False Bay Creek Water Flow

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Abstract

The False Bay Creek watershed on San Juan Island, WA, USA supplies freshwater for wells used by residents, drinking water for the city of Friday Harbor and water for agriculture and ranching in the lower watershed. On a small island, such as San Juan Island in the San Juan Archipelago, fresh water is precious and must be used efficiently to serve many people and competing interests. There is a strong community desire to conserve and recover ecological conditions in the False Bay Watershed, including improving habitat conditions for associated fish and wildlife. The community is interested in better characterizing and understanding the role for freshwater flows in the watershed, especially as it relates to the system's capacity to recover lost aquatic habitats and species. Water usage and flow in the creek, which is in the largest watershed on the island, is unknown as there has been no long-term monitoring of freshwater flow levels or water volume in the creek. This study was designed to initiate a long-term stream flow data collection and monitoring plan for False Bay Creek. This was accomplished by field sampling at two locations in the watershed, capturing precipitation and flow transitions from the end of the dry season (May-October) and the beginning of the wet season (October-May). Stream flow data was collected from 10/20/2021 to 11/24/2021 at two locations on False Bay Creek, one in the upper watershed downstream of a city pumping station "Aug-2" and one in the lower watershed in a culvert under Bailer Hill Road. The water flow at the Aug2 location ranged from 0.13 cubic feet per second on 10/20/2021 to a high of 13.98 cubic feet per second on 11/22/2021. The water flow in the culvert under Bailer Hill Road ranged from -0.22 cfs on 11/8/2021 to a high of 30.91 cfs on 11/24/2021. While the shift from summer to fall brought expected increases in precipitation, San Juan Island also received an unprecedented amount of rain fall (3.9 inches in 48 hours) from 11/12 to 11/14, causing flooding events and resulting in higher than expected flows, such as between 11/16-11/21 where sampling was impossible. The existing infrastructure was unable to handle the extreme flooding events. Given climate models predicting more intense storms with greater frequency, this flooding event provided a window into future stream flow collection needs and challenges. Here we report on initial flow monitoring and sampling methodology. Then we highlight the vulnerability of existing infrastructure on Bailer Hill Road and describe how drainage infrastructure and sampling design may need to be updated and more data collected prior to initiating any modifications to the dams in the watershed. I also recommend adding a future testing location below Trout Lake in the upper watershed and a future testing location below Lower Zylstra dam in the lower watershed to expand on the data collected in this study.

Keywords

watershed, water flow, creek monitoring, False Bay Creek, San Juan Island

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valuable information about the watershed. And finally, thank you for the funding provided by the Mary Gates Endowment.

Introduction

Fresh water is one of the most important resources on San Juan Island, WA, USA due to many reasons including: the small size of the island, the island's location in the rain shadow created by the Olympic Mountains which causes less rain to fall in this area than surrounding areas in Washington State, and because the soils on the island are low infiltration with a tendency for high run off (Hartley 2017). As European settlers began to homestead on the island in the 1800's, the importance of fresh water for agriculture resulted in the ditching of streams and the building of private ponds. Eventually the watershed was manipulated further with the more modern creations of Trout Lake dam, Upper Lake Zylstra and Lower Lake Zylstra dams (Pratt 2016). In addition to the dams on False Bay Creek (FBC), the City of Friday Harbor has three locations below Trout dam where water is pumped: Aug-1, Aug-2, and city's water treatment facility that transports water to Friday Harbor (Figure 1). In the lower watershed, there is a siphon in Upper Lake Zylstra that supplementally pumps water into Lower Lake Zylstra during the drier summer season as water is needed for agriculture downstream of Zylstra Lakes (McCutchen 2021). There is also an additional pump that takes water out of FBC in San Juan Valley that is operated by a cattle rancher from May-September (Sundberg 2021). The augmentations made to False Bay Creek (FBC) in the False Bay watershed have altered the natural flow of the freshwater and there is currently a lack of information about the amount of water that flows and how much water is diverted in the False Bay watershed.

A hydrological study was prepared on behalf of the San Juan Conservation District by Northwest Hydraulic Consultants (NHC) in 2017. The NHC report cited a lack of historical flow data for False Bay Creek and modeled water flow with the only discharge measurements available from three different years: 1974, 1997 and 2015. The 1974 data was taken downstream of Bailer Hill Road 12 times from February to November (Figure 1). The 1997 data was obtained from Trout Lake from December to August. The 2015 data was taken downstream of Wold Road and consisted of 9 data points from January to September (Hartley 2017). The 2017 study used the aforementioned flow data and paired it with historical precipitation data to create models of the watershed and drew conclusions about the flow of FBC. One conclusion was that the city helps maintain a more regular flow than there has been historically in FBC because of its pumping activities. A different report on the watershed was conducted for the Washington Water Trust (WWT) in 2011. This assessment used flow data from Nettle Creek and Trout Lake inflow data from 2003-2004 and projected this data with historic flows in the Samish River to estimate historic data for FBC watershed (Liermann 2011). The Samish River historical data (1943-1971 flow and fish data) was used to project historical flows in the False Bay watershed because the Nettle Creek flow and Trout Lake inflow showed similar patterns to the flows in the Samish River. In addition to this 2003-2004 flow correlation, both waterways have similar historic land-use and similar physical characteristics (Liermann 2011). Contrary to the NHC report, the Liermann report for WWT concluded that there has been reduced water flow in FBC watershed compared to the projected historic flows. The data presented in both studies could be improved with new methods that use more precise and extensive flow data for False Bay Creek.

Transforming the landscape with ditches and dams has ensured that the people on the island have freshwater but this has been done at the cost of the health of False Bay Creek Watershed (Wones et al. 2017). There are currently many restoration ideas and projects for the lower portion of the False Bay Creek Watershed that are aimed at restoring the creek to create more natural riparian habitats with the hopes that salmonids can be introduced into the ecosystem (Rot 2019). The existing habitat is not suitable for salmonids due to a lack of gravel beds because the creek has been ditched and flow has been channelized in the lower watershed for agricultural purposes (Wones et al. 2017). However, efforts are underway to restore the lower watershed riparian zone by planting willows and other shrubs near Bailer Hill Road to reduce the reed canary grass that chokes lower FBC. A greater understanding of the flow of False Bay Creek could help inform restoration and management decisions in the watershed.

The objective of this research study was to collect flow data in two locations in False Bay Creek to understand the freshwater flows in this estuarine system. This research study provided more robust flow data than had previously been recorded in the area so that future models and projections can be a better representation of the actual flow conditions of False Bay Creek. The initial hypothesis in this study was that stream flow measurements would correlate with stream depth data. However, as this hypothesis became untestable due to equipment issues, the study evolved into collecting flow data with enough precision to describe flows and make recommendations about future sampling.

Methods

Sampling Locations

A HACH FH950 velocity meter attached to a USGS TopSet Wading Rod was used to measure flow along a transect tape at the two sites in this study. The HACH and rod system were used in accordance with the user manual provided with device (HACH Company 2020). Two testing sites were selected for collecting flow data in the False Bay Creek watershed, including 'Aug2' and 'Bailer Hill Road' (BHR) (Figure 1). These sites were chosen because of their proximity to two established water height meter stations that San Juan County (SJC) placed in False Bay Creek in 2019. In addition, I selected these sites because they were what I thought to be a good representation of the two distinct segments in the False Bay Watershed (Figure 2). When data collection started, the water level of Upper Lake Zylstra was too low to collect flow rates over the dam. The Aug2 location is above Upper Lake Zylstra and therefore represents water flows from Trout Lake into Upper Lake Zylstra. Since there was no water flowing out of Upper Lake Zylstra, a point in the creek downstream was needed to represent rainfall and drainage only in the lower basin. The Bailer Hill Road site was selected for sampling in the lower basin because it is an easily accessible culvert and is located far enough downstream from Lower Lake Zylstra to represent the water flow activity in the lower part of the watershed.

Site 1: Aug-2 Data Collection

The 'Aug-2' location is near Wold Road and is downstream from a city pump station with the same name. To establish a replicable transect at this flow station, referred to as Aug2 in this study, two T-bars were installed on the downstream side of the height meter, one on the left bank and one on the right bank. The T-bar locations were placed above the flood line on each bank to ensure that the locations would not be in FBC during high run-off events. Flagger tape

was applied to the top of each T-bar so this testing site could be located for future studies. The GPS location for each T-bar was also recorded. A transect tape that measures feet and decimal feet was tied to the left bank T-bar as the 0 ft start reference and then pulled across the stream and tied off at the right bank T-bar. Total T-bar to T-bar length was recorded.

To measure flow at Aug2, the HACH FH950 rod system was first placed at the edge of the creek on the left bank and the location was entered into the HACH as the left starting position of the flow transect. An edge variable of 0.5 was chosen on both left and right bank due to the rocky and vegetated state of both edge locations. The roughness factor spans from 0.5 (very rough edge) to 1.0 (smooth, like steel) (HACH Company 2020). To start the stream profile, the left edge bank location along the transect and the water height was entered into the HACH, with left edge velocity automatically set at 0 ft/s. The HACH and rod system was then moved 0.3 feet to the right along the transect tape to measure the next flow point. The station location on the transect tape was entered and recorded, the water height was entered and recorded, the velocity meter adjusted to take one measurement at 60% water height and then the meter ran for 10 seconds to record the velocity at the second station. The HACH and rod system was moved 0.3 feet for the third reading and the above instructions were repeated. This process was repeated along the transect tape until the meter reached the right edge of the creek where the edge factor of 0.5 was chosen, distance on the transect tape recorded, water height recorded and velocity of 0 ft/s established the end of the water profile. The data on the HACH was then saved under the file name of “AUG2_#”, with the # being the 1 for the first day data collected, 2 for the second day data and so on. The stream profile was then recorded on

the data sheet as “final output” which included total area (sq ft), flow rate (cfs), mean depth (ft), cross section length (ft) and file name.

Site 2: Bailer Hill Road Data Collection

The second location where SJC installed a water height gauge is located downstream from the confluence of False Bay Creek and San Juan Valley Creek on the downstream side of the culvert under Bailer Hill Road. To establish this flow station, referred to as Bailer Hill Road (BHR) in this study, two T-bars were installed in line of the height meter, one on the left bank and one on the right bank. This location on False Bay Creek is prone to flooding so the T-bars were installed in locations that appear to be out of high flow mark of FBC. Flagger tape was applied to the top of both T-bars so the location can be used for future studies and their GPS locations were recorded for reference. A transect tape that measures feet and decimal feet was tied to the left bank T-bar as the 0 ft start reference and then pulled across the stream and tied off at the right bank T-bar. Total T-bar to T-bar length was recorded.

False Bay Creek runs through a culvert at the BHR station, so a “conduit” flow profile was used for this location. The bottom of the culvert where water flows is a concrete rectangle that measures 12 feet in width and 3.5 feet in height. Selecting the CONDUIT mode on the HACH, these dimensions were entered into the rectangle profile option. The height of the crown (top of the culvert) to the water line was measured, entered and recorded. The HACH and rod system were then placed in the middle point of the culvert’s width (6 ft) at the opening of the culvert, upstream from the height gauge and the location on the transect tape was recorded on the data sheet for reference. A one measurement profile was selected, water height measured and then rod adjusted to 40% of the water depth per HACH instructions. The

meter then recorded velocity for 10 seconds. Since this location is a conduit profile, only one velocity measurement was needed for the HACH to calculate total flow from the dimensions previously entered. Starting on the third day of data collection, I decided to collect the one-point 40% reading along with a two-point 20%/60% reading to observe the differences in the data produced from one-point vs. two-points. The data on the HACH was then saved under the file name of "BHR_#", with the # being 1 for the first day data collected, 2 for the second day data and so on. The stream profile was then recorded on the data sheet as "final output" which included flow rate (cfs), average velocity (f/s) and file name.

Water Height

San Juan County installed permanent height gauges in False Bay Creek in 2019, one at the Aug2 location and on the downstream side of the culvert at Bailer Hill Road. Each time the flow data was taken at Aug2 and BHR, the height of the water from the height gauge was recorded on the data sheet at each site and for each stream flow sampling event.

Data Analysis

The flow data from Aug2 and BHR were compiled into data tables then graphed using Excel and RStudio (R Core Team 2021) Precipitation data from Friday Harbor Airport was downloaded from NOAA and graphed using RStudio (R Core Team 2021). A time series analysis was then created using the two flow graphs, which were overlapped with the corresponding dates of precipitation measurements to observe if there was a correlation in the two data sets. A map of False Bay Creek and the testing locations was made using ArcGIS.

Results

Aug2 Flow

The first day of data collection on 10/20/2021 for the Aug2 site had the lowest flow of the Aug2 data with a flow of 0.13 cubic feet second (Table 1). The flow of water increased at the second day of data collection on 10/30/2021 to 0.93 cfs, dipped to 0.71 cfs for the third collection, and rose back up to 0.91 cfs on the fourth collection. The flow slowed again on 11/8/21 to 0.44 cfs then increased slightly on 11/10/21 to 0.66 cfs. Rainfall increased during the latter part of the study and the flow intensified to 3.84 cfs on 11/12/21. The creek was inaccessible for ten days following a historical rainfall event from 11/13-11/14 (Figure 3). The highest flow recorded was 13.98 cfs on 11/22 and decreased slightly on the last day of collection, 11/24, at 13.4 cfs (Figure 4).

BHR Flow

The water flow in FBC at the BHR culvert was low at the start of sampling (0.06 cfs), increased to 0.63 cfs on the second day of sampling, and then stayed below 0.37 cfs. On 11/12, the flow increased to 1.45 cfs using the one-point method and 0.85 cfs using the two-point method (Table 2). The lowest flows of water in the Bailer Hill Rd culvert were recorded on 11/3/21 at -0.16 cfs and on 11/8/21 at -0.22 cfs using the one-point method and -0.03 using the two-point method. Rainfall increased during the latter part of the study to the point that the culvert flooded and was inaccessible from 11/13 to 11/23. The final flow reading on 11/24 was the highest recorded with 30.91 cfs using the one-point method and 26.22 using the two-point method (Figure 4).

DISCUSSION

Flow and Precipitation

Stream flow was steady with minimal increases or decreases at the Aug2 and BHR locations from 10/20/21 to 11/7/21. During this period, precipitation levels and flow readings were low. This could be a period of soil moisture recharging in the False Bay Watershed (Figure 4). Both Aug2 and BHR flow increased on 11/12 from previous flow readings, which lines up with increased rainfall 11/8-11/11. The rainfall intensified from 11/13 through 11/15, dumping 3.9 inches of rain over those three days. The increased rainfall paired with low infiltration soil conditions created flooding conditions in many areas in the San Juan Islands.

Seven days after the flooding, a high flow rate persisted at Aug2 of 13.89 cfs on 11/22 and 13.4 cfs on 11/24 (Figure 4). In fact, even though flows had visually receded, the water flow in the upper watershed at Aug2 was 12.78 times higher post-flood than the average flow for the first 7 flow readings from late October to mid-November. The slight decrease in flow from the 22nd to the 24th shows that the quantity of water in the upper watershed was decreasing as the rainfall was also decreasing over this time.

The bottom contour of the stream bed at the Aug2 testing location changed from the pre-flooding data to the post-flooding data as sediment was flushed downstream (Figure 5). This change can be seen in the depression at about 5 feet and from 8 feet to 10 feet. The post with the SJC height meter is upstream of the transect and there is a more pronounced sediment build up behind this post that can be seen around the 6-foot mark in the transect.

The intense rainfall supplied enough water to the upper watershed that Upper Lake Zylstra was filled to a level where water began to flow over the dam. The overflow from the

dam overwhelmed the culvert at BHR and the road became a dam-like barrier itself, creating a flooded wetland as water could not freely flow downstream to False Bay. A flooding event like this one is common at BHR in February but are highly unusual for November (Dethier 2021). Even though the water flow had visually decreased since the flood, the water flow at the BHR culvert on 11/24 was 96 times greater than the average flow for the prior readings seven flow readings from late October to mid-November.

San Juan Island and much of the northwest received an unprecedented amount of rainfall from September 2021 to November 2021 which complicated my research project and changed how the watershed operated. During this rainfall event, Upper Lake Zylstra filled and water began to spill over the dam, causing flooding near the Bailer Hill Road culvert. The BHR county height sensor was lost in the flood and it was discovered that the data in the remaining height sensor at Aug2 was inaccessible. Due to the lost sensor and inaccessible senor data, I was unable to test my initial hypothesis without the historic height data to correlate to the flow data I had collected. My study was unable to correlate flow with historical data but I was able to collect flow data in two segments of the watershed during a seasonal transition with increased precipitation to set up for future studies and make recommendations about the current watershed.

Watershed

The data that I did collect and my time in the watershed has led me to be able to draw some conclusions about the freshwater flow in the False Bay Watershed. At the start of my study, I identified two different segments of False Bay Creek where I separated the upper watershed and the lower watershed at the Upper Lake Zylstra dam (Figure 2). During my study,

Upper Lake Zylstra filled with water to a point where water from the upper watershed spilled over the dam into the lower watershed. By observing this change in the dynamic of False Bay Creek, I have determined that the dam at Upper Lake Zylstra determines how the lower watershed functions. Not only does this reservoir control how much water is distributed from the upper watershed to the lower watershed, it also is a barrier to sediment run off from upper FBC to lower FBC.

The observations I made during my study of FBC water flow and witnessing the flooding event in November have led me to conclude that the infrastructure at BHR needs to be improved and tested for functionality before there are any modifications or removal of the dams at Zylstra Lake. The culvert at Bailer Hill Road likely needs to be increased in diameter or additional culverts may need to be installed because its current size was not sufficient to handle peak flows during the period of increased rain fall. The placement of the culvert is also problematic during flooding events because the natural path of the flooding waters is to the west of the current culvert. If the infrastructure is improved at BHR, I would recommend removing the Lower Lake Zylstra dam and building a fish ladder at the Upper Lake Zylstra (Figure 1).

Methodology Improvements

While the transect method that I used at Aug2 provides a more comprehensive look at the creek cross section where flow monitored, the culvert method that I used at BHR takes less time and could be a more efficient way of gathering data at more sites in the watershed. However, I would not recommend the BHR culvert for future flow data collection with the methods I used because of the many issues I encountered while sampling there. One additional

issue I encountered with the culvert at BHR is that the bottom is a rectangle culvert with a semi-circle culvert on top. When the water level reaches the semi-circle, as it did during the mid-November rain event, the rectangle culvert measurement would become inaccurate. Another issue is that the bottom is not uniform, as there were many large rocks, making the culvert reading there not as reliable. Additionally, the culvert's elevation is higher on the downstream side than it is on the upstream side (Krueger 2021), which is why I think I got negative flow readings there on multiple occasions.

Future Directions

For future studies of the freshwater flow of False Bay Creek, I would recommend additional sampling at a site located below Trout Lake but above Margot Lake. Flow data from this section of the creek would provide invaluable information about the amount of water coming out of Trout Lake before the flow is augmented by Aug-1, Aug-2 and the City of Friday Harbor's water treatment facility. For the next site, I would continue to monitor the Aug2 site location or sample at the culvert above Upper Lake Zylstra. Either of these locations would provide flow data for water going into the Zylstra Lakes. I would also recommend adding a site below Lower Lake Zylstra dam, preferably the rectangle culvert below the dam if the height of the flow is deep enough to measure using the velocity meter. Depending on the time of year and flooding events, the BHR culvert is an easily accessible location but may provide inaccurate data as mentioned previously. Instead of the BHR culvert, I would recommend a site 50-100 feet downstream of the culvert using the transect method that I used at Aug2 for more robust data about the flow near the mouth of False Bay Creek. If the HACH 9500 velocity meter can be approved by the manufacture to be used in saltwater conditions, a testing site in the estuary at

the mouth of FBC could prove to be a valuable flow testing location to record how much freshwater enters False Bay. Overall, I would suggest two locations in the upper watershed and two locations in the lower watershed to better understand how the system functions in its different segments and then add additional testing locations with information learned from these four locations. Then monitoring could be re-evaluated to determine if even greater resolution is required.

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Figures

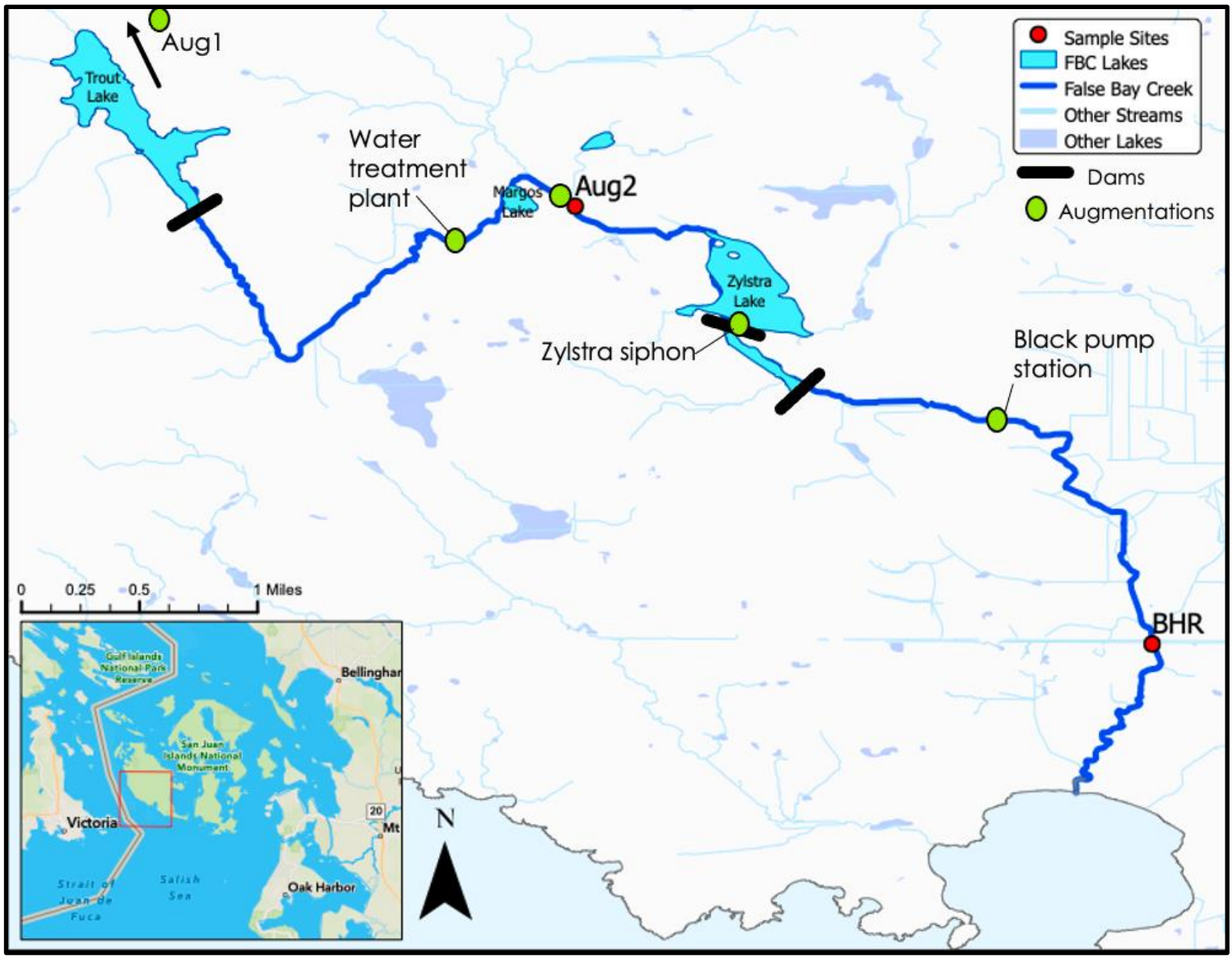

Figure 1. Map of augmentations to False Bay Creek, San Juan Island, WA, USA. Black bars indicate dam locations, green dots represent pumps, and red dots represent flow testing locations. Note: Aug1 is located on Lawson Lake and is located out of view.

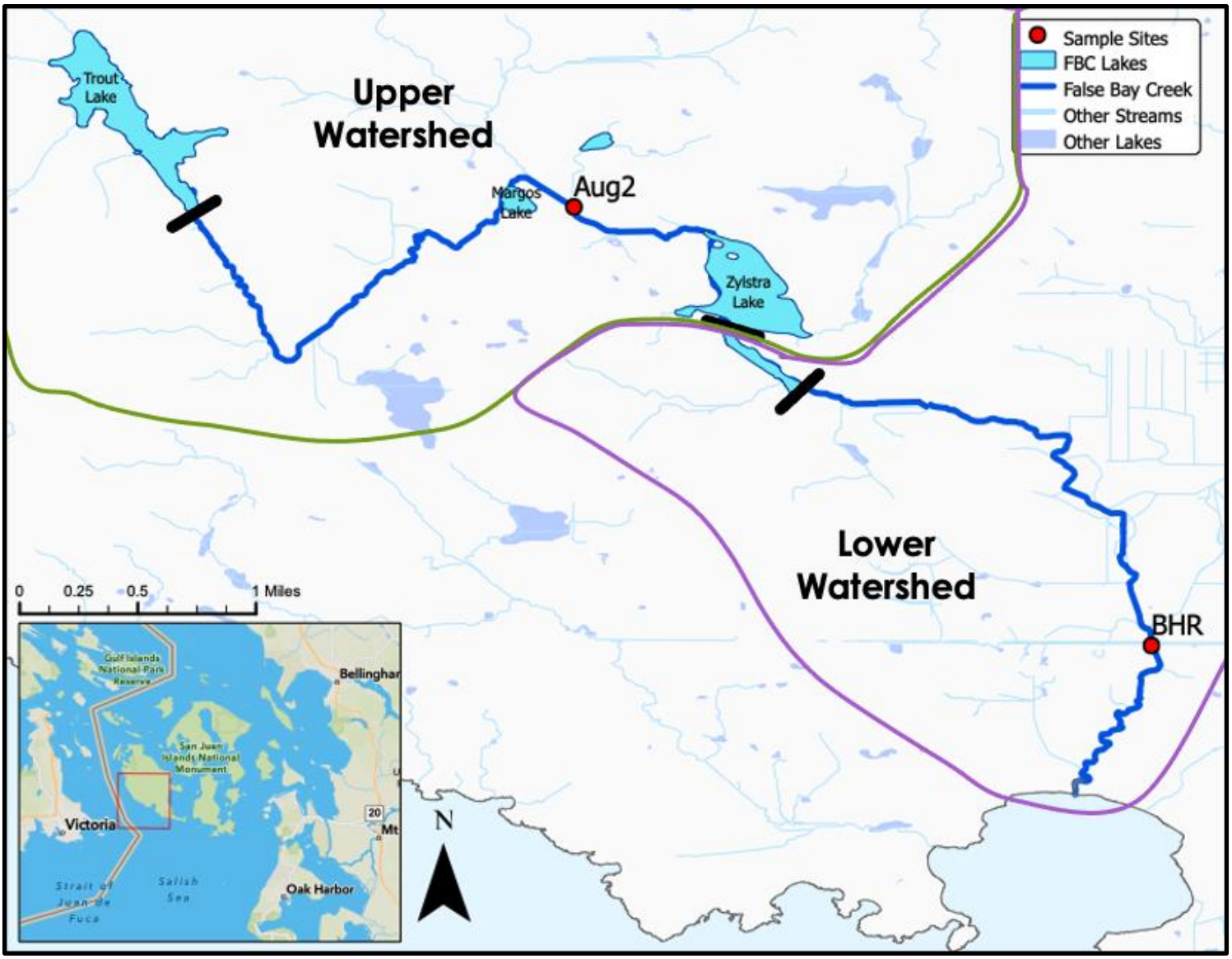

Figure 2. False Bay Creek watershed from Trout Lake to False Bay. Conceptual interpretation of the two key segments of False Bay watershed for this study, including the upper (green) and lower (purple) watershed units and the sampling locations selected for each segment. These boundaries are not an exact representation of the entire watershed as the map is zoomed in to highlight the study locations.

Table 1. Flow data taken in the downstream of the Aug2 pumping station on Wold Road, San Juan Island from 10/20/2021 to 11/24/2012. The data was collected using the stream transect method where flow was taken at 0.3 feet intervals across the testing site. The water height on the county data post was also recorded for refence.

Date	Number of stations	Area (sqf)	Flow (cfs)	Mean depth (ft)	Stream width (ft)	Transect length (ft)	County height (ft)
10/20/21	26	3.35	0.13	0.41	8.04	20.3	nd
10/30/21	25	6.87	0.93	0.78	8.8	20.12	0.57
11/1/21	23	4.74	0.71	0.55	8.6	20.15	0.68
11/3/21	28	5.94	0.90	0.67	8.9	20.20	0.70
11/8/21	28	5.69	0.44	0.68	8.4	20.2	0.58
11/10/21	29	5.42	0.66	0.64	8.5	20.15	0.64
11/12/21	31	10.64	3.84	1.11	9.6	20.15	1.21
11/22/21	35	24.6	13.89	2.41	10.2	20.2	2.42
11/24/21	33	22.04	13.4	2.1	10.5	20.2	2.18

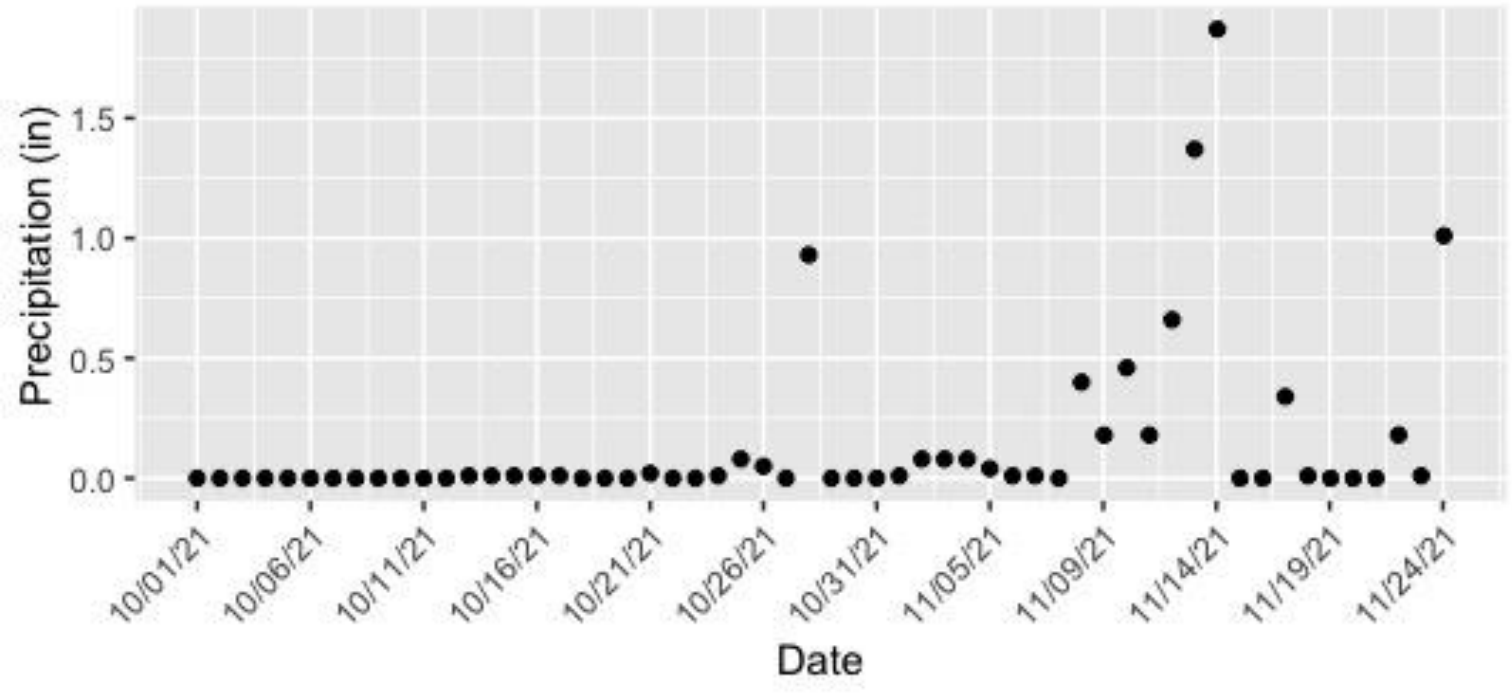

Figure 3. Graph of precipitation data from Friday Harbor Airport, San Juan Island for 10/1/21 to 11/24/21 (NOAA 2021).

Table 2. Flow data taken in the downstream end of the culvert on Bailer Hill Road, San Juan Island from 10/26/2021 to 11/24/2012. Starting on the third date of data collection, two different data points were taken using a one-point reading and a two-point reading to determine if the flow reading changed with the different methods. The water height on the county data post was also recorded for refence.

Date	Time	Depth of flow (ft)	Flow (cfs)	Avg velocity (ft/s)	Total area (sqft)	County height (ft)
10/26/21	9:25:32	1.4	0.06	0	16.8	0.87
10/30/21	13:01:26	1.5	0.63	0.03	18	0.87
11/1/21	11:48:29	2.6	0.31	0.01	31.2	0.9
11/1/21	11:50:01	2.6	0.37	0.01	31.2	0.9
11/3/21	9:42:02	1.65	-0.16	-0.01	19.8	0.95
11/3/21	9:45:02	1.65	0.02	0	19.8	0.95
11/8/21	14:05:03	1.6	-0.22	-0.01	19.2	0.92
11/8/21	14:07:00	1.6	-0.03	0	19.2	0.92
11/10/21	11:43:05	1.8	-0.01	0	21.6	1.1
11/10/21	11:44:06	1.8	0.17	0.01	21.6	1.1
11/12/21	10:38	1.98	1.45	0.06	23.76	1.3
11/12/21	10:49:37	1.98	0.85	0.03	23.76	1.3
11/24/21	10:43:33	3.58	30.91	0.72	42.96	2.9
11/24/21	10:45:02	3.58	26.22	0.61	42.96	2.9

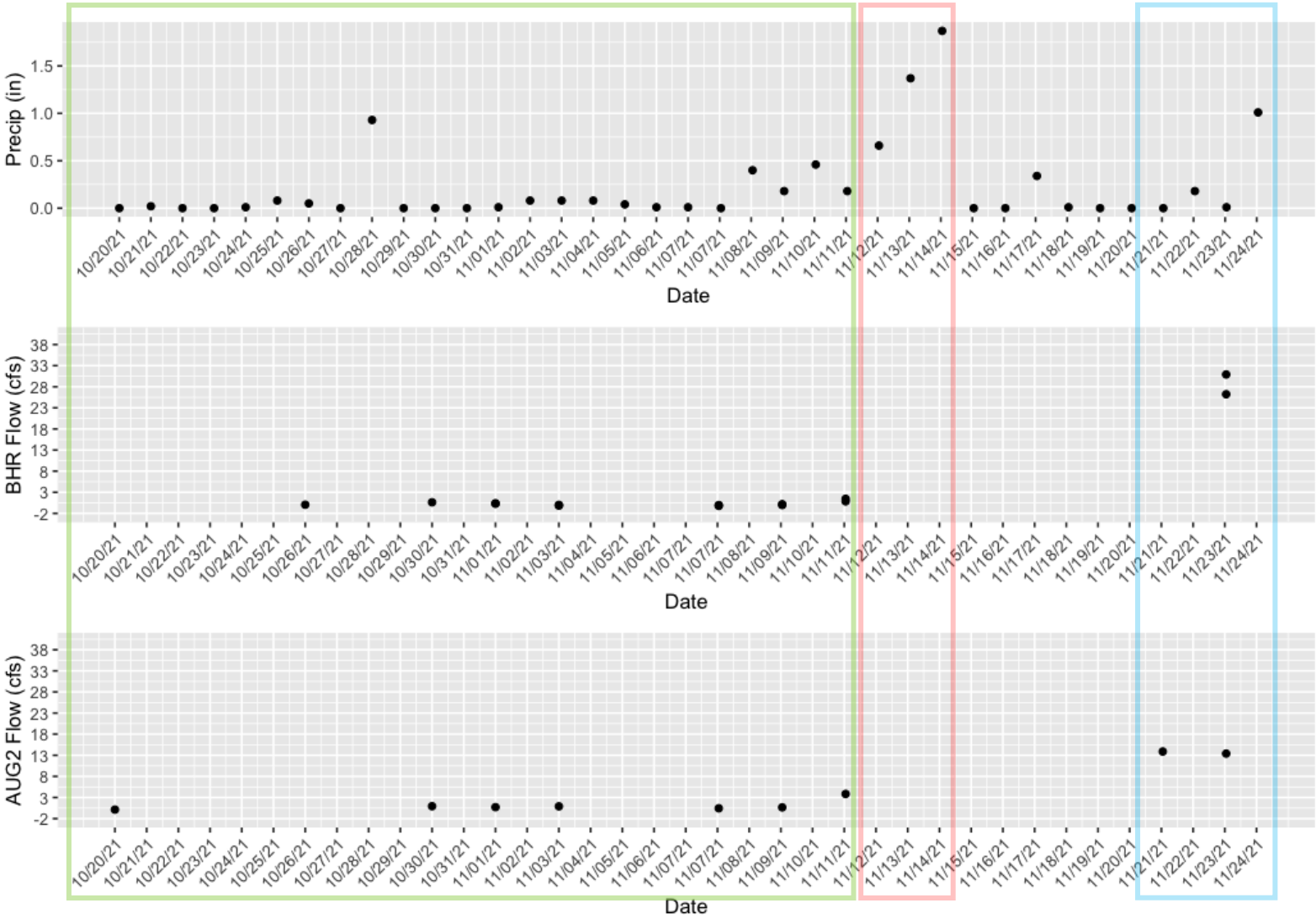

Figure 4. Precipitation and flow data from BHR and AUG2 from 10/20/21 to 11/24/21. The green box highlights the beginning of the study where there was low precipitation and low water flow. The red box highlights the flooding event with increased precipitation. The blue box highlights the end of the study after the flood, where flow rates were the highest.

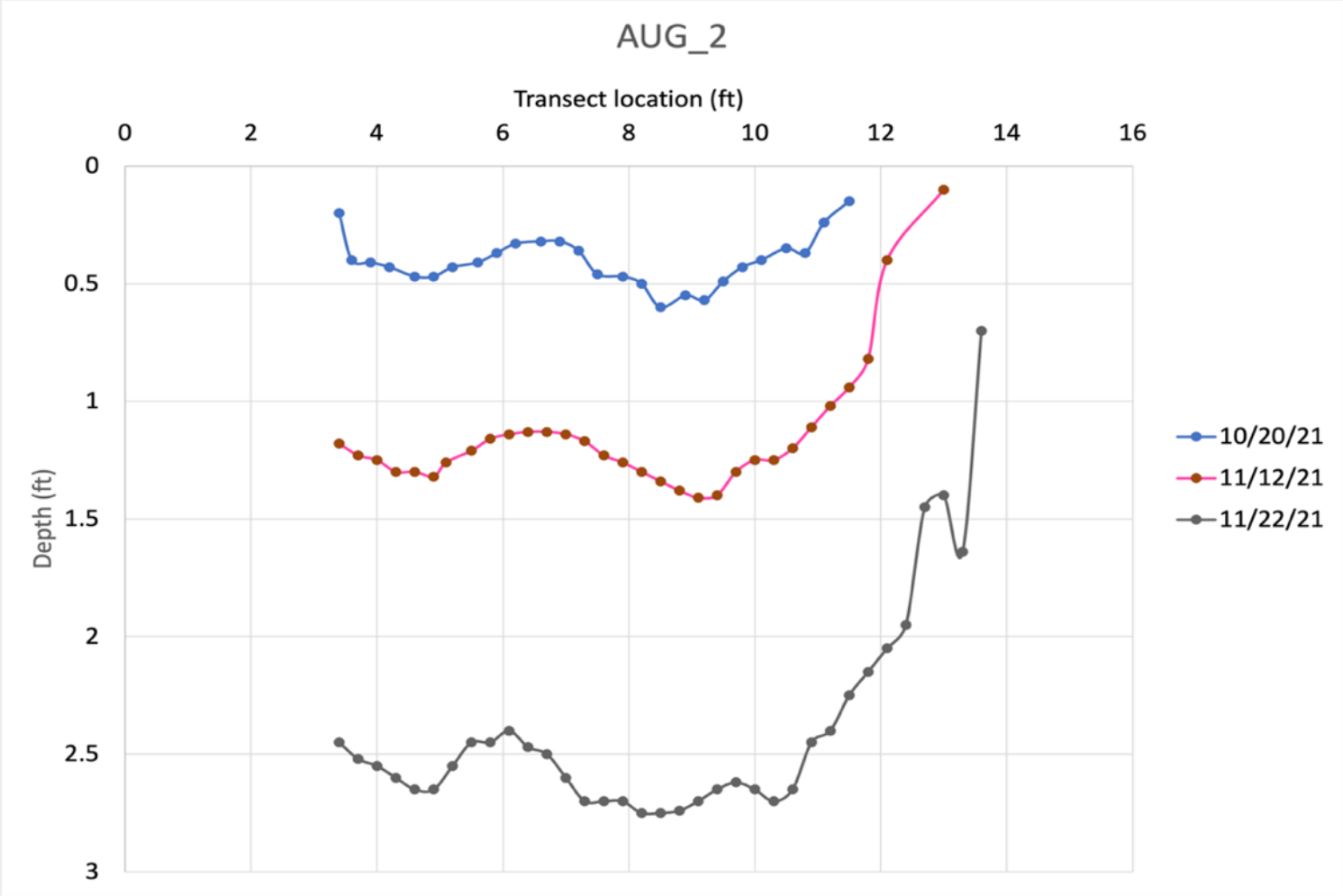

Figure 5. False Bay Creek at AUG2 location. Stream profiles from the start (blue), middle (red) and end (gray) of the study looking downstream as flow data was recorded from left bank to right bank. These three dates also represent low flow and low water height (blue), increased flow and water height (red), and the highest recorded flow and water height (gray).