TECHNICAL MEMORANDUM

Date:	09/20/2023
To:	Floodplains Reimagined Program Team
From:	Scott Wright
Project:	Floodplains Reimagined
Subject:	Flow and stage measurements at the Sanborn Slough Bifurcation Structure

1 INTRODUCTION

Roger Swanson, the manager of the Wild Goose Club, requested technical assistance related to flows along Butte Creek and Sanborn Slough in the vicinity of the Sanborn Slough Bifurcation Structure, which is located about 0.25 miles downstream from Colusa Highway on Butte Creek (Figure 1). Wild Goose Club is located near the north end of the Butte Sink and, along with Reclamation District 1004, has responsibility for managing the bifurcation structure. Wild Goose Club and RD 1004 manage the structure (opening and closing gates) to achieve specific flow splits between Butte Creek and Sanborn Slough during different times of the year. The bifurcation structure has three mechanisms for passing flow downstream: 1) a fish ladder that continuously passes flow; 2) three, five-foot diameter gated culverts, and 3) an overflow weir/spillway that activates at about 5.6 ft on the BTG gage. Quantitative information on the flow splits among the three mechanisms for passing flow is lacking, as no measured flow data have been available. To address this data gap, cbec conducted flow and stage measurements on Butte Creek and Sanborn Slough in the vicinity of the bifurcation structure during late 2022 and early 2023. This Technical Memorandum presents the results of these measurements.

2 FLOW MEASUREMENTS

2.1 METHODS

Six sets of flow measurements were made at three cross-sections bracketing the bifurcation structure between November 4, 2022, and February 15, 2023. During each site visit, measurements were made at: 1) a cross-section on Butte Creek upstream from the structure, 2) a cross-section downstream from the structure on Butte Creek and, 3) a cross-section on Sanborn Slough downstream from the structure (Figure 1). On two site visits, measurements were made at only two of the sites due to time limitations and the inability to safely access the Sanborn Slough site. For these site visits, flow at the third site was computed from the other two as described in the following section.

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Standard methods for measuring flows in channels with Acoustic Doppler Current Profilers (ADCP) were employed (Mueller et al, 2013). A River Pro 1200 kHz ADCP (RD Instruments) was deployed on an unmanned trimaran towed across the channel with a kayak or from a tagline. Boat position, speed, and direction were measured with continuous RTK-GPS integrated with the ADCP. At each cross-section, 8 – 18 transects were conducted from bank-to-bank, resulting in exposure times ranging from 728 – 1,542 seconds (USGS recommends exposure time greater than 720 seconds). The measurements were processed with the QRev software package (Mueller, 2016) to compute measured flows. Following each flow measurement, the water-surface elevation (WSE) at the cross-section was measured with RTK-GPS.

The dates of the measurements are shown graphically in Figure 2, along with the stage record from the BTG gage (Figure 1) as well as the flow record from the Butte Creek at Durham gage, which is located about 24 miles upstream where Butte Creek emerges from the foothills. Figure 2 shows that the first three measurements were made during relatively low flow conditions prior to a series of atmospheric river events that resulted in multiple substantial runoff events on Butte Creek. The final three measurements were made during higher stage conditions when the overflow weir was activated.

2.2 RESULTS

The results of the flow and WSE measurements are shown in Figure 3 and Tables 1 – 3. Error bars shown on Figure 3 are ±5%, a typical value for flow measurements with ADCPs. Flows at the upstream Butte Creek site ranged from 222 – 1,298 cfs with a corresponding stage range of 4.6 feet; flows on Sanborn Slough ranged from 175 – 677 cfs and flows at the downstream Butte Creek site ranged from 48 – 521 cfs. Figure 3 shows that the flow split was skewed toward Sanborn Slough for all measurements, i.e. Sanborn Slough flows were greater than flows on Butte Creek downstream from the bifurcation structure during all site visits. The majority of the flow going down Sanborn Slough at this time of year is generally consistent with the guidelines followed by the Wild Goose Club and RD 1004.

As footnoted in the Tables 1 and 2, on two site visits measurements were only possible at two of the sites. For these site visits, the flow at the third site was computed from the other two assuming a volume balance around the structure; that is, the flow at the upstream site is equal to the sum of the flows at the two downstream sites. This assumption was tested using the four site visits where flows were measured at all three sites. Computing the upstream flow from the two downstream sites resulted in errors of -9%, -4%, 3% and -13% for the four site visits. These error magnitudes are consistent with errors in the individual measurements indicating the validity of the volume balance approach.

Table 1. Flow and WSE measurements at the upstream Butte Creek cross-section

Date	Flow start time	Flow end time	Flow (cfs)	WSE time	WSE (ft NAVD88)	BTG stage (ft gage datum)
11/4/2022	13:09	13:34	222	14:12	59.09	3.58
11/23/2022	--	--	223[1]	--	--	--
12/8/2022	13:20	13:42	402	13:49	59.64	4.39
1/23/2023	15:05	15:24	1298	15:50	62.68	7.50
2/2/2023	11:18	11:45	787	16:15	61.58	6.27
2/15/2023	17:46	18:03	602	18:13	60.86	5.67

[1]Not measured; computed from a flow balance with the other two sites.

Table 2. Flow and WSE measurements at the Sanborn Slough cross-section

Date	Flow start time	Flow end time	Flow (cfs)	WSE time	WSE (ft NAVD88)
11/4/2022	10:51	11:07	184	11:11	58.71
11/23/2022	15:52	16:09	175	16:16	58.86
12/8/2022	12:15	12:35	265	12:50	59.51
1/23/2023	--	--	677[1]	--	--
2/2/2023	12:35	12:58	530	13:02	61.46
2/15/2023	14:20	14:37	516	14:45	60.84

[1]Not measured; computed from a flow balance with the other two sites.

Table 3. Flow and WSE measurements at the downstream Butte Creek cross-section

Date	Flow start time	Flow end time	Flow (cfs)	WSE time	WSE (ft NAVD88)
11/4/2022	15:36	16:04	58	16:10	56.53
11/23/2022	13:56	14:23	48	14:38	56.61
12/8/2022	10:10	10:32	150	11:14	58.17
1/23/2023	13:00	13:23	621	13:48	62.13
2/2/2023	14:57	15:23	228	15:42	59.04
2/15/2023	12:31	12:48	165	13:08	57.80

2.3 FLOW SPLITS

The flow split between Butte Creek and Sanborn Slough was computed as the percentage of the upstream flow that continued down Sanborn Slough (ratio of measured flow at Sanborn Slough to measured flow at the upstream Butte Creek site). The results of this calculation are shown in Figure 4. Error bars were computing by applying the ±5% flow measurement error to the individual measurements, then computing the minimum and maximum flow split percentages.

The first two sets of measurements were collected in November 2022, prior to any significant runoff events (Figure 2) when upstream flows were 222 – 223 cfs. Under these conditions, the flow split was approximately 70% – 85% down Sanborn Slough. The third set of measurements was made in early December 2022 following a runoff event that resulted in weir activation for a short period (the measurement was after weir activation ceased). The flow split shifted slightly toward Butte Creek, with 58% – 71% of the flow going down Sanborn Slough. The final three sets of measurements were made following a series of significant runoff events leading to higher stages and extended weir activation. The weir was spilling during all three measurements, though only very slightly for the final set of measurements on February 15 (Figure 2). The measurements on January 25 had the highest flows and stages and showed an approximately equal flow split between Butte Creek and Sanborn Slough (47% – 58% down Sanborn). As flows and stages declined, the flow splits for the February 2023 measurements became more skewed towards Sanborn Slough, which is generally consistent with the operations guidelines for the structure. On February 2, the flow split was 63% – 77% down Sanborn Slough and on February 15 it was 70% – 87% Sanborn, which was nearly identical to the flow splits measured in November 2022 (prior to the high flows).

3 CONTINUOUS STAGE MEASUREMENTS

Pressure transducers were installed at the downstream Butte Creek and Sanborn Slough sites on 12/7/2022 and removed on 4/28/2023, to measure depth/stage at 15-minute increments. A pressure transducer was not installed at the upstream Butte Creek site because the BTG gage was determined to be representative of stage in the upstream reach (based on paired RTK-GPS WSE measurements at both sites). A barometric pressure transducer was also deployed on land nearby and used to correct the transducer data for atmospheric pressure. The depth data from the transducers was converted to WSE data in NAVD88 using RTK-GPS measurements of WSE at the transducer locations during site visits. The BTG gage stage was also converted to NAVD88 using a shift of +55.23 feet, which was provided to cbec by MBK Engineers; this correction was verified by cbec by surveying WSEs at the gage during site visits.

The time series of WSEs at the BTG gage, the Sanborn Slough site, and the downstream Butte Creek site are shown in Figure 5. The WSE at the Sanborn Slough site closely tracks the BTG gage WSE, with an average difference in WSE of 0.24 ft over the measurement period. The WSE difference increased at higher stages and approached about 0.6 ft at the highest stages at BTG. Elevation drops of 0.24 ft and 0.6 ft correspond to water-surface slopes of 0.00012 and 0.00032 ft/ft, respectively, over the approximately 1,900 ft between the sites.

WSEs at the downstream Butte Creek site had a wider range than at Sanborn Slough; in particular, WSEs were substantially lower during low flow conditions. When upstream flows were low, WSEs at the downstream Butte Creek site were 2 – 3 ft lower than WSEs at BTG and Sanborn Slough. As flows and stages increased, and as the overflow weir was activated, WSEs downstream on Butte Creek approached WSEs on Sanborn Slough. Thus, there is a substantial head drop across the bifurcation structure on Butte Creek during low flow conditions that becomes much less as flow increases and the weir is activated. At the highest stages measured, WSEs on Sanborn Slough and downstream on Butte Creek were approximately equal.

4 SUGGESTIONS FOR FUTURE WORK

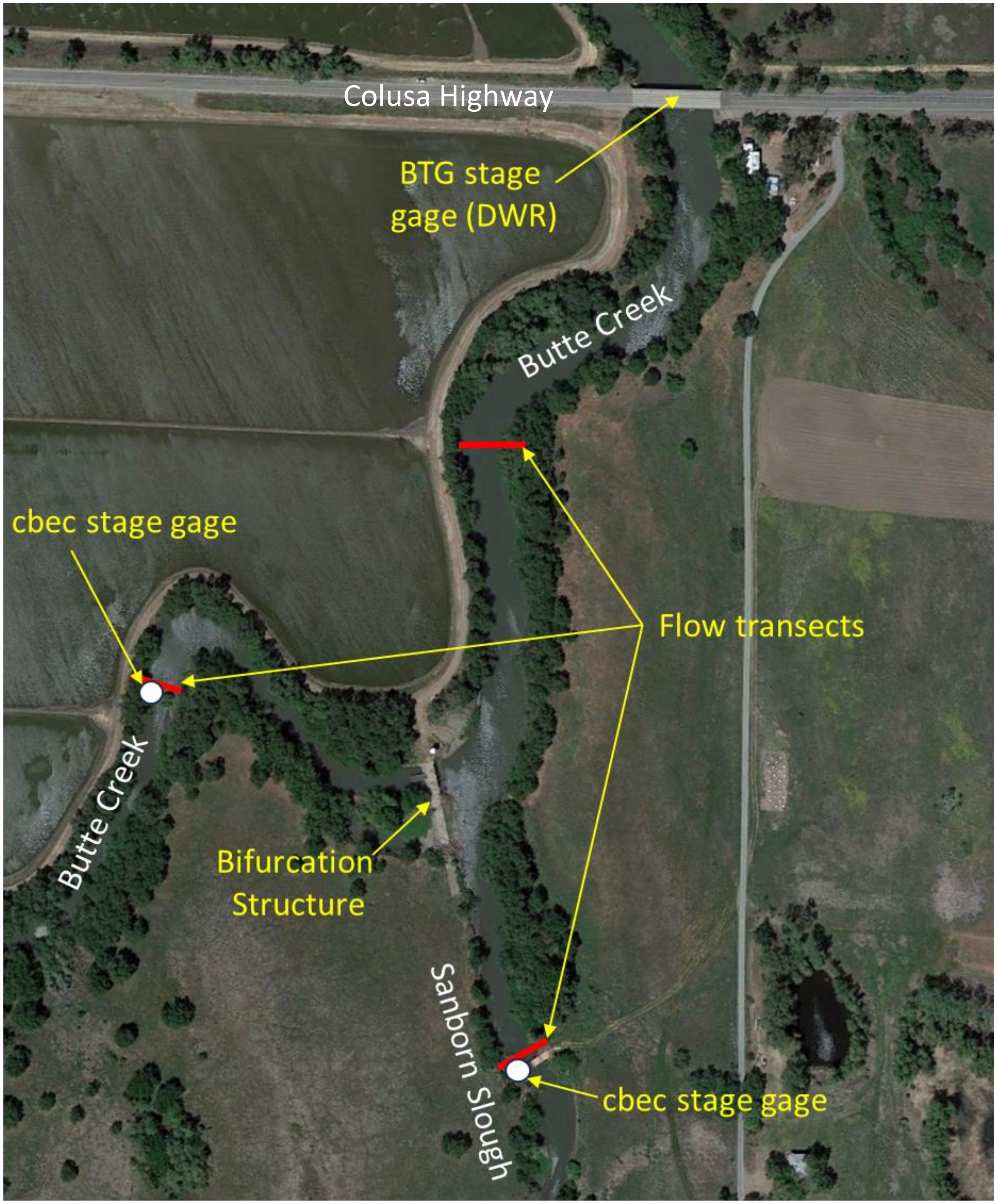
The flow and stage measurements documented herein are a good first step toward understanding the flows through the Butte Sink. However, several other structures influence the complicated flow patterns within the Sink and would benefit from further measurements and analysis, such as North Weir and End Weir, White Mallard Dam, Morton Weir, Drivers Cut Weir, Colusa Shooting Weir, and the Butte Slough Outfall Gates. A Butte Sink monitoring network, with some real-time capabilities, would benefit water managers within the Sink by providing information on inflows, flows within the Sink, and water levels/stages throughout. A monitoring network would also benefit conversations that occur within the Butte Sutter Basin Coordinated Operations Group (BSBCOG). Elements of such a network might include:

- Continuous stage and flow gages at the major structures
- Continuous stage measurements at key locations in the major channels
- Continuous stage measurements at key locations within the managed wetlands
- Continuous measurements of water temperature and other water quality constituents relevant to aquatic ecology and fish and wildlife habitat in the Sink

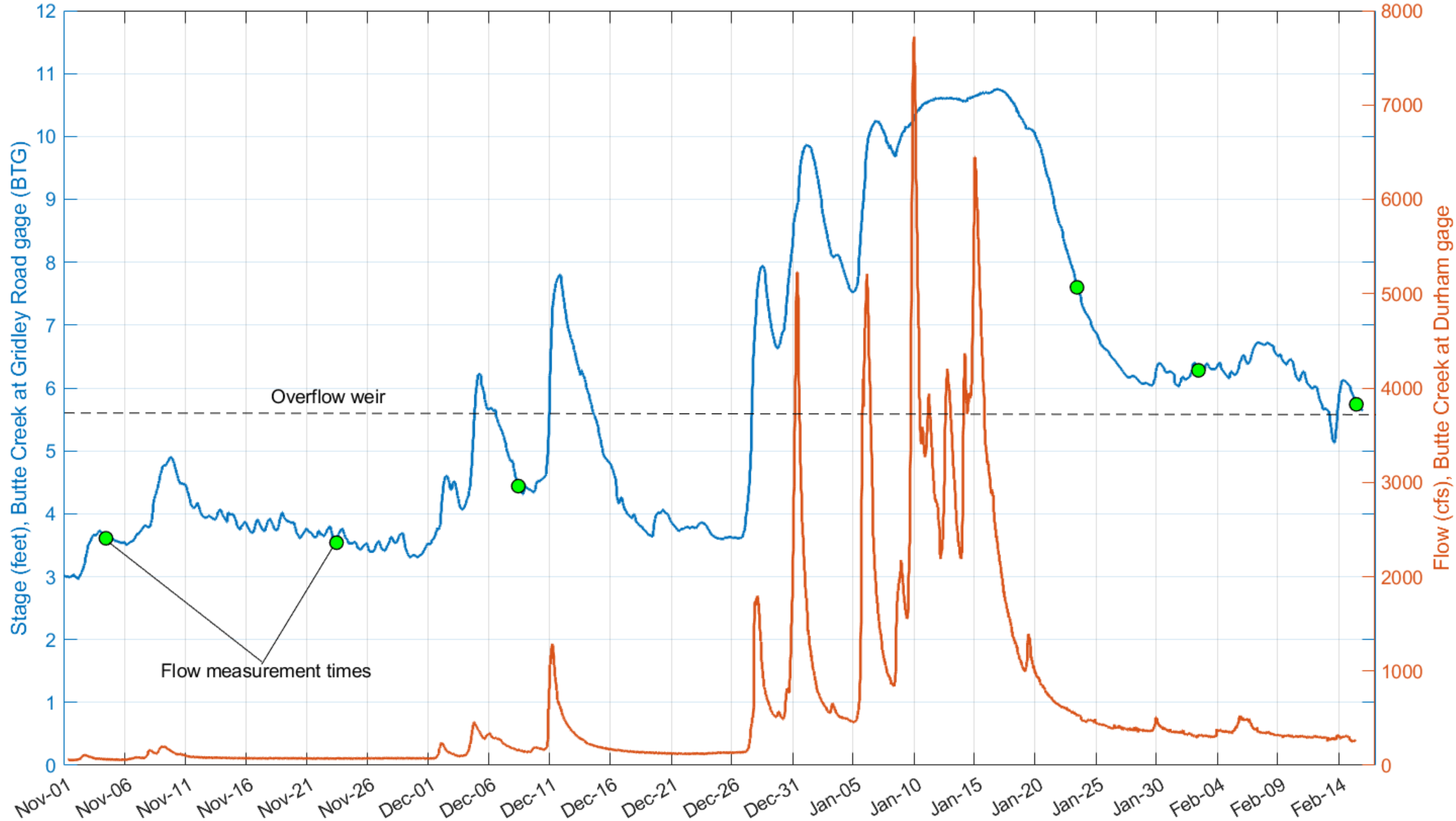
5 REFERENCES

Mueller, D.S., 2016, QRev—Software for computation and quality assurance of acoustic Doppler current profiler moving-boat streamflow measurements—User's manual for version 2.8: U.S. Geological Survey Open-File Report 2016–1052, 50 p., http://dx.doi.org/10.3133/ofr20161052.

Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A,, and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. http://dx.doi.org/10.3133/tm3A22.



Notes:	cbec eco engineering	**Location Map with Flow Measurement Transects**		
		Project No. 21-1028	Created By: SAW	**Figure 1**



Notes: BTG gage: https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=BTG
Durham gage: https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=BCD

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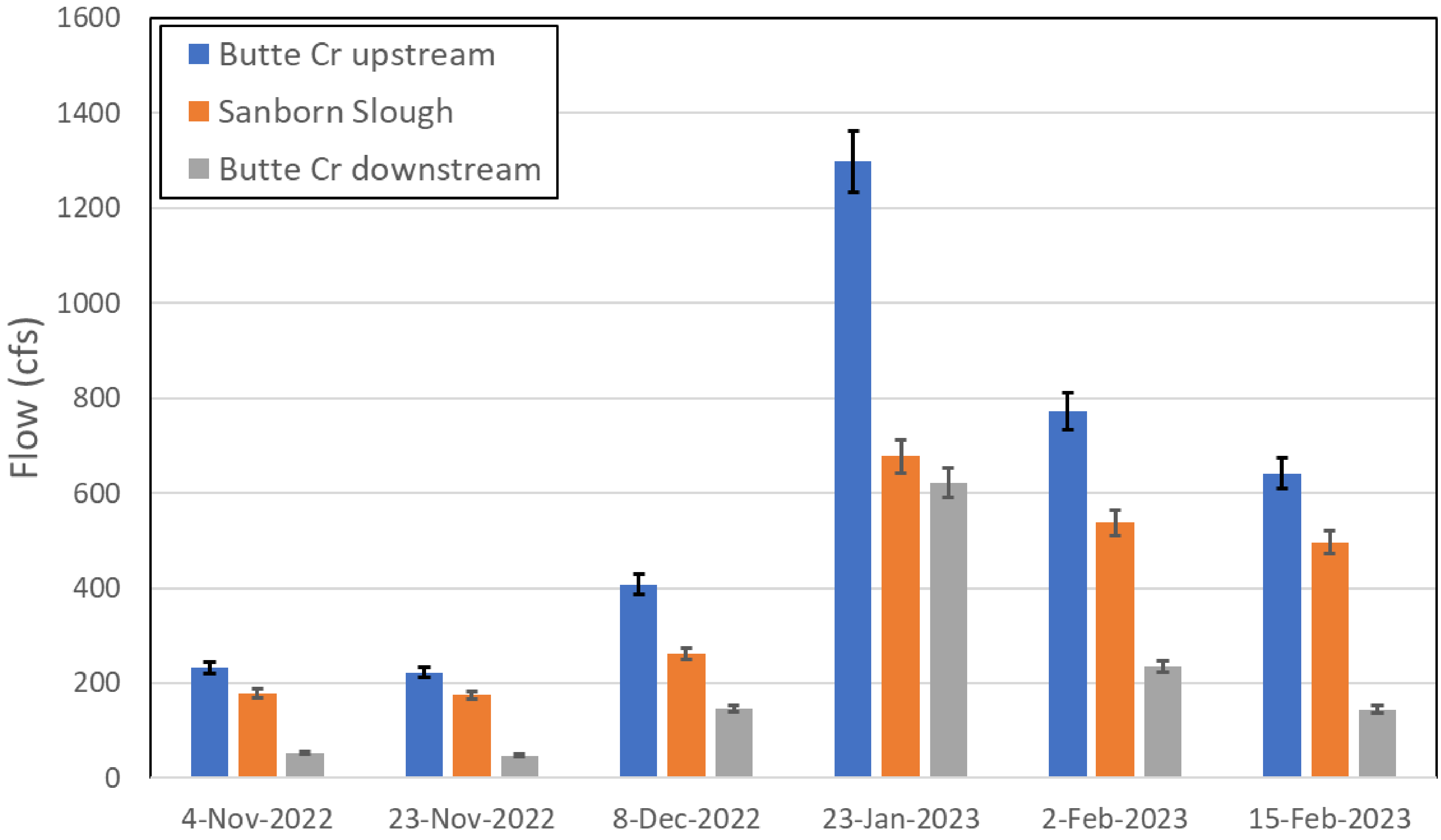
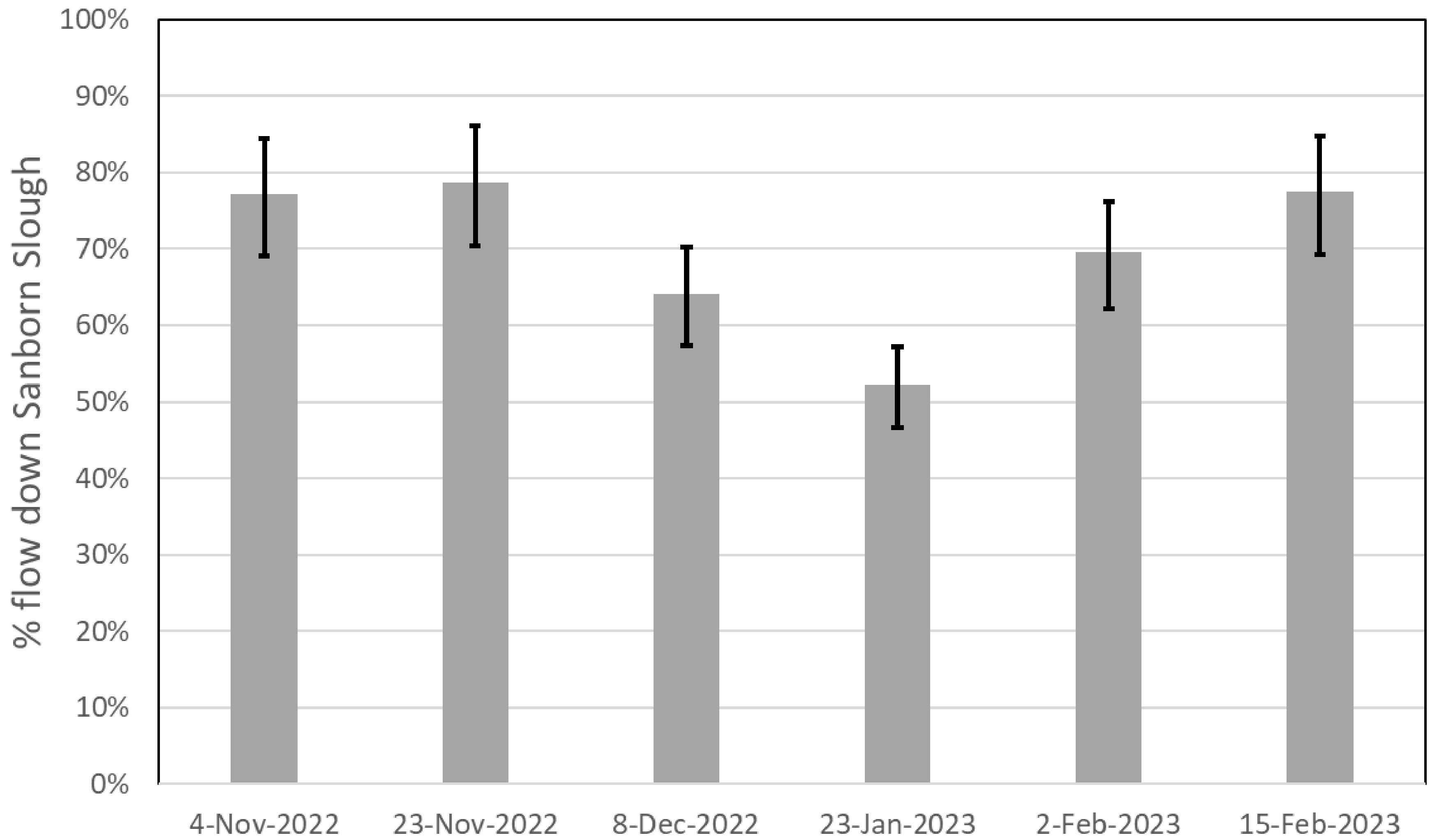
Flow measurement times along with stage at flow

Project No. 21-1028	Created By: SAW	**Figure 2**



Notes:	cbec eco engineering	**Measured flows at all three cross-sections**		
		Project No. 21-1028	Created By: SAW	**Figure 3**



Notes: Flow split computed as the ratio of flow at Sanborn Slough cross-section to flow at Butte Creek upstream cross-section

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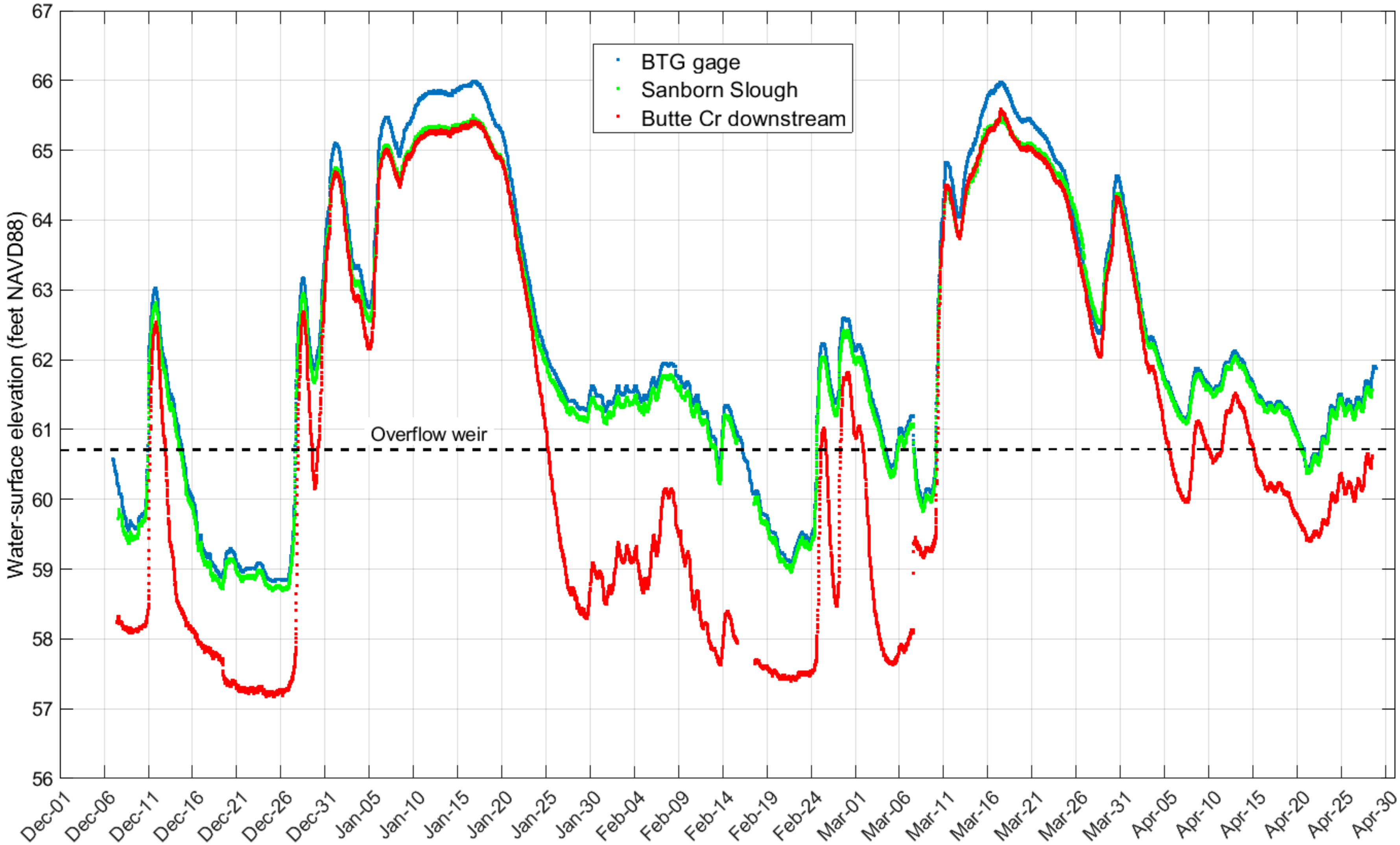
Sanborn Slough bifurcation structure flow splits

Project No. 21-1028	Created By: SAW	**Figure 4**



Notes:	cbec eco engineering	**Water-Surface Elevation time series**		
		Project No. 21-1028	Created By: SAW	**Figure 5**