McCosker Creek Restoration and Public Access Project:

Alder Creek Daylighting Additional Monitoring Elements - Final Report

2019 **2023**

San Francisco Estuary Institute

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Introduction

This report describes the monitoring plan that was developed and interprets the monitoring data collected for the East Bay Regional Park District (EBRPD) by the San Francisco Estuary Institute (SFEI) to help record changes in creek condition and function at the McCosker Creek Restoration and Public Access Project site. This restoration project was completed with assistance from a United States Environmental Protection Agency (EPA) San Francisco Bay Water Quality Improvement Fund grant. The project has daylighted and reconstructed 3,000 linear feet of the Alder Creek channel and its tributary Leatherwood Creek on the former McCosker Family property, after it had been flowing through an underground culvert since the 1950s. The daylighting project's specific stated restoration goals include:

- daylighting and restoring Alder and Leatherwood Creeks to functioning stream and associated riparian systems;
- removing invasive and non-native plants, and planting over 5,000 native plants and trees;
- creating habitat for wildlife and aquatic species, including rainbow trout, California red-legged frog, and the Alameda whipsnake; and
- reducing sediment impacts to San Leandro Creek associated with surface and bank erosion.

EBRPD owns and manages over 1,500 acres of property in the Upper San Leandro Creek watershed, including portions of the Robert Sibley Volcanic Regional Preserve and Huckleberry Botanic Regional Preserve. In 2010, the 250 acre McCosker property, which is adjacent to both parks, was donated to EBRPD by the McCosker Family, which had owned the property since the 1860s. The addition of this property increased the size and the continuity of EBRPD land holdings in the area, increasing the effectiveness of the land management that is practiced. However, initial assessment of the property revealed that previous actions on the property, namely the routing of Alder Creek into a straightened underground culvert to increase the area of valley floor available for quarry and equipment yard use, had significantly degraded the environmental quality of the property and its aquatic resources. Over the years, failure of the culvert had caused dangerous sinkholes to form and degradation of water quality through contribution of excess sediment and metal fragments. After receiving the property, EBRPD intended to open the area to the public as a part of the regional park system, but achieving that goal had to be delayed until the danger caused by the failing culverts could be resolved.

EBRPD recognized the unique opportunity to daylight Alder Creek to improve channel stability, aquatic and riparian habitat values, as well as provide a new public recreation area. They also recognized the challenging scale of the restoration effort, both in terms of the channel length and also the steepness of the channel gradient. A partnership with federal and state resource agencies would be required to successfully complete the project, and create a stable and functioning creek reach and a safe recreational area. EBRPD was able to develop a partnership with many agencies, including the U.S. EPA, California Wildlife Conservation Board, California Coastal Conservancy, California Natural Resources Agency, and the California Department of

Parks and Recreation to obtain the funds needed for the design, permitting, construction, and monitoring of the project.

As this project was being conceptualized, SFEI and EBRPD had concurrently been discussing the State's Wetland and Riparian Area Monitoring Plan (WRAMP) as a potential framework for monitoring. This framework was appealing for two reasons. First, it could highlight the wide range of benefits of this particular restoration project, which may not be fully recognized by only conducting permit-required monitoring. And second, it could provide a simple, yet sophisticated framework to help EBRPD go beyond just compliance monitoring in future restoration projects, such as the Coyote Hills Restoration and Public Access Project. WRAMP is a framework for the comprehensive monitoring and assessment of aquatic resources using a watershed approach. It utilizes three levels of assessment (similar to the EPA's three-tier monitoring and assessment framework) to pose and organize management questions, and select the appropriate data to answer each question. The three tiers of monitoring and assessment include:

- Level 1 assessments consist of map-based inventories of aquatic resources and related geographical data that have a direct effect on the distribution and abundance of aquatic resources. Level 1 questions include "Where are the stream resources?" and "What type of resources exist within the watershed?". These Level 1 maps also serve as base maps for Level 2 and 3 assessments.
- Level 2 assessments are rapid, field-based assessments that provide data on overall aquatic resource condition. In California, the California Rapid Assessment Method (CRAM) is the preferred Level 2 method. These assessments can cost-effectively extend the spatial area in which condition is known. Level 2 questions include "what is the condition of the stream within the project footprint?".
- Level 3 assessments are usually more intensive measures of specific resources that address specific topics of concern or research. For example, plant species composition, nesting bird surveys, fish spawning success, and groundwater recharge rates are all Level 3 data types. Level 3 questions focus on specific aspects of the project, such as "how is water temperature changing due to project implementation?".

Together, the three levels allow for the analysis of the abundance, distribution, condition, and detailed aspects of function and process of stream and wetland resources. The power of WRAMP is that it utilizes standardized methods for monitoring, assessing, and adaptively managing aquatic resources, a data management framework, and online access to project-related data. These components allow for effective project performance tracking, and provide a "common language" that allows for direct comparisons within an individual project through time, comparisons between projects, and comparisons between projects and the ambient population of streams/wetlands in the watershed or region. By making project and ambient information readily available, WRAMP increases the ability for coordination and collaboration with adjacent land owners/managers and other projects within the watershed, the region, or across the state.

The McCosker Creek Restoration and Public Access Project provided the first opportunity for EBRPD and SFEI to collaboratively apply the WRAMP framework and its stream and wetland monitoring and assessment tools, to a restoration project. It also afforded the opportunity to develop new carbon sequestration assessment methods within the framework. A portion of the EPA funds were directed towards SFEI to provide science support by designing and implementing a monitoring plan for the project that focused on non permit-required monitoring elements. In other words, the monitoring was intended as an opportunity to utilize the WRAMP framework to quantify additional ecological benefits provided by the project, and demonstrate the use of new and existing monitoring protocols as a model for more standardized and coordinated monitoring that could occur in future projects to support a regional approach to stream and wetland monitoring and assessment.

SFEI's monitoring plan was designed to assess overall ecological conditions of the pre- and post-construction stream and adjacent riparian areas within the project's restoration extent. The WRAMP framework was used to organize existing management questions into the three levels and to select a monitoring method(s) that would help answer those questions. Management questions selected for this monitoring plan include:

- Level 1: What length of new stream channel was created within the project, and where is it located? How can these changes be mapped and visualized?
- Level 2: What is the pre-construction and post-construction condition of Alder Creek? How is stream condition changing as the project matures? How does Alder Creek condition compare to adjacent streams outside of the project footprint?
- Level 3: Was the project able to create channel complexity and a robust in-channel and riparian vegetation community? What is the quality of aquatic habitat provided by Alder Creek? Are water temperatures in Alder Creek appropriate for supporting resident rainbow trout? How much carbon has been/will be sequestered due to the project?

Together, the answers to these questions allow for a more thorough assessment of the project's overall ecological enhancement, both through time and within its watershed context.

Project Location and Actions

The McCosker Creek Restoration and Public Access Project is located in the San Leandro Creek Watershed, which spans portions of Alameda and Contra Costa Counties. San Leandro Creek is a 49.4 mi^2 watershed that is divided into an upper and a lower portion based upon the presence of the Upper San Leandro Reservoir. While a small portion of the Upper San Leandro Creek Watershed drains the Town of Moraga, the majority drains an area of the relatively undeveloped East Bay Hills. This undeveloped open space and rangeland is characterized by a variety of vegetation communities, including grassland, oak and bay laurel woodland, redwood forest, and chaparral (Figure 1). This larger watershed area, inclusive of the Alder Creek tributary, drains to the 19,430 acre Upper San Leandro Reservoir, which was constructed in 1926, and is currently operated by the East Bay Municipal Utilities District (EBMUD).

The watershed downstream of the Upper San Leandro Reservoir has similar land use and vegetation communities as upstream of the reservoir. This portion of the watershed drains to

Lake Chabot, the lower reservoir on San Leandro Creek, which was constructed in 1875 and is operated by EBRPD. Downstream of Lake Chabot, San Leandro Creek drains urbanized portions of the cities of San Leandro and Oakland, mostly serviced by a network of underground stormdrains, before reaching the San Francisco Bay.

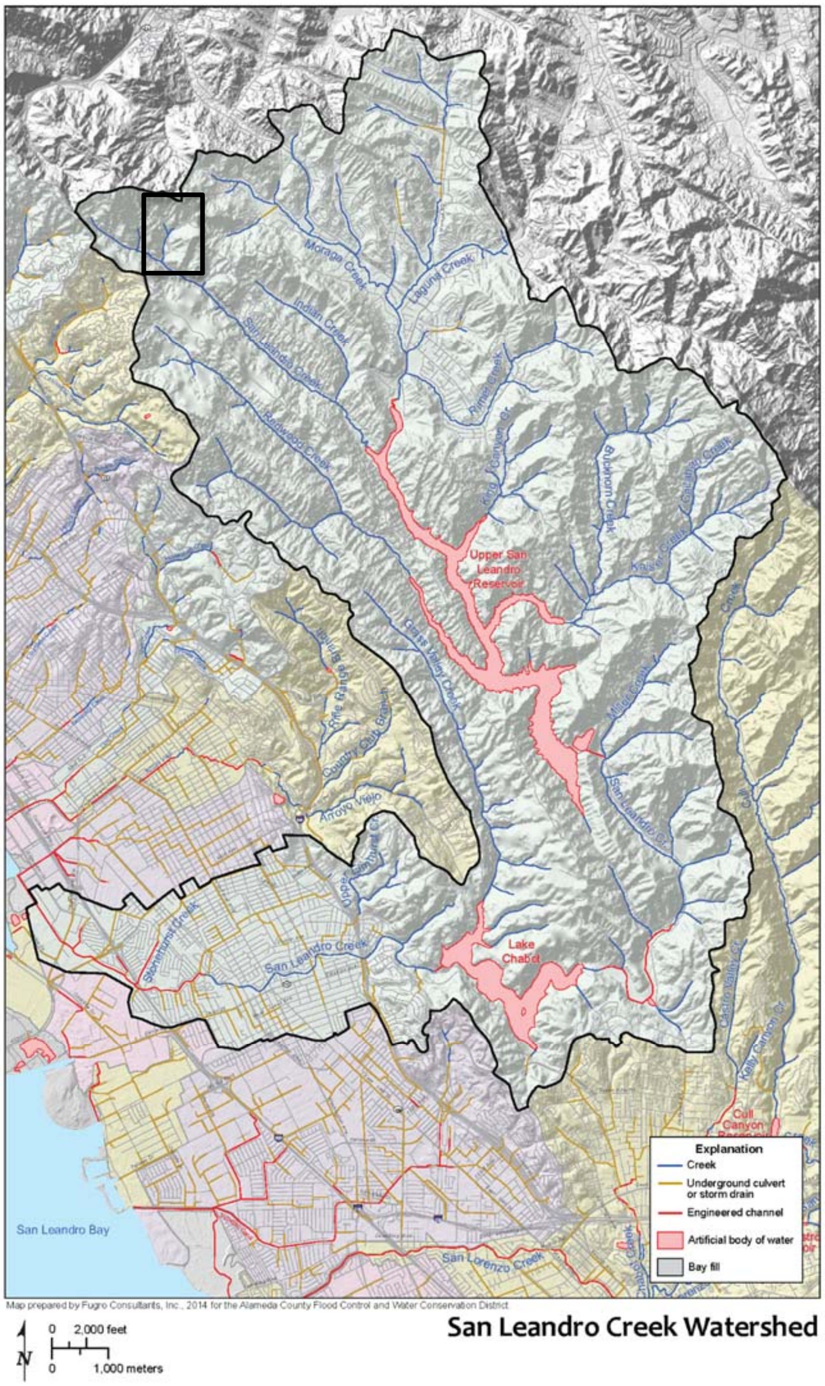

Figure 1. San Leandro Creek Watershed, highlighting the Upper San Leandro Reservoir and Lake Chabot in pink (ACFCWCD, 2023). The black inset box shows the location of the Alder Creek tributary watershed.

The Alder Creek watershed is relatively small, at only 0.34 mi^2 in size, and is a tributary to Upper San Leandro Creek. Alder Creek flows from north to south, flowing underneath Pinehurst Road in a culvert, to the confluence with Upper San Leandro Creek immediately at the culvert's outlet. The McCosker property only contains the lower portion of Alder Creek; its headwaters and its confluence with Upper San Leandro Creek are located on different properties (Figure 2).

The portion of Alder Creek within the McCosker property is relatively steep, with a significant difference in elevation between the top and the bottom of the property. Although the Alder Creek Daylighting Project also includes restoration of Leatherwood Creek, a small tributary to Alder Creek, as well as creation of adjacent recreation and camping areas, the primary focus of SFEI's monitoring efforts is on the daylighted and reconstructed portion of Alder Creek, shown in the yellow highlighted area of Figure 2.

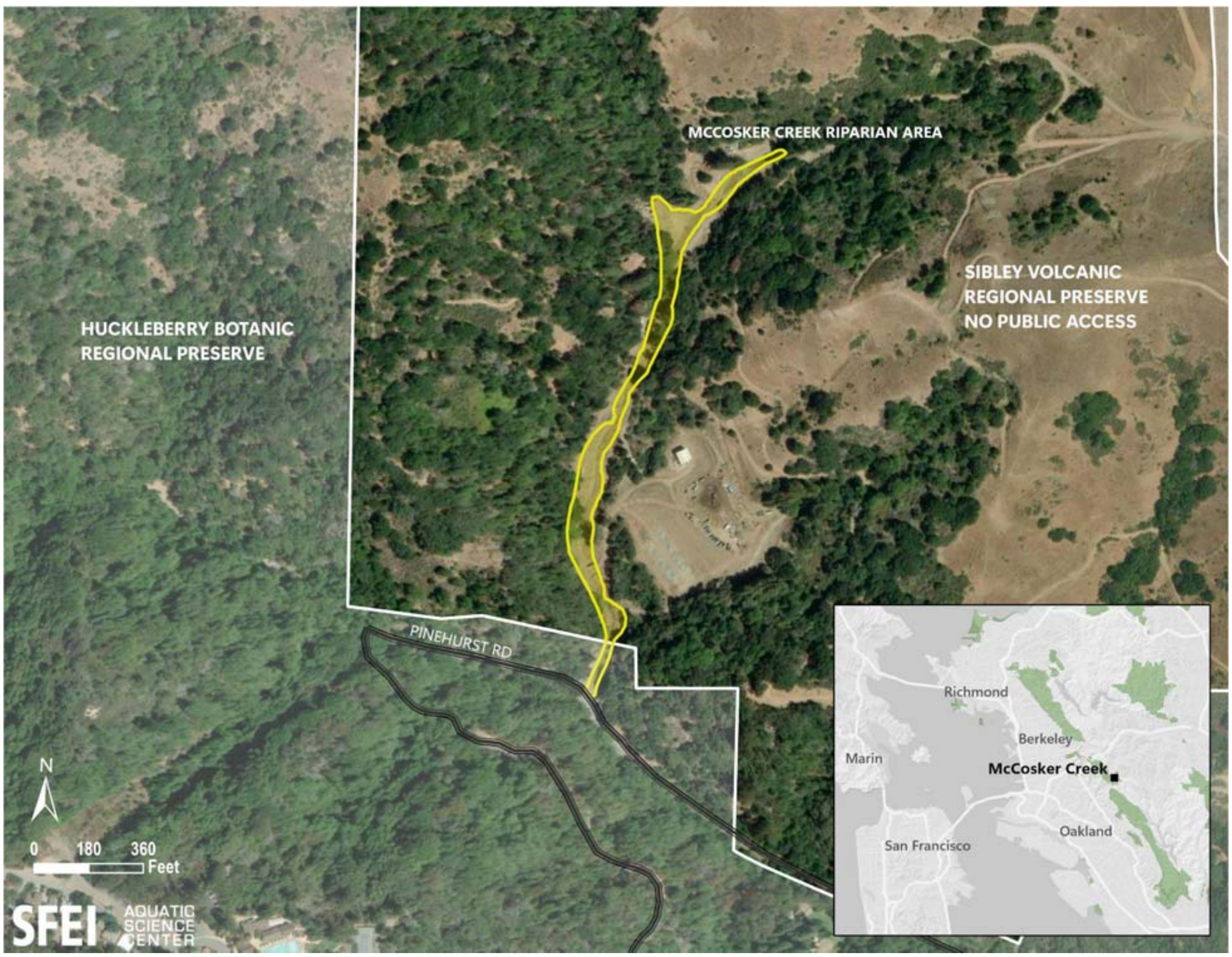

Figure 2. Location of the McCosker Creek Restoration and Public Access Project.

Alder Creek and the McCosker property was previously owned by the McCosker family since the 1860s. This property was homesteaded, ranched and farmed through the years. Beginning in 1958, Alder Creek was routed into an underground culvert to make additional space on the valley floor for paving, quarry and equipment yard operations. Culverting continued in additional reaches until approximately 1971. Alder Creek flowed through the metal culvert for decades, until the culvert began to deteriorate in the 1990s. As the culvert rusted, dangerous sinkholes formed in the valley floor, causing collapse of the overlying fill into the culvert, and subsequent transport of that sediment downstream to Upper San Leandro Creek. This degraded condition characterized the creek and the valley for almost two decades before the property was donated to EBRPD in 2010, and a restoration project was designed and implemented. The project aimed to daylight Alder Creek, and construct a stable step-pool channel that would provide appropriate aquatic habitat, encourage a healthy riparian corridor, reduce excess sediment erosion, and improve water quality. Construction initially began in late 2020, but experienced delays due to the Covid-19 pandemic. Phase 1 included construction of the daylighted channel in 2021, but planting of the lower channel was not completed until 2022. Phase 2 construction occurred in 2023 and included planting of the upper channel as well as many smaller elements across the project footprint.

Daylighting and construction of the new channel caused significant changes to occur in the valley cross-section (Figure 3). The previously flat valley bottom was graded to contain an appropriately sized channel, gently sloping banks, and the access road. The resulting project is EBRPD's largest creek restoration project, and the largest creek daylighting project in the East Bay.

Figure 3. Photographs illustrating the 2019 pre-construction (left) and 2023 Year 1 post-construction (right) condition of Alder Creek in a representative lower-watershed location. Notice the power pole for reference in both photos.

Monitoring Components

The daylighting of a channel is a significant alteration to the landscape that obviously causes substantial changes to the channel form, but also causes changes to channel function, habitat value, and geomorphic processes. These changes are complex and interrelated, and do not occur at a constant rate through time. It is improvement in processes, functioning and habitat value that are sought after in restoration projects, as the channel regains and works toward its historic resilience. This is where monitoring can become troublesome; it is obvious that there is no one single aspect of a creek that captures and quantifies all of the details of its functioning. Instead, it is the summation of many aspects of the channel together that accurately quantify its functioning. This idea shaped the development of this monitoring plan and the selection of specific monitoring components; multiple monitoring methods together would reveal a richer picture of the project's success.

With an overall goal of assessing the pre- and post-construction ecological functioning and habitat value of the newly daylighted creek, six monitoring components were selected to augment the permit-required monitoring:

- Water Temperature of Alder Creek and Upper San Leandro Creek,
- Ecological Condition using the California Rapid Assessment Method (CRAM),
- Physical Habitat Complexity,
- Aerial Photography using Unoccupied Aerial Systems (UAS),
- Carbon Sequestration, and
- Pre-project Channel Cross-section and Longitudinal Profile Surveys.

Details of the methods, results and implications for each component are described in the individual sections below.

Water Temperature of Alder Creek and Upper San Leandro Creek

Background

Many creeks across the Bay Area historically supported runs of anadromous steelhead trout (*Oncorhynchus mykiss*) and resident rainbow trout, particularly those creeks that provide quality habitat, including cool water temperatures, near continuous riparian canopy for shading, and consistent stream flow. The Upper San Leandro Creek watershed is one such watershed with multiple tributary creeks that historically supported *O. mykiss*. However, when Lake Chabot was constructed in 1875, and later the San Leandro dam in 1926, the watershed was no longer able to support the anadromous steelhead run because the dams created a barrier that prevented fish migration to and from the ocean. However, a population of resident rainbow trout remained upstream of the reservoir, utilizing the cool water and complex habitat found in the upper watershed channels. This population still remains, as Upper San Leandro Creek currently has a “definite population” of *O. mykiss* documented in the tributaries upstream of the reservoir (Leidy et al., 2005).

As a Federally-listed threatened species, *O. mykiss* faces many limiting factors in Bay Area watersheds. Besides lack of adequate in-channel habitat and lack of year-round surface water flow, warm water temperatures are one of the primary limiting factors for rainbow trout success. Water temperature is critical because it affects growth and feeding rates, metabolism, embryo and alevin development, the availability of food, and timing of life history events such as upstream migration, spawning (typically February through June) and rearing (typically late spring through late fall) (Carter, 2008). In addition to these effects, high temperatures can cause stress, and can even be lethal. Impacts of thermal stress are cumulative; the longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al., 1999).

A significant amount of research from Pacific Northwest streams has traditionally been used to define temperature tolerances and thresholds for *O. mykiss*. For example, the San Francisco Bay Regional Water Quality Control Board (SFB Regional Board) has utilized the following temperature guidelines for temperature impairment listing (TRP, 2023):

- 68 degrees F (20 degrees C) 7-day average daily maximum temperature for out-migration (March 11 through June 15)
- 75.2 degrees F (24 degrees C) lethal threshold temperature (March 1 through October 31)
- 67.3 degrees F (19.6 degrees C) summer rearing maximum weekly average temperature (March 1 through October 31), and 62.6 degrees F (17 degrees C) summer rearing rolling 7-day average temperature (March 1 through October 31)

These data are similar to those identified in a literature review conducted by Carter (2008) to inform recommendations for *O. mykiss* temperature thresholds for the North Coast Regional Water Quality Control Board to adopt in their Water Quality Control Plan for the North Coast Region (Basin Plan) (Table 1). Life stage chronic (sub-lethal) temperature thresholds are reported as the maximum weekly maximum temperature (MWMT) (otherwise known as the 7-day average of daily maximum temperatures), while lethal thresholds are reported as instantaneous temperatures. While the literature describes optimal temperatures in much greater detail, these thresholds serve as a simple upper threshold to consider for *O. mykiss* survival.

Table 1. Summary of water temperature thresholds for *O. mykiss* (Carter, 2008). Rearing occurs from late spring through late fall. Spawning, incubation and emergence typically occur February through June.

Life History Stage	MWMT threshold degrees F (degrees C)	Lethal threshold degrees F (degrees C)
Adult Migration	68.0 (20)	75.2 (24)
Low to moderate density rearing	64.4 (18)	75.2 (24)
High density rearing	60.8 (16)	75.2 (24)
Spawning, egg incubation, and fry emergence	55.4 (13)	68.0 (20)

However, Pacific Northwest streams typically have cooler water temperatures than those along the Central California Coast, which makes defining temperature values for the Bay Area more complex and challenging. Recently the SFB Regional Board and the Santa Clara Valley Water District convened an expert Technical Review Panel to conduct a Steelhead Regional Temperature Study to analyze available data, identify data gaps, and define studies to refine temperature guidelines to support Central California Coast steelhead. The Review Panel's recommendations (TRP, 2023) importantly do not provide specific temperature tolerances or thresholds, but instead highlight the complexity of the issue, the outdated nature of the agency guidance and the need for updated Bay Area specific studies.

Despite the well-documented temperature thresholds from the Pacific Northwest, resident rainbow trout are described as particularly hearty, and likely tolerant of warmer temperatures.

> "Rainbow trout are among the most physiologically tolerant of salmonids, which is why they are often the only salmonid found in streams that are thermally marginal" (Moyle et al., 2017).

While typical critical maximum thresholds are typically 75-79 degrees F (24-26 C), trout in California have been documented to survive short periods with water temperatures up to 91 degrees F (33 C) (Sloat and Osterback, 2013). These points illustrate that the existing temperature tolerances and thresholds might not be fully appropriate comparisons for Bay Area streams. But until additional studies are completed, these thresholds can at least provide an initial benchmark to consider.

As Alder Creek is intended to provide new rainbow trout habitat, it is critical to understand the seasonal surface water temperature and patterns, to assess if the daylighted channel is capable of providing suitable habitat. Due to the Mediterranean climate of the Bay Area, Alder Creek experiences warm and dry summer and fall months, which causes surface water in the creeks to seasonally rise in temperature. This component of the monitoring plan focused upon collecting continuous surface water temperatures for a portion of the year (June through October) at a location in Alder Creek, and a location upstream of the confluence in Upper San Leandro Creek. Data collection focused upon pre- and post-construction time frames to quantify existing temperatures and document any trends related to the daylighting of Alder Creek.

Methods

Temperature sensors were initially installed in June 2020. The team chose HOBO Pendant MX Water Temperature Data Logger sensors, programmed to record temperature every 15 minutes (to capture any potentially lethal temperature spikes). Each sensor was placed in a perforated PVC housing (Figure 4) and attached to rebar that was driven into the channel bed. The Alder Creek sensor was placed in a deep pool located in a short daylighted section of channel just upstream of Pinehurst Road (Figure 5). The channel at this location did not have much shade cover, but the pool was deep enough to place the sensor approximately 60 cm deep (Figure 6). The Upper San Leandro Creek sensor was placed in a well-shaded shallow pool (although it was the deepest pool within 200m of the confluence) approximately 15 cm deep (Figure 7).

Figure 4. Perforated PVC pipe holding in the temperature sensor. June 11, 2020.

Figure 5. Locations of temperature sensors placed in 2020 prior to construction on either side of Pinehurst Road. The Alder Creek sensor is also referred to as the “restoration site” and the Upper San Leandro Creek sensor is also referred to as the “reference site”.


Figure 6. 2020 deployment in an Alder Creek pool prior to construction. Left: PVC housing sticking out of the water near the bank, before the rebar was driven deeper into the water. Right: Downstream end of the pool just before entering the culvert going under Pinehurst Road. June 11, 2020.

Figure 7. 2020 temperature sensor deployment in Upper San Leandro Creek. Left: PVC housing attached to rebar sticking out of the water near an old car body. Right: Looking upstream at the old car body. The PVC is just visible in the middle of the picture. June 11, 2020.

In 2020, the Alder Creek sensor was deployed for the months of June and July, but was removed just before construction began. The Upper San Leandro Creek sensor was deployed for the months of June through October. In subsequent years, the team aimed to have the sensors deployed from May through October, however rainfall patterns, surface water levels, and construction progress caused minor variations in timing. In 2021, the Alder Creek sensor was deployed from April through September, in the deepest pool (upstream of a placed log) approximately 25 m upstream of Pinehurst road (Figure 8). During this year this location had very little vegetation, and thus no shade to cover the water in the pool. The Upper San Leandro Creek sensor was deployed April through October in the same location as 2020.

Figure 8. 2021 sensor deployment in Alder Creek. Left: PCV housing is located mid-channel on the upstream side of the placed log. Right: Looking upstream at the placed log, with the sensor on the upstream side (out of view). May 10, 2021.

The 2022-2023 rainy season had a large total amount of precipitation, causing channel morphology change at both monitoring locations. In Alder Creek, the placed log caused the scour of a deeper pool on the downstream side, and the channel was more heavily vegetated in general. In 2023, the sensor was placed in this deeper pool, and benefitted from the additional shading provided by the vegetation (Figure 9). In Upper San Leandro Creek, the high flows caused the car body to shift downstream, causing the scour of a new pool approximately 5 m upstream of the previous deployment location. The 2023 sensor was deployed in this deeper pool (Figure 10).


Figure 9. Left: 2023 sensor location in Alder Creek, in the pool on the downstream side of the placed log. Right: Looking upstream towards the sensor and the vegetated channel. November 20, 2023.

Figure 10. 2023 sensor deployment in Upper San Leandro Creek. Left: looking upstream at sensor (located near steering wheel), Right: looking downstream from sensor. November 20, 2023.

Results

The 15-minute interval water temperature datasets for each monitored year (2020-2023) are shown in Figures 11-14. For all figures the Alder Creek location is labeled as the Restoration Site and the Upper San Leandro Creek location is labeled as the Reference Site. The Alder Creek location was only monitored during June and July of 2020, before the sensors were removed for construction to begin. There are some gaps in the dataset due to battery failures and sensor failures, most notably during the latter half of 2021, first at the Upper San Leandro Creek location and then at the Alder Creek location.

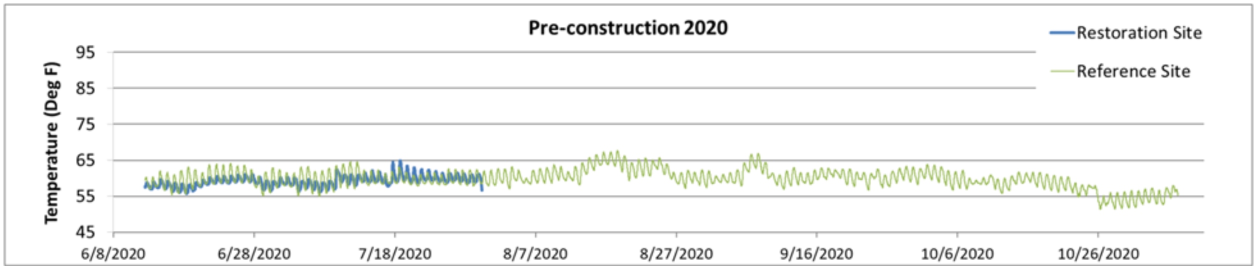

Figure 11. Fifteen minute interval temperature data prior to construction in 2020. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

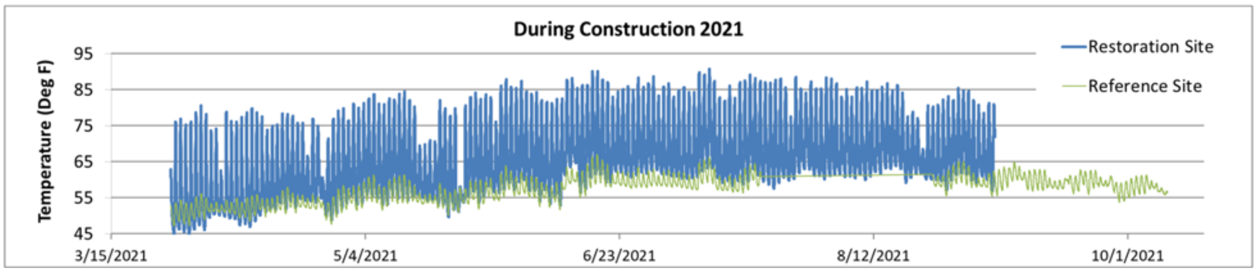

Figure 12. Fifteen minute interval temperature data during Phase 1 of construction in 2021. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

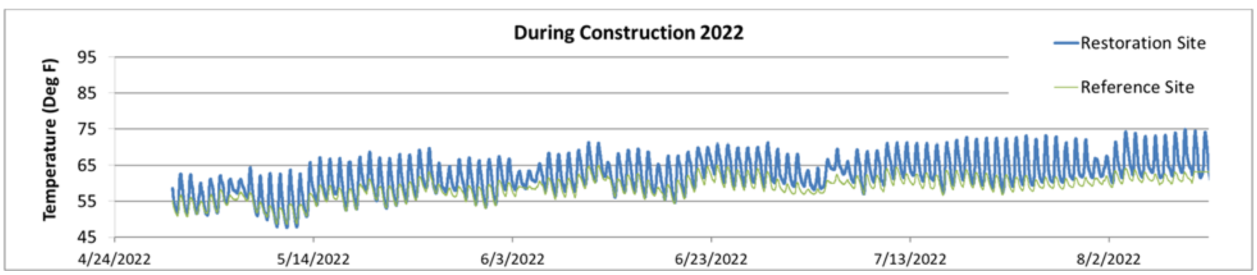

Figure 13. Fifteen minute interval temperature data during Phase 1 construction in 2022. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

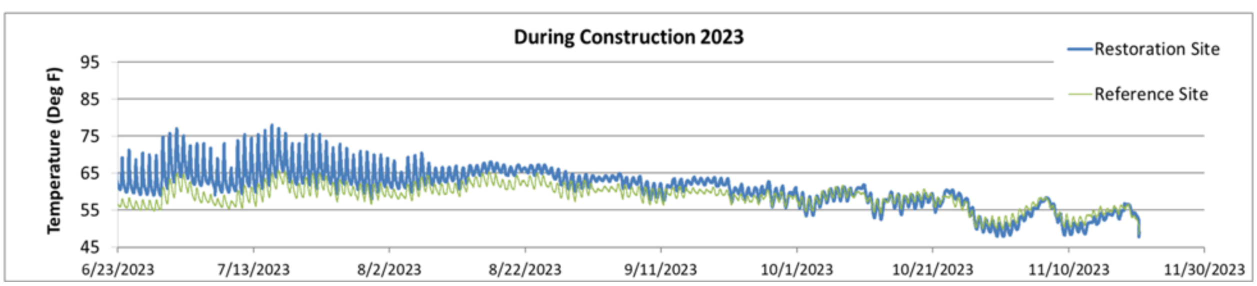

Figure 14. Fifteen minute interval temperature data during Phase 2 construction in 2023. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

Prior to construction in 2020, the temperatures in Alder Creek were similar and slightly less variable than in Upper San Leandro Creek, likely because the sensor was positioned in a deeper pool. At both locations during this year, temperatures ranged narrowly between 55-65 degrees F, with only 10 days recording temperatures slightly above 65 degrees in Upper San Leandro Creek. In the subsequent three years, the Upper San Leandro Creek location recorded similar temperatures throughout each season. However, the Alder Creek location displayed significant variability during the subsequent years. During Phase 1 construction in 2021, the creek had just been created and the water surface had no shading. The lack of shading, in addition to the pool being very shallow, caused large temperature swings between daily lows and highs, with many days above 85 degrees F, and a maximum temperature of 91 degrees F recorded in July. However, as Phase 1 construction continued in 2022, the newly planted/established vegetation began to shade the pool, causing a smaller variation in temperature, with recorded temperatures below 75 degrees F the entire season. In 2023 during Phase 2 construction, temperatures were similar to 2022 up until early August. Vegetation in the channel such as dense cattails (*Typha sp.*) grew quite rapidly in August, quickly providing significantly more shading for the creek. The water temperatures responded to the increased shading, with recorded daily maximums approximately 10 degrees F lower than recorded in July. Temperatures matched those recorded in Upper San Leandro Creek by October 1st. It is expected that continued vegetation growth, both in-channel cattails and willows and alders along the channel edge and on the banks, will only increase into the future, providing more consistent shading for the channel. Temperatures should respond accordingly, remaining much lower than those recorded during 2021, and likely matching or being very similar to those recorded in Upper San Leandro Creek.

Figures 15-18 show the continuous data for the hottest day of each year at Alder Creek, and Table 2 provides the monthly maximum temperatures and monthly average daily maximum temperatures at both monitoring sites. Pre-construction temperatures at Alder Creek were very similar to Upper San Leandro Creek (note the delayed peaks for the restoration site due to the specific heat properties of water and the deeper and relatively stagnant pool that the sensor was deployed in). In 2021, the peak recorded temperature in Alder Creek was over 90 degrees F, while San Leandro Creek was only 66 degrees F. In 2022 and 2023, the peak recorded temperature at Alder Creek decreased to about 75 degrees F, and from August on-ward temperatures remained below 70 degrees F.

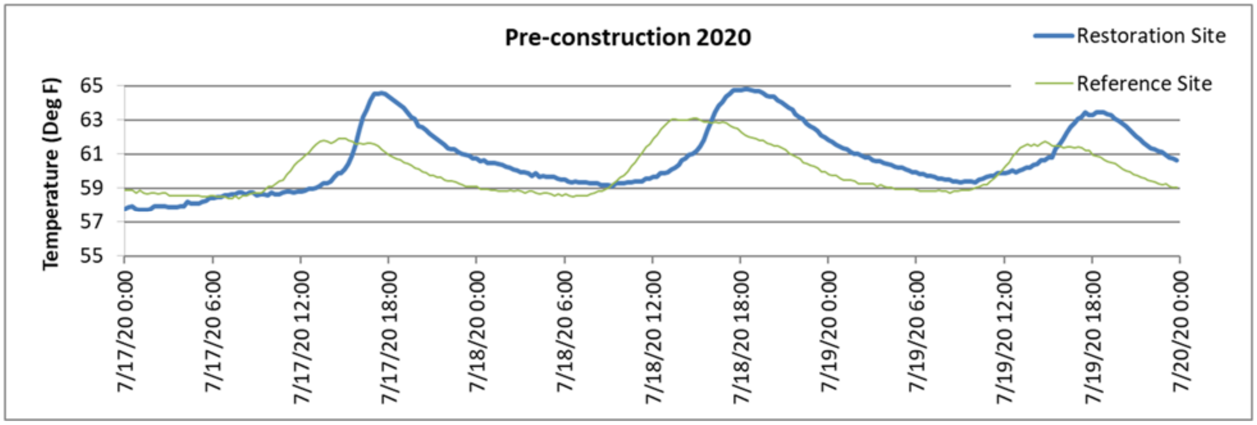

Figure 15. Temperatures at the monitoring locations over a 3-day period including the hottest day in 2020. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

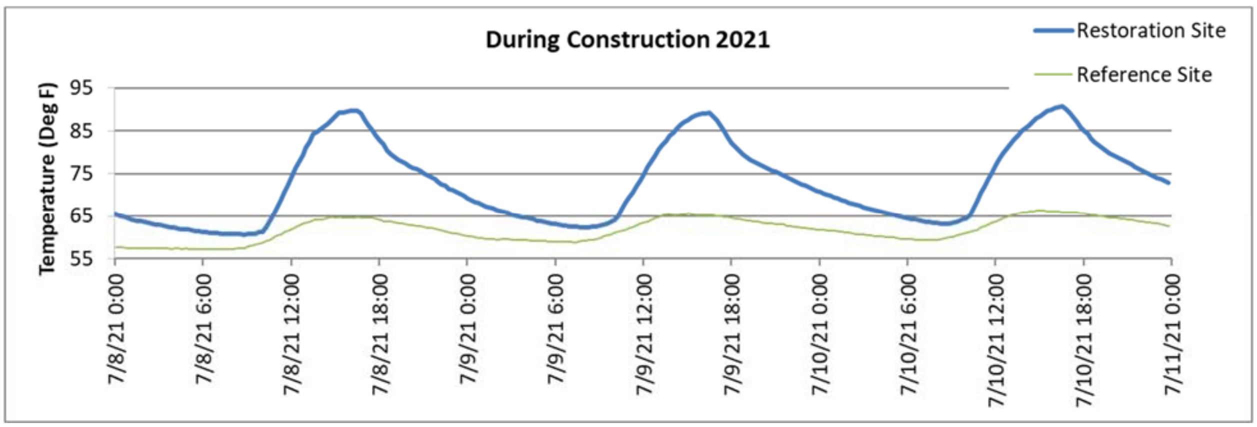

Figure 16. Temperatures at the monitoring locations over a 3-day period including the hottest day in the restoration location in 2021. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

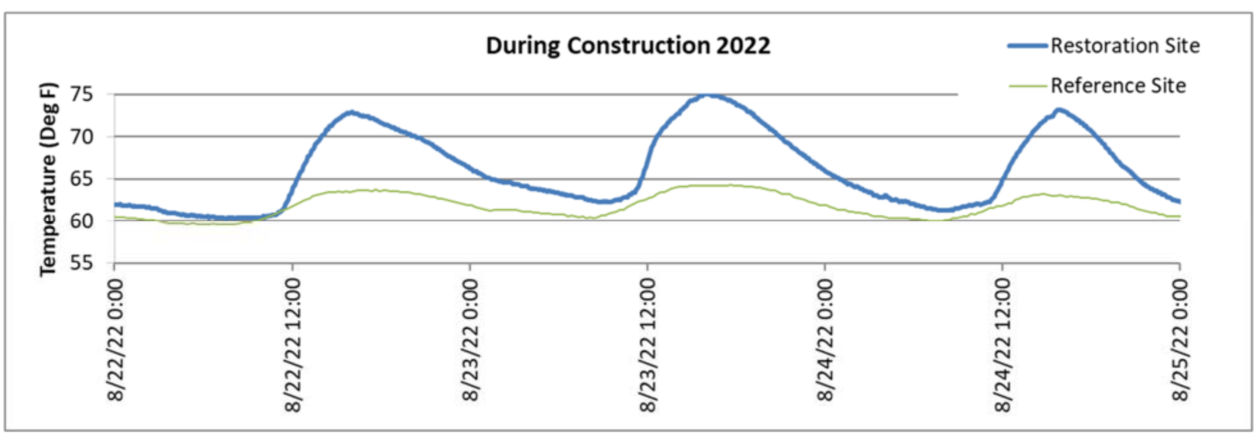

Figure 17. Temperatures at the monitoring locations over a 3-day period including the hottest day in the restoration location in 2022. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

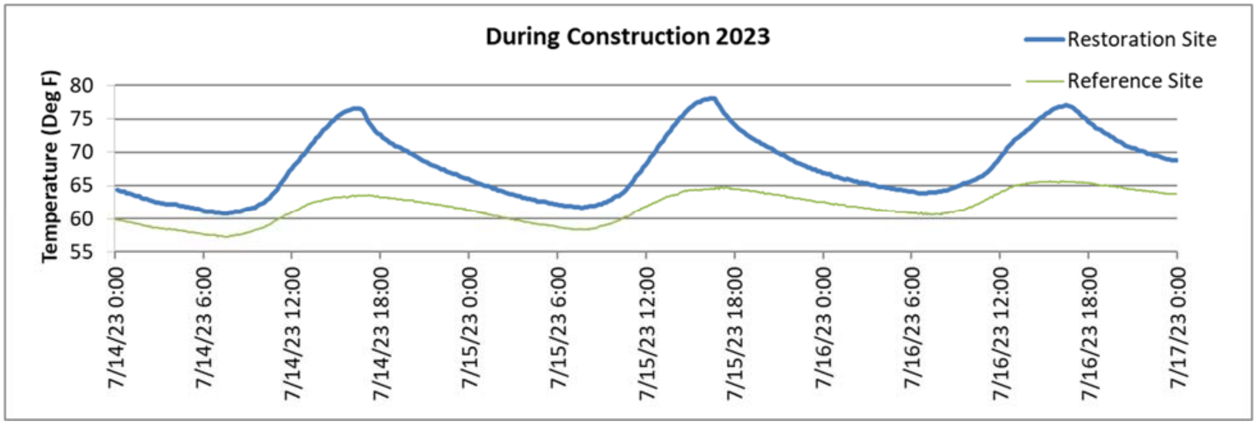

Figure 18. Temperatures at the monitoring locations over a 3-day period including the hottest day in the restoration location in 2020. The Alder Creek location is labeled as the Restoration Site, and the Upper San Leandro Creek location is labeled as the Reference Site.

Table 2. Monthly maximum temperatures and monthly average daily maximum temperatures at Alder Creek (Restoration Site) and Upper San Leandro Creek (Reference Site).

Month	Restoration Site Monthly Max Temp, °F	Restoration Site Monthly Average of Max Temp, °F	Reference Site Monthly Max Temp, °F	Reference Site Monthly Average of Max Temp, °F
June 2020	61	60	64	62
July 2020	65	61	65	62
April 2021	81	76	58	55
May 2021	88	80	64	59
June 2021	90	86	67	62
July 2021	91	86	66	63
May 2022	70	65	63	58
June 2022	71	69	65	62
July 2022	73	70	64	62
August 2022	75	73	64	63
June 2023	76	72	63	59
July 2023	78	73	66	62
August 2023	70	67	65	63
September 2023	65	63	62	61
October 2023	62	59	62	58
November 2023	58	54	58	55

Implications

Appropriate water temperatures are critical for salmonid success at each life stage. Monitoring water temperatures in Alder Creek and Upper San Leandro Creek offer the ability to understand (1) how the daylighting project affected water temperatures, (2) the progression of water temperature patterns as the project matured, and (3) if the temperatures meet the criteria described in the literature as potential suitable habitat for salmonids.

The 2020 Pre-construction dataset from Alder Creek unfortunately was only two months in duration, but it reveals an interesting trend. The probe at this time was located in a relatively deep bedrock pool that was likely thermally stratified. The water depth allowed for more consistent water temperatures at depth, regulating any solar energy that was reaching the water surface. These records are from June and July, long after any wet season surface runoff is contributed from the watershed. Instead, the Alder Creek watershed has a few discreet seeps and springs that consistently contribute very small volumes of water to the creek. This emergent groundwater typically is cool, helping to keep the water temperatures in downstream pools cool. But the important aspect for this time period is that any water contribution from the watershed was delivered to the pool via the culvert, meaning that the water was not exposed to solar insolation, and did not have the opportunity to heat up. This is reflected in the records; June and half of July Alder Creek temperatures had a tighter range and lower daily maximum temperatures as compared to Upper San Leandro Creek.

The 2021 temperature records reveal the impact of exposing the channel and its pools to solar energy. The channel was just constructed during late 2020 and into 2021, excavating the valley fill and creating the rough channel grading. During the early part of the season, the restoration plantings had not been installed, and the water in the pool was essentially exposed to full sun throughout the day. Planting progressed throughout the season, but the individual plants along the channel edge and on the banks were small and immature, and didn’t provide any meaningful shading. The temperature records in Figure 12 show the resulting effects of extreme daily temperature fluctuations (20 degrees F or more), even as early in the season as April. Only a small handful of days between April and September had daily maximum temperatures below the 75 degree F lethal threshold. This season also had the highest maximum temperature recorded at 91 degrees F in July. These temperatures are clearly in the range that is lethal to rainbow trout. Interestingly, the daily minimum temperature returned to approximately 60 degrees F or lower for almost every day of the season, reinforcing the clear impact of solar energy upon water temperature.

The 2022 and 2023 seasons brought a change in recorded temperature patterns, illustrating the progression and maturation of the restoration project. The 2022 season recorded Alder Creek temperatures that were consistently above the Upper San Leandro Creek temperatures by 5-10 degrees F, but had a small magnitude of variation as compared to 2021 (with daily fluctuations between 10-15 degrees F on any given day), and had a maximum seasonal high temperature of 75 degrees F, 16 degrees F lower than in 2021. This same pattern continued for the 2023 season, although July 2023 had a maximum temperature of 78 degrees F. However, given the warm summer air temperatures, the ample sunshine, and the available nutrients in the creek, the growth spurt of vegetation in late July into early August caused a shift in the temperature patterns. Beginning in mid-August, the daily temperature fluctuations in Alder Creek were smaller (less than 5 degrees F daily), the high daily temperatures were in the upper 60s, and then dropped to the lower 60s for September and October. The additional shading from the vegetation prevented the daily solar energy spikes in temperature, meaning that overall temperatures stayed more consistent and cooler.

This shift in temperature due to the additional shading provided by the growth of in-channel and riparian vegetation suggests that channel shading is the key towards keeping water temperatures cool in Alder Creek. In the future, if the majority of the project channel length is shaded, water temperatures throughout the summer and fall seasons will likely remain cool, with temperatures lower than what was recorded during the 2021-2023 seasons. It is possible that water temperatures could be similar to those recorded in 2020, when the channel was fully shaded inside the culvert. If Alder Creek temperatures are similar to those in Upper San Leandro Creek, the opportunity for Alder Creek to provide successful rearing and oversummering habitat significantly increases. Given the uncertainty around steelhead water temperature tolerances and thresholds, it is unclear if water temperatures in Alder Creek are currently appropriate for supporting resident rainbow trout. However, the data suggest that additional vegetation growth will likely keep surface water temperatures cooler, and perhaps in line with temperatures in Upper San Leandro Creek, which supports a successful population.

Future monitoring could continue to track the evolution of temperature patterns as the vegetation continues to mature. Continued tracking of vegetation height and density, such as through rapid assessment or physical habitat monitoring methods, will be important. Monitoring could include observations of the ability for rainbow trout to migrate between Alder Creek and Upper San Leandro Creek, because migration is an important survival strategy for trout in reaches with inappropriate water temperatures.

Stream Condition Employing CRAM

Background

Restoration projects are typically conducted on stream sites that are clearly not functioning, have significantly altered geomorphic processes, and are not providing quality habitat value for aquatic and/or wildlife species. Most projects are designed to transform the stream from its previous degraded state to a new and improved state, often with very specific goals for specific aspects of the stream. These specific goals are tracked via permit requirements, and can include items such as vegetation cover along transects, percent survival for planted vegetation, repeat photography, or field indicators of bank erosion at discrete locations. Historically, projects tended not to consider or assess the overall ecological condition of the stream, which is a more holistic picture of health that considers multiple specific goals and measures, because they were not required to or they did not have an appropriate method for this type of assessment. Recently restoration practitioners and resource agency staff are more often utilizing stream condition assessments to assess and track the progress of a project as it matures and becomes more resilient, and as a way to measure and communicate the project's successes.

The SFEI field team employed the California Rapid Assessment Method (CRAM) for streams and wetlands to assess the overall ecological condition of Alder Creek. CRAM is a standardized, rapid, statewide method that provides a cost-effective measure of condition. CRAM scores are based on visible indicators of physical and biological form and structure relative to statewide reference conditions (CWMW, 2013). CRAM provides numerical scores to estimate the overall potential of a wetland and its riparian area to provide levels of the ecological services expected of the resource, given its type and environmental setting.

CRAM scores are versatile, as they can be used to compare the condition of one stream to another, one reach of stream to another, and/or a single reach through time. CRAM reports a single, overall Index Score that provides a simple snapshot of condition at the highest level. However, it is also possible to "drill down" into the four Attribute Scores, and the individual Metric Scores that make up each Attribute, to better understand specific aspects of condition. In addition to the condition score, CRAM also utilizes a Stressor Checklist to identify existing stressors within the stream or immediate vicinity that might account for any low scores or that could be a potential issue in the future. Assessing the condition of a stream within a restoration project at multiple points in time, including pre-project and post-project, is an effective way to assess performance of the project, as well as troubleshoot its performance so that adaptive management actions can address any problems or issues.

Methods

Channel condition was assessed using CRAM for streams and wetlands (www.cramwetlands.org). The project team conducted CRAM assessments at three points in time: 1) in May 2019 to capture pre-construction conditions, 2) in June 2022 to capture Year 0 post-construction conditions (the as-built completed project condition), and 3) in June 2023 to capture Year 1 post-construction conditions. The CRAM Riverine module version 6.1 (CWMW, 2013) was used for all three time periods, with data collected in the field on paper datasheets, and entered into the online eCRAM database upon return to the office. Each year's assessment utilized at least two CRAM trained practitioners, with Sarah Pearce (the lead CRAM trainer in the state) present for all assessments, and responsible for data collection, entry and quality assurance. Other practitioners included Kristen Van Dam (EBRPD), Brook Vinnedge (EBRPD), Ed Culver (EBRPD), David Peterson (SFEI), and Jemma Williams (San Francisco Bay Joint Venture) (Figure 19). In addition, Sarah Pearce collected field photographs during each assessment.

Figure 19. Field photographs showing the field teams during various assessments.

The project team aimed to assess conditions at representative locations across the project footprint. A total of seven Assessment Areas (AAs) were assessed: five within the project footprint, and two outside of the footprint. Each AA inside the project footprint is named based upon location (from downstream to upstream): AA1, AA3, AA6, AA8, AA10 Lower (Figure 20). In addition, two other AAs were collected outside of the project footprint, intended to capture any potential channel change that was not due to the project. AA10 Upper is located upstream of the project footprint, while the San Leandro Creek Downstream AA (AA DS) is located across Pinehurst Road, on Upper San Leandro Creek. Each AA is approximately 100m in length, and follows guidance in the field book for appropriate placement and lateral boundaries. Of note, the 2019 AAs are slightly offset from the 2022 and 2023 AAs because the channel did not exist at the time of assessment. In particular, in 2019 AA2 was assessed, but because it partially overlaps with AA1 and AA3, these two were assessed instead during 2022 and 2023. Also, the 2019 AA5 has significant overlap with the 2022/2023 AA6, and thus the 2019 AA5 scores were used for annual comparison.

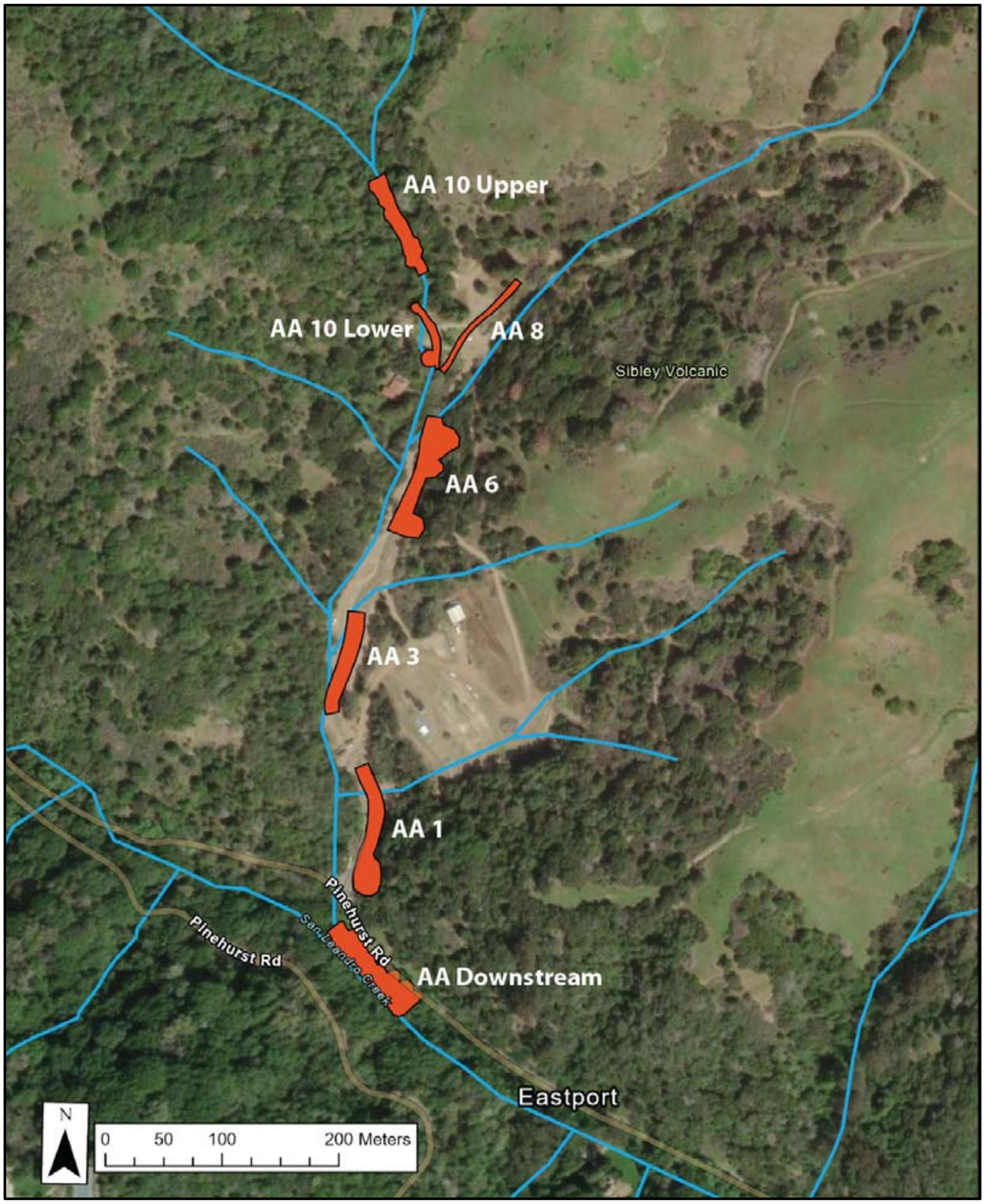

Figure 20. Map showing the location of the seven total CRAM Assessment Areas (AAs).

Results

A total of 21 CRAM assessments were completed during the three time periods, including the five AAs located within the project footprint (in-project), and two AAs located outside the project footprint (out-of-project). CRAM assessment scores, including the Overall Index Score (highlighted in blue), Attribute Scores (highlighted in green) and individual Metric Scores (white) are shown in Table 3. A representative photo from each of the seven AAs (2023) is shown in Figure 21 to illustrate the visual differences between AAs.

Table 3. CRAM assessment scores for each of the seven AAs and each time period (2019, 2022, and 2023). Overall Index Scores (highlighted in light blue) and four individual Attribute Scores (highlighted in light green) are shown along with individual metric scores. CRAM alphabetic scores (A, B, C, D) are translated to numeric scores (12, 9, 6, 3) in order to provide a numeric score, with these numeric metric scores shown. Upper San Leandro Creek AA Downstream (AA DS) and AA10 Upper are outside of the restoration project footprint, and thus are not expected to show significant change through time.

Assessment Area		AA1/2 2019	AA1 2022	AA1 2023	AA2/3 2019	AA3 2022	AA3 2023	AA5/6 2019	AA6 2022	AA6 2023	AA8 2019	AA8 2022	AA8 2023	AA10 Lower 2019	AA10 Lower 2022	AA10 Lower 2023	AA10 Upper 2019	AA10 Upper 2022	AA10 Upper 2023	AA DS 2019	AA DS 2022	AA DS 2023
Attribute	Metric																					
Buffer and Landscape Context		55.80	93.30	100.00	55.80	90.29	93.30	55.80	93.30	93.30	55.79	93.30	93.30	55.80	93.30	93.30	55.80	93.30	93.30	82.90	82.90	82.90
	Stream Corridor Continuity	3	12	12	3	12	12	3	12	12	3	12	12	3	12	12	3	12	12	12	12	12
	Buffer: Percent of AA with Buffer	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	9	9	9
	Buffer: Average Buffer Width	12	12	12	12	9	12	12	12	12	12	12	12	12	12	12	12	12	12	3	3	3
	Buffer: Buffer Condition	9	9	12	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	12	12	12
Hydrology		50.00	91.66	83.33	50.00	91.66	83.33	58.33	91.66	91.66	50.00	91.66	91.66	58.33	100.00	100.00	75.00	83.33	75.00	75.00	75.00	75.00
	Water Source	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	9	12	12
	Channel Stability	3	12	12	3	12	12	6	12	12	3	12	12	3	12	12	12	12	12	12	12	12
	Hydrologic Connectivity	3	9	6	3	9	6	3	9	9	3	9	9	6	12	12	3	6	3	6	3	3
Physical Structure		25.00	37.50	37.50	25.00	37.50	37.50	37.50	37.50	37.50	37.50	25.00	25.00	50.00	37.50	25.00	50.00	50.00	50.00	62.50	62.50	62.50
	Structural Patch Richness	3	6	6	3	6	6	6	6	6	6	3	3	9	6	3	9	9	9	12	12	12
	Topographic Complexity	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Biotic Structure		41.66	63.89	52.78	41.66	52.78	36.11	66.67	58.33	58.33	55.56	27.77	25.00	44.44	38.88	38.88	55.55	58.33	55.55	58.33	63.88	58.33
	PC: No. of plant layers	9	12	12	9	9	6	9	9	9	9	6	3	9	9	9	9	9	9	9	9	9
	PC: No. of codominants	6	9	6	6	6	3	6	9	9	6	3	3	3	6	9	3	6	3	6	6	6
	PC: Percent Invasion	3	12	12	3	6	3	12	9	9	9	3	3	9	9	6	12	12	12	12	9	12
	Horizontal Interspersion	6	6	6	6	6	3	6	6	6	6	3	3	3	3	3	3	3	3	3	6	3
	Vertical Biotic Structure	3	6	3	3	6	6	9	6	6	6	3	3	6	3	3	9	9	9	9	9	9
CRAM Index Score		43	72	68	43	68	63	55	70	70	50	59	59	52	67	64	59	71	68	70	73	70

Figure 21 Representative photo from each of the seven CRAM AAs in 2023, illustrating the visual differences between reaches. Top row left to right: AA1, AA 3, AA 6, AA8. Bottom row left to right: AA10 lower, AA10 upper, Upper San Leandro Creek Downstream AA (AA DS), and Sarah and Brook conducting an assessment.

The CRAM scores show that the assessed reaches of Alder Creek and Upper San Leandro Creek are in poor to fair condition, with variation in scores due to (1) assessment year (pre-construction versus post-construction), (2) location within the project, and (3) annual differences due to the type of Water Year and the progression of stream maturation. Plotting the CRAM Index Scores on the Bay Area Ecoregional Cumulative Distribution Function estimate (CDF) shows where these scores plot within the tertiles of condition (e.g. good, fair, poor), and also as compared to the population of stream resources in the Ecoregion (built using 40 ambient CRAM assessments collected between 2008-2013; for more information, visit: https://www.sfei.org/projects/california-rapid-assessment-method-wetlands-cram-hdcs-and-cdfs#sthash.zRdFfpbb.dpbs) (Figure 22). The full set of 21 Alder Creek scores range from the 4th to 62nd percentile of condition for the region.

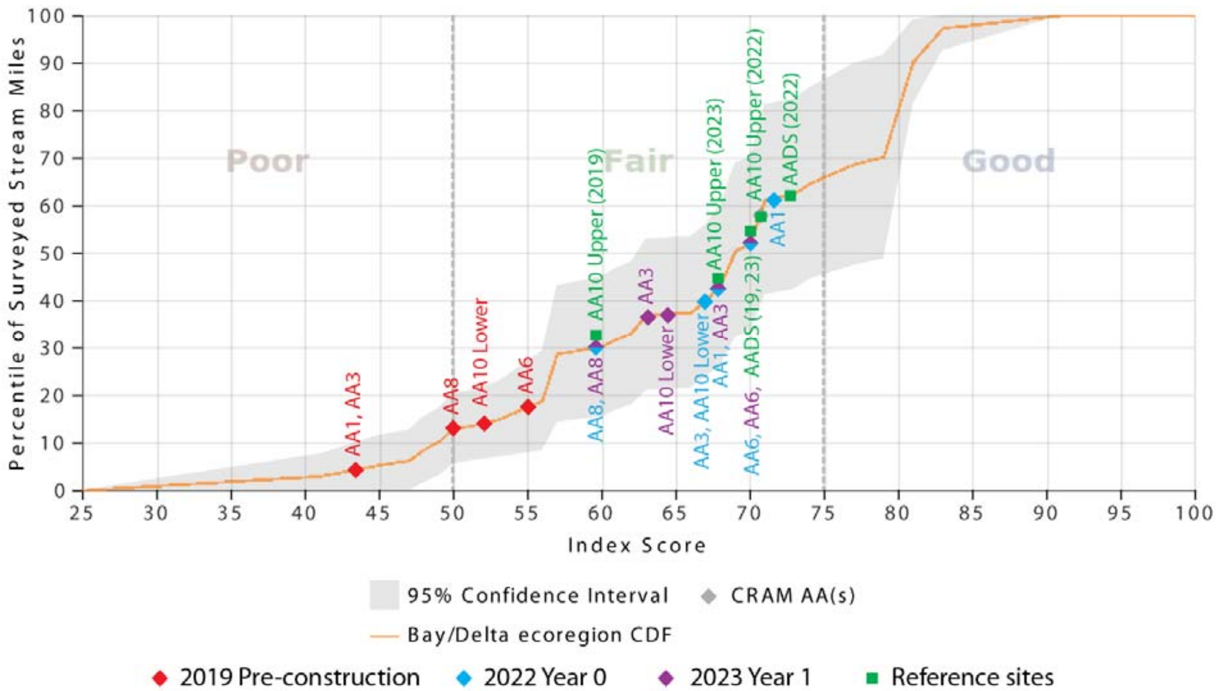

Figure 22. San Francisco Bay Area Ecoregional Cumulative Distribution Function (CDF) estimate, with the 2019 Pre-construction (red diamonds), 2022 Year 0 (blue diamonds), 2023 Year 1 (purple diamonds), and out-of-project reference sites AA 10 Upper and AA Downstream (green squares) CRAM Index Scores plotted.

First, the most significant differences in CRAM scores are due to the stage in the project that they represent, that is, the 2019 pre-construction survey or the 2022/2023 post-construction surveys. In 2019, scores for in-project AAs range between 43 and 55, in the poor to the lower side of fair condition class, and representing the 4th to 18th percentile of condition for the region. The 2019 scores reflect the non-functioning condition of the pre-project channel- either underground in a culvert or in a heavily failing culvert reach. The presence of the culvert influenced many of the underlying CRAM Metric scores: the adjacent culverted stream reaches affect the Aquatic Area Abundance Metric; the lack of the ability for the bed to be able to adjust in the Channel Stability and in the Hydrologic Connectivity Metrics; and the lack of complexity in the Structural Patch Richness and Topographic Complexity Metrics. AA 5/6 has the highest score of 55, due to the higher Biotic Structure Attribute Score. At this time, the culvert had almost entirely failed in this reach, and the channel was mostly exposed and had more vegetation than other unexposed reaches. In addition, the channel flows underneath overhanging mature riparian vegetation, which also contributed to the higher Biotic Structure Score. The 2022 (Year 0) and 2023 (Year 1) post-construction assessments show the immediate improvement in score due to the project. For these two time periods the in-project AAs range in score from 59 to 71, a full 16 points higher, and all in the fair condition class. These scores reflect the early condition of the newly created channel, and its emerging healthier geomorphic processes. In all cases, the Aquatic Area Abundance, the Channel Stability, and the Hydrologic Connectivity Metrics improved due to the removal of the underground culvert segments. In addition, the Structural Patch Richness and the Topographic Complexity Metrics now reflect conditions of the actual channel, as opposed to a culvert. And the metrics in the Biotic Structure Attribute reflect the plantings and riparian vegetation that is now growing along the channel. It is important to note that AAs 8 and 10 Lower exhibited lower scores post-construction for this Attribute due to the significant earth moving and channel construction that were required in this reach. However, these scores are expected to improve above pre-construction condition with additional time.

Second, CRAM scores show differences due to the location within the project. For example, AA1 and AA6 are located adjacent to existing mature overhanging riparian and hillslope vegetation, whereas AA3, AA8 and AA10 Lower are not. This results in higher Biotic Structure Attribute Scores (52.78 to 61.11) for the former group of AAs as compared to lower scores (25.00 to 50.00) for the latter group of AAs. Also, AA8 and AA10 Lower are located in a very steep reach that required placement of significant amounts of rock to maintain stability. Due to the narrow channel width, steep slope, and rock substrate, these two reaches have very little structural complexity presently, which is expressed in low scores in the Structural Patch Richness Metric. This same channel morphology, along with later planting in this reach, is also causing low scores in the Horizontal Interspersion and the Vertical Biotic Structure Metrics, reflecting the low amount of plant structure and growth to date.

And finally, scores varied from Year 0 to Year 1 due to both variations in precipitation between the two Water Years and maturation of the restoration project. For AA1 and AA3, the Hydrologic Connectivity Metric actually decreased in score due to the higher flows that occurred during WY2023, and the resulting minor adjustments in channel width and depth, that caused slight deepening of the channel. The Structural Patch Richness Metric decreased in AA10 Lower by a single grade from Year 0 to Year 1 due to a change in a single patch type; algae was not present in Year 1. The largest number of changes observed from Year 0 to Year 1 were in the metrics of the Biotic Structure Attribute. A variety of single letter grade changes occurred in each of the Metrics, with no obvious and clear trend evident. However, it does appear that a shift in the vegetation community from the initially planted and hydroseeded species to more successional species is occurring. For example, in AA8, the planted sterile lupine species that was prevalent in Year 0 was not present in Year 1, thus reducing the score for the Number of

Plant Layers. The presence of fewer plant species was also observed in AA1 and AA3 where the Number of Co-dominant Species score actually decreased because the growth of the tree and shrub species had shaded and blocked the earlier annual species from growing (e.g. sterile lupine, sweet clover). This kind of variability is typical between years, especially for young restoration project sites.

Besides plotting CRAM assessment scores on the CDF to place the project site conditions into the broader regional context, scores for restoration or mitigation projects can also be plotted on a Habitat Development Curve (HDC) to evaluate and track ecological conditions through time compared to expected project performance rates. An HDC plots the expected rate of improvement in condition since project completion. Ideally, project scores would plot on or above the curve, meaning that the project is “on track” towards ultimately reaching reference condition. Scores that plot below the curve can be targeted for adaptive management to bring them back onto the curve. Unfortunately, an HDC for riverine wetlands in the Bay Area has not yet been developed. Instead, Figure 23 shows the HDC for Vernal Pool wetlands in the Central Valley as an example. Regardless, project CRAM scores can still be plotted to visualize their improvement through time. Figure 24 shows the Alder Creek Overall Index Scores for the Pre-Construction condition (Year -1), 2022 Post-Construction (Year 0), and 2023 Post-Construction (Year 1), in addition to a handful of other known stream restoration projects from around the Bay Area for comparison. Note, only the five AAs that were within the restoration footprint are plotted. The chart illustrates the concept of plotting assessment scores collected at multiple time periods after construction of a restoration or mitigation project has been completed to be able to visually evaluate the progress of the project compared to similar other successful projects of different ages. This example is for the Overall Index Score level, which combines the four CRAM Attributes; HDCs can be (and should be) plotted at the Attribute Level to more accurately understand individual aspects of condition and the reasons for its rate of improvement through time for any given project.

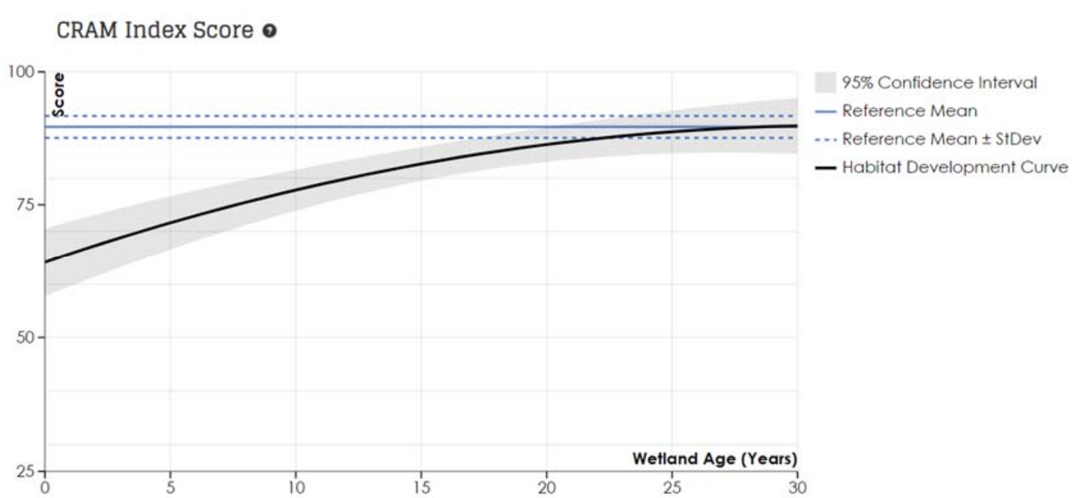

Figure 23. Example Habitat Development Curve for Vernal Pool System wetlands in California’s Central Valley.

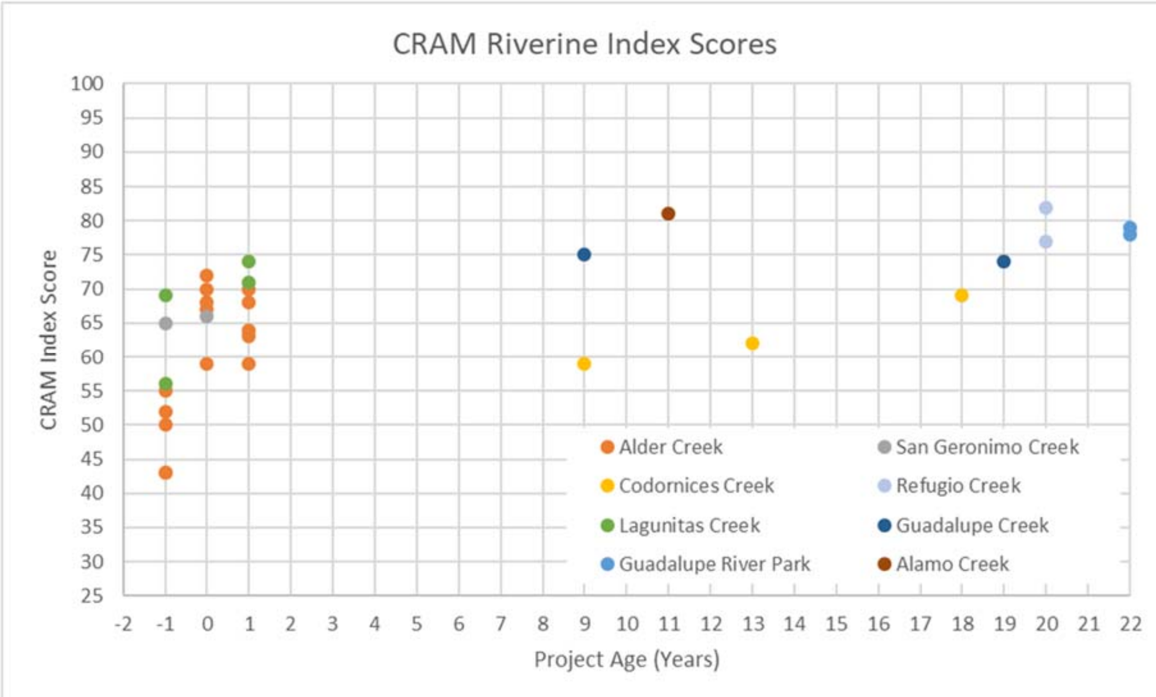

Figure 23. Distribution of Alder Creek CRAM scores (orange) plotted by time as compared to the project completion date (2022). Selected CRAM scores from other San Francisco Bay Area riverine restoration projects are included for comparison. A project age of zero indicates the project completion date. Negative ages indicate pre-construction assessments.

In addition to condition scores, CRAM also has a Stressor Checklist to identify existing stressors that are occurring in the channel or in the adjacent buffer and landscape, to help explain any potential low scores. The Checklist can also be used to identify management actions that could be taken. The Checklist is used to identify stressors that are present and to indicate which stressors are likely having a significant negative effect upon stream condition. Table 4 lists the stressors identified for each AA, and if they are simply present, or are present and having a significant negative effect. The stressors vary based upon year, and relate to the conditions on site at the time. For instance, the 2019 pre-construction assessments all indicate that “Flow obstructions (culverts, paved stream crossings)” were having a significant negative effect. However, the post-construction assessments indicated that no single stressor appears to be the primary reason for reductions in scores. It is interesting to note that a few new stressors were identified post-construction including the following: “Engineered channel” as a result of the large amount of rock that was placed to maintain channel stability, “Vegetation Management” for the maintenance work associated with the project, and “Nutrient Impaired” because of the amount of algae present in the Year 1 assessments was dramatic and noteworthy. The algae observed is likely due to the nutrients provided from upstream, and the abundant amount of sunshine, but is expected to decrease through time as the channel becomes more shaded. The only other stressor that should be highlighted is the “Lack of treatment of invasive plants adjacent to AA or in buffer”, as it was identified as an observed stressor at a few of the Year 1 assessments. The total number of invasives should be monitored into the future.

Table 4. CRAM Stressor Checklist results for each AA. Stressors that are present are marked with a 1, while stressors that are present and having a significant negative effect are marked with a 2.

	AA1/2 2019	AA1 2022	AA1 2023	AA2/3 2019	AA3 2022	AA3 2023	AA5/6 2019	AA6 2022	AA6 2023	AA8 2019	AA8 2022	AA8 2023	AA10 Lower 2019	AA10 Lower 2022	AA10 Lower 2023	AA10 Upper 2019	AA10 Upper 2022	AA10 Upper 2023	AA DS 2019	AA DS 2022	AA DS 2023
Hydrology																					
Point Source (PS) discharges (POTW, other non-stormwater discharge)																					
Non-point Source (Non-PS) discharges (urban runoff, farm drainage)																			1	1	1
Flow diversions or unnatural inflows																					
Dams (reservoirs, detention basins, recharge basins)			1			1															
Flow obstructions (culverts, paved stream crossings)	2	1	1	2	1		2	1	1	2	1	1	2	1					1	1	1
Weir/drop structure, tide gates																					
Dredged inlet/channel																					
Engineered channel (riprap, armored channel bank, bed)		1	1		1	1		1	1		1	1		1	1				1	1	1
Dike/levees																					
Groundwater extraction																					
Ditches (borrow, agricultural drainage, mosquito control, etc.)																					
Actively managed hydrology																					
Physical Structure																					
Filling or dumping of sediment or soils **(N/A for restoration areas)**																					
Grading/ compaction **(N/A for restoration areas)**																					
Plowing/Discing **(N/A for restoration areas)**																					
Resource extraction (sediment, gravel, oil and/or gas)																					
Vegetation management		1	1		1	1		1	1		1	1		1	1		1				
Excessive sediment or organic debris from watershed																					
Excessive runoff from watershed																					
Nutrient impaired (PS or Non-PS pollution)			1			1			1			1									1
Heavy metal impaired (PS or Non-PS pollution)																					
Pesticides or trace organics impaired (PS or Non-PS pollution)																					
Bacteria and pathogens impaired (PS or Non-PS pollution)																					
Trash or refuse																			1	1	1

	AA1/2 2019	AA1 2022	AA1 2023	AA2/3 2019	AA3 2022	AA3 2023	AA5/6 2019	AA6 2022	AA6 2023	AA8 2019	AA8 2022	AA8 2023	AA10 Lower 2019	AA10 Lower 2022	AA10 Lower 2023	AA10 Upper 2019	AA10 Upper 2022	AA10 Upper 2023	AA DS 2019	AA DS 2022	AA DS 2023
Biotic Structure																					
Mowing, grazing, excessive herbivory (within AA)																					
Excessive human visitation																					
Predation and habitat destruction by non-native vertebrates (e.g., *Virginia opossum* and domestic predators, such as feral pets)																					
Tree cutting/sapling removal										1				1					1	1	1
Removal of woody debris																					
Treatment of non-native and nuisance plant species					1						1	1		1							
Pesticide application or vector control					1									1							
Biological resource extraction or stocking (fisheries, aquaculture)																					
Excessive organic debris in matrix (for vernal pools)																					
Lack of vegetation management to conserve natural resources																					
Lack of treatment of invasive plants adjacent to AA or buffer	1	1	1	1		1			1	1					1			1			1
Buffer and Landscape Context																					
Urban residential									1												
Industrial/commercial																					
Military training/Air traffic																					
Dams (or other major flow regulation or disruption)																					
Dryland farming																					
Intensive row-crop agriculture																					
Orchards/nurseries																					
Commercial feedlots																					
Dairies																					
Ranching (enclosed livestock grazing or horse paddock or feedlot)																					
Transportation corridor	1	1	1	1	1	1	1	1	1										2	2	2
Rangeland (livestock rangeland also managed for native vegetation)								1	1		1	1	1	1	1	1	1	1			
Sports fields and urban parklands (golf courses, soccer fields, etc.)																					
Passive recreation (bird-watching, hiking, etc.)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
Active recreation (off-road vehicles, mountain biking, hunting, fishing)	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1
Physical resource extraction (rock, sediment, oil/gas)																					
Biological resource extraction (aquaculture, commercial fisheries)																					

Implications

Conducting CRAM assessments during Pre-construction and Post-construction time periods has allowed the project to monitor and track stream condition using a standardized methodology that can be compared across time and space. The scores clearly illustrate a number of details about the project- some are easily observed, and others are more subtle. Firstly, the scores quantified the poor to low fair conditions of the Pre-construction channel, all of which were in the lowest 20th percentile of condition for the Ecoregion. This quantification validates the project team's observations and professional judgment and justifies the habitat-related needs for the project. Secondly, the scores quantify the amount of change that occurred by Year 0 of the project. Scores increased significantly from 2019 to 2022, ranging from an increase of 9 points at AA8 up to 29 points at AA1 (both showing an amount of change greater than the published uncertainty level). The smaller amount of lift at AA8 is likely because this section of channel was not created until 2021 (later than the further downstream reaches) and the planting of this reach was not fully complete until 2023. It is expected that the scores for AA8 and AA10 Lower will continue to improve as the upper reaches have a chance to "catch up" with the lower reaches. The most amount of change occurred in the Buffer and Landscape Context Attribute and the Hydrology Attribute. Here the Stream Corridor Continuity metric increased from a 3 to a 12 with the removal of the culvert, and Channel Stability and Hydrologic Connectivity increased due to the change from a static culvert to a natural channel. And finally, the scores quantify the changes that occurred between Year 0 and Year 1, as the project begins to mature. For example, the Biotic Structure Attribute for the in-project AAs either stayed the same (two AAs) or slightly decreased (three AAs) between 2022 and 2023. The change did not consistently occur within a single metric across the AAs, but instead included reductions in Number of Plant Layers, Number of Co-dominants, Horizontal Interspersion, and Vertical Biotic Structure. It is not uncommon for slight changes of this magnitude to occur within restoration projects as the vegetation community evolves. Although the effect upon the score is small, tracking the details behind each of these scores allows for a greater understanding of how the plant community is actually changing. The fluctuating scores are not indicating a reduction in the "desired" plants, but instead indicating adjustment and evolution within the community. For instance, the Number of Co-dominants decreased in some AAs because larger plants were shading out some of the annual "weedy" species, preventing them from having enough cover to be a co-dominant, and reducing the total number of co-dominants present.

CRAM scores can also be utilized to evaluate undesired change that can alert managers of specific adaptive management actions that could be taken to improve conditions. For example, the scores for Hydrologic Connectivity between Year 0 and Year 1 decreased for AA1 and AA3, the lowest reaches of the project. This decrease in score indicates that the high flows of the 2023 Water Year caused slight channel deepening in these reaches. While we would expect (and want) some amount of modification of the channel cross sectional geometry in the first years of a project, this amount of change could be further explored using other datasets (e.g. the Physical Habitat data) and highlighted for monitoring in subsequent years. This monitoring will alert the project team if the channel begins to deepen or widen too much, so that it becomes unstable. The scores can also be used as a "trigger" for additional study or more detailed monitoring. For instance, if CRAM scores show a decrease in condition in a specific Metric or

Attribute, the project team can investigate the potential reasons, and perhaps respond by conducting additional data collection.

It is expected that CRAM scores will continue to have small year-to-year variations as the project matures over the next 5-10 years, but in general scores will progress in an upward trajectory. It is reasonable to expect all of the AAs to reach Fair to Good condition classes over the coming decade. If desired, CRAM can be used as a tool to predict future condition at a specific future point in time (e.g. 20 years Post-construction), making documented assumptions about the likely future state. These predictions can be used as a discussion tool among the resources agencies to help think about the likely performance of the project, even when it has only recently been completed.

These initial CRAM assessments provide quantifiable tracking of the project's progress and performance. Assessments should be conducted in the future as "one of many" tools in the monitoring toolbox because it is the only tool that provides a holistic snapshot of the overall ecological condition and allows the project's ecological conditions to be compared to other projects in the region. Monitoring frequency can be adjusted to meet the project's needs, however it is suggested that assessments be conducted in 2024 (Year 2), 2025 (Year 3), 2027 (Year 5), and 2032 (Year 10). Monitoring frequency or additional assessments could be added if a significant change occurs (e.g. large flood event, severe drought, wildfire, significant engineered modification to the channel).

Physical Habitat

Background

California's Surface Water Ambient Monitoring Program (SWAMP) is a State and Regional Water Board program that monitors ambient stream condition across the state. SWAMP was established in 2000, and since then has been collecting data in a standardized manner that allows for comparison between streams and quantification of trends through time. The SWAMP program has developed a number of standardized sampling methods to assess benthic macroinvertebrates, algae, water quality and chemistry, as well as physical habitat within the stream. This Physical Habitat component of stream habitat characterization, known as PHab, collects data on the structure and complexity within the channel, including bankfull width, wetted width, water depth, bed grain size distribution, algae and coarse particulate matter presence/absence, channel habitat type proportions, channel slope, channel sinuosity, vegetation characteristics, canopy cover density, and bank and bed characteristics including anthropogenic structures and actions. This dataset collects very detailed information for 150m long channel reaches, and can be used to quantify change in structure and complexity, as well as explaining measured BMI, algae, or fish communities.

It is expected that restoration projects will increase in their physical habitat complexity through time, as the channel develops and matures. This is particularly true for daylighted channels because they are newly constructed and initially begin only with the complexity that was built into the project. After construction is complete, wet season flows should create variation in the channel bed and banks, including the deposition of bars and the scour of pools, and the in-channel and riparian vegetation community should develop, shaping the channel as it does so. The PHab methodology provides detailed data on the channel and its vegetation that can be tracked through time to understand how the channel is evolving and increasing in complexity.

Methods

The project team collected PHab data during two time periods, 2022 at Year 0 post-construction and again in 2023 at Year 1 post-construction. Data was not collected prior to construction as most of the channel was culverted, and was inaccessible and not appropriate for this method. A total of four PHab stations were completed: three in the project footprint, and one downstream in Upper San Leandro Creek. In all instances, the PHab stations were placed so that they overlap with an existing CRAM AA (PHab 1 overlaps with AA1, PHab6 overlaps with AA6, PHab8 overlaps with AA8, PHabDS overlaps with AA Downstream [in Upper San Leandro Creek]) (Figure 24). It is important to note that the PHab stations are slightly longer than the CRAM AAs, however the majority of the station overlaps. Data was collected employing the SWAMP standardized Physical Habitat published methodology (Ode et al., 2016). Data was collected in the field on paper datasheets, and entered into a custom Excel spreadsheet for data analysis upon return to the office (Figure 25).

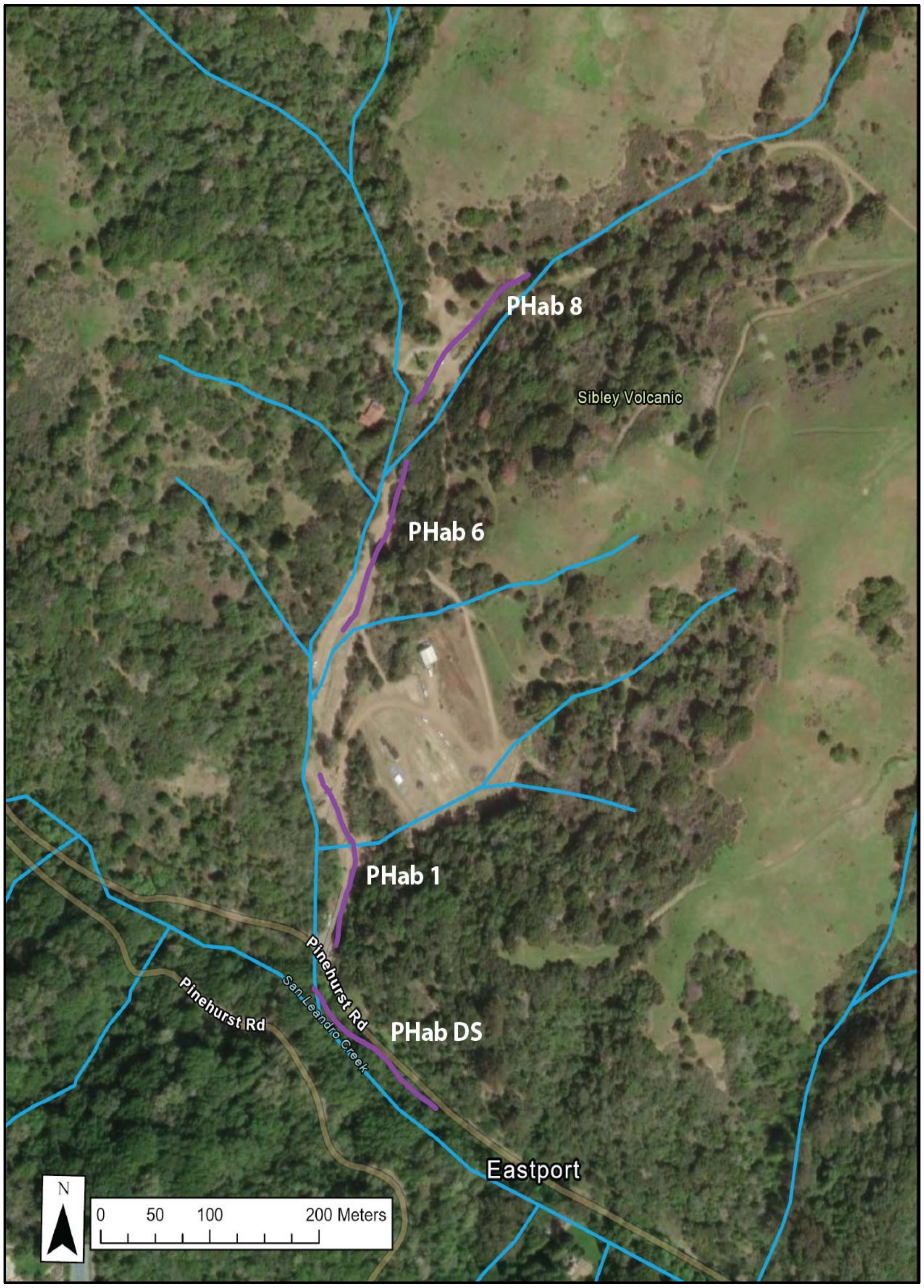

Figure 24. Map showing the location of the four total PHab stations (purple reaches) surveyed in 2022 and 2023.

 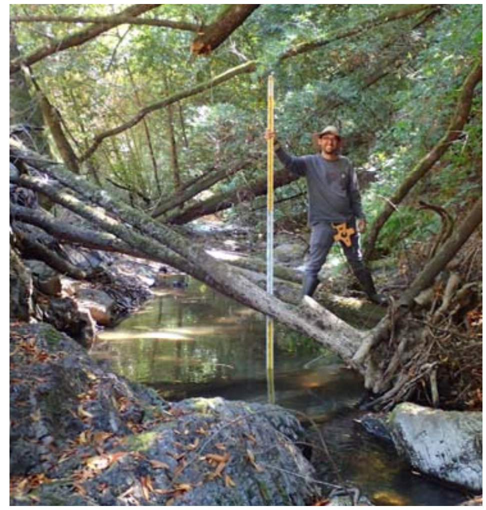

Figure 25. Field photographs illustrating PHab data collection at the PHabDS station (Upper San Leandro Creek) reach during 2023.

Results

The PHab methodology includes analyses of many individual aspects of channel and vegetation complexity. For ease of analysis, each aspect will be discussed separately below.

Channel Bankfull Width and Depth

The average bankfull width and depth calculated from the 11 measures collected in each station are displayed in Table 5 by year. The data illustrate that PHab 1, PHab 6, and PHabDS all slightly increased in width by 10-40 cm, while PHab1 was the only location that changed depth, decreasing (shallowing) by 0.07m. This amount of change is near the threshold of measurement in the field, and illustrates the difficulty of measuring bankfull in a newly constructed channel that has not necessarily conveyed a bankfull flow yet. It is possible that this minor shallowing could represent deposition of sediment that has eroded from the banks in the upstream reaches.

Table 5. Average bankfull channel width and depth.

Station-Year	Bankfull Width (m)	Bankfull Depth (m)
PHab1-2022	3.11	0.42
PHab1-2023	3.20	0.35
PHab6-2022	2.39	0.32
PHab6-2023	2.81	0.34
PHab8-2022	2.33	0.37
PHab8-2023	2.32	0.36
PHabDS-2022	5.13	0.54
PHabDS-2023	5.29	0.53

Channel grain size distribution

The grain size distribution was quantified by measuring the grain size of 100 individual clasts at each station. The median grain size (D50), and in a normal distribution one standard deviation from the median (D16 and D84) are reported for each station (Table 6). However, because the channel was constructed, and the design required a significant amount of large rock to be placed on the bed to maintain stability, the distribution is not normal (Figure 26). Instead it is skewed, with a long tail to the right, representing the largest boulder-sized rocks that were placed in the channel (Figure 27). While the largest clasts represented by the tail are not intended to be mobile (placed for channel stability), the majority of the measured grains (perhaps 70%), including smaller clasts used in construction, could be mobile in larger flood events. The skewed distribution is also evident by comparing the median (D50) and the mean for each station, and seeing the large difference between the two values.

Table 6. Grain size distribution for each station, including the D16, D50, D84 and mean measures.

Station-Year	D16	D50	D84	Mean
PHab1-2022	2	9	298	114
PHab1-2023	2	31	240	113
PHab6-2022	2	34	174	87
PHab6-2023	2	26	148	72
PHab8-2022	1	46	197	92
PHab8-2023	2	21	140	66
PHabDS-2022	1	6	80	45
PHabDS-2023	2	13	96	49

Figure 26. Illustration of the large grain size of the placed rock within the channel.

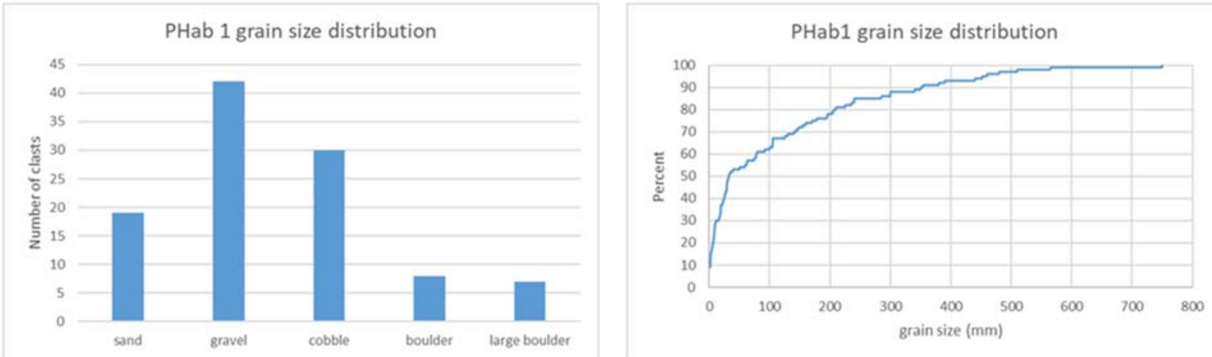

Figure 27. Plots of the grain size distribution at PHab 1 to illustrate the skewed distribution of grain sizes.

Channel Embeddedness

During grain size distribution measures, any cobble or boulder that was selected also had a measure of embeddedness collected. Embeddedness is the amount of the larger clast that is covered with (buried by) fine sediment. Embeddedness negatively affects the ability for salmonids to spawn; even if the channel has appropriately-sized spawning sediment, if those clasts are too buried in fine sediment, the fish is unable to successfully build a redd. In addition, excess fine sediment deposition can cause reduced growth and survival for juvenile salmonids as well as a reduction in the amount of macroinvertebrate food sources that are available (Suttle et al., 2004). For these reasons, it is desirable for a channel to have lower embeddedness values. Baigun (2003) defined “low” substrate embeddedness as less than 35%, which was important for successful summertime steelhead habitat. Table 7 displays the embeddedness values for each PHab station. Every PHab station (in both years) has an average embeddedness value that is approximately 30%. PHab8 has the largest amount of change between years, changing from 23% to 35%.

Table 7. Average embeddedness value at each PHab station.

	Embeddedness (percent)
PHab 1- 2022	28
PHab 1- 2023	29
PHab 6- 2022	30
PHab 6- 2023	27
PHab 8- 2022	23
PHab 8- 2023	35
PHabDS- 2022	29
PHabDS- 2023	31

Channel Slope

The slope of the channel thalweg was surveyed at each station each year. The slope values illustrate the difference between stations, and help set expectations for the habitat units that are present. In other words, we might expect more riffle and rapid units in PHab8 (steepest slope) and more pool, glide, and run units in PHab1 (gentle slope). Given that the channel was designed to remain stable, it isn't expected that any significant change will occur between years. Table 7 reports the overall slope for the station in percent for each year. Interestingly, the channel slope for all four stations decreased, ranging between 0.13% and 0.52% decrease. This does not represent large amounts of change, but given that it occurred in a single year, it is likely worth evaluating in future years to see if the slope continues to decrease.

Table 7. Channel thalweg slope for each PHab station (in percent).

Station-Year	Slope (percent)
PHab1-2022	4.64
PHab1-2023	4.48
PHab6-2022	5.56
PHab6-2023	5.39
PHab8-2022	11.38
PHab8-2023	10.86
PHabDS-2022	2.52
PHabDS-2023	2.39

Channel Habitat Units

Within each station, the percentage of the total station length composing each habitat unit was estimated. Because of the relatively high flows that occurred in Water Year 2023, it is expected that the percentage of each unit will slightly adjust. This development of channel units reflects active geomorphic processes in action, such as scour, deposition, sediment transport, and sediment sorting. Additionally, the presence of each habitat unit is important to the success of resident trout, as they need pools, riffles and glides for different life history stages. Riffles and glides provide spawning habitat and macroinvertebrates for a food source, while pools provide resting and cover habitat. Rush et al. (2000) and Peterson et al. (1992) suggested that the optimal ratio between pools and riffles is approximately 1:1, and pools and riffles combined should account for 40 to 60% of the total habitat unit to best support trout. Table 8 lists the percentage of each habitat unit comprising each PHab station channel length for each year. The data illustrate that meaningful change did occur between Year 0 and Year 1. For example, for the three in-project stations, the percentage of pool habitat increased (approximately doubled) between years. This increase came at the expense of rapids (for PHab8) and riffles (for PHab1 and PHab6). These changes are consistent with the observed decrease in slope; higher slope units have been replaced with lower slope units. Interestingly, the field team noticed that PHabDS had filled with additional sediment between years, which is confirmed by the decrease in pools (existing pools were filled in with sediment) and increase in glides and riffles in this reach. The pool to riffle ratio improved for all three in-project stations, with each having a ratio closer to 1:1 in Year 1. And all four PHab stations have a percentage of pools and riffles together that is greater than 50%.

Table 8. Percentage of each habitat unit comprising the PHab station total channel length.

	Cascade/ Falls	Rapid	Riffle	Run	Glide	Pool	Pool to Riffle ratio	Percentage of pools and riffles
PHab 1- 2022	**0**	**11**	**62**	**6**	**8**	**14**	1:4.6	76
PHab 1- 2023	**0**	**11**	**57**	**0**	**2**	**31**	1:1.8	88
PHab 6- 2022	**0**	**0**	**80**	**0**	**2**	**18**	1:4.4	98
PHab 6- 2023	**0**	**2**	**61**	**0**	**4**	**33**	1:1.9	94
PHab 8- 2022	**0**	**39**	**37**	**9**	**0**	**16**	1:2.3	53
PHab 8- 2023	**0**	**8**	**59**	**0**	**0**	**34**	1:1.8	93
PHabDS- 2022	**0**	**0**	**55**	**3**	**10**	**33**	1:1.7	88
PHabDS- 2023	**0**	**0**	**61**	**0**	**21**	**18**	1:2.1	79

Channel canopy cover

In-channel and riparian vegetation provide many functions including shading, contribution of allochthonous material, and cover elements, each contributing towards the habitat value provided by the channel. Within the methodology, a spherical densiometer was utilized to measure canopy cover at 11 locations within each PHab station length. Higher values of canopy contribute to greater shading of the water surface, keeping water temperatures cool throughout the summer and fall season. Table 9 displays the mean densiometer measure (with a maximum of 17, representing the 17 dots on the densiometer that are counted as having canopy cover or not), the standard deviation of the densiometer measure, and the conversions to percent canopy cover. The standard deviation canopy cover provided information about how variable the cover is across the station; lower standard deviations mean that the cover is more similar than higher standard deviations, which mean that there is higher variability across the station. The data illustrate that the three in-project stations have much lower canopy cover as compared to the PHabDS station in Upper San Leandro Creek. In particular, PHab8 has the lowest amount of cover, due to the later planting of the site, and the lesser water availability for riparian vegetation in this portion of the project due to the high channel and valley slope. The data also show that the average cover increased between Year 0 and Year 1 for all stations, with the cover for all three stations combined essentially doubling between years. The data also illustrate the high values for the standard deviation for the in-project stations. This is because each station has at least one of the 11 measurements that has existing mature riparian vegetation that is independent of actions that occurred within the daylighting project that overhangs the channel. These locations have very different cover values than those where newly planted vegetation provides the only cover.

Table 9. Canopy cover (in percent) at each PHab station as measured by a spherical densiometer. Densiometer measures have a maximum value of 17, meaning that 100% canopy cover is present.

Station-Year	Mean densiometer measure	Standard deviation densiometer measure	Average canopy cover (%)	Standard deviation canopy cover (%)
PHab1-2022	3.386	4.121	20	24
PHab1-2023	5.636	5.14	33	30
PHab6-2022	3.477	4.751	20	28
PHab6-2023	7.772	5.834	46	34
PHab8-2022	1.522	3.836	9	23
PHab8-2023	2.000	3.741	12	22
PHabDS-2022	14.318	1.997	84	12
PHabDS-2023	15.325	1.475	90	9

Riparian Vegetation

In addition to canopy cover, the riparian vegetation that grows along the channel banks contributes to the overall condition and functioning of the stream. Riparian vegetation cover can provide shading of the water surface, but also contributes to allochthonous material, delivery of nutrients to the channel, channel roughness during high flows, bank stability via root networks, and habitat and cover for wildlife. The PHab methodology groups riparian vegetation into five different types: barren ground, herbs/grasses, woody shrubs that are <0.5m in height, all vegetation that is 0.5 to 5m in height, and trees and saplings that are >5m in height. At each station, field staff make 22 observations of vegetation, right and left bank at 11 locations throughout the station, quantifying the amount of cover of each vegetation type at that location. Table 10 displays the percentages of cover for each vegetation type. For instance, in Year 0 (2022) the PHab1 station had 18% of observations with 10-40% barren ground, 18% of observations with 40-75% barren ground, and 64% of observations with >75% cover of barren ground, meaning that a significant amount of the banks were not vegetated. As a second example, considering all vegetation between 0.5 and 5m in height, the data show that the density of this vegetation increased between Year 0 and Year 1. In 2022 most of the observations had cover of 10-40%, however in 2023 most observations had cover of 40-75%, and 18% of the observations had cover >75%. The patterns in Table 10 show that for the three in-project stations, the amount of barren ground decreased, the amount of herbs/grasses and all vegetation 0.5 to 5m increased, and the cover provided by woody shrubs <0.5m in height increased in two of the three stations.

The last category in Table 10 is the Trees and Saplings >5m in height. For PHab1, some cover of existing mature trees is included in the observations, but the data show the rapid growth of the planted alders and willows at this station, with an increase in observations of all cover classes. PHab6 shows the same pattern, albeit a smaller increase, as fewer alders and willows are planted in this reach. PHab8 shows a very modest increase in higher cover classes, but still has 86% of observations without any tall trees or saplings in 2023.

Table 10. Riparian vegetation types. Percentage of the 22 observations made (11 locations, right and left bank) in each density class, by vegetation type.

Station - Year	Barren					Herbs/grasses					Woody shrubs <0.5m					All veg 0.5 to 5m					Trees and Saplings >5m				
	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%
PHab1-2022			18	18	64	5	41	36	18		64	36				14	27	54	5		90		5		5
PHab1-2023		9	55	36			27	46	27		73	27						36	50	14	59	5	28	5	5
PHab6-2022				68	32	9	14	77			41	59				9	9	77	5		81	5		9	5
PHab6-2023		9	91					77	23		36	64						14	68	18	72	9		14	5
PHab8-2022				18	82		50	50			32	68				9	77	14			91			9	
PHab8-2023		9	59	27	5		5	45	50		9	86	5				18	63	14	5	86		9	5	
PHabDS-2022		5	14	27	54		32	45	18	5	59	32	9			5	18	59	18		13		23	41	23
PHabDS-2023		5	36	50	9		13	73	14		64	36					4	5	36	55	5		27	27	41

Figure 27. Example of the growth, and resulting increased canopy cover from the young planted alder trees in PHab1. See the same group of alders on the right side of each photo: Year 0 (2022) on the left, and Year 1 (2023) on the right.

Instream Habitat Complexity

Specific structural patches, vegetation, and structures can provide important habitat complexity elements in the channel for aquatic and terrestrial species. Greater amounts of complexity provide opportunity for species to move based upon their needs. Ideally the daylighted channel would develop dense patches of multiple complexity elements. Even elements such as artificial structures and filamentous algae can be beneficial (to an extent), by providing shading and cover, and contributing to the base of the food web, respectively. Table 11 displays the percentage of observations at each PHab station within each density class for the nine habitat complexity types. For example, observations of aquatic macrophytes (plant species such as cattail [*Typha sp.*]) grew very densely in certain locations in PHab1 during 2023, but for PHab6 and PHab8 the density decreased. The amount and density of filamentous algae increased for all three in-project stations (Figure 28). And finally, a few locations within PHab6 developed exposed tree roots in 2023, as a result of minor bank erosion as the channel adjusted.

Table 11. Instream habitat complexity types. Percentage of the 11 observations made in each density class, by habitat complexity type.

	Aquatic Macrophytes					Artificial Structures					Boulders				
	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%
PHab1-2022	9	37	18	36		82		9	9			9	55	36	
Phab1-2023	36	10	9	27	18	73		9	18				45	28	27
PHab6-2022	27	73				91			9			36	55	9	
PHab6-2023	91	9				100						18	55	27	
PHab8-2022		91	9			91		9					82	18	
PHab8-2023	55	45				91		9					73	27	
PHabDS-2022	100					82	9		9		9	82	9		
PHabDS-2023	100					91			9			27	64	9	
	Filamentous Algae					Live Tree Roots					Overhanging Vegetation				
	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%
PHab1-2022	27	28	18	27		100					9	27	64		
Phab1-2023		18	28	45	9	100					9	91			
PHab6-2022	73	9	9	9		100					46	36	18		
PHab6-2023		9	55	36		64	36					55	45		
PHab8-2022	18	82				100					64	36			
PHab8-2023	18	19	18	45		100					9	82	9		
PHabDS-2022	91	9				9	27	46	18		27	64	9		
PHabDS-2023	36	64				46	27	27			27	55	18		
	Undercut Banks					Woody Debris <0.3 m					Woody Debris >0.3 m				
	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%	0%	<10%	10-40%	40-75%	>75%
PHab1-2022	100					91	9				82	18			
Phab1-2023	100						100				91	9			
PHab6-2022	91	9				91	9				91	9			
PHab6-2023	100					9	91				100				
PHab8-2022	100					100					100				
PHab8-2023	100						100				100				
PHabDS-2022	82		18				91	9			36	55	9		
PHabDS-2023	91			9		9	18	73			45	9	46		

Figure 28. Filamentous algae observed in Alder Creek during Year 1 monitoring (2023).

Transect Substrates

This final aspect of channel complexity considers the organic material, macroalgae, and macrophytes that may or may not exist within the channel bed where grain size measurements were collected. In this methodology, observations of coarse particulate organic matter (CPOM), macroalgae that is attached to the substrate, macroalgae that is not attached to the substrate, and any macrophytes are made for every clast that is selected for grain size measurement. These observations provide additional information about organic material growing or resting on the bed, and can be used to help explain and interpret the macroinvertebrate community that is found to be present if benthic macroinvertebrate samples are collected. In other words, there are not thresholds or amounts of each type of material that are desirable within any given channel. Table 12 displays the percentage of observations for each measure that are present or absent, or if the channel bed was dry at that location. The only significant change observed for CPOM is in PHab8 where the amount present significantly dropped in Year 1 (2023). The percentage of observations of macroalgae cover, both attached and unattached, was below 20% for all stations and in both years. Additionally, the percentage of observations of macrophytes was also low (<10%) for all stations and both years.

Table 12. Transect substrate types. Percentage of the 100 observations made at each station, by transect substrate type. CPOM is coarse particulate organic matter.

Station Year	Measure	Absent	Present	Dry
PHab1-2022	CPOM	13	36	51
PHab1-2023	CPOM	67	33	0
PHab6-2022	CPOM	0	47	53
PHab6-2023	CPOM	54	45	1
PHab8-2022	CPOM	11	64	25
PHab8-2023	CPOM	72	28	0
PHabDS-2022	CPOM	52	43	5
PHabDS-2023	CPOM	46	54	0
Station Year	**Measure**	**Absent**	**Present**	**Dry (not evaluated)**
PHab1-2022	Macroalgae Cover, Attached	7	11	83
PHab1-2023	Macroalgae Cover, Attached	32	16	51
PHab6-2022	Macroalgae Cover, Attached	0	1	99
PHab6-2023	Macroalgae Cover, Attached	17	18	65
PHab8-2022	Macroalgae Cover, Attached	2	0	98
PHab8-2023	Macroalgae Cover, Attached	23	10	68
PHabDS-2022	Macroalgae Cover, Attached	91	0	10
PHabDS-2023	Macroalgae Cover, Attached	42	1	57
Station Year	**Measure**	**Absent**	**Present**	**Dry (not evaluated)**
PHab1-2022	Macroalgae Cover, Unattached	15	1	84
PHab1-2023	Macroalgae Cover, Unattached	31	11	58
PHab6-2022	Macroalgae Cover, Unattached	0	0	100
PHab6-2023	Macroalgae Cover, Unattached	29	8	64
PHab8-2022	Macroalgae Cover, Unattached	2	0	98
PHab8-2023	Macroalgae Cover, Unattached	22	11	67
PHabDS-2022	Macroalgae Cover, Unattached	91	0	10
PHabDS-2023	Macroalgae Cover, Unattached	43	0	57
Station Year	**Measure**	**Absent**	**Present**	**Dry**
PHab1-2022	Macrophyte Cover	13	5	82
PHab1-2023	Macrophyte Cover	91	9	0
PHab6-2022	Macrophyte Cover	0	4	96
PHab6-2023	Macrophyte Cover	100	0	0
PHab8-2022	Macrophyte Cover	2	4	94
PHab8-2023	Macrophyte Cover	97	3	0
PHabDS-2022	Macrophyte Cover	91	0	10
PHabDS-2023	Macrophyte Cover	100	0	0

Implications

The Physical Habitat methodology collects a large amount of very detailed data about each sampled station. Each data point contributes towards understanding the complexity and composition of the channel, and as a whole, is intended to help explain the findings from any biological sampling that occurs, such as benthic macroinvertebrates, algae, or fisheries sampling. Although this monitoring effort did not include any biological sampling, the PHab methodology was selected because no other methodology provides the level of detail about the channel, its dimensions, its substrate, and its vegetation. Additionally, PHab data is a good complement to the more general CRAM assessment data, because it provides the detail to quantify the channel complexity and habitat value that CRAM is assessing at the reach scale.

The section above described trends that are observed within each individual component of the PHab methodology. But taken as a whole, the data can help "tell the story" of the channel, how it has changed from Year 0 to Year 1, and how it might continue to change into the future.

In general, the daylighting project has created a relatively stable channel that is maturing, even only after a single year since project completion has elapsed. The relatively wet 2023 Water Year provided the flows to begin to modify and adjust the channel, and allow the vegetation community to grow and mature. Despite the steep channel slope, no major headcuts have developed, likely due to the large amount of boulder placed within the channel. Channel dimensions remain nearly the same between years, with only minor widening observed. Sediment transport is occurring, with observations of scour around hard elements (e.g. boulders, logs), as well as observations of sediment deposition in bars. In the upper portion of the project, the grain size slightly fined between years, perhaps due to sediment input from upstream, or localized fine sediment sourced from minor channel geometry adjustments. Input of fine sediment in PHab 8 is also recorded as an increase in the amount of embeddedness in Year 1. Overall, sediment in the daylighted channel appears to be moving downstream and depositing in the lower gradient reach (e.g. PHab1), where the bankfull depth slightly decreased and the D50 grain size slightly coarsened (from fine gravel to medium gravel). Channel slope not only controls aspects of channel geometry and grain size, but also controls the development of channel habitat units, and the plant community that can develop. Across the full gradient of slope in the three in-project stations, the majority of each station is riffle habitat, followed by pool habitat. In Year 1 the ratio of pool to riffle became closer to 1:1, with the development of more pool habitat than existed in Year 0. The daylighting project created an entirely new channel, which was initially completely barren before planting occurred. Vegetation measures illustrate that the project as a whole has low canopy cover, but that amount of cover increased, with the growth of the plantings. The amount of barren ground decreased, while the amount of vegetation (e.g. herbs/grasses, all vegetation 0.5 to 5m) increased in Year 1. The PHab8 station has the least amount of vegetation, as it was completed later than the downstream portion of the project, and likely has more limited ability to support dense willow and alder riparian vegetation due to its steep slope. In addition, Year 1 had an increase in the in-channel vegetation (e.g. cattails) and amount of filamentous macroalgae. This vegetation increased the amount of cover available, while also providing more shading for the water surface.

In the future, the channel will likely continue to adjust by modifying its dimensions and reworking the bed through scour and deposition, changing the makeup of channel habitat units in the process. The vegetation community will continue to mature, with trees and shrubs becoming more dominant, likely shading out many of the annual early-succession and weed species. The additional shading may ultimately reduce the density of macrophytes and algae in the channel, but this could be balanced out by continued nutrient inputs from upstream sources. The condition of the channel, and the habitat that it provides, is expected to improve over the next 5-10 years, following the trajectory of other riverine restoration projects in the area.

Drone-based Aerial Imagery

Background

Unoccupied Aerial Systems (UASs), or drones, provide a particularly powerful set of tools for providing a synoptic view of a project and how it changes over time. High resolution photography collected using UAS can help provide a literal snapshot in time of what a site looked before, during, and after a restoration project occurs. This data can be used to map aquatic resources, direct and support more intensive survey and monitoring activities, and effectively convey the impact of the restoration work.

SFEI leveraged an =suite of UAS to produce a wide variety of data products that can be used to map and characterize the project areas before, during and after the restoration efforts were complete. A pre-construction survey was conducted on May 8th, 2019, in addition to an intermediate survey on October 20th, 2022, and a final survey after the project was completed on October 20th, 2023. The systems used technologically improved equipment and software for each subsequent flight. Each of these surveys resulted in: (1) high resolution, true color, orthomosaic imagery, (2) Digital Elevation Models (DEM) (both a Digital Surface Models (DSM) and Digital Terrain Models (DTM)), (3) three dimensional point clouds, (4) three dimensional mesh models, and (5) a processing report.

Methods

SFEI conducted each UAS survey in coordination and with approval from the East Bay Regional Park District. Approval was given after extensive flight planning, safety considerations and mitigation were made and detailed in EBRPD UAS flight approval applications. EBRPD was notified before each flight occurred and once it had concluded for the day. Flight planning software was utilized to plan and automate all UAS survey flights. This allowed for previous survey flight plans to be improved or repeated in order to achieve the best results and ensure safe flight paths above the project area. The use of ground control points were used in order to increase the absolute accuracy of the data products. Product quality was seen to increase over time as UAS technology advanced over time. The vehicles that were used ranged from a 3DR Solo, a DJI Mavic 2 Pro, and a DJI Phantom 4 RTK. Some of the technological advancements that were leveraged over time that increased product quality from previous flights include: Terrain follow capabilities, object detection and avoidance, increased return to home accuracy and capabilities, and Real Time Kinematics (RTK) GPS capabilities.

The McCosker Alder Creek's site geography posed a number of challenges for UAS flights, which were navigated to maximize safety while reliably providing necessary data outcomes. The project area starts at the downstream end of a winding valley and rises significantly in elevation to the upstream end of the project. This change in elevation posed a challenge that was navigated differently depending on the technological capabilities at the time. Furthermore, a UAS pilot can not see the top of the project area from the bottom, which added complexity given that the pilot in control must be able to visually see the Unoccupied Aerial Vehicle (UAV) during the entire flight. Another challenge was posed by the large number of tall trees on either side and in the middle of the steep sided valley as well as a set of high voltage power lines that drape across the middle of the valley. In order to mitigate the operational dangers of these potential obstacles, the site was split into two flight areas, on either side of the high voltage powerlines. Once terrain follow functionality was available for flight planning software, local Digital Terrain Models were uploaded to flight planning software in order to ensure that the UAV maintained a consistent height above the ground level. This not only increased the consistency of the ground sampling distance in the imagery collected, but also increased safety of flight operations by clearing trees and other potential hazards, while avoiding the need for time consuming manual flights to check the absolute elevations of each hazard, which was used in initial UAS surveys of the site. Additional improvements in flight planning software eventually allowed the UAS to travel down the valley, whereas previously the UAS could not fly to a lower elevation than it's take off elevation. This improvement allowed the UAS operators to start the flight at the top of the site where visibility was best and make full use of the terrain follow options even though the UAV decreased its absolute elevation as it follows the dropping topography from the top of the site. Automatic Object Detection and Avoidance on the DJI UAS helped increase the level of safety and confidence during flights. The last survey made use of an RTK enabled UAS which incorporated a RTK capable GPS receiver that took in the normal signals from the Global Navigation Satellite Systems along with a correction stream to achieve increased positional accuracy. This helped to increase the GPS accuracy of the vehicles and absolute accuracy of the resulting data products.

For each survey, once flight operations had been completed, resulting data was uploaded using ESRI's Site Scan (previously 3DR Site Scan) for processing and display of resulting data products. Reprocessing occurred as improvements in data processing software occurred to achieve better results. The final data products were organized by flight date, packaged and delivered to EBRPD.

Results

Each survey was successfully completed and used to produce into the following products:

- High resolution, true color, orthomosaic imagery
- Digital Elevation Models (DEM)
    - Digital Surface Models (DSM)
    - Digital Terrain Models (DTM)
- Three dimensional point clouds
- Three dimensional mesh models
- Processing report

The orthoimagery from the three flights can be explored using the web maps linked below:

- 2019 UAS Orthoimagery
- 2022 UAS Orthoimagery
- 2023 UAS Orthoimagery

An overview of the orthomosaic imagery for each flight is shown in Figure 29. The high resolution of the imagery allows for visualization of the amount of change that has occurred within the project. For example, Figures 30-34 show side-by-side imagery illustrating specific aspects of change that have occurred between years:

- Figure 30: Vegetation growth that has occurred between 2022 and 2023 within the planted vegetation, such as alders, willows, coyote brush, and other herbs and shrubs. This location, near the middle of the project, highlights the increase in canopy size for individual plantings.
- Figure 31: Increase in cattail growth and shading of the stream at the temperature probe location.
- Figure 32: The 2019 valley floor with visible sinkholes due to the failing culvert as compared to the newly created channel morphology in 2022
- Figure 33: Location of the 2019 hanging culvert and large knickpoint in the valley floor as compared to the 2023 valley floor that has been lowered in elevation upstream of the knickpoint to create a consistent channel gradient.
- Figure 34: Illustration of the large grain size of the placed rock in the channel. This size rock helps maintain channel stability, and is clearly evident in the measured grain size distributions within the Physical Habitat data. These large grain sizes are not suitable for rainbow trout spawning, but instead, may help capture and retain smaller grain sizes that are suitable.

Figure 29. Orthomosaics from the 2019, 2022 and 2023 UAS surveys

Figure 30. Comparison between 2022 and 2023 illustrating the increase in canopy size of individual plantings.

Figure 31. Comparison between 2022 and 2023 illustrating the increase in cattail growth at the temperature probe location.

Figure 32. Comparison of the valley morphology in 2019 with visible sinkholes due to the failing culvert, with the 2022 valley morphology that features the newly created channel.

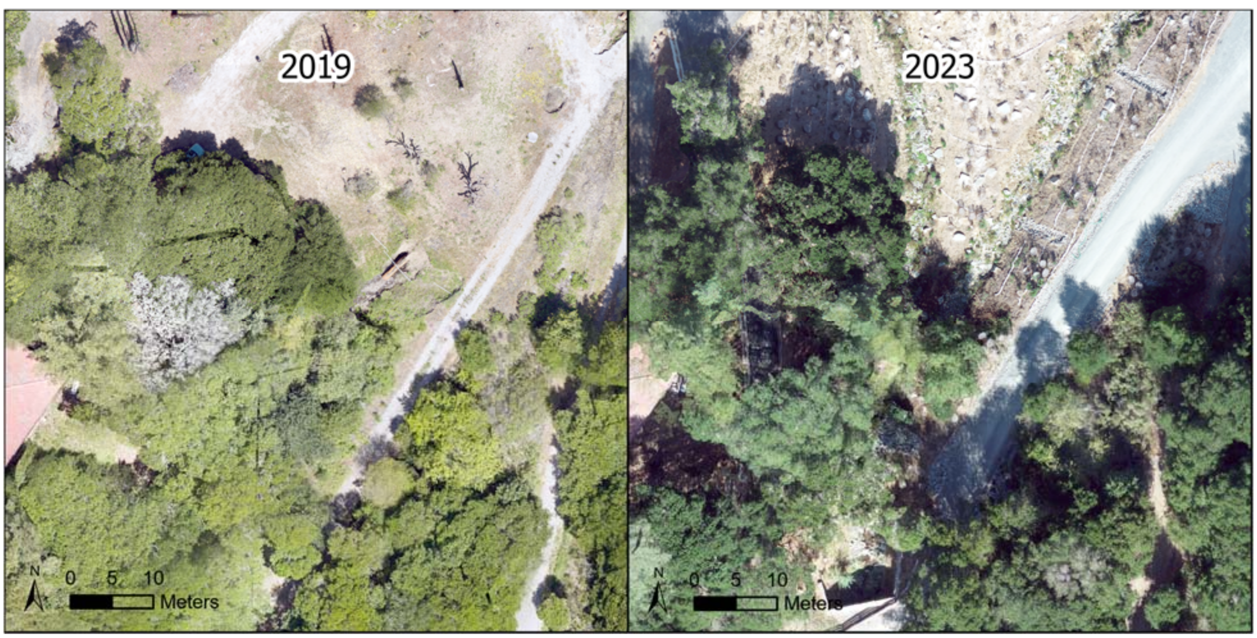

Figure 33. Comparison of the 2019 location of the hanging culvert and knickpoint with the 2023 newly created channel morphology.

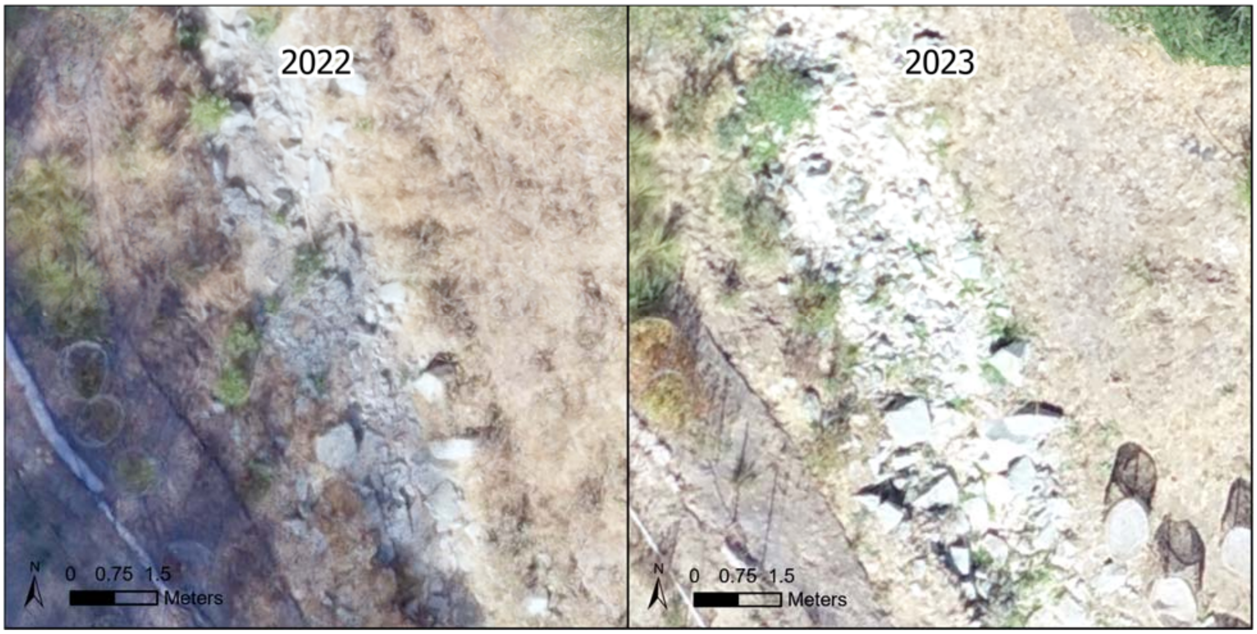

Figure 34. Illustration of the size of the placed rock in the channel bed, and its effect upon the grain size distribution of the channel and suitability for rainbow trout spawning.

Implications

These different products can be used in a wide range of applications such as mapping and visualization. Furthermore, with multiple years of surveys, change analysis can be conducted between the flight products.

Orthoimagery can be used for visual inspection and assessment of a number of focuses: vegetation presence, distribution, density, and health; Habitat type mapping; Park asset and structure inventory; and daylighted stream length, width and location. This data is complementary to ground field data collection and can be used to extrapolate those more precise ground measurements across the study area. This imagery is also a powerful communication asset to help to visually convey the impact of the work that has been accomplished at the site to project stakeholders and the public.

The Digital Elevation Models (DEMs) include both Digital Terrain Models and Digital Surface Models (DSM). These two types of DEMs can be subtracted from one another to estimate the height of structure and vegetation when the ground is visible adjacent to them. These products are not as accurate as when derived from LiDAR point clouds, but still provide actionable information at lower cost. This data can be used to estimate the height of individual structure and vegetation on the site. Furthermore, the elevation data can be used to create virtual cross sections of the stream or even to compute volumetric estimates of sediment and capacity within the channel, as well as material that has been removed from the site for this project.

Point cloud data and 3D models can be used for similar uses as the DEM rasters, but also provide the additional opportunity for virtual fly throughs of the site or to provide other types of virtual experiences of the park/restoration site to the public without having to be on site. This is a powerful communication tool that could be leveraged for augmented reality or virtual reality experiences.

These data products provide valuable snapshots in time of the conditions of the site before, during and after the daylighting project that can be referenced in the future. We expect that with ongoing improvements to technology that these data assets will only become more valuable for communication needs and future analysis.

Carbon Sequestration

Background

Native habitat restoration projects can contribute to climate change mitigation goals by sequestering carbon in vegetation and soils (Dybala et al., 2019; Lewis et al., 2015; Matzek et al., 2015). Following restoration, it may take years to decades to realize the full suite of restored ecosystem functions, and in some cases disturbance from restoration activities may lead to a transient reduction in ecosystem benefits relative to baseline conditions (Matzek et al., 2016). In the case of carbon sequestration, restoration projects such as the Alder Creek Daylighting Project can offer meaningful long-term carbon and climate benefits, but may entail a short-term net loss of carbon from the ecosystem to the atmosphere (primarily as CO_2), depending on the prior condition of the site and the degree of vegetation removal and soil disturbance required during construction. Understanding the climate implications of EBRPD land management activities requires predicting and monitoring how management actions affect ecosystem carbon storage over time.

Carbon sequestration analysis

SFEI evaluated the predicted effects of restoration activities on vegetation carbon stocks. Carbon losses from the site due to grading and vegetation removal were modeled from remote sensing data and standard decomposition assumptions, and carbon gains following restoration were predicted with tools and simple models specific to the region. Estimated carbon losses and gains over time were combined to predict net changes in the site’s carbon stocks over the next 100 years.

Results of the carbon sequestration analysis indicate that for the first decade following construction, the site is expected to be a net carbon source (will lose carbon) due to removal and chipping/mulching of the site’s prior vegetation. Following this transient period, carbon sequestration by restored vegetation will likely outweigh carbon losses, converting the site to a net sink for atmospheric CO_2. Over the 100 years following restoration, the Alder Creek site is expected to store a cumulative 40 metric tons of carbon more than it stored in its pre-construction condition, equivalent to a 25% increase over baseline (pre-construction) carbon storage.

A detailed description of the carbon sequestration analysis methods and findings can be found in the **McCosker Creek Restoration and Public Access Project Carbon Sequestration Technical Report**.

Carbon monitoring prospectus

The carbon sequestration analysis revealed several sources of uncertainty in carbon estimation methods, including poor representation of EBRPD vegetation communities (Gonzalez et al., 2015), highly uncertain carbon estimates for understory vegetation and dead wood (Saah et al., 2016), and coarse spatial resolution relative to the typical project scale. In a second technical report (the prospectus), SFEI outlined an approach to develop methods and estimation tools for efficient and more accurate carbon storage assessments on EBRPD lands.

SFEI reviewed literature on UAS-based, lidar-based, and other imagery-based biomass carbon monitoring, and explored options to tailor these methods to EBRPD sites. Based on this review, SFEI identified data collection and analysis efforts that could be used to develop low-cost methods for biomass carbon monitoring. Proposed work includes paired field carbon inventories and UAS or CRAM-based surveys to develop regionally-specific relationships to estimate (a) forest or woodland tree carbon storage, (b) carbon storage in understory vegetation and dead biomass pools, and (c) carbon storage in shrubland vegetation. If enacted, the proposed methods could make it easier for land managers across the EBRPD and the broader region to track changes in ecosystem carbon storage due to management actions and natural disturbance.

The proposed approach to develop a carbon monitoring method is described in **McCosker Creek Restoration and Public Access Project Methods Development Prospectus for Biomass Carbon Monitoring**.

Pre-Construction Channel Surveys

Background

In 2019, prior to any construction, the project team conducted channel (or valley) cross section and channel (or valley) longitudinal profile surveys to assist in quantifying pre-project conditions. The data was collected with the intent that post-project repeat surveys could be conducted to illustrate channel change due to the project. However, after the initial surveys, it was learned that the project consultant was conducting a much higher density of detailed surveys associated with permit compliance. Therefore, additional surveys were not conducted post-construction, as they would be duplicative.

Despite the cessation of data collection, this pre-project data can be combined with digital terrain models (DTM) from the 2023 Unoccupied Aerial Systems (UAS) surveys to create quite striking comparisons that highlight the magnitude of change that occurred within this project. Visuals of the change in channel profile and the change in valley cross section can be a high-impact addition to the overall restoration story.

Methods

Geomorphic surveys were conducted by Sarah Pearce and Alicia Gilbreath on April 30th, and Sarah Pearce and Kristen Van Dam on May 1st, 2019, before any construction began (Figure 35). The survey included seven channel/valley cross sections placed in representative locations throughout the project footprint, as well as a channel thalweg longitudinal profile that extended from the confluence with Upper San Leandro Creek to just above the upper boundary of the project footprint (Figure 36). Cross sections and the longitudinal profile were surveyed using a Nikon autolevel, tripod, metric stadia rod, and transit tapes. Each end of the cross sections were monumented with a piece of 1” rebar driven vertically into the ground, and capped with a survey marker. Locations of each cross section were noted on the longitudinal profile, however no monuments were placed to mark the upstream or downstream end of the profile. Attempts to reoccupy the monuments after construction suggest that all monuments were removed as part of construction, preventing exact reoccupation of survey locations. All survey data is in relative elevation, that is, it is not tied directly to any existing benchmarks to determine exact elevation above sea level. However, surveys did utilize any hard feature (e.g. the pavement of Pinehurst road, culvert top and bottom elevations, concrete walls) and any pre-construction survey markers that were present to help place the survey in vertical space.

Figure 35. Surveying the channel longitudinal profile in the AA Downstream reach (Upper San Leandro Creek).

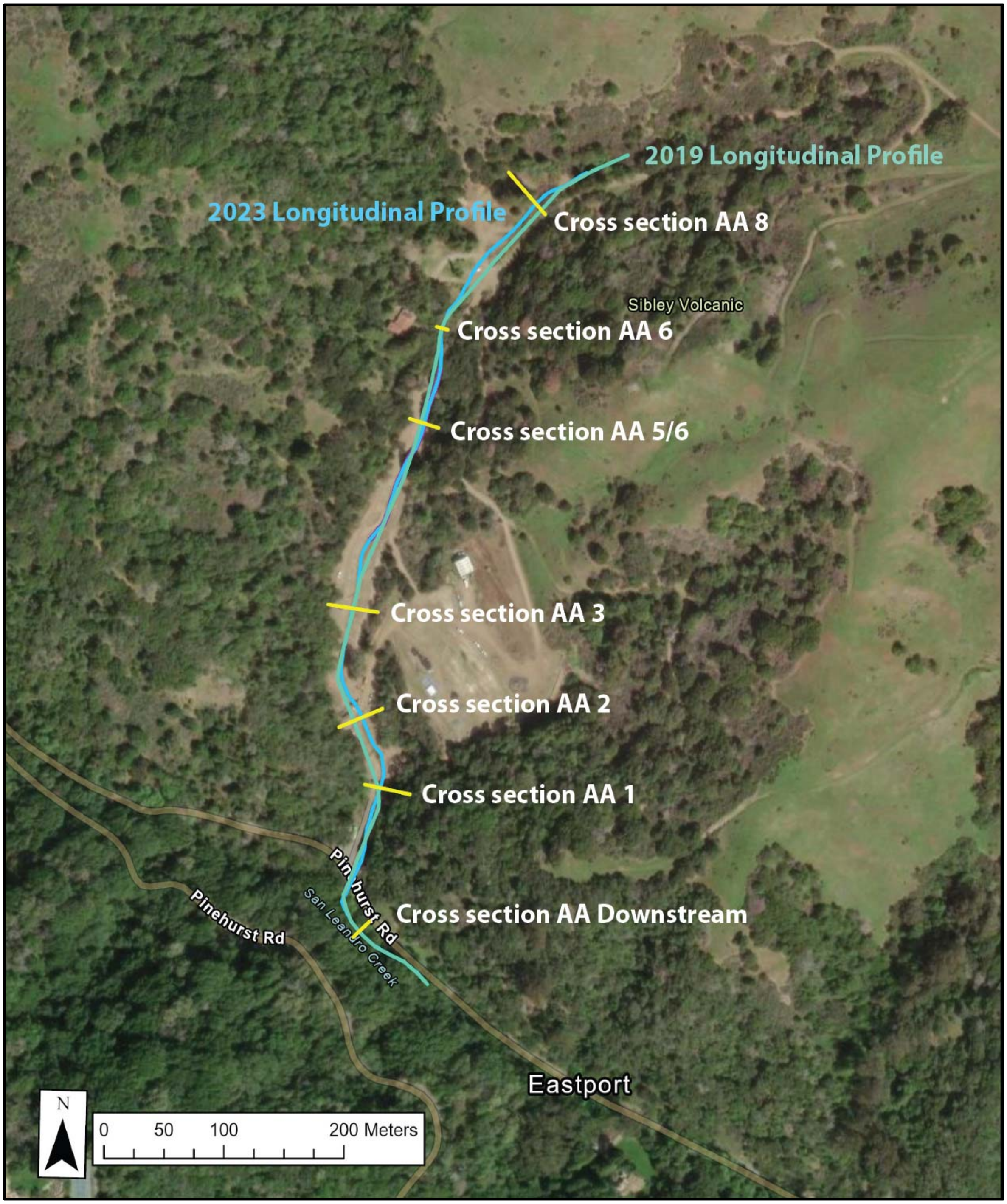

Figure 36. Map illustrating the locations of the seven channel cross sections (yellow lines) and the length of the 2019 (light green) and 2023 (light blue) channel longitudinal profiles.

Results

Simple plots of the seven channel/valley cross-sections (Figure 37 and 38) and the channel longitudinal profile (Figure 39) illustrate the pre-construction topography of the property. Notably, cross-sections AA1 and AA2 illustrate the flat valley floor, with the stream existing in the underground culvert. However, cross-section AA5/6 illustrates a reach where the culvert had failed, and the severely altered channel and culvert debris were exposed. And finally, the channel longitudinal profile illustrates the reaches where Alder Creek was exposed, reaches where it was culverted, reaches where the culvert was failing, and spot locations where the field team could survey the elevation of the sinkholes as compared to the adjacent valley floor elevation. In addition, the significant knickpoint (4.95 m in height) in the channel just upstream of the on-property residence is visible, indicating the instability of the system (Figure 40).

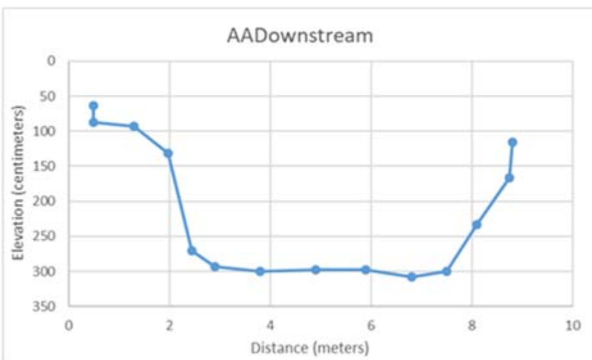

Figure 37. Left: Pre-construction channel cross section in the AA Downstream reach (Upper San Leandro Creek). Right: Photo looking downstream at the surveyed cross section location.

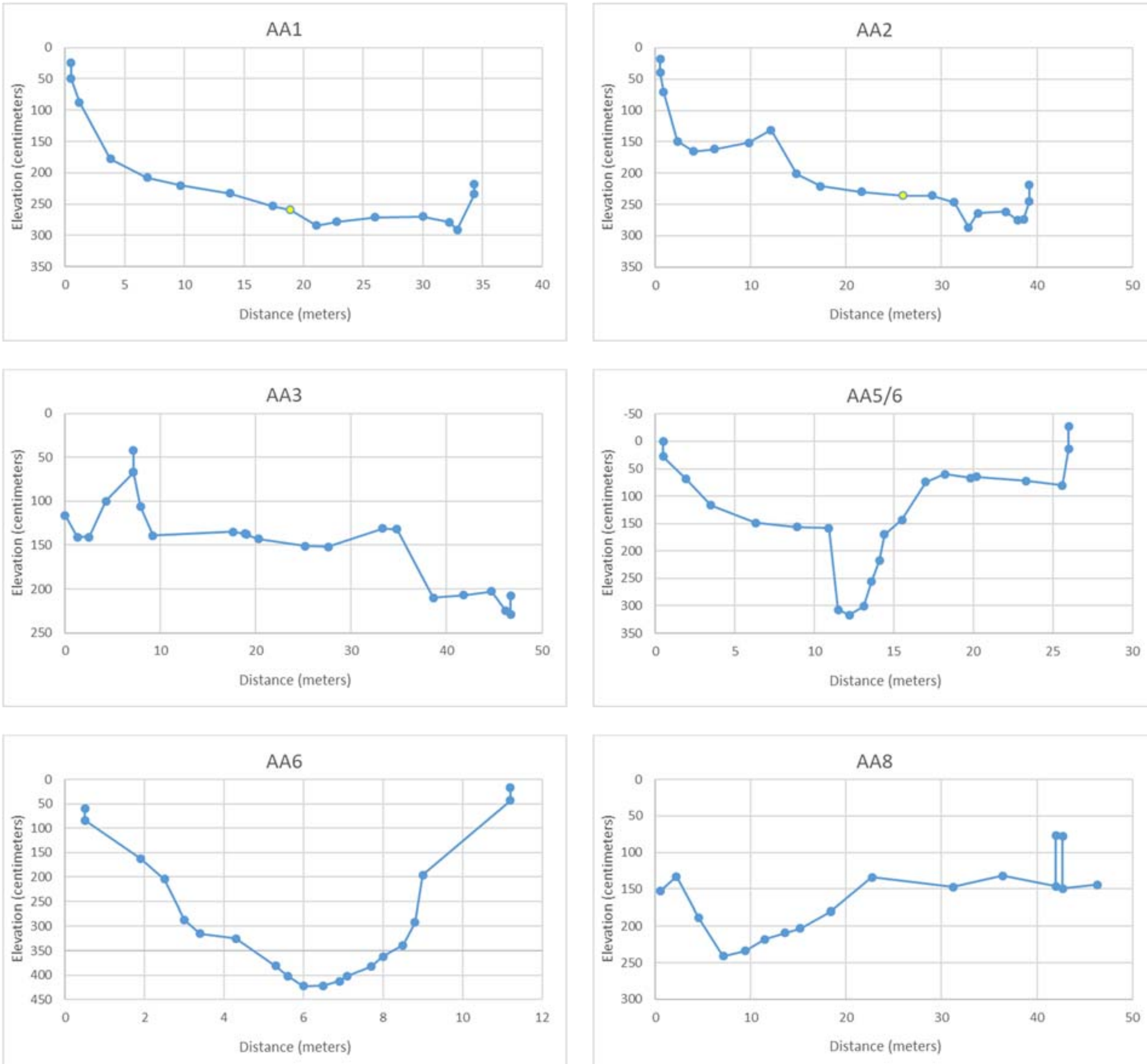

Figure 38. Pre-construction channel cross sections in the project footprint. Top left: Valley cross section in AA1. Yellow data point indicates the valley surface elevation above the culvert centerline. Top right: Valley cross section in AA2. Yellow data point indicates the valley surface elevation above the culvert centerline. Middle left: Valley cross section in AA3. Middle right: Valley and channel cross section in AA5/6. This location corresponds to the 2019 CRAM AA5, and the 2022 and 2023 CRAM AA6. Lower left: Channel cross section in 2019 AA6. This location is upstream and outside of the 2022 and 2023 AA6. Lower right: Valley cross section in AA8. Note the variable scales between plots.

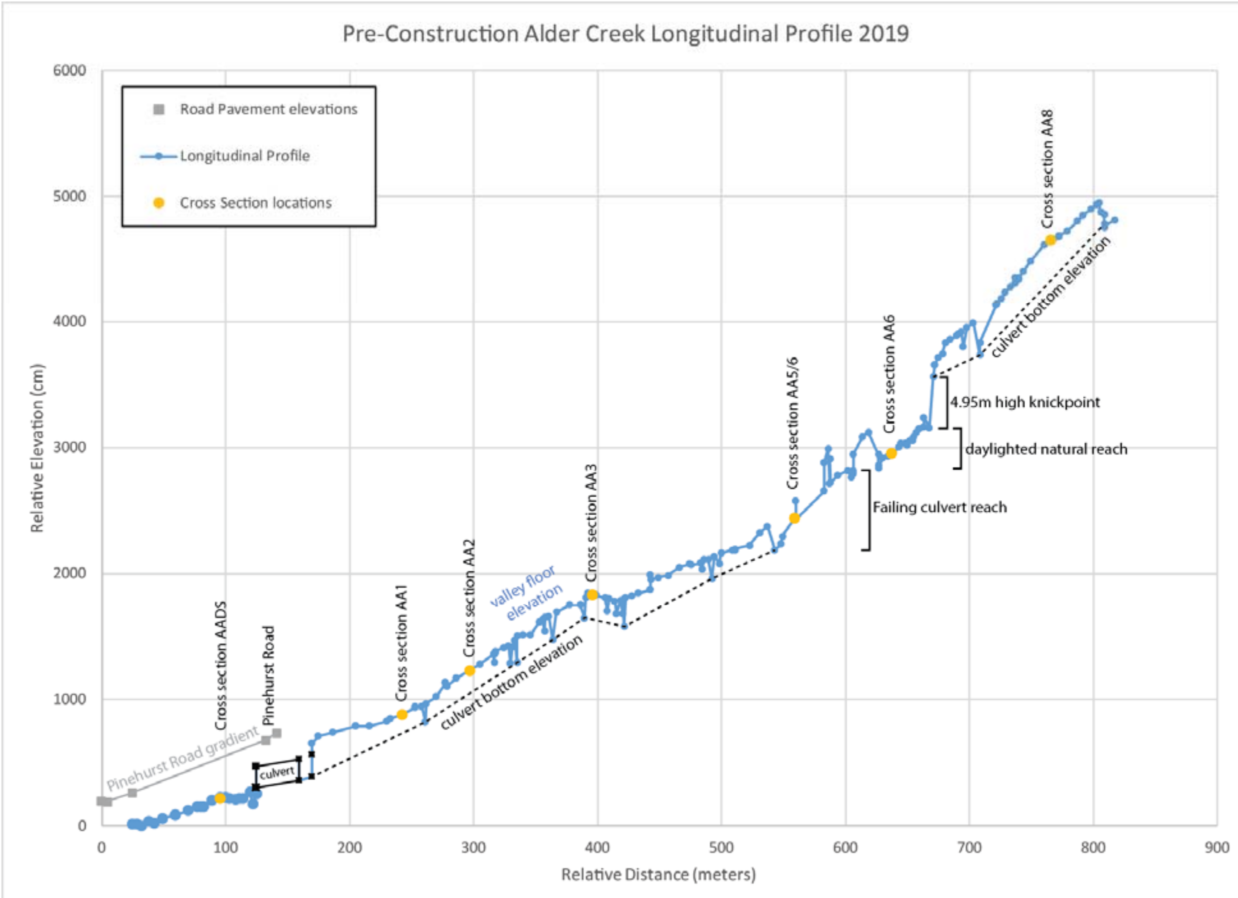

Figure 39. Pre-construction channel thalweg longitudinal profile. Profile extends from downstream in the AADS reach (Upper San Leandro Creek) upstream to the project boundary at the upstream end of the project.

Figure 40. Field photograph looking upstream at the knickpoint (labeled 4.95m high knickpoint in Figure 39) and collapsed culvert.

Although additional surveys were not completed after construction began, the pre-construction data can be combined with digital terrain model (DTM) data derived from the UAS surveys to illustrate the magnitude of change that has occurred. For example, Figure 41 shows the channel/valley cross section in CRAM AA1. In 2019, the valley floor was the dominant feature, without any hint of the channel, and only survey markers indicating the location of the underground culvert. However, the elevation data derived from the UAS survey at the same cross section location indicates the amount of change that has occurred through the construction of the new channel bed and banks. This same comparison can be completed for the cross section in CRAM AA8 (Figure 42), illustrating the extreme amount of excavation that was completed to create a stable channel bed. And finally, the comparison of the channel/valley longitudinal profile reveals the excavation that was required within the project to create a stable channel profile, given the steep valley slope (Figure 43).

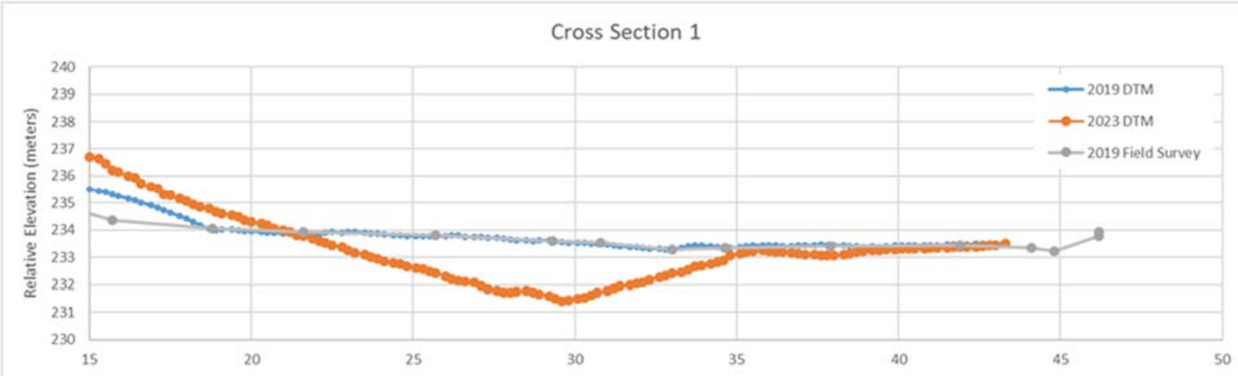

Figure 41. Comparison of field-surveyed 2019 channel/valley cross sectional morphology and 2019 and 2023 Unoccupied Aerial Systems survey derived channel/valley cross sectional morphology (digital terrain model, DTM) in CRAM AA1.

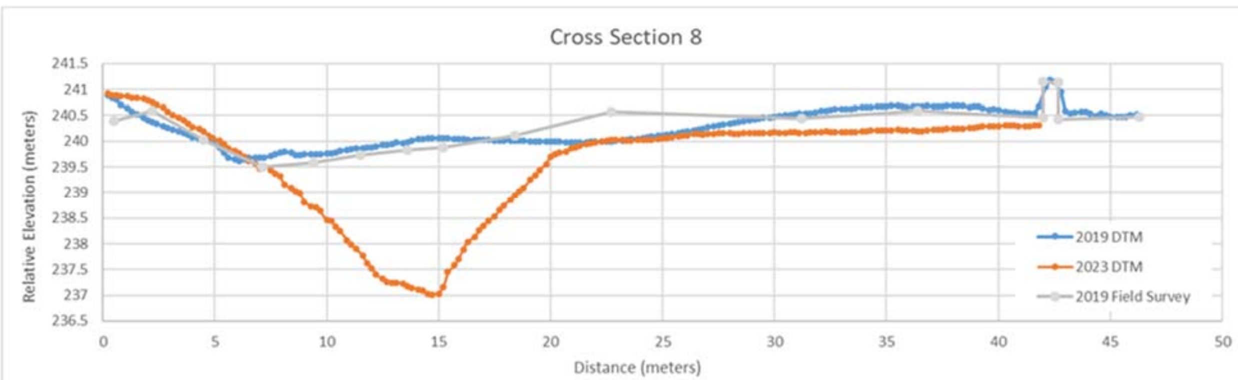

Figure 42. Comparison of field-surveyed 2019 channel/valley cross sectional morphology and 2019 and 2023 Unoccupied Aerial Systems survey derived channel/valley cross sectional morphology (digital terrain model, DTM) in CRAM AA8.

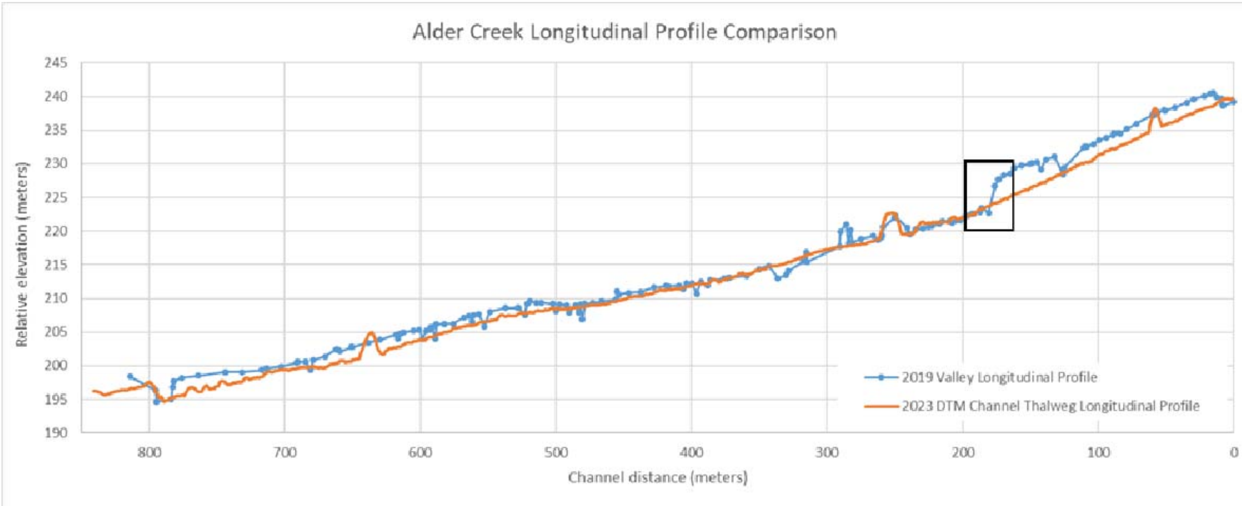

Figure 43. Comparison of field-surveyed 2019 channel/valley longitudinal profile (orange) and 2023 Unoccupied Aerial Systems survey derived channel longitudinal profile (blue). Elevation is relative. Profile length and elevation were best fit to each other using a number of known locations between the two surveys. The three peaks in the 2023 surveys are capturing the three new constructed bridge elevations, while the downstream-most 50m of the 2023 survey captures Pinehurst road elevation rather than the thalweg elevation. The black inset box shows the location of Figure 44.

Figure 44. Comparison between the 2019 valley morphology (left) and the 2023 valley morphology (right) at the hanging culvert location. See inset black box on the longitudinal profile in Figure 43 for this location.

Implications

Although channel surveys in these locations were not continued after construction was completed, the collection of Pre-Construction data helps illustrate the magnitude of change that occurred due to the daylighting and restoration of Alder Creek. The cross section data illustrates how significantly the valley has changed, and the volume of sediment that was excavated to make a new, stable channel. The longitudinal profile also illustrates the magnitude of change that has occurred, particularly in the creation of a new channel with the appropriate channel gradient throughout the project footprint. Removal of the culverted reaches and the overlying valley fill, and removal of the hanging culvert and knickpoint will help maintain stability and return geomorphic functioning to the watershed.

Discussion

SFEI's monitoring plan for the McCosker Creek Restoration and Public Access Project utilized the WRAMP framework to organize management questions by level, select appropriate monitoring methods, and manage the resulting data. The management questions included:

- Level 1: What length of new stream channel was created within the project, and where is the new channel located? How can these changes be mapped and visualized?
- Level 2: What is the pre-construction and post-construction condition of Alder Creek? How is condition changing as the project matures? How does condition compare to adjacent streams outside of the project footprint?
- Level 3: Was the project able to create channel complexity and a robust in-channel and riparian vegetation community? What is the quality of aquatic habitat provided by Alder Creek? Are water temperatures in Alder Creek appropriate for supporting resident rainbow trout? How much carbon has been/will be sequestered due to the project?

While the data in the sections above provide specific answers to some of these questions, others require synthesis of data from multiple methods to provide appropriate responses. The section below addresses questions that focus on more holistic aspects of Alder Creek's ecological functioning by synthesizing data from each method, with the goal of telling "the full story" of the restoration.

How much new channel was created, and how can the project's changes be mapped and visualized?

Obviously the project's detailed construction-level plans and drawings are the most accurate way to quantify the exact length and location of the newly daylighted channel. However, these drawings are not necessarily the most efficient way to communicate the changes brought about by the project, which arguably is just as important as conducting the project itself. The UAS orthomosaic imagery and associated data products provide a means for that communication.

First, mapping the new channel location on these products allows for highly accurate updated channel mapping to be submitted to the California Aquatic Resources Inventory (CARI) mapping through the CARI editor hosted on EcoAtlas (www.ecoatlas.org). CARI is the best available statewide aquatic resource map, and serves as the basemap for reporting and summarizing stream lengths using the Landscape Profile Tool in EcoAtlas. Updating length and location changes to the stream network keeps the statewide map up-to-date. Second, the orthomosaic imagery, which provides high resolution aerial photography of the project, provides side-by-side pre-construction and post-construction images to help “tell the story” of the project’s actions. Comparisons between 2019 and 2022 show the dramatic change in the valley morphology, with the construction of the new channel, and the significant excavation of material in the upstream reach. Comparisons between 2022 and 2023 show more subtle changes, as the channel makes small adjustments, or as the vegetation grows in height and increases in cover. These Level 1 products tell the story in pictures, visually illustrating the value of the project and the substantial amount of change it was created.

What is the condition of the daylighted channel?

Overall channel condition and complexity has been greatly increased due to the project, and provides much more capacity for desired functions and processes to occur within the creek corridor. But it is important to acknowledge that the project has only been completed for a single year and additional improvement is likely in the coming years and decades. The CRAM assessments illustrate that the pre-construction channel condition was in poor to lower-fair condition, with scores in the 4th to 18th percentile of condition for the Bay Area. The removal of the culvert and construction of the new channel immediately improved many aspects of condition, including: the longitudinal connectivity of the riparian corridor, the channel stability, the hydrologic connectivity with the floodplain and adjacent uplands, the number of structural patches present, the topographic complexity, and the vegetation community. CRAM scores in Year 0 were significantly higher, with scores entirely in fair condition, and in the 30th to 61st percentile of condition for the Bay Area. Scores in Year 1 were slightly lower than in Year 0, but remained in fair condition, and in the 30th to 52nd percentile of condition. This amount of variability in scores from year to year is typical in restoration projects as channel dimensions adjust and the vegetation community matures and grows.

How much complexity has been created within the daylighted channel?

In addition to improvements in condition, the complexity of the channel and its riparian corridor has also significantly increased due to the daylighting project. Within the pre-construction culverted reach, Alder Creek had zero complexity. Only the failing culverted reaches and the short portion of natural daylighted channel provided any complexity. In contrast, the newly created channel has many structural elements (e.g. large woody debris, boulders, in-channel vegetation, pools, bars), a variety of channel thalweg slopes (ranging between 4 and 11%), many habitat units (e.g. pools, riffles, rapids), a variety of grain sizes (silt and sand up to 75 cm placed boulders), important biotic complexity on the substrate (CPOM, macroalgae), and a wide range of plant species, heights, densities and cover provided by the young in-channel and riparian vegetation. Some elements of complexity were designed and constructed, however others have naturally developed during the single year since project completion. The channel complexity is significantly greater than the culverted channel, and is expected to increase as the young channel continues to mature.

What is the quality of aquatic habitat provided?

Aquatic habitat quality is largely dependent upon the complexity of the channel as described above, and thus is still developing. However, as compared to the culverted channel, the complexity of the daylighted channel has significantly increased and will likely continue to increase over the next decade and beyond. Currently, the aquatic habitat quality is seasonally variable, as illustrated by the dry reaches of the channel during Year 0 and Year 1. But the channel does provide habitat for aquatic species when surface water is present. For instance, EBRPD staff observed juvenile resident rainbow trout in the middle reaches of Alder Creek during Year 0 (early spring 2022), proving that if you build it they will come.

Aquatic habitat will benefit from future larger flows that will cause scour, creating deeper pools and areas of undercut banks, as well as transporting and depositing sand and gravel sized sediment in appropriate locations within the channel. Deeper pools will provide areas of cooler water that will last longer into the summer/fall months, while undercut banks can provide cover and velocity shelters during high flows. Deposits of sediment can provide appropriately sized spawning substrate from trout and also support benthic macroinvertebrates. Currently much of the channel is maintaining its dimensions as constructed, however the flows of Water Year 2023 illustrate that minor adjustments have occurred. For instance, some scour has occurred around boulders and logs (e.g. the pool where the temperature probe was located), and some evidence of slight incision and slight bank erosion is visible. A more diverse and complex channel will ultimately provide higher quality aquatic habitat.

The majority of the project length does not yet have significant riparian vegetation to provide cover and shading for the channel. This results in the growth of filamentous macroalgae, which was excessive in some reaches during Year 1. It also allows for growth of dense stands of cattails, which homogenize habitat units and shallow the channel by trapping fine sediment. However, the cattail growth can provide shading to the channel, which keeps water temperatures cool, as observed in the last months of the summer/fall season during Year 1. While water temperatures during construction were too warm to support resident rainbow trout, it appears that the amount of vegetation growth that occurred by the fall of Year 1 provided just enough shading so that water temperatures reached the threshold of being able to support resident oversummering rainbow trout. Until the riparian vegetation has matured, it is possible that this pattern of warm water temperatures early in the summer, followed by cooler water temperatures after enough in-channel vegetation has grown may continue.

How can the geomorphic and vegetative change that has occurred be visualized?

Each of the monitoring elements included in this monitoring plan produce visual representations of change that has occurred within the project footprint. Specific data products could be selected for additional graphic design and storytelling for a specific element of the project. For example, the comparisons of pre-construction and post-construction channel cross sections illustrate the removal of the flat valley topography, and the creation of the new channel. Continued high resolution cross sections (especially since construction is now complete) can track channel dimensions as it adjusts through time. The patterns in water temperature can be visualized, showing the change in daily temperature values due to the rapid growth of cattails and other in-channel vegetation during August of the Year 1 monitoring. Geomorphic elements of the PHab data can be plotted to show the variability along each PHab station, or can be plotted to show the change between monitoring years. Plots of grain size distribution or bankfull channel width/depth could alert managers to channel morphological change while it is in progress. Vegetative elements of PHab could also be plotted by PHab station length, to illustrate areas of more dense canopy cover or areas of rapid growth, by type and by right/left bank. And finally, specific metrics in CRAM are easily visualized, including the channel topographic complexity, which illustrates macro- and micro-topographic variability in the channel cross section, and the horizontal interspersion, which shows the complexity in the vegetation zones across the assessment area. In addition, each CRAM assessment is supported by a number of field photographs, which can be very powerful in illustrating the progression of a project.

Will this project contribute to carbon sequestration?

The benefit of conducting this monitoring outside of permit constraints is the ability to provide science support to EBRPD, to further their ability to quantify the carbon loss and sequestration associated with their projects. This monitoring element had two main objectives. First, to estimate the amount of carbon sequestered during the long-term, but also the amount of carbon loss to the atmosphere during the short-term due to project actions. And secondly, to develop new methods for reducing uncertainty in carbon estimation specifically for EBRPD lands.

The estimated amounts of carbon lost from the project during construction, and later stored in the project due to revegetation follow the project team's conceptual model. That is, it is expected that initially the project site would be a net carbon source because of the removal of existing vegetation and trees in order to construct the new channel. However, because of the increased amount of trees and vegetation planted in the project footprint, as well as naturally recruited vegetation, it is expected that significant amounts of carbon will ultimately be sequestered. Over the long term (~100 years), the results suggest that an additional 40 metric tons of carbon will be stored in the project area over the pre-construction condition. For the first time, these results *quantify* the expected carbon-related outcomes and suggest that carbon sequestration should be a planned important co-benefit of future restoration projects.

However, the estimation process revealed the many sources of uncertainty that exist in estimating carbon without collecting any supporting field data. The project team developed a new methodology within the prospectus that provides low-cost methods for biomass carbon monitoring specific to EBRPD lands. These methods represent a real contribution to Bay Area carbon science, and could be tested and refined in future projects. As a result, every EBRPD project could more accurately quantify carbon loss and storage, and the District as a whole could track and report changes in carbon storage due to both management actions and natural disturbance.

What is the overall value of the daylighting project?

Details about the individual components of the restoration have been documented through the permit-required monitoring and these additional monitoring elements. Taken individually, none of these methods are able to “tell the full story” of the restoration, and highlight its benefits and overall value.

Prior to construction, Alder Creek had low function, essentially only transporting water from the watershed downstream to Upper San Leandro Creek. The increased valley floor area provided economic value to the McCosker family, but the culverted channel provided very limited habitat value, and little geomorphic process or function. The watershed only provided a small fraction of the ecological value that it did historically.

As envisioned and designed, the project aimed for one large-scale holistic goal, and multiple detailed goals. Specifically, the project aimed to restore Alder Creek to a functioning system, and to remove invasive and non-native plants and replace with natives, to create habitat for wildlife and aquatic species (including rainbow trout, California red-legged frog, and Alameda whipsnake), and reduce surface and bank erosion into Upper San Leandro Creek. Measuring the status and progress of the detailed goals is much more straightforward than measuring the larger goal, although the ultimate measure of success is creating a functioning system. The “weight of evidence” approach of combining multiple monitoring elements to tell the story is the most practical way to measure progress towards a fully functioning system. The monitoring that has occurred within this project illustrates that although Alder Creek has only been daylighted for a single year, the function and value of the channel have significantly improved, and it is likely that the “fully functional” goal will eventually be achieved.

The value of the new channel, the restoration project, and its monitoring includes, but is not limited to:

- A newly created geomorphically functioning channel that is able to adjust its geometry to the amount of water and sediment delivered to it from the watershed;
- Geomorphic processes such as active sediment sourcing, transport, sorting, deposition, and delivery to downstream reaches;
- A natural channel bed that allows for flowing surface water to interact with the air, the sun, the sediment and the vegetation, exchanging nutrients and organic matter;
- Greater connection between surface water and the groundwater table;
- Habitat for the recruitment and growth of in-channel and riparian vegetation;
- Habitat for aquatic species, including algae, benthic macroinvertebrates and fish. New potential spawning, rearing, and oversummering habitat for resident rainbow trout;
- Habitat for riparian and upland wildlife species, providing habitat for feeding, foraging, reproduction, migration, and cover;
- Improved channel and riparian condition;
- Improved channel stability and reduced delivery of excess sediment downstream;
- Increased long-term carbon sequestration;

- A new recreation area for hiking, bird watching, and camping free from dangerous sinkholes, that increases the area of EBRPD lands, and contributes to their mission;
- Increased aesthetic value of the watershed;
- Demonstration of the daylighting of a previously neglected stream reach;
- Demonstration of how UAS flights can contribute detailed imagery and DEM data to a project;
- Demonstration of how carbon monitoring can be included within all restoration projects; and
- Demonstration of the WRAMP framework for a Bay Area restoration project, and guidance for future use in other projects.

This list of values is certainly not exhaustive, but is intended to illustrate many of the values that are not always considered when designing and implementing a restoration project. And because the channel is only a year post-construction, the number and magnitude of these values are expected to increase into the future.

Recommendations for future monitoring

This monitoring plan provides an example of how the WRAMP framework can be used to organize management questions, select appropriate monitoring methods, and manage monitoring data for a project. The framework is intentionally flexible and adaptable, and is beneficial because it utilizes standardized methods, and creates a space for coordination and collaboration. This framework can be utilized in future EBRPD projects to help the District monitor and track the performance of their projects, make comparisons between projects, make comparisons between their projects and their ambient stream and wetland resources, and make comparisons between their resources and resources in the region or the state. Use of the online EcoAtlas toolset can help manage, visualize, and communicate project progress and outcomes to regulatory agencies, stakeholders, and the interested public.

Specific to Alder Creek, we recommend that some monitoring elements should continue past the required monitoring time frame. For example, certain aspects of the permit-related monitoring may be valuable because they track project progress or because they inform management decisions, and thus should be continued as needed. Specifically considering the monitoring elements that were included in this monitoring plan, it is recommended that water temperature monitoring, condition assessment using CRAM, and future carbon estimates be continued into the future. Water temperature monitoring is relatively low effort, requiring only monthly visits to the sensors, and minor amounts of data processing and analysis. Yet the data is very informative for understanding the appropriateness of the habitat that has been created for supporting trout. Monitoring could continue for the next 2-5 years (occurring only during the summer/fall season), until enough riparian vegetation has grown to shade the water surface, and maintain cool temperatures throughout the season. Condition assessment using CRAM provides a low-cost but very powerful assessment of overall ecological condition. Two days of fieldwork for two people, plus minor preparation and data analysis, will allow the reassessment of the AAs included in this project. CRAM data provides the “common language” to track performance through time, allows for the use of established CRAM tools, and allows comparison to other projects or ambient conditions. EBRPD has trained CRAM practitioners in-house that can conduct the assessments. CRAM could be performed during Year 2 (2024), Year 5 (2027), and Year 10 (2032), plus anytime a major change occurs within the project (e.g. a large flood, a wildfire). This would provide consistent data across the lifetime of the project, and allow for linkages to other projects in the region. And finally, this project offers the opportunity to conduct some of the recommended actions and monitoring described within the carbon sequestration prospectus, to further develop a baseline dataset for the East Bay, reduce uncertainty in carbon estimates related to restoration projects, and bring EBRPD to the forefront of the science within the East Bay.

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