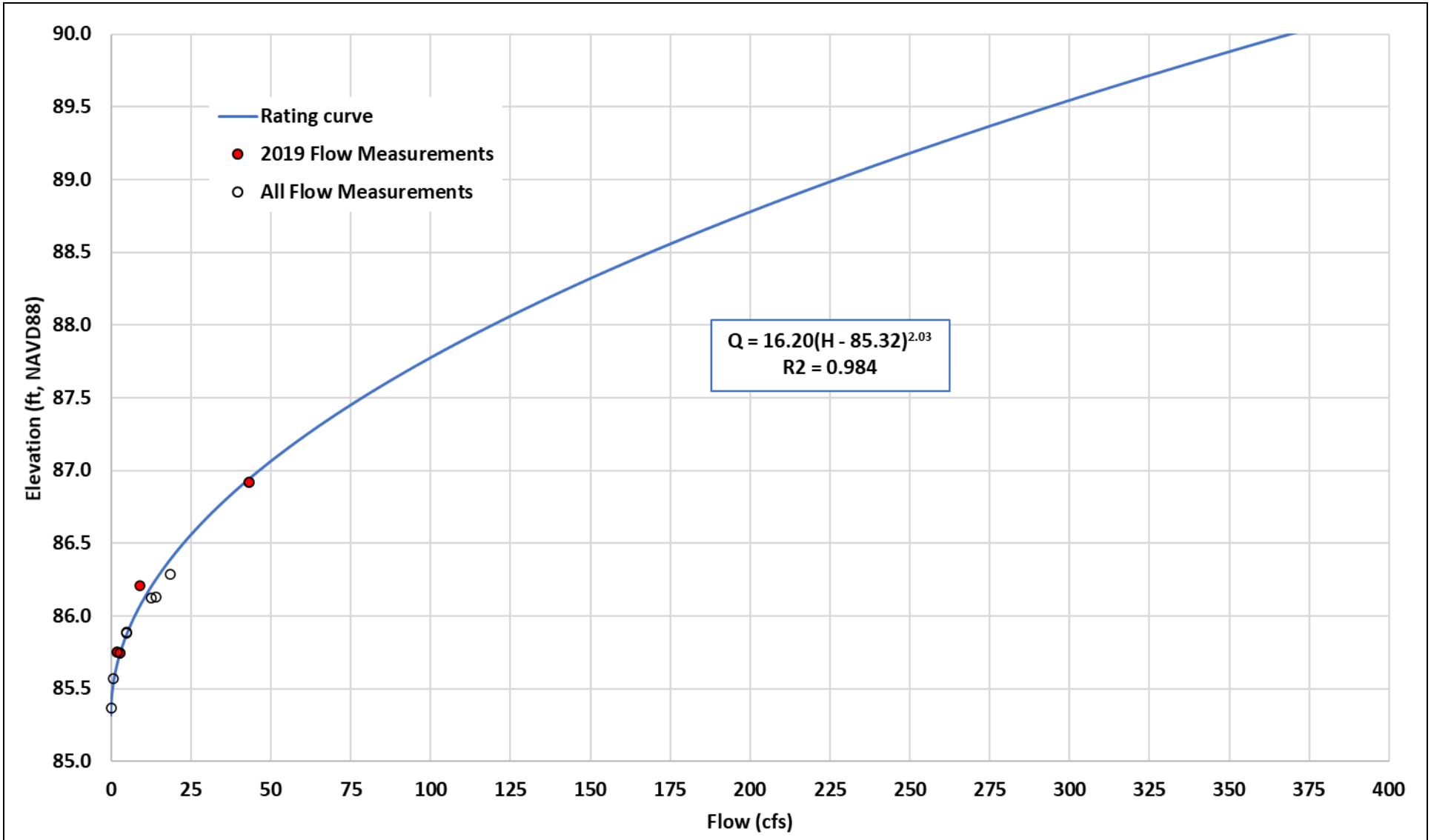
College Lake Hydrologic Monitoring for Water Year 2019

Casserly Creek Upstream Discharge

Project No. 17-1003-3	Created By: CMC	**Figure 6**



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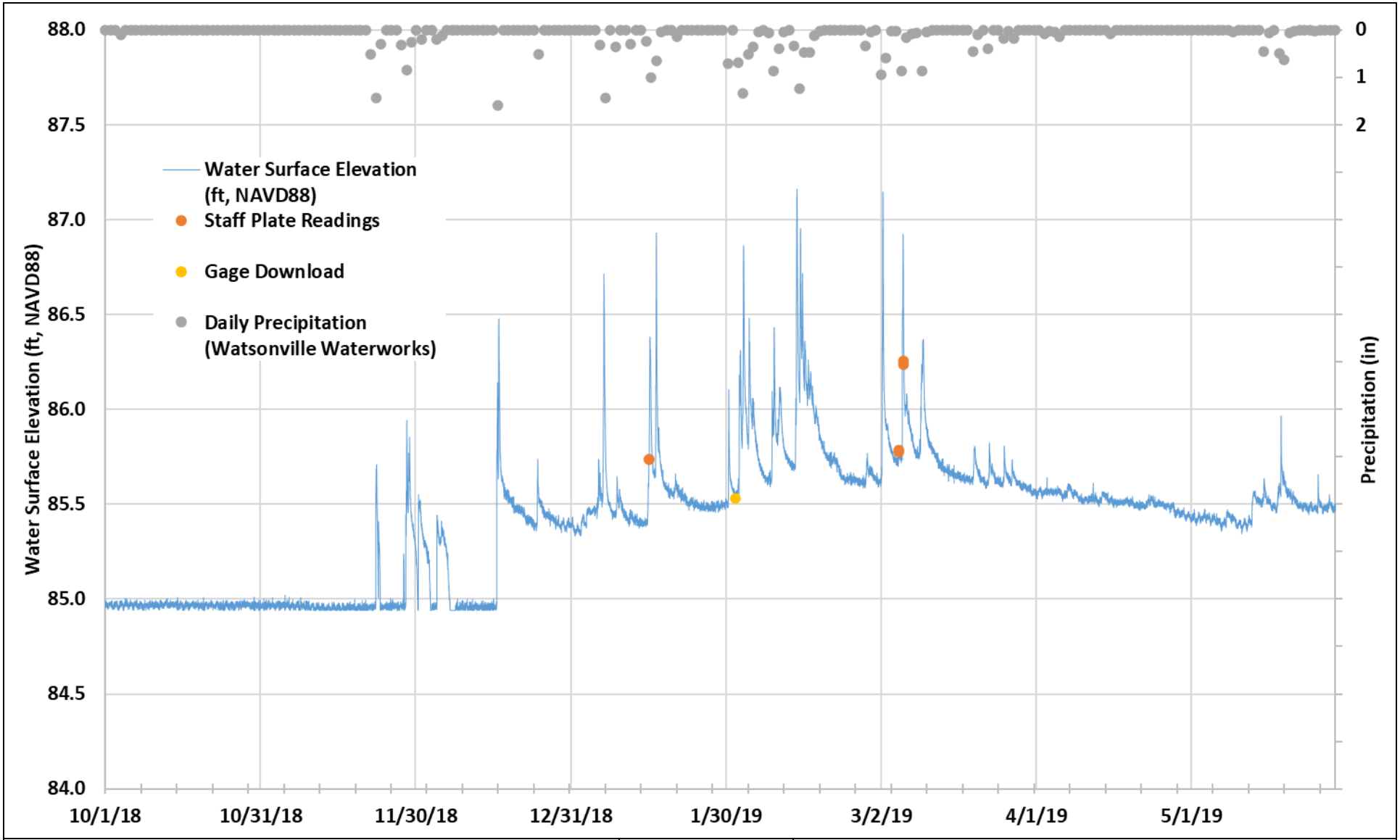
College Lake Hydrologic Monitoring for Water Year 2019

Fairgrounds Creek Rating Curve

Project No. 17-1003-3	Created By: CMC	**Figure 7**

9/28/2020



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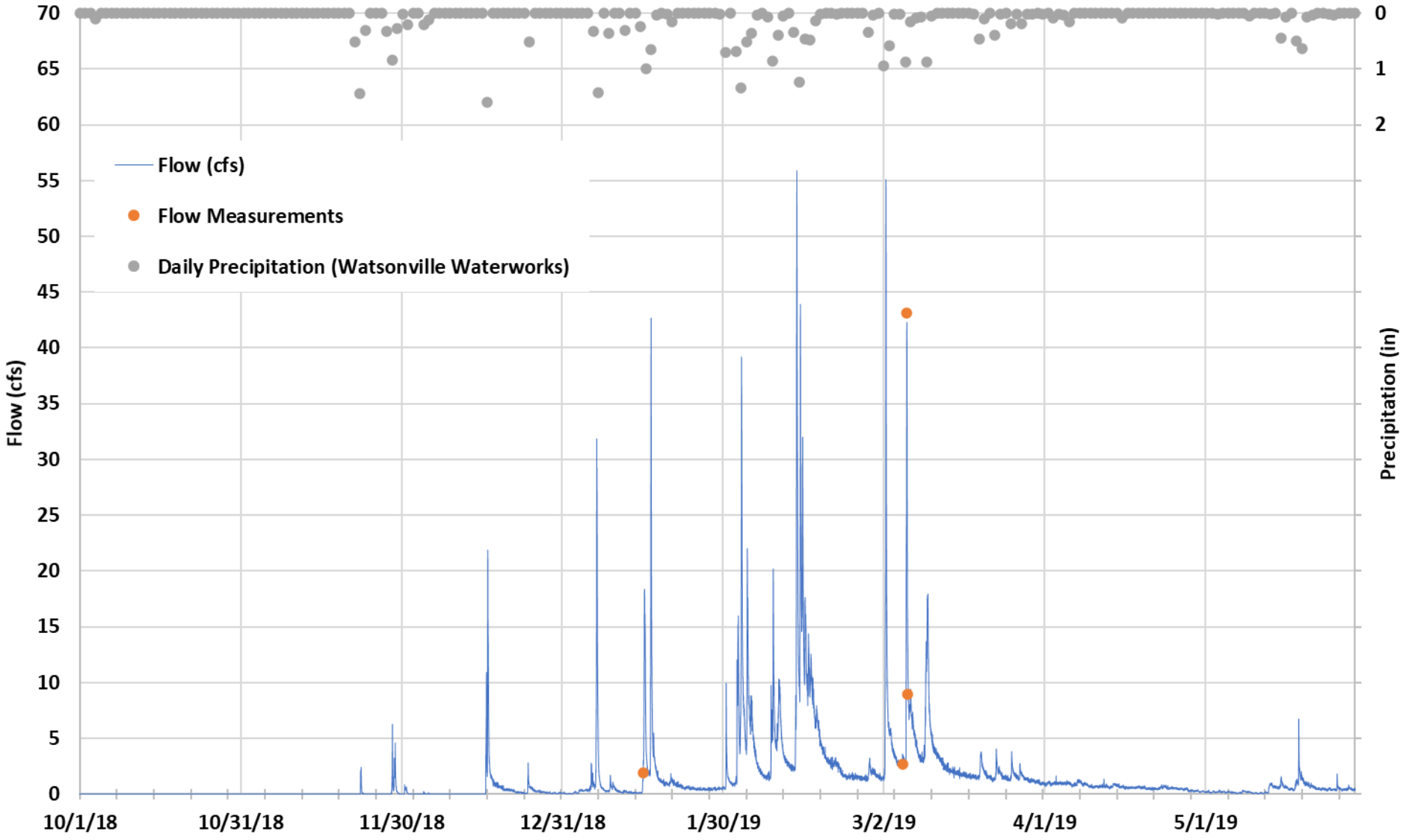
College Lake Hydrologic Monitoring for Water Year 2019

Fairgrounds Creek Stage

Project No. 17-1003-3	Created By: CMC	**Figure 8**



Notes:

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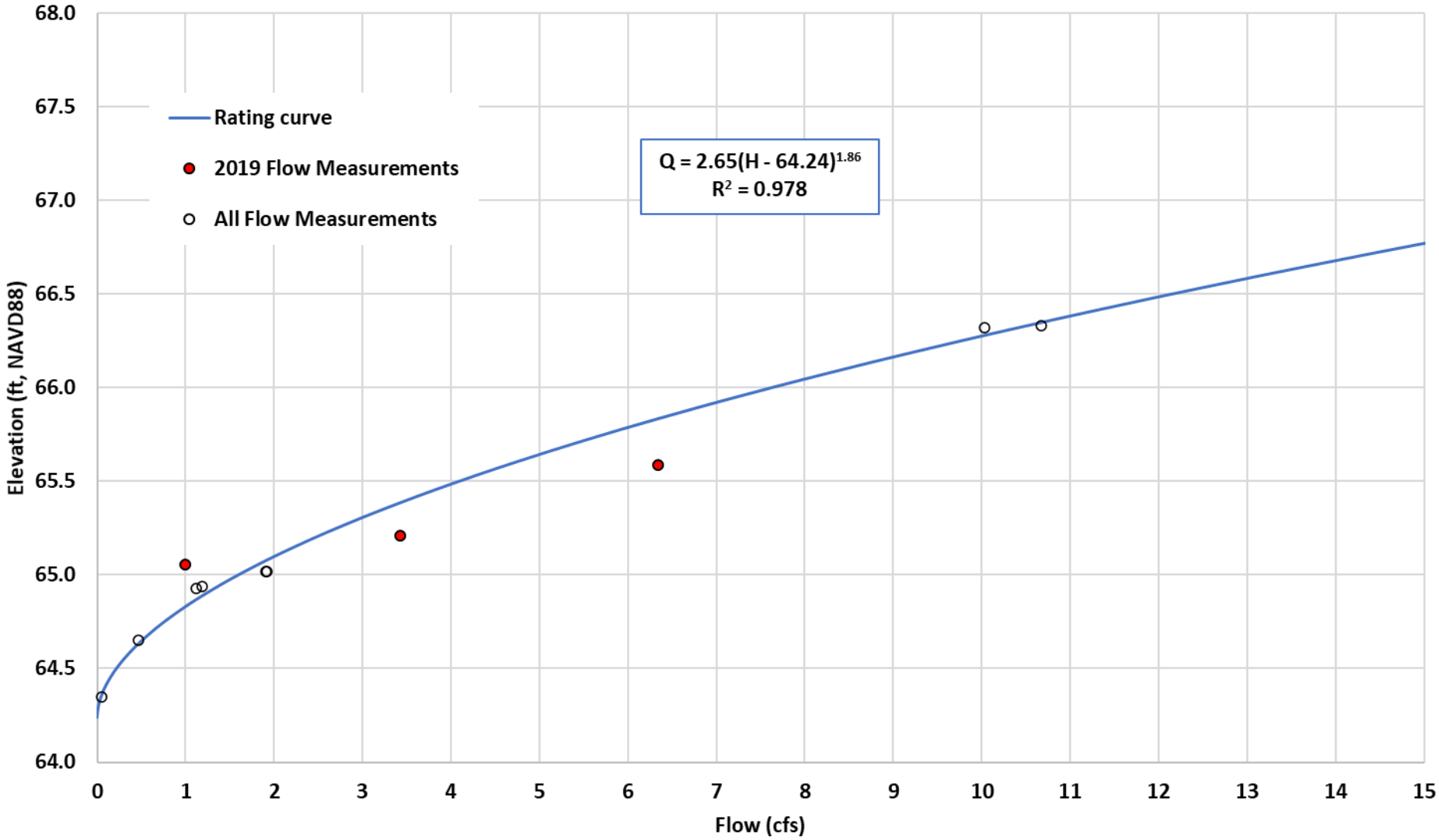
College Lake Hydrologic Monitoring for Water Year 2019

Fairgrounds Creek Discharge

Project No. 17-1003-3	Created By: CMC	**Figure 9**

9/28/2020



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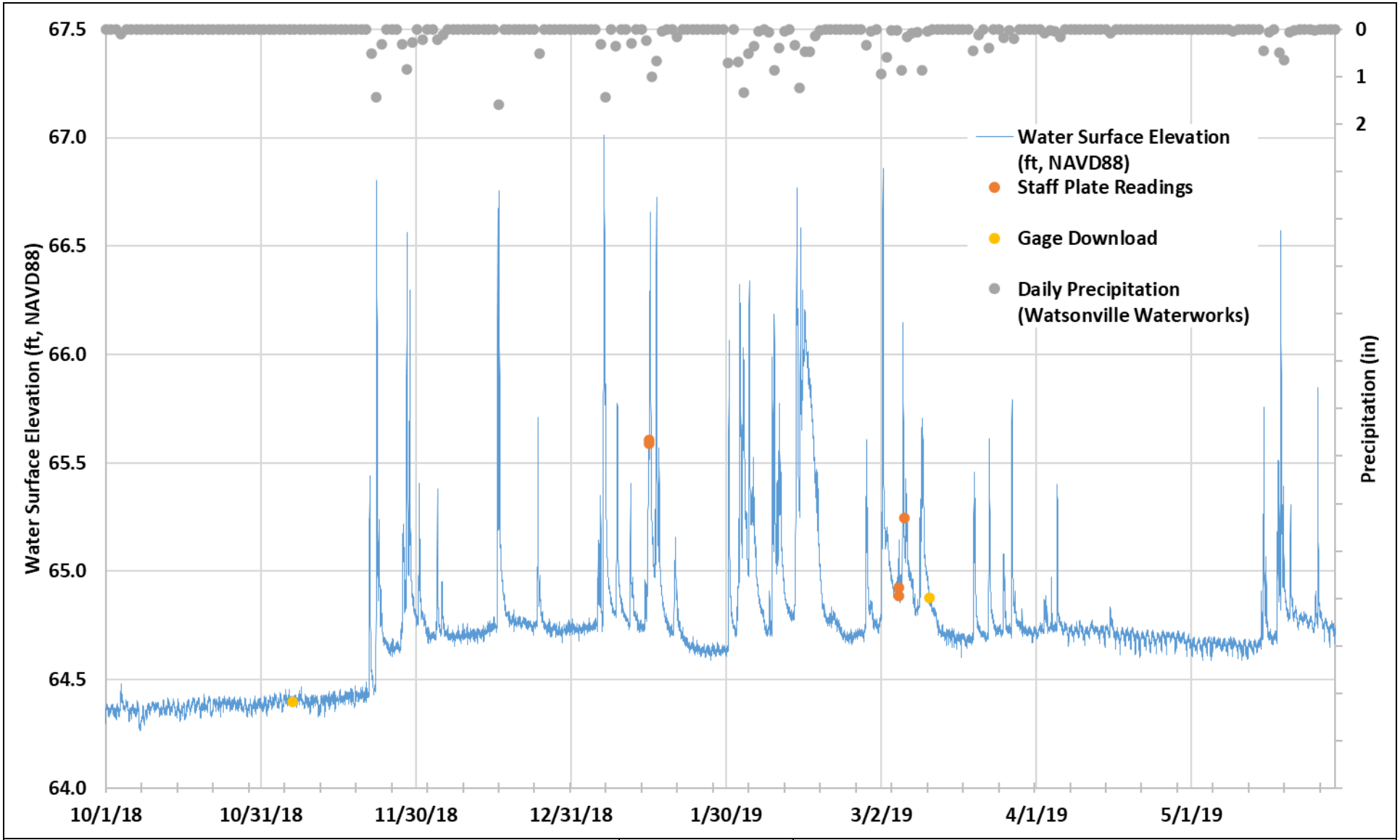
College Lake Hydrologic Monitoring for Water Year 2019

Paulsen Creek Rating Curve

Project No. 17-1003-3	Created By: CMC	**Figure 10**

9/28/2020



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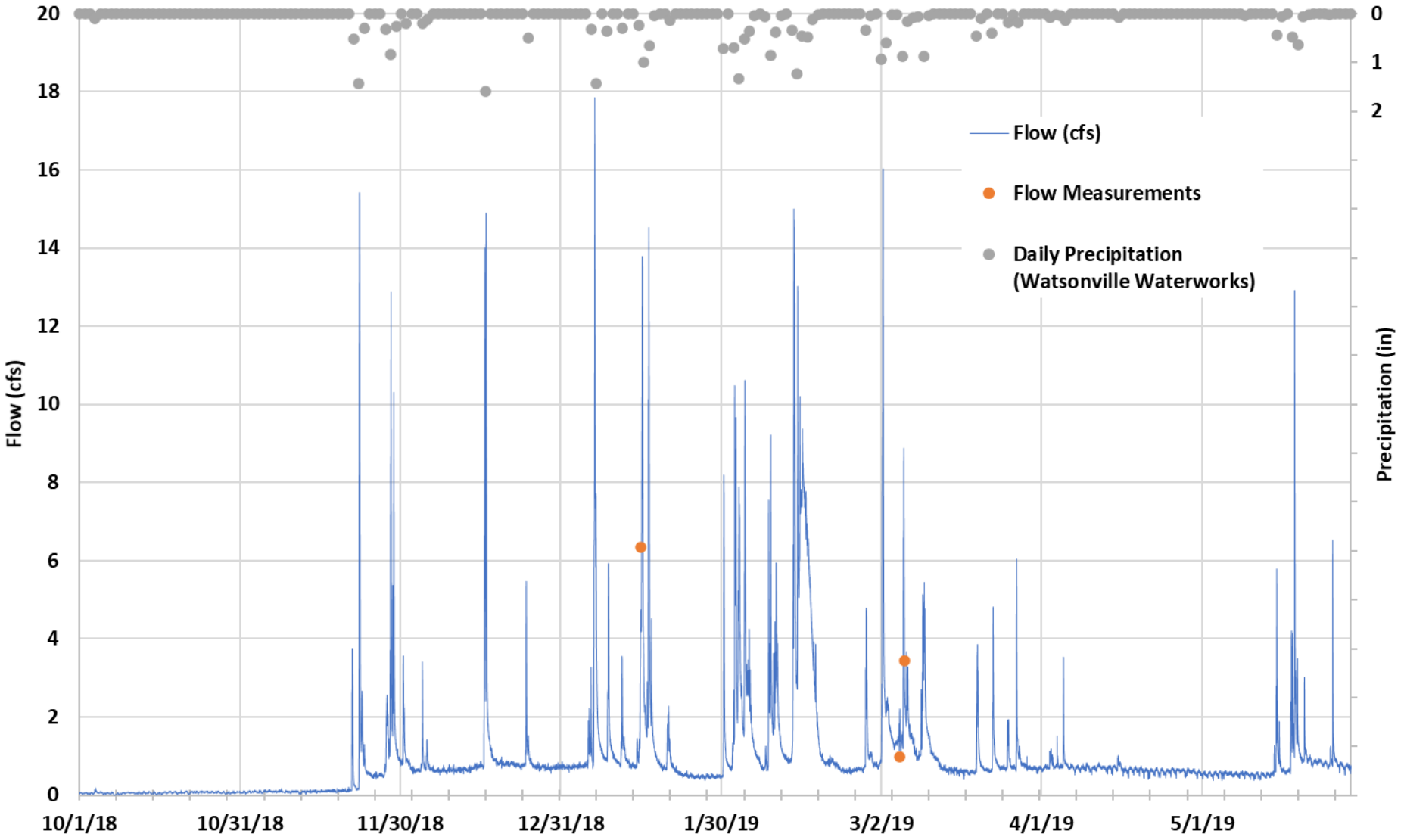
College Lake Hydrologic Monitoring for Water Year 2019

Paulsen Creek Stage

Project No. 17-1003-3 | Created By: CMC | **Figure 11**

9/28/2020



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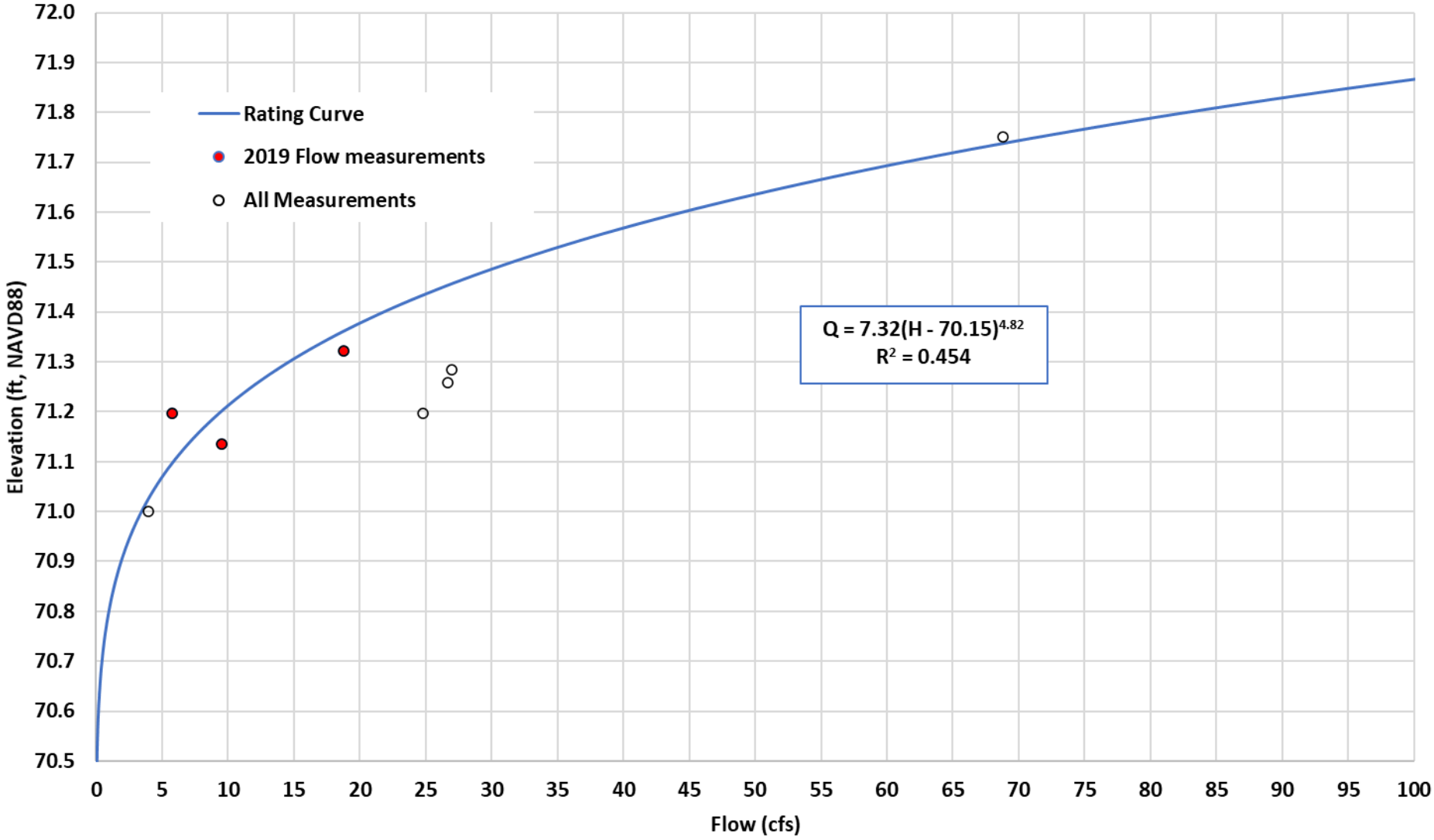
College Lake Hydrologic Monitoring for Water Year 2019

Paulsen Creek Discharge

Project No. 17-1003-3	Created By: CMC	**Figure 12**



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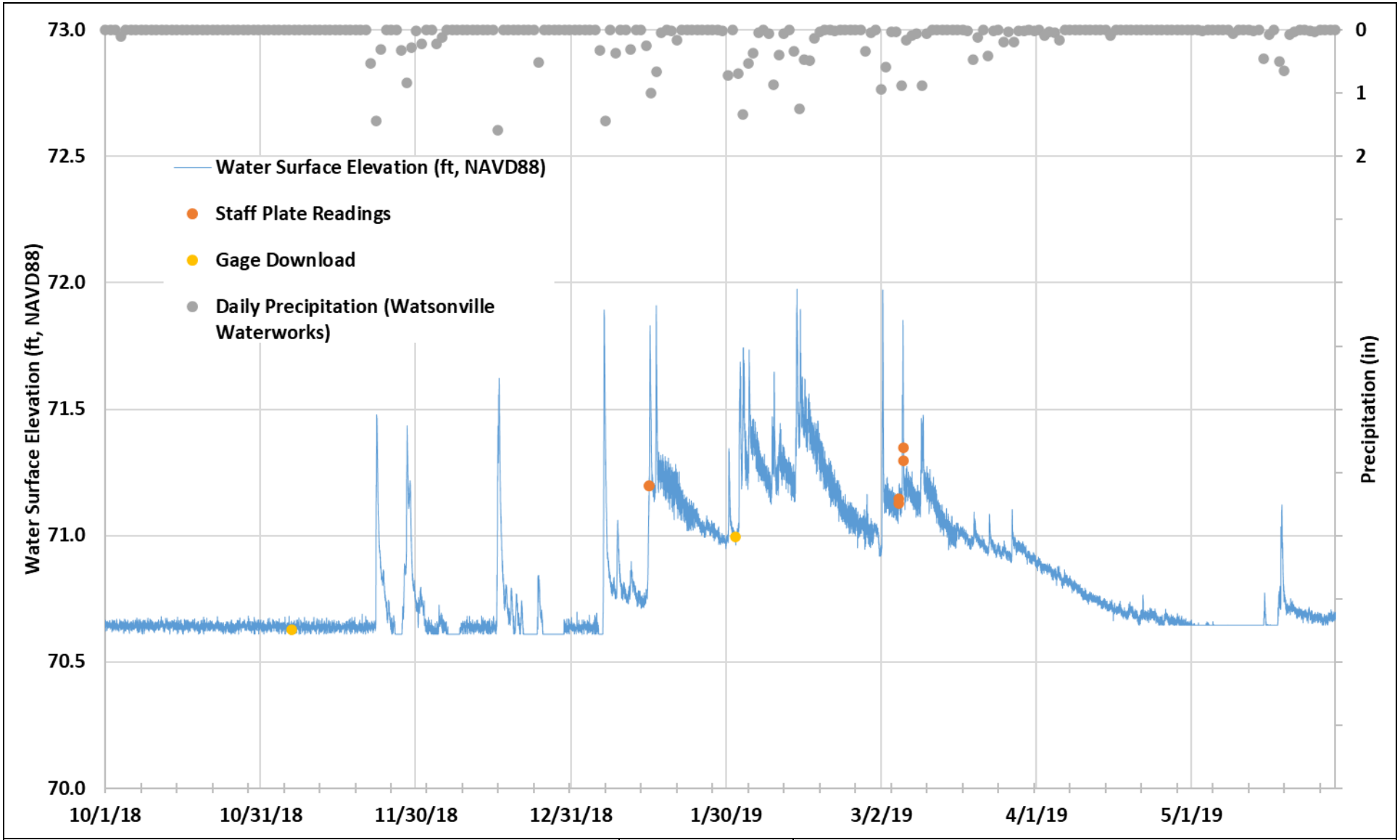
College Lake Hydrologic Monitoring for Water Year 2019

Pinto Creek Rating Curve

Project No. 17-1003-3	Created By: CMC	**Figure 13**



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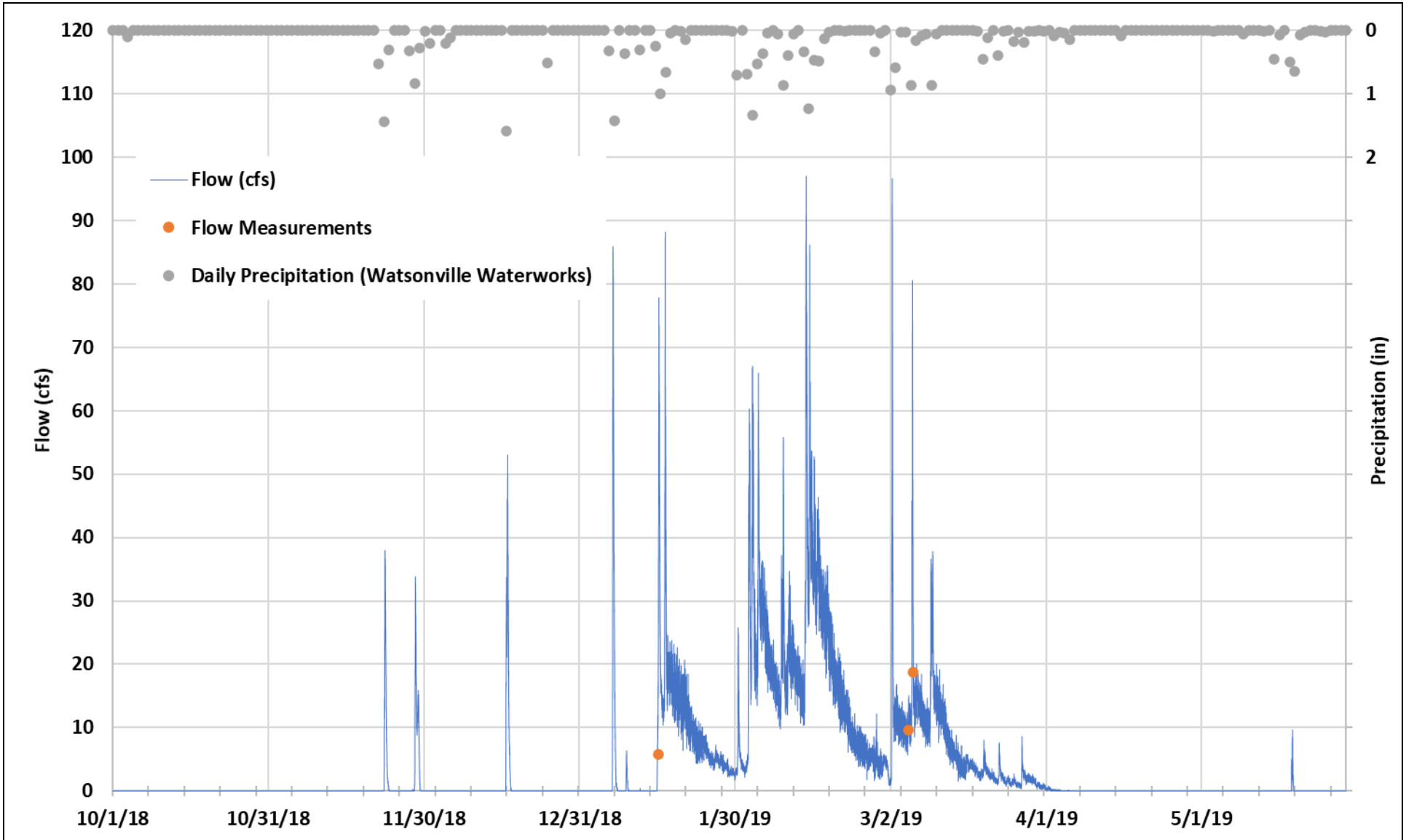
College Lake Hydrologic Monitoring for Water Year 2019

Pinto Creek Stage

Project No. 17-1003-3 | Created By: CMC | **Figure 14**



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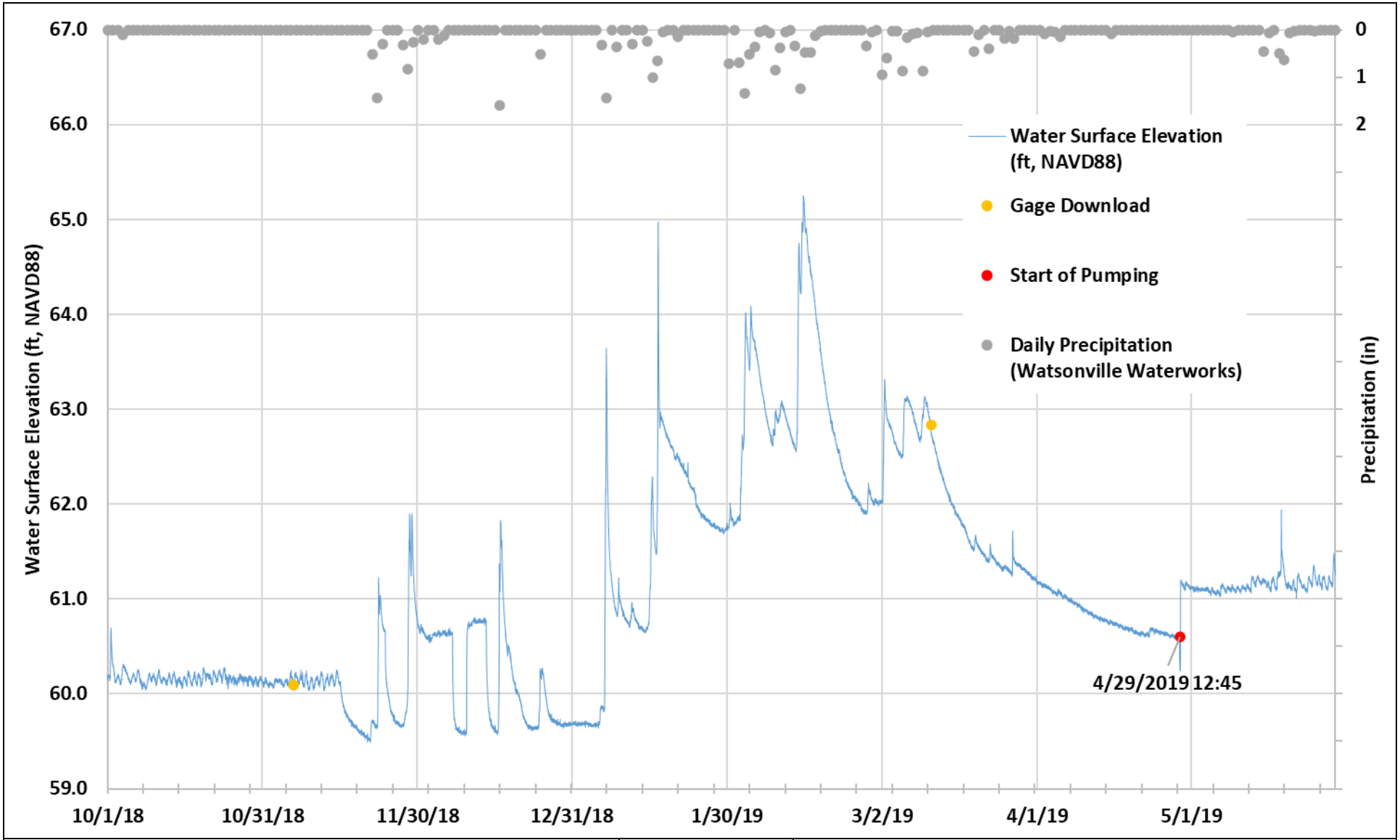
College Lake Hydrologic Monitoring for Water Year 2019

Pinto Creek Discharge

Project No. 17-1003-3	Created By: CMC	**Figure 15**



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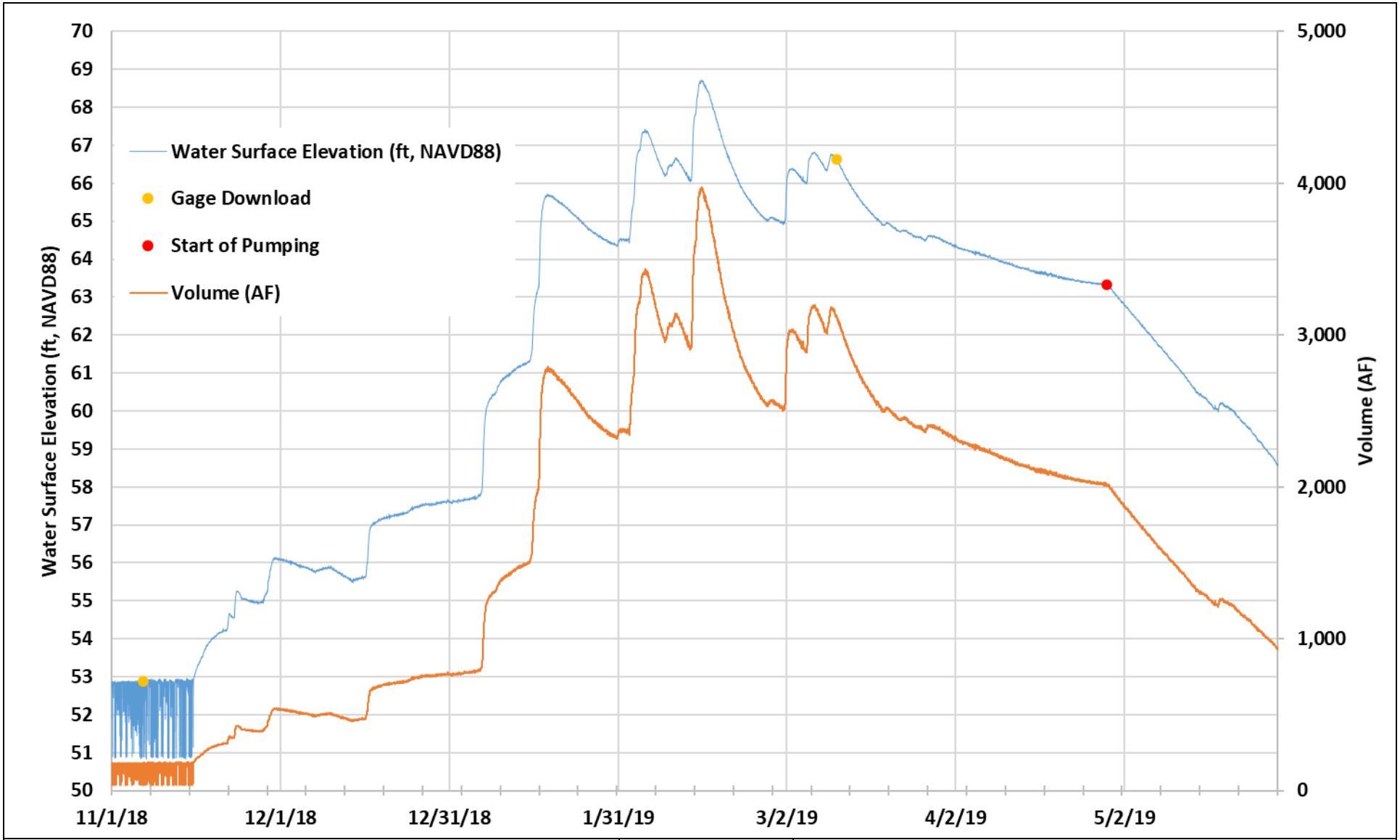
College Lake Hydrologic Monitoring for Water Year 2019

Salsipuedes Creek Stage

Project No. 17-1003-3	Created By: CMC	**Figure 16**

9/28/2020

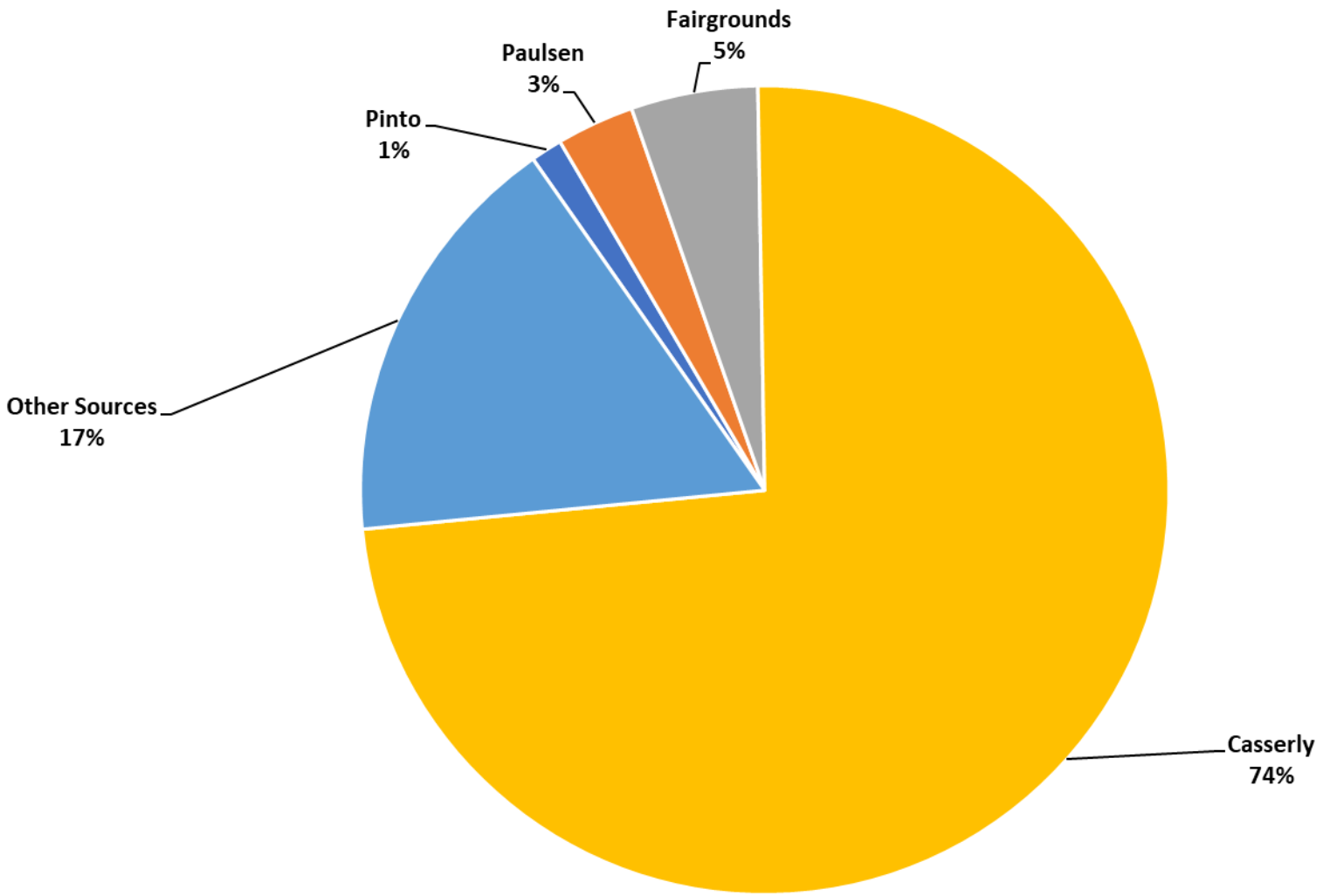


Notes:

College Lake Hydrologic Monitoring for Water Year 2019

College Lake Stage and Estimated Storage

Project No. 17-1003-3	Created By: CMC	**Figure 17**



Notes: Period of water budget analysis: 10/26/2018 - 3/15/2019.

College Lake Hydrologic Monitoring for Water Year 2019

Breakdown of Estimated Inflows to College Lake

Project No. 17-1003-3	Created By: CMC	**Figure 18**