Faith Valley
WY2024 Streamflow Summary Report - FINAL

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1. Introduction and Project Background

This report describes streamflow conditions on the reach of the upper West Fork of the Carson River that flows through Faith Valley Meadow, CA, from water year (WY) 2019 through WY2024. Since 2020, Trout Unlimited (TU) has been partnering with American Rivers (AR) to monitor pre- and post-project conditions upstream and downstream of meadow restoration. Beginning in August of 2022 and continuing through October of 2024, Faith Valley meadow was restored to reconnect the channel to its floodplain using beaver-dam analog (BDA) and grade control techniques. In August and September of 2022, a grade control structure and a pilot set of 14 BDAs were constructed. In summer and fall of 2023, an additional 25 BDAs were added and four from 2022 were repaired. In August-Sept of 2024, adaptive management of the structures took place, including repairing and fortifying 26 structures and constructing 3 additional structures. This report focuses on the most recent year of data collected at the gages (WY2024) and compares it to previous years of data; including the three years of pre-restoration project streamflow data (WY2019 – WY2021). WY2024 represents the second full year of post-project streamflow conditions. The data presented in this report are meant to provide insights into the watershed's streamflow dynamics, to observe the affects that flow releases from the Upper and Lower Lost Lake reservoirs have on streamflow conditions, and to monitor output measures of the restoration project, including increasing quantity of outflow relative to inflow as well as decreasing temperatures during the dry season (Jun-Nov). Comparison of pre- and post-project data can provide useful data for restoration managers and downstream water rights holders.

2. Methods

The upper West Fork Carson River flows through Faith Valley meadow (Figure 1), which sits at approximately 7500 feet in elevation in the upper watershed. Continuous stage and streamflow data from gaging stations at the upstream and downstream ends of the meadow are presented in this report. American Rivers (AR) installed two gages in November of 2018; Faith Valley Upstream 1 (FV US-1) and Faith Valley Downstream (FV DS) and began monitoring flow in WY2019. In WY2020, Trout Unlimited (TU) began partnering with American Rivers to assist in refinement of gage installations and field techniques and to analyze the data collected. An additional upstream gage was installed by TU and AR in August 2020- this gage is referred to as Faith Valley Upstream 2 (FV US-2). Each gage site is comprised of 1 to 3 pressure transducers collecting 15-minute depth and temperature data, a protective stilling well, and a staff plate for calibration. The site is equipped with one barometric pressure transducer to correct for atmospheric pressure. Gages were visited roughly monthly in the dry season by AR; manual streamflow measurements were conducted along with data downloads. AR provided TU with pressure transducer data, manual streamflow measurement data, field notes and photos. The stage record was then calibrated and corrected for stage shifts by TU, and a rating curve developed from the manual streamflow measurements was applied to provide continuous streamflow records at these sites. The focus of the monitoring is to capture low flows from roughly July through October, the results from this time period will be emphasized in this report.

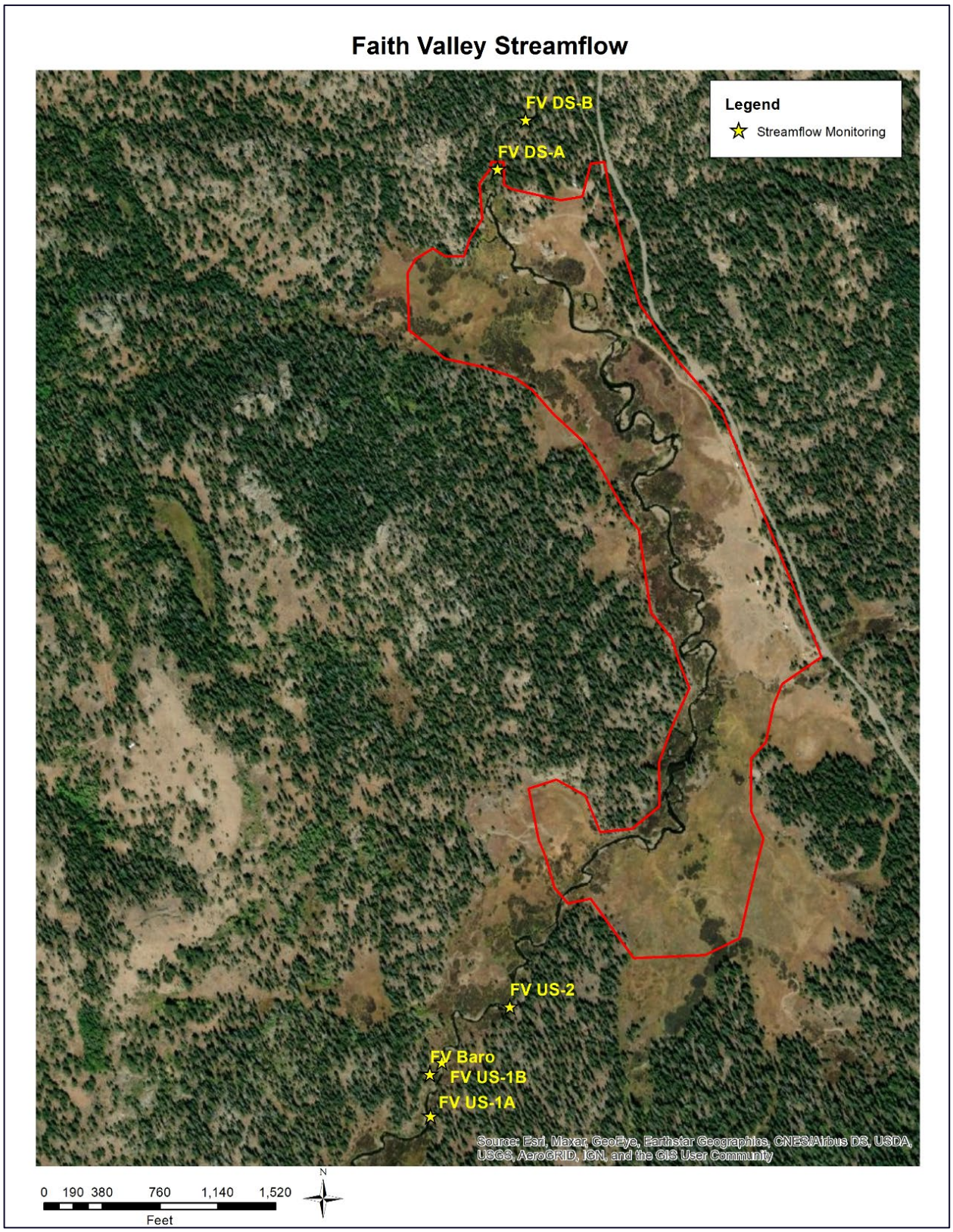

Figure 1. Streamflow gage locations in Faith Valley, CA.

3. Hydrologic Conditions

3.1 Precipitation

The upper West Fork Carson River is a snowmelt dominated system, with the highest flows occurring in spring and early summer. Annual precipitation in snowmelt systems is commonly measured as Snow Water Equivalent (SWE), which is equal to the depth of water contained in the snowpack when it melts. SWE was measured from WY2019 through WY2024 at the nearby NRCS Forestdale Creek SNOTEL station (Station ID 1049). This station is at an elevation of 8017 feet, and is situated on the western slopes of mountains forming the upper West Fork Carson River watershed divide near Forestdale Creek. Figure 2 shows continuous SWE in inches recorded at the Forestdale Creek SNOTEL station from the beginning of WY2019 (Oct 1, 2018) through the end of WY2024 (Sept 30, 2024), as compared to the long-term (30 year) median SWE and the maximum SWE reported over all years of record at the station. The median peak SWE is 32.9 inches occurring on April 3 annually, and the median meltout date (SWE=0) is May 30.

These data show that WY2024 was a near-median year. Snowpack at the start of the water year was below median, and early-season dry conditions continued through mid-January. A large mid-January storm brought the snowpack to near the median. The largest storm of the season occurred in early March, and increased snowpack above the median. For the remainder of the season, the snowpack remained above median, and reached a peak SWE of 38.9 inches on April 9, 2024. As snowmelt began, SWE decreased slowly from mid-April through early May, then decreased rapidly through the rest of the spring. The snowpack here melted (SWE=0) on June 5, 2024, six days after the median meltout date of May 30th.

These data also show hydrologic conditions in the previous years of the study. WY2023 was an extremely wet year with a record-high snowpack. WY2023 was the wettest year of the study period, and for the majority of the winter WY2023 defined the maximum SWE recorded at the station. Peak SWE was reached on April 9 at 78.6 inches, and snow did not melt out until July 3, 2023, approximately five weeks after the median meltout date of May 30. Looking back to previous years within the study period, WY2019 was also a wet year, with SWE at or above the long-term median for the entirety of the year. Peak SWE was at 59.6 inches on April 9, 2019, and SWE reached zero on June 22, 2019. WY2020 was a drier year, with 28.9 inches of SWE measured at the season peak on April 9, 2020. The snowpack melted and SWE reached zero on May 30, 2020, the median date of meltout. WY2021 was drier than 2020, with a below-median peak SWE of 23.9 inches recorded on March 26, 2021. The snowpack melted out on May 15, 2021, approximately two weeks before the median meltout date. WY2022 was the driest year of the study, with a below-median peak SWE of 22.3 inches recorded on March 10, 2022. The snowpack melted out on May 26, 2022, a few days before the median meltout date.

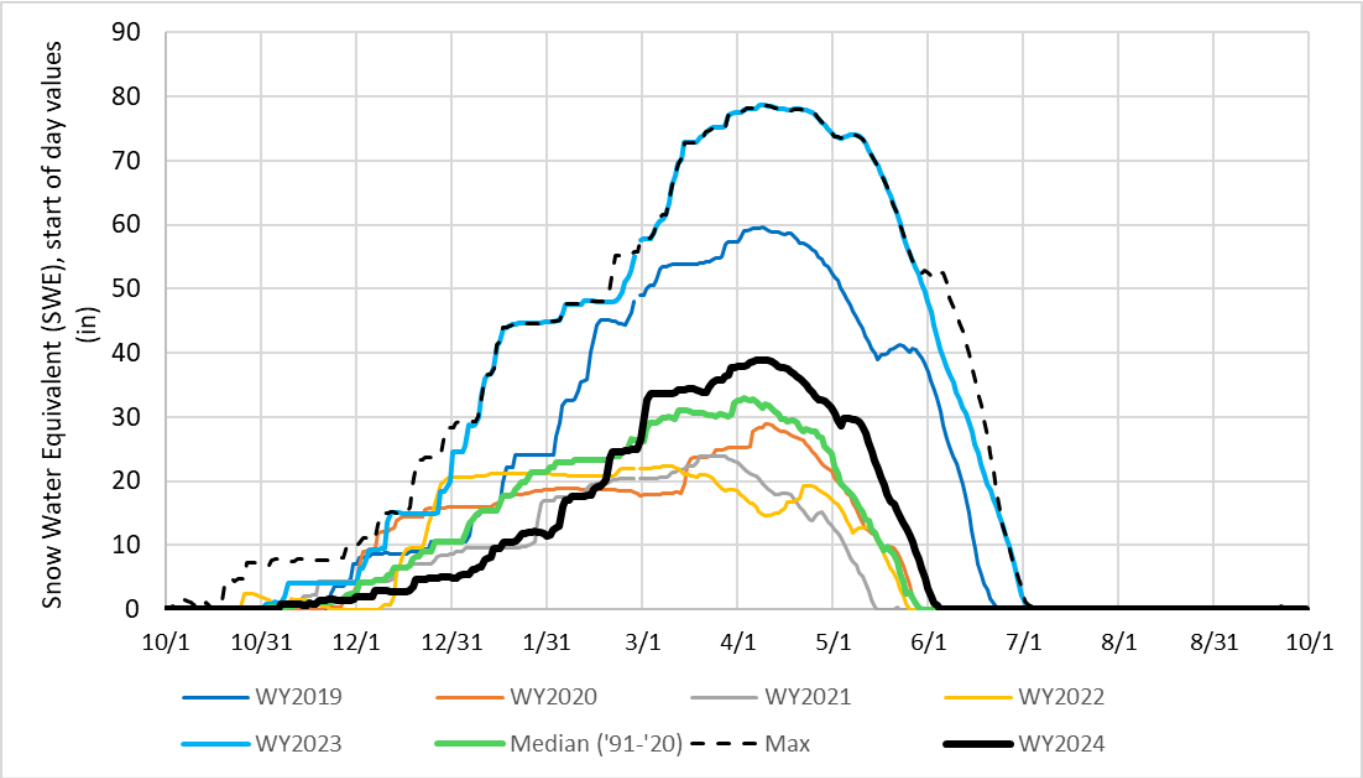

Figure 2. SWE (in) from WY2019 through WY2024 at NRCS Forestdale Creek SNOTEL station (Station ID 1049), compared to annual median and maximum SWE (in).

3.2 Flow releases, 2019 – 2024

Flow releases from Upper and Lower Lost Lakes, a pair of reservoirs upstream of Faith Valley meadow, contribute flow to the system. Each year from early to mid-October, water is released from the reservoirs into the channel at a rate ranging from 0.99 – 10.62 ft3/sec. These flow releases were managed by the Carson Water Subconservancy District (CWSCD) and occurred in WYs 2019 – 2024. Table 1 summarizes the data provided to AR by CWSD documenting the volume of flow released during the study period.

Date/Time	Release rate (cfs)	Note
WY2019		
10/1/2019 11:30	9.37	Gate opened, released 9.37 cfs.
10/4/2019 11:30	8.73	On Oct 4 at 11:30 AM the flow rate had dropped to 7.72 cfs. Increased flow to 8.73 cfs.
10/9/2019 11:30	8.41	On Oct 9 at 11:30 AM the flow rate had dropped to 6.03 cfs. Increased flow to 8.41 cfs.
10/14/2019 11:30	0.99	On Oct 14 at 11:30 AM the flow rate had dropped to 0.99 cfs. Gate closed.
WY2020		
10/1/2020 11:00	8.89	Gate opened, released 8.89 cfs.
10/5/2020 10:00	9.13	On Oct 5 at 10:00 AM the flow rate had dropped to 6.39 cfs. Increased flows to 9.13 cfs.
10/9/2020 11:00	2.13	On Oct 9 at 10:00 AM the flow rate had dropped to 1.93 cfs. Increased flows to 2.13 cfs.
10/12/2020 11:30	0.99	On Oct 12 at 11:30 AM the flow rate had dropped to 0.99 cfs. Gate closed.

WY2021		
10/4/2021 11:00	6.53	Gage reading at 11:00 AM.
10/4/2021 13:00	7.04	Gage reading at 1:00 PM.
10/7/2021 1:00	0	Gage reading of 0.0 at 9:00 AM. Assume flow hit 0 cfs at 1 AM on October 7.
WY2022		
10/3/2022 10:30	8.97	Gate opened, released 8.97 cfs.
10/6/2022 9:30	7.26	Gage reading at 9:30 AM
10/6/2022 9:45	10.62	Gage reading at 9:45 AM
10/11/2022 13:45	0.99	Gage reading at 1:45 PM. Gate closed at 1:45 PM
WY2023		
10/6/2023 11:15	8.65	Gate opened, released 8.65 cfs.
10/11/2023 11:15	7.12	Gage reading at 11:15 AM. Gate closed at 11:15 AM.
WY2024		
10/3/2023 10:15	8.79	Gate opened, released 8.79 cfs.
10/7/2024 10:15	6.82	Gage reading at 10:15 AM.
10/7/2024 10:15	9.87	Gage reading at 10:15 AM.
10/9/2024 8:45	5.96	Gage reading at 8:45 AM.
10/9/2024 8:45	6.39	Gage reading at 8:45 AM.
10/14/2024 9:45	0	Gage reading at 9:45 AM.

Table 1. Flow releases from Lost Lakes, WY2019 – WY2024

3.3 WY2024 Streamflow and Temperature

Streamflow data from WY2024 are presented below. Data from the upstream and downstream sites are compared to each other, and compared to previous years of data. Special attention is paid to the time periods during which the water release from Lost Lakes is moving through the meadow, as well as to the low-flow season (July-October). The volume of release water measured at upstream and downstream gages was calculated for each year.

Figure 3 shows a comparison of flows between the FV Upstream 1, FV Upstream 2 and FV Downstream, as well as compared to the volume of water released from Lost Lakes in WY2024. In mid-June, at the start of the measurement season, flow at the sites were between approximately 40 and 60 ft3/sec, and fluctuated strongly due to daily freeze-thaw cycles. Flow receded quickly in mid-June, before briefly rising again in late June due to increased snowmelt. Flow again dropped quickly from early July through late July, with an early summer storm on July 20, 2024 causing a spike in flow at all sites. Flows decreased more slowly in August, before reaching baseflows near 1 ft3/sec in mid-August. Flows in August were slightly lower at the downstream site than the upstream sites. Short spikes and dips in flow were observed in August; these are presumed to be human and/or beaver activities – the site is near a campground, and beaver activity was observed near the gage in

most years of gaging. By early September, baseflows at the lower site were slightly higher than baseflows at the upstream site. Slight flow differences may be due variation in the gaining and losing dynamics at these sites.

Previous studies have shown an increase in downstream baseflow compared to inflow in restored meadows, especially in drought conditions (Hunt et al. 2018). Conceptually, restoration activities raise the water table in a restored meadow, which then acts a reservoir, as water infiltrates the meadow soils during snowmelt season, and this water then slowly drains during the dry season. During the spring, flows may be higher upstream as the meadow soils saturate, then in the dry season this relationship may reverse, with flows higher downstream than upstream. Hydrograph data from WY2024 generally support this conceptual model. Flows are higher upstream in the spring and early summer; then in early September 2024, this relationship reverses, with flows slightly higher downstream than upstream.

Flow was released from the Lost Lakes reservoir starting on October 3, 2024. At all sites, flow rose and fell quickly in response to the volume of water being released from upstream, before receding to a level similar to before the release took place, suggesting that the released water flows unimpeded through the restoration site. Flows at all sites increased rapidly when the release commenced on October 3, 2024, and remained elevated near 9 ft3/sec. During the release, flows are roughly similar to the volume of base flow plus the volume of released water. Flows then receded when the release was shut off in mid-October. Flows at the downstream gage remained slightly higher than flows upstream. The volume of released water appeared to flow freely through the system in all years of the study; see Appendix A of this document for hydrographs and discussion from years 2019 – 2023.

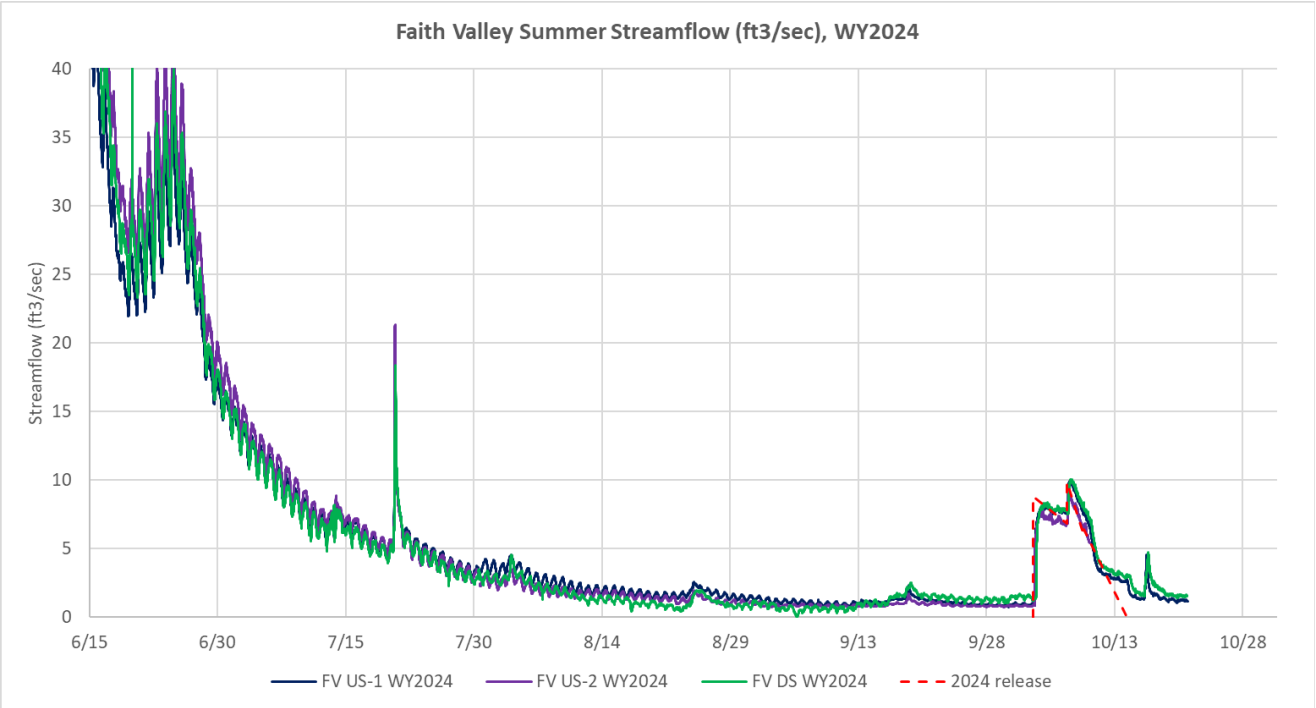

Figure 3. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2024.

Figures 4 – 6 show daily average streamflow compared within each site for the period of record (WY2019 – WY2024 for FV US 1 and FV DS, and late WY2020 – WY2024 for site FV US 2). For consistency between water years, flow is shown from July through October – flows in June of 2023 were too high to measure. Flow were last collected on October 21, 2024. On October 23-24, 2021, a storm caused a large spike in stage too high to assign flow to, data from October 23, 2021 – October 31, 2021 are not included. Flow at each gage in the dry season appears to be strongly influenced by the amount of precipitation received in the year. Streamflow at each site was highest in WY2023 and WY2019, the wettest years of the study. Flows started highest at the beginning of the monitoring season, and continued to have the highest baseflows of any year, particularly in WY2023. The driest years of the study, WYs 2020, 2021 and 2022, saw lower flows at the beginning of the season which quickly receded to low baseflows. WY2024, a near-median year in terms of precipitation, had higher flows at the beginning of the season than the drought years, but low baseflows similar to those observed during the dry years in the late summer and fall. Detailed analysis of flow and temperature data from WY2019 – WY2023 are included in Appendix A to this report.

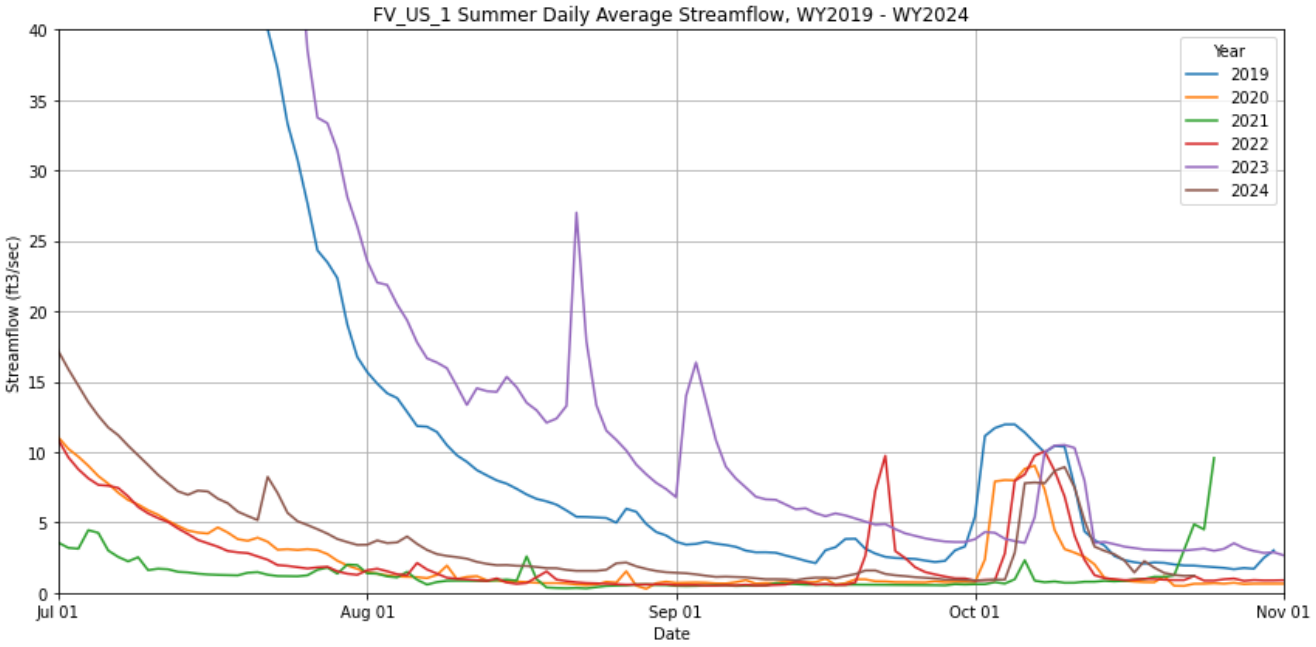

Figure 4. Daily average summer streamflow conditions, FV US 1, WY2019 – WY2024.

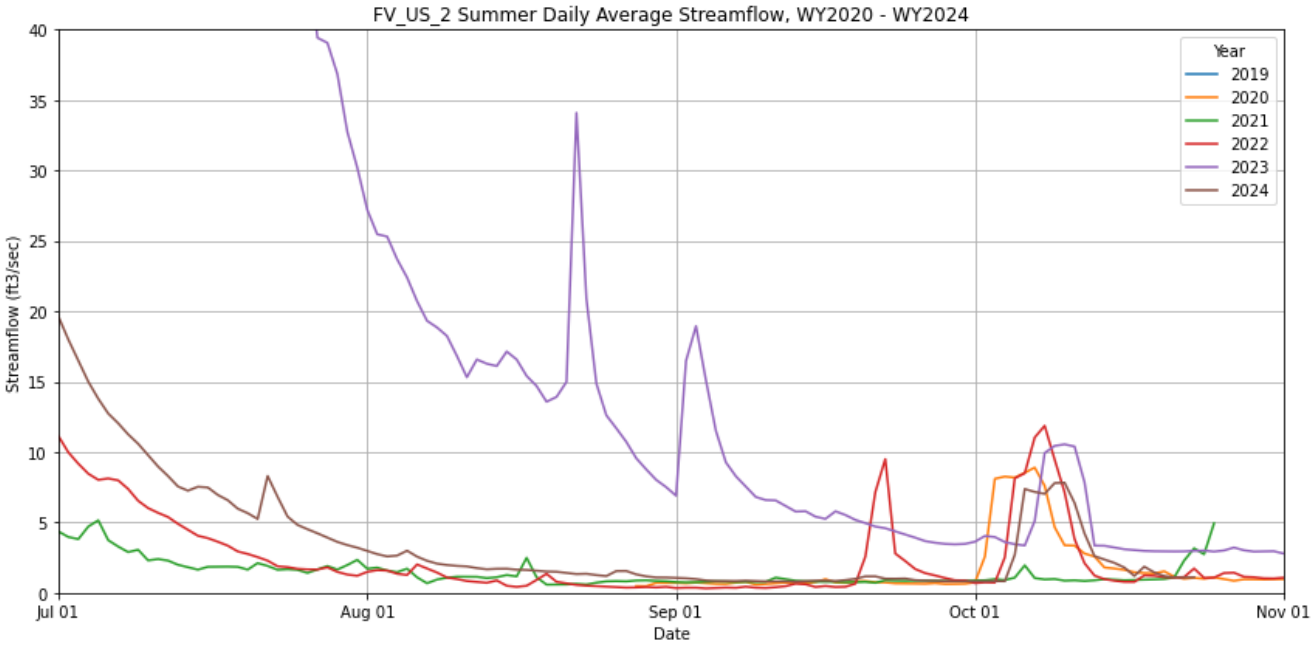

Figure 5. Daily average summer streamflow conditions, FV US 2, WY2020 – WY2024.

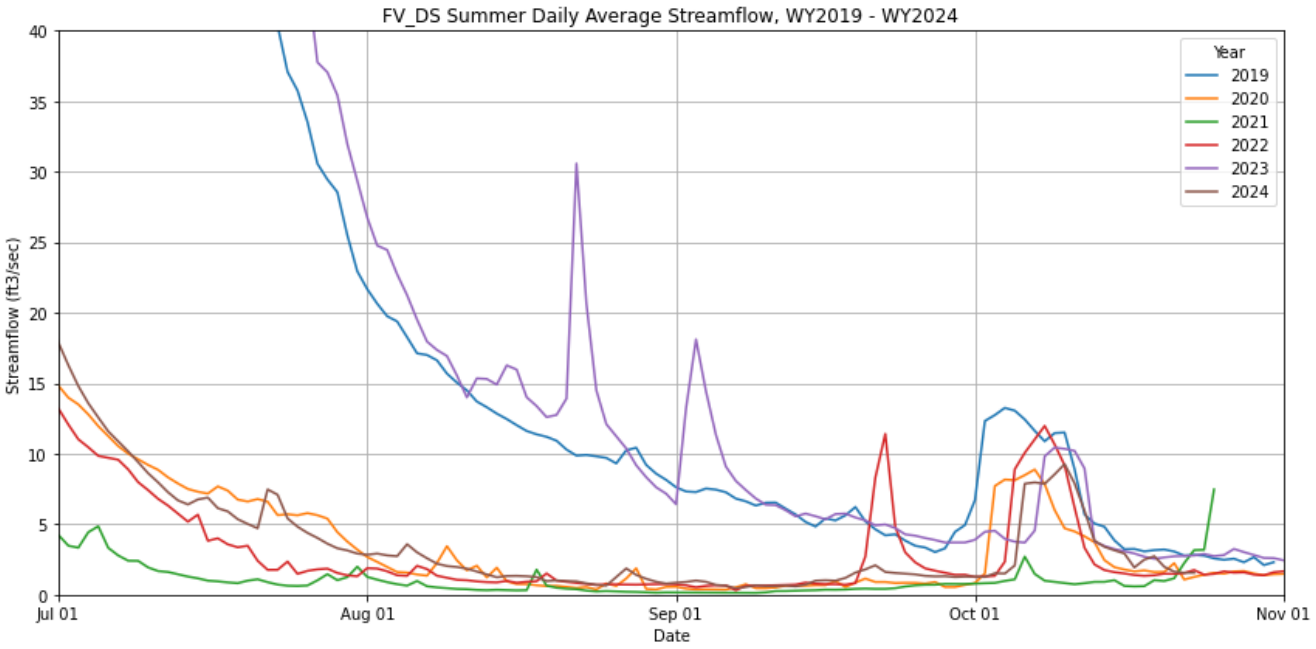

Figure 6. Daily average summer streamflow conditions, FV DS, WY2019 – WY2024.

The upstream and downstream flow volume in September of all years of the study period was compared to assess the output performance measure of downstream baseflow enhancement in the dry season. Figure 7 shows a plot of the difference between the mean daily average streamflow at the upstream FV US 1 site, chosen as it has the longest record, subtracted from the downstream site for all dates in September. Lines that are positive mean there is more flow at the downstream site, while negative lines indicate higher flows at the upstream site. WY2019 is excluded due to higher uncertainty in this year. Large spikes and dips, such as in WY2022 and 2023, are due the lagtime between spikes caused by September rainstorms. The trends show from early September to late September, flows generally shift from losing to gaining at the downstream site, though noise in the data adds to uncertainty. This is true for the pre-project years as well as the post-project years.

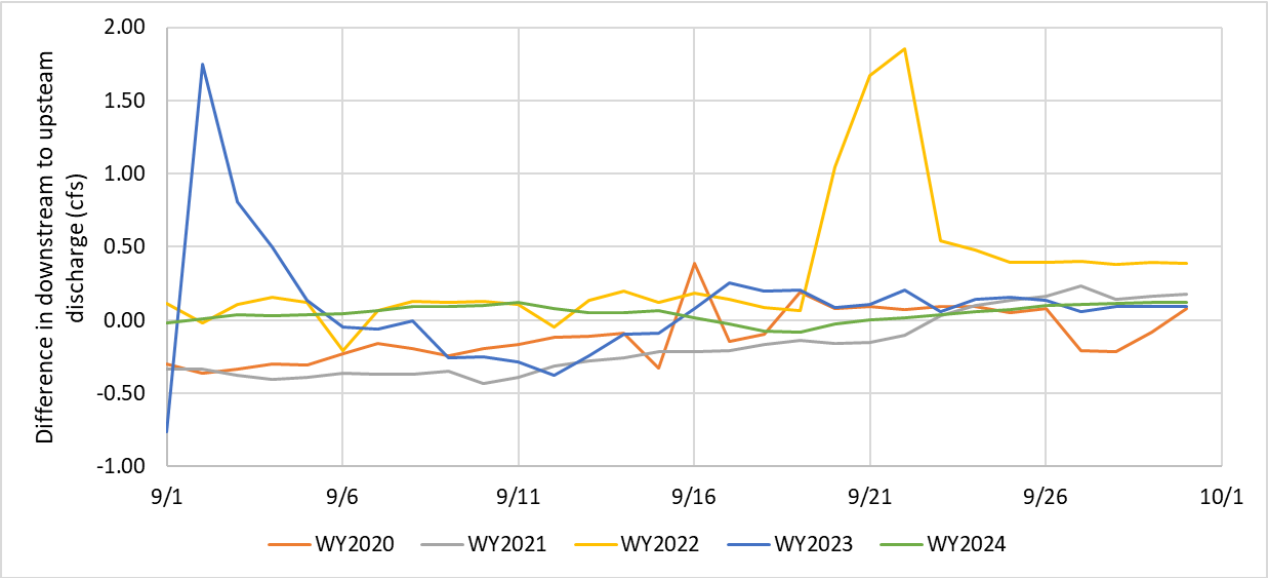

Figure 7. Differences in September flow volume over time (ft3/sec). Negative values indicate higher flow upstream than downstream, positive values indicate higher flow downstream than upstream.

September Flow Volume, Acre-Feet		
Year	**FV US 1**	**FV DS**
2020	45.62	39.72
2021	33.34	23.12
2024	65.96	68.73

Table 2. Differences in September flow volume.

Table 2 shows the volume of flow as calculated at the FV US 1 site, chosen as it has the longest record, as compared to the FV DS site. Only years without large spikes in September flow are displayed. It shows that there is higher flow upstream than downstream in September of 2020 and 2021, but this relationship reverses in WY2024. WY2020 and 2021 were very dry years, which makes comparison more difficult, but the restoration may have contributed to this enhancement in downstream baseflow.

To assess the output performance measure of increased quantity of outflow (relative to inflow) during June-Nov, Table 3 shows the volume of flow for the entirety of the dry season, June-October, for the averaged values of the upstream sites compared to the downstream site. There is likely a high degree of uncertainty in this calculation, especially in the higher water years, because the majority of the water flows during snowmelt and higher flow season (June, July), when difficult access allows for fewer measurements and higher uncertainty in the rating curves. When the same calculation is done for the August – October period (Table 4), when confidence in flow measurements are higher, flows upstream to downstream are similar to each other and between years. WY2019 has the most uncertainty and is considered an outlier. The difference in flow volume generally varies between years, but does not show a consistent trend between pre- and post-restoration years.

Dry Season (June - October) Flow Volume, Acre-Feet			
Year	FV US (mean)	FV DS	Difference (DS-US)
2019	8987	9566	580
2020	1229	2510	1281
2021	1339	1033	-306
2022	2534	2637	103
2023	11586	6786	-4800
2024	4432	4296	-136

Table 3. Dry season (June – October) flow volume.

Dry Season (August - October) Flow Volume, Acre-Feet			
Year	FV US (mean)	FV DS	Difference (DS-US)
2019	1006	1518	511
2020	245	322	77
2021	160	115	-45
2022	307	384	77
2023	1600	1596	-4
2024	325	332	6

Table 3. Late dry season (August – October) flow volume.

Figure 8 shows 15-minute temperature for the sensors used for stage data for each site (FV US 1, FV US 2, FV DS) for July through November of WY2024. These data show that all sites experience strong daily fluctuations in temperature, but the range of variability is lower at the downstream site than at the upstream sites. Deeper water and more shading at this site may enhance this effect. During the flow release, the diurnal temperature variability diminished. This may be due to the short residence time of the water traveling though the site during the release, with less time for the water to warm and cool within the meadow system. This provides another piece of evidence that the released water moves freely through the system.

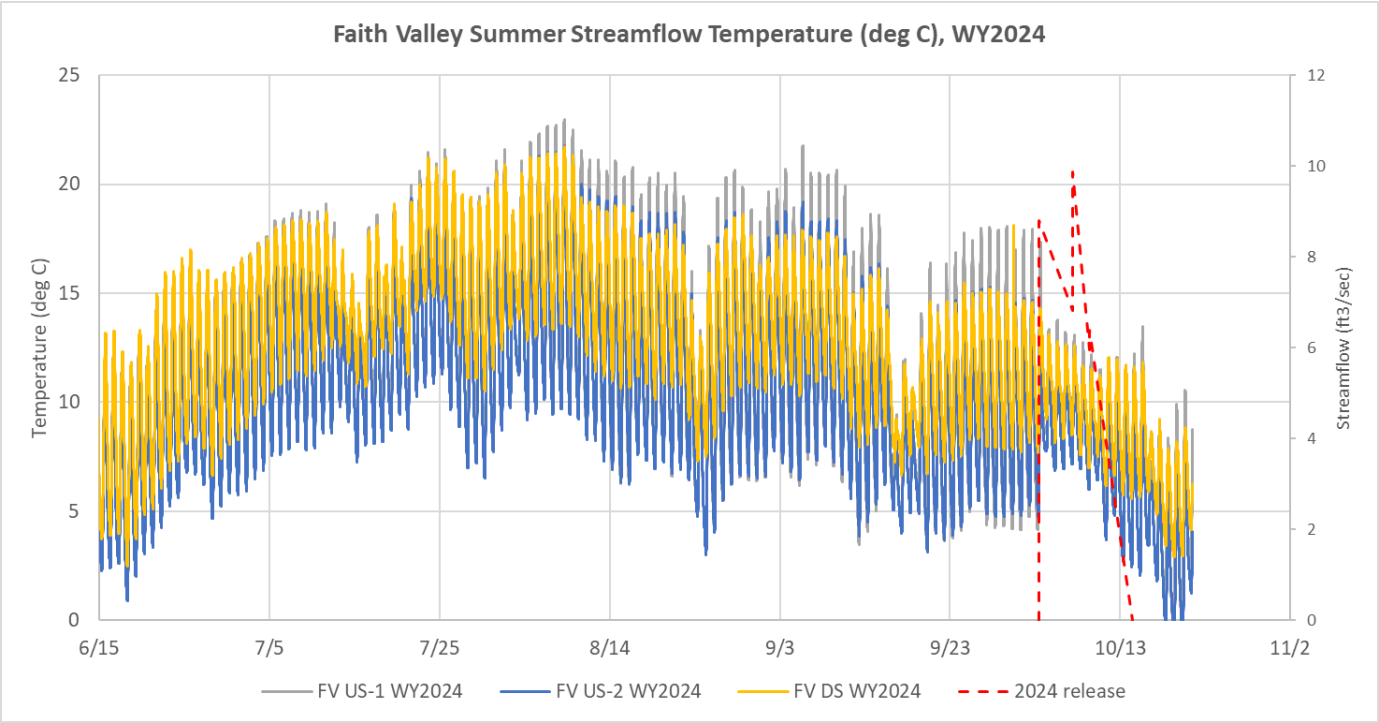

Figure 8. 15-minute summer streamflow temperature at all sites compared to the timing of released water flow, WY2024.

Figure 9 shows daily average temperature for the summer of WY2024 at each gage site. It shows that daily average temperatures are slightly higher at the downstream site than at the upstream site. Each gage site has been equipped with between 1 and 3 sensors that measure stage and temperature between WY2019 and WY2024. Figure 10 shows the daily average temperature averaged between all upstream gage sensors (FV US 1 and FV US 2 sensors), and all downstream gage sensors. This plot shows that in the system pre-project as well as post project, downstream temperatures are slightly higher upstream than downstream. This difference becomes greater in later years (WY2023 and WY2024), but all temperatures are well below the temperature range suitable for fish inhabiting the system. Several studies have investigated the optimal temperature, the temperature that causes stress, and the upper lethal temperature for Lahontan Cutthroat Trout (Coffin et al. 1995, Pahl, R. 2017, Titus and Vanicek, 1988, Vigg and Koch. 1980). Vigg and Koch (1980) determined that Marble Bluff strain (Pyramid-Truckee system) LCT in Truckee River water had an upper lethal temperature of 21.8 degrees C. Titus and Vanicek (1988) found that LCT mortality increased significantly when the fish were stressed by angling at 18 degrees C or higher. According to the USFWS Lahontan Cutthroat Trout Recovery Plan, optimal fluvial cutthroat trout habitat is characterized by clear cold water with temperatures averaging about 13 degrees C ± 4 degrees C. Daily average temperatures for both sites are well below the upper lethal temperature of 22 degrees C. and consistently below the incipient stress temperature of 18 degrees C.

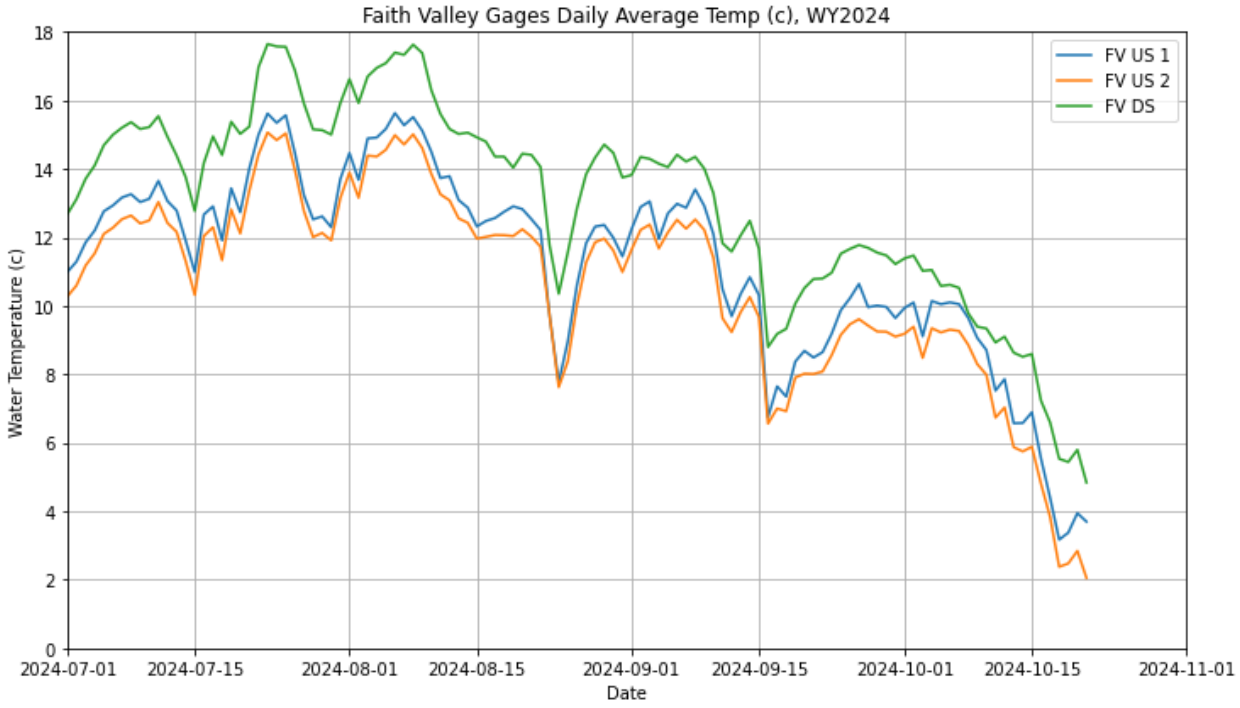

Figure 9. Daily average summer streamflow temperature at all sites, WY2024.

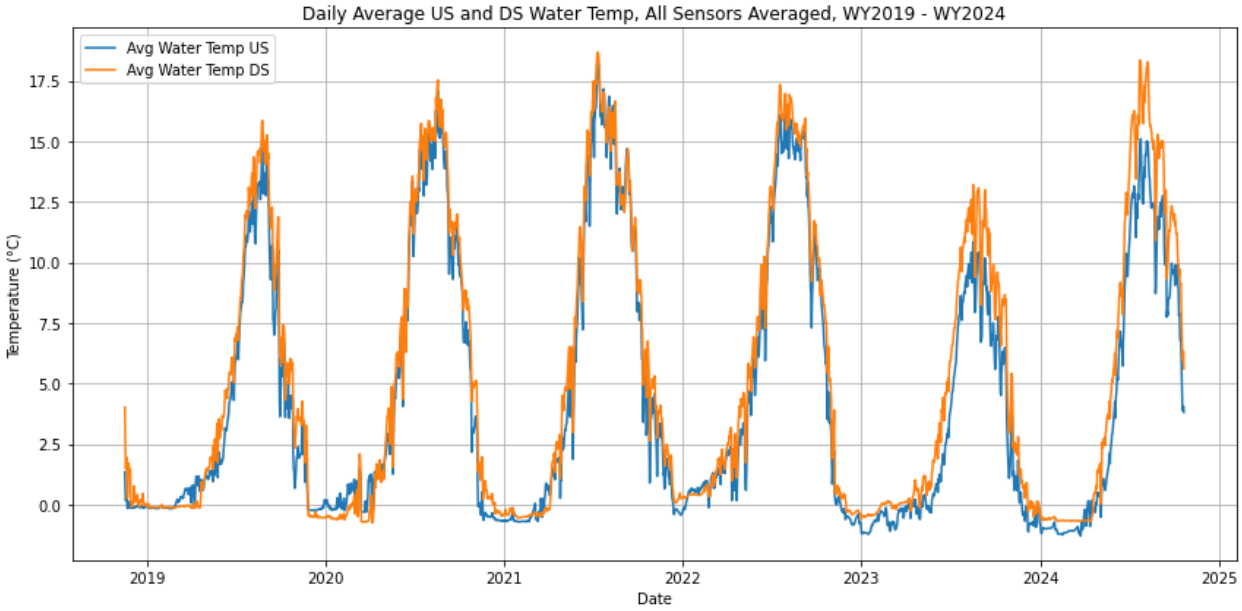

Figure 10. Daily average streamflow temperature averaged across all upstream and downstream temperature sensors, WY2019 – WY2024.

4. Calculation of release volumes as observed in Faith Valley Meadow

Table 5 shows a calculation of the total amount of flow recorded at the upstream (FV US-1) and downstream (FV DS) gages each year during the time that the flow release from Lost Lakes was observable in Faith Valley meadow. To calculate these volumes, the flow in each 15-minute timestep that showed a rise in flow due to

the release was summed and converted to acre-feet. The baseflow from before and after the release was averaged, summed, converted to acre-feet and subtracted from the total release flow volume. Column 1 shows the year, column 2 shows the total release flow volume calculated at the FV US-1 gage, column 3 shows the total release flow volume calculated at the FV DS gage, and column 4 shows the percent difference from upstream to downstream. Note that in a natural stream channel, a streamflow measurement that is considered good to excellent still has an expected error of 2% to 5%, so some variation in results upstream to downstream and to reported release volumes is expected (Rantz et al. 1982). Repeat measurements used in rating curve development can reduce this error. Uncertainty also arises from estimations of baseflow during the release. Confidence is highest in volume calculations for WY2023 and 2024, when manual streamflow measurements were collected immediately before, after and during the release. Confidence is also high for WY2022, when manual streamflow measurements were collected before and during the release. Confidence is still high for WY's 2019, and 2020 when comparing upstream to downstream sites, but lower when comparing to total reported release volumes as fewer streamflow measurements near the time of release were available. Confidence is lowest for WY2021, as the low flows observed tend to have higher measurement errors.

Year	Calculated Upstream Release Volume (AF)	Calculated Downstream Release Volume (AF)	Percent difference, upstream to downstream
WY2019	160.11	158.96	-0.7%
WY2020	112.76	113.08	0.3%
WY2021	4.96	4.66	-6.0%
WY2022	111.03	112.05	0.9%
WY2023	67.03	65.69	-2.0%
WY2024	60.79	61.88	1.8%

Table 5. Volume of flow releases in Faith Valley meadows, as calculated by AR/TU gaging sites.

This table shows that in all years, calculated flow volumes were similar between upstream and downstream sites, generally within the margin of expected error for flow measurements within a natural channel. WY2021 has the highest volume of water lost from upstream to downstream; this could be because this was the driest year of the study, and dry conditions in the meadow may have lead to increased absorption and evapotranspiration, but also lower flows have a higher error in manual measurements; likely it is a combination of the two. In the post-restoration years (WY2022 though WY2024) a difference in flow volume of 1.8% and -2% was calculated. These numbers are within the expected margin of error for this type of study, and similar to pre-restoration years. These data provide further evidence that the flow release water moves freely through the restored system.

5. Discussion/Conclusion

From WY2019 to WY2024, dry season flows including flows released from the Lost Lakes reservoirs upstream of Faith Valley were monitored at both upstream and downstream Faith Valley gage sites. Data from WY2024 represent the second full year of post-construction data from the meadow; construction took place in the summers of 2022 and 2023, and adaptive management continued in WY2024. Data were analyzed in the context of the overall goals of the restoration project: to improve dry season baseflows downstream of the project site, to decrease temperatures and temperature variability, and to monitor the volume and timing of the flow release that passes through the restored meadow, and determine how the restoration may affect downstream water rights holders.

Six years of streamflow gaging from the upstream and downstream ends of Faith Valley meadows shows several trends within the summer and fall season. Summer streamflows are highest during and just after the snowmelt season, when most water is entering the meadow from the mountain snowpack in the headwaters. Freeze-thaw cycles during this time produce strong diurnal fluctuations (on the order of 10 ft3/s). Spring and summer storms often produce small streamflow peaks during the summer season. Baseflow in the meadow is generally reached in mid- to late summer. Data from WY2024 represent a near-median year, with precipitation near the average snowpack measured at the nearby Forestdale Creek SNOTEL; these conditions lead to streamflows that were higher than in the drought years during spring runoff, but similar in baseflow conditions.

Restoration activities in this meadow aim to raise the water table, which then acts a reservoir, infiltrating soils during snowmelt season, with water slowly draining during the dry season. Hydrograph data from WY2024 generally support this conceptual model. Flows are higher upstream in the spring and early summer; then in early September 2024, this relationship reverses, with flows slightly higher downstream than upstream. Late season (October) baseflows were higher at the downstream site than at the upstream sites.

In WY2024, as in previous years, temperature fluctuated strongly throughout the day, and daily average temperature reached their highest point in July of 2024. Data from September 2022 through October 2024 show an improvement in temperature variability at the downstream end of the meadow following construction. Downstream temperatures are slightly higher than upstream temperatures in WY2024, but still within the optimal temperature range for cutthroat trout.

During WY2024, released water appeared to flow freely through the project site, as it had in the three years of pre-project monitoring. In general, flows rise and fall quickly in response to the releases, and increases in flow rate are of a similar magnitude to those being released. In all water years, the volume of flow passing through the meadow was calculated from both upstream and downstream gages, and in each year volumes were similar from upstream to downstream, indicating that release water was not lost to the meadow in either pre- or post-restoration years.

Six years of water temperature data also provide evidence that the released water is moving freely though the system. In the pre-project data (WY2019-WY2021), temperatures were observed to fluctuate strongly through the dry season, likely due to low flow conditions allowing heating and cooling in the degraded portions of the meadow. However, during the flow releases, the released water passing through the gaging stations was similar in temperature upstream and downstream, and temperature was less variable, implying that the

released water was traveling efficiently through the baseflow channel. The low residence time provided little time for water to interact with the meadow system.

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Appendix A
Summary of WY2019 – WY2023 Streamflow and Temperature

Streamflow data from WY2019 through WY2023 are presented below. In each year data from the upstream and downstream sites are compared to each other. Special attention is paid to the time periods during which the water release from Lost Lakes is moving through the meadow, as well as to the low-flow season (July-October). The volume of release water measured at upstream and downstream gages was calculated for each year.

2.3.1 Summary of WY2019 Streamflow

Figure 3 shows a comparison of flows between the FV Upstream 1 and FV Downstream in WY2019, as well as compared to the volume of water released from Lost Lakes.

In early July, flow at both of these sites was at about 60 ft^3/sec, and fluctuated strongly due to daily freeze-thaw fluctuations at the end of the snowmelt season (Figure 3). Flow receded steadily starting in July, and continued to recede through August, punctuated by small spikes due to summer storms. Upstream and downstream flows were similar to each other early in the season, but starting in early August, flows at the downstream site became higher than the upstream site, and flows remained slightly higher throughout the dry season. Flow leveled out in mid-September as a fall baseflow of between 2.5 and 3 ft^3/sec was reached. Diurnal fluctuations in flow due to evapotranspiration can be seen during this time. Flow rose sharply at both sites on October 1, 2019 due to the flow release. Flow was elevated to between approximately 9.5 and 13 ft^3/sec at the Upstream 1 site, and between 10 and 15 ft^3/sec at the downstream site until October 9, 2019, when released flows gradually receded until the shutoff. Flows then continued at a baseflow of approximately 1.75 ft^3/sec upstream and approximately 2.5 ft^3/sec downstream through October 2019. At both sites, in October 2019, flow rose and fell quickly in response to the volume of water being released from upstream, before receding to a level similar to before the release took place.

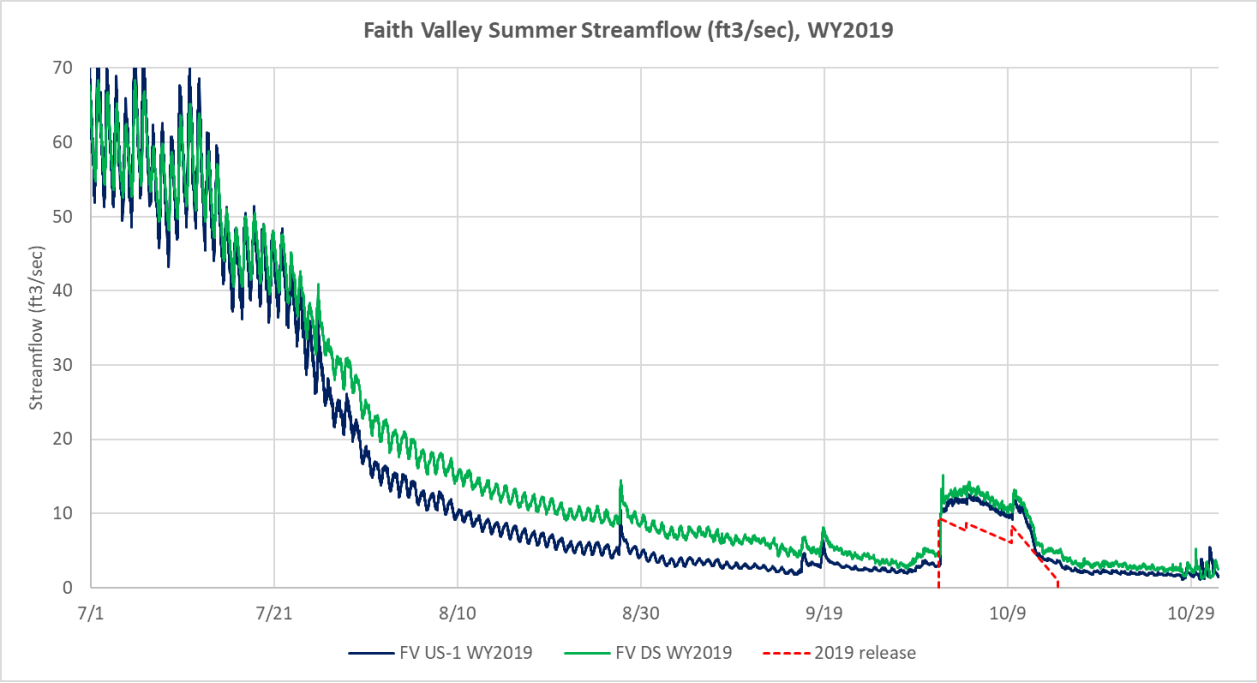

Figure 3. Comparison of streamflow at Faith Valley Downstream, Faith Valley Upstream 1 and released water flow, WY2019.

Figure 4 shows 15-minute water temperature in degrees Celsius from both the upstream and downstream sites for the summer of WY2019, compared to the timing of the flow release. Temperatures show strong daily

variability, with the coldest temperatures in the early morning and warmest temperature in the late afternoons, with temperature swings of about 10 degrees C or more per day. Average temperatures were at about 7 degrees C at the start of the monitoring season, then rose to a season high in late August and early September. The highest daily temperatures are just above 20 degrees C. Following these highs, temperatures followed an overall downward trend through October.

Figure 5 shows a more detailed plot of temperature in September and October of 2019. At this scale we can see that before the flow release, the high temperatures at the upstream site were slightly higher than at the downstream site, the low temperatures dip lower as well – overall the upstream site has a higher temperature variability. During the flow release, the temperature variability diminished, and upstream and downstream temperatures match each other almost exactly. This may be due to the short residence time of the water traveling though the site during the release, with less time for the water to warm and cool within the meadow system.

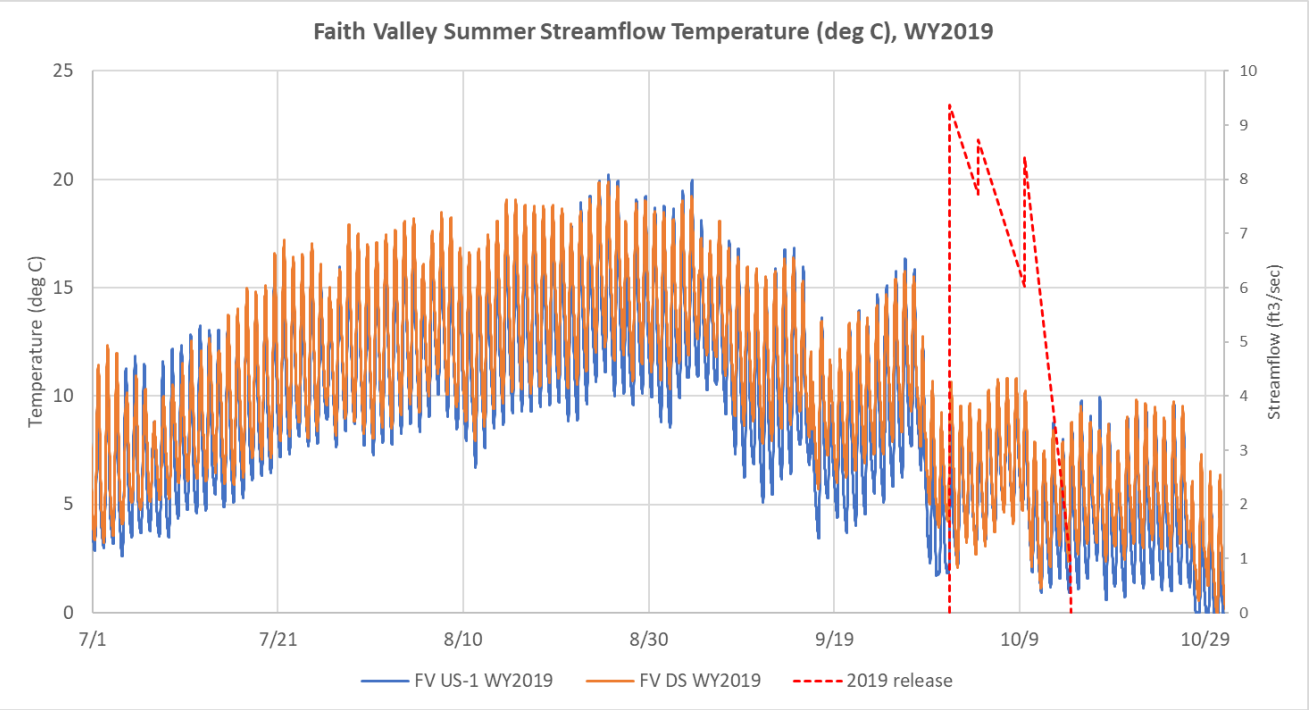

Figure 4. Summer streamflow temperature at all sites compared to the timing of released water flow, WY2019.

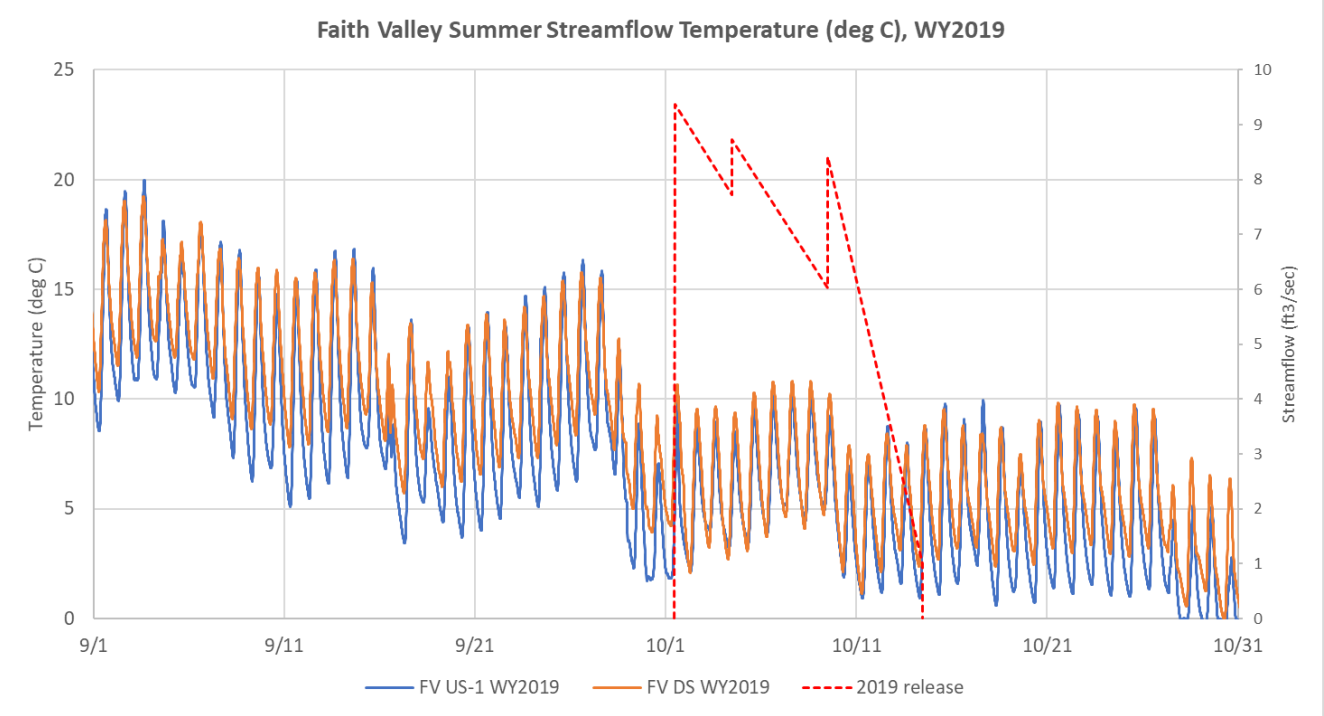

Figure 5. September and October streamflow temperature at all sites compared to the timing of released water flow, WY2019.

2.3.2 Summary of WY2020 Streamflow

Figure 6 shows a comparison of flows between the FV Upstream 1, Faith Valley Upstream 2 and FV Downstream, as well as compared to the volume of water released from Lost Lakes in WY2020.

In early June, flow at the Upstream and Downstream sites was similar to each other at about 40 ft^3/sec, and fluctuated strongly due to daily freeze-thaw cycles. Flow receded steadily from June through August, punctuated by small spikes due to summer storms. Starting in early July, flow at the downstream site was higher than the upstream site, but flows at all sites reached a similar low baseflow in mid-August 2020. Flow at both sites leveled out in mid-August as a fall baseflow of about 0.6 - 0.7 ft^3/sec was reached. Diurnal fluctuations in flow due to evapotranspiration can be seen during this time. Flow rose sharply at all sites on October 1, 2020 due to the flow release. Flow was elevated to between approximately 8 and 10 ft^3/sec until October 7, 2020, when released flows gradually receded until the release shutoff. Flows then continued to flow at a baseflow of approximately 1 – 1.3 ft^3/sec through October 2020. Baseflow at the downstream site was slightly higher than the upstream sites in late October following the release.

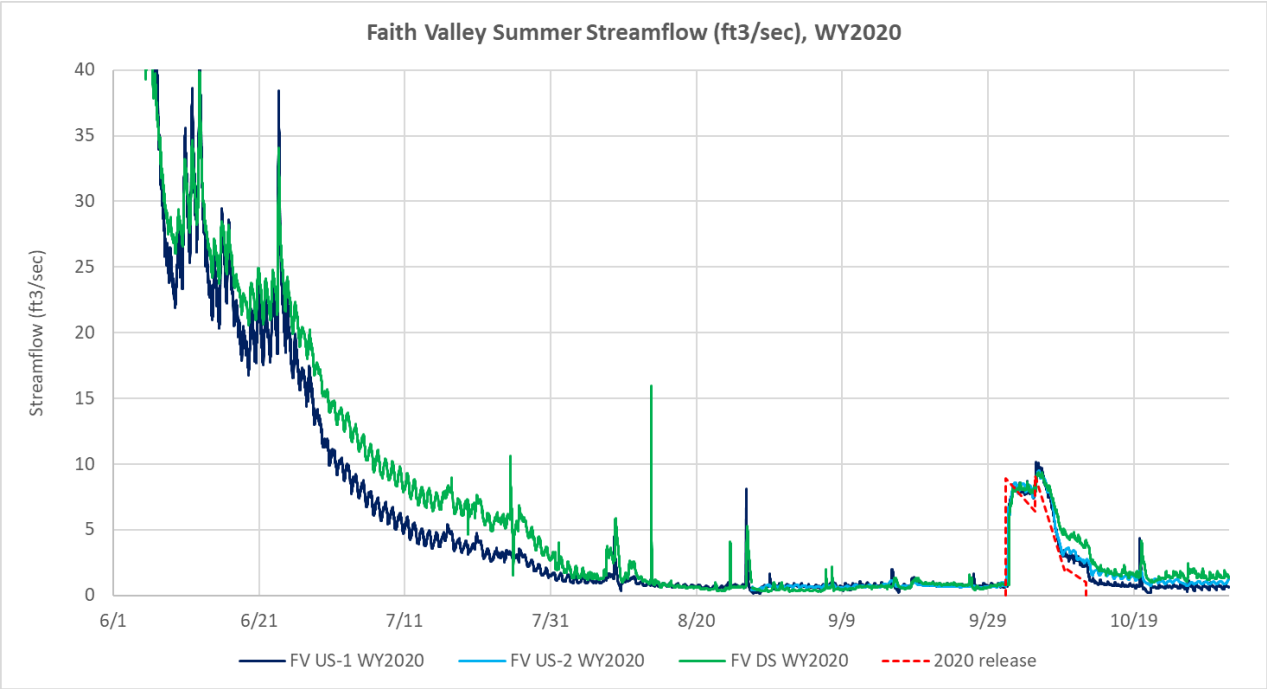

Figure 6. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2020.

Figure 7 shows 15-minute water temperature in degrees Celsius from both the upstream and downstream sites for the summer of WY2020, compared to the timing of the flow release. As seen in 2019, temperature fluctuated strongly throughout the day, but less so at the downstream site than at the upstream sites. Average temperatures were at about 6 degrees C at the start of the monitoring season, then rose to a season high in mid-August. The highest temperatures of the season were observed at the upstream site, at about 23.8 degrees C. Following these highs, temperatures followed an overall downward trend through October. Higher temperatures and greater variability in WY2020 compared to WY2019 were likely due to the lower overall streamflows observed this season.

Figure 8 shows a more detailed plot of temperature in September and October of 2020. At this scale we can see the smaller diurnal variability at the downstream site compared to upstream. Again, during the flow release, the temperature variability diminished, and upstream and downstream temperatures match each other more closely. This may again be due to the short residence time of the water traveling though the site during the release. Following the release, downstream water temperatures were higher than those observed upstream by about 2 degrees Celsius.

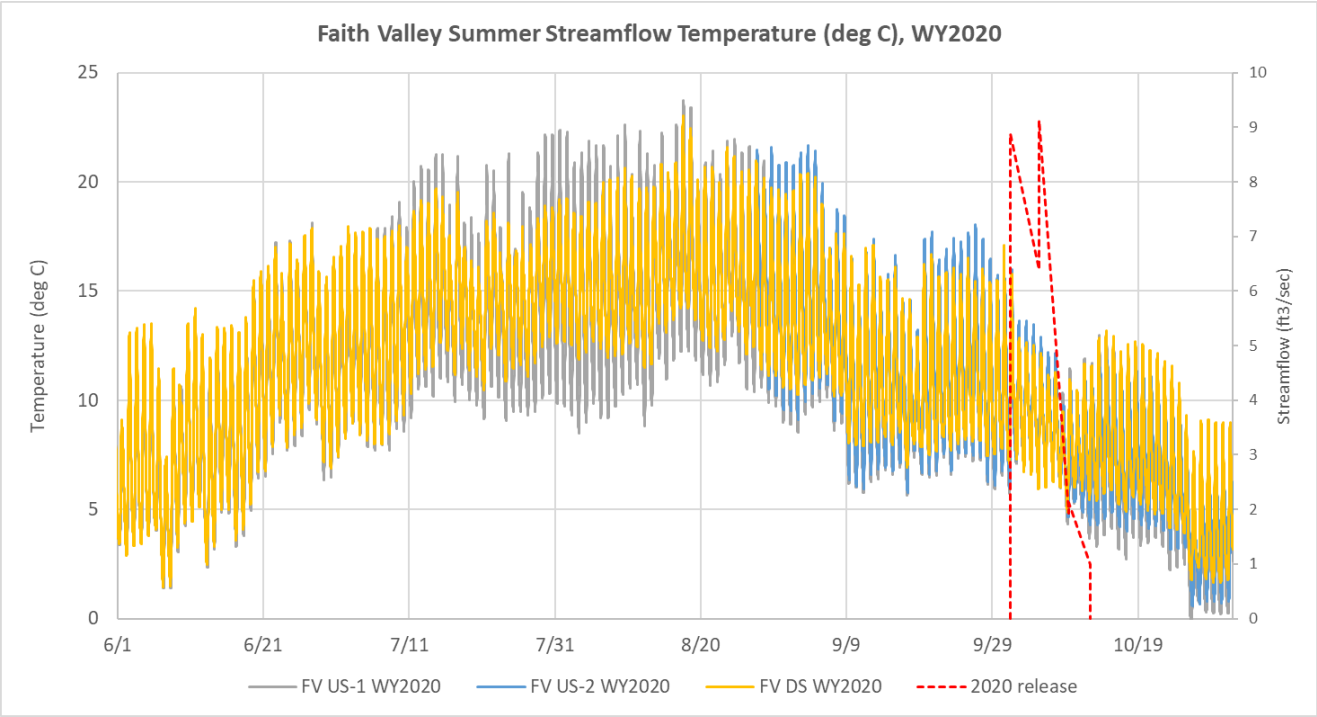

Figure 7. Summer streamflow temperature at all sites compared to the timing of released water flow, WY2020.

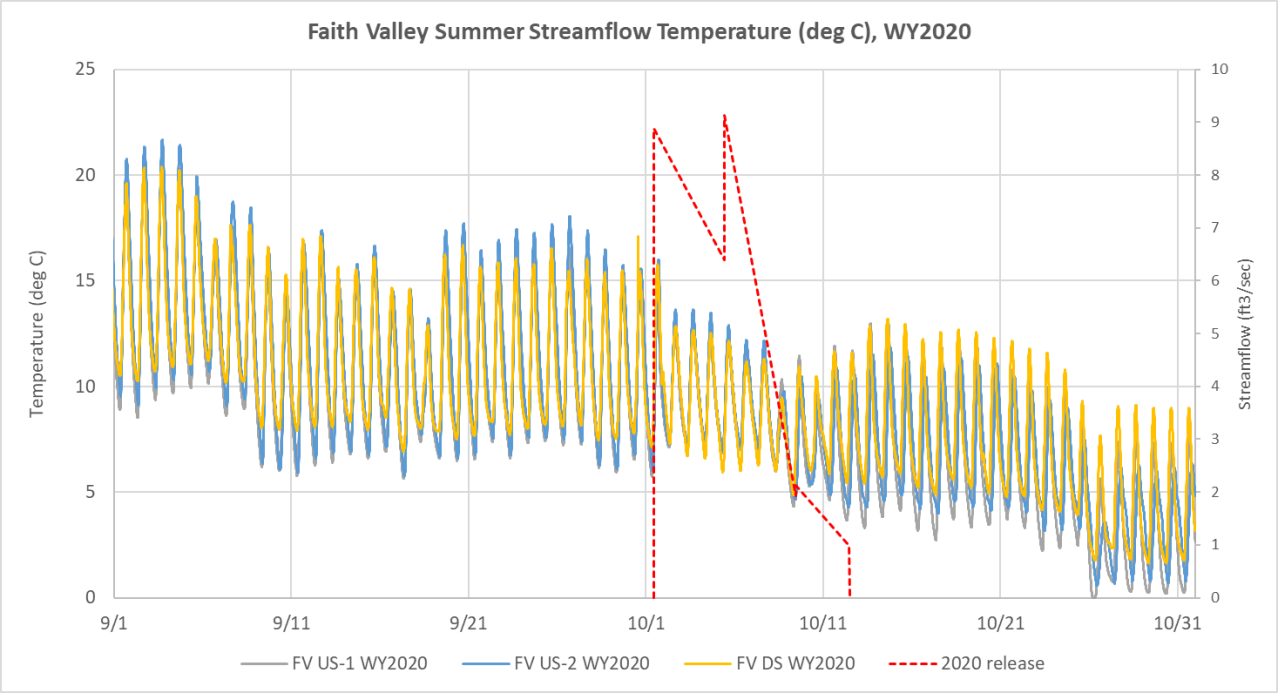

Figure 9. September and October streamflow temperature at all sites compared to the timing of released water flow, WY2020.

2.3.3 Summary of WY2021 Streamflow

Figure 10 shows a comparison of flows between the FV Upstream 1, FV Upstream 2 and FV Downstream, as well as compared to the volume of water released from Lost Lakes in WY2021. In mid-June at the start of the measurement season, flow at the Faith Valley US-1 site was at about 24 ft^3/sec, flow at FV US-2 was at 21

ft^3/sec, and flow at the FV DS site was approximately 19 ft^3/sec. Flow at all sites fluctuated strongly due to daily freeze-thaw cycles (Figure 10). Flow receded steadily from June through July, punctuated by small spikes due to summer storms. Flow leveled out in mid-July and a very low summer baseflow of about 0.7 ft^3/sec upstream and 0.3 ft^3/sec downstream was reached. Diurnal fluctuations in flow due to evapotranspiration can be seen during this time. Flow rebounded slightly in September to about 0.5 – 0.7 ft^3/sec. Flow rose in early October at all sites due to the flow release then receded shortly thereafter to base flow.

Flow at the upstream sites were similar to each other through the year in WY2021. In this dry water year, gaining and losing patterns were slightly different between the upstream and downstream sites than in previous years. In early June, flow at the downstream site was lower than the upstream site, then switched to being slightly higher in mid-June, before dropping to baseflow levels lower than the upstream site mid-July. In early October prior to the release, baseflow at all sites was at about 0.7 ft^3/sec. The peak flow at the sites was about 3 – 3.5 ft^3/sec in response to the release, lower than the peak flow being released from the reservoirs. This may be due to dry antecedent conditions causing some of the release water to be absorbed into the channel bed upstream of the site, or due to the peak flows dissipating between the release point and the meadow due to the brief nature of the release.

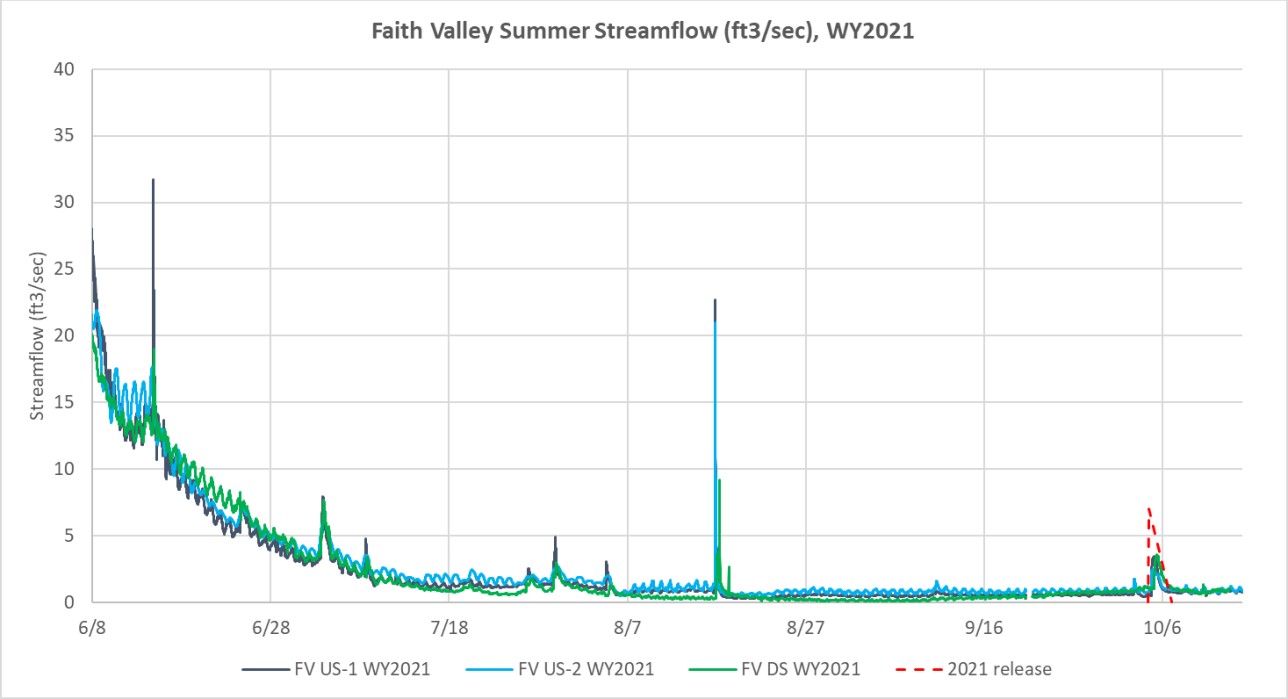

Figure 10. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2021.

Figure 11 shows 15-minute water temperature in degrees Celsius from both the upstream and downstream sites for the summer of WY2021, compared to the timing of the flow release. As seen in previous years, temperature fluctuated strongly throughout the day, but the magnitude of the variability varied more between sites and between times of year, likely due to low-flow conditions. Average temperatures were at about 8 degrees C at the start of the monitoring season, then rose to a season high in mid-July. The highest temperatures of the season were observed at the FV US-2 site, at about 25.1 degrees C. Following these highs, temperatures followed an overall downward trend through October.

Figure 12 shows a more detailed plot of temperature in September and October of 2021. Again, during the flow release, the temperature variability diminished, but the effect was short lived due to the brief nature of the flow release. Following the release, temperatures at all sites continued to decrease with the arrival of fall rains.

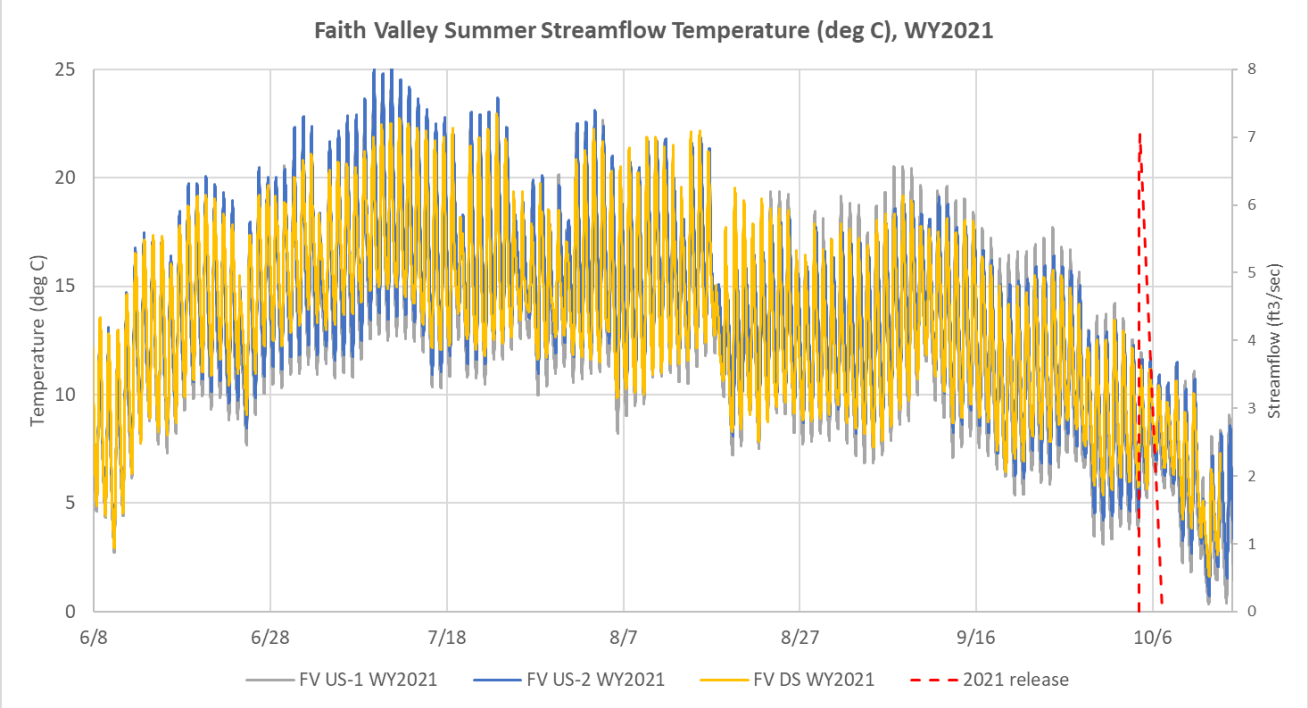

Figure 11. Summer streamflow temperature at all sites compared to the timing of released water flow, WY2021.

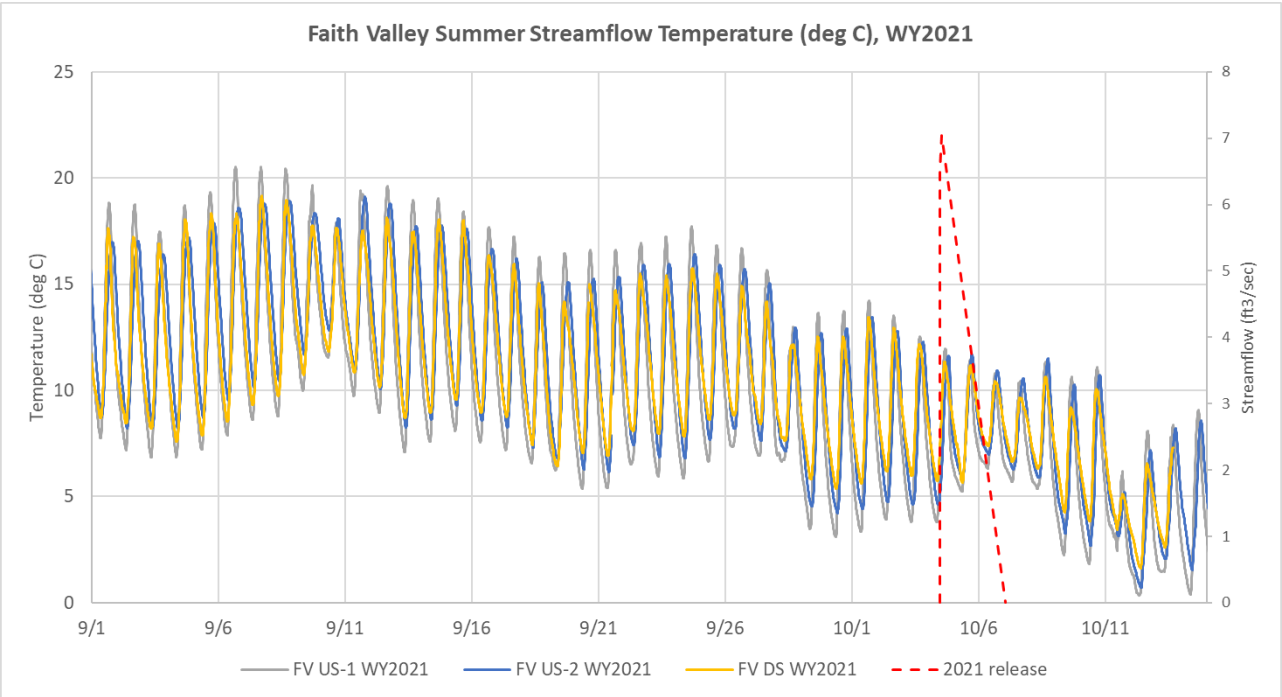

Figure 12. September and October streamflow temperature at all sites compared to the timing of released water flow, WY2021.

2.3.4 Summary of WY2022 Streamflow

Figure 13 shows a comparison of flows between FV Upstream 1, FV Upstream 2 and FV Downstream, and the volume of water released from the Lost Lakes reservoirs in WY2022. In mid-June, flow at the upstream sites was at about 16 ft^3/sec, and flow downstream was about 18 ft^3/sec, the lowest early-season flows of the study period. Flow receded through early August, reaching a summer baseflow of about 0.3 to 0.6 ft^3/sec at all sites. At the downstream site, many short spikes and dips in flow were observed in July; these are presumed to be human and/or beaver activities – the site is near a campground, and beaver activity was observed near the gage in the summer of 2022. In early and mid-August, small spikes observed at all gages are attributed to summer thunderstorm precipitation briefly increasing the flow at the site. Starting in August 2022, spikes and dips at the downstream site can be attributed to restoration activities, which took place from August 15, 2022 through September 13, 2022. Activities included site preparation and fish relocation, dewatering upstream of the FV DS gage, and construction of the grade control structure and pilot BDAs. Following construction, an early fall rainstorm elevated flows from September 18 through September 2022. Flows at all sites rose and fell quickly in response to the storm, then base flows remained slightly elevated after, especially at the downstream site. The Lost Lakes flow release began on October 3, 2022. Flows at all sites increased rapidly, remained elevated between about 8 and 14 ft^3/sec, then dropped with the shut-off of the release on October 11, 2022. Flows at the downstream site remained slightly higher than at the upstream site following the release.

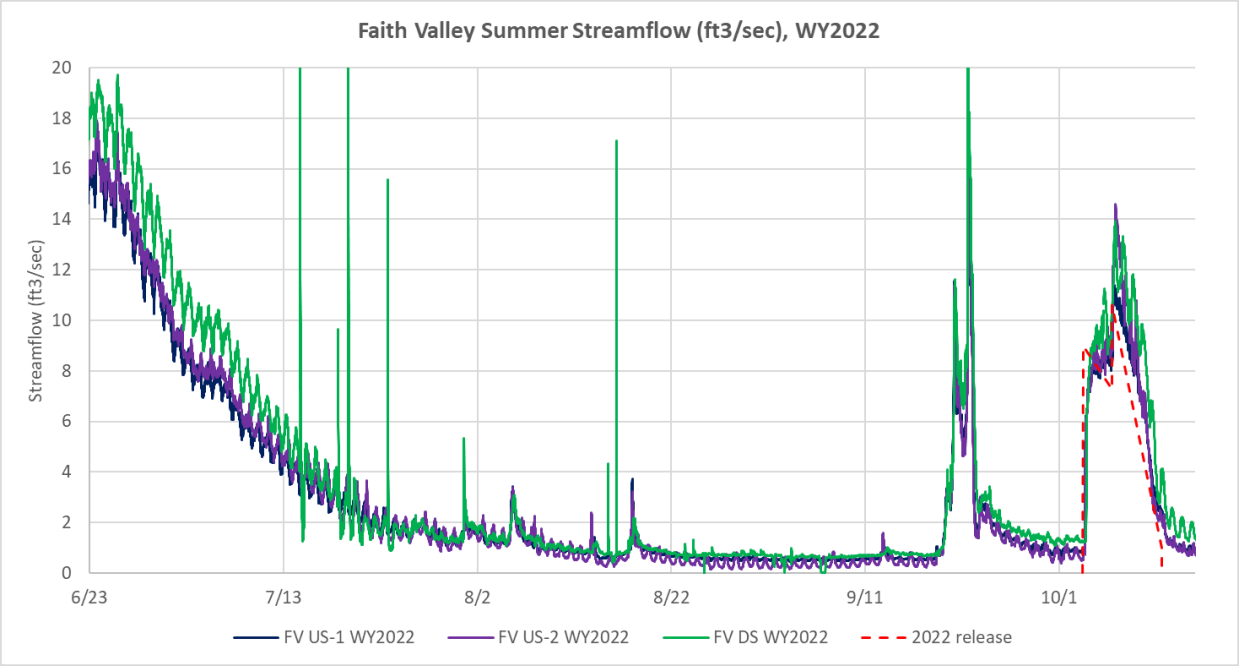

Figure 13. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2022.

Figure 14 shows 15-minute water temperature in degrees Celsius from both the upstream and downstream sites for the summer of WY2022, compared to the timing of the flow release. As seen in previous years, temperature fluctuated strongly throughout the day, but the magnitude of the variability was greater between sites and between times of year, likely due to low-flow conditions. Average temperatures were at about 10 degrees C at the start of the monitoring season, then rose to a season high in mid-July. The highest

temperatures of the season were observed at the FV US-2 site, at about 23.2 degrees C on July 20, 2022. Following these highs, water temperatures remained elevated through much of the dry season, with daily maximum temperatures above 2- degrees C through mid-September, after which temperatures followed an overall downward trend through October.

Figure 15 shows a more detailed plot of temperature in September and October of 2022. At this scale we can see the diurnal variability diminished during the mid-September rainstorm and during the flow release, evidence that these flows were traveling through the system quickly, as they did prior to construction. Following the flow release, the downstream temperature variability was much lower compared to the upstream sites.

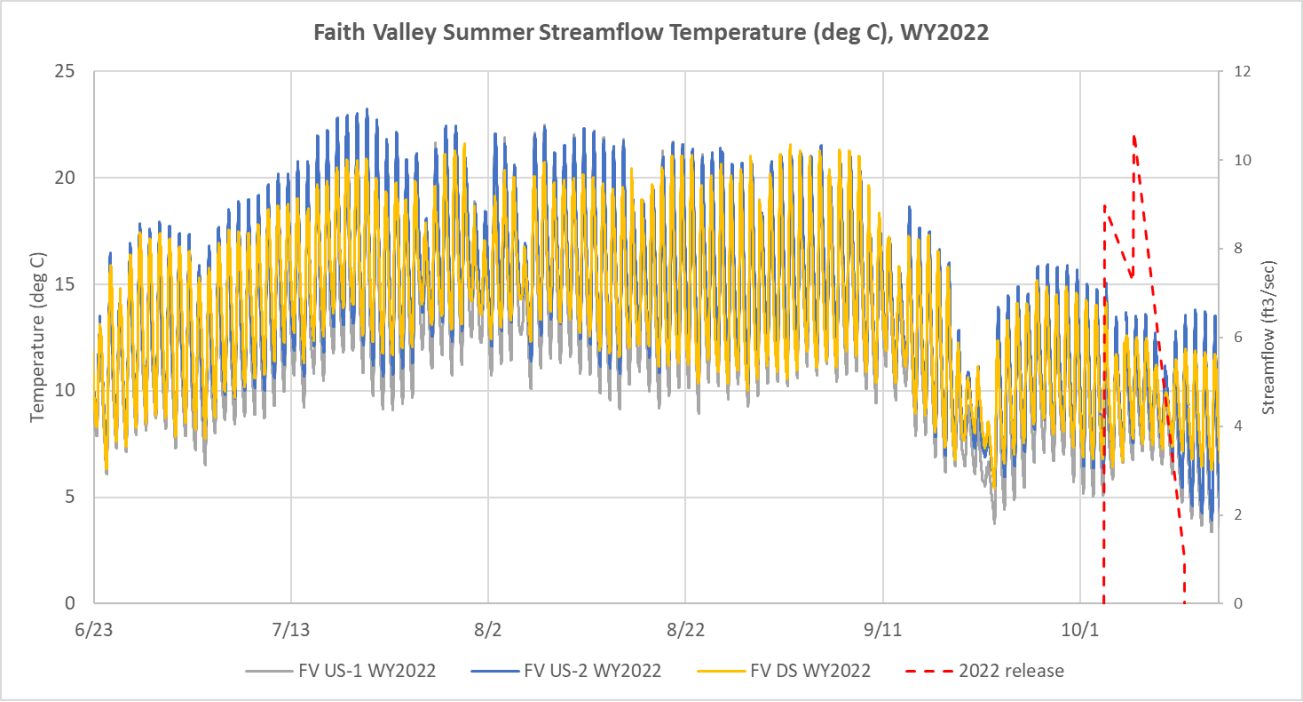

Figure 14. Summer streamflow temperature at all sites compared to the timing of released water flow, WY2022.

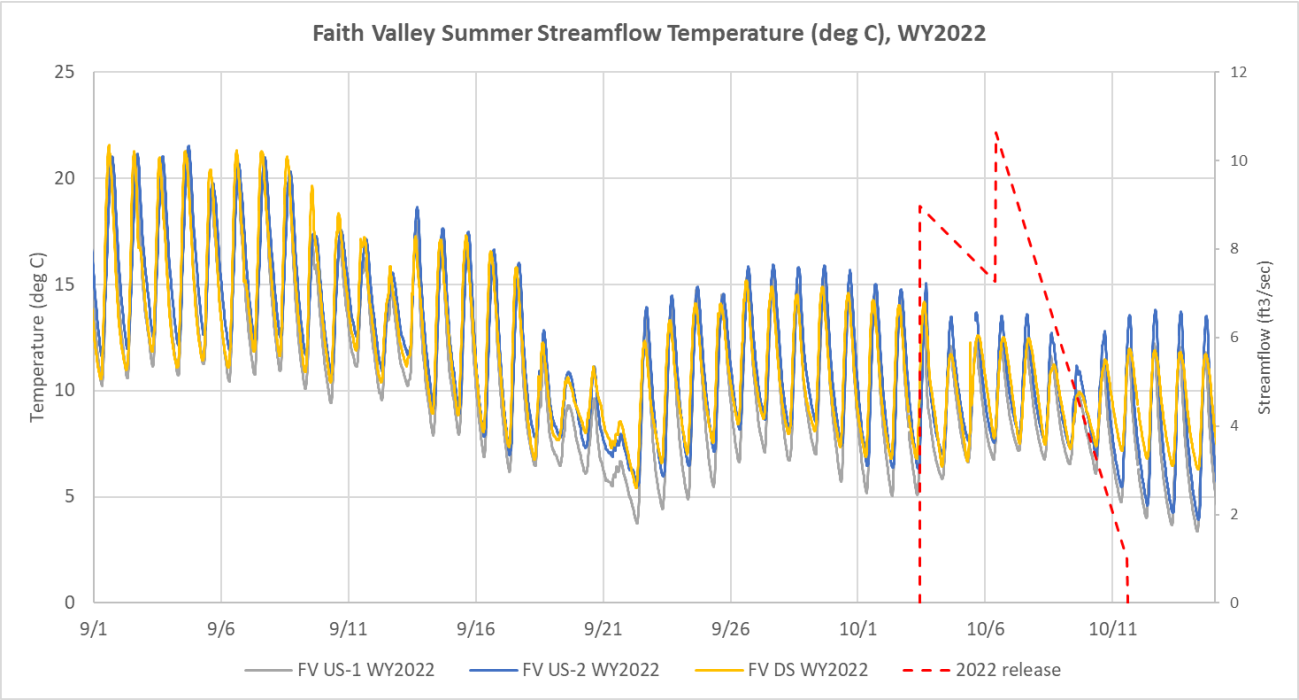

Figure 15. September and October streamflow temperature at all sites compared to the timing of released water flow, WY2022.

2.3.4 Summary of WY2023 Streamflow

Figures 16 and 17 show a comparison of flows between FV Upstream 1, FV Upstream 2 and FV Downstream, and the volume of water released from the Lost Lakes reservoirs in WY2023. Flow measurements were begun for the season in July, as the channel was not wadable in June. In mid-July, flow at the upstream and downstream sites was at about 90 ft^3/sec, the highest early-season flows of the study period. Flow receded quickly through early August, and spiked in response to storms in August and September. A higher than usual baseflow of about 3.5 ft^3/sec was reached in late September. The Lost Lakes flow release began on October 6, 2022. Flows at all sites increased rapidly, remained elevated at near 11 ft^3/sec. During the release, flows are roughly similar to the volume of base flow plus the volume of released water. Flows then dropped with the shut-off of the release on October 11, 2022.

Previous studies have shown an increase in downstream baseflow compared to inflow in restored meadows, especially in drought conditions (Hunt et al. 2018). Conceptually, restoration activities raise the water table in a restored meadow, which then acts a reservoir, as water infiltrates the meadow soils during snowmelt season, and this water then slowly drains during the dry season. During the spring, flows may be higher upstream as the meadow soils saturate, then in the dry season this relationship may reverse, with flows higher downstream than upstream. During the WY2023 dry season, hydrographs and manual measurements show that flows upstream are slightly higher than flows downstream from July through August, then downstream flows are slightly higher then upstream from August through the flow release. This relationship then reverses again, with downstream flows slightly lower than upstream for a period in late October. However, all differences are slight, ranging from 5% to less than 1%; variation upstream to downstream is smaller than in previous years. In such an unusually large water year, soils may still have been saturated throughout the dry season; future monitoring in drier post-project year may show a downstream flow augmentation benefit.

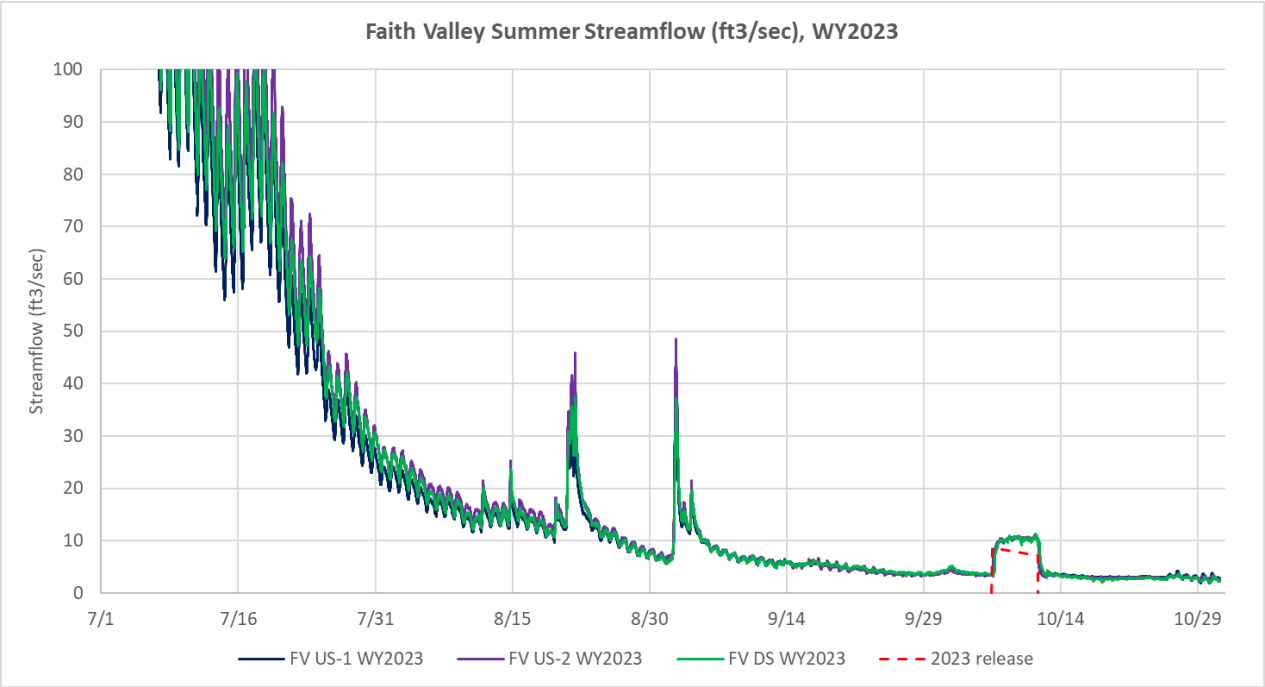

Figure 16. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2023.

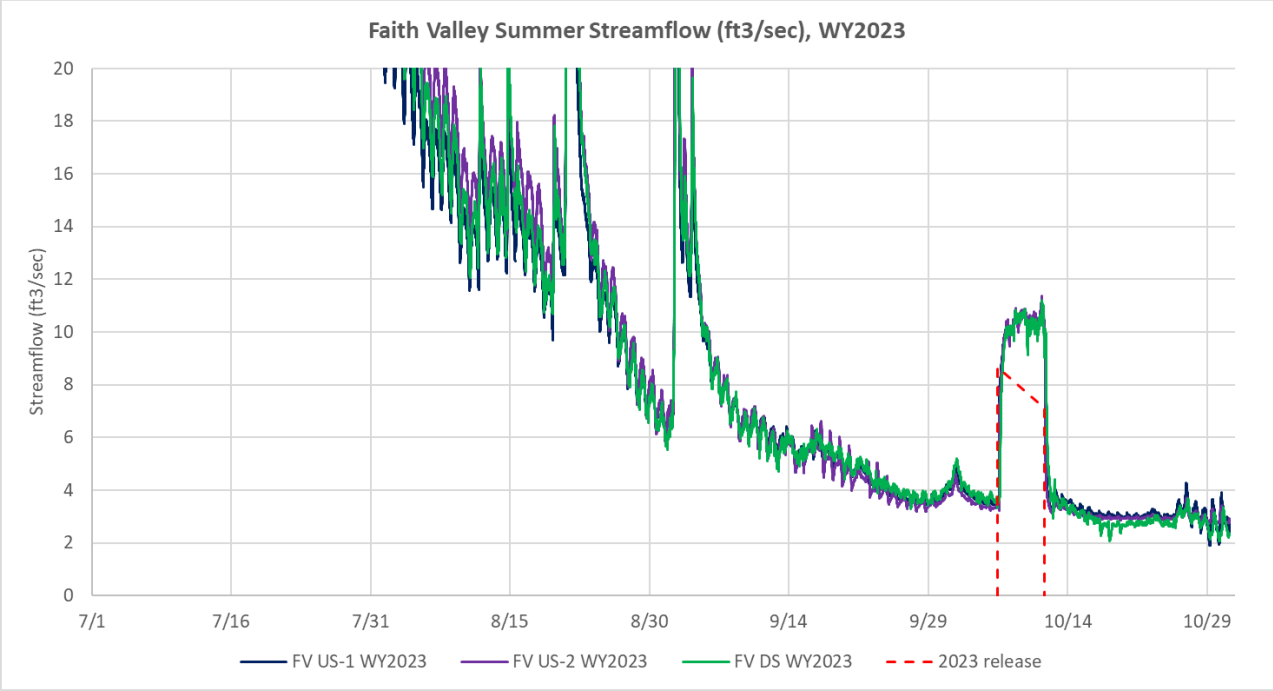

Figure 17. Comparison of streamflow at Faith Valley Upstream and Downstream sites and released water flow, WY2023, with focus on low flows.

Figure 18 shows 15-minute water temperature in degrees Celsius from both the upstream and downstream sites for the summer of WY2023, compared to the timing of the flow release. Overall temperatures were much lower than in previous years; the highest temperature of the year was recorded at downstream site at only 16.7 degrees in mid-August. Average temperatures were at about 5 degrees C at the start of the monitoring season, then rose to a season high in mid-August of about 10 to 13 degrees C. As seen in previous years,

temperature fluctuated strongly throughout the day. The downstream site had higher overall temperatures in July and August, but in September and October this site had lower high temperatures than the upstream site, and less variability in its daily temperature range. Temperatures at all site continued to cool from mid-August through late October.

Figure 19 shows a more detailed plot of temperature in September and October of 2023. At this scale we can see the diurnal variability is diminished at the downstream site while high temperatures remain similar to or lower than the upstream sites. A similar pattern holds during the flow release.

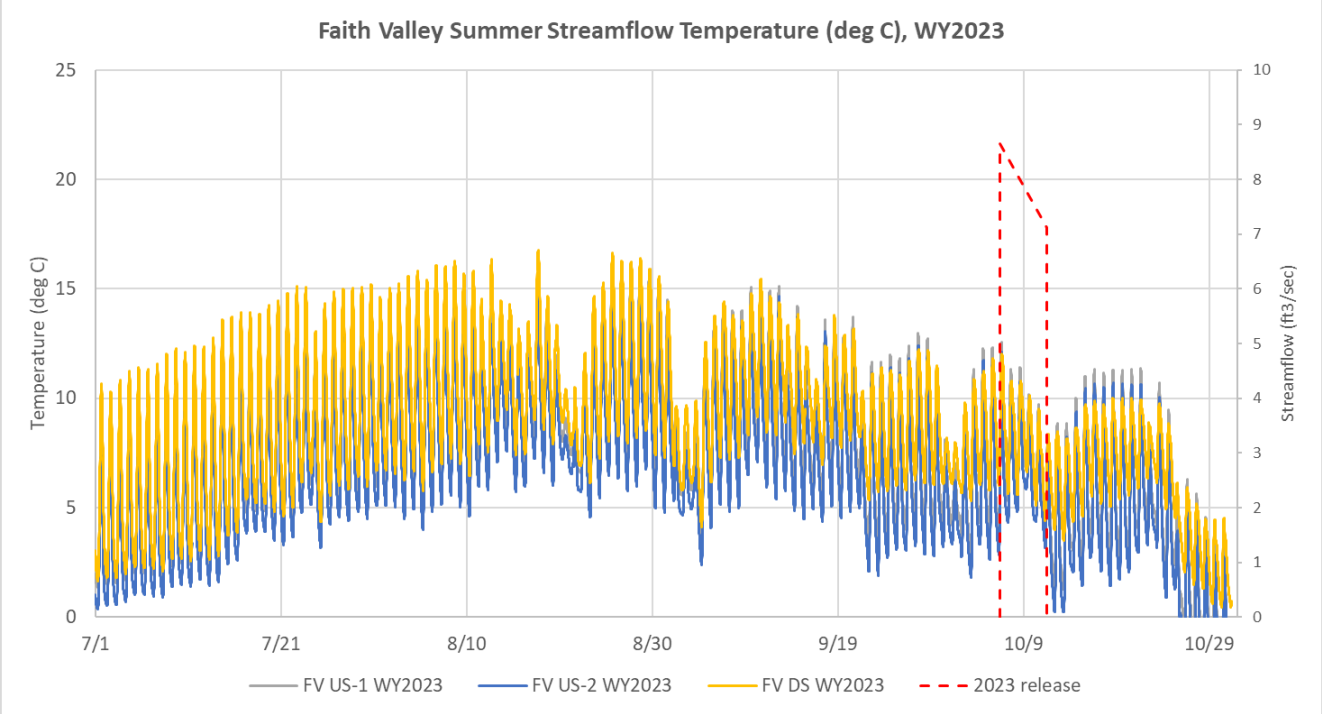

Figure 18. Summer streamflow temperature at all sites compared to the timing of released water flow, WY2023.

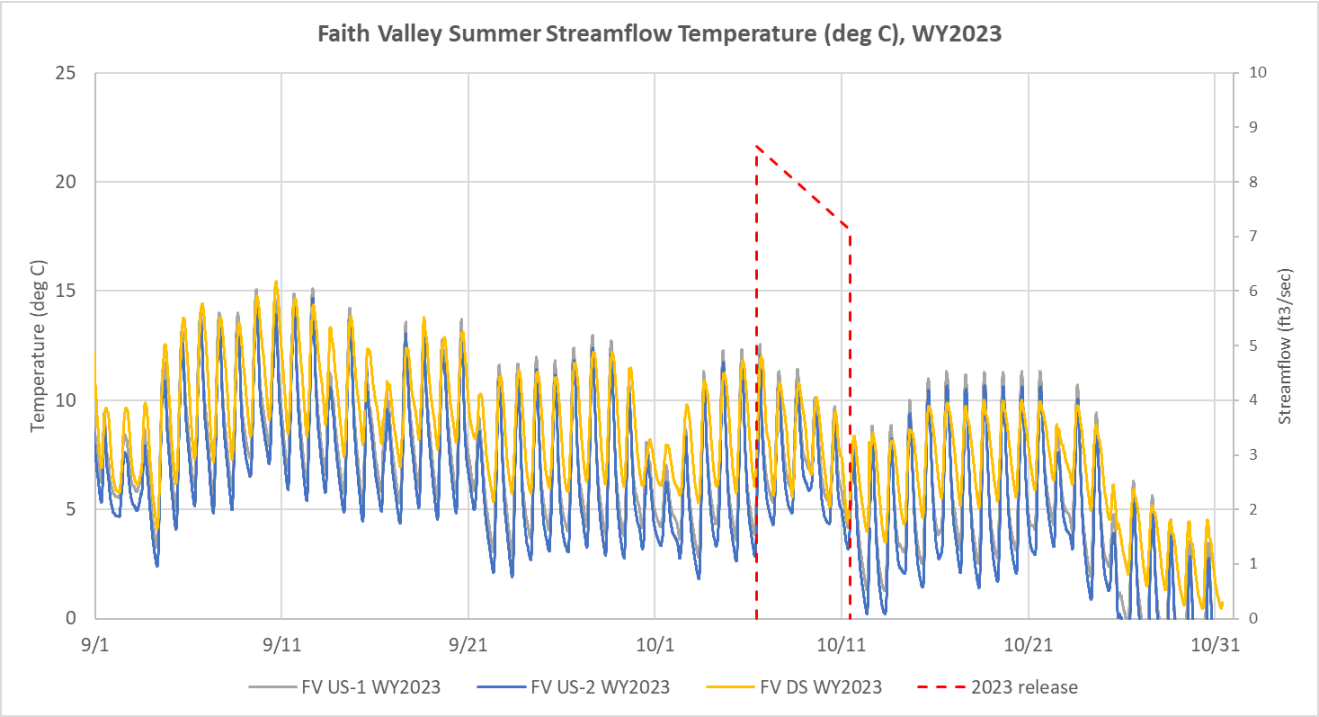

Figure 19. September and October streamflow temperature at all sites compared to the timing of released water flow, WY2023.