Restoration of Priority Meadows in the Walker Watershed
Grant Agreement Number P1796011

FINAL MONITORING REPORT

January 2022

Contents

Purpose and Goals

The purpose of the *Restoration of Priority Meadows in the Walker Watershed Project* is to restore three priority meadows in the upper West Walker watershed: Upper and Lower Sardine Meadows and Cloudburst Meadow. Two of the meadows (Upper and Lower Sardine) are within critical habitat for Yosemite toad, a species listed as threatened under the Endangered Species Act (ESA). The overarching goals of the project are to 1) protect and improve ecosystem services at three priority sites for meadow restoration in the Walker watershed, and 2) protect, enhance and increase Yosemite toad habitat in important climate refugia. The purpose of monitoring for this project is to quantify project performance toward achieving project goals and objectives. This monitoring report represents a deliverable for Task 5 of the Grant Agreement. It presents the results of monitoring during the 2018-2021 field seasons and monitoring occurring prior to the 2018 field season, where applicable.

Background and Summary of Restoration Activities

The grant performance period originally included the 2018, 2019 and 2020 field seasons (generally May through November of each year depending on weather). The grant period was extended to include the 2021 field season to allow additional time for adaptive management. Monitoring under the CDFW grant commenced in Spring 2018. In 2018, we accomplished restoration activities at Lower Sardine and Cloudburst Meadows. The grade control structure at Cloudburst Meadow could not be completed due to complications with having rock delivered on steep Sonora Pass and was deferred to fall 2019. During the 2019 field season we completed the grade control structure and filled additional channel features at Cloudburst Meadow and full construction activities at Upper Sardine Meadow. We also we completed small-scale adaptive management activities at Lower Sardine Meadow. In 2020, we accomplished adaptive management activities at all sites and we conducted limited additional adaptive management at Cloudburst in 2021. Construction activities at Lower Sardine occurred September 17 to October 18, 2018 with adaptive management in 2019. Construction activities at Cloudburst Meadow occurred October 1-5, 2018 and September 25-27, 2019 with adaptive management in 2020 and 2021. Construction activities at Upper Sardine occurred September 27-29, 2019 with adaptive management in 2020. See Annual Summaries of Restoration Implementation for more details about construction activities. This report presents the results of pre- and post-restoration monitoring at each site.

Objectives, Performance Measures, Metrics and Monitoring Methods

The table below presents the performance measures for each objective included in the grant agreement and identifies the metrics and monitoring methods to quantify them. We have updated the table to include tracking of performance measures through 2021.

Objectives, Performance Measures, Metrics and Monitoring Methods

Objectives	Sub-objectives	Performance Measures	Metrics	Monitoring Method(s)	Monitoring Sites	2021 Performance Measure Results
Improve meadow condition and function on 18 acres of mountain meadow. Provide natural water storage, flood attenuation, cooling and filtering of water, improved aquatic and riparian habitat for native species, and increased resilience under climate change	Improve overall meadow condition on 18 acres	Improved wetland condition over baseline	Increased attributes and overall CRAM score: hydrology, physical and biotic attributes	CRAM: Slope Wetlands	All	Increased index score and hydrology scores over baseline at all sites. Increased biotic score at Upper Sardine Meadow.
		18 acres restored	18 acres restored	GPS measurements/ GIS mapping	All	18 acres restored
	Fill and stabilize unnatural channels to improve natural sheetflow on 13 acres	2080 feet of unnatural channels filled/stabilized	Length of channels filled/stabilized	Photo points/GPS measurements	All	2200 feet of unnatural channels filled/stabilized
		Gully incision rate is zero feet/year on 2080 feet of treated channel.	Incision rate	Cross-sections and longitudinal profiles	All	Gully incision reduced 1-4 ft. Incision rate is zero feet/year on 2200 feet of treated channel.
	Headcuts stabilized to reduce soil loss and meadow dewatering Reduced sediment entering Sardine and Cloudburst Creeks	15 Headcuts stabilized; 3 Grade control structures installed to prevent erosion; Migration rate of 15 headcuts is reduced to zero	Number and migration rate (feet/year) of headcuts	General: Photo points/headcut measurements; Grade control headcuts: cross-sections and longitudinal profiles	All	Migration rate reduced to zero for 11 measured headcuts measured. 21 photo-documented headcuts stabilized. 3 grade control structures installed to address large headcuts.
	Increased Groundwater level as an indicator of water storage	Groundwater level raised significantly over baseline post-restoration	Groundwater level (feet below meadow surface)	Groundwater monitoring	Lower Sardine	Minimum depth to groundwater increased by 0.6 ft adjacent to culvert installation. Depth to groundwater

Objectives	Sub-objectives	Performance Measures	Metrics	Monitoring Method(s)	Monitoring Sites	2021 Performance Measure Results
	capacity improvement					maintained within 1 ft of meadow surface for >25 days annually post-restoration.
	Meadow vegetation protected and enhanced on 2 acres	Groundcover at least 70% on all areas disturbed by construction	Percent vegetation cover	Photo points/visual assessment of cover (step point method)	All	70% cover established at 6 out of 9 (67%) of transects.
		0.5 acres / 500 feet of meadow planted with riparian shrubs and sod plugs	Area/length of newly planted meadow	Photo points/GPS measurements	All	0.2 acres / 200 feet along stream channel planted with riparian shrubs
		Plantings and plugs show establishment and new growth one year after planting	Percent survival	Survivorship monitoring	All	Not measured
		Vegetation vigor improved over baseline; Vegetation water stress decreased over baseline	Normalized Difference Vegetation Index (NDVI)/Normalized Difference Water Index (NDWI)	Remote Sensing using Climate Engine	All	Slight trend toward increased plant vigor at Lower Sardine and Cloudburst. No trend toward decreased water stress observed.
Maintain and enhance Yosemite toad populations and occupied breeding habitat at two meadow sites		580 feet of road currently threatening breeding sites removed	Length of road treated	Photo points/GPS measurements	Lower Sardine	580 feet of road decompacted
		660 feet of new trail created	Length of new trail		Lower Sardine	660 feet of new trail created
		10 headcuts stabilized; 2 Grade control structures installed to prevent erosion	Number and migration rate (feet/year) of headcuts	General: Photo points/headcut measurements; Grade control headcuts:	All	Migration rate reduced to zero for 4 measured headcuts measured. 6 photo-documented headcuts stabilized. 2

Objectives	Sub-objectives	Performance Measures	Metrics	Monitoring Method(s)	Monitoring Sites	2021 Performance Measure Results
		Migration rate of 10 headcuts is reduced to zero		cross-sections and longitudinal profiles		grade control structures installed to prevent erosion
		Extent of suitable shallow water breeding sites increased above baseline by one year after site treatment	Extent and duration of suitable breeding sites	Surface water monitoring and mapping	Lower Sardine	Extent of suitable shallow water breeding sites maintained. Restored area supports shallow surface water but not long enough for breeding. One new shallow water area adjacent to culvert install.
		Number of occupied breeding sites increased above baseline by one year after site treatment	Number of occupied breeding sites	Toad population monitoring	Lower Sardine	1 new breeding site in Upper Sardine post-restoration.
		Toad population increased above baseline by one year after site treatment.	Number of toads observed	Toad population monitoring	Lower/ Upper Sardine	*Number of unique individuals increased at Upper Sardine, maintained at Lower Sardine.

*There are too many uncertainties about the Upper Sardine toad population to attribute the increase in toad population at Upper Sardine to restoration.

Monitoring Methods and Results

California Rapid Assessment Method (CRAM)

We conducted pre-project assessments using the CRAM method for slope wetlands (which includes wet meadows) at each of the three project sites in August 2018. At each of the project sites we established an Assessment Area (AA) between 1-2 hectares per the CRAM Slope Wetlands Field Book V. 6.1 procedures for medium sized wetlands which call for the AA to establish one edge oriented perpendicular to the overall wetland flow and to extend from the upland edge to the channel center line (See Appendix A for maps of AAs). In Lower and Upper Sardine Meadows, we treated Sardine Creek as the channel centerline and positioned the AA to encompass the headcut and channel fill project areas. We repeated CRAM assessments post-project in August 2020, two years post-restoration for Lower Sardine and Cloudburst (implemented over two seasons), and one year post-restoration at Upper Sardine.

The results of the CRAM assessments are summarized in Table 1 below. The CRAM Summary Assessment Reports are included as Appendix A. The full assessments are available online through the EcoAtlas database (https://www.ecoatlas.org/regions/ecoregion/statewide?cram=1.

Attribute	**Lower Sardine**		**Cloudburst**		**Upper Sardine**	
	2018	**2020**	**2018**	**2020**	**2018**	**2020**
Buffer and Landscape Context	65.29	65.29	68.29	68.29	55.79	55.79
Hydrology	54.17	75.00	66.67	87.50	58.33	75.00
Physical Structure	75	75	62.5	62.5	62.5	62.5
Biotic Structure	85.42	85.42	91.67	91.67	85.42	93.75
Index Score (Total)	**70**	**75**	**72**	**77**	**66**	**72**

Table 1: CRAM Attribute and Index score for each site. All scores are out of a possible 100.

Restoration increased the composite Index Score for each meadow over baseline. Specifically, meadow restoration increased the hydrology scores for each meadow over baseline. Restoration increased the score for hydroperiod at each meadow, defined as "the characteristic frequency and duration of inundation or saturation of a wetland during a typical year" (CRAM 2017). It increased the bank height ratio score at Cloudburst Meadow, as restoration repaired the primary channel. The project also increased the biotic structure score for Upper Sardine, where additional plant life forms were observed following restoration.

Photo Points

We established photo points at each of the three sites in summer 2018. We established a set of nine photo points at Lower Sardine, eight photo points at Upper Sardine and eight photo points at Cloudburst Meadow to provide visual documentation of change pre- and post-project. Figures 1-3 show the location of photo points and as-built project features at each site. We took photos twice each season, once in the spring/early summer and once in the fall. The full set of paired pre- and post-construction photos 2018 - 2021 are included in Appendix B.

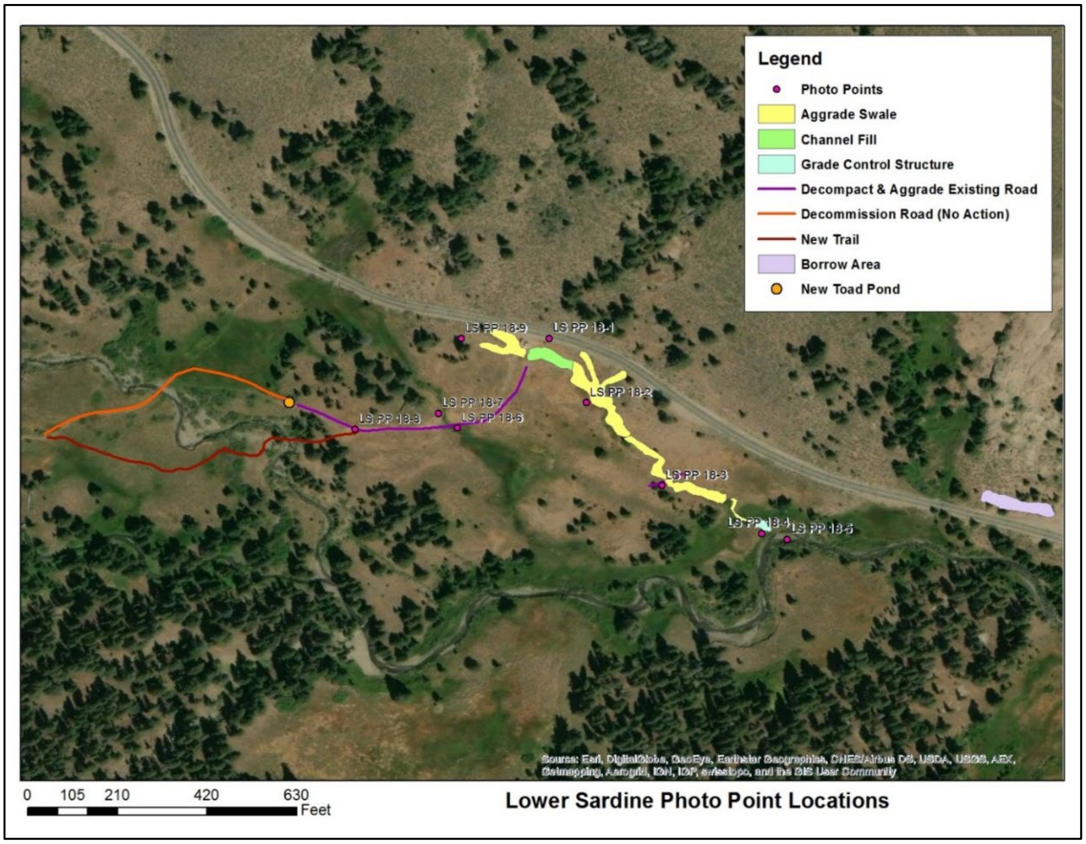


Figure 1. Location of photo points in Lower Sardine Meadow and as-built project features

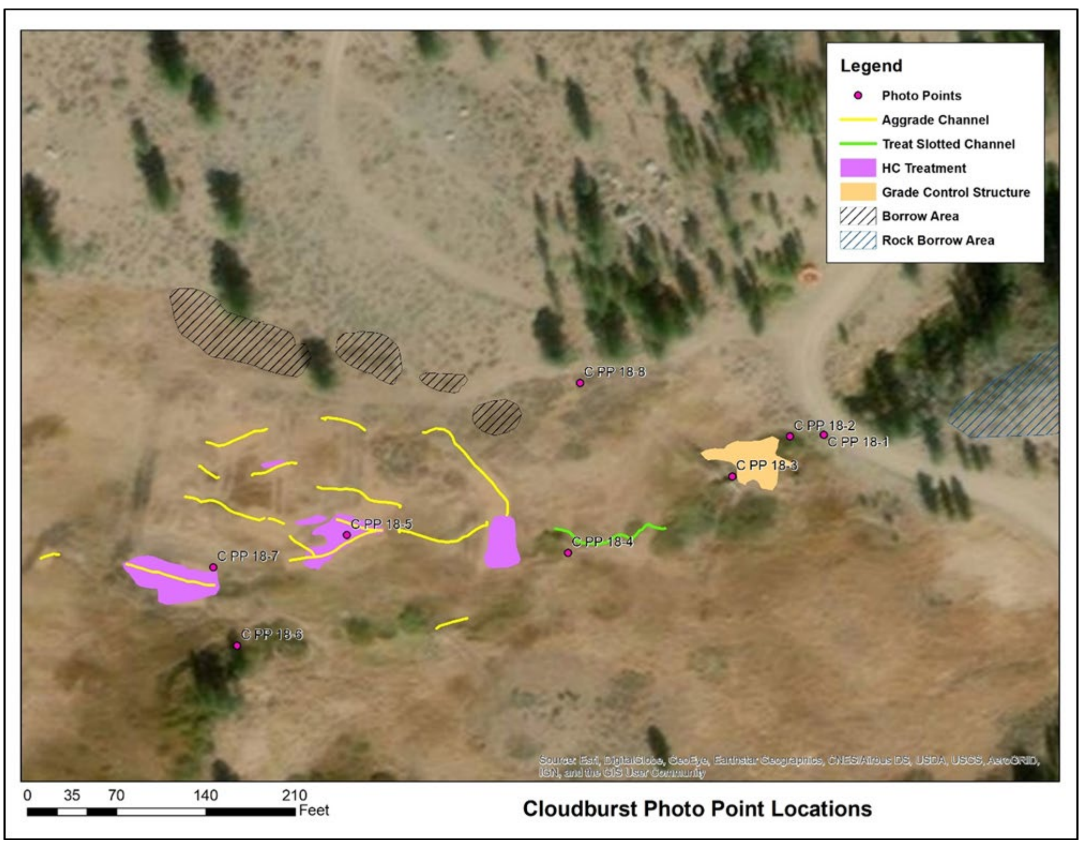


Figure 2. Location of photo points in Cloudburst Meadow and as-built project features

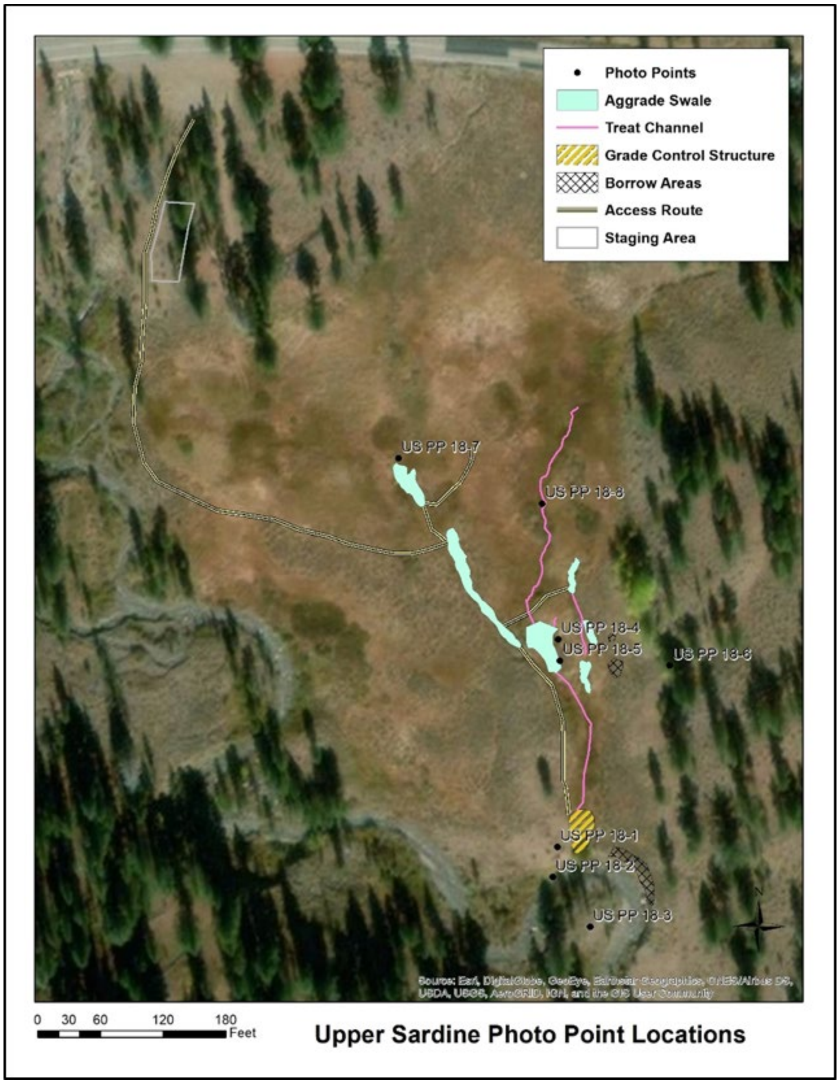


Figure 3. Location of photo points in Upper Sardine Meadow and as-built project features

Cross Sections and Longitudinal Profiles

Forest Creek Restoration (FCR) completed a set of cross section surveys at each site and a longitudinal profile at Lower Sardine Meadow (only site with continuous channel) in 2016 as part of the design process. Waterways Consulting (Waterways) also surveyed cross-sections at Upper Sardine as part of development of engineered designs in 2019. FCR repeated cross sections and the longitudinal profile at Lower Sardine and repeated cross sections in Cloudburst Meadow following construction in October 2018. Waterways repeated cross sections in Upper Sardine Meadow in summer 2020.

Cross-section locations are shown on the as-built design drawings (Figures 4-5, 8 and 10-11). Note there are two versions of as-built drawings for Upper Sardine – the GPS version included as Figure 10 produced by Forest Creek Restoration and the engineer's version, showing cross-sections included as Figure 11.

Figures 6, 9 and 12 compare pre- and post-construction cross-sections and Figure 7 compares the pre- and post-construction longitudinal profiles for Lower Sardine. See Appendix C for full set of as-built drawings, cross sections and longitudinal profile. Construction raised the elevation of the channel bed by approximately 2-3 feet in Lower Sardine and raised the elevation of erosion features by 1-3 feet in Cloudburst and 1-4 feet in Upper Sardine.

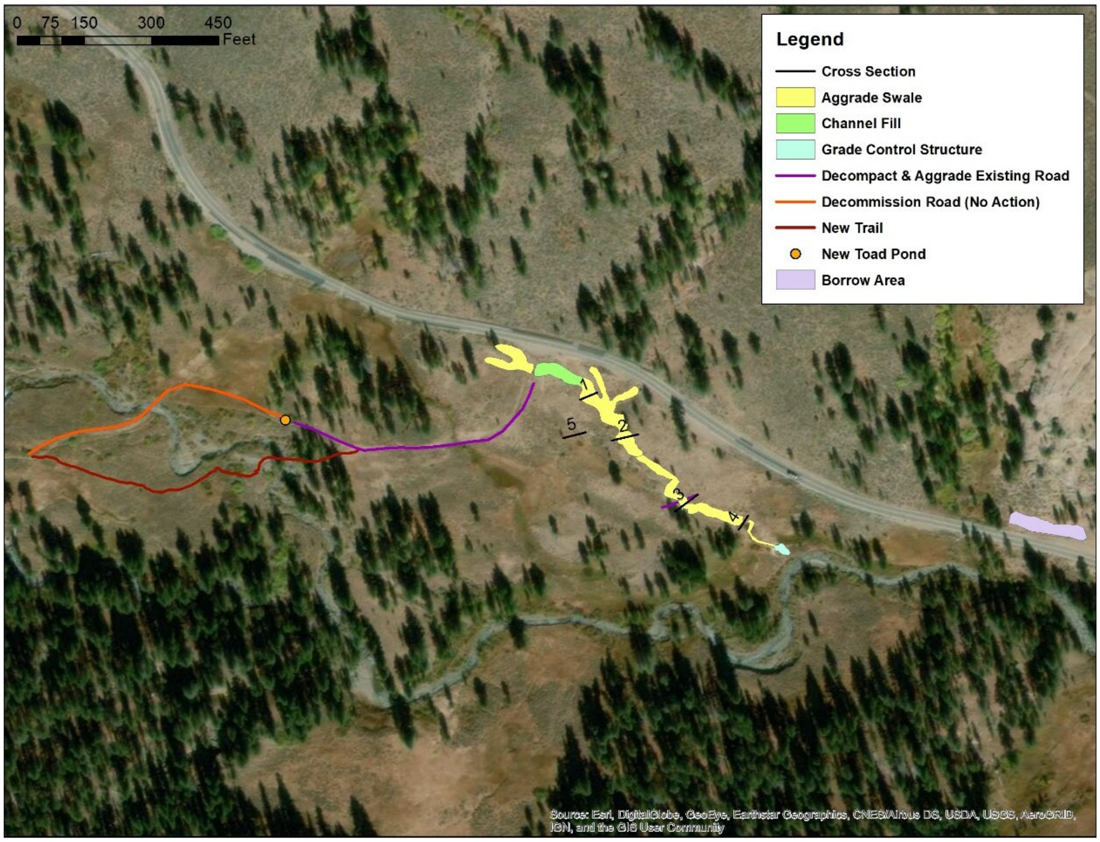


Figure 4. As-built designs for Lower Sardine Meadow showing full project area. Shows the location of cross-section surveys and the extent of project features developed using GPS.

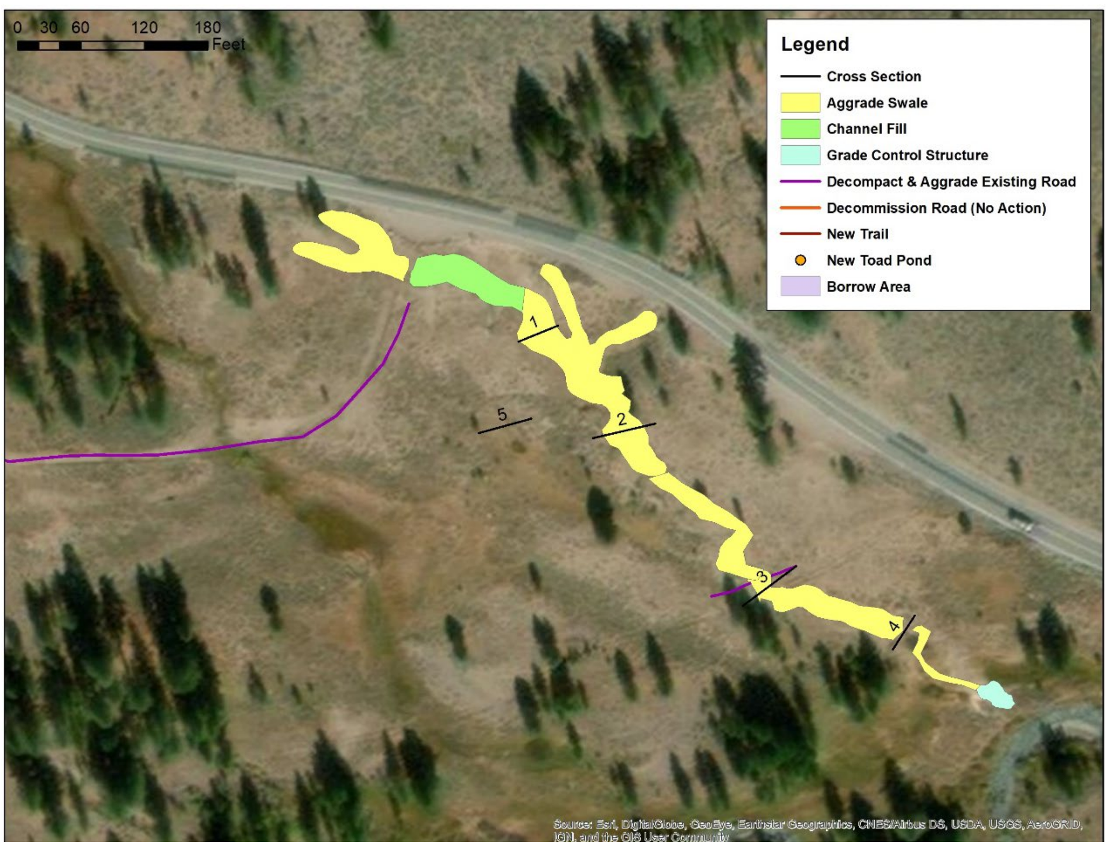


Figure 5. As-built design drawings for Lower Sardine Meadow zoomed in on the tributary swale treatment area. Shows the location of cross-section surveys.

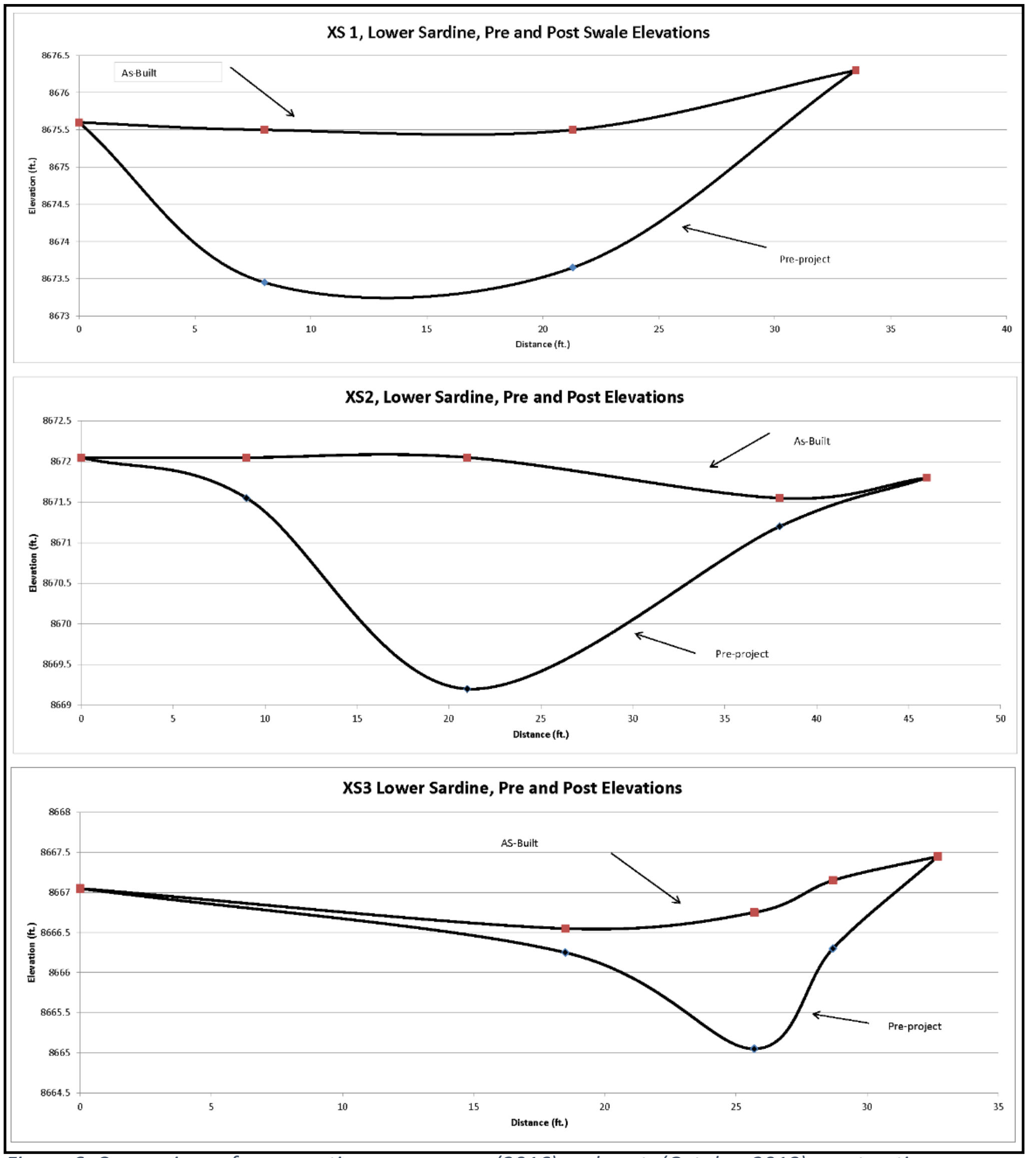


Figure 6. Comparison of cross section surveys pre- (2016) and post- (October 2018) construction.

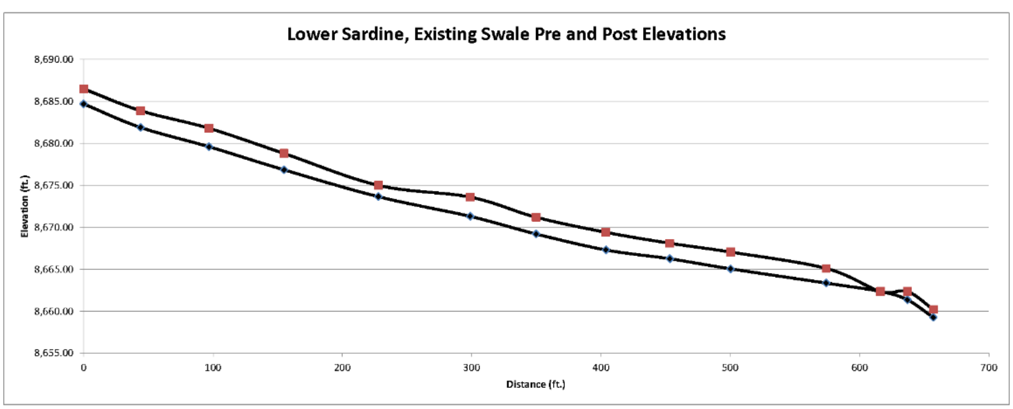


Figure 7. Comparison of longitudinal profile surveys pre- (2016) and post- (October 2018) construction.

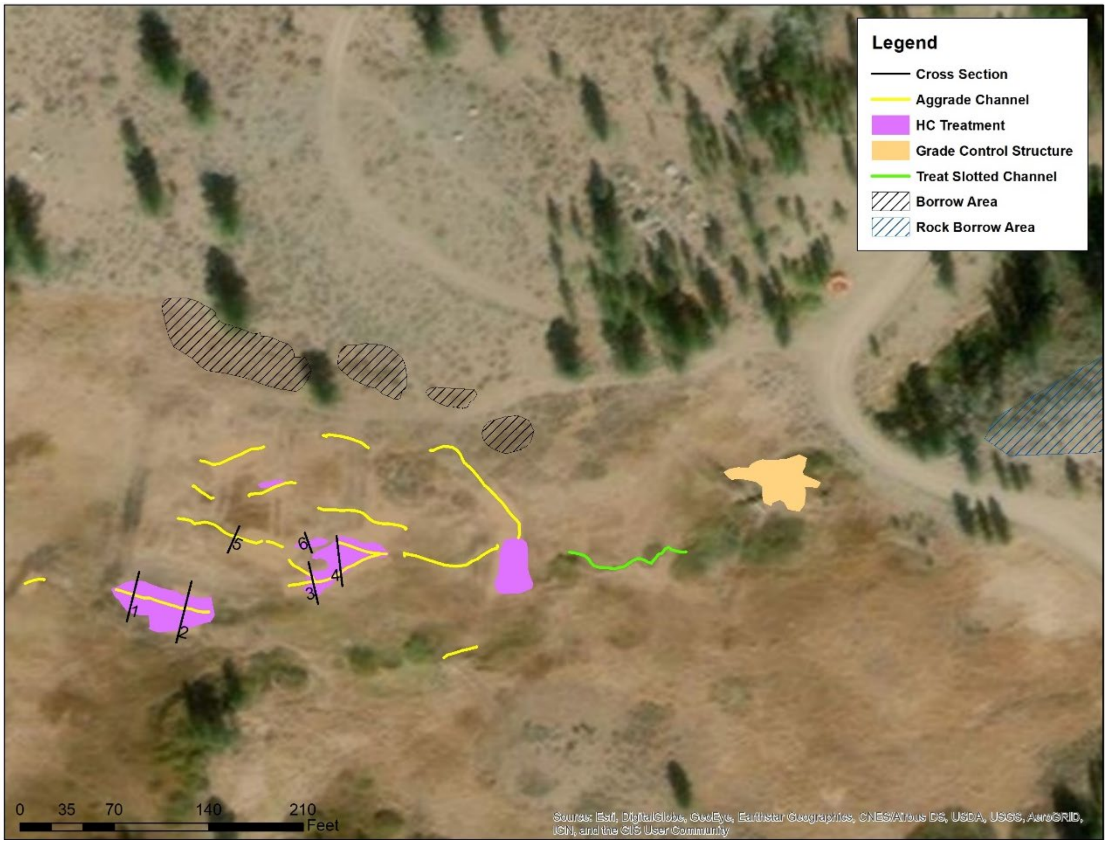


Figure 8. As-built designs for Cloudburst Meadow. Shows the location of cross-section surveys and the extent of project features developed using GPS.

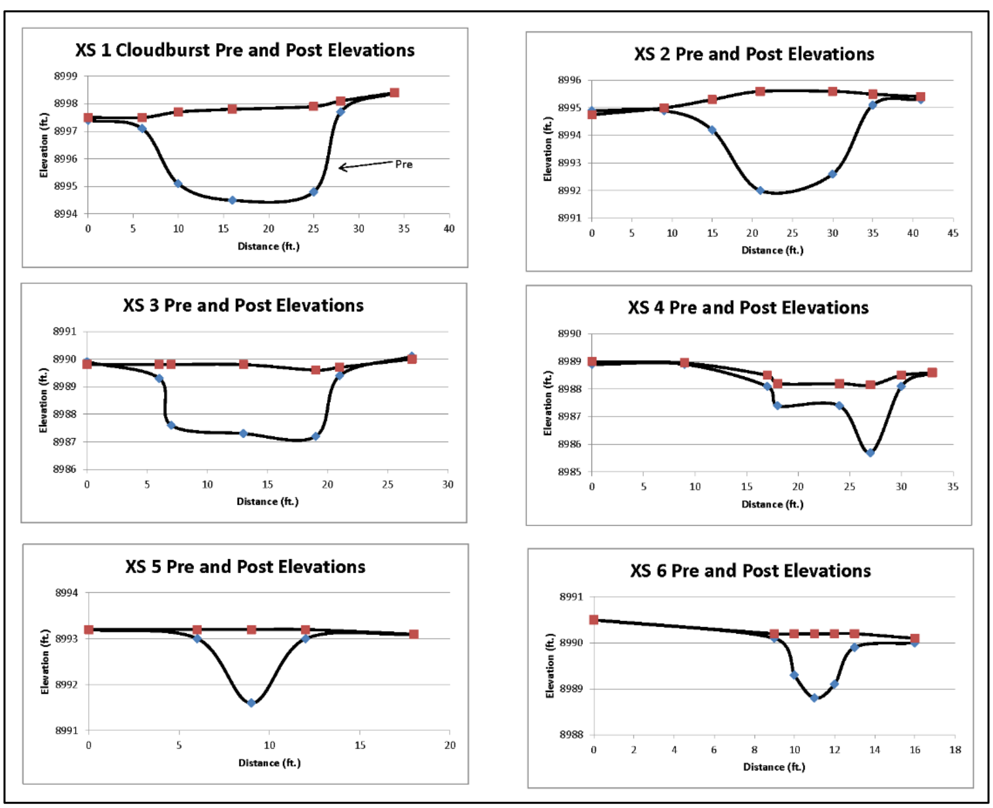


Figure 9. Comparison of cross section surveys pre- (2016) and post- (October 2018) construction for Cloudburst.

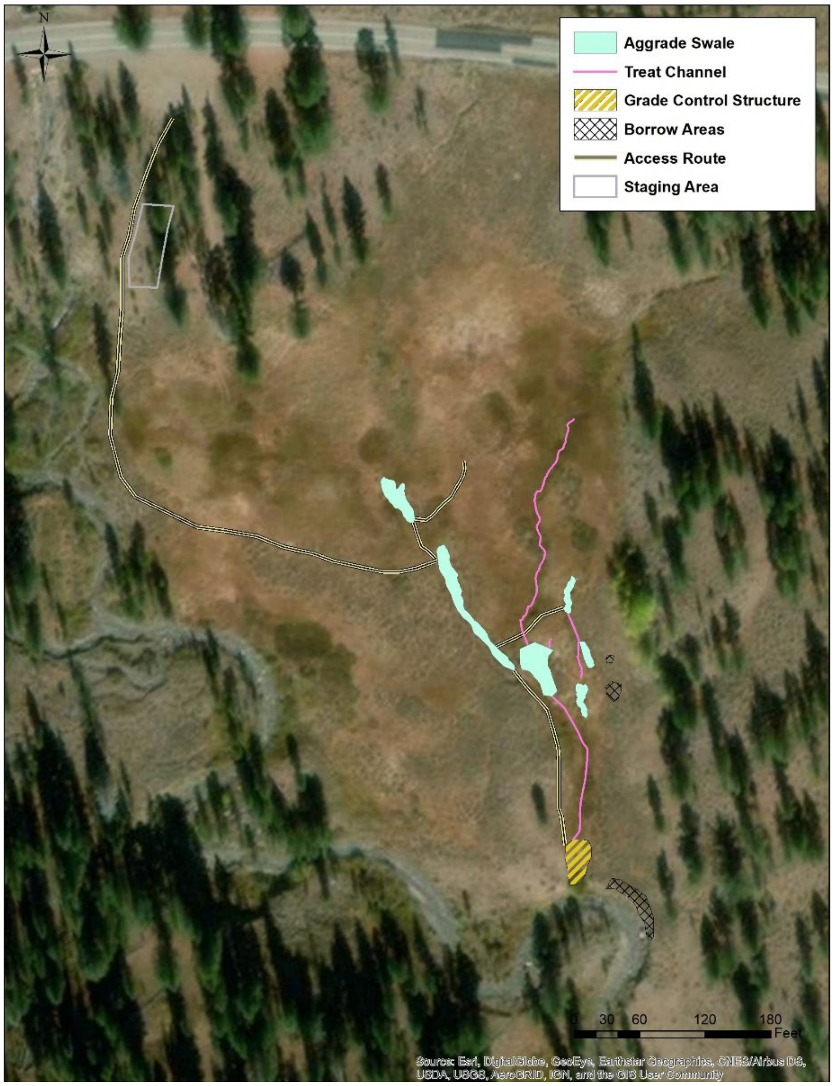


Figure 10. As-built designs for Upper Sardine showing the extent of project features developed using GPS.

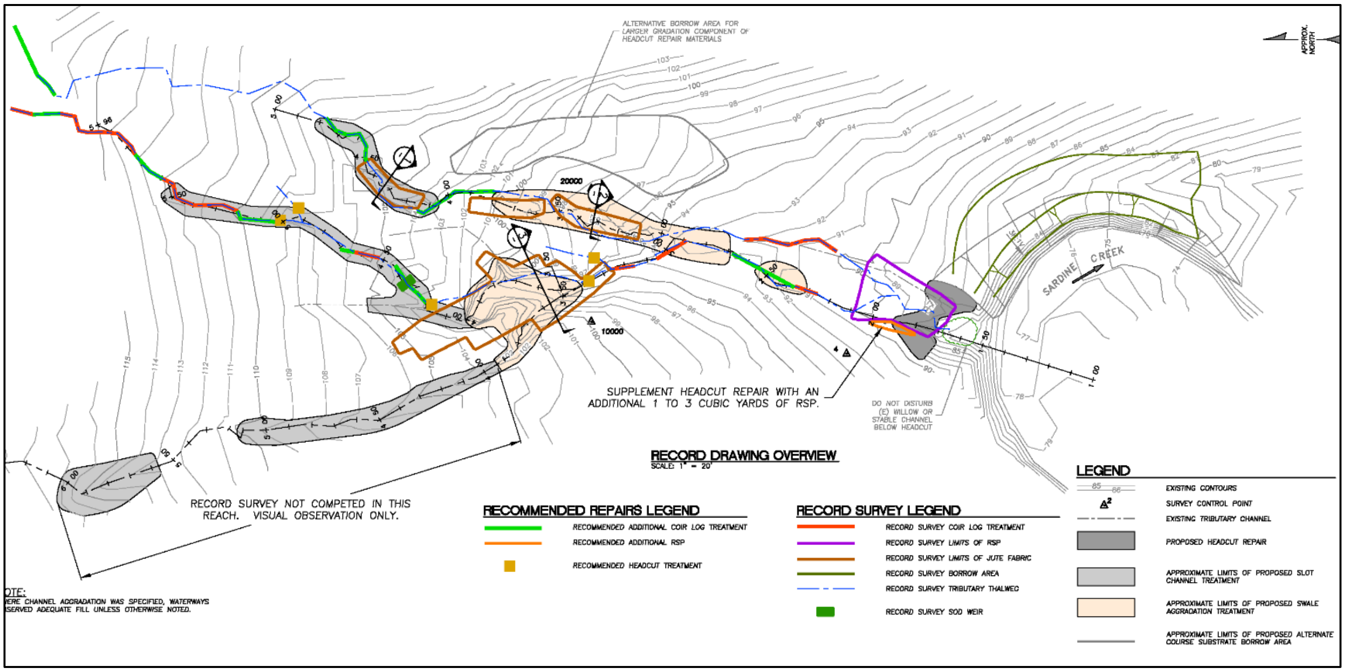


Figure 11. Engineered as-built designs for Upper Sardine showing the location of cross-sections.

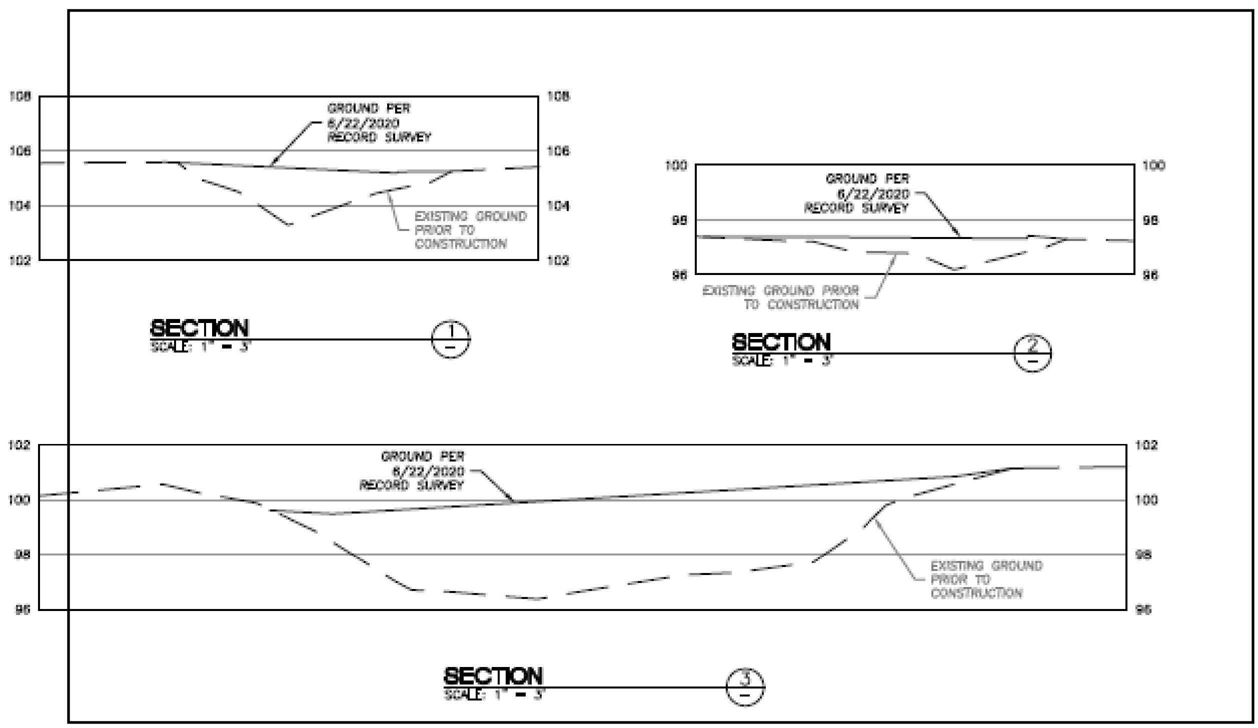


Figure 12. Comparison of cross section surveys pre- (2019) and post- (2020) construction for Cloudburst.

GPS Measurements

FCR used a Trimble GPS to delineate the extent of restoration activities following construction in October 2018 and October 2019. These features are shown in Figures 4, 8, and 10 and Appendix C and were used to quantify the extent of treated features using GIS. The lengths of the various restoration treatments applied at each site are shown in Tables 2-4 below.

In Lower Sardine Meadow, the project treated approximately 875 linear feet of eroding tributary swale and 580 linear feet of decommissioned Off Highway Vehicle (OHV) road. It also constructed approximately 660 feet of new hiking trail in Lower Sardine. At Cloudburst meadow, the project treated a total of 780 linear feet of erosional channel/swale features. The project applied fill to recontour and arrest headcuts and filled narrow channels in the meadow surface. The project also applied both techniques at a subset of features where both techniques were warranted, such as where both headcuts and channel overlapped (see Figure 8). In Upper Sardine Meadow, the project treated a total of 760 linear feet of erosional channel/swale features. The project applied fill to arrest headcuts and aggrade erosional swales and filled narrow channels. Overall, the project treated 2,200 linear feet of erosional features across the three sites.

Treatment	**Length (ft)**
Aggraded Swale	875
De-compacted OHV Road	580
New Trail	660

Table 2. Length of restoration treatment features in Lower Sardine Meadow.

Treatment	**Length (ft)**
Headcut Treatment Only	95
Aggraded Channel Only	460
Headcut Treatment & Aggraded Channel	140
Treat Slotted Channel	85
Total	780

Table 3. Length of restoration treatment features in Cloudburst Meadow. A subset of features included headcut treatment and aggrading the channel. See Figure 8.

Treatment	**Length (ft)**
Aggrade Swale	315
Treat Channel	445
Total	760

Table 4. Length of restoration treatment features in Upper Sardine Meadow.

Headcuts

We photographed and used GPS to mark the location of headcuts and took more detailed measurements to quantify changes in headcut migration for a subset of representative headcuts. Design consultants monitored the largest headcuts at each site with topographic surveys. We conducted initial pre-project monitoring in Lower Sardine and Cloudburst Meadows in October 2018 and at Upper Sardine in September 2019. We did not observe headcuts at Lower Sardine besides the large headcut at the grade control location, which is included in the longitudinal profile and photo points. Post-project monitoring occurred in October 2019 at Cloudburst Meadow and in August 2020 at both sites. Headcut monitoring was scheduled but could not be completed in 2021 due to early snow and road closures affecting the sites. Headcut monitoring locations for Cloudburst and Upper Sardine are shown in Figures 13 and 15. At Cloudburst and Upper Sardine, we established a set of representative headcuts for detailed headcut migration monitoring denoted by the prefix “HC” in the figures. At the remaining headcuts, we took photos and GPS locations but did not take detailed measurements (indicated by the prefix “NM”).

At each headcut measured, we installed two permanently monumented points downstream of the headcut on the left and right banks of the channel perpendicular to flow, then strung a measuring tape across these points. We measured the horizontal distance from the tape to the headcut face and rim at 0.5-foot intervals from left to right (facing upstream toward the headcut rim). The first measurement was taken at the left edge of the erosion and then measurements were taken at 0.5-foot intervals across the headcut until we reached the right edge of erosion. We took measurements of the “headcut rim”, which is the furthest point of erosion, and the “headcut face,” which is the highest point on the vertical face of the headcut from the pool, to capture changes in each feature.

We noted the maximum horizontal point from the tape and took a photo of it. We also took a photo of each headcut looking upstream at the tape and took a GPS location for each feature. Where the rim or face of the headcut transitioned to a channel above the headcut, we could not take measurements, but noted the location of the channel feature (see data gaps in the plots in Figures 14 and 15). We also measured vertical depth of the headcut just downstream of the first drop pool. Vertical depth and maximum horizontal length to headcut rim (maximum migration point) are presented in Tables 5 and 6.

Cloudburst

In Cloudburst meadow, we established a set of six representative headcuts for detailed headcut migration monitoring shown in Figure 13. The large fill location at the east (upstream) end of the project was not feasible to measure due to its large size, but is included in photo point monitoring and cross section surveys by FCR. The results of the headcut migration monitoring for 2018-2020 are presented in Figure 14 and Table 5 below. For the post-construction surveys, many of the rebar monuments had been buried during construction, but we were able to relocate monuments using a metal detector. However, as the project completely filled each headcut feature, none of the previously surveyed locations exhibited a headcut during the post-project survey, so no measurements were taken. Each feature was documented with a photo to show this change. These photos are included in Appendix D. Based on the lack of measurable headcut rim, we assume a migration rate of zero feet per year. If we assume a post-project drop pool depth of 0 feet, the project reduced headcut depth by an average of 2.3 feet. Photo documentation showed that the four headcuts that were not measured were also filled by the project and did not exhibit a headcut during post-project monitoring (see Appendix D).

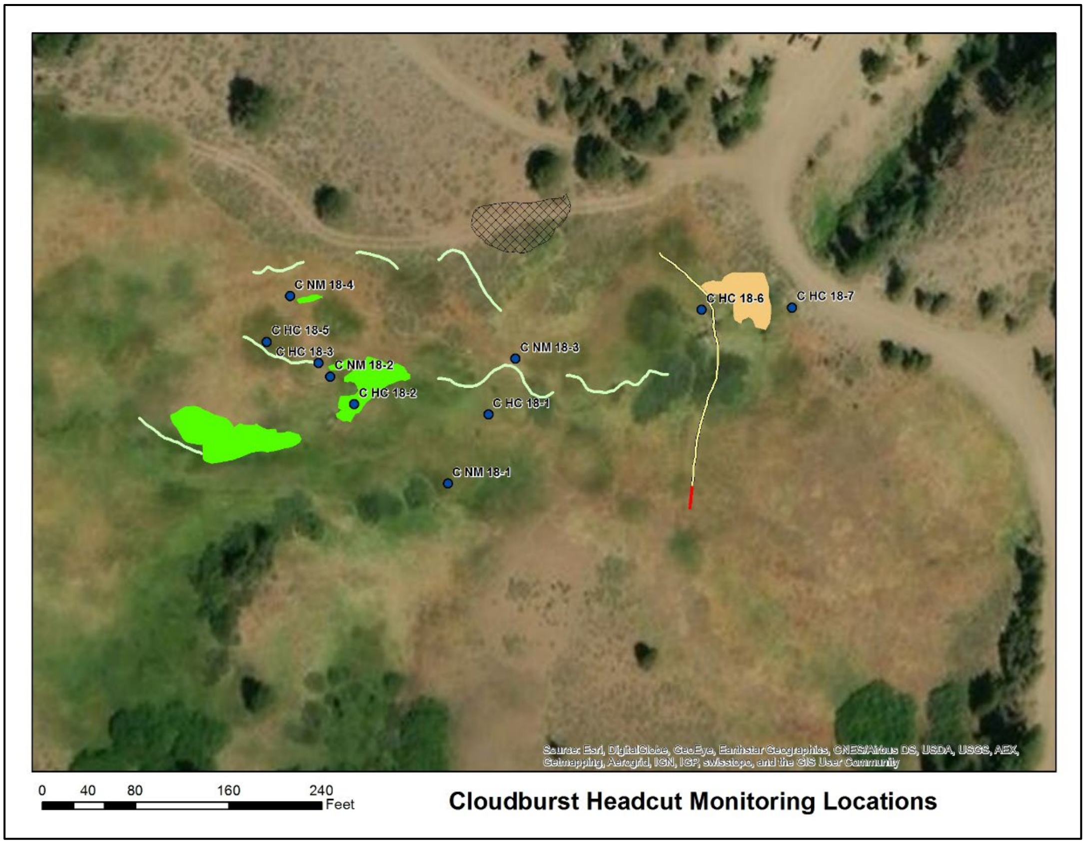
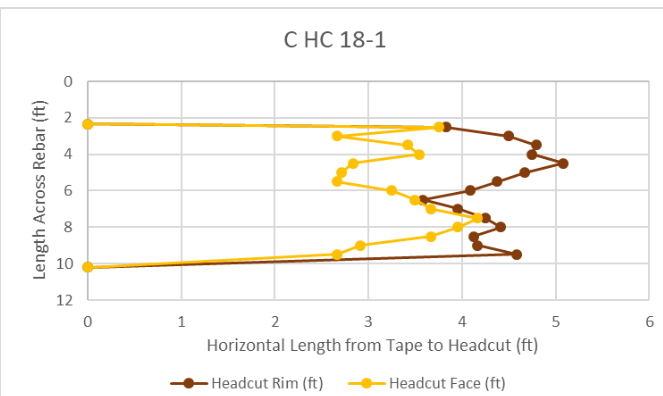
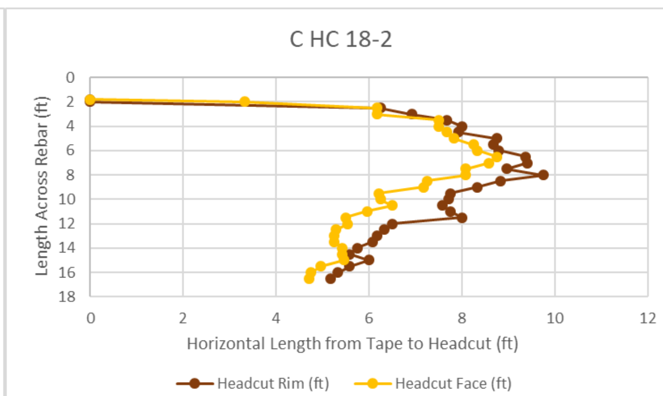
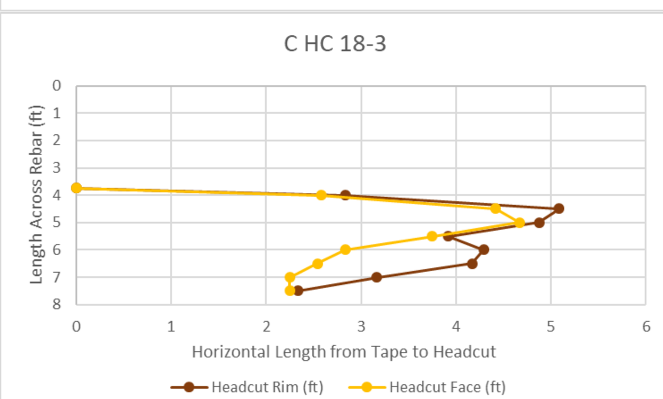
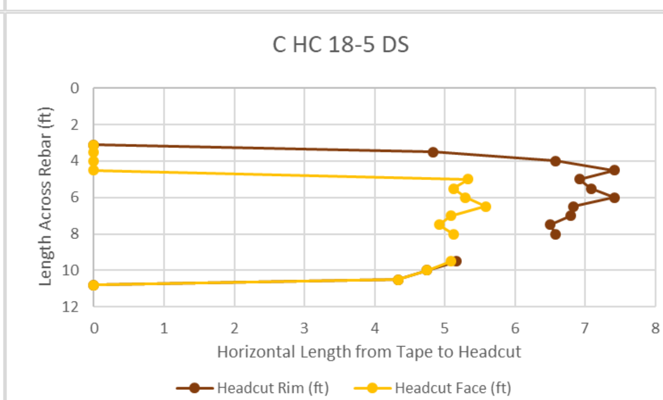


Figure 13. Headcut monitoring locations in Cloudburst Meadow. Locations with detailed headcut monitoring are indicated by the prefix "C HC." Other headcuts are indicated by the prefix "C NM."









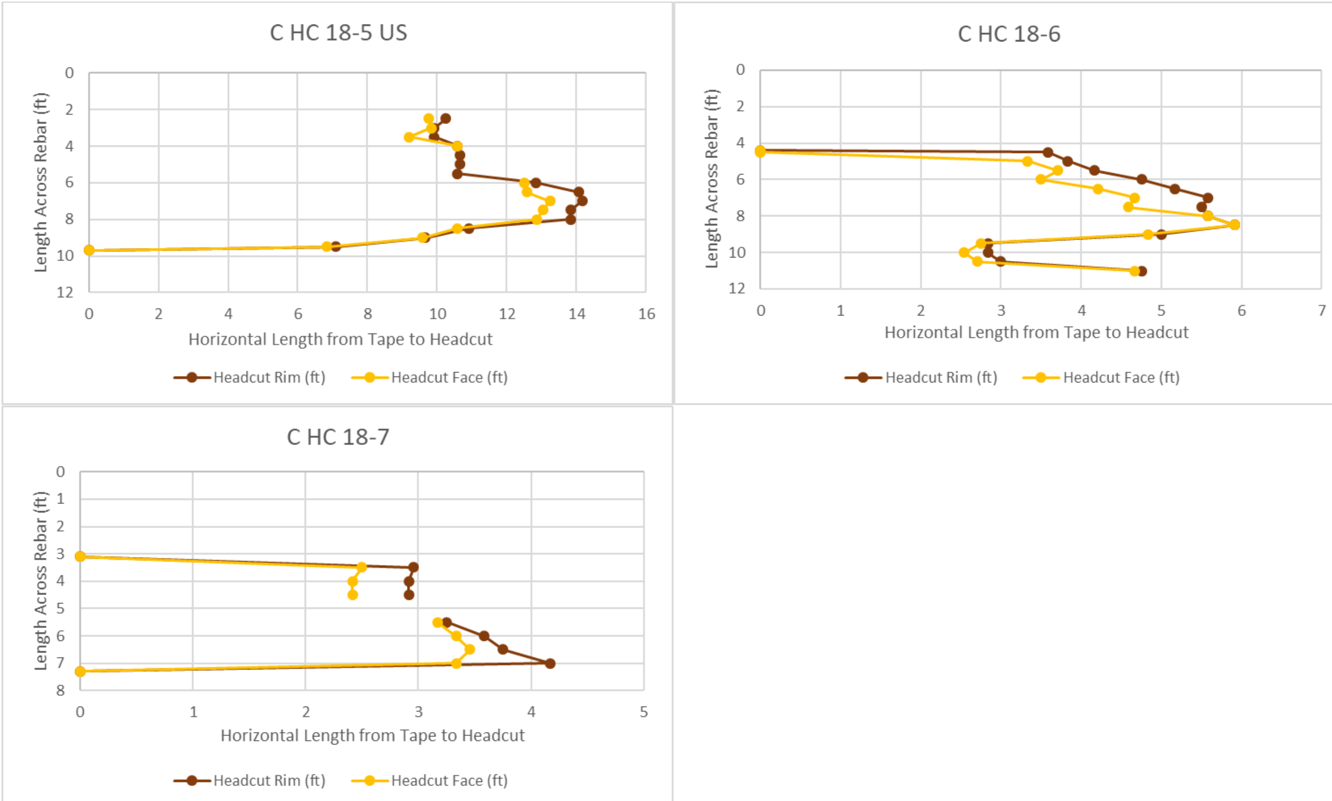


Figure 14. The results of headcut monitoring in Cloudburst Meadow showing the lengths from the measuring tape to the headcut rim (farthest edge of erosion) and headcut face (highest point on the vertical face above the drop pool). C HC 18-5 had two sub-headcuts, one upstream (US) and one downstream (DS). We took separate measurements of each feature from the same tape position. The gaps in data in C HC 18-5 DS and C HC 18-7 are due to the headcut transitioning into a channel above the headcut. At C HC 18-5 the headcut face was not well defined between 4.5 and 5.5 and no measurements were taken.

Headcut ID	2018 Max Horizontal Length to Headcut Rim (ft)	2018 Vertical Depth (ft)	2019	2020
C HC 18-1	5.1	2.0	No headcut	No headcut
C HC 18-2	9.8	2.9	No headcut	No headcut
C HC 18-3	5.1	2.3	No headcut	No headcut
C HC 18-5 DS	7.4	1.3	No headcut	No headcut
C HC 18-5 US	14.2	missing	No headcut	No headcut
C HC 18-6	5.9	2.4	No headcut	No headcut
C HC 18-7	4.2	2.8	No headcut	No headcut

Table 5. Maximum horizontal length to headcut rim (maximum migration point) and vertical depth. Note: the maximum horizontal length is relative to the tape position and should not be used for comparison between headcuts. Due to the placement of fill, features did not exhibit headcut rims or drop pools post-project and were not measured.

Upper Sardine

In Upper Sardine, we established a set of five representative headcuts for detailed headcut migration monitoring shown in Figure 15. The results of the headcut migration monitoring from 2018 and 2020 are presented in Figure 16 and Table 6 below. The heavy equipment used during construction buried several of the rebar monuments, so we were not able to relocate rebar at U HC 2 or U HC 3 but were able to locate flagging at U HC 3 and match photos at each. The project filled each headcut feature except U HC 1, which was not filled during construction in 2019. The feature was part of FCR's original design, but not Waterways updated design and was not included during initial construction. The filled features did not exhibit a headcut during the post-project survey and no measurements were taken. Each feature was documented with a photo to show this change. These photos are included in Appendix D. The results for U HC 1 are shown in Figure 16 and Table 6-7.

For HC 2-5, we assume a migration rate of zero feet per year based on the lack of measurable headcut rim post implementation. For HC 1, the maximum horizontal length remained the same from 2019 to 2020, but the average horizontal lengths indicate horizontal headcut migration of 0.3-0.4 feet (4-5 inches) per year. For HC 2-5 we assume a post-project drop pool depth of 0 feet (based on the lack of drop pool). For HC 1, monitoring indicates an increase in depth of 0.4 ft. It was challenging to relocate the same point to measure for vertical depth, so this could be an artifact of sampling, but it seems reasonable based on the horizontal migration observed. If we include all the measured headcuts including HC 1, the project reduced headcut depth by an average of 1.2 feet. Photo documentation showed that the six of the seven primary headcuts that were not measured were also filled by the project and did not exhibit a headcut during post-project monitoring (see Appendix D).

From the headcut monitoring, the project team is aware that the construction did not address HC 1, however we determined the feature did not warrant the cost and disturbance of re-entry with heavy equipment. We will continue to observe and photo-document the feature to ensure more aggressive adaptive management is not warranted.

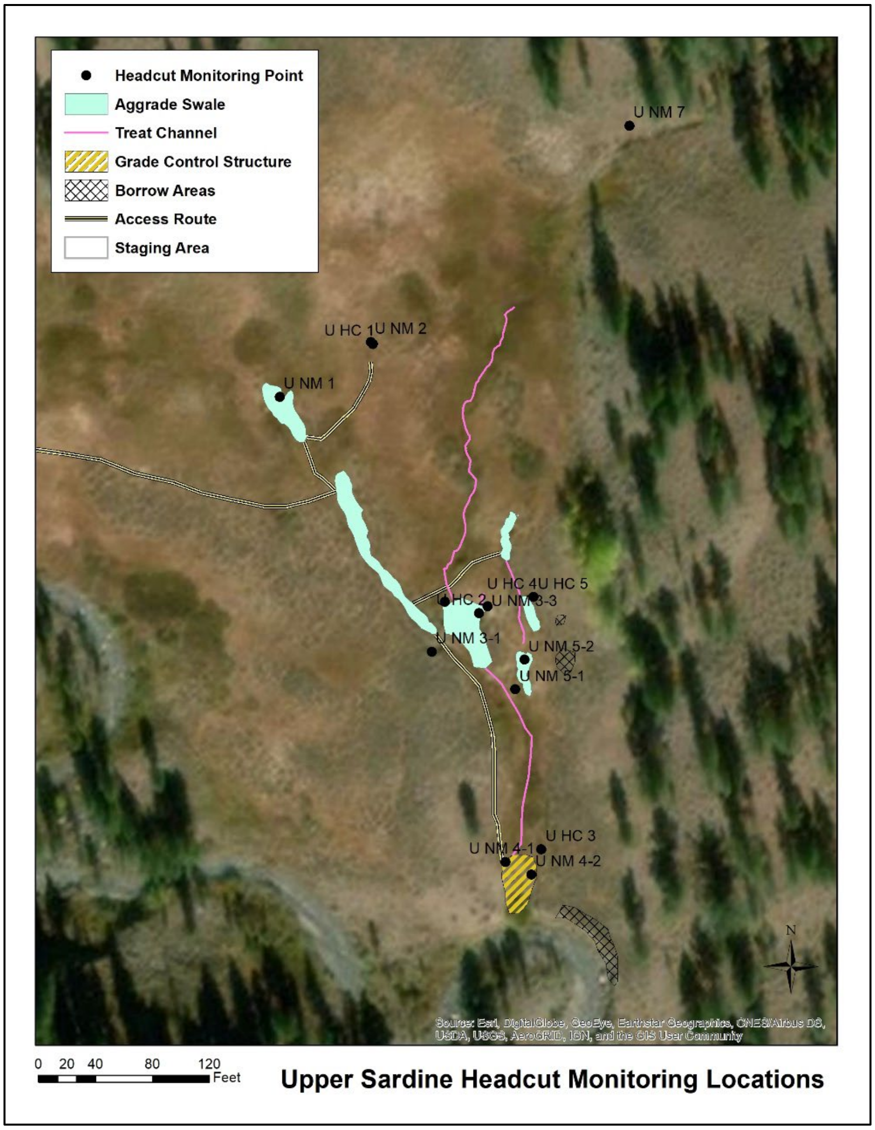


Figure 15. Headcut monitoring locations in Upper Sardine Meadow. Locations with detailed headcut monitoring are indicated by the prefix "C HC." Other headcuts are indicated by the prefix "C NM."

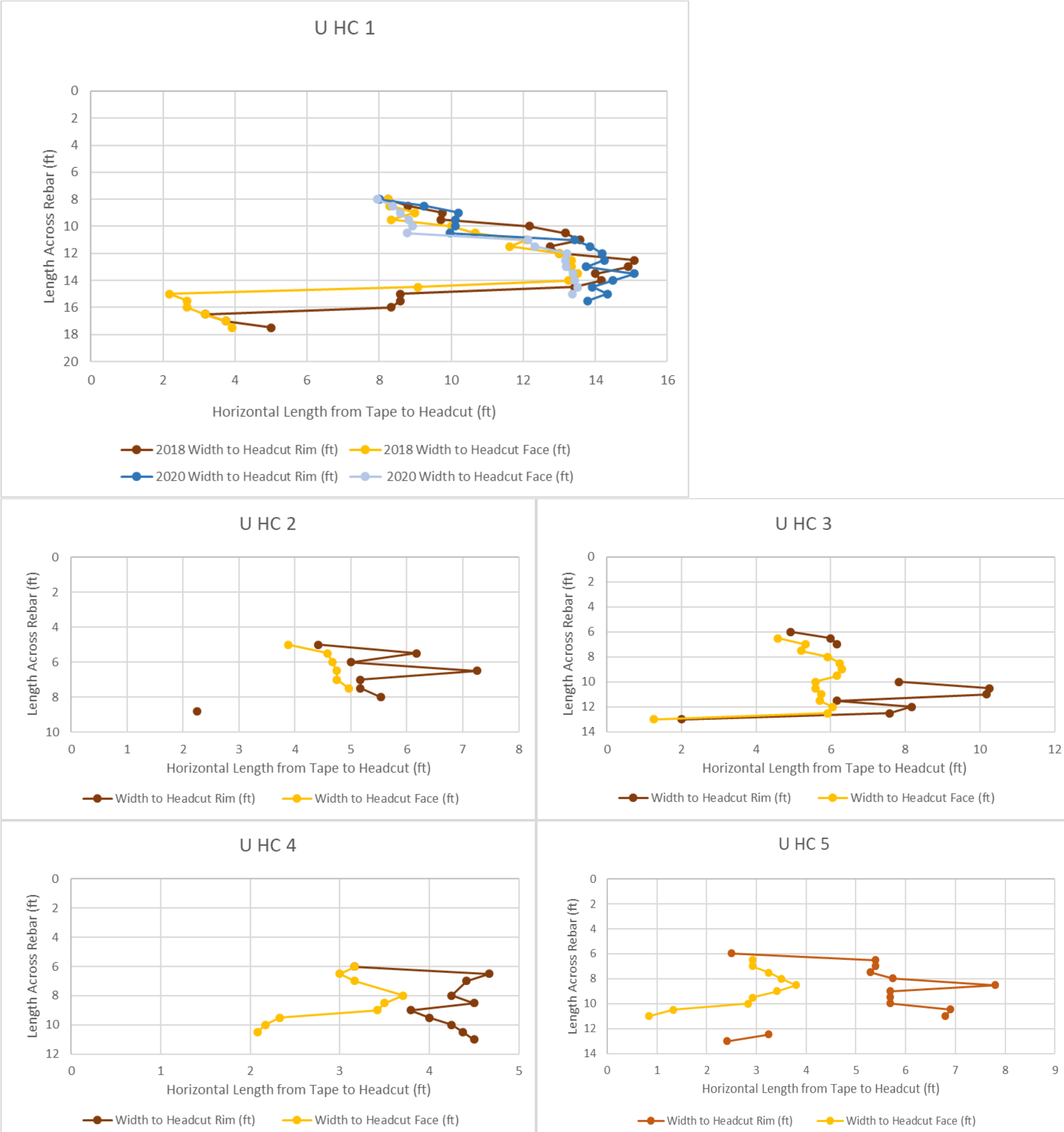


Figure 16. The results of headcut monitoring in Upper Sardine showing the lengths from the measuring tape to the headcut rim (farthest edge of erosion) and headcut face (highest point on the vertical face above the drop pool). The gaps in data in U HC 2, 3 and 5 are due to the headcut transitioning into a channel above the headcut. Results for U HC 1 for 2018 are shown in yellow/brown and 2020 are shown in blue.

Headcut ID	2019 Max Horizontal Length (to Headcut Rim)	2019 Vertical Depth (ft)	2019 Max Horizontal Length (to Headcut Rim)	2019 Vertical Depth (ft)
U HC 1	15.1	1.1	15.1	1.5
U HC 2	7.3	missing	No headcut	No headcut

U HC 3	10.3	1.4	No headcut	No headcut
U HC 4	4.7	1.6	No headcut	No headcut
U HC 5	6.9	2.3	No headcut	No headcut

Table 6. Maximum horizontal length to headcut rim (maximum migration point) and vertical depth. Note: the maximum horizontal length is relative to the tape position and should not be used for comparison between headcuts).

2019 Average Horizontal Length (ft)		2020 Average Horizontal Length (ft)		Migration Rate (ft/yr)	
Headcut Rim	**Headcut Face**	**Length to Rim**	**Length to Face**	**Headcut Rim**	**Headcut Face**
11.9	10.4	12.4	11.3	0.3	0.4

Table 7. Average headcut data for U HC 1 pre- and post-project and annual headcut migration rate.

Groundwater

We established a set of six groundwater wells in Lower Sardine Meadow in spring 2018. Groundwater wells are 0.5 inches in diameter and were installed at a depth of up to 10 feet using the method developed by Amy Merrill PhD at Stillwater Sciences that has been adopted as the Sierra Meadows Partnership's Sierra Meadows Wetland and Riparian Area Monitoring Protocol (SM-WRAMP). Groundwater well locations are shown in Figure 17. GW A, B and C are located where we expected to see groundwater changes as a result of the 2018 restoration activities. GW F is located where we expected to see changes following the installation of two new culverts under Highway 108 in 2019. GW E is located in a current wet swale to act as a control, and GW D is associated with the two existing Yosemite toad breeding sites. Each well was equipped with a Solonist automatic data logger that takes hourly measurements. A barologger was installed at the project area for compensation of atmospheric pressure.

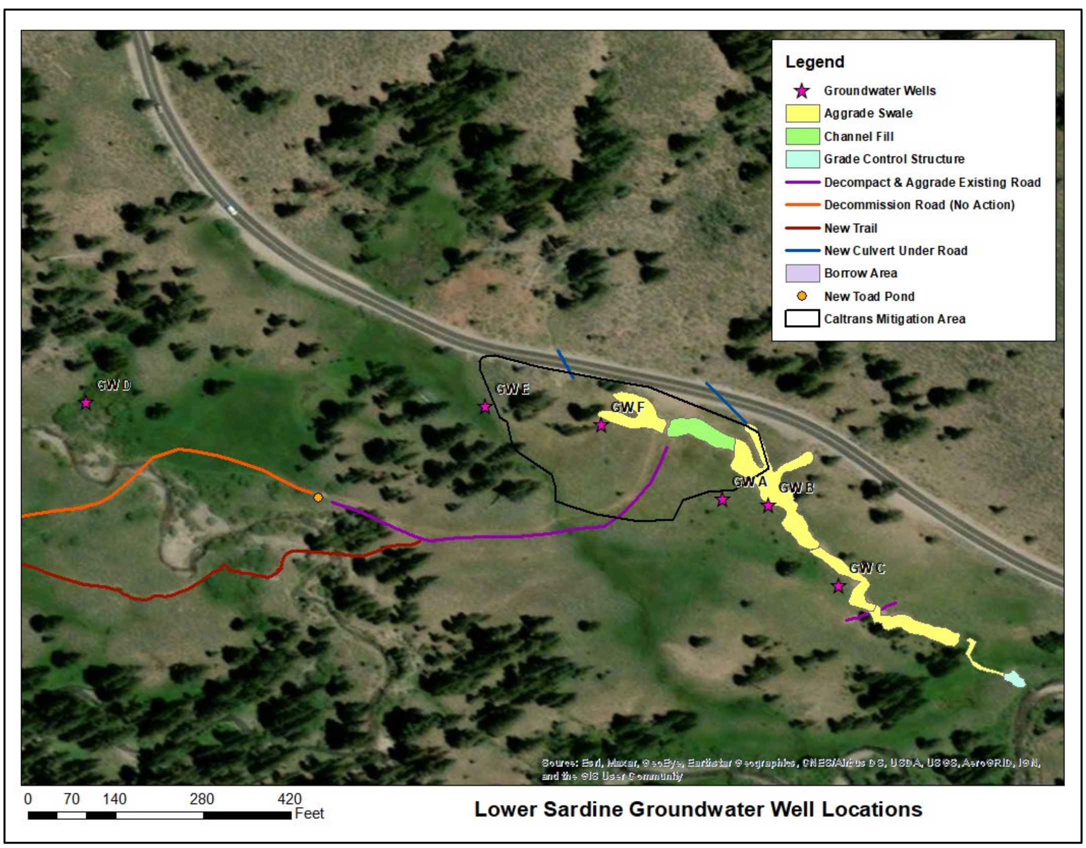


Figure 17. Groundwater well locations in Lower Sardine Meadow.

We installed all wells on June 28, 2018, except GW C, which had installation complications. We reinstalled GW C on July 3, 2018. Manual readings were taken from July 2018 through October 2021, except for GW C, which started October 2018. Logger data spans the period June 29, 2018 to October 19, 2021, except for GW C, which starts July 4, 2018 and GW F, which was dry at installation, so we pulled the logger to prevent theft and re-deployed it prior to the wet season in October 2018. Restoration occurred in fall 2018 and the new culverts were installed in fall 2019. The results of manual groundwater measurements (Table 8 and Figure 18) and logger data showing relative groundwater level (Figure 19) are presented below. For context about annual precipitation for the site, see Figure 20. The manual measurements for GW C are presented but not the logger data. The logger data was challenging to rectify with manual measurements and the shallow well depth meant it was frequently dry, providing less valuable data.

Well ID	**Groundwater Depth (ft)**										
	Date										
	7/3/18	10/2/18	7/3/19	7/16/19	10/21/19	7/18/20	8/11/20	11/4/20	6/17/21	9/15/21	10/19/21
A	7.79	5.89	0.00	1.55	5.04	4.10	4.66	5.86	2.70	4.96	5.24
B	7.01	5.09	0.53	1.47	4.44	3.64	4.23	5.23	2.53	4.40	4.49
C	NM*	5.30	0.00	0.29	5.08	4.66	5.63	>5.82***	2.23	>5.82***	>5.82***
D	0.97	2.24	0.27	0.36	1.38	1.62	1.91	1.95	0.87	2.28	1.91
E	0.36	0.30	0.67	0.67	0.96	0.84	0.73	1.02	0.78	0.73	0.98
F	>9.65**	>9.65**	5.00	7.70	9.38	9.43	9.46	9.46	9.40	9.44	9.43

*Table 8. Manual groundwater monitoring results at Lower Sardine in 2018-2021. *NM = Not Measured. Groundwater Well C was not measured on July 3, 2018 because it had just been installed. ** Groundwater Well F was dry during these measurements. The depth of the well is 9.65 feet, so we assume the depth to water table is greater than 9.65 feet. ***Groundwater Well C was dry during this measurement. The depth of the well is 5.82 feet, so we assume the depth to water table is great than 5.82 feet.*

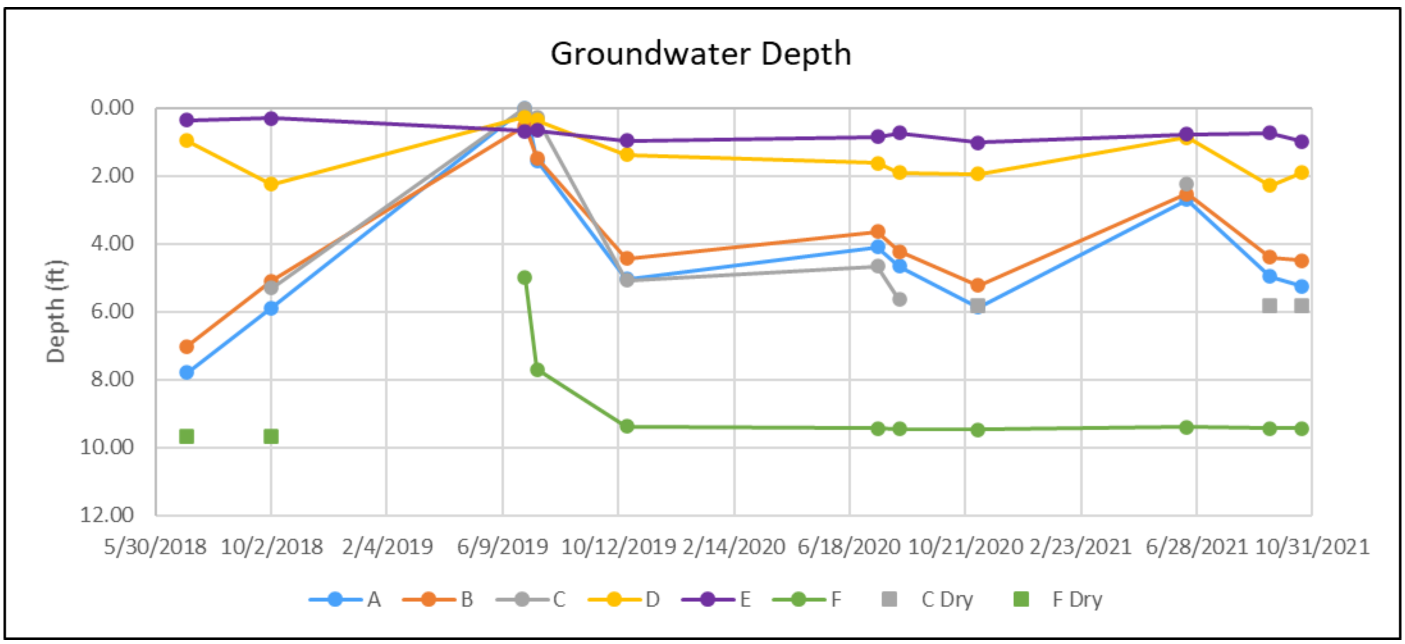


Figure 18. Results of manual groundwater measurements in Lower Sardine 2018-2021 from Table 8. Depth of well for dry measurements for GW C and F are shown with squares. We assume the depth is greater than 5.82 feet for GW C and 9.65 ft for GW F.

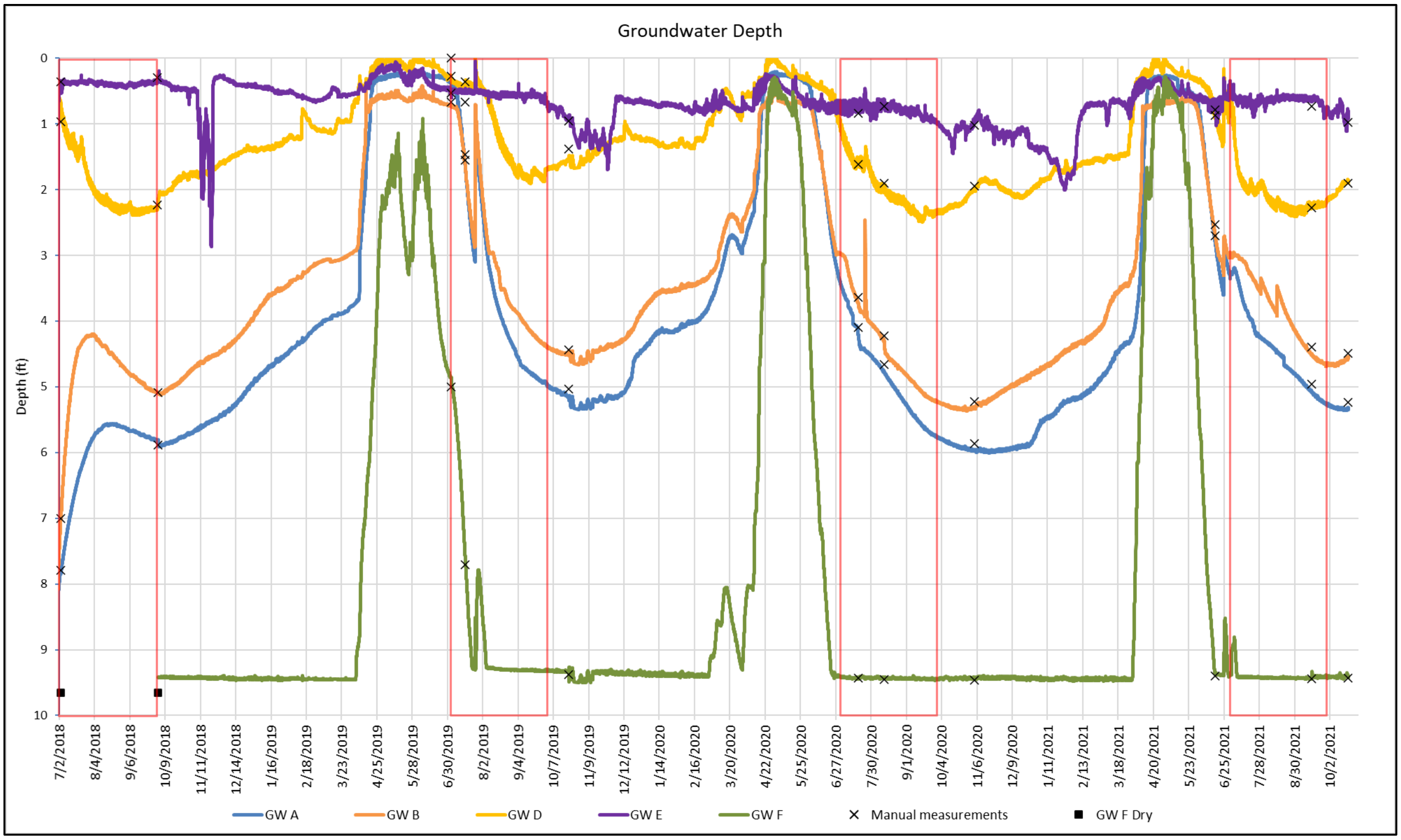


Figure 19. Manual groundwater measurements and automatic logger data for Lower Sardine 2018-2021. Manual measurements are indicated by black Xs. The manual measurements when GW F was dry are indicated with black squares and we assume a depth of greater than 9.65 ft. The GW F logger was not in place from July 3, 2018 to October 21, 2018, but then was replaced during the October 21, 2018 measurement, at which the well was dry. We uncertain about whether the well remained dry from October 21, 2018 to April 4, 2019 based on logger values. The summer period July 1-Sept 1 for each year is indicated by the red rectangles for ease of comparison.

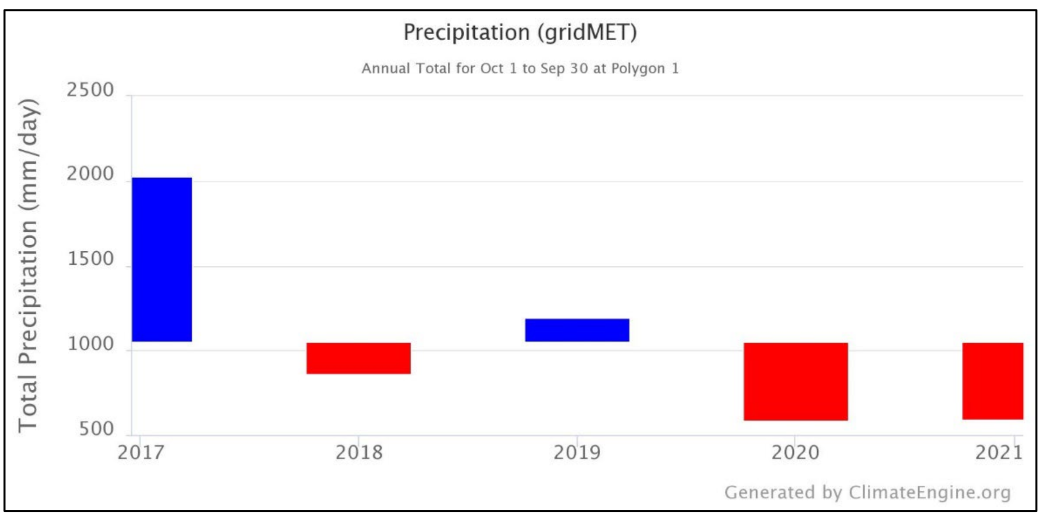


Figure 20. Annual water year precipitation totals (October 1 – September 30) 2017-2021 for Lower Sardine Meadow derived from Climate Engine. Blue bars indicate above average precipitation and red indicate below average.

In general, we see the anticipated pattern for the Sierra Nevada of ground water levels rising substantially during the spring snowmelt period (June-July) and gradually lowering as the site dries out from spring to fall. GW E faintly exhibited this pattern, but then showed a pattern of a more substantial lowering of groundwater in late fall into winter. We had planned to use GW E as a control for GW A, B and C, but it is located adjacent to a swale the turned out not to draw down during the dry season and was wet throughout the manual measurement season. GW D is located away from the work area and shows a more similar patter to the other wells and serves as a better control for climatic variation.

The GW F logger was not in place from July 3, 2018 to October 21, 2018, but then was replaced during the October 21, 2018 measurement, at which the well was dry. For the period October 21, 2018 to April 4, 2019, based on the logger values we are unsure whether the well remained dry. The values should correspond to the dry measurement on October 21, 2018, but they are nearly equal to and even slightly less than logger values in 2020 well the well contained measurable water. The logger values for GW A and B exhibit an atypical pattern for the period from installation through end of July compared to subsequent years, and counter to what would be anticipated for the period. This is likely an artifact of installation, as groundwater seeps into the perforated wells. The period from early August on for GW A and B exhibits values and a pattern similar to subsequent years and is useful for comparison. This atypical pattern compounded the already limited period of pre-project data, limiting comparison with early season 2018 data.

Minimum depth to groundwater

Wet meadows depend on groundwater rising to the surface or into the root zone for a period of time long enough to create hydric soil conditions that support wetland vegetation. We observed minimum depths to groundwater between 0 (GW D) and 0.99 (GW F) feet during the spring snowmelt period 2019-2021. In all wells except GW F, groundwater depths rose to within one foot of the meadow surface and were sustained for a period of at least 50 days each season 2019-2021. Although we lack the data to make a full pre- and post-restoration comparison for GW A and B, the data indicates that post-restoration, these sites exhibit a pattern of seasonally high groundwater. In 2019 for GW F, the minimum depth to groundwater was 0.99 feet and groundwater depth was within one foot of the meadow surface for one day. In 2020 and 2021, the minimum depth was 0.33-0.38 feet (a ~0.64-foot increase over 2019) and groundwater depth was within one foot of the meadow surface for 28-30 days. This demonstrates a marked increase despite above average precipitation in 2019 and very below average precipitation in 2020 and 2021. GW D, which is in the vicinity of the occupied Yosemite toad breeding ponds, had a minimum depth of zero feet and a maximum depth of 2.5 feet to groundwater. The site maintained groundwater depth within one foot of the meadow surface for between 80 and 145 days.

Maximum depth to groundwater

For GW A and GW B we see a rise in the maximum depth to groundwater in 2019 compared to 2018, but it corresponds to above average precipitation. In 2020 we similar maximum depths to 2018 despite 2020 having more significantly below average precipitation than 2018, which could indicate the groundwater in the restored area is more resilient to low precipitation conditions, but it is not a strong trend.

Analysis for GW F is complicated by the lack of logger data for the period July 3, 2018 to October 21, 2018. We assumed the logger would remain dry and removed the logger to minimize potential for theft. Based on the patterns of ground water seeping in and rising after installation, we cannot be sure this did not occur for GW F and cannot assume the well was dry for this period. However, we do know that the well was dry on October 2, 2018 (well depth 9.65 ft) and had water at 9.46 feet on November 4, 2020 and 9.43 feet on October 19, 2021, despite slightly below average precipitation in 2018 and very below average precipitation in 2020 and 2021, indicating an increase of at least 0.19 feet compared to pre-restoration conditions in a drier year.

Surface Water (Breeding Habitat Monitoring)

The US Forest Service conducted monitoring of the extent and duration of shallow surface water as an indicator of potential Yosemite toad breeding habitat in Lower Sardine Meadow. They measured the extent and duration of shallow surface water two times during the summers of 2017 and 2019-2021, once shortly after breeding and another about one month later as the meadow dried. During the first survey each year, they delineated all contiguous wetted areas of similar habitat and called these microsites. They categorized the habitat of each microsite into one of three categories. Potholes had defined shoreline and depressional topography, flooded vegetation had flat topography flooded with standing or shallow flowing water, and channels were streams or had a clear flow path. In each microsite, they estimated the maximum length, maximum width, and percent of the area with water. The area of surface water is calculated as (length*width)*percent water. In each area, they measured the maximum depth. The desiccation of each microsite over the summer is calculated as 1-(area at survey 2/ area at survey 1). Surface water in breeding areas dries naturally in Sierra Nevada meadows, and for successful Yosemite toad breeding, water needs to be present at least six to eight weeks after eggs are laid.

The US Forest Service missed monitoring in 2018 due to coordination and capacity constraints. In 2017, sites were delineated by hand. In 2019-2021 the US Forest Service used GPS to digitize the features to show spatial distribution. The 2017 drawings are not accurate enough to be digitized and included in mapping, but it was possible to adequately match features with those digitized in 2019-2021 in the restored area for comparison pre- and post-restoration. The results of the 2019-2021 monitoring are shown in Figure 21. 2019 data can act as partial pre-restoration data, as the culverts were installed in late summer 2019. The attribute data was only analyzed for 2017 and 2019 – presented below. The 2020-2021 had data quality issues resulting from issues associated with entering and downloading data from the tablet, so comparison between years would not have been accurate.

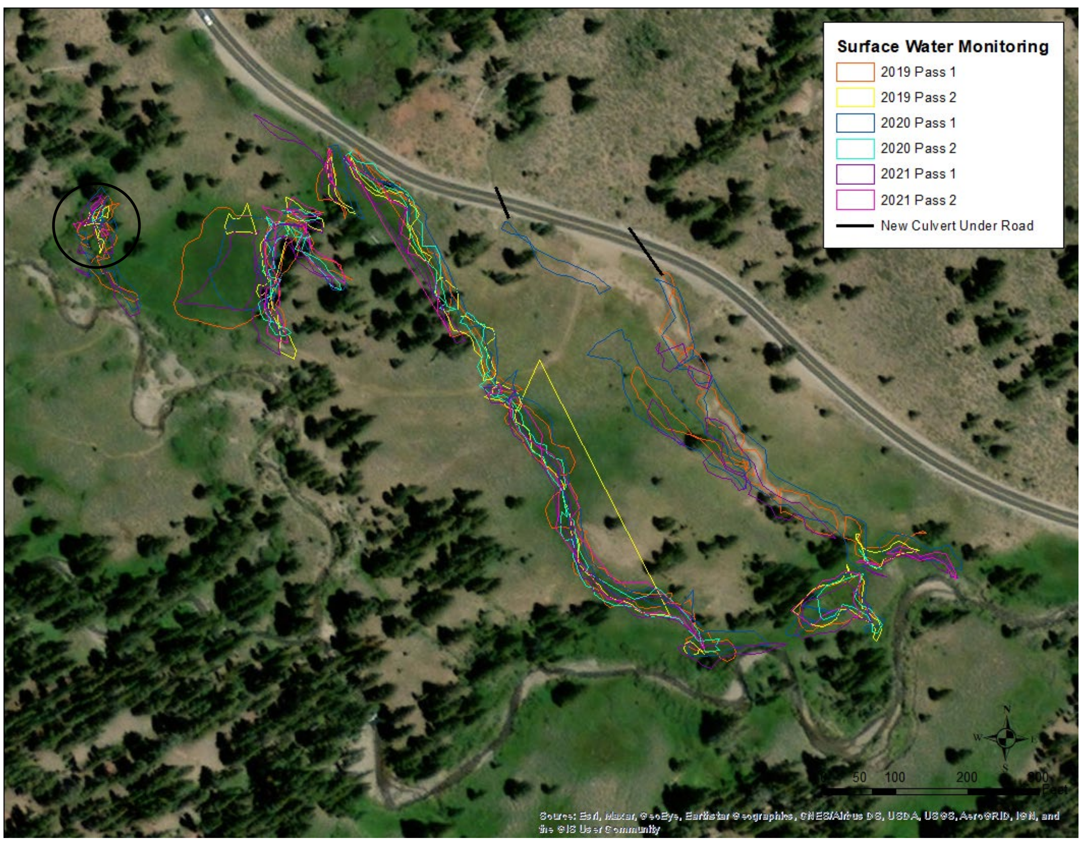


Figure 21. Results of surface water monitoring at Lower Sardine in 2019-2021. The first or second survey (pass) and year are indicated. The first surveys (passes) are indicated with darker colors and the second surveys (passes) are indicated with lighter colors. The polygon in center with long straight edge is overestimated due to an error inputting the feature in the field. The black circle indicates occupied breeding habitat.

Despite limited accuracy, the GPS polygons provide a general sense of the spatial pattern of surface water between passes and seasons. The spatial distribution of polygons is fairly consistent between years. Although not shown in Figure 21, the hand delineated 2017 maps show a similar pattern to the 2019-2021 data in the gully fill area, with water present at the first monitoring (pass) but absent during the second monitoring (pass).

The data demonstrates that post-restoration, the restored area consistently supports shallow surface water each season during the first monitoring (pass), although it does not last through the second monitoring (pass). There is also a new polygon adjacent to one of the new culverts during the first monitoring in 2020 that was not show in 2019, demonstrating rewatering of this area of the meadow. However, this polygon is not indicated in 2021. This could be an artifact of sampling or due to the second year of very low below average precipitation. Despite numerous areas having water persisting though the second monitoring period, breeding has consistently only been observed at two small pothole features at the west end of the meadow (black circle in Figure 21).

2017 and 2019 Analysis
The amount of surface water decreased over both 2017 and 2019 summers at Lower Sardine Meadow, which is typical in Sierra Nevada meadows. The total area of surface water changed from 3,805 m^2 at the first survey to 795 m^2 at the second survey in 2017, and from 11,294 m^2 at the first survey to 1766 m^2 at the second survey in 2019. This surface water was delineated into 34 microsites in 2017 and 19 microsites in 2019. Of the 34 microsites in 2017, 15 (44%) dried completely and of the 19 microsites in 2019, 8 (42%) dried completely. Of sites that had water at the second survey, the average desiccation of surface water area was 56.3% ± 34.2 (sd, range=0-98.3%) in 2017 and 41.6% ± 36.7 (sd, range=0-99.5%) in 2019. The average area of microsites decreased from 111.9 ± 177.5 (sd) to 36.2 ± 42.97 in 2017 and 594.4 ± 1812 to 160.5 ± 213.2 in 2019. Maximum depths remained relatively consistent over the summers.

Flooded vegetation microsites tended to be larger early season but also tended to dry the most. For example, the largest microsite was a shallow (maximum depth=0.05) gently sloping area of flooded meadow vegetation. This microsite was estimated to be approximately 1,008 m^2 during the first survey in 2017 and dried to approximately 22 m^2 a month later.

Toad Population Monitoring
The US Forest Service initiated a Yosemite toad population study, using Capture-Mark-Recapture (CMR) surveys during the breeding season in 2016 in Upper and Lower Sardine Meadows. They conducted surveys at both sites during the 2016-2021 breeding seasons. This is part of a larger study that is planned to continue for at least 10 years to provide information to US Fish and Wildlife Service about the toad populations at these sites. The data is collected annually by the Humboldt Toiyabe National Forest (HTNF). At the conclusion of the 2019 season, the Forest Service Amphibian Team Leader, Cathy Brown provided statistical analysis of population estimates; however, based on this pilot analysis, the US Forest Service monitoring team determined this analysis was not appropriate until more years of data (10+ years) are available to capture a full toad life cycle, so it was not performed for the 2020 and 2021 data. Table 9 provides the actual number of individuals observed for all seasons and new individuals tagged for comparison across years. The statistical estimates for 2016-2019 are included in Appendix E. Observations of egg masses are provided (where available) and distinct breeding locations are also indicated in Table 9

The HTNF aimed to conduct surveys during peak breeding at each site, but was originally constrained by the Highway 108 closures, causing peak breeding to be missed at Lower Sardine (where breeding typically occurs five to seven days earlier than Upper Sardine) in 2016-2017. In subsequent years, the HTNF was provided access during road closure for surveys. The variability in duration of surveys is due to variability of the breeding season, with longer surveys corresponding to longer duration of the breeding season.

2016
In 2016, the HTNF conducted CMR surveys from May 31st to June 2nd. At Upper Sardine Meadow, 21 unique individuals were tagged. This equates to an estimated 46 ± 6 breeding males present, and one female was counted over the three-day period. Females are harder to find than males. A total of 17 egg masses were counted within Upper Sardine Meadow. At Lower Sardine, 13 individuals were tagged. Peak breeding was

missed at Lower Sardine. Tadpoles were already present at Lower Sardine. Two egg masses and over 1,000 tadpoles were identified within Lower Sardine Meadow.

2017

In 2017, surveys occurred June 19th to 23rd at both Upper and Lower Sardine Meadows. At Upper Sardine Meadow, 83 unique individuals were handled, and 60 new toads were tagged over a five-day period. There were 10 breeding pairs that were not tagged at the time of survey due to the pairs being in amplexus. A total of 25 egg masses were counted within Upper Sardine Meadow. At Lower Sardine, eight unique individuals were handled and five new toads were tagged over a five-day period. This equates to an estimated 7 ± 0.2 breeding males present and no females were counted over the five-day period. Peak breeding was missed at Lower Sardine. Tadpoles were already present at Lower Sardine. Four egg masses and approximately 400 tadpoles were counted within Lower Sardine Meadow.

2018

In 2018, the CMR survey occurred May 21st to May 24th at Upper Sardine. A total of 78 unique individuals were handled and 26 new toads were tagged over the 3-day period. There were 12 breeding pairs that were not tagged at the time of survey due to amplexus. Toads were only surveyed three out of the four days due to a snowstorm that occurred on the second day of survey. The CMR survey occurred May 14th to 18th at Lower Sardine Meadow. A total of 39 unique individuals were handled and 30 new toads were tagged over the five-day period. There were six breeding pairs that were not tagged at the time of survey due to amplexus. This equates to an estimated 36 ± 0.3 breeding males present and a count of three females over the five-day period. On May 18th, a total of 16 egg masses were identified within Lower Sardine Meadow.

2019

In 2019, the CMR survey occurred June 13th to 24th at Upper Sardine. A total of 164 unique individuals were handled and 99 new toads were tagged over the nine-day period. There were 22 breeding pairs that were not tagged at the time of survey due to amplexus. On June 13th, a total of 45 egg masses were identified within Upper Sardine Meadow. The CMR survey occurred June 10th to 14th at Lower Sardine Meadow. A total of 48 unique individuals were handled and 21 new toads were tagged over the five-day period. There were five breeding pairs that were not tagged at the time of survey due to amplexus. This equates to an estimated 45 ± 0.4 breeding males present and there was a count of 3 females over the 5-day period. A total of 20 egg masses were counted within Lower Sardine Meadow.

2020

In 2020, the CMR survey occurred from May 9th to May 22nd at Upper Sardine Meadow. Due to COVID-19 restrictions, Upper Sardine Meadow was only surveyed five times in that 14 day period. A total of 171 unique individuals were handled and 82 new toads were tagged over the 5-day period. On May 21, a total of six egg masses were identified within Upper Sardine Meadow. The total number of egg masses at Upper Sardine was unclear because many had already hatched by the time the final survey was conducted on May 22. The CMR survey occurred May 8th to May 21st at Lower Sardine Meadow. Due to COVID-19 restrictions, Lower Sardine was only surveyed four times in that 14-day period. At Lower Sardine, 54 unique individuals were handled and 13 new toads were tagged over the 4 day period. It is unclear how many egg masses were present at Lower Sardine because many had already hatched by the time of the final survey on May 21st.

2021

In 2021, the CMR survey occurred from May 10th to May 29th at Upper Sardine Meadow. Upper Sardine Meadow was surveyed 13 times in that 20-day period. A total of 235 unique individuals were handled and 78 new toads were tagged over the 13-day period. A total of 34 egg masses were identified within Upper Sardine Meadow. This year individuals, as well as egg masses were identified in the big meadow where the Upper Sardine Restoration project occurred. In 2021, the CMR survey occurred from May 7th to May 14th at Lower

Sardine. Lower Sardine was surveyed six times in that eight-day period. A total of 45 unique individuals were handled and 10 new toads were tagged.

	2016		2017		2018		2019		2020		2021	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Unique Individuals	21	13	83	8	78	39	164	48	171	54	235	45
New Individuals Tagged			60	5	26	30	99	21	82	13	78	10
Egg Masses	17	2	25	4	ND	16	45	20	6	ND	34	ND
Tadpoles (if applicable)		1000		400								
Distinct Breeding Locations	3	2	3	2	3	2	3	2	3	2	**4**	2

Table 9. Results of Yosemite toad CMR surveys in Upper and Lower Sardine Meadows 2016 – 2021. ND = No data. Note the additional distinct breeding location in Upper Sardine in 2021.

The number of unique individuals gives a picture of the breeding population each season at each meadow. Male toads breed annually but females do not always breed each year, so it a challenge to estimate the actual number of toads in the population. The number of new individuals tagged indicates the level of recruitment at the site. In 2016-2017, the HTNF was piloting in a new survey technique and has greater confidence in their data from 2018 on. For Upper Sardine if we see a marked increase in unique individuals, as well as new individuals tagged between 2018 and 2020-2021. For Lower Sardine the numbers of unique individuals is fairly consistent, but the number of new individuals declines between 2018 and 2020 and 2021.

There are too many unknowns to attribute the marked increase in number of individuals in Upper Sardine to restoration, which only affected a portion of the breeding area, although it may play a role. But a highlight is that in 2021, the HTNF observed egg masses (indicating breeding) in the vicinity of the restoration project for the first time (Figure 22). Note the increase from three to four distinct breeding locations for Upper Sardine from 2020 to 2021 in Table 9. Although the surface water breeding habitat monitoring was not conducted in Upper Sardine, the HTNF noted distinct breeding areas during CMR surveys. Also, in general the HTNF observed breeding toads utilizing the restored area in Upper Sardine (Figure 23).

In Lower Sardine, breeding consistently only occurred in two well-established perennial ponds at the west end of the meadow. The restoration project did affect this area, so we do not associate the decline in new individuals tagged with restoration, and as will Upper Sardine there are many unknowns. But the project did protect this consistent breeding habitat by obliterating the road and re-routing the trail away from it.

Figure 22. Photo of egg masses in the restored area in Upper Sardine Meadow in May 2021. Zoomed out (left) and zoomed in (right). See dark spots at the base of the flag.

Figure 23. Photo of Yosemite toads in the restored area of Upper Sardine Meadow during breeding season 2021. A breeding pair is shown in left photo.

Visual Assessment of Cover

We conducted visual assessment of cover at each meadow post-project to determine whether the project was achieving stabilization at areas disturbed during construction per the requirements of the Section 401 Water Quality Certification which states, “the goal for stabilization should be 70% of the natural vegetation coverage.” In 2018-2021, we visually assessed cover on disturbed areas and documented with photos. In 2020 and 2021 we also established transects to quantify percent cover based on the Step Point Method (University of Idaho College of Natural Resources, 2009). Under this method, we established sampling locations by selecting a representative restored feature, laying a tape measure parallel to the feature, then picking a randomized location on the tape. We used this point on the tape to establish a transect perpendicular to the restored feature, starting two feet beyond the observable edge of the feature. We took a GPS point and photo at each end of the transect. We then walked each transect and made observations of *disturbed by construction* or *vegetative cover* at specified intervals ensuring at least 50 tallies.

Maps showing transect locations, transect results and representative photos are presented in Figures 24-34 and Tables 10-12. A slight snow had fallen just before fieldwork in 2021, but we were able to clear snow enough to conduct transects. Given this, we included photos from both 2020 and 2021 to illustrate vegetation cover.

Lower Sardine

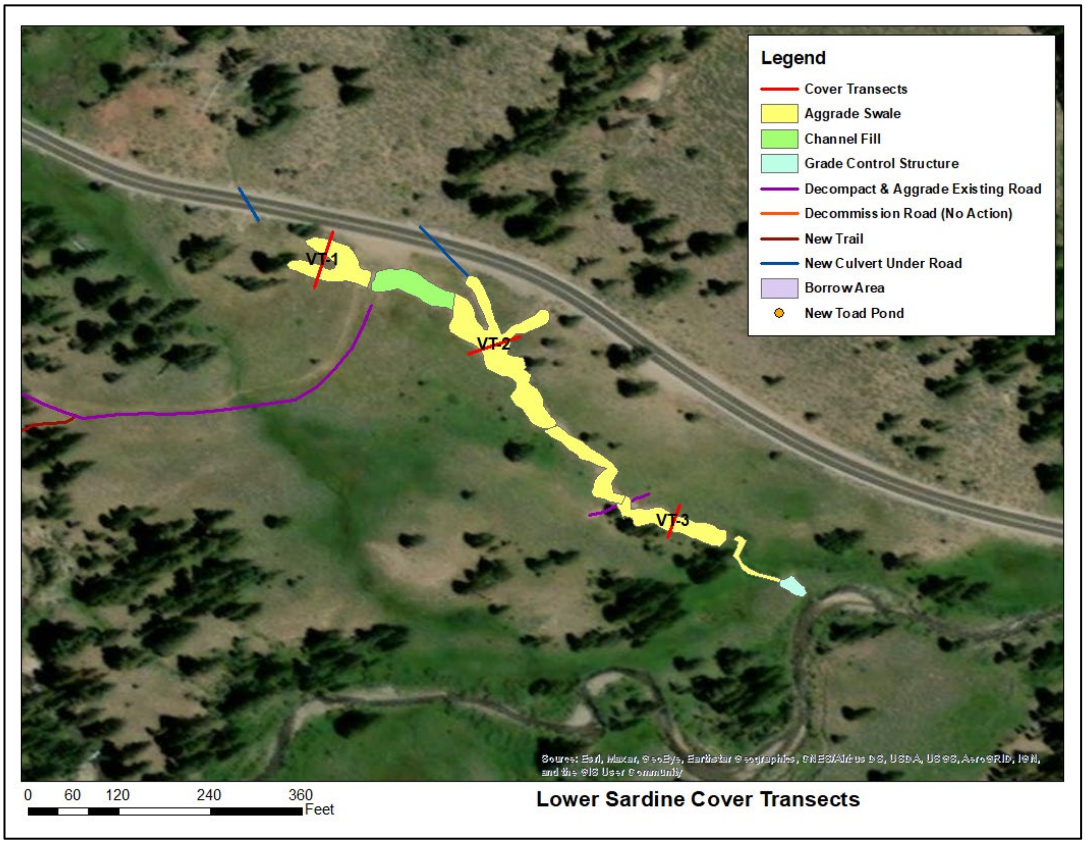


Figure 24. Cover transect locations in Lower Sardine Meadow.

Site/Transect	Percent Vegetative Cover	
	November 4, 2020	**October 19, 2022**
Lower Sardine		
VT 1	53	59
VT 2	31	**70**
VT 3	65	**74**

Table 10. Results of Step Point Method monitoring for vegetative cover at Lower Sardine.

Overall, vegetation is re-establishing rapidly at Lower Sardine, except for the most upstream portion of the project, which has not yet re-established to 70 percent of natural vegetation (VT-1). This portion of the project was naturally drier and received more compaction during construction, as equipment accessed the site. We will continue to monitor this area and apply sod plugs or other means to encourage vegetation growth if conditions do not improve. The middle and lower portion of the swale are having more vegetative recruitment, as indicated by VT-2 and VT-3. The grade control structure is beginning to become vegetated, but is not yet at 70% cover since additional rock was added in 2020.

Figure 25. VT 1 in 2020 (left); Looking upslope toward VT-2 in 2021 (right).

Figure 26. VT-3 in 2020 (left) and 2021 (right).

Figure 27. Photo of grade control structure from September 2021.

Cloudburst

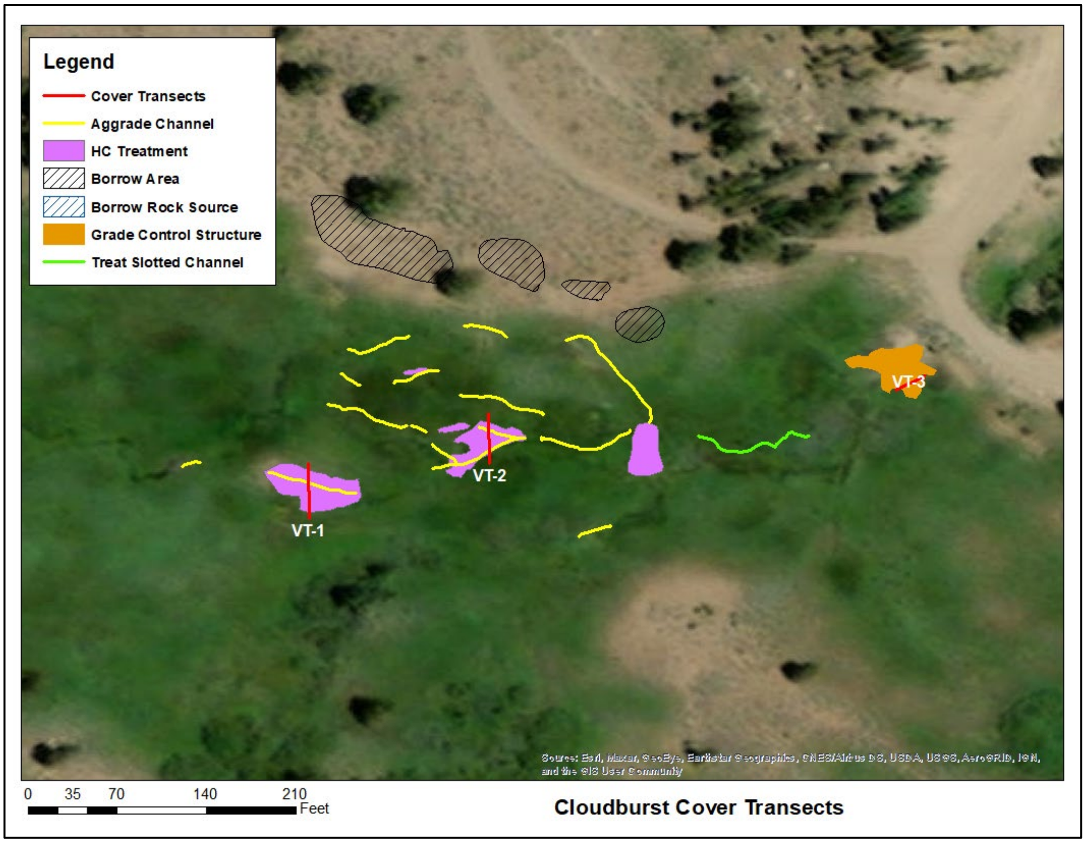


Figure 28. Cover transect locations in Lower Sardine Meadow.

Site/Transect	Percent Cover	
	November 4, 2020	October 19, 2021
Cloudburst		
VT 1	55	**81**
VT 2	61	**92**
VT 3	?	63

Table 11. Results of Step Point Method monitoring for vegetative cover at Cloudburst. VT 3 was established in 2021.

Vegetation is re-establishing rapidly on areas disturbed by 2018 construction activities in Cloudburst Meadow. Most of the headcut repair areas are exceeding 70% cover, as evidenced by VT-1 and VT-2. Vegetation is beginning to re-establish on areas disturbed by construction of the grade control structure in 2019, but is not yet 70% of natural as indicated by VT-3. Additionally, a portion of the structure was re-disturbed in 2020. We will continue to monitor this area and adaptively manage, if needed.

Figure 29. VT-1 (left) and VT-2 (right) in 2021.

Figure 30. Looking from VT-3 toward grade control in 2020 (left), and photo of VT-3 from 2021 (right).

Upper Sardine

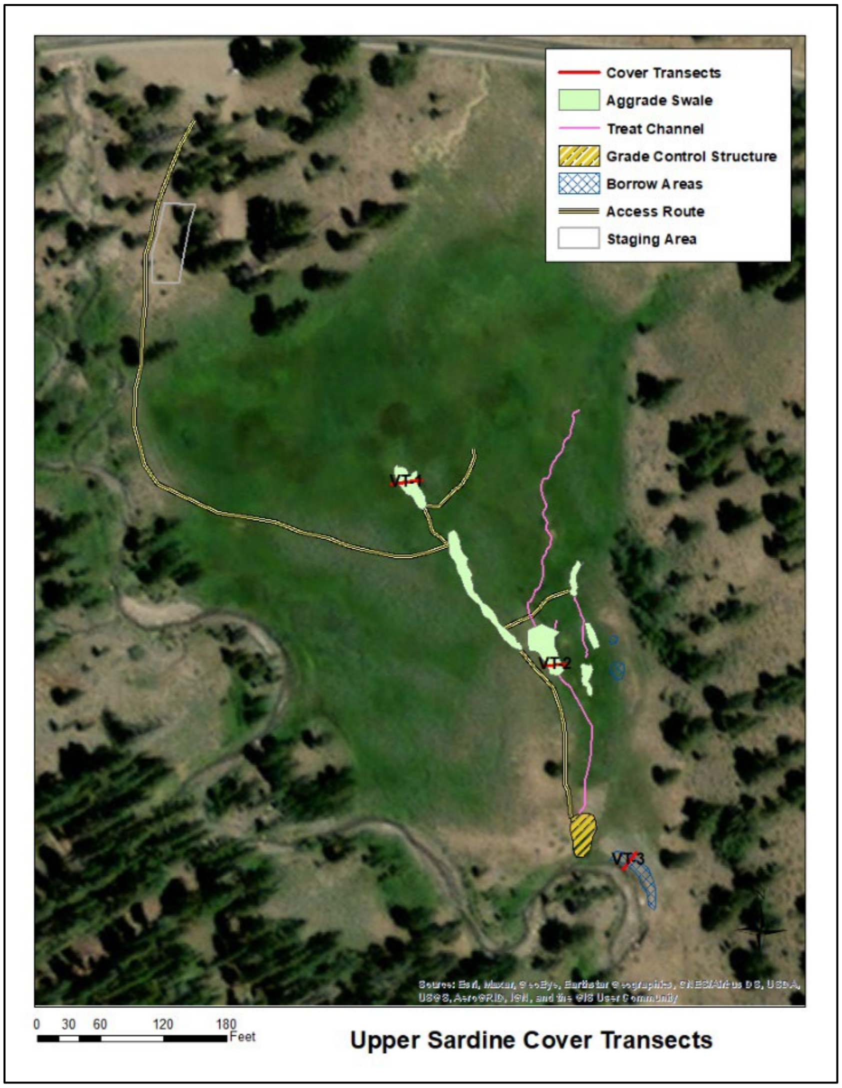


Figure 31: Cover transect locations in Lower Sardine Meadow.

Site/Transect	Percent Cover	
	November 4, 2020	October 19, 2021
Upper Sardine		
VT 1	58	**77**
VT 2	68	**88**
VT 3		66

Table 12: Results of Step Point Method monitoring for vegetative cover at Cloudburst. VT 3 was established in 2021.

Vegetation is re-establishing rapidly on areas disturbed by 2019 construction activities in Upper Sardine Meadow. The headcut repair areas have re-established greater than 70% cover, as indicated by VT 1 and VT 2. Although the grade control is comprised of mostly rock, it has shown some regrowth, although not at 70% cover. Additional wattles were installed for erosion control in 2020. The borrow area has also had slower regrowth but the erosion fabric and wattles have been successful at reducing erosion and cover is approaching 70% as indicated by VT-3. We will continue to monitor sites and adaptively manage to encourage cover if needed.


Figure 32. Looking up at VT-1 in 2021 (left). VT-2 in 2021 (right).

Figure 33. Grade control in 2021.


Figure 34. Borrow area in 2021 (left) and VT-3 in 2021 (right).

Planting and Survivorship Monitoring

The project planted ~60-70 willow stakes in Lower Sardine Meadow in fall 2020 (Figure 35). Planting occurred along both sides of approximately 200 feet (approximately 0.2 acres) of Sardine Creek in the location where the decommissioned OHV route used to cross the stream. Survivorship monitoring was scheduled, but could not be completed in 2021 due to early snow and road closures affecting the sites.

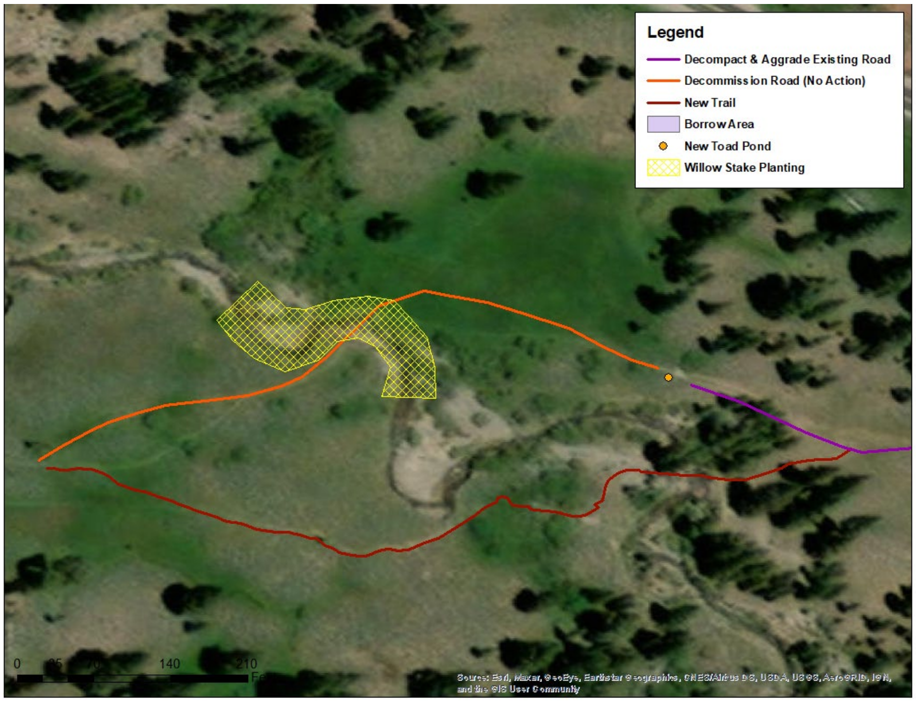


Figure 35. Location of willow stake planting at former OHV route crossing in Lower Sardine Meadow

Figure 36. Photos of willow stake planting along Sardine Creek in Lower Sardine Meadow in 2020

Remote Sensing Using Climate Engine

We used Climate Engine to evaluate changes in the Normalized Difference Vegetation Index (NVDI) and the Normalized Difference Water Index (NDWI) pre- and post-project at Lower Sardine, Upper Sardine, and Cloudburst. NDVI is an index of greenness and indicates plant vigor and NDWI is an index of vegetation water content and indicates wetness of a meadow. In both cases, calculations result in a value between -1 and 1 with larger values representing greater vegetation vigor for NDVI and water content for NDWI. NDVI and NDWI are both related to water year precipitation, with greater precipitation resulting in higher NDVI and NDWI values. For example, years with above average precipitation totals generally show above average NDVI values and above average NDWI values. However, NDVI and NDWI vary inversely to each other over a season. Plant wetness (NDWI) is correlated with wetter times of the year, while plant vigor (NDVI) is delayed by several months.

At each site, we used the Landsat Surface Reflectance dataset. We compared annual mean summer NDVI (July 1 - September 30) to water year precipitation totals (October 1 – September 30) to assess changes in meadow vegetation post restoration. We used the mean, due to the relatively small size of the project sites. We compared data from 2008 (10 years pre-restoration) through 2021, which is two years post-restoration for Upper Sardine, and three years post-restoration for Lower Sardine and Cloudburst. We analyzed data from polygons of areas within each meadow that were likely to be affected by restoration (Figure 37).

Figure 37. Polygons used for NDVI/NDWI calculations at Upper Sardine (left), Lower Sardine (middle) and Cloudburst (right).

NDVI

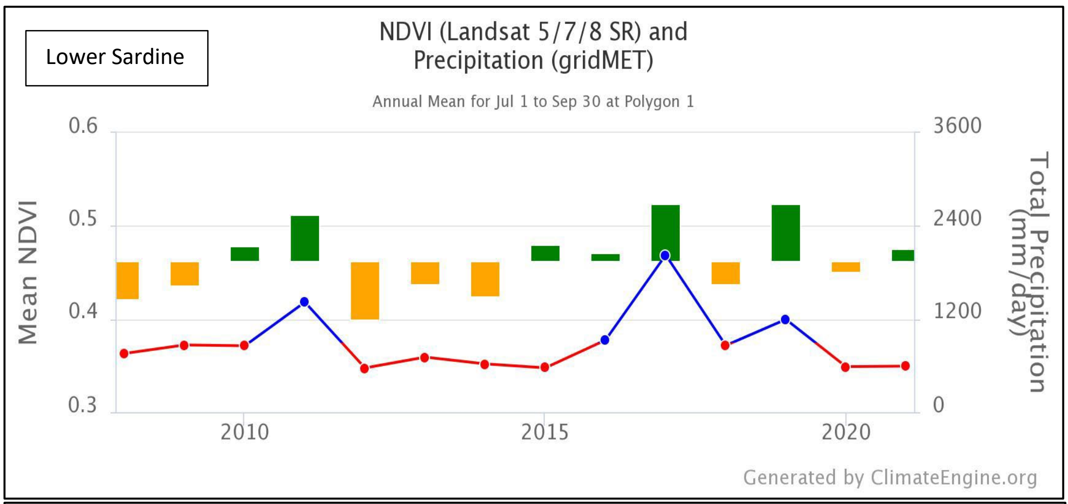
Mean summer NDVI values and water year precipitation totals are show in Figure 38. Above average precipitation (blue points) paired with below average NDVI (yellow bars) suggest a stressed meadow, while above average NDVI values (green bars) despite below average precipitation values (red points) suggest meadow resilience. Lower Sardine and the majority of Cloudburst were restored in 2018. In 2019, at both sites we see above average precipitation paired with relatively high NDVI, indicating the typical pattern of NDVI following above average precipitation. This is similar to 2011, but the precipitation is lower and the NDVI is higher in 2019 suggesting greater resilience in 2019. However, we see a similar pattern in Upper Sardine in 2019 (restored in fall 2019), indicating other factors may have had a greater influence than restoration that season.

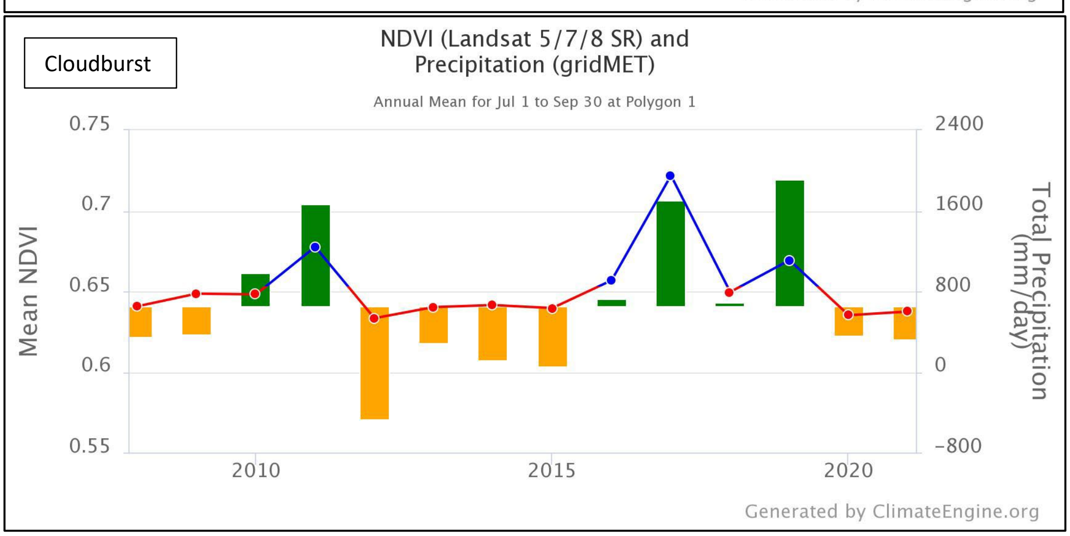
In Lower Sardine, we see low below average precipitation paired with slightly below average NDVI in 2020 and above average NDVI in 2021. The pattern in 2021 indicates resilience, but is very close to the pattern for 2015 pre-restoration, so the trend is challenging to attribute to restoration.

In Cloudburst, in 2020 and 2021 we see low below average precipitation paired with moderately below average NDVI, following the typical pattern of NDVI following below average precipitation. The NDVI is slightly less below average than for years with similar precipitation pre-restoration, but not a strong trend.

Upper Sardine also exhibits very low below average precipitation paired with moderately below average NDVI for 2020 and 2021, but the pattern is very similar to years with similar precipitation pre-restoration indicating a lack of trend toward increased resilience because of restoration.

Overall, in 2021 Lower Sardine exhibited the pattern characteristic of a resilient meadow, but it is not very different than certain years pre-restoration. Cloudburst does not demonstrate the pattern of a resilient meadow but may be slightly more resilient than pre-restoration. Upper Sardine does not demonstrate a trend toward increased resilience post-project. This analysis is based on a limited number of post-project years for comparison. A stronger trend may emerge over time.





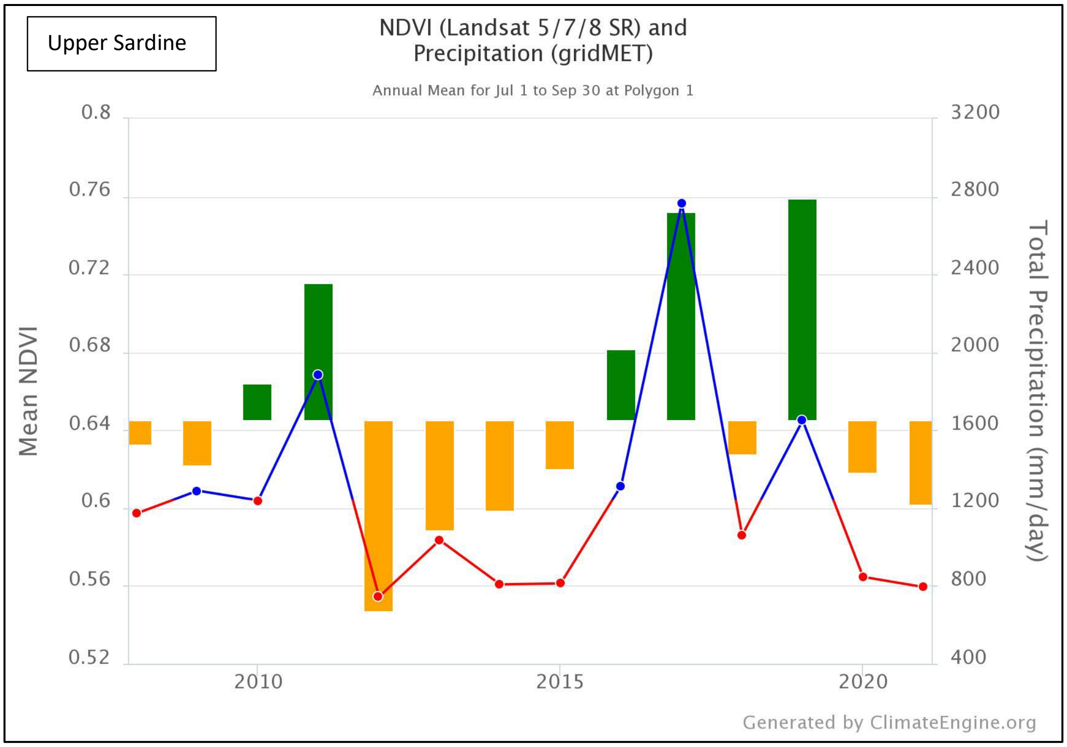
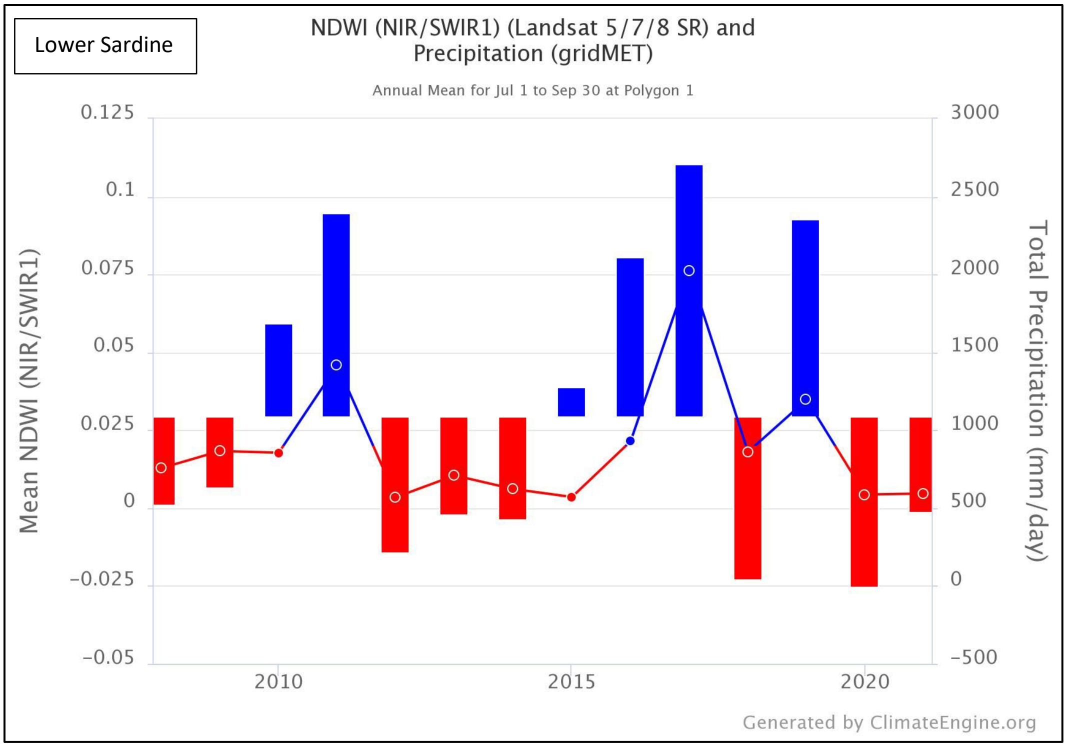
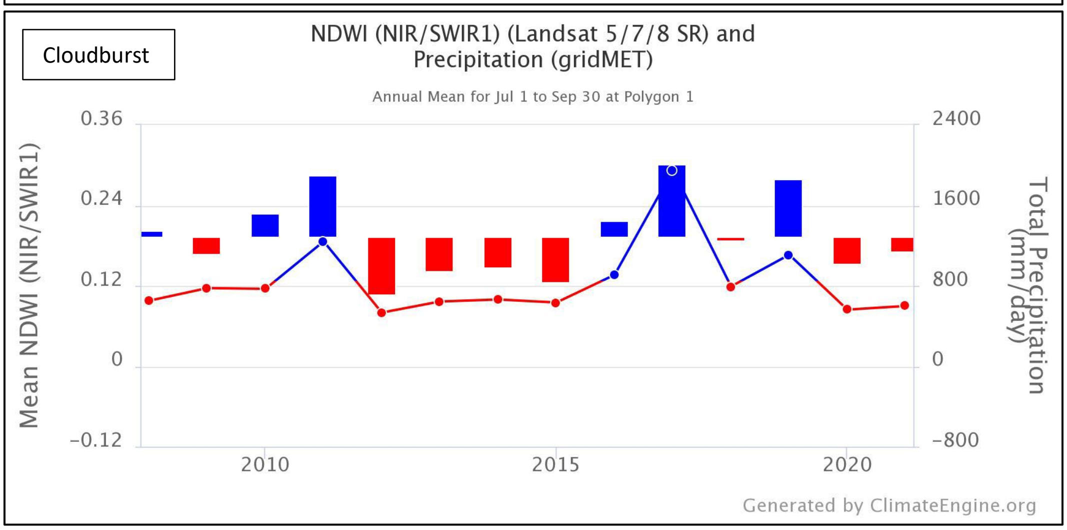


Figure 38. Comparison of mean summer NDVI and water year precipitation at Lower Sardine (top) and Cloudburst (middle) and Upper Sardine (bottom) 2008-2021. Precipitation is indicated by the points and lines. Blue and red indicate above and below average, respectively. NDVI is indicated by the bars. Green and yellow indicate above and below average, respectively.

NDWI

Mean summer NDWI values and water year precipitation totals are show in Figure 39. Like NDVI, years with below average precipitation (red line) paired with above average NDWI (blue bars) indicate a resilient meadow. The sites exhibit the typical pattern of NDWI following above and below average precipitation. We do not see the anticipated pattern indicating increased resilience post-project. At Cloudburst in 2021 we see low below average precipitation paired with slightly below average NDWI compared with similar pre-restoration years, but it is not a strong trend. Overall, we do not see the anticipated effects of restoration relative to pre-restoration years, but may begin to pick up more of a trend in subsequent years following restoration.


Lower Sardine
NDWI (NIR/SWIR1) (Landsat 5/7/8 SR) and Precipitation (gridMET)
Annual Mean for Jul 1 to Sep 30 at Polygon 1
Mean NDWI (NIR/SWIR1)
Total Precipitation (mm/day)
0.125
0.1
0.075
0.05
0.025
0
−0.025
−0.05
3000
2500
2000
1500
1000
500
0
−500
2010
2015
2020
Generated by ClimateEngine.org


Cloudburst
NDWI (NIR/SWIR1) (Landsat 5/7/8 SR) and Precipitation (gridMET)
Annual Mean for Jul 1 to Sep 30 at Polygon 1
Mean NDWI (NIR/SWIR1)
Total Precipitation (mm/day)
0.36
0.24
0.12
0
−0.12
2400
1600
800
0
−800
2010
2015
2020
Generated by ClimateEngine.org

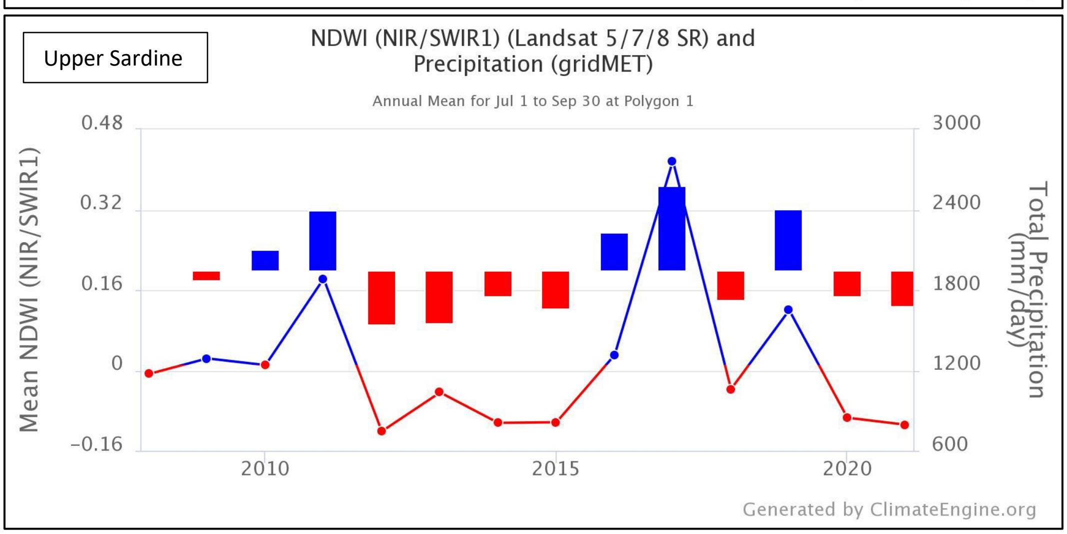

Upper Sardine
NDWI (NIR/SWIR1) (Landsat 5/7/8 SR) and Precipitation (gridMET)
Annual Mean for Jul 1 to Sep 30 at Polygon 1
Mean NDWI (NIR/SWIR1)
Total Precipitation (mm/day)
0.48
0.32
0.16
0
−0.16
3000
2400
1800
1200
600
2010
2015
2020
Generated by ClimateEngine.org

Figure 39. Comparison of mean summer NDWI and water year precipitation at Lower Sardine (top), Cloudburst (middle), Upper Sardine (bottom), 2008-2021. Precipitation is indicated by the points and lines. Blue and red indicate above and below average, respectively. NDWI is indicated by the bars. Blue and red indicate above and below average, respectively.

Adaptive Management Considerations

The project team visited the sites at least twice each season following restoration, once immediately following snowmelt and once at the conclusion of the summer field season (late August or September) to visually assess the projects and determine the need for adaptive management. In 2019, adaptive management included applying additional erosion control fabric and installing additional slash to prevent erosion channels from forming at Lower Sardine.

In 2020, we conducted adaptive management at all sites. At Lower Sardine meadow, we used hand labor to acquire and place additional rock to adjust the contour of the of the grade control structure. We installed additional erosion control fabric and coir logs to further manage low paths and reduce erosion. At Cloudburst Meadow, we used equipment to acquire and place additional alluvium to adjust the contour of the grade control structure. We placed additional erosion control fabric to ensure erosion control while disturbed areas are becoming revegetated. At Upper Sardine Meadow, we used hand labor to place additional coir logs in channels and headcut areas to fill channels and direct flow. We placed additional erosion control fabric to ensure erosion control while disturbed areas are becoming revegetated. In 2021, adaptive management included hand repair to help ensure flows were directed to the grade control and installing additional coir logs in remaining slotted channels.

American Rivers will continue to engage in monitoring to close out permits and evaluate the need for adaptive management for a period of five years following completion of implementation in 2019. At least once per season we will visit each site to conduct photo point monitoring and visually assess restored features including grade control structures and filled headcuts and channels for damage, erosion and/or knickpoints. We will continue to visually assess HC 1 at Upper Sardine to evaluate the need for intervention. We will continue to visually assess vegetation cover as long as needed to meet the 70% cover stand for stabilization required by the Water Quality Certification for the Project. The HTNF plans to continue the Yosemite toad population monitoring for at least another five years (through 2025).