Appendix F: Beaver Inventory 2016-2024

Overview and Survey Methods

This Appendix reports the results of beaver monitoring in Faith Valley from 2016 to 2024. The purpose of this monitoring effort was to evaluate the persistence and geomorphic impacts of natural beaver structures in Faith Valley and estimate the effects of the project on these metrics post-implementation. Beaver surveys were conducted from a confined reach just upstream of the project boundary to the steep boulder cascade just below the downstream end of the project area (Figure 1). We collected data once in 2016 and 2017 and then began to collect data twice per year. Surveys were conducted in spring (June/July) and fall (September/October) of each year to evaluate dam persistence through high-flow spring runoff and new dam construction during the summer and fall months. During each survey, we systematically surveyed the area described above and collected GPS points for all complete (channel-spanning) beaver dams (Photo 1), partial beaver dams (Photo 2), and lodges (Photo 3). We recorded whether each structure was complete – defined as channel-spanning, or partial (either partially blown out or partially constructed) and noted evidence of recent beaver activity (e.g. fresh sedges added, chew sticks) that would indicate that the dam was actively used by beaver. The height from the channel bed to the top of the dam both above and below the structure was also recorded to estimate the amount of sediment aggraded behind the dam. Starting in 2018, waypoints were also collected at the upstream end of the pond behind each channel-spanning dam to quantify the ponded area created by each dam. After phase 1 implementation in fall of 2022, we modified the methodology to account for the beaver dam analogues (BDAs) built for the project. In addition to natural beaver structures, we recorded the presence of channel-spanning (Photo 4) or partial BDAs (Photo 6) and recorded BDAs with evidence of recent beaver activity as “BDA+Beaver” (Photo 5). The same measurements described above were collected for all complete BDAs. It is also important to note that beaver monitoring in fall 2023 occurred on October 5th. All posts for the 2023 installed and repaired features were installed by September 13th but work to complete the weave on features continued through October 19th. Therefore, a subset of features counted as partial BDAs were completed as full BDAs by the conclusion of implementation in 2023.

Examples of Beaver/BDA Feature Types:

Photo 1. Example of complete/channel-spanning dams in Fall 2021 (left) and Spring 2022 (right).

Photo 2. Example of a blown out partial dam in spring 2022 (left) and partially constructed dam in fall 2022 (right).

Photo 3. Example of a beaver lodge in fall 2019.

Photo 4. Examples of BDAs without beaver activity in fall 2022 (left) and fall 2023 (right)

Photo 5. Example of BDA with evidence of beaver in fall 2022– not easily visible in photo, but note chew stick in foreground

Photo 6. Examples of a partially built BDA (left) where willow weave was not completed (fall 2022) and a blown out BDA (right) in fall 2023.

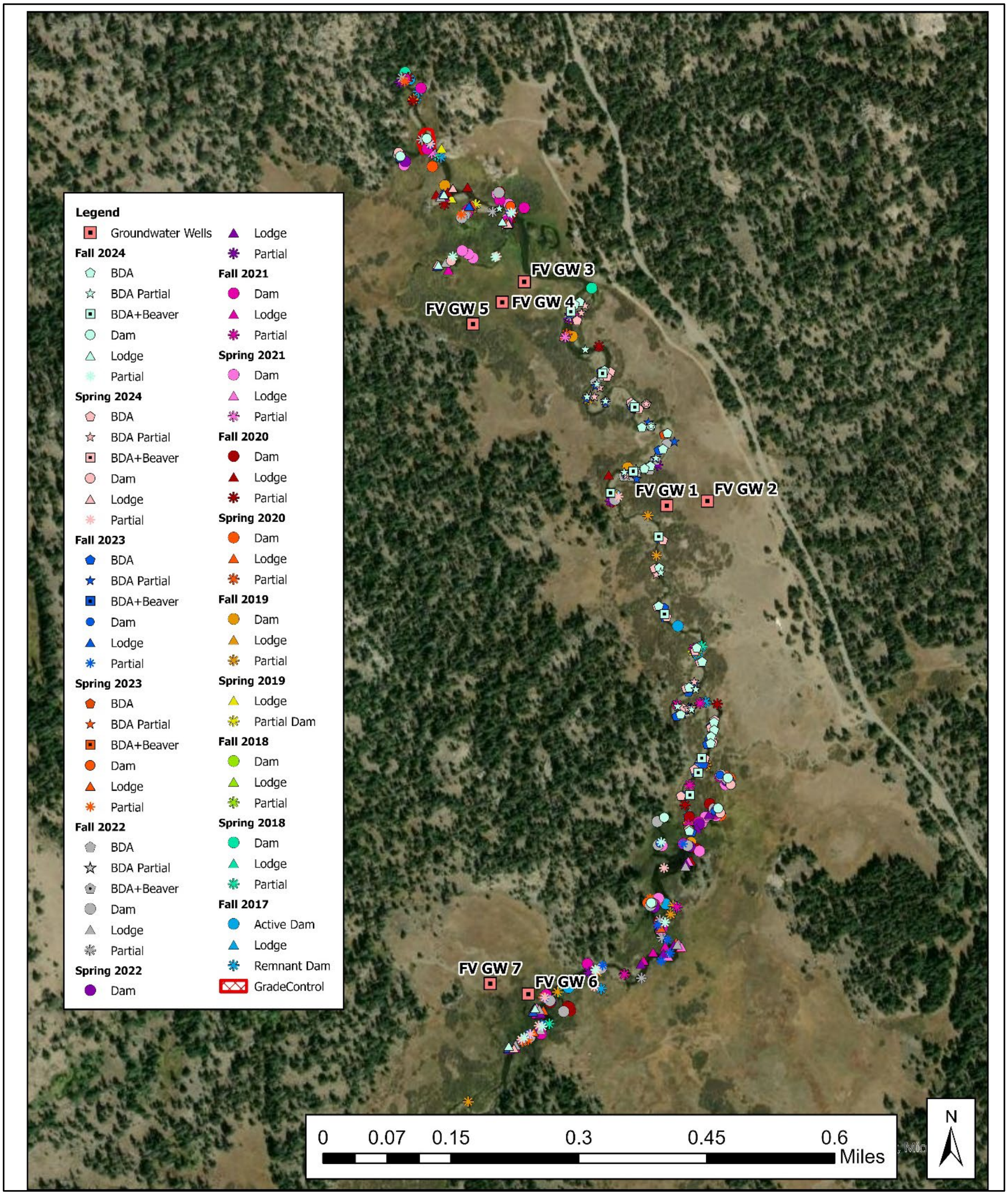

Figure 1. Map showing the extent of beaver monitoring data from 2016-2024 in Faith Valley. Different colors represent different surveys, while different point shapes represent different structure types. An interactive version where different survey layers can be turned on and off is available in Appendix F.1.

Data Cleaning

We created a variety of visualizations to assess changes in the number and persistence of dams over time and how these changes affected total sediment aggradation and beaver pond area in Faith Valley. Before creating these visualizations, we applied several filters to reduce noise in the survey data. First, we excluded all structures that were constructed on tributaries off of the main channel by applying an 80ft buffer to a digitized channel centerline in ArcGIS Pro and dropping all observations that fell outside of this buffer. While these structures could provide some information about total beaver activity in Faith Valley, they were not consistently included in all surveys and therefore made year-over-year comparisons problematic. Second, pond area, sediment aggradation, and structure persistence were calculated only using data from complete/channel-spanning structures, as these data were not collected for partial structures. Zero channel-spanning structures were present in spring of 2019, so no data from that survey is included in the visualizations below even though a survey was conducted that spring.

Changes in Beaver Activity and Beaver Dam Persistence

Expected and Observed Patterns

In general, we would expect the number of channel-spanning structures to be lower in the spring and higher in the fall each year, as beaver dams often get blown out by high spring snowmelt flows and are subsequently rebuilt during lower summer/fall baseflows. We would also expect to see larger decreases in the number of channel-spanning structures in years with larger spring snowmelt floods. During the monitoring period, 2017, 2019, and 2023 had above average spring runoff, while all other years were average or below average (Figure 2). 2023 had the largest runoff during the monitoring period, while 2022 had the smallest (Figure 2). Based on these data, we would expect to see large reductions in the number of channel-spanning structures between fall 2016 and spring 2017, fall 2018 and spring 2019, and fall 2022 and spring 2023.

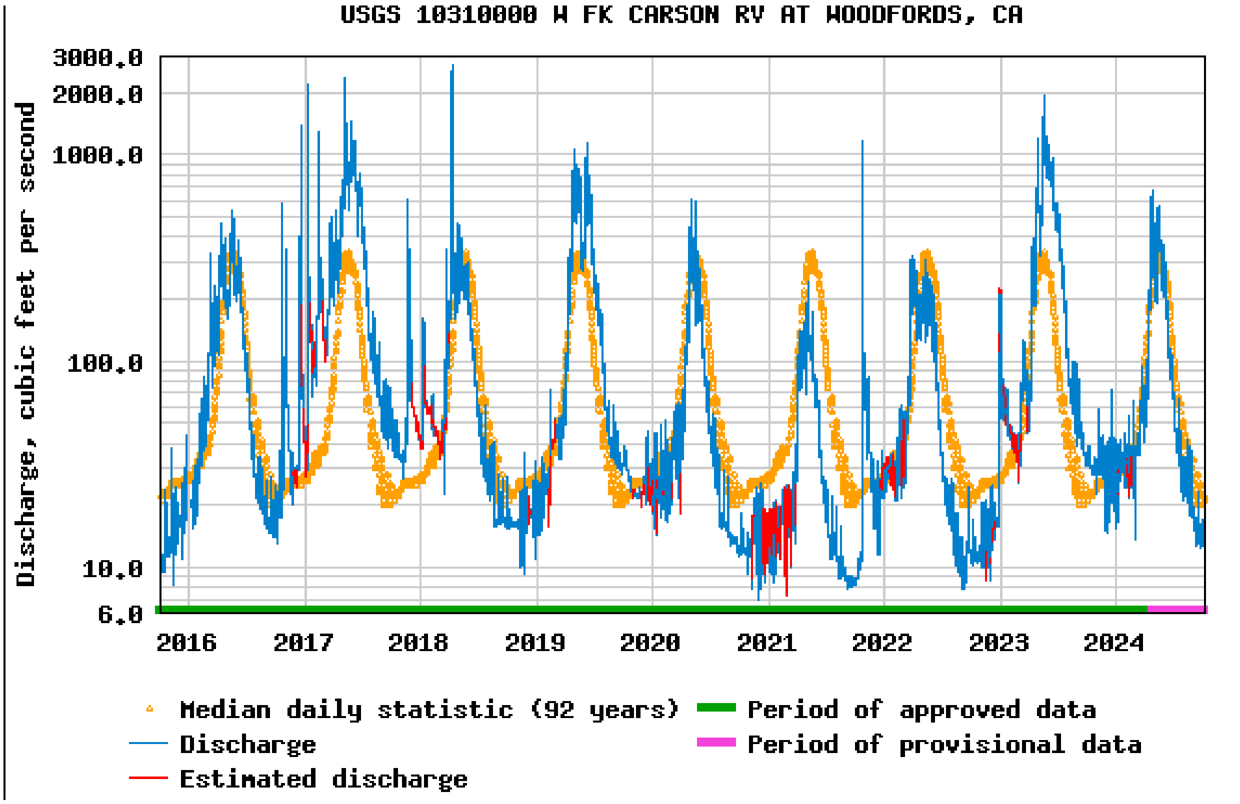

Figure 2. Line graph showing measured and average stream discharge in the West Fork Carson River for WY2016-WY2023. Streamflow data are from USGS gauge 1031000, West Fork Carson River near Woodfords, CA, which is approximately 15 miles downstream of Faith Valley Meadow.

Monitoring data generally fit the expected pattern of fewer complete structures in the spring and more channel-spanning structures in the fall of each year (Figure 3, Table 1). For each year in which spring and fall surveys were conducted (2018-2024), there were either more channel-spanning structures in the fall survey than the spring or the same number in both surveys (Figure 3). However, the largest reductions in the number of channel-spanning structures did not always occur following winters with above-average snowpack. All channel-spanning structures blew out following the above-average winter of 2018-2019 (Figure 3), and almost all blew out following the high precipitation winter of 2016-2017 and record-breaking winter of 2022-2023 (including most BDAs installed in 2022). However, the largest decrease in the number of channel-spanning structures occurred between fall 2021 and spring 2022 (Figure 3), which was the driest winter during the monitoring period (Figure 2). The most likely explanation for this anomaly is that a large early season storm in late fall 2021 caused a rapid and substantial spike in streamflow (Figure 2). This spike was likely responsible for blowing out the majority of channel-spanning structures between the fall 2021 and spring 2022 surveys, as it occurred approximately a month after the fall 2021 survey.

Spatially, beaver activity in Faith Valley Meadow has mostly been concentrated in the upstream and downstream ends of the project reach, with relatively little natural beaver activity in the middle reach (Figure 1). Several large dams were built in the upper meadow above the middle groundwater well transect that persisted through fall of 2022, but these structures have not been re-built after blowing out during spring runoff in 2023. A large dam near the downstream end of the project (~700 feet upstream of the grade control) persisted from 2021-2023, but blew out during spring runoff in 2024 and had not been re-built at the time of the fall 2024 survey. However, beaver are still active in the lower meadow and have built and continue to maintain a large dam on the upstream end of the grade control structure constructed during phase 1 of the project.

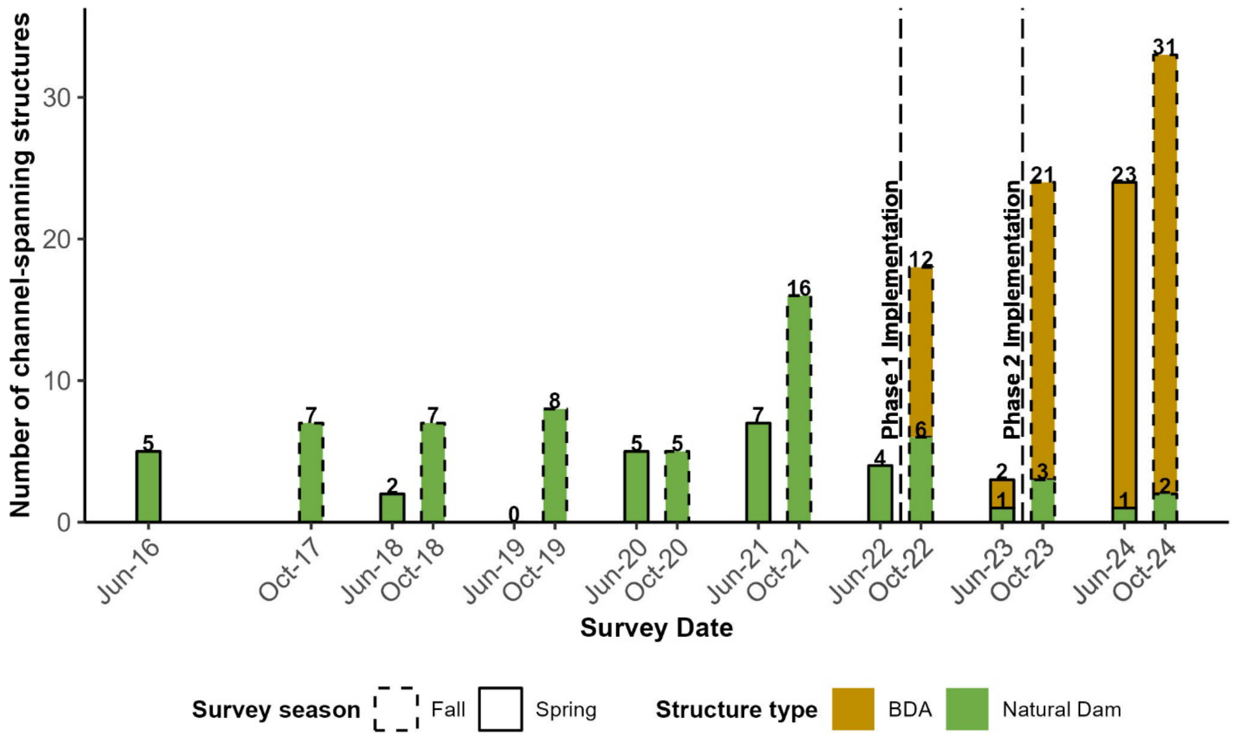

Figure 3. Bar graph showing the number of channel-spanning structures observed in each survey. Bars for fall surveys have a dotted outline, while bars from spring surveys have solid lines. BDAs are shown in brown, while natural dams are shown in green. Labels denote the number of channel-spanning structures present in each survey.

Beaver Features 2016-2024

Survey	Dam	Lodge	Partial	BDA	BDA Partial	BDA + Beaver	Total Dams
Spring 2016	5	2	10	0	0	0	5
Fall 2017	7	2	5	0	0	0	7
Spring 2018	2	3	9	0	0	0	2
Fall 2018	7	4	14	0	0	0	7
Spring 2019	0	3	3	0	0	0	0
Fall 2019	8	5	18	0	0	0	8
Spring 2020	5	5	4	0	0	0	5

Beaver Features 2016-2024							
Survey	Dam	Lodge	Partial	BDA	BDA Partial	BDA + Beaver	Total Dams
Fall 2020	5	9	8	0	0	0	5
Spring 2021	7	8	5	0	0	0	7
Fall 2021	16	8	9	0	0	0	16
Spring 2022	4	11	8	0	0	0	4
Fall 2022	6	8	9	3	2	9	18
Spring 2023	1	5	4	1	12	1	3
Fall 2023	3	5	11	21	18	0	24
Spring 2024	1	4	10	23	16	0	24
Fall 2024	2	4	5	20	13	11	33

Table 1. Number of structures observed during each survey from spring 2016 through fall 2024. BDA + Beaver indicates BDAs with evidence of beaver activity.

We also observed whether dams were active with evidence of recent beaver activity (e.g. fresh sedges added to the dam, fresh chew sticks, etc.) to understand which structures were actively being used/maintained by beaver. Similarly, the number of active structures has fluctuated over time but is generally higher in the fall than in the spring (Figure 4). The number of active structures ranged from zero (spring 2019) to 14 (fall 2021). After phase 1 implementation, there was evidence that beaver were starting to colonize BDAs constructed in fall 2022, as nine BDAs had evidence of recent beaver activity in fall 2022 and one had evidence of recent beaver activity in spring 2023 (Table 1, Figure 4). The total number of active structures appears to be much lower in 2023 than in previous years, which is likely due to the exceptionally large snowpack and high runoff in winter/spring 2023 rather than an effect of the project. During 2024, beaver activity appeared to rebound during the summer months, with eight BDAs showing clear evidence of recent beaver activity (chew sticks, fresh sedges, etc.) during the fall survey (Figure 4). At one of the upstream BDAs, beavers have been adding onto the BDA and creating additional dams in the side channel created by the BDA. This data demonstrates that beavers are engaging with the BDAs, encouraging for the hope that beaver will take over and maintain the structures over the longer term.

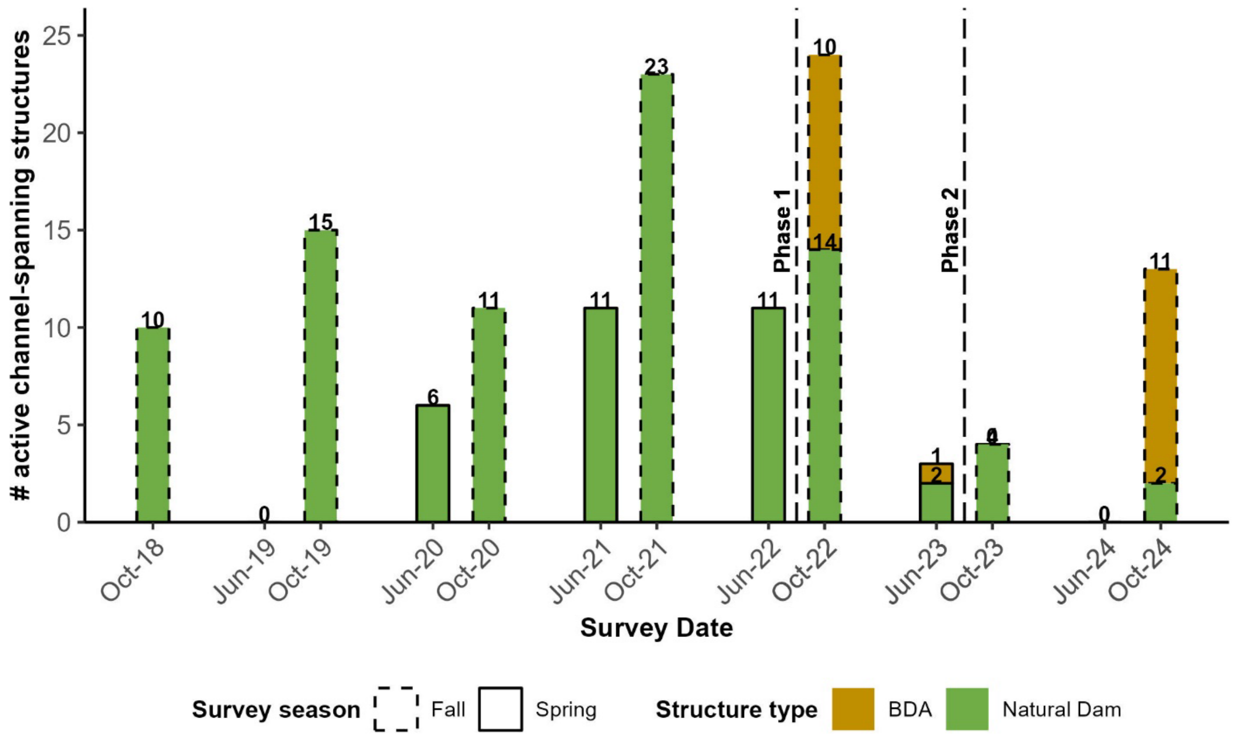

Figure 4. Bar graph showing the total number of channel-spanning structures with evidence of recent beaver activity in each survey. Dashed outlines denote fall surveys, while solid outlines denote spring surveys. BDAs are shown in brown and natural dams are shown in green. Labels denote the number of active structures present during each survey.

Beaver Dam Persistence

In addition to an inventory of the total number of channel-spanning and active structures, we calculated an approximation of beaver dam "persistence" over time by calculating the change in the number of channel-spanning structures from one survey to the next. With this method, positive numbers denote a net increase in channel-spanning structures relative to the previous survey while negative numbers denote a net decrease relative to the previous survey. In accordance with the patterns described above, there is often a decrease in the number of channel-spanning structures between fall and spring surveys and an increase between spring and fall surveys. This demonstrates the pattern of dams blowing out in the spring and then being rebuilt during late summer/early fall baseflow. Before implementation, persistence ranged from a loss of 12 dams in spring 2022 to an increase of 8 dams in fall of 2018 (Figure 5, Table 2). As discussed above, the large decrease in channel-spanning structures between fall 2021 and spring 2022 was likely caused by the large spike in streamflow in November 2021. After phase 1 implementation in fall 2022, the total number of structures increased drastically due to the large number of BDAs constructed. However, most of these structures (12 out of the 14 built) had at least some damage in spring of 2023, due to the very high flow of spring 2023. Phase 2 construction in fall of 2023 recovered these losses (Figure 5), and the structures installed during phase 2 persisted through winter 2023/2024 (Figure 5). The net increase of two BDAs from fall 2023 to spring 2024 is because the fall 2023 survey was completed prior to the weave being completed on the final BDAs in October 2023, thus they were counted as partial dams at the time of the fall 2023 survey. Due to the limited post-project data it is difficult to determine how project construction has affected dam persistence. However, the lack of major damage to any BDAs during winter 2023/2024 (evidenced by no net loss in BDA structures between fall 2023 and spring 2024) demonstrated that the BDAs persisted through spring runoff during an average runoff year.

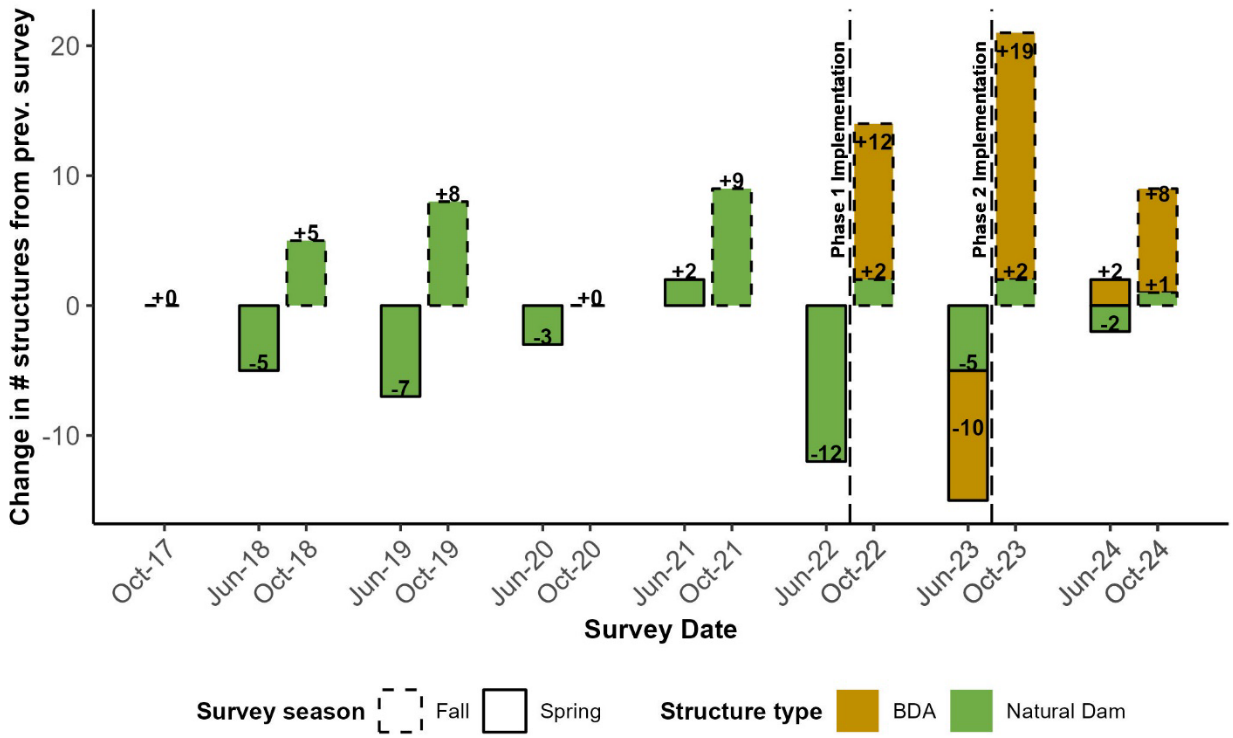

Figure 5. Bar graph showing the change in the number of channel-spanning structures from the previous survey. Positive numbers indicate a net gain in structures relative to the previous survey, while negative numbers indicate a net loss. Fall surveys have solid outlines, while spring surveys have dashed outlines. BDAs are shown in brown; natural dams are shown in green.

Beaver Dam Persistence 2016-2024

Season	Change in # dams excluding BDAs	Change in # dams including BDAs
NA to Fall 2017	0	0
Fall 2017 to Spring 2018	-5	-5
Spring 2018 to Fall 2018	5	5
Fall 2018 to Spring 2019	-7	-7
Spring 2019 to Fall 2019	8	8
Fall 2019 to Spring 2020	-3	-3
Spring 2020 to Fall 2020	0	0
Fall 2020 to Spring 2021	2	2
Spring 2021 to Fall 2021	9	9

Beaver Dam Persistence 2016-2024		
Season	**Change in # dams excluding BDAs**	**Change in # dams including BDAs**
Fall 2021 to Spring 2022	-12	-12
Spring 2022 to Fall 2022	2	14
Fall 2022 to Spring 2023	-5	-15
Spring 2023 to Fall 2023	2	21
Fall 2023 to Spring 2024	-2	0
Spring 2024 to Fall 2024	1	9

Table 2. Change in number of channel-spanning structures between surveys both including and excluding BDAs.

Evaluation of Project Objectives

The primary project objectives with regard to beaver were to increase the persistence of grade control at two locations, locally aggrade the channel of the West Fork Carson River behind beaver dams and BDAs, and increase the extent of beaver ponds. The objective to increase the persistence of grade control at two locations was developed based on the dynamic of two large, persistent dams that were maintaining grade in the downstream (near the grade control) and upstream (upstream of restoration activities) reaches blowing out following the high runoff of 2017. This objective has been partially

Photo 7. New beaver dam built on the upstream end of the grade control constructed in 2022 (left) and persistent BDAs providing grade control. Photos from October 2023 (left) and September 2024 (right).

achieved by installing the grade control structure at the downstream end of the meadow. The grade control structure has persisted since construction in fall 2022 and has been colonized by beaver since fall 2023 (Photo 7). Beyond the grade control, monitoring is demonstrating a trend toward increasing the number and persistence of channel-spanning dams throughout the meadow. As previously discussed, all BDAs installed during phase 2 included in the fall 2023 survey persisted through winter 2023/2024, and the overall number of channel-spanning structures that provide grade control has drastically increased post-project (Figure 3). Additional seasons of data would be needed to evaluate persistence of phase 2 structures over the longer term and with more substantial flow. Additionally, the project may have helped the large, persistent beaver dam located upstream of the grade control structure (which was controlling grade and creating flooded conditions) persist through the high flows of the 2022/2023 winter, but it was subsequently blown out in the 2023/2024 winter. Progress towards the other two project objectives is discussed in the following sections.

Sediment Aggradation

To quantify progress towards the objective of aggrading the channel of the West Fork Carson River in Faith Valley Meadow, we estimated the total amount of sediment aggraded by natural and constructed dams by measuring the dam height above the channel bed both upstream and downstream of the dam, then subtracting the upstream measurement from the downstream measurement. While this is an imperfect measurement of sediment aggradation, it provides a rough estimate of the amount of sediment captured by each dam. Total aggradation for each survey was calculated by adding together the aggradation values calculated for each dam observed in that survey. As with other metrics reported above, the total amount of sediment captured behind dams was generally lower in the spring and higher in the fall, likely because of the higher number of dams present in most fall surveys (Figure 6). Before implementation, total sediment aggradation ranged from 3.2 ft (spring 2020) to 11.7 ft (fall 2021). After phase 1 implementation in fall 2022, total aggradation was not noticeably higher than pre-project levels (Figure 6), as the freshly built BDAs had not had time to aggrade any sediment at the time of the survey. Notably, the BDAs installed during phase 1 recorded *negative* aggradation values in spring of 2023 (i.e. more sediment below the dam than above). This is likely a product of the extremely high runoff in spring 2023, which scoured upstream of the BDAs and often deposited new gravel bars on the downstream side of the structures. Overall aggradation after phase 2 implementation in fall 2023 was higher than any previous measurement (17.0 ft, Figure 6). Most of this aggradation is attributed to the newly constructed BDAs but is a product of how the BDAs were constructed rather than actual sediment movement and accumulation after construction. BDAs constructed in 2023 were built with an “apron” of sediment and gravel on the upstream side to improve durability, which also inflated the aggradation numbers for these structures due to the methodology used in our measurements. During both Spring 2024 and Fall 2024, aggradation values were much lower (5.6 and 4.85 ft respectively). This decrease is also likely a byproduct of the construction and survey methods rather than a true effect of the project, as the aforementioned sediment aprons had an entire runoff season to spread out before the spring 2024 survey, leading to lower measured aggradation values. Additional survey data would help to accurately evaluate how BDAs installed during the project affect channel aggradation over the long term.

In addition to the total amount of sediment captured behind all dams observed in each survey, we calculated a normalized “aggradation per structure” metric by dividing total aggradation for each survey by the number of dams observed in that survey. Aggradation per structure varied from 0.12 ft per structure (fall 2022) to 6.3 ft per structure (spring 2023) and had a less consistent pattern than other metrics reported above (Figure 7). The extremely high aggradation per structure reported for natural dams in spring 2023 is because only one large natural dam was present during that survey, so its large aggradation value skewed the normalized value for that survey. The high aggregation at this feature is interesting though, as it persisted for three seasons contributing to aggregation in this reach, until it was blown out in 2023/2024. Following implementation, BDAs have had lower normalized aggradation per structure than natural dams (Figure 7), likely because they are newly constructed and have not yet had time to accumulate sediment. Data from future surveys would show whether BDAs are as effective as natural dams at aggrading the channel bed. We had hoped this methodology would provide a quick, basic way to quantify aggregation, but after observing the construction of BDAs with the upstream apron and the inconsistency sediment build-up even within structures, we would recommend using a more robust method to quantify aggregation for subsequent projects.

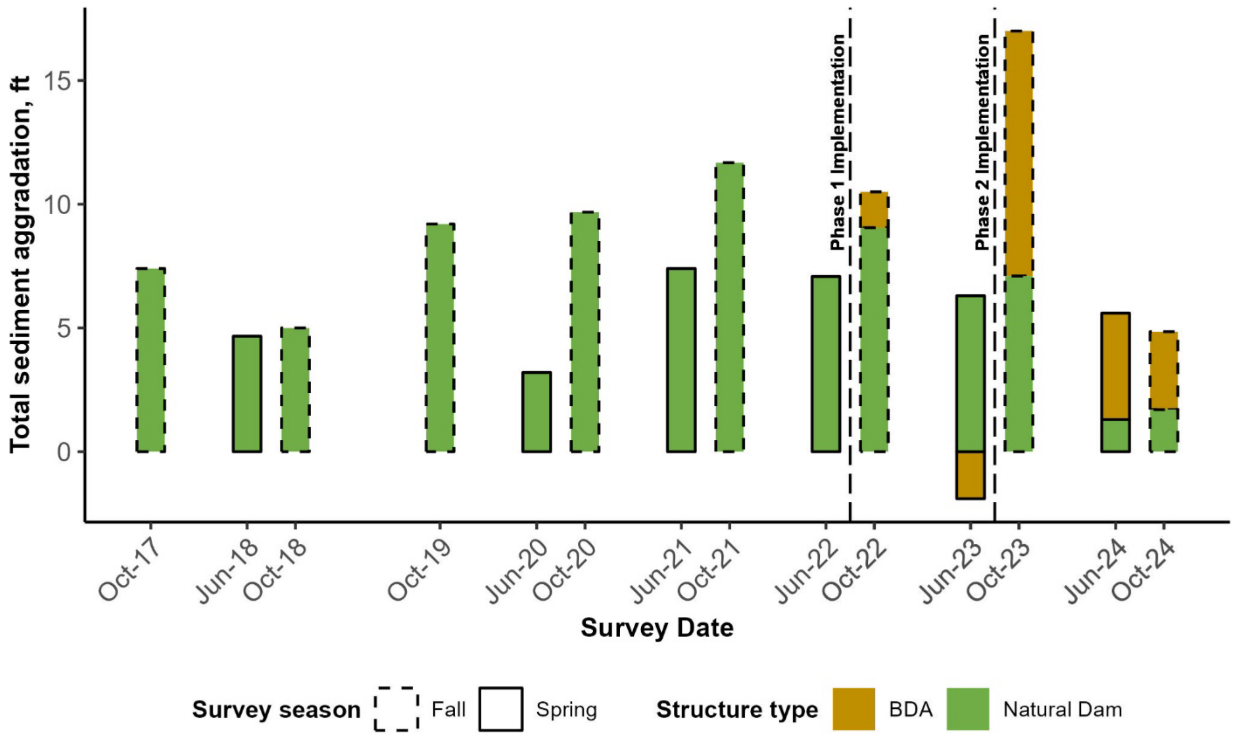

Figure 6. Bar graph showing the total amount of sediment stored behind all dams observed in each survey. Surveys conducted in the fall have dashed outlines, while spring surveys have solid outlines. BDAs are denoted by brown bars, while natural dams are denoted by green bars.

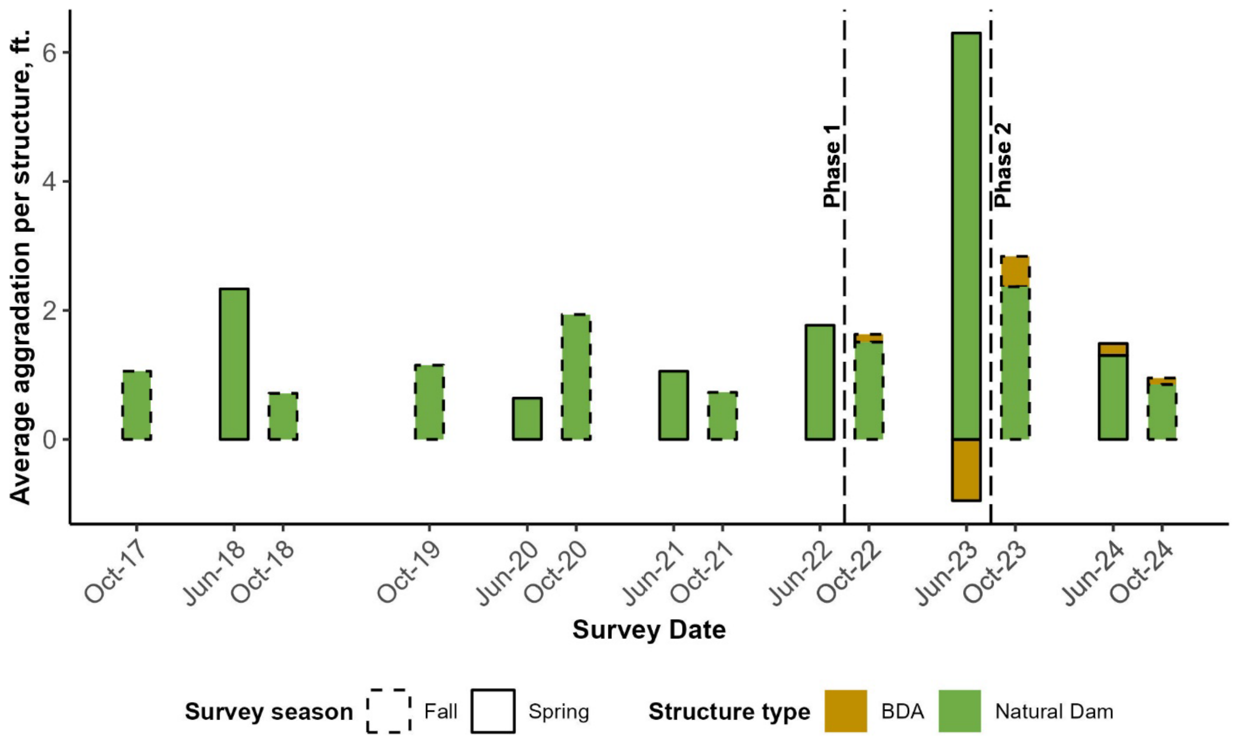

Figure 7. Bar graph showing the average amount of sediment aggraded per channel spanning structure for each survey from October 2017 through October 2024. Surveys conducted in the fall have dashed outlines, while spring surveys have solid outlines. BDAs are denoted by brown bars, while natural dams are denoted by green bars

Beaver Pond Area

Pond area was estimated by calculating the distance between each dam waypoint and the corresponding pond waypoint taken at the upstream end of the ponded water above that dam. This pond length was then multiplied by the average channel width through Faith Valley (18.8 meters based on manual measurements of satellite imagery) to obtain a rough estimate of pond area. These values are likely to be underestimates, as the straight line distance between dam and pond waypoints is shorter than the actual more sinuous pond length and many ponds extend beyond the width of the channel, but it allows for a consistent methodology to compare across seasons. Pond area data was limited, as pond waypoints were not collected before 2018 and data is missing from spring 2019, fall 2020, spring 2021, and spring 2023. Pond area was highest during the fall 2021 survey (Figure 8), which corresponds with the large number of natural structures observed during this survey (Figure 3). There were also more natural ponds in the survey area during Fall 2021 (13) than at any other point during the monitoring period. However, as noted above, beaver monitoring occurring prior to the end of construction in 2023, which likely under-represented the number of ponds and pond area created by the project in fall 2023. Most of the ponds in fall 2021 were no longer present in spring of 2022, and overall pond area declined by roughly 75% between fall 2021 and spring 2022 (Figure 8). Following this substantial decline, pond area increased after both phase 1 and phase 2 implementation due to the addition of BDAs (Figure 8). Much of the pond area added by phase 1 was lost when the majority of these structures suffered damage and became partial structures in spring 2023. Based on monitoring through 2023, the BDAs installed and repaired in phase 2 were ponding significantly more water than any previous survey aside from fall 2021, and this effect has persisted in Fall 2024. These data suggest that the project is achieving its objective of increasing the extent and duration of ponded water in Faith Valley, but additional surveys would be needed to determine whether this effect persists.

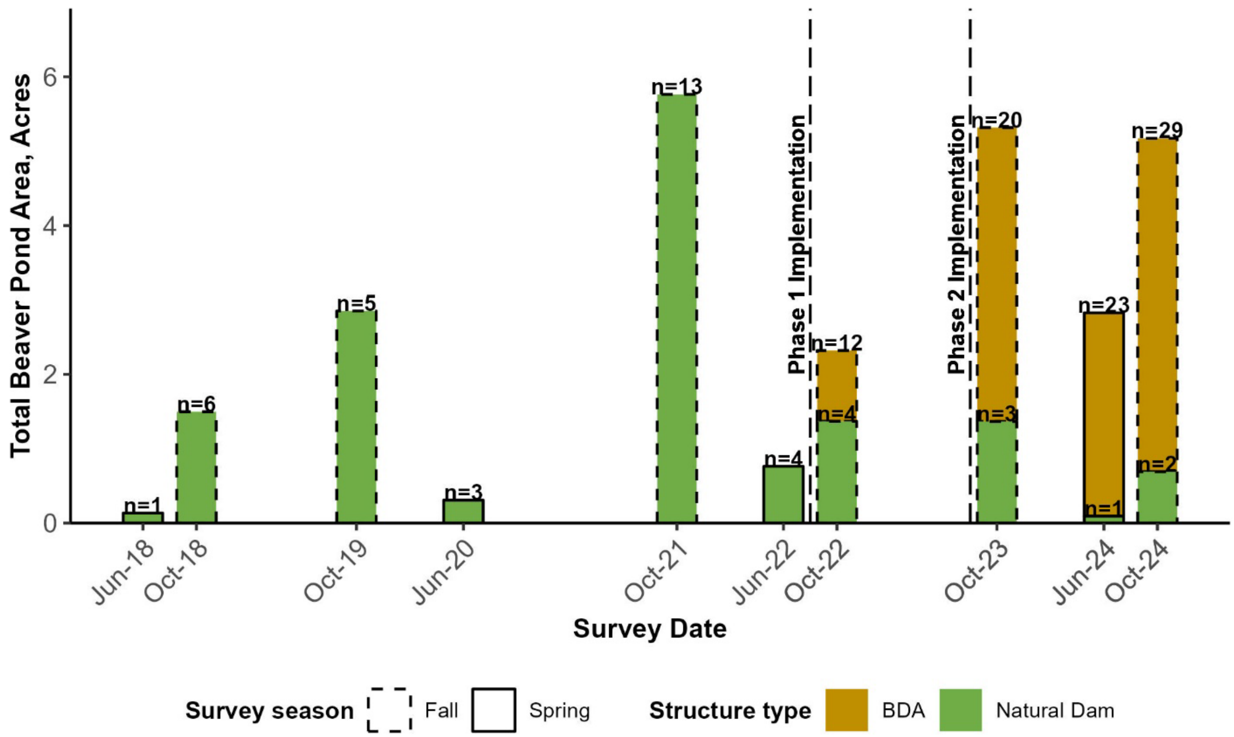

Figure 8. Bar graph showing total beaver pond area in Faith Valley for each survey. Data from spring surveys has a solid outline, while data from fall surveys has a dashed outline. Ponds created by BDAs are shown in brown, while ponds created by natural dams are shown in green. Labels denote the number of ponds observed in each survey. Surveys were conducted between June 2020 and October 2021, but pond waypoints from these surveys are missing.

Conclusions

Overall, monitoring data generally fits the expected seasonal fluctuations in beaver dam quantity and persistence in Faith Valley Meadow. While it is not yet clear whether the project has achieved the objective of increasing the persistence of natural structures, monitoring from 2024 suggests that Phase 2 BDAs are persisting through spring runoff, increasing the extent and duration of ponded water throughout Faith Valley, and likely increasing groundwater storage throughout the meadow (see groundwater monitoring in Appendix H). However, additional monitoring data is needed to confirm that these effects persist in the years following implementation. Based on visual assessment, BDAs are pushing flow onto the lower elevation portions of the meadow surface throughout the meadow, and the newly constructed natural dam on the grade control is backwatering a substantial portion of the lower meadow. Although the aggregation results from this protocol are relatively inconclusive, increasing the persistence of channel spanning dams and dissipating stream energy by spreading flows should result in increased aggregation over time. There is also evidence that beaver have colonized BDAs following construction in 2022, 2023, and 2024, which is promising the long-term success of the project. Overall, beaver monitoring data from 2016 to 2024 indicates that the project is making progress towards its goals, however since the project was only fully implemented in 2023, additional data is needed to show the long-term effects of the project.

Photo 8. Photo of ponded area associated with large beaver dam built on the grade control, October 2024.