Russian River Biological Opinion Status and Data Report

Year 2019 – 2020

Sonoma Water

January 2023

Suggested Citation

Martini-Lamb, J. and Manning, D. J., editors. 2023. Russian River Biological Opinion Status and Data Report Year 2019. Sonoma County Water Agency, Santa Rosa, CA. 349 p.

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Table of contents

List of Appendices

CHAPTER 1 Introduction

On September 24, 2008, the National Marine Fisheries Service (NMFS) issued a 15-year Biological Opinion for water supply, flood control operations, and channel maintenance conducted by the U.S. Army Corps of Engineers (USACE), Sonoma County Water Agency (Water Agency), and Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed (NMFS 2008). The Biological Opinion authorizes incidental take of threatened and endangered Chinook salmon, coho salmon, and steelhead pending implementation of a Reasonable and Prudent Alternative (RPA) to status quo management of reservoir releases, river flow, habitat condition, and facilities in portions of the mainstem Russian River, Dry Creek, and Russian River Estuary. Mandated projects to ameliorate impacts to listed salmonids in the RPA are partitioned among USACE and the Water Agency. Each organization has its own reporting requirements to NMFS. Because coho salmon are also listed as endangered by the California Endangered Species Act (CESA), the Water Agency is party to a Consistency Determination issued by the California Department of Fish and Wildlife (CDFW) in November 2009. The Consistency Determination mandates that the Water Agency implement a subset of Biological Opinion projects that pertain to coho and the Water Agency is required to report progress on these efforts to CDFW.

Project implementation timelines in the Biological Opinion, and Consistency Determination, specify Water Agency reporting requirements to NMFS and CDFW and encourage frequent communication among the agencies. The Water Agency has engaged both NMFS and CDFW in frequent meetings and has presented project status updates on many occasions since early 2009. Although not an explicit requirement of the Biological Opinion or Consistency Determination, the Water Agency has elected to coalesce reporting requirements into one annual volume for presentation to the agencies. The following document represents the eleventh report for year 2019-2020. Previous annual reports can be accessed at http://www.sonomawater.gov.

Water Agency projects mandated by the Biological Opinion and Consistency Determination fall into six major categories:

- Biological and Habitat Monitoring;
- Habitat Enhancement;
- California Environmental Quality Act (CEQA) Compliance and Permitting;
- Planning and Adaptive Management;
- Water and Fish Facilities Improvements; and
- Public Outreach.

This report contains status updates for planning efforts, environmental compliance, and outreach but the majority of the technical information we present pertains to monitoring and habitat enhancement. The Biological Opinion requires extensive fisheries data collection in the mainstem Russian River, Dry Creek, and Estuary to detect trends and inform habitat enhancement efforts. The report presents each data collection effort independently and the primary intent of this document is to clearly communicate recent results. However, because Chinook salmon, coho salmon, and steelhead have complex life history patterns that integrate all of these environments, we also present a synthesis section to discuss the interrelated nature of the data. Some monitoring programs are extensions of ongoing Water Agency efforts that were initiated a decade or more before receipt of the Biological Opinion.

References

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation District in the Russian River Watershed. September 24, 2008.

CHAPTER 2 Public Outreach

Biological Opinion Requirements

The Biological Opinion includes minimal *explicit* public outreach requirements. The breadth and depth of the RPAs, however, *implies* that implementation of the Biological Opinion will include a robust public outreach program.

RPA 1 (Pursue Changes to D1610 Flows) mandates two outreach activities. First, it requires Sonoma Water, with the support of NMFS staff, to conduct outreach "to affected parties in the Russian River watershed" regarding permanently changing Decision 1610. Second, the RPA requires Sonoma Water to update NMFS on the progress of temporary urgency changes to flows during Section 7 progress meetings and as public notices and documents are issued.

RPA 2 (Adaptive Management of the Outlet Channel) requires that within six months of the issuance of the Biological Opinion Sonoma Water, in consultation with NMFS, "conduct public outreach and education on the need to reduce estuarine impacts by avoiding mechanical breaching to the greatest extent possible."

Finally, RPA 3 (Dry Creek Habitat Enhancements, refers to public outreach in the following mandate, "Working with local landowners, DFG[1] and NMFS, Water Agency[2] will prioritize options for implementation" of habitat enhancement.

The remaining RPAs do not mention public outreach.

Water Agency Public Outreach Activities – 2019

Meetings

Public Policy Facilitating Committee (PPFC) meeting - The PPFC met on April 22, 2019 at the Lake Sonoma Visitors Center. Notices for the meetings were sent out to approximately 800 individuals and agencies and a press release was issued. Approximately 50 people attended the meeting.

In 2019, the meeting included Overview of the 2018 projects and a preview of 2019 projects. Presentations included: Russian River Estuary Management Project Monitoring, Jessica Martini-Lamb, Sonoma Water Environmental Resources Manager; Dry Creek Habitat Enhancement Project Update & Monitoring Effort, David Manning, Sonoma Water Environmental Resources Manager and Neil Lassettre, Sonoma Water Principal Environmental Specialist; Fish Habitat Flows & Water Rights Project, Jessica Martini-Lamb, Sonoma Water Environmental Resources Manager and Barry Dugan, Sonoma Water Principal Programs Specialist.

[1] DFG (Department of Fish and Game) is now known as the California Department of Fish and Wildlife.
[2] Sonoma County Water Agency is now know as Sonoma Water

Community Meetings, Events & Tours – The 11th Annual Russian River Estuary Lagoon Management Community Meeting was held on August 28, 2019 at the Jenner Community Center. The meeting included discussions of 2018 Lagoon Management review (Martini Lamb); Adaptive Management Plan Update, Dane Behrens, Environmental Science Associates; Fisheries Monitoring Results, David Cook, Sonoma Water; Water Quality Monitoring Results, Jeff Church, Sonoma Water; Invertebrate Monitoring Results, Jessica Martini-Lamb, Sonoma Water; Monitoring Pinnipeds at Jenner, Andrea Pecharich, Sonoma Water.

About 40 people attended the meeting.

Ribbon Cutting Event for Dry Creek USACE CAP Project – On April 22, 2019 the U.S. Army Corps of Engineers (Army Corps) and Sonoma Water hosted a ribbon-cutting celebration and a Design Agreement signing ceremony at the site of the completed Reach 4 on Dry Creek. The event was attended by more than 100 guests, including Brigadier General Kimberly Colloton from the Army Corps, and Congressman Jared Huffman. The event was also hosted by the property owner, Ferrari-Carano Winery & Vineyards, who have been supporters and partners in the project. The event marked the completion of Reach 4 under the Army Corps CAP program, which brings the habitat enhancement total to more than three miles of the six miles required under the Biological Opinion. The Design Agreement signing allows the two agencies to continue to work together to complete the remaining three miles of the project.

Tours held for public officials and others (coordinated with NMFS, CDFW, Corps and Sonoma Water staff)

May 28, 2019 -- Staff from Congressman Mike Thompson's North Coast and Washington, D.C. offices along with USACE and Sonoma Water staff toured a Dry Creek Habitat Enhancement site located just downstream of the Warm Springs Dam.

June 18, 2019 – Sonoma Water Board Members and County Supervisors Lynda Hopkins and James Gore, Jessica Martini-Lamb, David Manning and various SW staff participated in a half-day river float to educate key officials about conditions along the Russian River and how current conditions correlate to conditions identified in the Fish Habitat Flows and Water Rights Project Draft EIR.

Other Outreach

Monthly BO Updates to WAC and TAC – On a monthly basis, Sonoma Water provides an update on all Biological Opinion activities to the Water Advisory and Technical Advisory committees, which consist of the agency's water contractors. The reports are also posted to Sonoma Water's website.

Truett Hurst Salmon Run: In February of 2019 Sonoma Water participated in an event hosted by Truett Hurst Winery and attended by several hundred members of the public. Staff set up in informational table and led tours of the Dry Creek Habitat Enhancement site that is located on the winery property.

Fish Flow Videos – Sonoma Water staff worked with a consultant to produce a series of hand-drawn video segments to improve communication and understanding of key topics contained in Fish Habitat Flows and Water Rights Project Draft EIR.

Free Media –In 2019, press releases were issued on community meetings regarding the estuary and Dry Creek, and the Public Policy Facilitating Committee meeting.

Electronic Media – Sonoma Water updated its Biological Opinion webpage, including links on new documents and meetings. In addition, Sonoma Water posted videos on the Fish Flow DEIR and the Mirabel Fish Passage Improvement Project, which can be accessed via the agency's website. Email alerts interested stakeholders regarding activities in the estuary were issued numerous times in 2019 for four separate river mouth closings.

CHAPTER 3 Pursue Changes to Decision 1610 Flows

Two major reservoir projects provide water supply storage in the Russian River watershed: 1) Coyote Valley Dam/Lake Mendocino, located on the East Fork of the Russian River three miles east of Ukiah, and 2) Warm Springs Dam/Lake Sonoma, located on Dry Creek 14 miles northwest of Healdsburg. The Water Agency is the local sponsor for these two federal water supply and flood control projects, collectively referred to as the Russian River Project. Under agreements with the USACE, the Water Agency manages the water supply storage space in these reservoirs to provide a water supply and maintain summertime Russian River and Dry Creek streamflows.

The Water Agency holds water-right permits[1] issued by the State Water Resources Control Board (SWRCB) that authorize the Water Agency to divert[2] Russian River and Dry Creek flows and to re-divert[3] water stored and released from Lake Mendocino and Lake Sonoma. The Water Agency releases water from storage in these lakes for delivery to municipalities, where the water is used primarily for residential, governmental, commercial, and industrial purposes. The primary points of diversion include the Water Agency's facilities at Wohler and Mirabel Park (near Forestville). The Water Agency also releases water to satisfy the needs of other water users and to contribute to the maintenance of minimum instream flow requirements in the Russian River and Dry Creek established in 1986 by the SWRCB's Decision 1610. These minimum instream flow requirements vary depending on specific hydrologic conditions (normal, dry, and critical) that are based on cumulative inflows into Lake Pillsbury in the Eel River watershed.

NMFS concluded in the Russian River Biological Opinion that the artificially elevated summertime minimum flows in the Russian River and Dry Creek currently required by Decision 1610 result in high water velocities that reduce the quality and quantity of rearing habitat for coho salmon and steelhead. NMFS' Russian River Biological Opinion concludes that reducing Decision 1610 minimum instream flow requirements will enable alternative flow management scenarios that will increase available rearing habitat in Dry Creek and the upper Russian River, and provide a lower, closer-to-natural inflow to the estuary between late spring and early fall, thereby enhancing the potential for maintaining a seasonal freshwater lagoon that would likely support increased production of juvenile steelhead and salmon.

Changes to Decision 1610 are under the purview of the SWRCB, which retained under Decision 1610 the jurisdiction to modify minimum instream flow requirements if future fisheries studies identified a benefit. NMFS recognized that changing Decision 1610 would require a multi-year (6

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[1] SWRCB water-right permits 12947A, 12949, 12950 and 16596.
[2] Divert – refers to water diverted directly from streamflows into distribution systems for beneficial uses or into storage in reservoirs.
[3] Re-divert – refers to water that has been diverted to storage in a reservoir, then is released and diverted again at a point downstream.

to 8 years) process of petitioning the SWRCB for changes to minimum instream flow requirements, public notice of the petition, compliance with CEQA, and a SWRCB hearing process. To minimize the effects of existing minimum instream flows on listed salmonids during this process, the Russian River Biological Opinion stipulated that the Water Agency "will seek both long term and interim changes to minimum flow requirements stipulated by D1610." The permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion are summarized in Figure 3.1.

Permanent Changes

The Russian River Biological Opinion requires the Water Agency to begin the process of changing minimum instream flows by submitting a petition to change Decision 1610 to the SWRCB within one year of the date of issuance of the final Biological Opinion. The Water Agency filed a petition with the SWRCB on September 23, 2009, to permanently change Decision 1610 minimum instream flow requirements. The requested changes are to reduce minimum instream flow requirements in the mainstem Russian River and Dry Creek between late spring and early fall during normal and dry water years and promote the goals of enhancing salmonid rearing habitat in the upper Russian River mainstem, lower river in the vicinity of the Estuary, and Dry Creek downstream of Warm Springs Dam. NMFS' Russian River Biological Opinion concluded that, in addition to providing fishery benefits, the lower instream flow requirements "should promote water conservation and limit effects on in-stream river recreation." NMFS' recommended changes, based on observations during the 2001 interagency flow-habitat study and the 2007 low flow season, to achieve these goals are provided in the Russian River Biological Opinion (NMFS 2008) and are summarized in Figure 3.1.

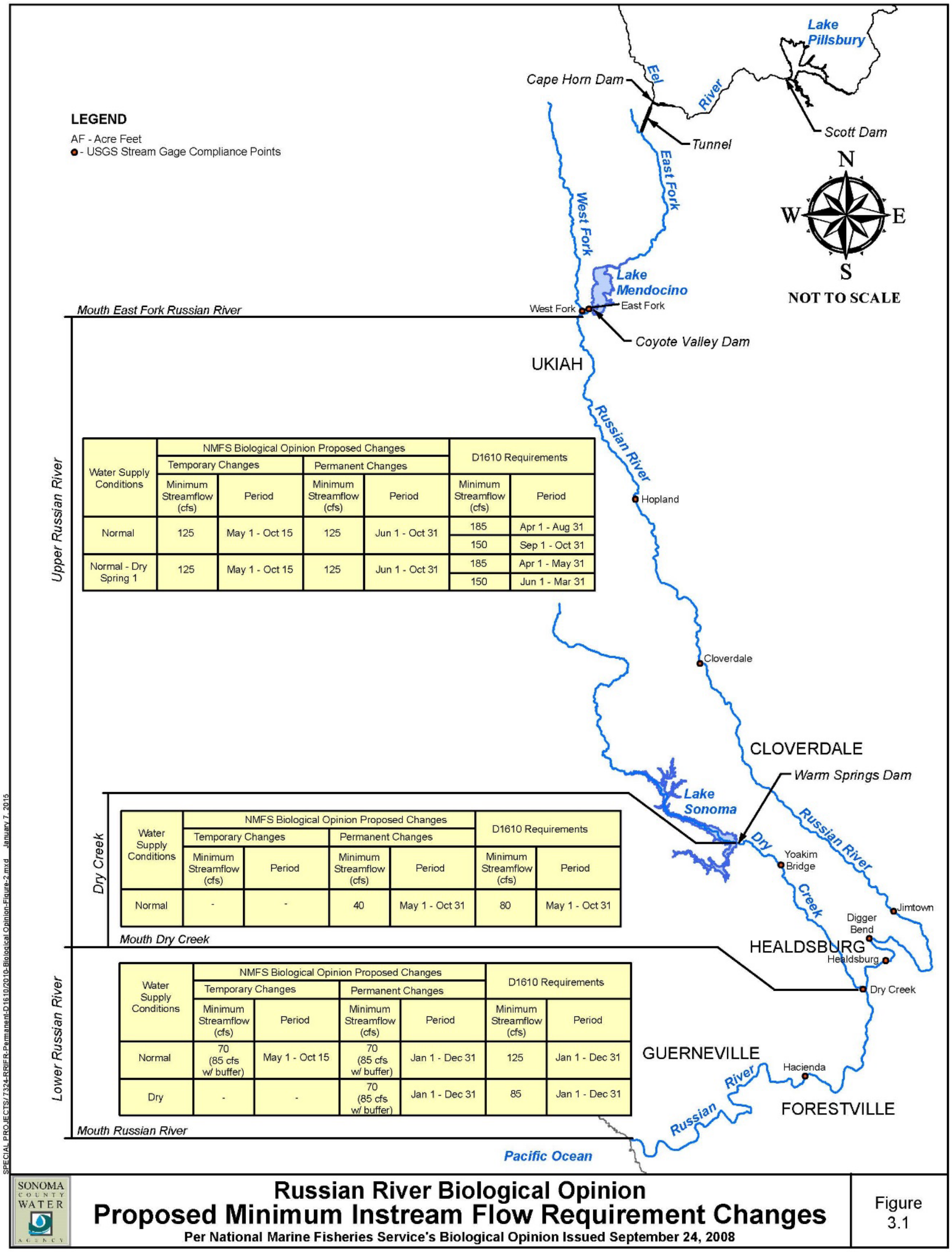
Summary Status

The SWRCB issued a second amended public notice of the Water Agency's petition to modify Decision 1610 for public comment on March 29, 2010. Following filing of the petition to change Decision 1610, the Water Agency issued a Notice of Preparation (NOP) of an Environmental Impact Report (EIR) for the Fish Habitat Flows and Water Rights Project (Fish Flow Project).

A Draft Environmental Impact Report (EIR) was released for public review on August 19, 2016. The public comment period closed on March 10, 2017, after extending the comment period to allow additional time to review an errata released on January 26, 2017. Sonoma Water staff worked on responding to comments received on the Draft EIR in 2019.

Temporary Changes

Until the SWRCB issues an order on the petition to permanently modify Decision 1610, the minimum instream flow requirements specified in Decision 1610 (with the resulting adverse impacts to listed salmonids) will remain in effect, unless temporary changes to these requirements are made by the SWRCB. The Russian River Biological Opinion requires that the Water Agency petition the SWRCB for temporary changes to the Decision 1610 minimum instream flow requirements beginning in 2010 and for each year until the SWRCB issues an



Upper Russian River

Water Supply Conditions	NMFS Biological Opinion Proposed Changes – Temporary Changes: Minimum Streamflow (cfs)	Temporary Changes: Period	Permanent Changes: Minimum Streamflow (cfs)	Permanent Changes: Period	D1610 Requirements: Minimum Streamflow (cfs)	D1610 Requirements: Period
Normal	125	May 1 - Oct 15	125	Jun 1 - Oct 31	185	Apr 1 - Aug 31
					150	Sep 1 - Oct 31
Normal - Dry Spring 1	125	May 1 - Oct 15	125	Jun 1 - Oct 31	185	Apr 1 - May 31
					150	Jun 1 - Mar 31

Dry Creek

Water Supply Conditions	NMFS Biological Opinion Proposed Changes – Temporary Changes: Minimum Streamflow (cfs)	Temporary Changes: Period	Permanent Changes: Minimum Streamflow (cfs)	Permanent Changes: Period	D1610 Requirements: Minimum Streamflow (cfs)	D1610 Requirements: Period
Normal	-	-	40	May 1 - Oct 31	80	May 1 - Oct 31

Lower Russian River

Water Supply Conditions	NMFS Biological Opinion Proposed Changes – Temporary Changes: Minimum Streamflow (cfs)	Temporary Changes: Period	Permanent Changes: Minimum Streamflow (cfs)	Permanent Changes: Period	D1610 Requirements: Minimum Streamflow (cfs)	D1610 Requirements: Period
Normal	70 (85 cfs w/ buffer)	May 1 - Oct 15	70 (85 cfs w/ buffer)	Jan 1 - Dec 31	125	Jan 1 - Dec 31
Dry	-	-	70 (85 cfs w/ buffer)	Jan 1 - Dec 31	85	Jan 1 - Dec 31

Figure 3.1. A summary of the permanent and temporary changes to Decision 1610 minimum instream flow requirements specified by NMFS in the Russian River Biological Opinion.

order on the Water Agency's petition for the permanent changes to these requirements. NMFS' Russian River Biological Opinion only requires that petitions for temporary changes "request that minimum bypass flows of 70 cfs be implemented at the USGS gage at the Hacienda Bridge between May 1 and October 15, with the understanding that for compliance purposes SCWA will typically maintain about 85 cfs at the Hacienda gage. For purposes of enhancing steelhead rearing habitats between the East Branch and Hopland, these petitions will request a minimum bypass flow of 125 cfs at the Healdsburg gage between May 1 and October 15."

Summary Status

The Water Agency submitted a Temporary Urgency Change Petition to the SWRCB on April 24, 2019, to comply with the requirements of the Russian River Biological Opinion (Appendix 3-1). The SWRCB issued an Order approving the Water Agency's TUCP on June 20, 2019 (Appendix 3-2).

The SWRCB's Order made the following changes to the Water Agency's permits until October 15, 2019: minimum instream flow in the upper Russian River (from its confluence with the East Fork of the Russian River to its confluence with Dry Creek) remained at or above 125 cfs; and minimum instream flow in the lower Russian River (from its confluence with Dry Creek to the Pacific Ocean) remained at or above 70 cfs. For purposes of compliance with the Order, the minimum instream flow requirements for the upper Russian River were measured on a 5-day running average of average daily stream flow measurements, provided that instantaneous flow would be no less than 110 cfs. The minimum instream flow for the lower Russian River was based on instantaneous flow measurements and was no less than 70 cfs.

The Order included several terms and conditions, including requirements for fisheries habitat monitoring and regular consultation with National Marine Fisheries Service and California Department of Fish and Wildlife regarding fisheries conditions, preparation of a water quality monitoring plan and summary data report, reporting on hydrologic conditions of the Russian River system), and reporting of activities and programs implemented by the Water Agency and its contractors to assess and reduce water loss and promote increasing water use efficiency.

Reports to fulfill the terms of the Order were prepared and submitted to the SWRCB and are provided in Appendix 3-3. Water quality monitoring results were posted to the Water Agency website and are provided in Appendix 3-3. Water quality monitoring in the Russian River Estuary is further discussed in Chapter 4.

References

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation District in the Russian River Watershed. September 24, 2008.

CHAPTER 4 Estuary Management

4.0 Introduction

The Russian River estuary (Estuary) is located approximately 97 kilometers (km; 60 miles) northwest of San Francisco in Jenner, Sonoma County, California. The Estuary extends from the mouth of the Russian River upstream approximately 10 to 11 km (6 to 7 miles) between Austin Creek and the community of Duncans Mills (Heckel 1994). When a barrier beach forms and closes the river mouth, a lagoon forms behind the beach and reaches up to Vacation Beach.

The Estuary may close throughout the year as a result of a barrier beach forming across the mouth of the Russian River. The mouth is located at Goat Rock State Beach (California Department of Parks and Recreation). Although closures may occur at any time of the year, the mouth usually closes during the spring, summer, and fall (Heckel 1994; Merritt Smith Consulting 1997, 1998, 1999, 2000; Sonoma Water and Merritt Smith Consulting 2001). Closures result in ponding of the Russian River behind the barrier beach and, as water surface levels rise in the Estuary, flooding may occur. The barrier beach has been artificially breached for decades; first by local citizens, then the County of Sonoma Public Works Department, and, since 1995, by the Sonoma County Water Agency. Sonoma Water's artificial breaching activities are conducted in accordance with the Russian River Estuary Management Plan recommended in the Heckel (1994) study. The purpose of artificially breaching the barrier beach is to alleviate potential flooding of low-lying properties along the Estuary.

The National Marine Fisheries Service's (NMFS) Russian River Biological Opinion (NMFS 2008) found that artificially elevated inflows to the Russian River estuary during the low flow season (May through October) and historic artificial breaching practices have significant adverse effects on the Russian River's estuarine rearing habitat for steelhead, coho salmon, and Chinook salmon. The historical method of artificial sandbar breaching, which is done in response to rising water levels behind the barrier beach, adversely affects the Estuary's water quality and freshwater depths. The historical artificial breaching practices create a tidal marine environment with shallow depths and high salinity. Salinity stratification contributes to low dissolved oxygen at the bottom in some areas. The Biological Opinion (NMFS 2008) concludes that the combination of high inflows and breaching practices impact rearing habitat because they interfere with natural processes that cause a freshwater lagoon to form behind the barrier beach. Fresh or brackish water lagoons at the mouths of many streams in central and southern California often provide depths and water quality that are highly favorable to the survival of rearing salmon and steelhead.

The Biological Opinion's Reasonable and Prudent Alternative (RPA) 2, Alterations to Estuary Management (NMFS 2008) requires Sonoma Water to collaborate with NMFS and to modify Estuary water level management in order to reduce marine influence (high salinity and tidal inflow) and promote a higher water surface elevation in the Estuary (formation of a fresh or brackish lagoon) for purposes of enhancing the quality of rearing habitat for young-of-year and age 1+ juvenile (age 0+ and 1+) steelhead from May 15 to October 15 (referred to hereafter as the “lagoon management period”). A program of potential, incremental steps are prescribed to accomplish this, including adaptive management of a lagoon outlet channel on the barrier beach, study of the existing jetty and its potential influence on beach formation processes and salinity seepage through the barrier beach, and a feasibility study of alternative flood risk measures. RPA 2 also includes provisions for monitoring the response of water quality, invertebrate production, and salmonids in the Estuary to the management of water surface elevations during the lagoon management period.

Barrier Beach Management

Adaptive Management Plan

RPA 2 requires Sonoma Water, in coordination with NMFS, California Department of Fish and Wildlife (CDFW), and the U.S. Army Corps of Engineers (USACE), to annually prepare barrier beach outlet channel design plans.

Sonoma Water contracted with Environmental Science Associates (ESA) to prepare the Russian River Estuary Outlet Channel Adaptive Management Plan. The approach of the plan was to meet the objective of RPA 2 to the greatest extent feasible while staying within the constraints of existing regulatory permits and minimizing the impact to aesthetic, biological, and recreational resources of the site. Sonoma Water, in collaboration with the resource management agencies, conducted an extensive review of the plan in 2018. This update resulted in a substantial update to the 2019 plan. The measures developed in the 2019 management plan, when implemented, may not fully meet the objective established by the RPA. The concept of this approach has been developed and continues to evolve in coordination with NMFS, CDFW, and California State Parks. Estuary management for 2019 was discussed at a meeting on March 28, 2019, that included representatives from NMFS and CDFW, as well as Sonoma Water, Bodega Marine Laboratory, the U.S. Army Corps of Engineers, the North Coast Regional Water Quality Control Board, and ESA. A draft of the 2019 plan was provided to the Estuary Management Team (Section 9) on March 28, 2019, for review. Comments on the draft plan from these representatives informed the revision of the draft plan to create the final plan, which was finalized on May 22, 2019.

Beach Topographic Surveys

A monthly topographic survey of the beach at the mouth of the Russian River is also required under RPA 2. Topographic data was collected monthly in 2019 and provided to NMFS and CDFW. The April 2019 topographic survey was cancelled due to the presence of neonate (less than 1 week old) harbor seals at the mouth of the Russian River. The November 2019 survey was postponed due to wave conditions that prevented safe access to the beach until December 4, 2019. This resulted in two December 2019 surveys. The beach topographic maps are provided in Appendix 4-1. The topographic maps provide documentation of changing beach widths and crest heights, which influence both flood risk and the need to respond to river mouth closures through beach management activities.

2019 Beach and River Mouth Conditions

A barrier beach formed four times in 2019. All four river mouth closures ended in self-breaches and Sonoma Water did not conduct water level management activities (Table 4.0.1). The Russian River mouth was closed to the ocean for a total of 27 days (or 7%) in 2019.

Table 4.0.1. Summary of Russian River mouth closures in 2019. No beach management activities were conducted in 2019.

Closure Date	Beach Management Date	No. Days Closed	Activity Time[1]	Water Elevation (ft)[2]	Beach Management Activity[3]	Excavated Volume (CY)[4]
15-May	16-May	1	None	6.24	None	0
18-Jul	3-Aug	16	None	8.56	None	0
18-Oct	22-Oct	4	None	5.23	None	0
21-Nov	27-Nov	6	None	8.26	None	0

[1] Estimated period that excavator/bulldozer equipment was on the beach.

[2] Water surface elevation recorded at the Jenner gage located at the Jenner Visitor's Center.

[3] Beach management activity consists of a pilot channel to initiate an artificial breach of the barrier beach or outlet channel to form a lagoon.

[4] Estimated volume of sand excavated with heavy equipment during artificial breach or lagoon management activity.

Lagoon Management Period Closures, Outlet Channel Implementation, and Self-Breaches

Time series of Estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 4.0.1 for the entire 2019 lagoon management season (ESA 2020). The lagoon water level time series (Figure 4.0.1a) summarizes the fully-tidal conditions in the Estuary throughout summer, and also shows the closure events that occurred later in the fall. During the management period, Russian River flows were higher than during the dry 2019 conditions, and similar to the wet 2017 conditions. As shown in Figure 4.0.1d, flows at Hacienda did not drop below 150 cubic feet per second (cfs) at any time in 2019.

As in prior years, wave heights declined in May and June and were lowest through July, August, and September (Figure 4.0.1b). Although swell events during the summer tended to have wave heights of less than 5 feet, there were almost ten events where wave periods were above 18 seconds; long-period waves are known to be more effective at moving sand onto the beach. The location of the inlet played a role in the shape of the beach and the hydrology of the estuary, similarly to 2017. As with that year, wet conditions forced the mouth to migrate north, and led to an elongated channel in spring and summer, before the mouth eventually breached near the jetty on August 3rd (ESA 2020).

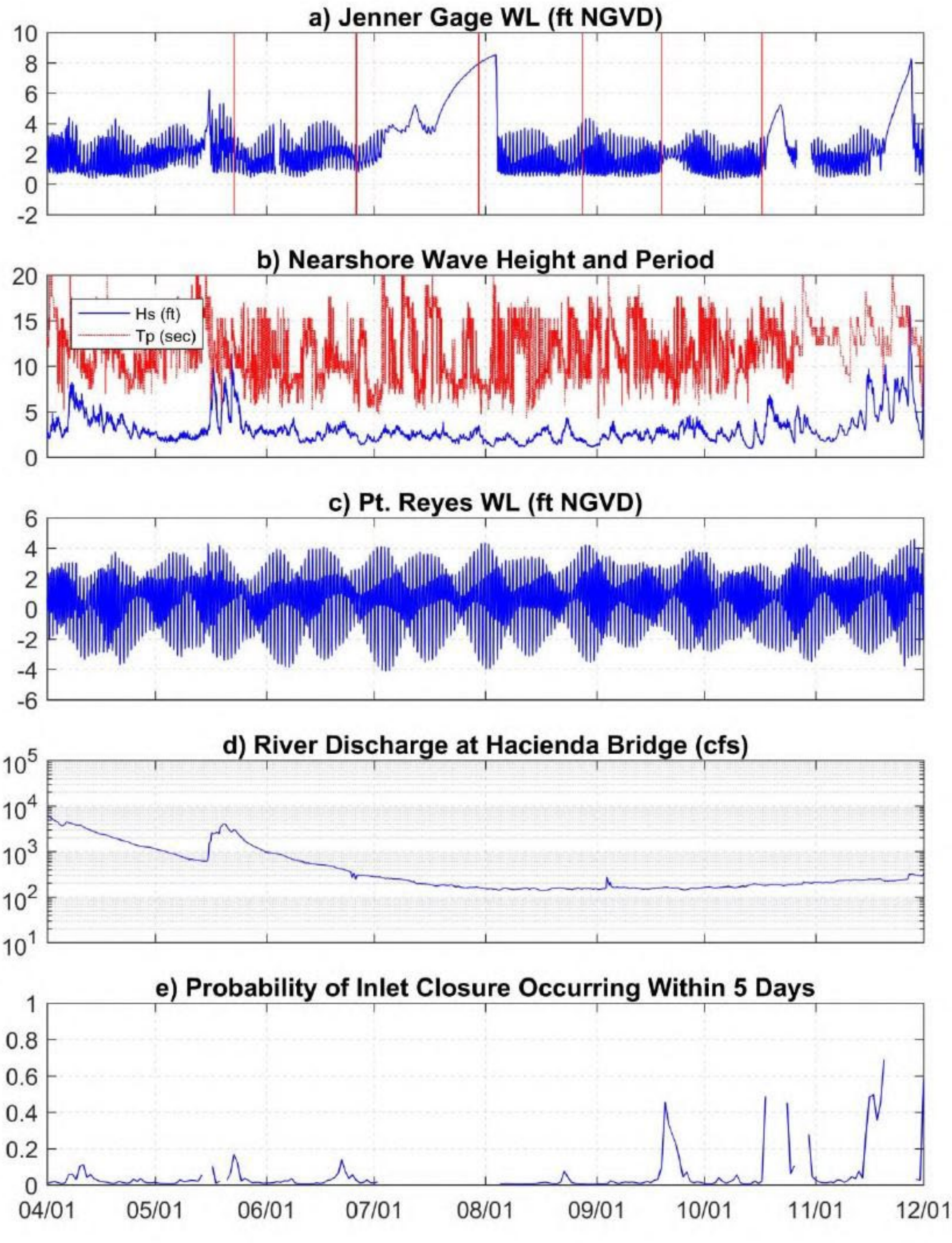


Figure 4.0.1. Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2019.

During the 2019 lagoon management period, Sonoma Water staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. The winter of 2018/2019 was relatively wet, including two runoff events surpassing 40,000 cubic feet per second (cfs) in February alone. The peak event crested at 72,000 cfs at the USGS Hacienda Bridge gauge on February 27th. Overall, the winter had similarities to the winter of 2016/2017, and was a return to wet conditions after the relatively dry winter of 2017/2018. As a result of these high flow conditions, the beach north of the jetty groin experienced extensive erosion during the winter and was reconstructed by waves throughout the management season. The mouth closed for an extended period of time in July and August (Figure 4.0.1) as sediment discharged during the winter began to weld back onto the beach, similar to conditions observed in August of 2017. The mouth also experienced several brief periods of muted tides (less than 2-foot tide range) in May (Figure 4.0.2), and September (Figure 4.0.3), before fully closing after the end the management season in late October (Figure 4.0.1) and November. All observed closure events coincided with waves having peak periods greater than 16 seconds (Figure 4.0.1).

Appendix O of the 2020 Russian River Estuary Adaptive Beach Management Plan (ESA 2020) offers lessons learned based on 2019 observations of the Estuary, associated physical processes, and Sonoma Water's planning for outlet channel management. These are summarized here and may be found in ESA 2020 for fuller context:

- After similar conditions between the wet years of 2017 and 2019, there is more confirmation of some of the expected patterns that develop. In both years, most of the beach eroded during the peak flow events, and then remained at the north end of the beach in spring, allowing the inlet to be elongated and frictional during the management season, which contributes to behavior of both the beach and the mouth. In 2019 this contributed to the mouth having muted tidal conditions for two weeks, prior to closing in July.
- A key finding of both the 2017 and 2019 wet years is that closure events in mid-summer may be more likely during wet years. Otherwise, these events tend to be rare in summer since wave conditions are typically too weak. Evidence from these two years suggests that sediment supply to the nearshore zone during high winter discharge may cause the sediment to form sand bars, which then facilitate mid-summer closure.

As noted in earlier reports, ocean waves with sufficient power to move sand into the inlet are needed to close the river mouth. These wave conditions occur predominantly in the early part of the management season and again in the fall at the end of the season. However, waves with low height but long periods ('long-period swell waves') can also induce inlet closure or a reduced-size inlet that causes tidal muting.

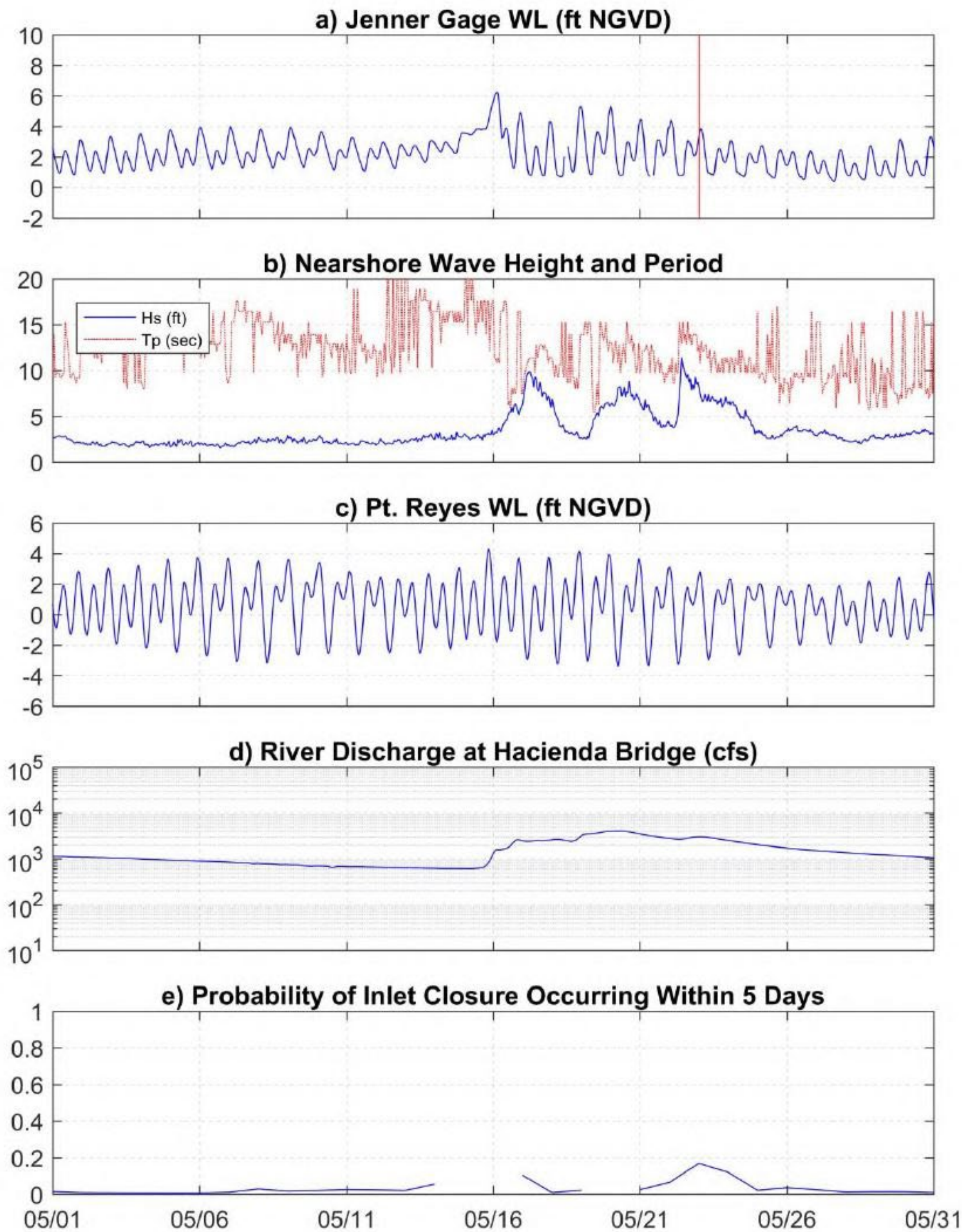


Figure 4.0.2. Estuary, Ocean, and River Conditions Compared with Closure Probability: May 2019

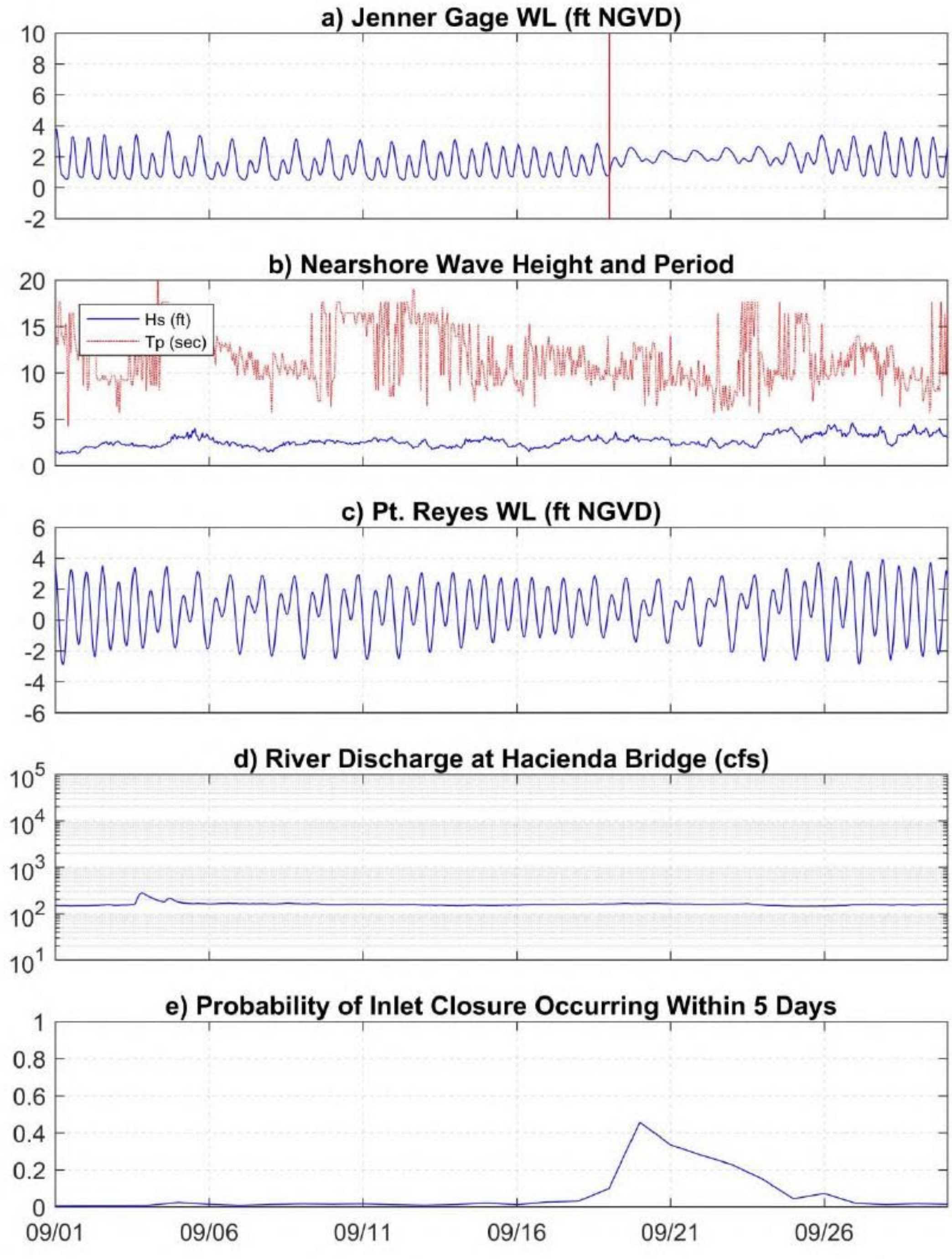


Figure 4.0.3. Estuary, Ocean, and River Conditions Compared with Closure Probability: September 2019.

Artificial Breaching

There were four mouth closures in 2019; two occurred during the lagoon management season. No beach management activities were conducted by Sonoma Water in 2019 as the closures ended in self-breaching of the barrier beach. There were signs that a manual breach may have been performed by people on the beach following the July 18th closure. More information about the wave and water level conditions during these closures are available in Appendix O of the 2020 Russian River Estuary Adaptive Beach Management Plan (ESA 2020).

Flood Risk Management Study

The Russian River Biological Opinion, RPA 2, includes a Flood Risk Reduction step if it proves difficult to reliably achieve raised water surface elevation targets based on implementation of a lagoon outlet channel or modification of the existing jetty. Should those actions be unsuccessful in meeting estuarine water surface elevation goals, RPA 2 states that Sonoma Water "will evaluate, in coordination with NMFS and other appropriate public agencies, the feasibility of actions to avoid or mitigate damages to structures in the town of Jenner and low-lying properties along the Estuary that are currently threatened with flooding and prolonged inundation when the barrier beach closes and the Estuary's water surface elevation rises above 9 feet. Such actions may include, but are not limited to, elevating structures to avoid flooding or inundation."

As described in earlier annual reports, the first effort to address flood risk management feasibility was compilation of a preliminary list of structures, properties, and infrastructure that would be subject to flooding/inundation as the result of sandbar formation and if the Estuary were allowed to naturally breach. As required by RPA 2, Sonoma Water submitted a preliminary list of properties, structures, and infrastructure that may be subject to inundation if the barrier beach at the mouth of the Russian River was allowed to naturally breach. This preliminary list was updated for the California Coastal Commission Coastal Development Permit application process. Allowing Estuary water surface elevations to rise to between 10 and 12 feet NGVD (the estimated water surface elevation if the barrier beach was allowed to naturally breach per consultation with NMFS) may potentially inundate portions of properties.

As described in previous reports, Sonoma Water was awarded federal funding from the National Oceanic and Atmospheric Administration (NOAA) under its Habitat Blueprint framework to provide funds to the United States Geological Survey (USGS) expansion of its sea level rise model (the Coast Storm Modeling System or CoSMoS) from Bodega Bay north along the Sonoma Coast to Point Area, including the Russian River Estuary up to Duncans Mills, to be used to inform adaptation planning and Estuary management efforts (model included both open and closed river mouth conditions). These model scenarios were incorporated into the Our Coast, Our Future (OCOF) web platform by Point Blue Conservation Science (http://beta.ourcoastourfuture.org/index.php?page=russian-river-project-team). Sonoma Water hopes to use the CoSMoS and OCOF information to inform future flood risk feasibility studies of sea level rise and climate change effects on estuary flood risk and habitat management. In 2018, Sonoma Water began identifying next steps for the flood risk scope of work and plan to meet with resource agencies in 2020 to more fully develop the work to be completed.

Conclusions and Recommendations

A barrier beach formed four times in 2019. All four river mouth closures ended in self-breaches and Sonoma Water did not conduct water level management activities (Table 4.0.1). The Russian River mouth was closed to the ocean for a total of 27 days (or 7%) in 2019.

Two of the four mouth closures in 2019 occurred during the lagoon management season. No beach management activities were conducted by Sonoma Water in 2019 as the closures ended in self-breaching of the barrier beach. There were signs that a manual breach may have been performed by people on the beach following the July 18th closure.

4.1 Water Quality Monitoring

Water quality monitoring was conducted in the lower, middle, and upper reaches of the Russian River Estuary, including two tributaries and the Maximum Backwater Area (MBA), between the mouth of the river at Jenner and Vacation Beach near Guerneville. Sonoma Water staff continued to collect data to establish baseline information on water quality in the Estuary, gain a better understanding of the longitudinal and vertical water quality profile during the ebb and flow of the tide, and track changes to the water quality profile that may occur during periods of barrier beach closure, partial or full lagoon formation, lagoon outlet channel implementation, and sandbar breach.

Saline water is denser than freshwater and a salinity “wedge” (halocline) forms in the Estuary as freshwater outflow passes over the denser tidal inflow. During the Lagoon Management Period, the lower and middle reaches of the Estuary up to Sheephouse Creek are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater. The upper reach of the Estuary transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates upstream to Duncans Mills during summer low flow conditions and barrier beach closure. Additionally, river flows, tides, topography, and wind action affect the amount of mixing of the water column at various longitudinal and vertical positions within the reaches of the Estuary. The Maximum Backwater Area encompasses the area of the river between Duncans Mills and Vacation Beach that is generally outside the influence of saline water, but within the upper extent of inundation and backwatering that can occur during tidal cycles and lagoon formation.

The Estuary experienced two (2) closures during the 2019 management period, which runs from 15 May to 15 October. However, there were two (2) additional closures that occurred outside of the management period at the end of the monitoring season. The barrier beach closed on 18 October and remained closed for four (4) days until self-breaching on 22 October. The barrier beach closed for the last time of the calendar year for six (6) days from 21 November to 27 November before breaching naturally.

Methods

Continuous Multi-Parameter Monitoring

Water quality was monitored using YSI Series 6600 multi-parameter datasondes. Hourly salinity (parts per thousand), water temperature (degrees Celsius), dissolved oxygen (DO; percent saturation), dissolved oxygen (milligrams per liter), and pH (hydrogen ion) data were collected. Datasondes were cleaned and recalibrated periodically following the YSI User Manual procedures, and data was downloaded during each calibration event.

Seven (7) stations were established for continuous water quality monitoring, including three stations in the mainstem Estuary, two tributary stations, and two stations in the MBA near Villa Grande and Monte Rio (Figure 4.1.1). One mainstem Estuary station was located in the middle reach at Patty's Rock upstream of Penny Island (Patty's Rock Station). One tributary station was located in the mouth of Willow Creek, which flows into the middle reach of the Estuary (Willow Creek Station). Two mainstem Estuary stations were located in the upper reach; downstream of Freezeout Creek in Duncans Mills (Freezeout Creek Station) and downstream of Austin Creek in Brown's Pool (Brown's Pool Station). The other tributary station was located downstream of the first steel bridge in lower Austin Creek, which flows into the mainstem Russian River above Brown's Pool Station. Two mainstem stations were located in the MBA; one in a pool across from Patterson Point in Villa Grande (Patterson Point Station) and the other downstream of Monte Rio Beach (Monte Rio Station).

The rationale for choosing mainstem Estuary sites, including the Brown's Pool Station, was to locate the deepest holes at various points throughout the Estuary to obtain the fullest vertical profiles possible and to monitor salinity circulation and stratification, hypoxic and/or anoxic events, and temperature stratification. Sondes were located near the mouths of Willow and Austin Creeks to collect baseline water quality conditions and monitor potential changes to water quality (e.g., salinity intrusion) resulting from tidal cycling or inundation during partial or full lagoon formation. The Patterson Point station was established to monitor potential changes to water quality conditions (including potential salinity migration) in the MBA while inundated during lagoon formation (Figure 4.1.1).

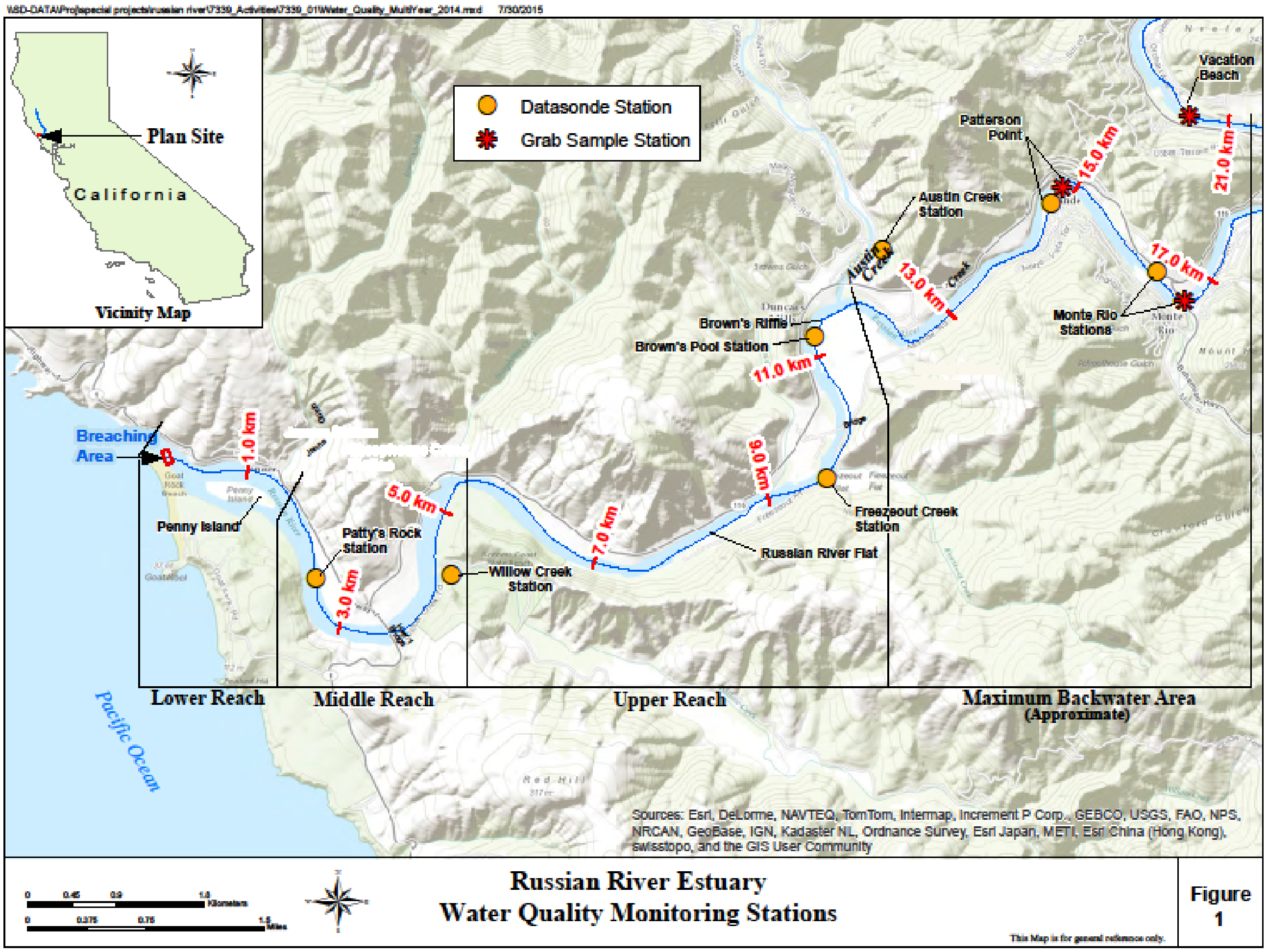


Figure 4.1.1. 2019 Russian River Estuary water quality monitoring stations.

Mainstem Estuary and MBA monitoring stations up to Patterson Point were comprised of a concrete anchor attached to a steel cable suspended from the surface by a large buoy (Figure 4.1.2).

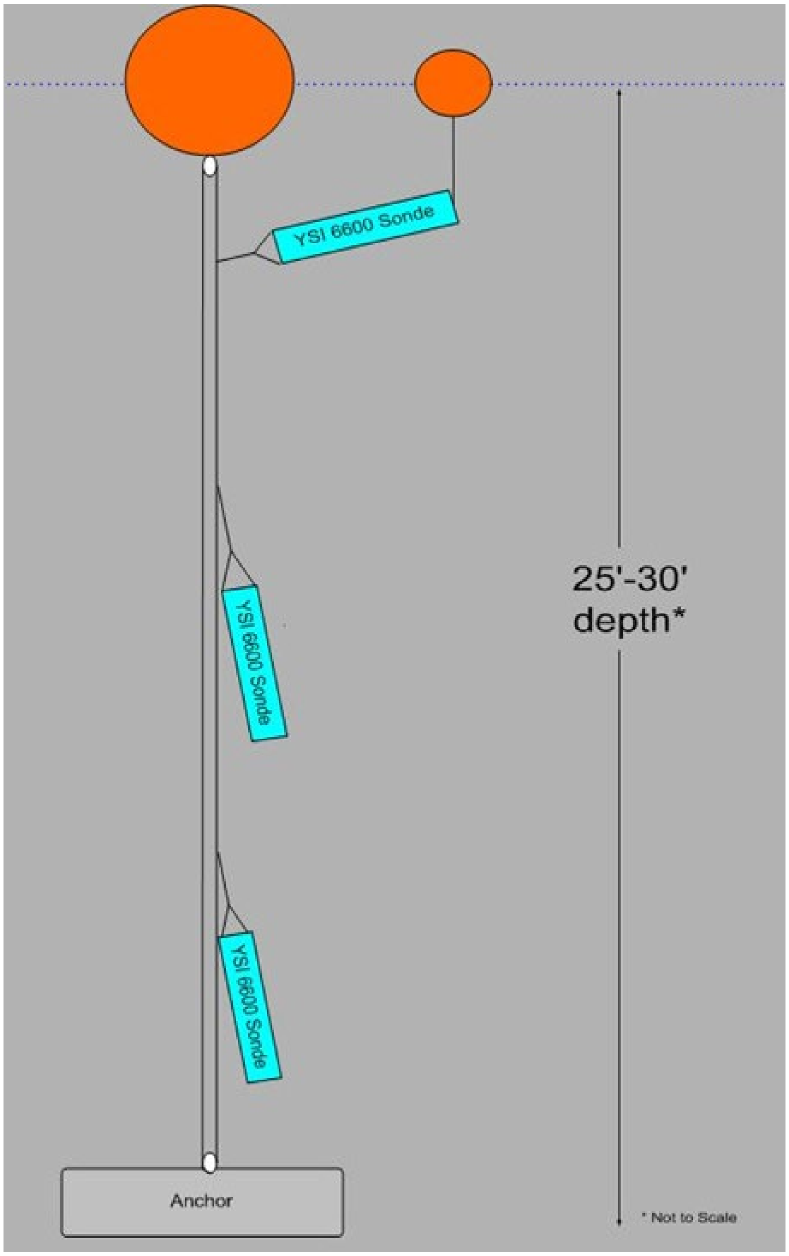


Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.

The Patty's Rock, Freezeout Creek, Brown's Pool, and Patterson Point stations had a vertical array of two datasondes to collect water quality profiles. The Patty's Rock station, located in the middle reach of the Estuary, is predominantly saline and had sondes placed near the surface at approximately 1 meter depth (~1m), and at the mid-depth (~4-5m) portion of the water column. Stations in the upper reach of the Estuary, where the halocline is deeper and the water is predominantly fresh to brackish, had sondes placed at the bottom (~8-10m) and mid-depth (~4-7m) portions of the water column. The Patterson Point monitoring station, located in the MBA, also had datasondes placed at the bottom (~10-13m) and mid-depth (~6-7m) portions of the water column (Figure 4.1.2). Sondes were located in this manner to track vertical and longitudinal changes in water quality characteristics during periods of tidal circulation, barrier beach closure, lagoon formation, lagoon outlet channel implementation, and sandbar breach.

The monitoring stations in Austin Creek and Willow Creek consisted of one datasonde suspended at approximately mid-depth (~1-2m during open conditions) in the thalweg at each respective site.

The Patty's Rock, Willow Creek, Freezeout Creek, Brown's Pool, and Patterson Point stations were deployed from April to November. The Austin Creek sonde was deployed from April to the end of September when a lack of flow and adequate water depth required equipment removal for the remainder of the season. The Monte Rio sonde was deployed from June to October before being removed for the season due to station accessibility issues.

Grab Sample Collection

In 2019, Sonoma Water staff continued to conduct nutrient and indicator bacteria grab sampling at three stations in the freshwater segment of the Russian River Estuary referred to as the Maximum Backwater Area (MBA), including one station established in 2010 just downstream of the Monte Rio Bridge (Monte Rio Station). The 2019 grab sampling effort represented the sixth year of collecting samples at Patterson Point in Villa Grande (Patterson Point Station) and downstream of the Vacation Beach summer dam (Vacation Beach station). Refer to Figure 4.1.1 for grab sampling locations.

Sonoma Water staff collected grab samples weekly from 14 May to 15 October. Additional focused sampling (collecting three samples over a ten-day period) was conducted following or during specific river management and operational events including removal of summer recreational dams.

Nutrient sampling was conducted for total organic nitrogen, ammonia, unionized ammonia, nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen, total phosphorus, total orthophosphate, dissolved and total organic carbon, total dissolved solids, and turbidity, as well as for *Chlorophyll a*, which is a measurable parameter of algal growth that can be tied to excessive nutrient concentrations and reflect a biostimulatory response. Grab samples were also collected for the presence of indicator bacteria including total coliforms, *Escherichia coli* (E. coli) and Enterococcus. These bacteria are considered indicators of water quality conditions that may be a concern for water contact recreation and public health.

Nutrients, organic carbon, total dissolved solids, turbidity, and *Chlorophyll a* grab samples were analyzed at Alpha Analytical Labs in Ukiah, and bacterial grab samples were analyzed at the Sonoma County Department of Health Services (DHS) lab in Santa Rosa.

The sampling results for total nitrogen, total phosphorus, turbidity, *Chlorophyll a*, and bacterial indicators are analyzed and discussed below.

Results

Water quality conditions in 2019 were similar to trends observed in sampling from 2004 to 2018. The lower and middle reaches are predominantly saline environments with a thin freshwater layer that flows over the denser saltwater layer. The upper reach transitions to a predominantly freshwater environment, which is periodically underlain by a denser, saltwater layer that migrates up and downstream and appears to be affected in part by freshwater inflow rates, tidal inundation, barrier beach closure, and subsequent tidal cycles following reopening of the barrier beach. The river upstream of Brown’s Pool is considered predominantly freshwater habitat. The lower and middle reaches of the Estuary are subject to tidally-influenced fluctuations in water depth during open conditions and inundation during barrier beach closure, as is the upper reach and the MBA to a lesser degree.

Table 4.1.1 presents a summary of minimum, mean, and maximum values for temperature, depth, dissolved oxygen, pH, and salinity recorded at the various datasonde monitoring stations. Data associated with malfunctioning datasonde equipment has been removed from the data sets, resulting in the data gaps observed in the graphs presented as Figures 4.1.3 through 4.1.30. These data gaps may affect minimum, mean, and maximum values of the various constituents monitored in 2019, including temperature, dissolved oxygen, pH, and salinity at the Freezeout Creek bottom sonde for the entire season; and DO at the Patterson Point mid-depth sonde from the beginning of October into November. Sondes were not placed at Sheephouse Creek in 2019 due to a shortage of properly functioning datasondes.

Although gaps exist in the 2019 data that affect sample statistics, Sonoma Water staff have collected long time-series data on an hourly frequency for several years at most of these stations, and it is unlikely that the missing data appreciably affected the broader understanding of water quality conditions within the estuary. The following sections provide a brief discussion of the results observed for each parameter monitored.

Table 4.1.1. Russian River Estuary 2019 Water Quality Monitoring Results. Minimum, mean, and maximum values for temperature (degrees Celsius), depth (meters), dissolved oxygen concentration (milligrams per Liter), dissolved oxygen (percent) saturation, hydrogen ion (pH units), and salinity (parts per thousand).

Monitoring Station ***Sonde***	**Temperature** (°C)	**Depth** (m)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (%) saturation	**Hydrogen Ion** (pH)	**Salinity** (ppt)
Patty's Rock						
Surface						
April 24, 2019 - November 19, 2019						
Min	11.3	0.7	5.1	56.9	7.6	0.1
Mean	17.3	1.1	8.9	99.9	8.1	12.3
Max	**24.3**	**1.8**	**24.3**	**293.3**	**8.9**	**31.5**
Mid-Depth						
April 24, 2019 - November 19, 2019						
Min	11.2	4.1	0.2	2.3	7.6	0.1
Mean	13.6	4.9	6.2	70.1	8.9	27.1
Max	**18.3**	**5.1**	**13.9**	**160.5**	**11.2**	**33.9**
Willow Creek						
Mid-Depth						
April 15, 2019 - November 4, 2019						
Min	10.5	0.0	0.0	0.0	6.7	0.1
Mean	16.9	1.3	8.2	88.4	7.6	8.1
Max	**24.8**	**5.4**	**16.0**	**201.3**	**8.8**	**27.0**
Freezeout Creek						
Mid-Depth						
April 24, 2019 - November 19, 2019						
Min	10.7	4.1	2.4	25.4	7.2	0.1
Mean	19.5	4.3	9.0	98.4	8.0	0.6
Max	**25.3**	**7.2**	**13.0**	**140.2**	**8.5**	**10.4**
Brown's Pool						
Mid-Depth						
April 24, 2019 - November 19, 2019						
Min	10.9	5.2	4.4	49.7	7.5	0.1
Mean	19.4	5.6	8.7	94.1	7.9	0.1
Max	**25.3**	**6.0**	**11.5**	**121.5**	**8.3**	**0.2**
Bottom						
April 24, 2019 - November 19, 2019						
Min	10.9	8.8	0.1	1.1	6.5	0.1
Mean	18.6	9.6	4.5	48.0	7.4	0.1
Max	**24.8**	**10.3**	**11.4**	**120.8**	**8.2**	**0.2**

Table 4.1.1. (cont.)

Monitoring Station	Temperature	Depth	Dissolved Oxygen	Dissolved Oxygen	Hydrogen Ion	Salinity
Sonde	(°C)	(m)	(mg/L)	(%) saturation	(pH)	(ppt)
Austin Creek						
Surface						
April 16, 2019 - September 30, 2019						
Min	11.7	0.1	3.8	39.7	7.5	0.1
Mean	17.4	0.4	8.1	84.4	7.8	0.1
Max	**22.2**	**1.7**	**10.6**	**108.0**	**8.1**	**0.2**
Patterson Point						
Mid-Depth						
April 24, 2019 - November 19, 2019						
Min	10.5	6.0	3.7	42.9	7.3	0.1
Mean	19.4	6.5	8.3	93.2	7.7	0.1
Max	**24.3**	**7.0**	**11.5**	**134.3**	**8.2**	**0.1**
Bottom						
April 24, 2019 - November 19, 2019						
Min	10.0	10.0	0.2	1.8	6.8	0.1
Mean	18.5	10.9	6.8	71.9	7.2	0.1
Max	**23.8**	**13.0**	**11.4**	**132.1**	**8.0**	**0.2**
Monte Rio						
Mid-Depth						
June 7, 2019 - October 8, 2019						
Min	15.8	0.8	7.2	82.9	7.4	0.1
Mean	22.7	1.0	8.8	102.2	7.7	0.1
Max	**26.3**	**1.6**	**11.6**	**136.1**	**8.2**	**0.1**

Salinity

Full strength seawater has a salinity of approximately 35 parts per thousand (ppt), with salinity decreasing from the ocean to the upstream limit of the Estuary, which is considered freshwater at approximately 0.5 ppt (Horne, 1994). The Patty's Rock mid-depth sonde in the middle reach was located in a predominantly saline environment, whereas the surface sonde was located at the saltwater-freshwater interface (halocline or salt wedge) and recorded both freshwater and saltwater conditions. In the lower and middle reaches of the Estuary, salinities can range as high as 30 ppt in the saltwater layer, with brackish conditions prevailing at the upper end of the salt wedge, to less than 1 ppt in the freshwater layer on the surface. The Willow Creek sonde was located just upstream of the confluence with the Russian River, where predominantly freshwater conditions observed in the creek during higher springtime flows transitioned to a brackish environment during lower dry season flows.

In the upper reach, the Estuary typically transitions from predominantly saline conditions to brackish and freshwater conditions in the Heron Rookery area. Upstream, the Freezeout Creek station is located in a predominantly freshwater environment; however, brackish conditions can occur during open estuary conditions with lower in-stream flows, as well as during barrier beach closure or perched conditions. The Brown's Pool station is located in predominantly freshwater habitat that periodically experiences brackish conditions in the upper reach of the Estuary, just downstream of the confluence with Austin Creek and the beginning of the MBA.

The Austin Creek, Patterson Point and Monte Rio stations are located in the MBA in freshwater habitat that can become inundated during high tides, barrier beach closures, perched conditions, and lagoon formation. Elevated salinity levels were not observed at any of the stations in the MBA during either open or closed barrier beach conditions in 2019.

Lower and Middle Reach Salinity

The Patty's Rock station is located at River Kilometer 2.5 (RK 2.5), which is approximately 2.5 km upstream from the river mouth. The surface sonde at the Patty's Rock station was suspended at a depth of approximately 1 meter, and experienced frequent hourly fluctuations in salinity during open conditions. These fluctuations are influenced by freshwater inflows, tidal movement and expansion and contraction of the salt wedge. The freshwater layer was observed to deepen and become more persistent at the surface sonde during closed barrier beach conditions (Figure 4.1.3). Concentrations ranged from 0.1 to 31.5 ppt at the Patty's Rock surface sonde with a mean salinity value of 12.3 ppt (Table 4.1.1).

The mid-depth sonde at the Patty's Rock station was suspended at a depth of approximately 5 meters, and also experienced frequent fluctuations in salinity concentrations, though to a lesser degree than the surface sonde. Concentrations ranged from 0.1 to 33.9 ppt at the Patty's Rock mid-depth sonde with a mean salinity value of 27.1 ppt (Table 4.1.1).

The Estuary experienced two closures following the 2019 management period, including one closure that lasted 16 days between 18 July and 3 August (Figure 4.1.3). Declines in salinity during barrier beach closure and lagoon formation were due to a combination of freshwater inflows increasing the depth of the freshwater layer over the salt layer, a reduction in tidal inflow, the compression and leveling out of the salt layer, and seepage of saline water through the barrier beach. Salinity returned to pre-closure levels within a few hours after the barrier beach reopened, although the time required to return to pre-closure conditions can vary between closure events. This variability is related to the strength of subsequent tidal cycles, freshwater inflow rates, topography, relative location within the Estuary, and to a lesser degree, wind mixing.

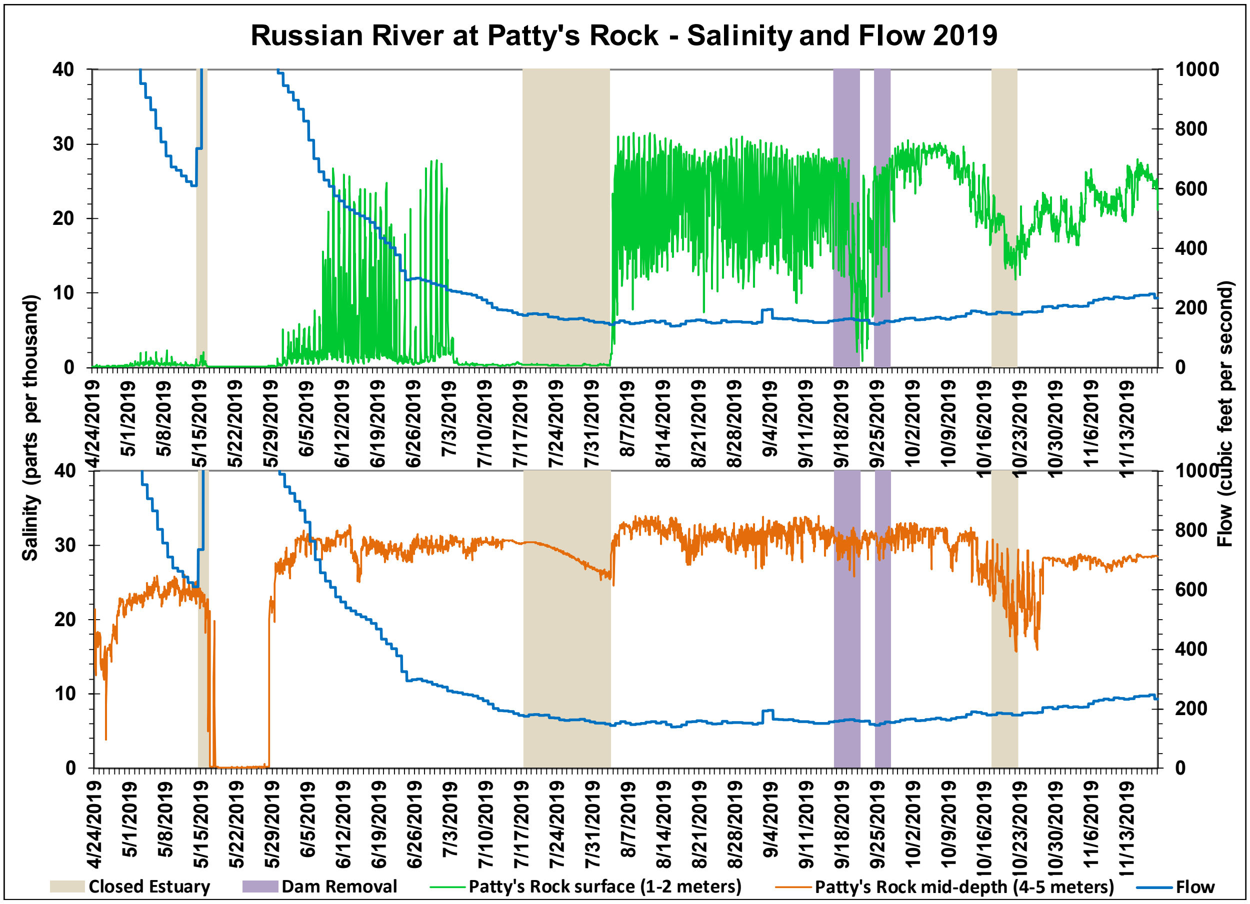


Figure 4.1.3. 2019 Russian River at Patty's Rock Salinity and Flow Graph

The Willow Creek station is located approximately 300 meters upstream from the confluence of Willow Creek with the mainstem Russian River, which occurs at RK 4.2. The Willow Creek station was located in predominantly freshwater habitat until June and July when declining spring flows and increasing tidal action allowed saline water to periodically migrate to this station during open conditions. However, conditions returned to predominantly freshwater habitat through July and were not observed to become brackish until early August after the extended July barrier beach closure (Figure 4.1.4)

Salinity was observed to generally remain brackish through the rest of the monitoring season, including during the October barrier beach closure (Figure 4.1.4). However, salinity concentrations were observed to fluctuate significantly at times during open barrier beach conditions, with concentration generally declining during closed conditions. The mean salinity concentration observed at the Willow Creek station was 8.1 ppt, with a minimum concentration of 0.1 ppt, and a maximum concentration of 27.0 ppt (Table 4.1.1).

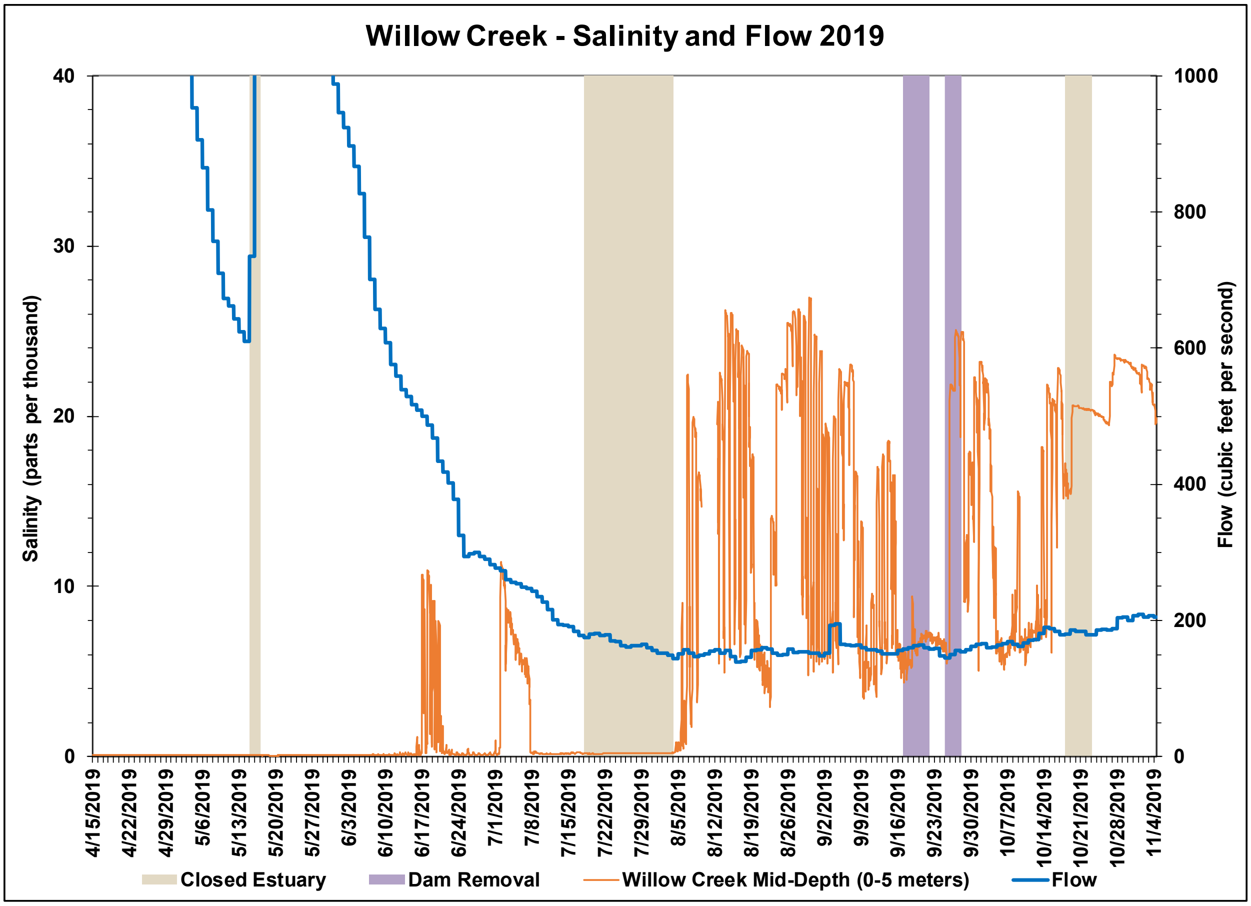


Figure 4.1.4. 2019 Willow Creek Salinity and Russian River Flow Graph

Upper Reach Salinity

Two stations were monitored in the upper reach in 2019; Freezeout Creek and Brown's Pool. Both stations included a bottom sonde and a mid-depth sonde, however the bottom sonde at the Freezeout Creek station malfunctioned and did not collect data for the entire season. Sondes were located in this manner to track changes in the presence and concentration of salinity in the water column as well as the presence of thermal refugia for salmonids.

The Freezeout Creek station is located at River Kilometer 9.5 (RK 9.5), in a pool approximately 300 meters downstream of the confluence of Freezeout Creek and the mainstem of the river. This station was located in a predominantly freshwater habitat that was periodically subject to elevated salinity levels during the season as the salt wedge migrated up the Estuary during open conditions (Figure 4.1.5). The mid-depth sonde at Freezeout Creek had a mean salinity concentration of 0.6 ppt, and salinity levels that ranged from 0.1 to 10.4 ppt.

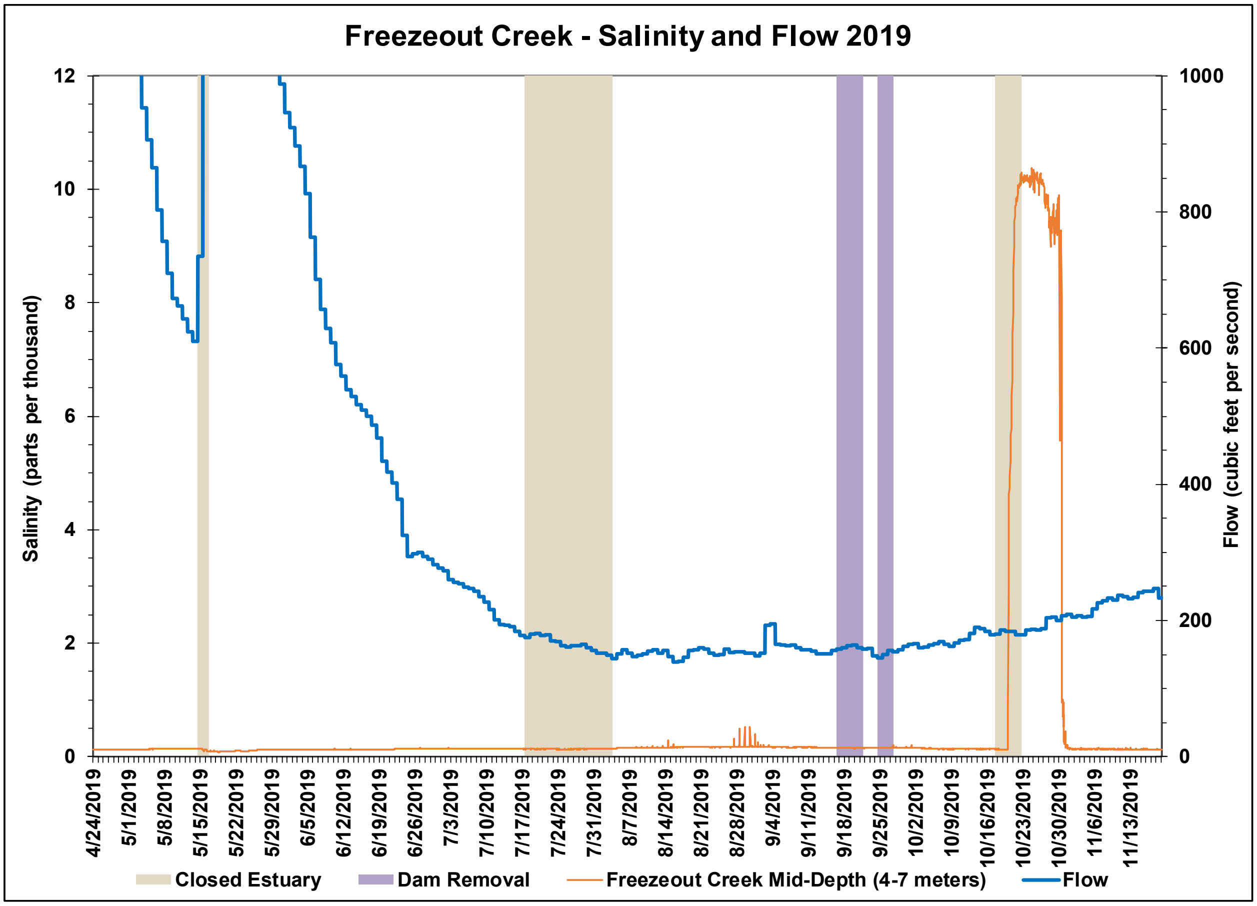


Figure 4.1.5. 2019 Russian River at Freezeout Creek Salinity and Flow Graph

The Brown's Pool station is located at RK 11.3 in a pool that is approximately 10m deep. Brown's Pool is located immediately downstream of Brown's Riffle (RK 11.4) and the confluence of Austin Creek and the mainstem Russian River, which is located at RK 11.65. Brown's Riffle is generally considered the demarcation between the Estuary and the MBA, where salinity levels have not been observed to occur past this point.

This station did not experience any elevated salinity levels and remained freshwater habitat during the entire monitoring season of 2019 (Figure 4.1.6). The bottom sonde at Brown's Pool had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.2 ppt (Table 4.1.1). The mid-depth sonde at Brown's Pool also had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.2 ppt.

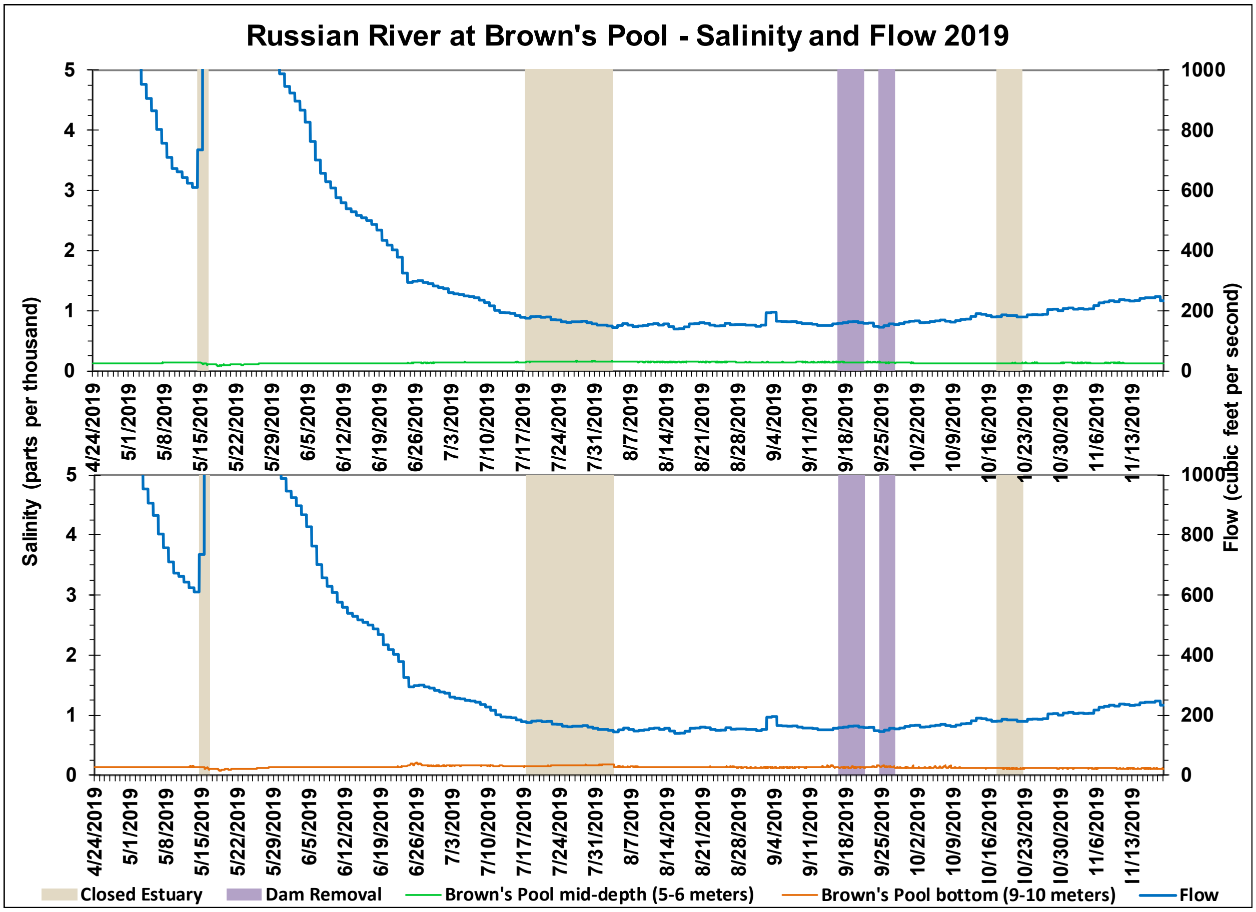


Figure 4.1.6. 2019 Russian River at Brown's Pool Salinity and Flow Graph

Maximum Backwater Area Salinity

Three stations were located in the MBA, including one tributary station in lower Austin Creek and two mainstem Russian River stations located at Patterson Point (RK 14.9) and Monte Rio (RK 16.1) (Figure 4.1.1).

None of these stations were observed to have salinity levels above normal background conditions expected in freshwater habitats, during both open and closed barrier beach conditions (Figures 4.1.7 through 4.1.9).

The Austin Creek station had a mean salinity concentration of 0.1 ppt, with a minimum of 0.1 ppt and a maximum of 0.2 ppt. The Patterson Point bottom sonde had a mean salinity concentration of 0.1 ppt, a minimum concentration of 0.1 ppt, and a maximum concentration of 0.2 ppt. The Patterson Point mid-depth sonde had a mean salinity concentration of 0.1 ppt, a minimum concentration of 0.1 ppt, and a maximum concentration of 0.1 ppt. The Monte Rio station had a mean salinity concentration of 0.1 ppt, a minimum concentration of 0.1 ppt, and a maximum concentration of 0.1 ppt.

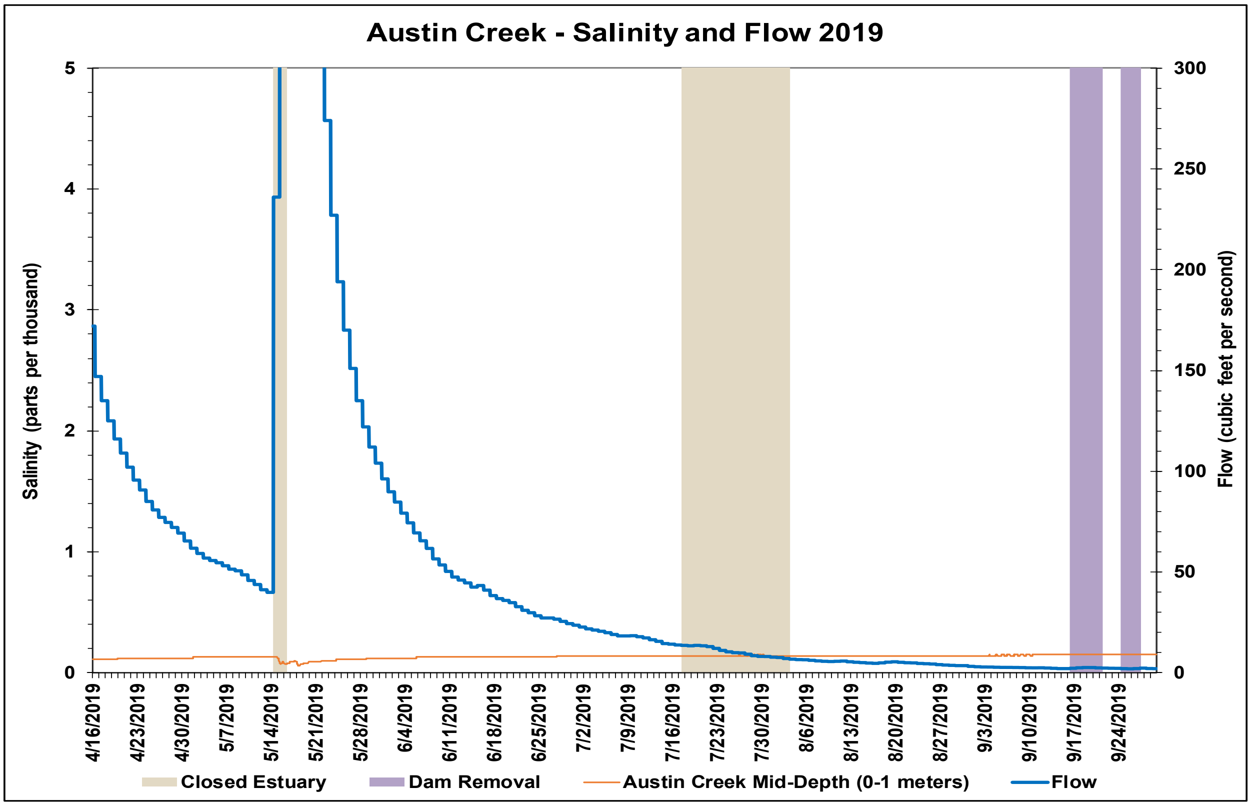


Figure 4.1.7. 2019 Austin Creek Salinity and Flow Graph. Sonde pulled early due to low water levels.

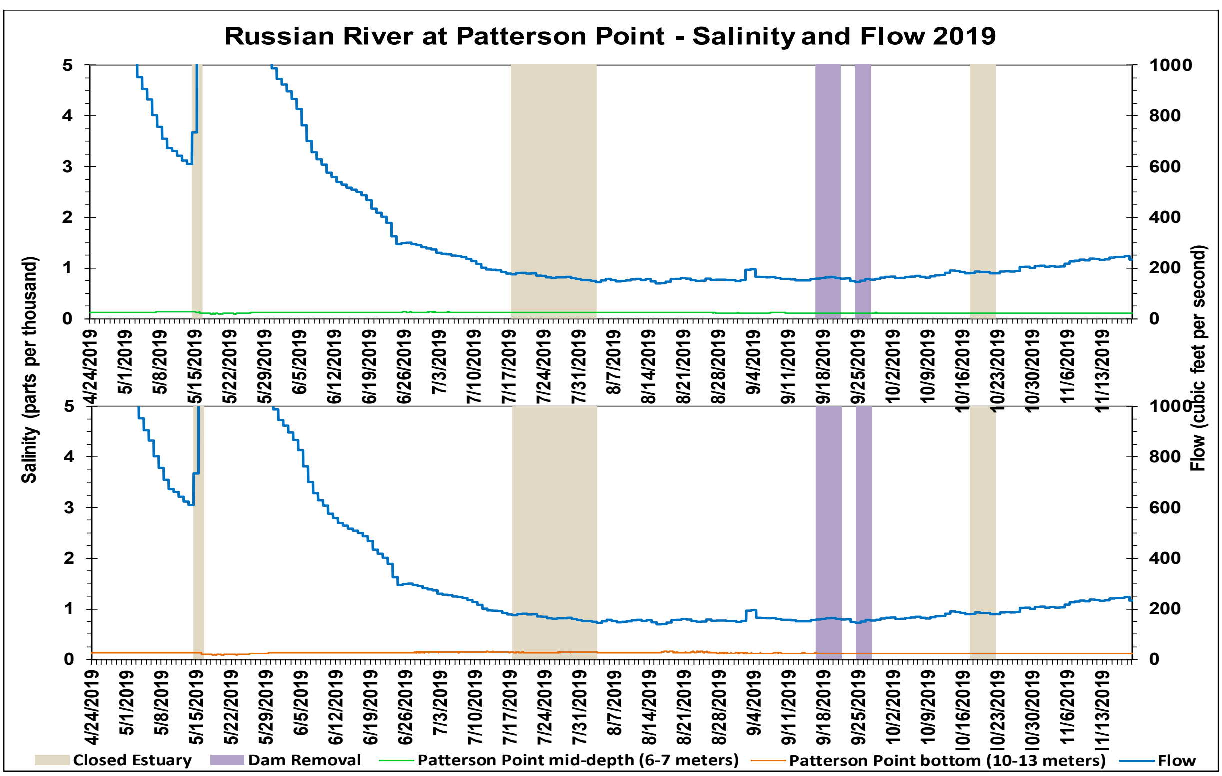


Figure 4.1.8. 2019 Russian River at Patterson Point Salinity and Flow Graph.

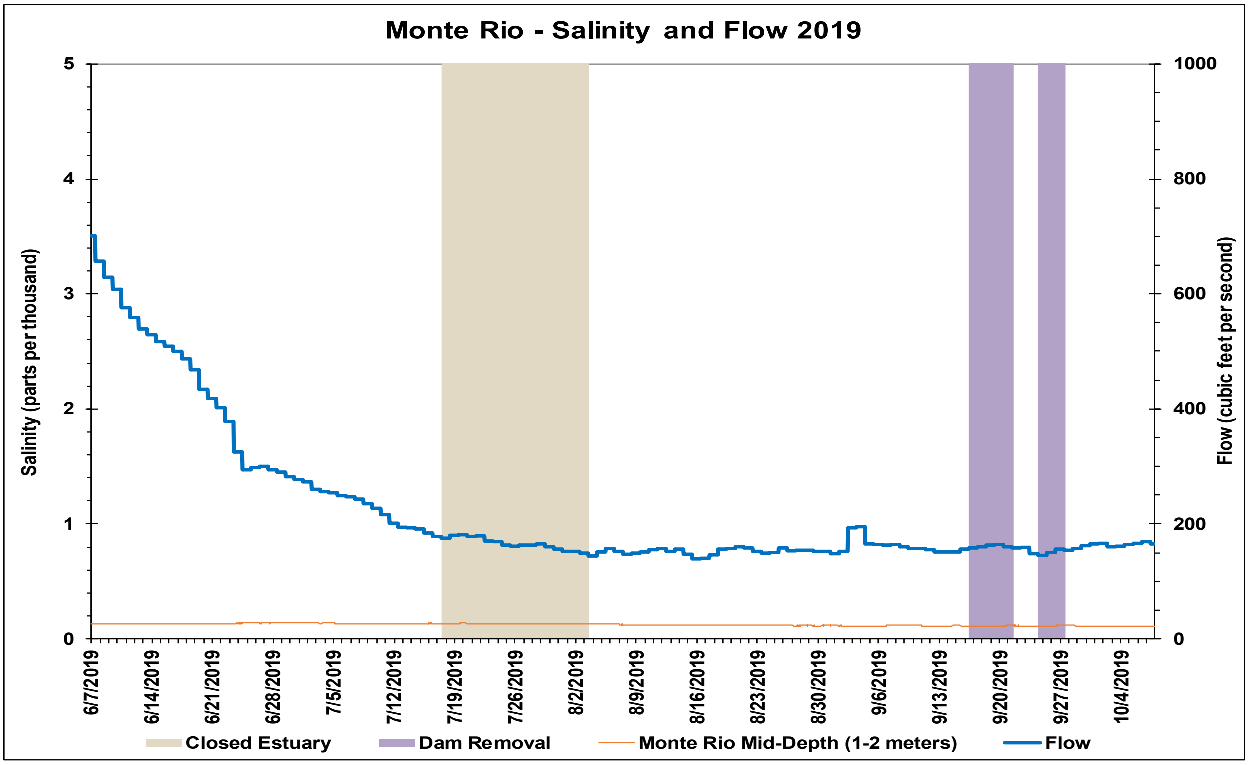


Figure 4.1.9. 2019 Russian River at Monte Rio Salinity and Flow Graph. Sonde pulled early due to limited access.

Temperature

During open estuary conditions, mainstem water temperatures were reflective of the halocline, with lower mean and maximum temperatures typically being observed in the saline layer at the bottom and mid-depth sondes compared to temperatures recorded in the freshwater layer at the mid-depth and surface sondes (Figures 4.1.10 through 4.1.13). The differences in temperatures between the underlying saline layer and the overlying freshwater layer can be attributed in part to the source of saline and fresh water. During open estuary conditions, the Pacific Ocean, where temperatures are typically around 10 degrees Celsius (°C), is the source of saltwater in the Estuary. Whereas, the mainstem Russian River, with water temperatures reaching as high as 27 °C in the interior valleys, is the primary source of freshwater in the Estuary.

During closed Estuary conditions, increasing temperatures associated with fresh/saltwater stratification were observed to occur at the Patty's Rock station (Figure 4.1.10). Density and temperature gradients between freshwater and saltwater play a role in stratification and serve to prevent/minimize mixing of the freshwater and saline layers. During the hot summer months, when the estuary is closed or the river mouth is perched and the supply of cool tidal inflow is reduced, solar radiation heats the overlying freshwater surface layer and underlying saline layer. The overlying freshwater surface layer restricts the release of this heat from the underlying saline layer, which can result in higher water temperatures in the underlying saline layer than in the overlying freshwater layer. Stratification-based heating has also been observed to result in higher temperatures in the mid-depth saline layer compared to the bottom layer in deep pools, forming a three-layered water column. This stratification-based heating can also contribute to

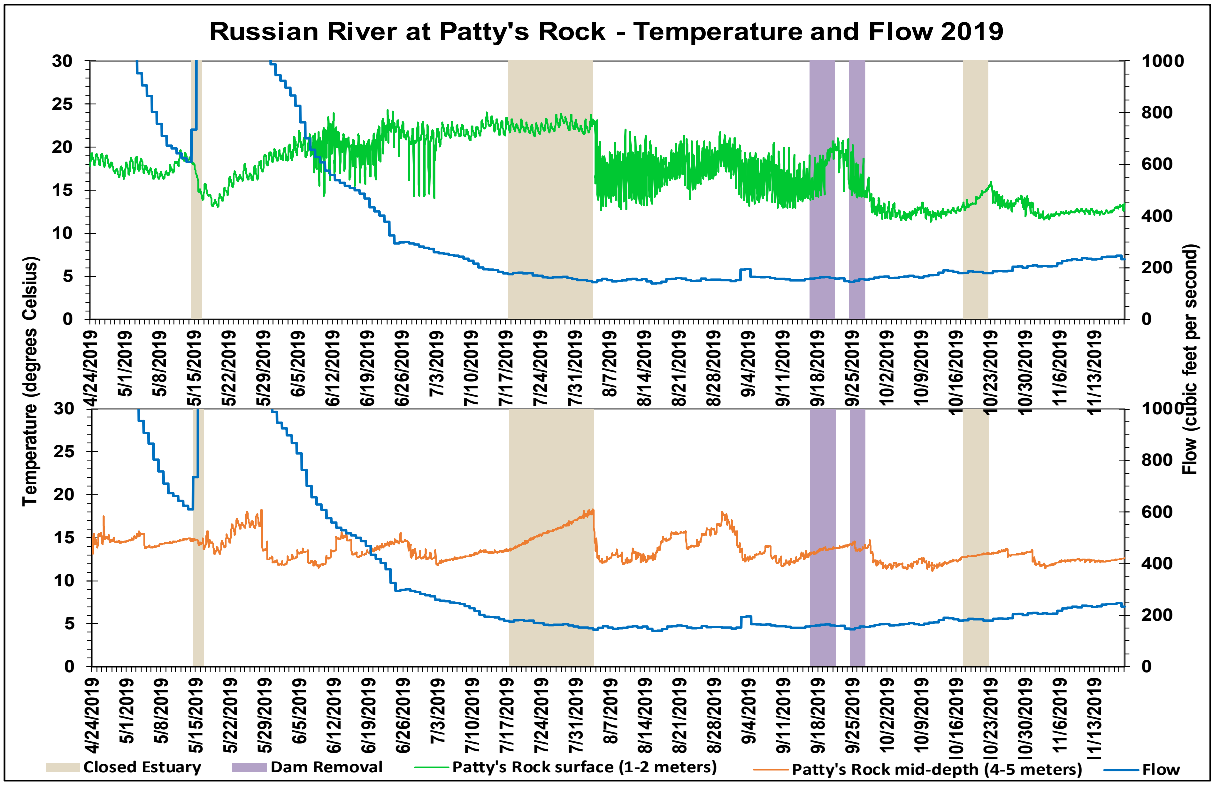


Figure 4.1.10. 2019 Russian River at Patty's Rock Temperature and Flow Graph

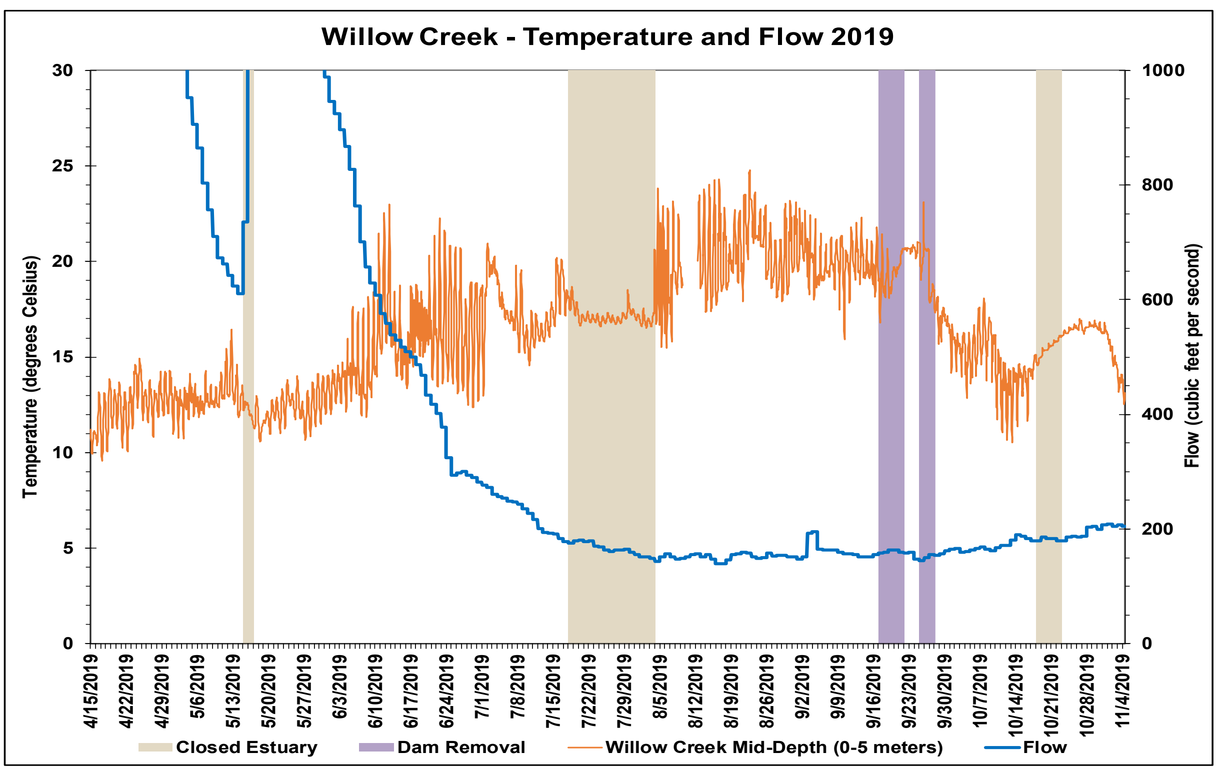


Figure 4.1.11. 2019 Willow Creek Temperature with Russian River Flow Graph

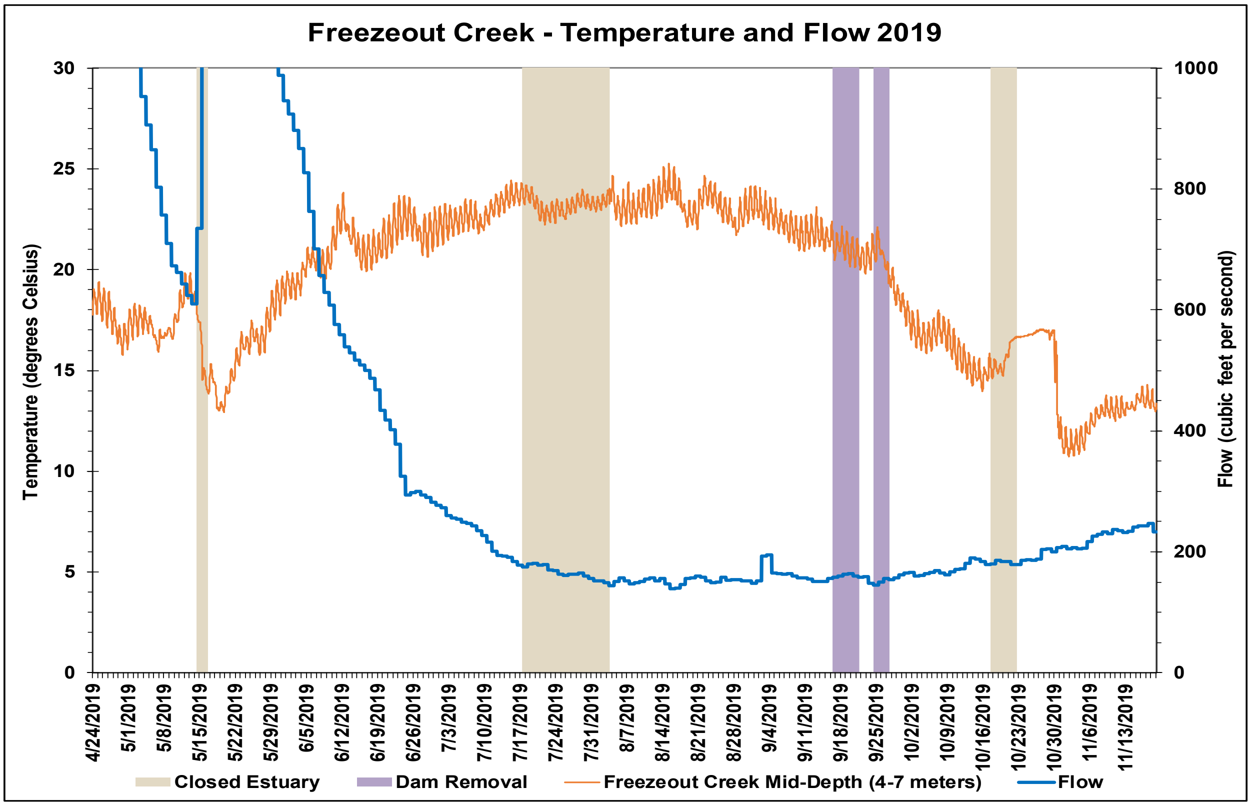


Figure 4.1.12. 2019 Russian River at Freezeout Creek Temperature and Flow Graph

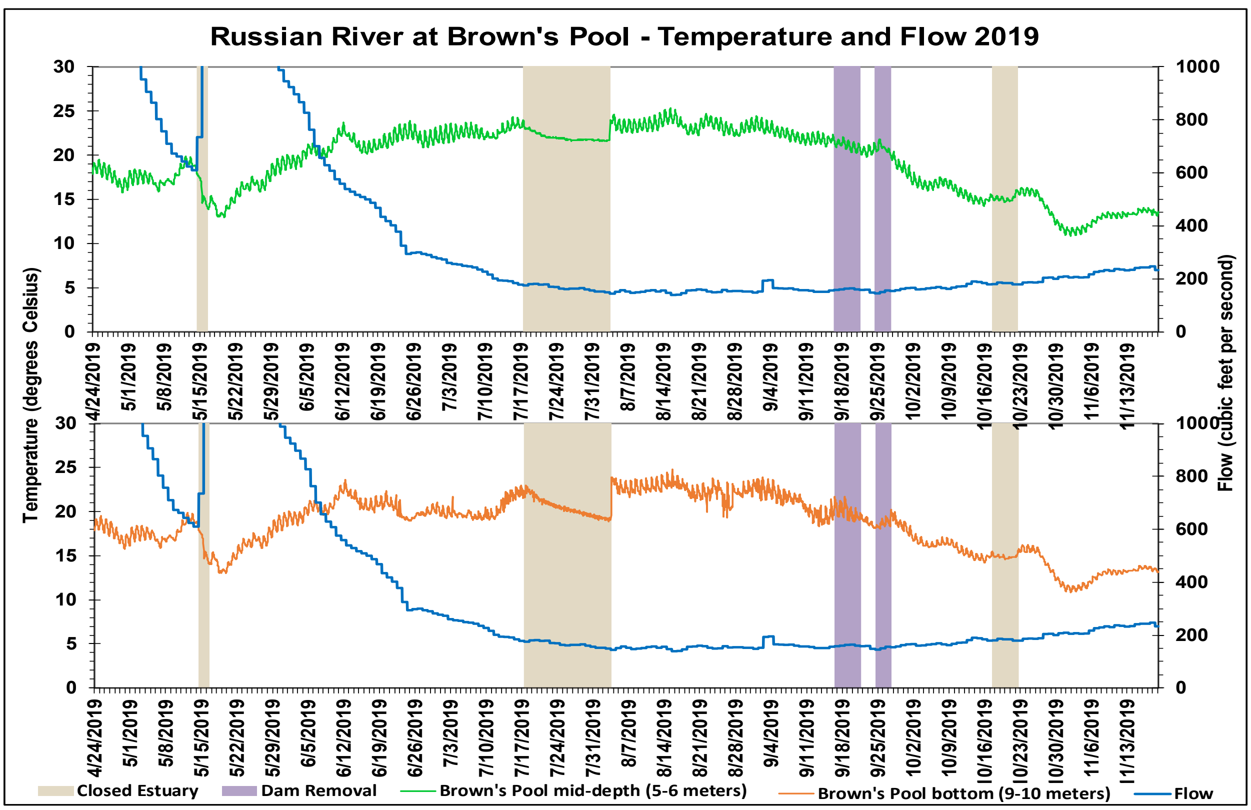


Figure 4.1.13. 2019 Russian River at Brown's Pool Temperature and Flow Graph

higher seasonal mean temperatures in the saline layer than would be expected to occur under open conditions.

Lower and Middle Reach Temperature

The Patty's Rock surface sonde was located at the freshwater/saltwater interface and was observed to have a maximum temperature of 24.3 °C (Table 4.1.1). Whereas, the mid-depth sonde was located primarily in saltwater and had a maximum temperature of 18.3 °C. Maximum temperatures at the surface sonde were observed in brackish water during open barrier beach conditions in June and in freshwater during closed barrier beach conditions in August. Maximum temperatures at the bottom sonde were observed in saline water during open barrier beach conditions in May and closed conditions in August (Figures 4.1.10 and 4.1.3). The Patty's Rock surface sonde had a mean temperature of 17.3 °C and a minimum temperature of 11.3 °C. The mid-depth sonde had a mean temperature of 13.6 °C and a minimum temperature of 11.2 °C.

The Willow Creek station had a maximum temperature of 24.8 °C, which occurred on 22 August in brackish water and open conditions (Figures 4.1.11 and 4.1.4). The mean temperature was 16.9 °C, and the minimum temperature was 10.5 °C. Elevated salinity was periodically observed in June and early July with mainstem flows dropping below 500 cfs (Figure 4.1.4). However, the station did not become predominantly brackish to saline until August following the extended July closure. Temperatures were observed to fluctuate with the movement of saline water into and out of the station, resulting in both heating and cooling during open and to a lesser degree, closed Estuary conditions (Figure 4.1.11).

Upper Reach Temperature

Overall estuarine temperatures in both the saline layer and freshwater layer were typically warmest at the upper reach stations, as observed at Freezeout Creek and Brown's Pool, and became progressively cooler as the water flowed downstream, closer to the cooling effects of the coast and ocean.

The Freezeout Creek mid-depth sonde had a maximum temperature of 25.3 °C, a mean temperature of 19.5 °C, and a minimum temperature of 10.7 °C (Table 4.1.1). Maximum temperatures were observed to occur in freshwater during open estuary conditions in August (Figures 4.1.12 and 4.1.5). Minimum temperatures occurred in freshwater during open conditions in November (Figure 4.1.12).

The Brown's Pool bottom sonde had a maximum temperature of 24.8 °C, a mean temperature of 18.6 °C, and a minimum temperature of 10.9 °C (Table 4.1.1). The Brown's Pool mid-depth sonde had a maximum temperature of 25.3 °C, a mean temperature of 19.4 °C, and a minimum temperature of 10.9 °C. Under open and closed conditions, daily temperatures were often lower at Brown's Pool bottom sonde compared to the mid-depth sonde, which suggests that thermal stratification may be occurring at depth (Figure 4.1.13). It is also possible that a groundwater or tidally influenced source could be contributing colder water at depth, or it could a combination of effects occurring in tandem. Minimum temperatures at the Brown's Pool station were observed in freshwater habitat during open conditions in November (Figures 4.1.13 and 4.1.6).

Maximum Backwater Area Temperature

Austin Creek had a maximum temperature of 22.2 °C, a mean temperature of 17.4 °C, and a minimum temperature of 11.7 °C (Table 4.1.1). Following a decrease in temperatures during storm flows in May, temperatures gradually increased through the summer and typically coincided with increases in air temperatures (Figure 4.1.14). However, maximum daily temperatures were also observed to decline during the latter half of the extended July closure event (Figure 4.1.14).

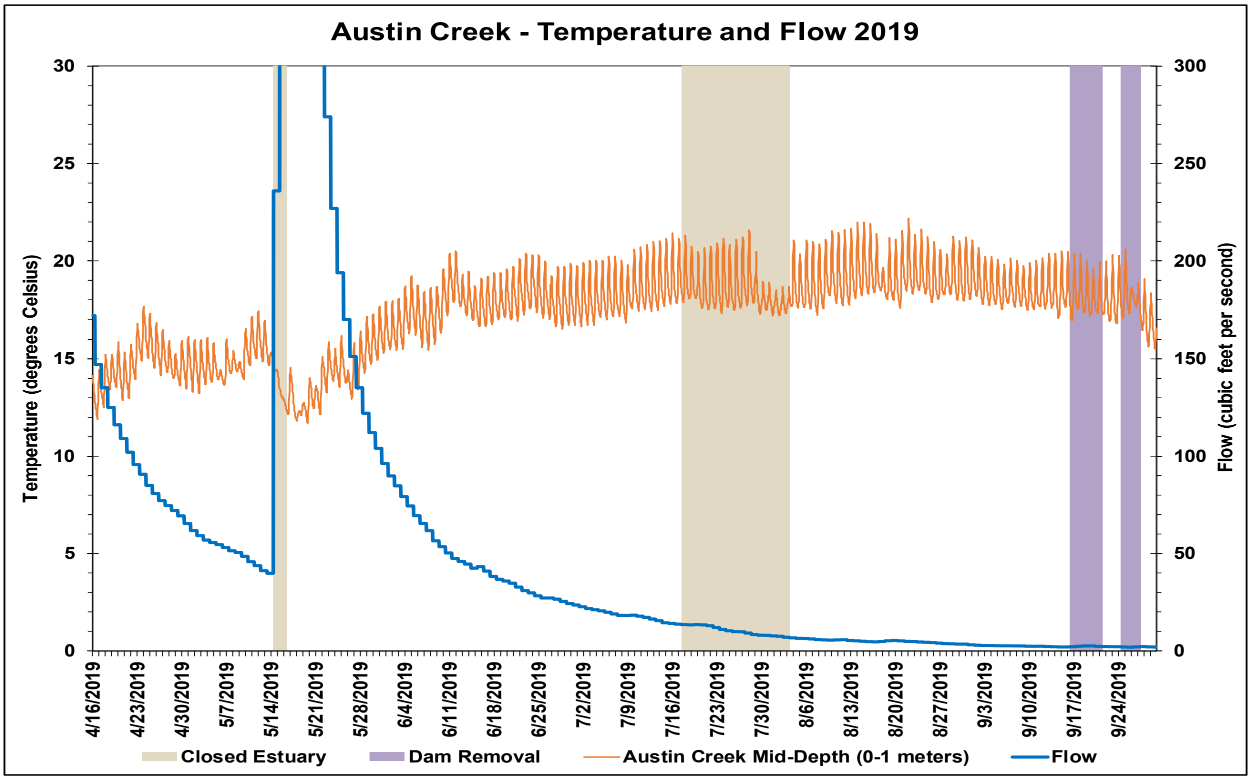


Figure 4.1.14. 2019 Austin Creek Temperature and Flow Graph. Sonde pulled early due to low water levels.

The Patterson Point bottom sonde had a maximum temperature of 23.8 °C, a mean temperature of 18.5 °C, and a minimum temperature of 10.0 °C (Table 4.1.1). The Patterson Point mid-depth sonde had a maximum temperature of 24.3 °C, a mean temperature of 19.4 °C, and a minimum temperature of 10.5 °C. Under open and closed conditions, temperatures were often lower at the bottom sonde compared to the mid-depth, which suggests that thermal stratification may be occurring (Figure 4.1.15). It is also possible that a groundwater source could be contributing colder water at depth, or it could a combination of effects occurring in tandem. Temperatures continued to decline with atmospheric temperatures through the end of the season (Figure 4.1.15).

The Monte Rio station had a maximum temperature of 26.3 °C, a mean temperature of 22.7 °C, and a minimum temperature of 15.8 °C during the abbreviated monitoring period (Table 4.1.1). Closed estuary conditions were not observed to have a significant effect on temperatures, which was consistent with data from previous monitoring efforts at Monte Rio (Figure 4.1.16).

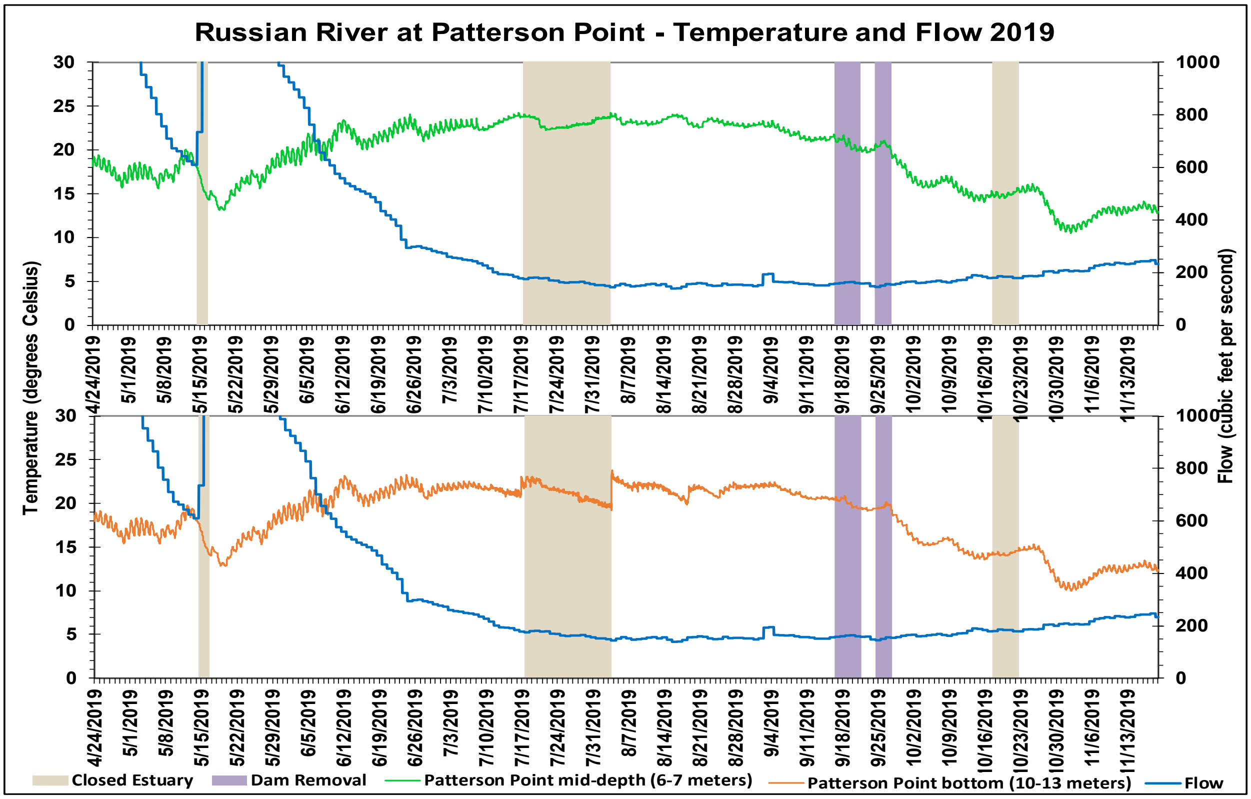


Figure 4.1.15. 2019 Russian River at Patterson Point Temperature and Flow Graph

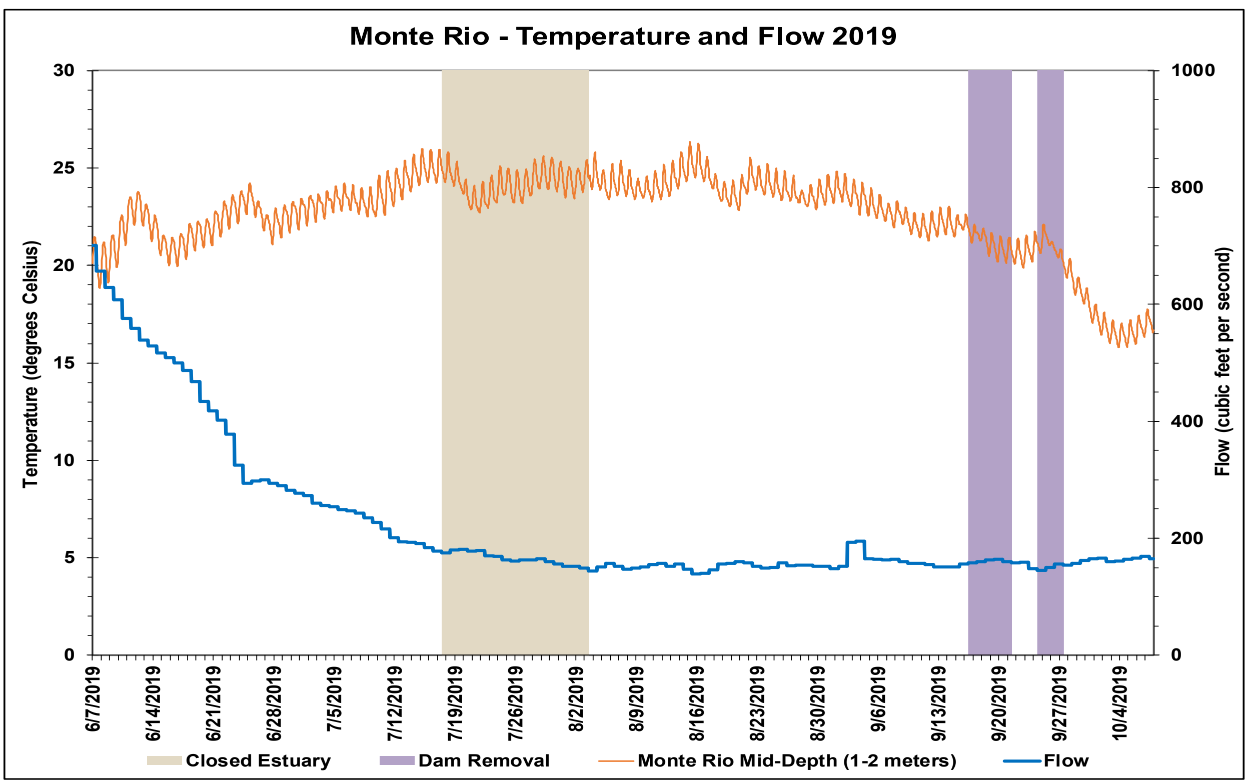


Figure 4.1.16. 2019 Russian River at Monte Rio Temperature and Flow Graph. Sonde pulled early due to limited access.

Dissolved Oxygen

Dissolved oxygen (DO) levels in the Estuary, including the MBA, depend upon factors such as the extent of diffusion from surrounding air and water movement, including freshwater inflow. DO is affected by salinity and temperature stratification, tidal and wind mixing, abundance of aquatic plants, and presence of decomposing organic matter. DO affects fish growth rates, embryonic development, metabolic activity, and under severe conditions, stress, and mortality. Cold water has a higher saturation point than warmer water; therefore, cold water is capable of carrying higher levels of oxygen.

DO levels are also a function of nutrients, which can accumulate in water and promote plant and algal growth that both produce and consume DO during photosynthesis and respiration. Estuaries tend to be naturally eutrophic because land-derived nutrients are concentrated where runoff enters the marine environment in a confined channel[1]. Upwelling in coastal systems also promotes increased productivity by conveying deep, nutrient-rich waters to the surface, where the nutrients can be assimilated by algae. Excessive nutrient concentrations and plant, algal, and bacterial growth can overwhelm eutrophic systems and lead to a reduction in DO levels that can affect the overall ecological health of the system.

Lower and Middle Reach Dissolved Oxygen

Mean dissolved oxygen concentrations at Patty's Rock were generally higher at the surface sonde compared to the mid-depth sonde. Whereas the Patty's Rock surface sonde had a mean DO concentration of 8.9 mg/L, the mid-depth sonde had a mean DO concentration of 6.2 mg/L (Table 4.1.1). The mid-depth and surface sondes were both observed to experience supersaturation conditions, and occasional hypoxic conditions. These supersaturation and hypoxic events were observed during open and closed conditions (Figure 4.1.17).

The effect of closed conditions at the surface sonde was variable as DO concentrations were observed to increase to supersaturation conditions before declining to normal concentrations during the October closure (Figure 4.1.17). The Patty's Rock surface sonde had a minimum DO concentration of 5.1 mg/L (Table 4.1.1). Minimum concentrations were observed to occur in brackish to saline water during open conditions (Figures 4.1.17 and 4.1.3).

DO concentrations were observed to become hypoxic at the Patty's Rock mid-depth sonde during open and closed conditions (Figure 4.1.17). The minimum DO concentration at the mid-depth sonde was 0.2 mg/L, which occurred before and during the July closure event (Table 4.1.1).

The Patty's Rock surface sonde, and mid-depth sonde to a lesser degree, experienced hourly fluctuating supersaturation events. Supersaturation events were observed at the surface sonde during open and closed estuary conditions, as well as during summer dam removal (Figure 4.1.17). Supersaturation events typically occurred during open conditions at the mid-depth sonde. At times when oxygen production exceeds the diffusion of oxygen out of the system, supersaturation may occur (Horne, 1994). DO concentrations exceeding 100% saturation in the

[1] National Estuarine Eutrophication Assessment by NOAA National Centers for Coastal Ocean Science (NCCOS) and the Integration and Application Network (IAN), 1999.

water column are considered supersaturated conditions. Because the ability of water to hold oxygen changes with temperature, there are a range of concentration values that correspond to 100% saturation. For instance, at sea level, 100% saturation is equivalent to approximately 11 mg/L at 10 °C, but only 8.2 mg/L at 24 °C. Consequently, these two temperature values roughly represent the range of temperatures typically observed in the Estuary.

The Patty's Rock surface sonde had a maximum DO concentration of 24.3 mg/L, which corresponded to 293% saturation (Table 4.1.1). The maximum DO concentration at the mid-depth sonde was 13.9 mg/L, which corresponded to 161% saturation (Table 4.1.1).

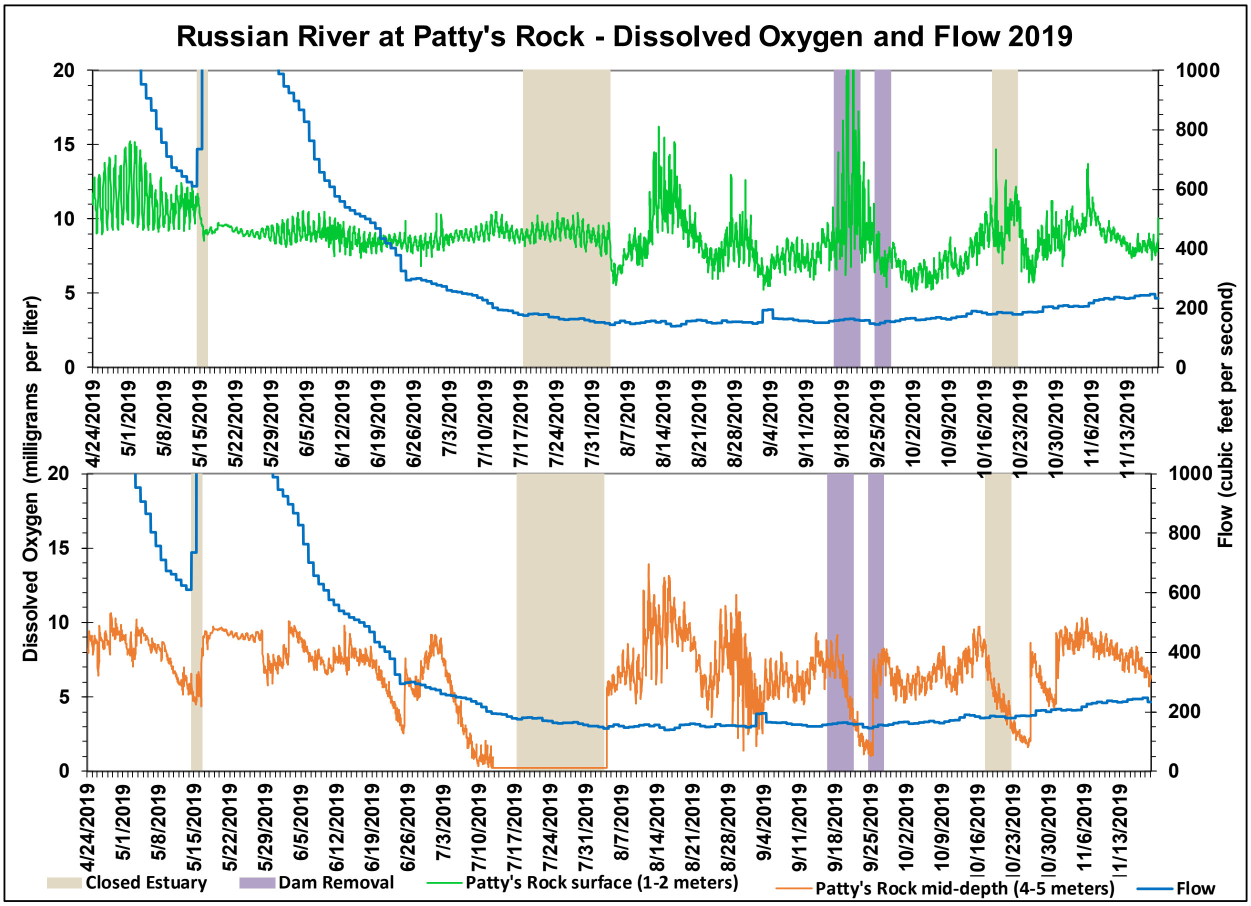


Figure 4.1.17. 2019 Russian River at Patty's Rock Dissolved Oxygen and Flow Graph

Dissolved oxygen concentrations in Willow Creek were observed to fluctuate in response to a variety of events including tidal water movement, saline intrusion, and open or closed Estuary conditions. Large diurnal swings in dissolved oxygen concentrations were observed to occur with frequent supersaturation events in both brackish and freshwater during open barrier beach conditions (Figure 4.1.18). Whereas, dissolved oxygen concentrations were observed to steadily decline over a period of days during the July barrier beach closure in freshwater conditions. However, dissolved oxygen concentrations were observed to recover between and after closures as oxygenated saline water or freshwater migrated back into the station (Figure 4.1.18).

The Willow Creek sonde had a minimum DO concentration of 0.0 mg/L, a mean DO concentration of 8.2 mg/L, and a maximum DO concentration of 16.0 mg/L (201%) (Table 4.1.1).

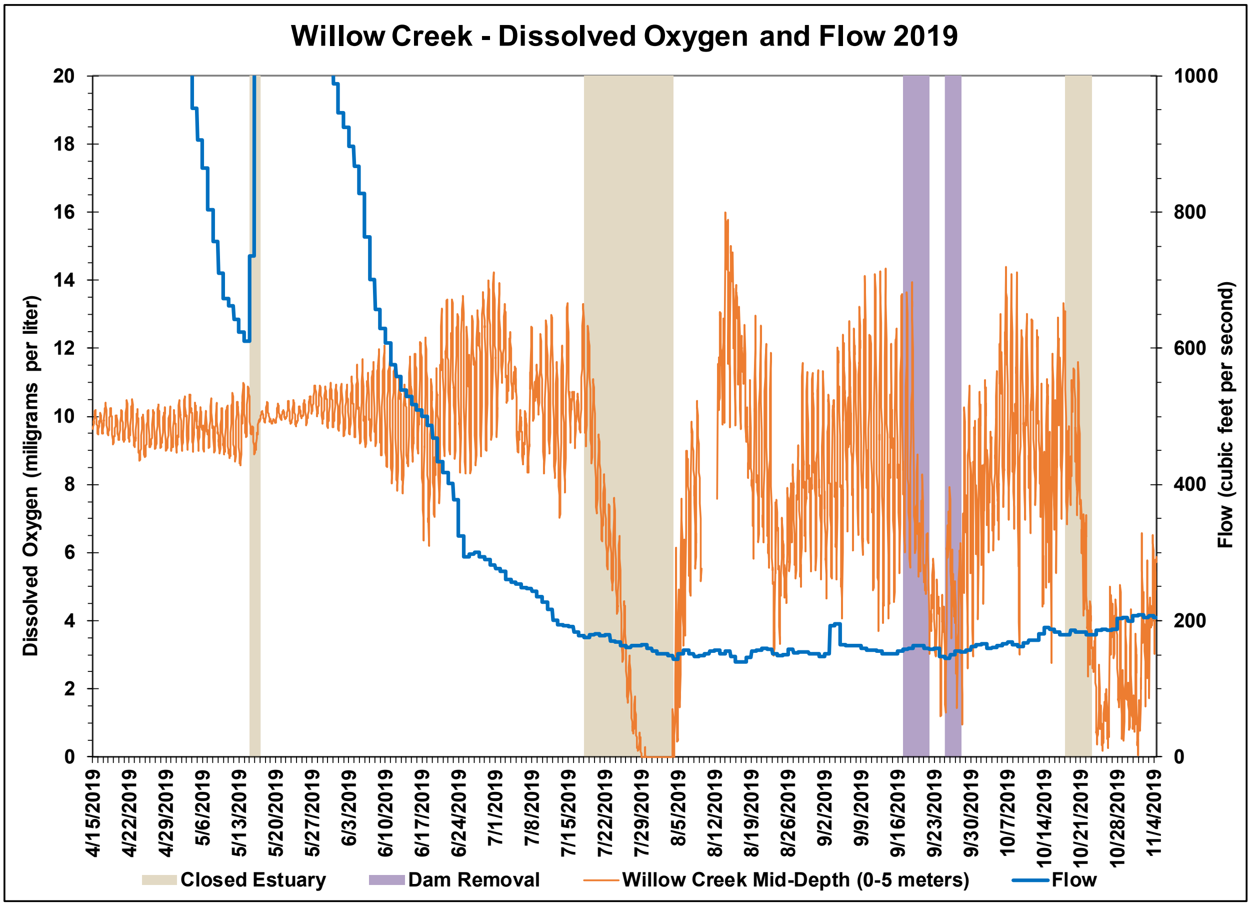


Figure 4.1.18. 2019 Willow Creek Dissolved Oxygen and Russian River Flow Graph

Upper Reach Dissolved Oxygen

Dissolved oxygen concentrations in the upper reach were influenced by the presence or absence of salinity, with lower minimum and mean DO concentrations typically observed in brackish water and higher minimum and mean concentrations observed in freshwater, especially during closed conditions. Although the bottom sonde at Freezeout Creek malfunctioned and salinity concentrations were not recorded, the mid-depth of the station remained a predominantly freshwater habitat that was subject to elevated salinity levels as the salt wedge migrated up the Estuary during and following the October closure event (Figure 4.1.5). Whereas, the Brown's Pool station remained freshwater habitat during the entire monitoring season with no elevated salinity levels recorded in 2019 (Figure 4.1.6).

Depressed oxygen concentrations approaching hypoxic levels were observed to occur at the Freezeout Creek mid-depth sonde in brackish habitat following the October closure (Figure 4.1.19). Whereas, hypoxic and anoxic conditions were observed to occur in freshwater habitat during open and closed conditions at the bottom of the Brown's Pool station, and to a lesser degree at the mid-depth sonde during the July closure (Figure 4.1.20).

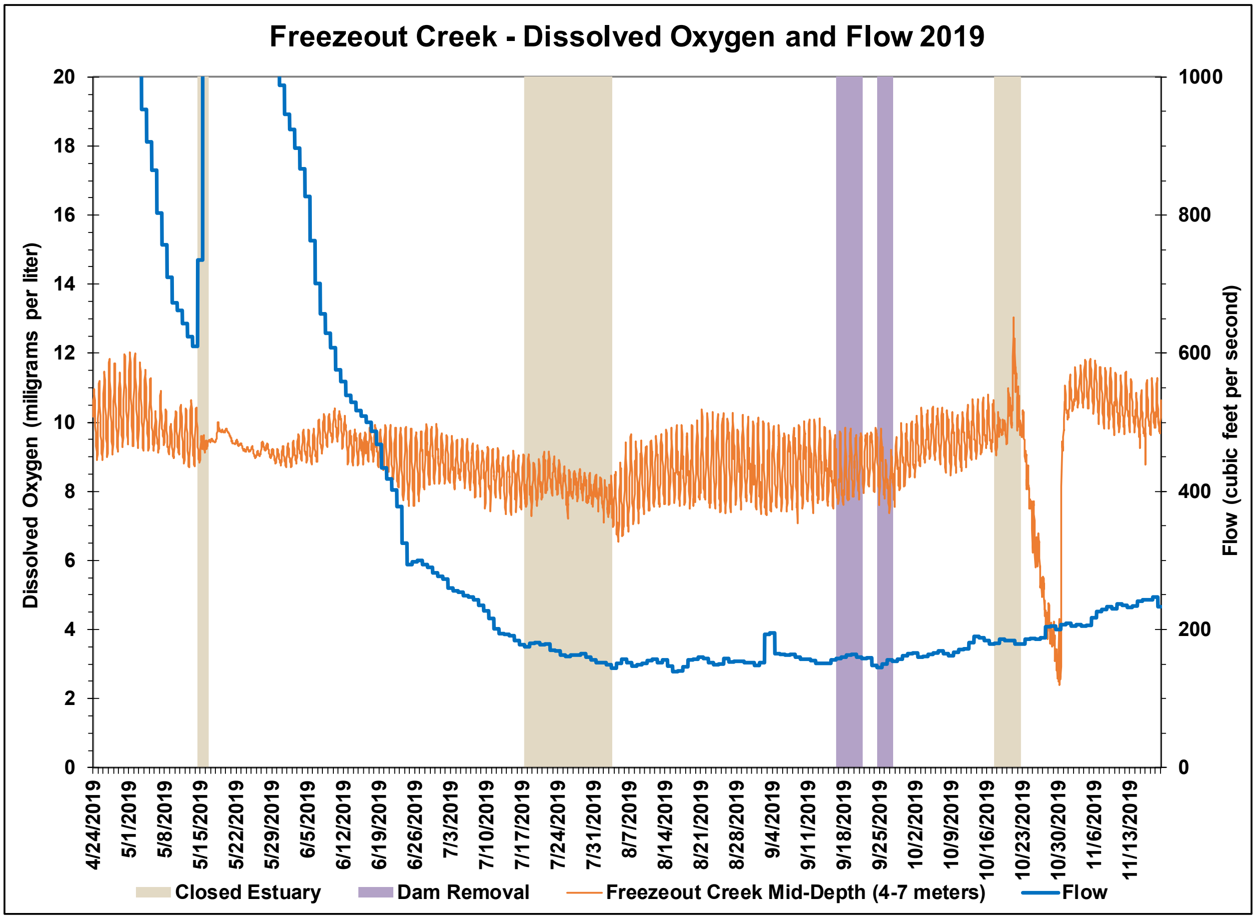


Figure 4.1.19. 2019 Russian River at Freezeout Creek Dissolved Oxygen and Flow Graph

The Freezeout Creek mid-depth sonde had a minimum concentration of 2.4 mg/L, a mean DO concentration of 9.0 mg/L, and a maximum concentration of 13.0 mg/L (140%) (Table 4.1.1).

The Brown's Pool mid-depth sonde had a minimum concentration of 4.4 mg/L, a mean DO concentration of 8.7 mg/L, and a maximum concentration of 11.5 mg/L (122%) (Table 4.1.1). The Brown's Pool bottom sonde was observed to have a minimum DO concentration of 0.1 mg/L, a mean concentration of 4.5 mg/L, and a maximum concentration of 11.4 mg/L (121%) (Table 4.1.1).

The bottom of Brown's Pool remained freshwater habitat during the entire monitoring season in open and closed conditions (Figure 4.1.6). DO concentrations remained relatively stable in freshwater conditions through the first half of June with flows above 400 cfs, and through August following the extended July closure. However, depressed concentrations as low as 0.1 mg/L were observed to occur during open conditions in late June extending through the closure in

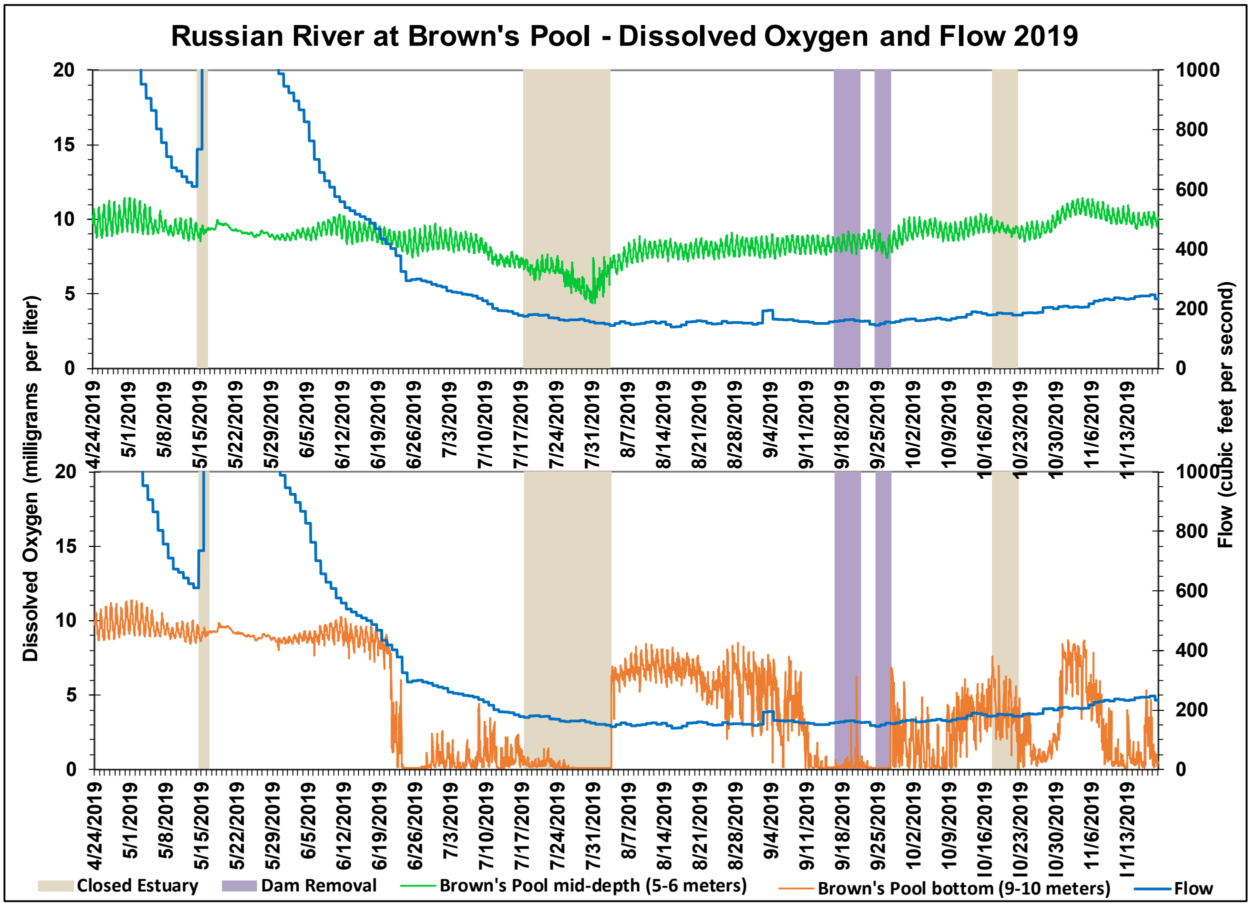


Figure 4.1.20. 2019 Russian River at Brown's Pool Dissolved Oxygen and Flow Graph

July, and again in early September through the latter half of the monitoring season (Figure 4.1.20).

Maximum Backwater Area Dissolved Oxygen

The Austin Creek sonde was deployed from April to the end of September when a lack of flow and adequate water depth required equipment removal for the remainder of the season. During that period, the Austin Creek station had a minimum DO concentration of 3.8 mg/L, a mean concentration of 8.1 mg/L, and a maximum concentration of 10.6 mg/L (108%) (Table 4.1.1).

Minimum concentrations at Austin Creek were observed when flows dropped to approximately 2 cfs in late September (Figure 4.1.21).

The Patterson Point bottom sonde had a minimum DO concentration of 0.2 mg/L, a mean concentration of 6.8 mg/L, and a maximum concentration of 11.4 mg/L (132%). The bottom sonde was predominantly hypoxic to anoxic from July through August under open and closed conditions and remained depressed through October (Figure 4.1.22).

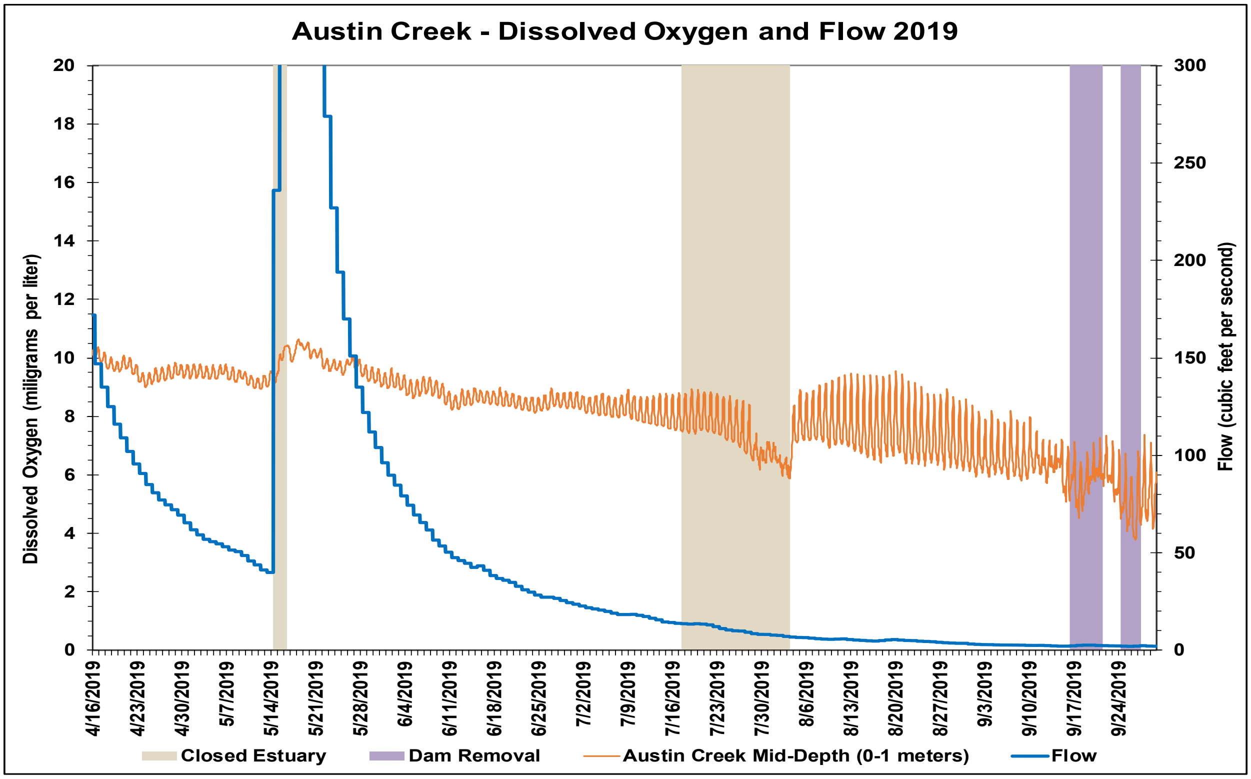


Figure 4.1.21. 2019 Austin Creek Dissolved Oxygen and Flow Graph. Sonde pulled early due to low water levels.

The Patterson Point mid-depth sonde had minimum, mean, and maximum DO concentrations of 3.7, 8.3, and 11.5 mg/L (134%), respectively (Table 4.1.1). DO concentrations were observed to remain relatively stable in freshwater conditions, with depressed concentrations as low as 3.7 mg/L being observed to occur during the extended closure in late July (Figure 4.1.22). The DO sensor malfunctioned and no data were recorded during October or November.

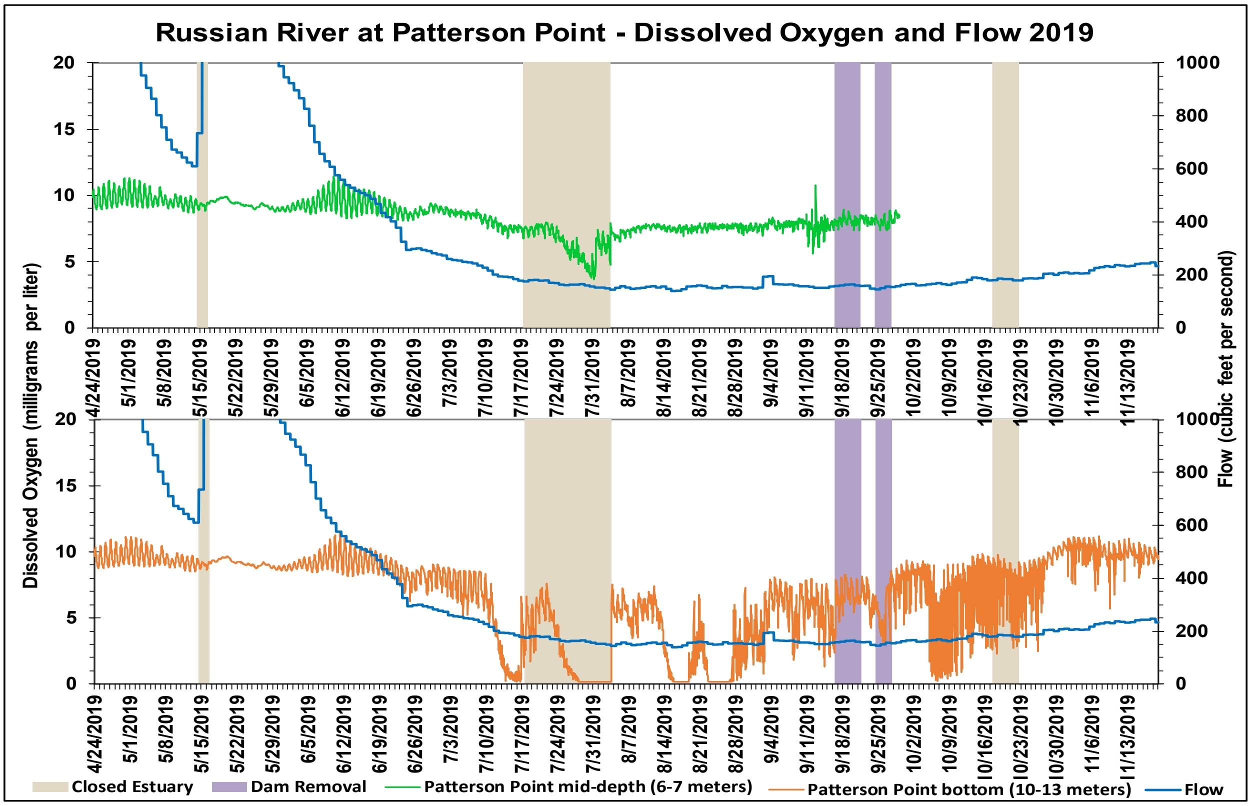


Figure 4.1.22. 2019 Russian River at Patterson Point Dissolved Oxygen and Flow Graph

The Monte Rio Station had a minimum concentration of 7.2 mg/L, a mean DO concentration of 8.8 mg/L, and a maximum concentration of 11.6 mg/L (136%) during the abbreviated monitoring period (Table 4.1.1). The minimum DO concentration occurred on 4 August during open conditions just after the extended July closure (Figure 4.1.23). Although there were some temporally localized DO concentrations between 7 and 8 mg/L, DO concentrations did not appear to be significantly affected by summer flows, closed conditions, or summer dam removal and remained above 8 mg/L, on average, during both open and closed conditions (Figure 4.1.23).

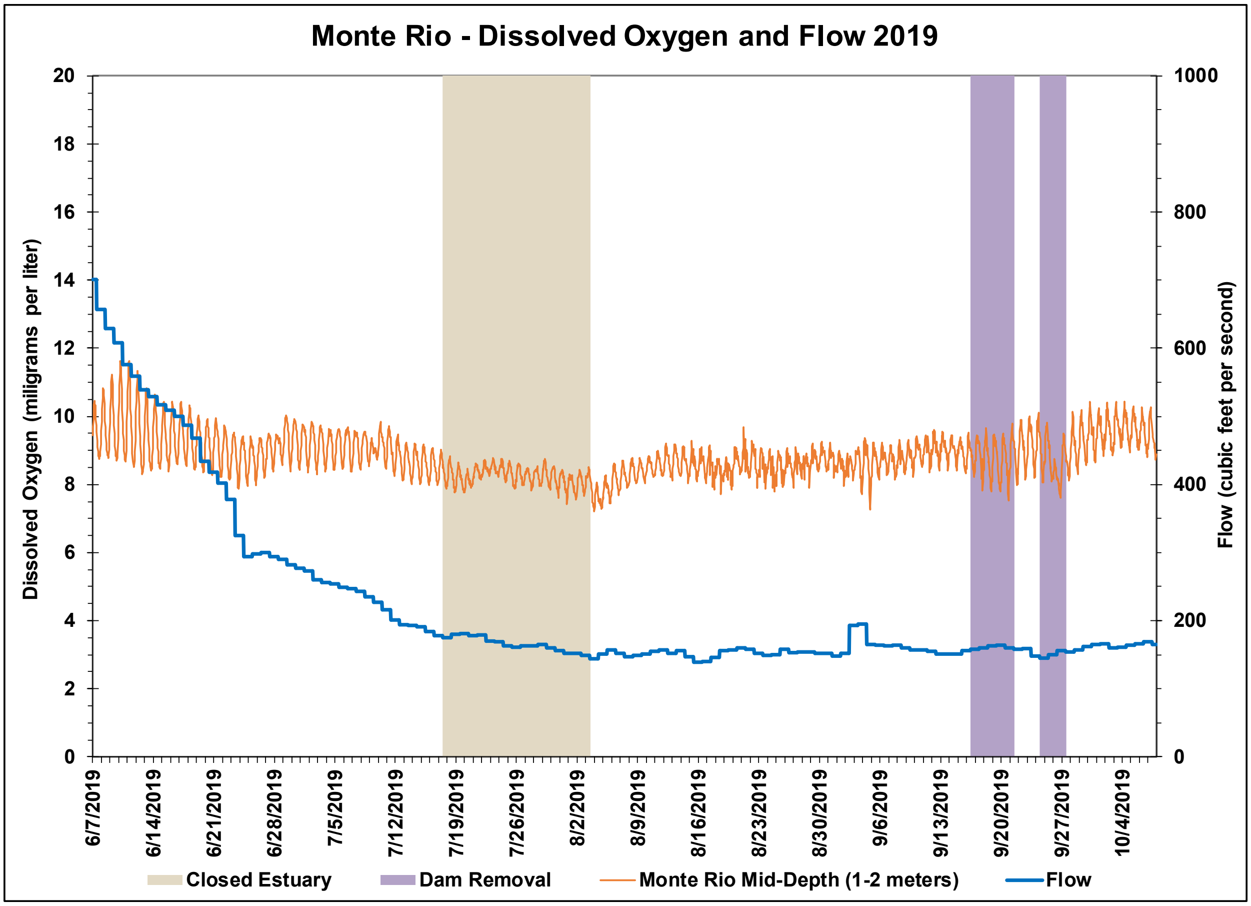


Figure 4.1.23. 2019 Russian River at Monte Rio Dissolved Oxygen and Flow Graph. Sonde pulled early due to limited access.

Hydrogen Ion (pH)

The acidity or alkalinity of water is measured in units called pH, an exponential scale of 1 to 14 (Horne, 1994). Acidity is controlled by the hydrogen ion H+, and pH is defined as the negative log of the hydrogen ion concentration. A pH value of 7 is considered neutral, freshwater streams generally remain at a pH between 6 and 9, and ocean derived salt water is usually at a pH between 8 and 9. When the pH falls below 6 over the long term, there is a noticeable reduction in the abundance of many species, including snails, amphibians, crustacean zooplankton, and fish such as salmon and some trout species (Horne, 1994).

Lower and Middle Reach pH

The Patty's Rock surface sonde had a minimum pH value of 7.6, a mean pH value of 8.1, and a maximum pH value of 8.9 pH (Table 4.1.1). The Patty's Rock mid-depth sonde had a minimum pH value of 7.6, a mean pH value of 8.9, and a maximum pH value of 11.2 pH. A maximum value of 11.2 pH is unusually high and it appears the pH sensor began to malfunction and drift from it's calibration point during anoxic conditions in early July, when values should have been declining, and continued through the rest of the season (Figures 4.1.24 and 4.1.17).

Patty's Rock pH values were observed to vary with increases and decreases of DO concentrations, with higher values generally observed during supersaturation conditions and lower values during hypoxic conditions (Figures 4.1.24 and 4.1.17). This relationship between DO and pH was also observed at the mid-depth sonde even with the seasonal upward drift in overall pH values.

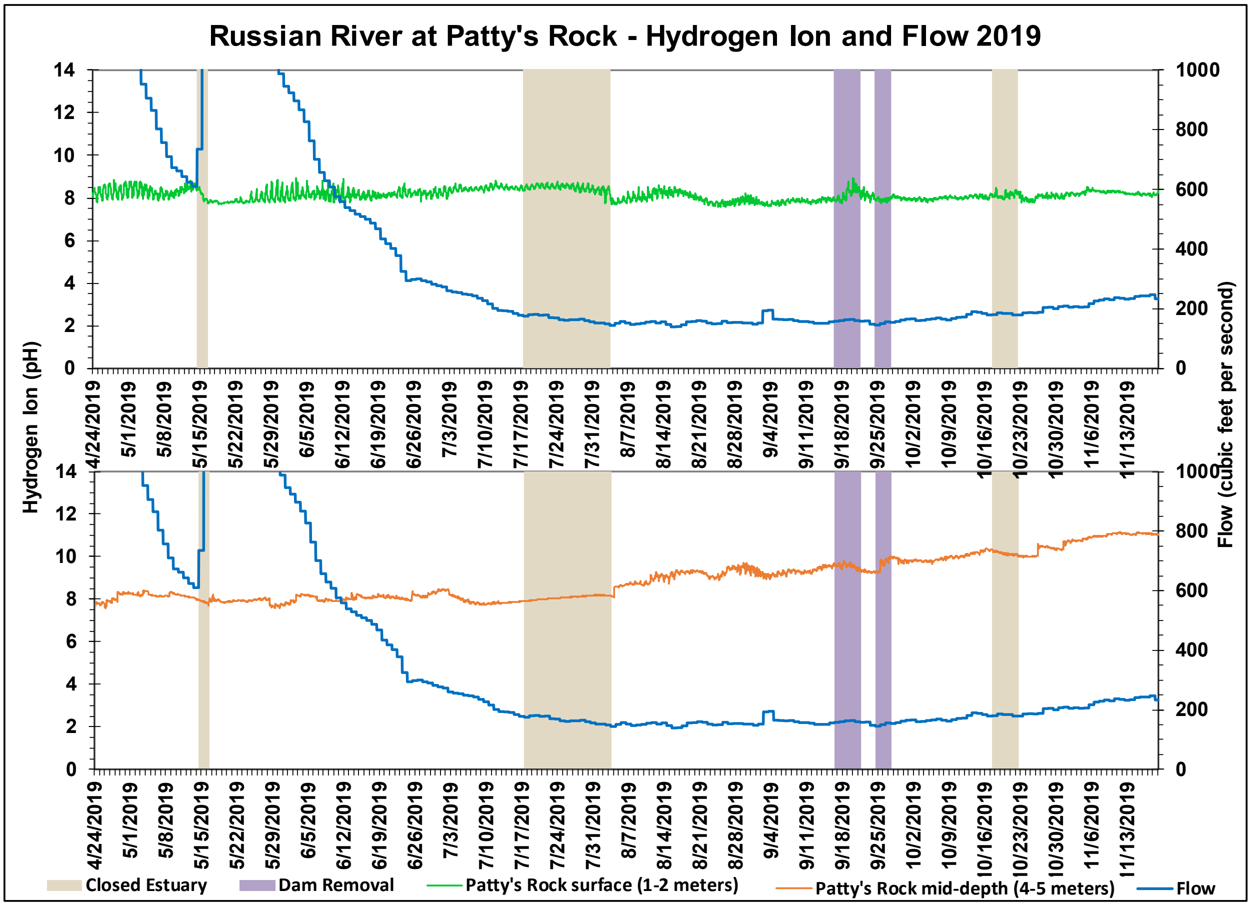


Figure 4.1.24. 2019 Russian River at Patty's Rock Hydrogen Ion and Flow Graph

The Willow Creek station had a minimum pH value of 6.7, a mean pH value of 7.6, and a maximum pH value of 8.8 (Table 4.1.1). The Willow Creek station also had pH values that were observed to vary with increases and decreases of DO concentrations, as well as with fluctuations in salinity associated with reduced freshwater flows, tidal influence, and Estuary closures (Figures 4.1.25 and 4.1.18).

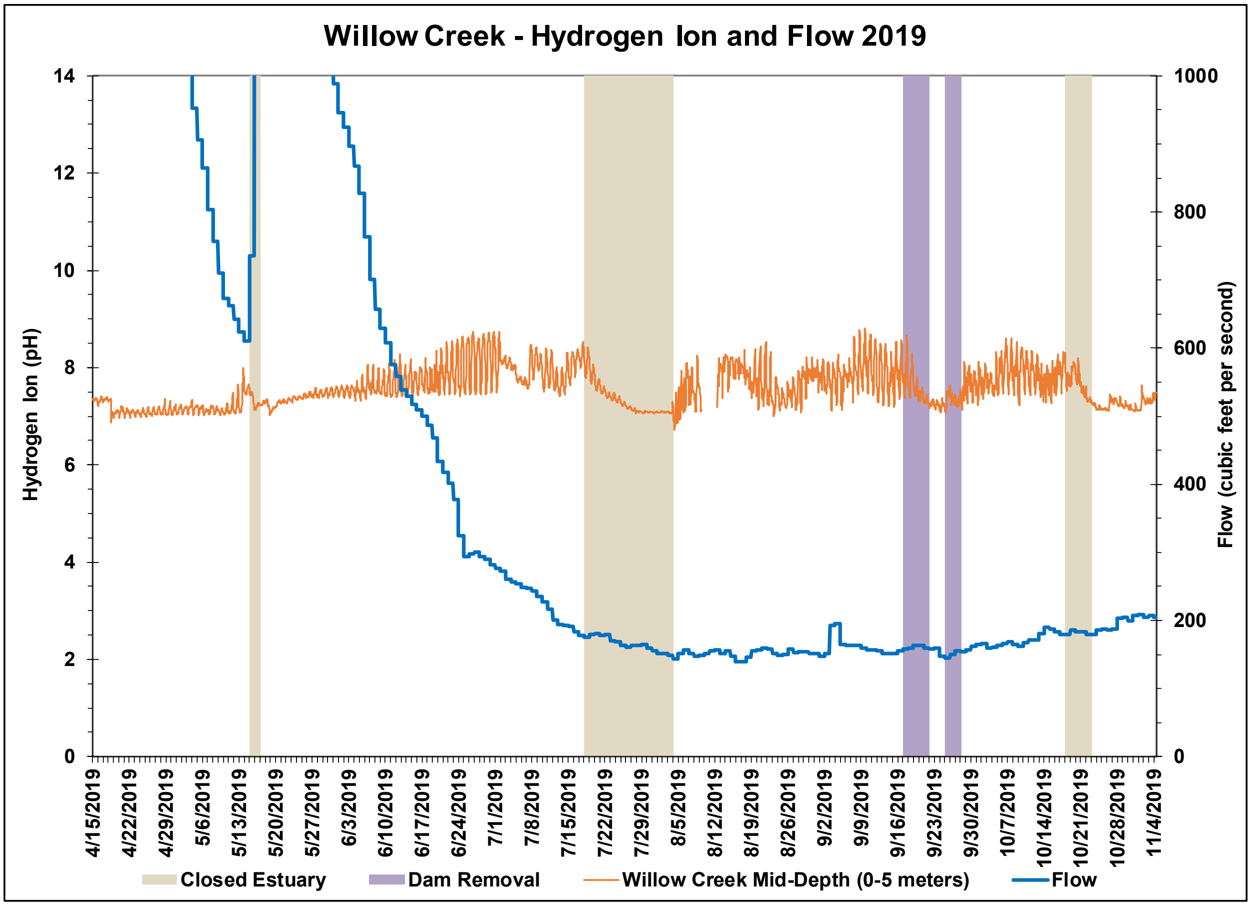


Figure 4.1.25. 2019 Willow Creek Hydrogen Ion and Russian River Flow Graph

Upper Reach pH

The Freezeout Creek mid-depth sonde recorded a minimum pH value of 7.2, a mean pH value of 8.0, and a maximum pH value of 8.5 (Table 4.1.1). The Freezeout Creek station had pH values that were observed to vary with DO concentrations in the presence of both freshwater and brackish water (Figures 4.1.26 and 4.1.19).

The Brown’s Pool mid-depth sonde had a minimum pH value of 7.5, a mean pH value of 7.9, and a maximum pH value of 8.3 (Table 4.1.1). The Brown’s Pool bottom sonde had a minimum pH value of 6.5, a mean pH value of 7.4, and a maximum pH value of 8.2 (Table 4.1.1). Minimum pH values occurred at the bottom sonde in freshwater during anoxic conditions when the Estuary was open (Figures 4.1.27 and 4.1.20).

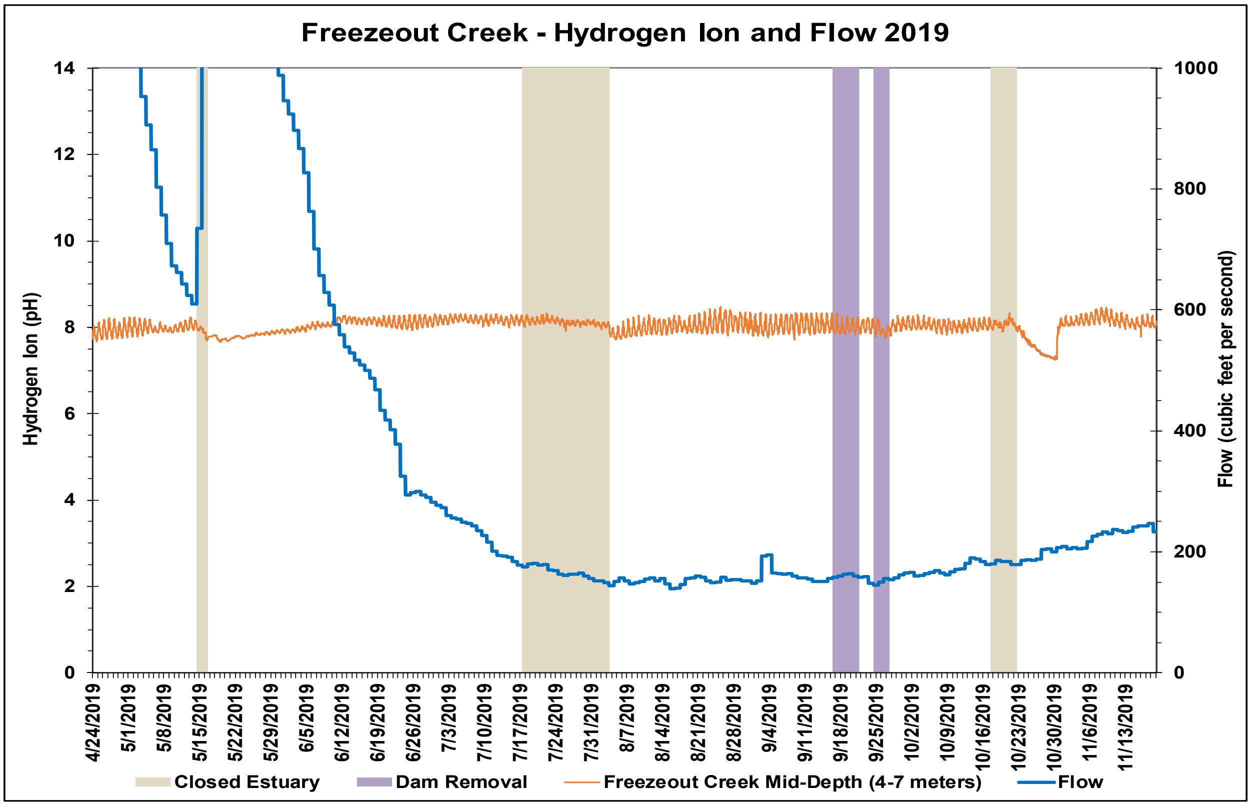


Figure 4.1.26. 2019 Russian River at Freezeout Creek Hydrogen Ion and Flow Graph

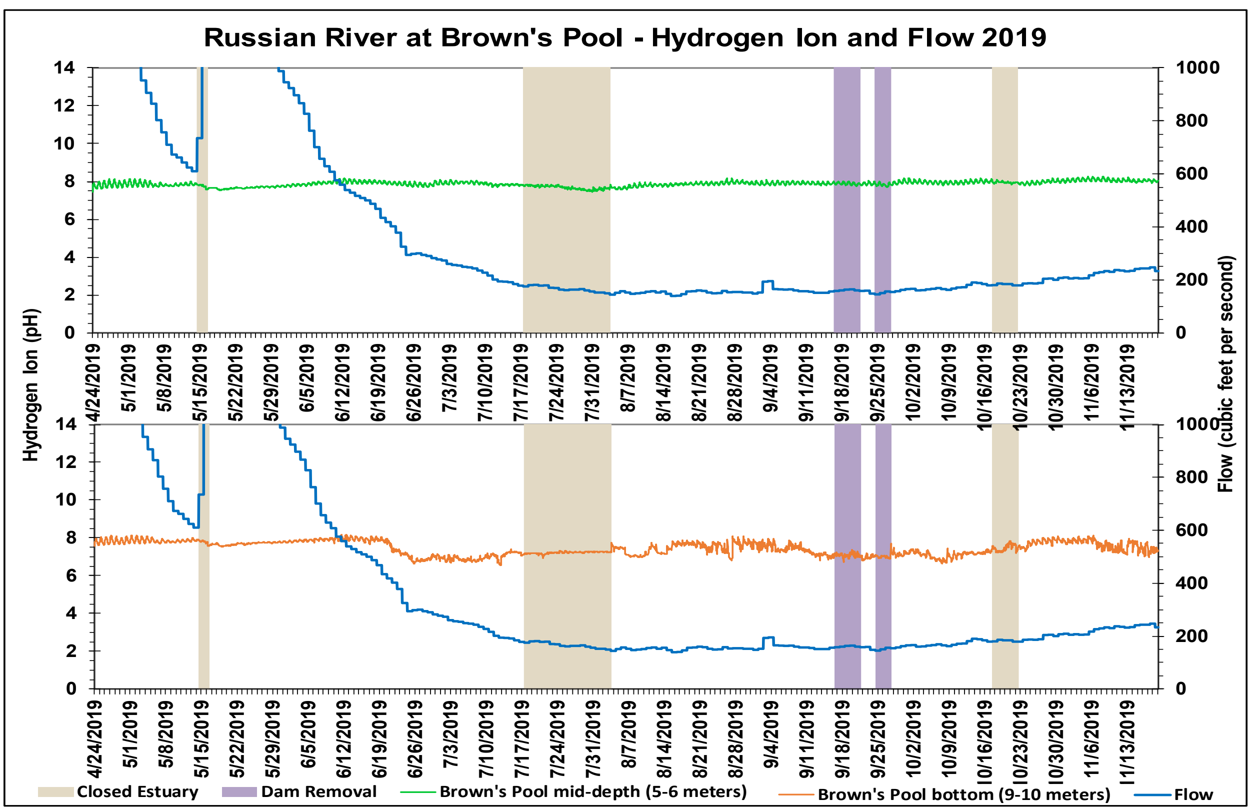


Figure 4.1.27. 2019 Russian River at Brown's Pool Hydrogen Ion and Flow Graph

Maximum Backwater Area pH

The Austin Creek sonde had a minimum pH value of 7.5, a mean pH value of 7.8, and a maximum pH value of 8.1 (Table 4.1.1). The Austin Creek sonde also had pH values that were generally observed to vary with increases and decreases of DO concentrations, though not as significantly as some of the mainstem stations (Figures 4.1.28 and 4.1.21).

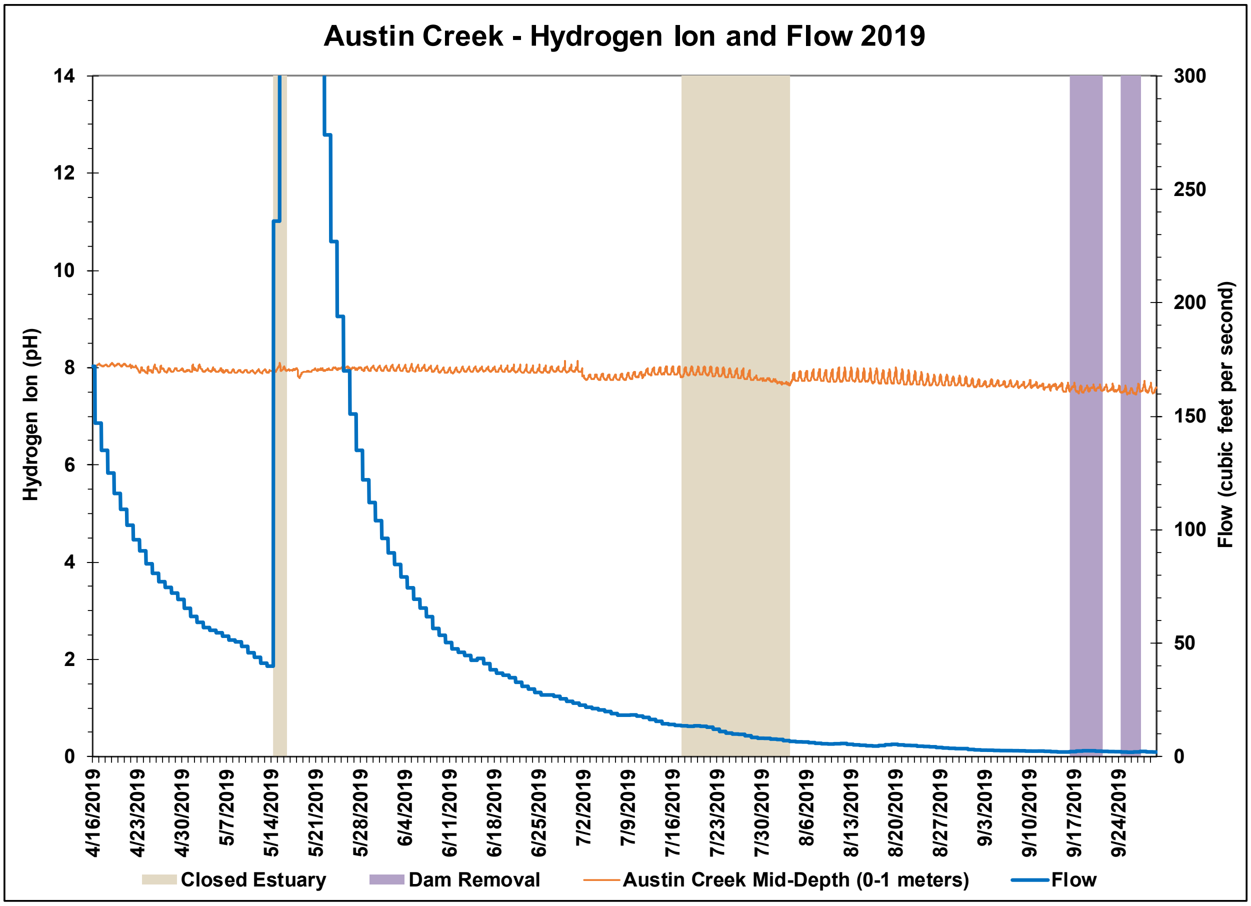


Figure 4.1.28. 2019 Austin Creek Hydrogen Ion and Flow Graph. Sonde pulled early due to low water levels.

The Patterson Point mid-depth sonde had a minimum pH value of 7.3, a mean pH value of 7.7, and a maximum pH value of 8.2 (Table 4.1.1).The Patterson Point bottom sonde had a minimum pH value of 6.8, a mean pH value of 7.2, and a maximum pH value of 8.0 (Table 4.1.1). The Patterson Point sondes also had pH values that were generally observed to vary with increases and decreases of DO concentrations, although values did not appear to be significantly affected by summer flows or closed conditions and remained fairly stable through the monitoring period (Figures 4.1.29 and 4.1.22).

The Monte Rio sonde recorded a minimum pH value of 7.4, a mean pH value of 7.7, and a maximum pH value of 8.2 (Table 4.1.1). Again, the sonde here recorded pH values that were generally observed to vary with increases and decreases of DO concentrations (Figures 4.1.30 and 4.1.23). Overall, pH values did not appear to be significantly affected by summer flows or closed conditions and remained fairly stable through the monitoring period (Figure 4.1.30).

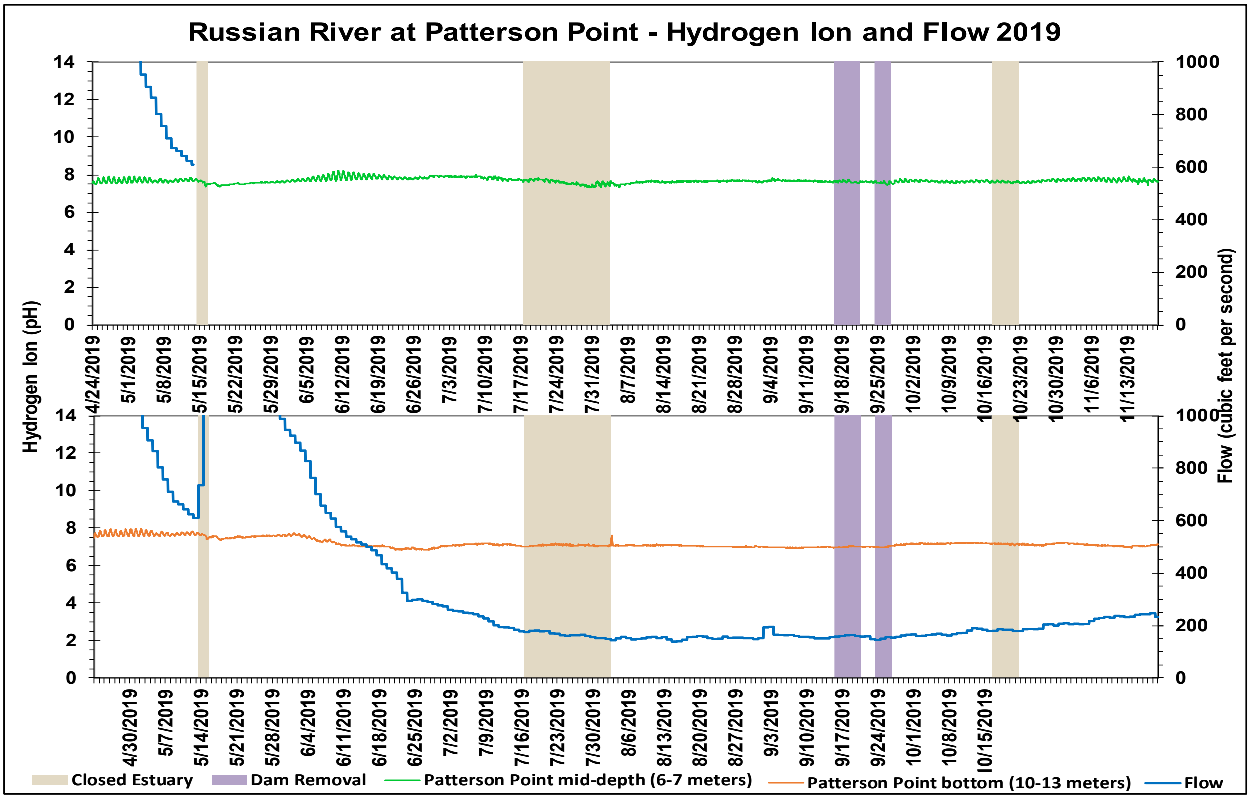


Figure 4.1.29. 2019 Russian River at Patterson Point Hydrogen Ion and Flow Graph

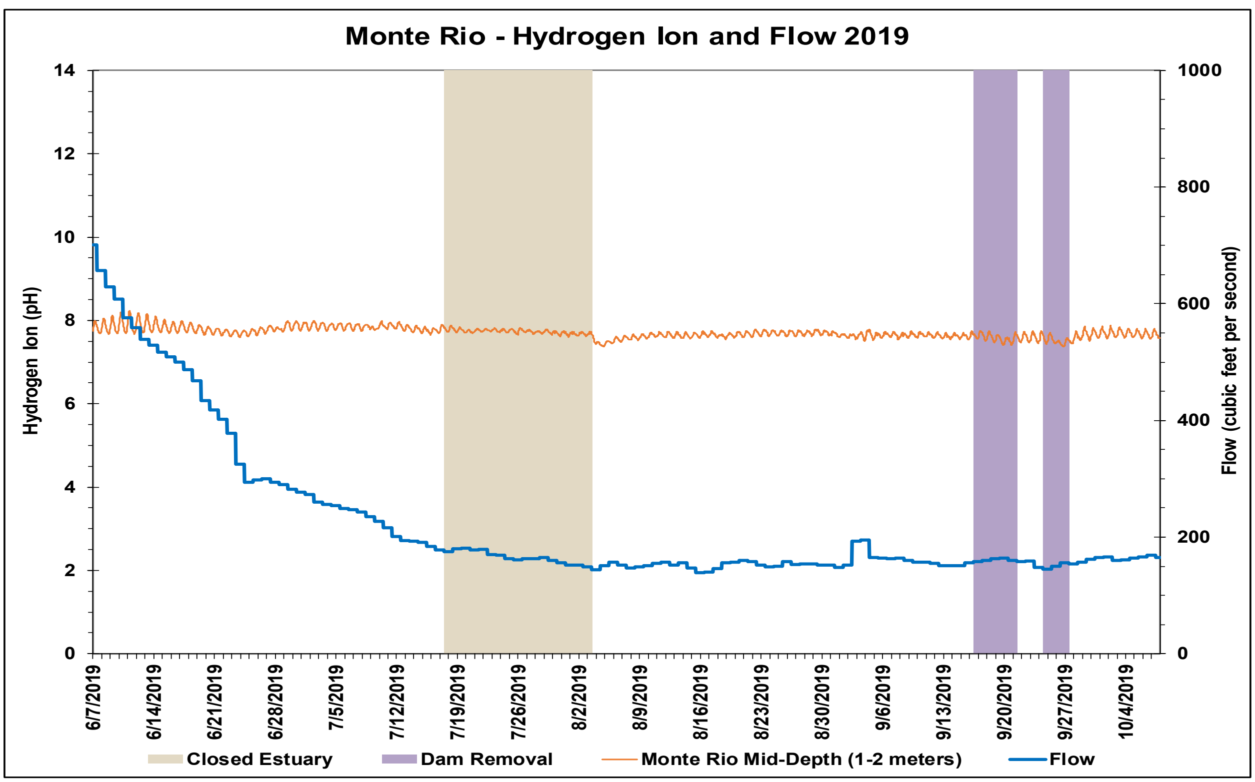


Figure 4.1.30. 2019 Russian River at Monte Rio Hydrogen Ion and Flow Graph. Sonde pulled early due to limited access.

Grab Sampling

Sonoma Water staff conducted weekly grab sampling from 14 May to 15 October at three freshwater stations in the MBA, including Patterson Point, Monte Rio, and Vacation Beach (Figure 4.1.1). Additional focused sampling was conducted during and after summer dam removal in late September, where Sonoma Water staff would collect three samples in ten days (Tables 4.1.2 through 4.1.4). Samples collected and analyzed for nutrients, turbidity, *chlorophyll a*, and indicator bacteria are discussed below. Other sample results including organic carbon, and dissolved solids are not discussed, but are included as an appendix to the report.

Nutrients

The United States Environmental Protection Agency (USEPA) has established section 304(a) nutrient criteria across 14 major ecoregions of the United States. The Russian River was designated in Aggregate Ecoregion III (USEPA, 2013a). USEPA's section 304(a) criteria are intended to provide for the protection of aquatic life and human health (USEPA, 2013b). The following discussion of nutrients compares sampling results to these USEPA criteria. However, it is important to note that these criteria are established for freshwater systems, and as such, are only applicable to the freshwater portions of the Estuary. Currently, there are no numeric nutrient criteria established specifically for estuaries.

The USEPA desired goal for total nitrogen in Aggregate Ecoregion III is 0.38 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Calculating total nitrogen values requires the summation of the different components of total nitrogen; organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN), and nitrate/nitrite nitrogen.

The EPA criteria for Total Nitrogen was exceeded three times at Monte Rio and Patterson Point and twice at Vacation Beach with Hacienda flows ranging from 152 cfs to 3,060 cfs (Tables 4.1.2 through 4.1.4). All exceedances, except for an anomalous result at Patterson Point, were observed to occur during the May storm events and open estuary conditions at the beginning of the season, with all three stations exceeding the criteria on 14 May and 21 May (Figure 4.1.31). Whereas some of the lowest total nitrogen values observed at the freshwater stations occurred during open conditions in the latter half of the monitoring season with flows as low as 150 cfs (Tables 4.1.2 through 4.1.4). Overall, total nitrogen exceedances constituted 9.5% of all samples collected (Figure 4.1.31).

The maximum total nitrogen concentration observed at Patterson Point was 24 mg/L on 13 August during open conditions with a flow of approximately 153 cfs, although this was most likely a result of sampling error (Table 4.1.2). Aside from this result, the maximum concentration observed at Patterson Point was 0.38 mg/L which occurred twice in May during elevated storm flows (Figure 4.1.31). Excluding the 13 August result, the mean concentration at Patterson Point was 0.18 mg/L. The minimum concentration at Patterson Point was 0.0047 mg/L, which occurred on 20 August during open conditions with a flow of approximately 157 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September with a concentration of 0.18 mg/L (Table 4.1.2).

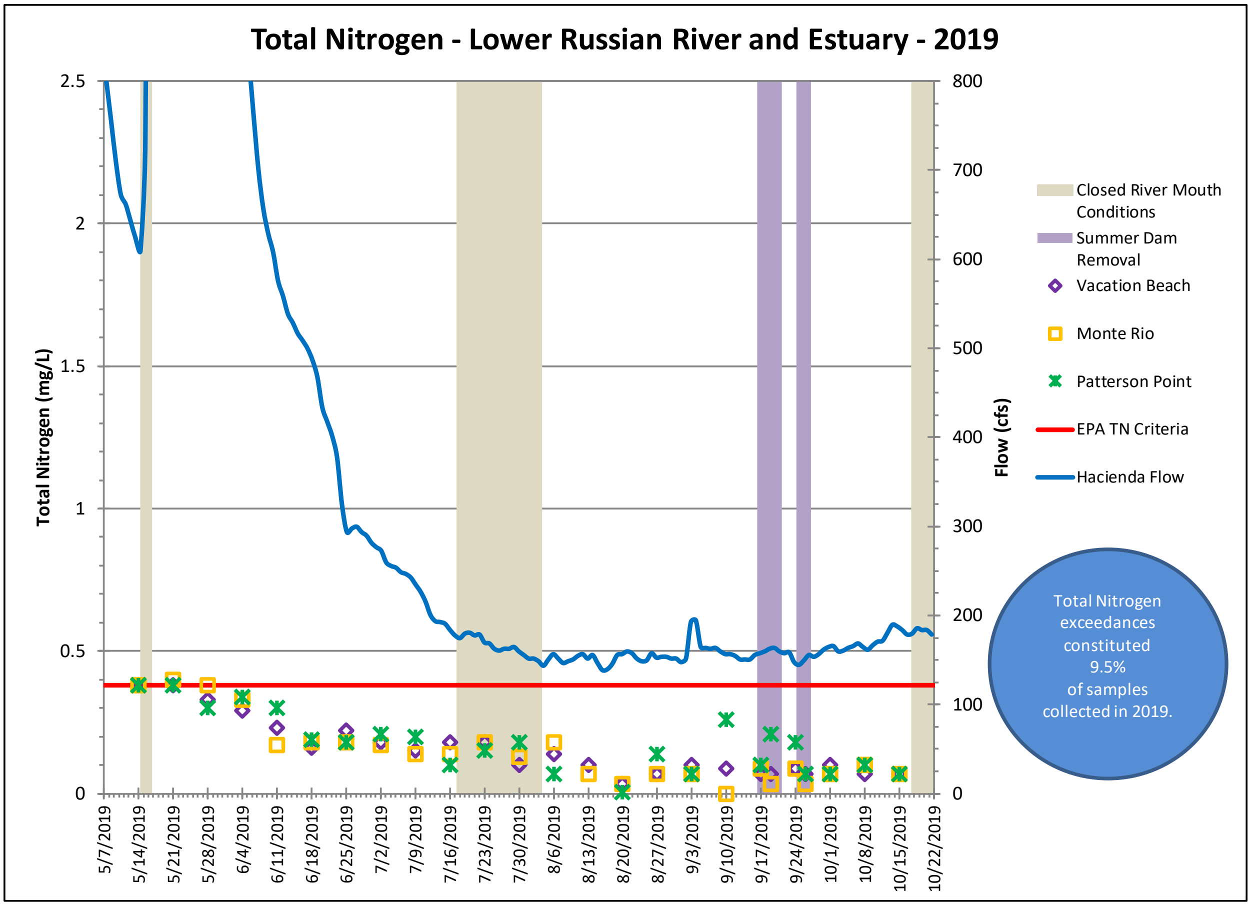


Figure 4.1.31. 2019 Russian River Grab Sampling Results for Total Nitrogen

Table 4.1.2. 2019 Russian River at Patterson Point Station Grab Sample Results

Patterson Point*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	Total Coliforms (Colilert)	Total Coliforms Diluted 1:10 (Colilert)	E. coli (Colilert)	E. coli Diluted 1:10 (Colilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)***		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/14/2019	18.7	**0.38**	**0.11**	**3.3**	**0.0031**	2419.6	2851	6.3	<10	2.0	610	Open	2.91
5/21/2019	14.6	**0.38**	**0.13**	**50**	ND	>2419.6	8664	**435.2**	**295**	**214.2**	3060	Open	0.76
5/28/2019	17.0	0.30	**0.063**	**13**	**0.0023**	721.5	1565	60.2	52	36.8	1300	Open	1.47
6/4/2019	18.5	0.34	**0.059**	**7.1**	**0.0026**	>2419.6	2014	26.2	10	20.9	867	Open	
6/11/2019	21.3	0.30	**0.035**	**3.3**	**0.0069**	119.9	1439	13.2	10	15.6	576	Open	1.90
6/18/2019	20.6	0.19	**0.032**	**2.5**	**0.0021**	816.4	738	12.2	<10	6.3	487	Open	1.47
6/25/2019	22.7	0.18	**0.036**	**2.6**	**0.0037**	1299.7	2064	13.4	<10	2.0	294	Open	1.60
7/2/2019	22.8	0.21	**0.034**	2.2	**0.0074**	1732.9	1664	24.6	<10	8.6	273	Open	2.02
7/9/2019	22.5	0.20	**0.034**	1.6	**0.0022**	1986.3	1314	15.8	<10	16.1	235	Open	3.54
7/16/2019	24.5	0.10	**0.038**	**3.1**	**0.0062**	>2419.6	4884	17.1	41	17.1	184	Open	3.58
7/23/2019	22.8	0.15	**0.036**	**2.7**	**0.0052**	>2419.6	5475	76.3	96	28.1	170	Closed	6.41
7/30/2019	24.2	0.18	**0.043**	1.7	**0.0036**	>2419.6	3873	24.6	63	20.9	160	Closed	7.97
8/6/2019	23.1	0.070	**0.037**	**2.4**	ND	>2419.6	5475	5.2	10	4.1	157	Open	0.72
8/13/2019	23.3	**24**	**0.059**	1.7	ND	2419.9	1935	4.1	10	6.3	152	Open	0.55
8/20/2019	22.9	0.0047	**0.036**	2.0	0.0016	1203.3	1211	8.6	10	6.3	157	Open	0.55
8/27/2019	22.9	0.14	**0.039**	1.6	ND	1986.3	1236	28.1	31	6.3	153	Open	1.60
9/3/2019	22.8	0.070	**0.033**	**2.4**	0.0012	1732.9	1222	15.6	20	3.1	193	Open	0.55
9/10/2019	21.4	0.26	**0.027**	0.97	ND	1046.2	9.6	10.7	<10	9.7	157.0	Open	1.22
9/17/2019	21.1	0.10	**0.025**	1.6	ND	770.1	683	7.4	<10	9.8	158	Open	0.72
9/19/2019	20.8	0.21	**0.024**	1.1	ND	866.4	836	79.8	86	**69.1**	163	Open	1.43
9/24/2019	20.3	0.18	**0.022**	1.0	ND	686.7	703	8.6	<10	5.2	148	Open	1.94
9/26/2019	21.0	0.070	0.019	1.3	0.0010	980.4	771	8.6	10	21.3	150	Open	1.47
10/1/2019	17.2	0.070	0.020	1.3	0.0012	648.8	441	6.3	<10	12.2	165	Open	0.59
10/8/2019	16.6	0.10	0.020	1.4	ND	325.5	373	6.3	20	16.9	165	Open	1.98
10/15/2019	14.5	0.070	0.020	2.0	ND	307.6	262	42.8	52	35.5	188	Open	0.63

* All results are preliminary and subject to final revision

** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.

*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.

**** United States Geological Survey (USGS) Continuous-Record Gaging Station (Flow rates are preliminary and subject to final revision by USGS).

Recommended EPA Criteria based on Aggregate Ecoregion III

Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L

Total Nitrogen: 0.38 mg/L

Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L

Turbidity: 2.34 FTU/NTU

CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:

Beach posting is recommended when indicator organisms exceed any of the following levels:

Total coliforms: 10,000 per 100 ml

E. coli: 235 per 100 ml

Enterococcus: 61 per 100 ml

The maximum total nitrogen concentration observed at Monte Rio was 0.40 mg/L on 21 May during elevated storm flows and open conditions with a flow of approximately 3060 cfs (Table 4.1.3). The mean concentration at Monte Rio was 0.15 mg/L. The minimum concentration at Monte Rio was a non-detect (ND), which occurred on 10 September during open conditions with a flow of approximately 157 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September with a concentration of 0.088 mg/L (Table 4.1.3).

The maximum total nitrogen concentration observed at Vacation Beach was 0.38 mg/L which occurred twice in May during elevated storm flows and open conditions with flows of approximately 610 cfs and 3060 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.15 mg/L. The minimum concentration at Vacation Beach was 0.035 mg/L, which occurred

Table 4.1.3. 2019 Russian River at Monte Rio Station Grab Sample Results

Monte Rio*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	Total Coliforms (Colilert)	Total Coliforms Diluted 1:10 (Colilert)	E. coli (Colilert)	E. coli Diluted 1:10 (Colilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)****		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/14/2019	18.4	**0.38**	**0.14**	**3.1**	**0.0045**	>2419.6	3255	18.9	<10	5.2	610	Open	2.99
5/21/2019	15.0	**0.40**	**0.12**	**50**	**0.0031**	>2419.6	**14136**	**344.8**	**443**	**328.2**	3060	Open	0.76
5/28/2019	16.8	**0.38**	**0.068**	**14**	**0.0023**	2419.6	1223	37.3	20	31.8	1300	Open	1.14
6/4/2019	18.7	0.33	**0.059**	**7.3**	**0.0029**	>2419.6	3076	20.1	41	21.1	867	Open	
6/11/2019	21.4	0.17	**0.039**	**3.8**	**0.014**	1299.7	1722	24.3	10	7.5	576	Open	1.52
6/18/2019	20.6	0.18	**0.034**	**2.6**	**0.0062**	980.4	1274	18.5	10	7.4	487	Open	1.35
6/25/2019	23.1	0.18	**0.036**	**2.5**	**0.0046**	1119.9	1935	42.0	62	8.6	294	Open	1.39
7/2/2019	22.0	0.17	**0.037**	2.1	**0.0060**	>2419.6	1674	24.3	<10	8.5	273	Open	1.90
7/9/2019	22.9	0.14	**0.034**	1.7	**0.0072**	1413.6	1259	107.1	134	53.4	235	Open	3.50
7/16/2019	24.2	0.14	**0.039**	**2.6**	**0.0069**	>2419.6	7701	30.5	31	8.6	184	Open	3.50
7/23/2019	23.3	0.18	**0.036**	**2.5**	**0.0067**	>2419.6	4884	105.0	134	39.7	170	Closed	6.41
7/30/2019	24.6	0.13	**0.037**	2.0	**0.0036**	>2419.6	**24196**	186.0	171	**1119.9**	160	Closed	7.97
8/6/2019	23.5	0.18	**0.035**	2.1	0.0015	>2419.6	6131	8.5	10	4.1	157	Open	0.63
8/13/2019	23.5	0.070	**0.029**	1.3	ND	>2419.6	3255	4.1	<10	3.0	152	Open	0.80
8/20/2019	23.0	0.035	**0.034**	1.8	ND	1046.2	1236	9.8	10	2	157	Open	0.55
8/27/2019	23.2	0.070	**0.035**	1.5	ND	1413.6	933	21.6	10	7.4	153	Open	1.94
9/3/2019	23.2	0.070	**0.028**	1.9	0.0013	1986.3	1126	27.5	41	**132**	193	Open	0.50
9/10/2019	21.4	ND	**0.025**	0.98	ND	980.4	1211	6.3	<10	8.4	157.0	Open	1.60
9/17/2019	21.0	0.088	**0.022**	1.4	**0.11**	966.4	932	5.2	<10	4.1	158	Open	0.67
9/19/2019	20.2	0.035	**0.023**	1.2	ND	613.1	565	31.3	10	13.2	163	Open	1.39
9/24/2019	20.5	0.088	0.020	1.2	ND	387.3	546	6.3	10	3.0	148	Open	1.94
9/26/2019	20.9	0.035	0.019	1.2	ND	816.4	496	6.2	10	12.2	150	Open	1.68
10/1/2019	16.9	0.070	0.020	1.4	ND	313.0	345	3.1	10	8.4	165	Open	0.67
10/8/2019	16.4	0.10	0.019	1.4	ND	248.1	428	12.1	52	5.1	165	Open	2.15
10/15/2019	14.0	0.070	0.019	2.0	ND	579.4	441	64.4	86	11.9	188	Open	1.18

* All results are preliminary and subject to final revision

** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.

*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.

**** United States Geological Survey (USGS) Continuous-Record Gaging Station (Flow rates are preliminary and subject to final revision by USGS).

Recommended EPA Criteria based on Aggregate Ecoregion III

Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L

Total Nitrogen: 0.38 mg/L

Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L

Turbidity: 2.34 FTU/NTU

CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:

Beach posting is recommended when indicator organisms exceed any of the following levels:

Total coliforms: 10,000 per 100 ml

E. coli: 235 per 100 ml

Enterococcus: 61 per 100 ml

Table 4.1.4. 2019 Russian River at Vacation Beach Station Grab Sample Results

Vacation Beach*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	Total Coliforms (Colilert)	Total Coliforms Diluted 1:10 (Colilert)	E. coli (Colilert)	E. coli Diluted 1:10 (Colilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)****		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/14/2019	18.0	**0.38**	**0.14**	**3.0**	**0.0019**	>2419.6	3654	4.1	10	5.2	610	Open	2.86
5/21/2019	14.9	**0.38**	**0.12**	**42**	**0.0019**	>2419.6	9804	**488.4**	**279**	**325.5**	3060	Open	0.76
5/28/2019	17.0	0.33	**0.069**	**15**	**0.0019**	1732.9	110	62.4	31	36.8	1300	Open	0.97
6/4/2019	19.1	0.29	**0.058**	**6.3**	**0.0026**	>2419.6	3255	23.3	10	38.4	867	Open	
6/11/2019	21.2	0.23	**0.039**	**3.2**	**0.0050**	1046.2	1354	14.6	30	11.0	576	Open	1.31
6/18/2019	20.4	0.16	**0.040**	**2.7**	**0.0037**	866.4	836	8.6	10	3.1	487	Open	1.22
6/25/2019	22.8	0.22	**0.035**	2.3	**0.0028**	1119.9	1670	10.9	10	2.0	294	Open	1.31
7/2/2019	22.0	0.18	**0.035**	1.8	**0.0059**	1413.6	2105	14.8	20	21.6	273	Open	1.73
7/9/2019	22.7	0.15	**0.036**	1.5	**0.0057**	1553.1	1850	18.9	10	8.5	235	Open	3.50
7/16/2019	24.6	0.18	**0.035**	**2.5**	**0.0069**	2419.6	1565	13.4	<10	25.9	184	Open	3.50
7/23/2019	23.3	0.18	**0.034**	**3.3**	ND	1732.9	3448	7.5	<10	7.3	170	Closed	6.41
7/30/2019	24.3	0.10	**0.033**	2.0	**0.0040**	>2419.6	1722	7.8	<10	10.7	160	Closed	8.01
8/6/2019	23.9	0.14	**0.033**	**3.0**	0.0015	1732.9	1935	32.3	<10	5.2	157	Open	0.59
8/13/2019	23.6	0.10	**0.030**	**3.0**	0.0014	1986.3	1789	10.7	10	16	152	Open	1.01
8/20/2019	23.1	0.035	**0.031**	**3.2**	ND	1936.3	1515	19.7	20	11.0	157	Open	0.55
8/27/2019	23.5	0.070	**0.033**	**3.1**	0.0015	1203.3	1918	16	10	8.3	153	Open	2.02
9/3/2019	23.2	0.10	**0.026**	**3.4**	**0.0019**	1732.9	1722	39.9	20	13.4	193	Open	0.55
9/10/2019	21.4	0.088	**0.028**	**2.6**	ND	1553.1	1126	4.1	<10	4.1	157	Open	1.85
9/17/2019	21.2	0.070	**0.023**	**3.4**	ND	1203.3	1354	14.6	<10	9.8	158	Open	0.76
9/19/2019	20.2	0.070	**0.033**	**4.0**	ND	1203.3	1236	18.3	20	60.5	163	Open	1.35
9/24/2019	20.7	0.088	**0.030**	**3.6**	ND	1299.7	1046	14.8	20	52.1	148	Open	1.90
9/26/2019	20.8	0.070	**0.026**	1.2	ND	1413.6	1553	21.1	10	54.8	150	Open	1.85
10/1/2019	16.9	0.10	0.021	**3.2**	ND	920.8	813	11	<10	13.4	165	Open	0.93
10/8/2019	16.7	0.070	0.020	**3.1**	ND	579.4	594	26.6	20	48.7	165	Open	2.27
10/15/2019	14.1	0.070	**0.022**	**4.0**	ND	613.1	369	12	20	48.0	188	Open	1.47

* All results are preliminary and subject to final revision
** Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors.
*** Total nitrogen is calculated through the summation of the different components of total nitrogen:
organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN) and nitrate/nitrite nitrogen.
**** United States Geological Survey (USGS) Continuous-Record Gaging Station (Flow rates are preliminary and subject to final revision by USGS).

Recommended EPA Criteria based on Aggregate Ecoregion III
Total Phosporus: 0.02188 mg/L (21.88 ug/L) ≈ 0.022 mg/L
Total Nitrogen: 0.38 mg/L
Chlorophyll *a* : 0.00178 mg/L (1.78 ug/L) ≈ 0.0018 mg/L
Turbidity: 2.34 FTU/NTU

CDPH Draft Guidance for Fresh Water Beaches - Single Sample Values:
Beach posting is recommended when indicator organisms exceed any of the following levels:
Total coliforms: 10,000 per 100 ml
E. coli: 235 per 100 ml
Enterococcus: 61 per 100 ml

on 20 August during open conditions and a flow of approximately 157 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September with a concentration of 0.088 mg/L (Table 4.1.4).

The USEPA's desired goal for total phosphates as phosphorus in Aggregate Ecoregion III has been established as 21.88 micrograms per liter (µg/L), or approximately 0.022 mg/L, for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Total phosphorus concentrations at the freshwater monitoring stations exceeded the U.S. EPA criteria approximately 85.3% of the time, continuing a trend of consistent exceedances observed in previous years (Figure 4.1.32).

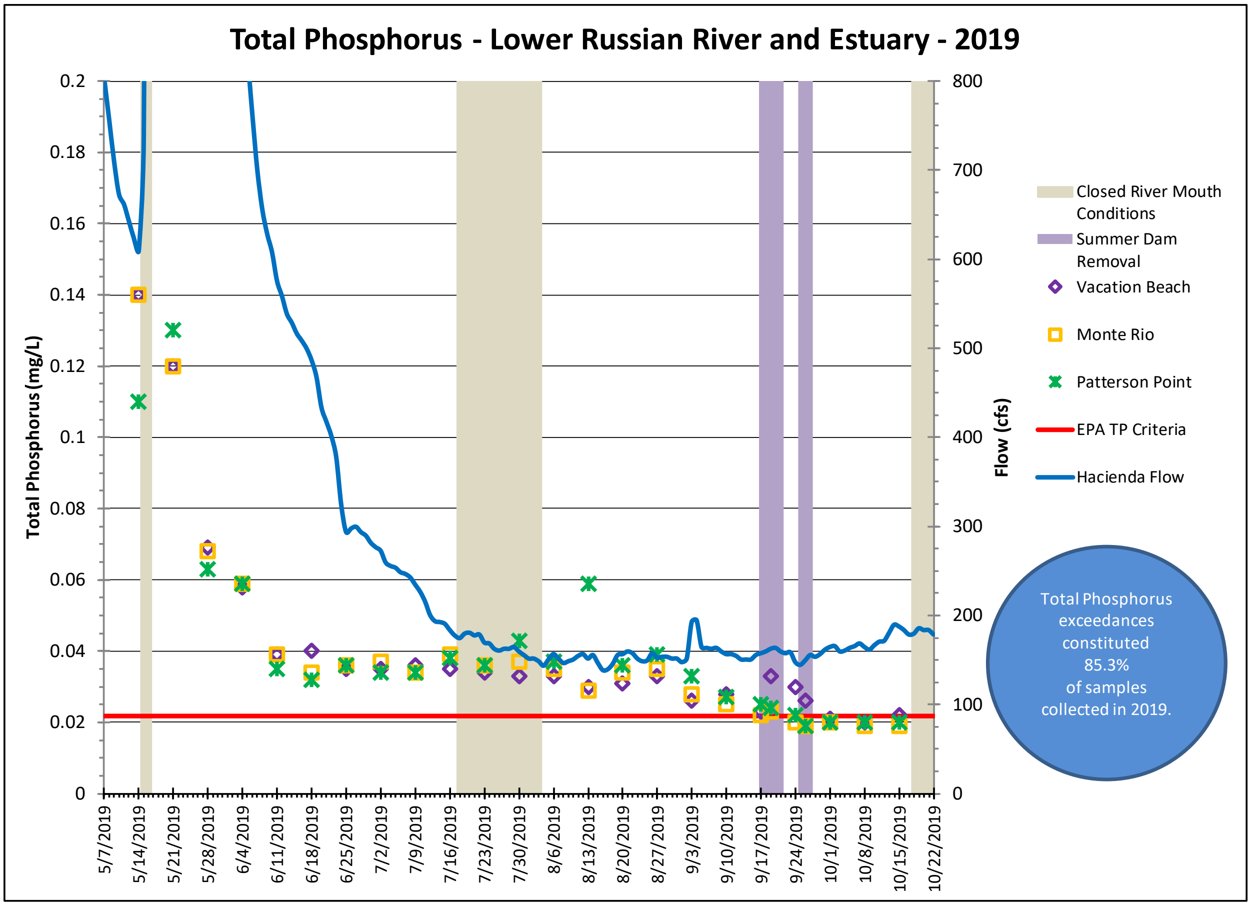


Figure 4.1.32. 2019 Russian River Grab Sampling Results for Total Phosphorus

Exceedances occurred during open and closed Estuary conditions, and in river flows ranging from 148 cfs to 3,060 cfs. Total phosphorus values were observed to generally be higher in the spring and early summer, especially during elevated storm flows in May, and trending downward through the rest of the season (Figure 4.1.32).

The maximum total phosphorus concentration observed at Patterson Point was 0.13 mg/L on 21 May during open conditions with a flow of approximately 3,060 cfs (Table 4.1.2). The mean concentration at Patterson Point was 0.041 mg/L. The minimum concentration at Patterson Point was 0.019 mg/L, which occurred on 26 September during open conditions and summer dam removal with a flow of approximately 150 cfs (Figure 4.1.32). Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a concentration of 0.022 mg/L (Table 4.1.2).

The maximum total phosphorus concentration observed at Monte Rio was 0.14 mg/L on 14 May during open conditions with a flow of approximately 610 cfs (Table 4.1.3). The mean concentration at Monte Rio was 0.040 mg/L. The minimum concentration at Monte Rio was 0.019 mg/L, which occurred three times during open conditions, including summer dam removal in the latter half of the season, with flows ranging from 150 cfs to 188 cfs (Figure 4.1.32). Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a concentration of 0.020 mg/L (Table 4.1.3).

The maximum total phosphorus concentration observed at Vacation Beach was 0.14 mg/L on 14 May during open conditions with a flow of approximately 610 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.041 mg/L. The minimum concentration at Vacation Beach was 0.020 mg/L, which occurred on 8 October during open conditions and a flow of approximately 165 cfs (Table 4.1.4). Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a concentration of 0.030 mg/L (Table 4.1.4).

Turbidity

The EPA recommended criteria of 2.34 nephelometric turbidity units (NTU) for turbidity was primarily exceeded at Monte Rio and Patterson Point during elevated storm and spring flows during the first half of the season, and predominantly at Vacation Beach throughout the season (Tables 4.1.2 through 4.1.4). Exceedances were observed to occur during open and closed estuary conditions with Hacienda flows ranging from 148 cfs to 3,060 cfs (Figure 4.1.33). Streamflow over the Vacation Beach summer dam and through the fish ladder appears to be a contributing factor to the frequent elevated turbidity values at the Vacation Beach station.

There were eleven (11) exceedances of the Turbidity EPA criteria at Patterson Point, nine (9) exceedances at Monte Rio, and twenty (20) exceedances at Vacation Beach (Figure 4.1.33). These exceedances of the Turbidity criteria occurred approximately 53.3% of the time under open and closed conditions and during summer dam removal in flows that ranged from 148 cfs to 3060 cfs.

The maximum turbidity value observed at Patterson Point was 50 NTU on 21 May during open conditions with a flow of approximately 3060 cfs (Table 4.1.2). The mean value at Patterson Point was 4.6 NTU. The minimum value at Patterson Point was 0.97 NTU, which occurred on 10 September during open conditions with a flow of approximately 157 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a value of 1.0 NTU (Table 4.1.2).

The maximum turbidity value observed at Monte Rio was 50 NTU on 21 May during open conditions with a flow of approximately 3060 cfs (Table 4.1.3). The mean value at Monte Rio was 4.5 NTU. The minimum value at Monte Rio was 0.98 NTU, which occurred on 10 September during open conditions with a flow of approximately 157 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a value of 1.2 NTU (Table 4.1.3).

The maximum turbidity value observed at Vacation Beach was 42 NTU on 21 May during open conditions with a flow of approximately 3060 cfs (Table 4.1.4). The mean value at Vacation Beach was 5.1 NTU. The minimum value at Vacation Beach was 1.2 NTU, which occurred on 26 September during open conditions and summer dam removal with a flow of approximately 150 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a value of 3.6 NTU (Table 4.1.4).

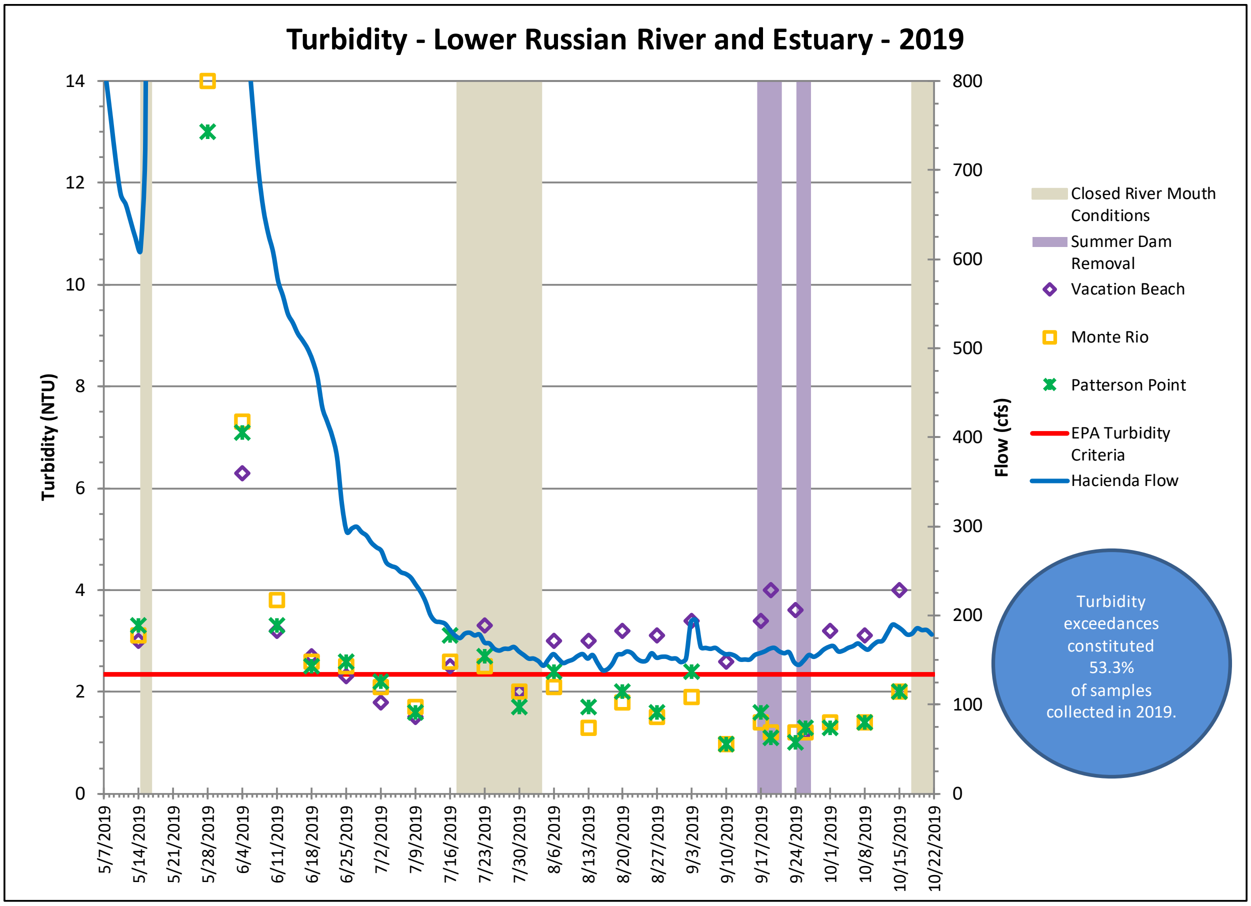


Figure 4.1.33. 2019 Russian River Grab Sampling Results for Turbidity

Chlorophyll a

In the process of photosynthesis, *Chlorophyll a* - a green pigment in plants, absorbs sunlight and combines carbon dioxide and water to produce sugar and oxygen. *Chlorophyll a* can therefore serve as a measurable parameter of algal growth. Qualitative assessment of primary production on water quality can be based on *Chlorophyll a* concentrations. A U.C. Davis report on the Klamath River (1999) assessing potential water quality and quantity regulations for restoration and protection of anadromous fish in the Klamath River includes a discussion of *Chlorophyll a* and how it can affect water quality. The report characterizes the effects of *Chlorophyll a* in terms of different levels of discoloration (e.g., no discoloration to some, deep, or very deep discoloration). The report indicated that less than 10 µg/L (or 0.01 mg/L) of *Chlorophyll a* exhibits no discoloration (Deas and Orlob, 1999). Additionally, the USEPA criterion for *Chlorophyll a* in Aggregate Ecoregion III is 1.78 µg/L, or approximately 0.0018 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). However, it is important to note that the EPA criterion is established for freshwater systems, and as such, is only applicable to the freshwater portions of the Estuary. Currently, there are no numeric *Chlorophyll a* criteria established specifically for estuaries.

Chlorophyll a concentrations exceeded the 0.01 mg/L level once at Monte Rio during the monitoring period, the level recommended to prevent discoloration of surface waters (Tables

4.1.2 through 4.1.4). In addition, *Chlorophyll a* concentrations exceeded the EPA criteria approximately 48.0% of the time at the stations throughout the season under open and closed Estuary conditions, and during flows ranging from approximately 150 cfs to 3060 cfs (Figure 4.1.34). Similar to the trend for total phosphorus, *Chlorophyll a* values were observed to generally be higher in the spring and early summer, especially during elevated storm flows in May, and trending downward through the rest of the season (Figure 4.1.34).

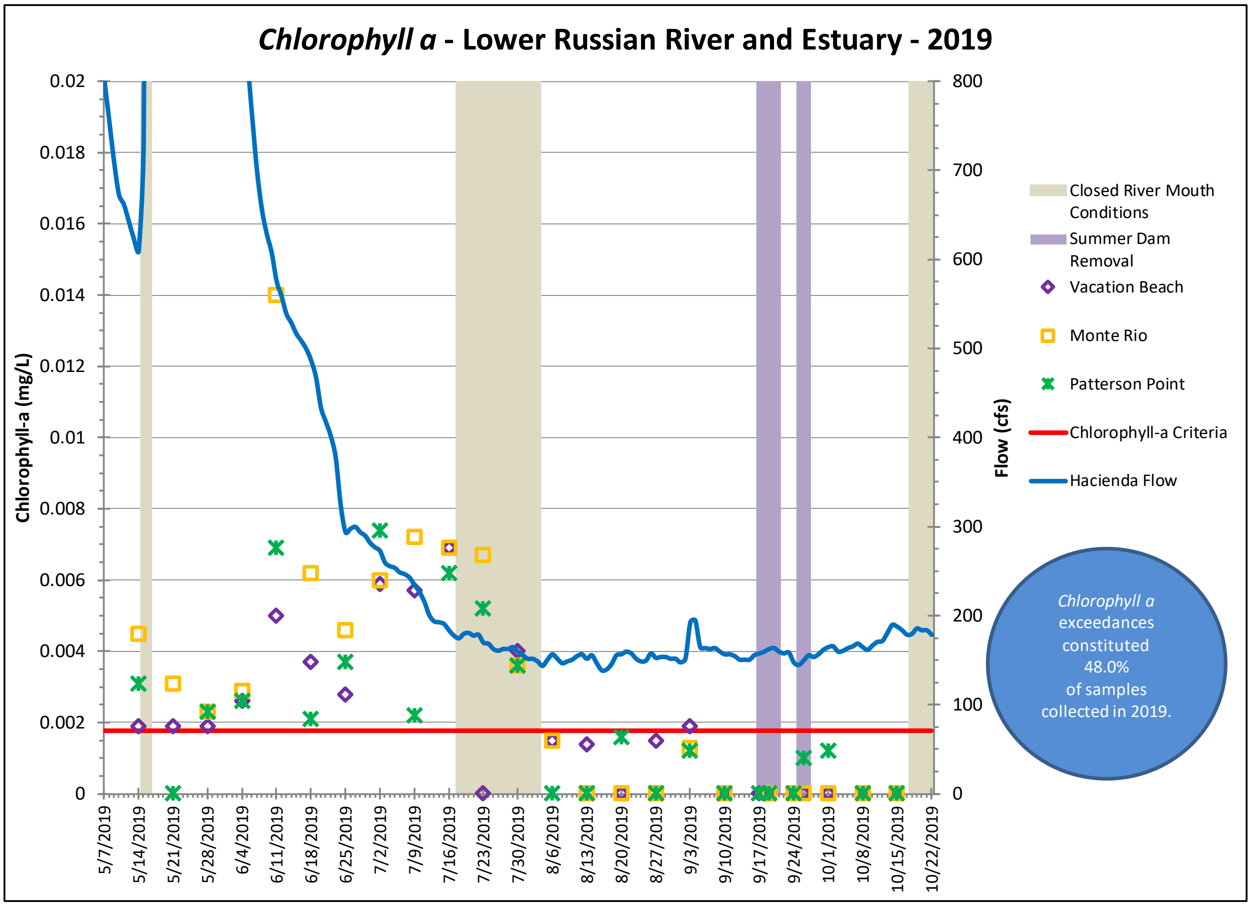


Figure 4.1.34. 2019 Russian River Grab Sampling Results for *Chlorophyll a*

The maximum *Chlorophyll a* concentration observed at Patterson Point was 0.0074 mg/L on 2 July during open conditions with a flow of approximately 273 cfs (Table 4.1.2). The mean value at Patterson Point was 0.0020 mg/L. The minimum value at Patterson Point was ND, which occurred ten (10) times, primarily in the latter half of the season, during open conditions and summer dam removal with flows that ranged from 148 to 3060 cfs. Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a value of ND (Table 4.1.2).

The maximum *Chlorophyll a* concentration observed at Monte Rio was 0.11 mg/L on 17 September during open conditions with a flow of approximately 158 cfs (Table 4.1.3). The mean value at Monte Rio was 0.0072 mg/L. The minimum value at Monte Rio was ND, which occurred ten (10) times in the latter half of the season during open conditions and summer dam removal with flows that ranged from 148 to 188 cfs (Figure 4.1.34). Finally, the lowest flow recorded during the sampling events was approximately 148 cfs, which occurred on 24 September, with a value of ND (Table 4.1.3).

The maximum *Chlorophyll a* concentration observed at Vacation Beach was 0.0069 mg/L on 16 July during open conditions with a flow of approximately 184 cfs (Table 4.1.4). The mean value at Vacation Beach was 0.0020 mg/L. The minimum value at Vacation Beach was ND, which occurred ten (10) times in the latter half of the season during open and closed conditions with flows that ranged from 148 to 188 cfs. Finally, the lowest flow recorded during the sampling was approximately 148 cfs, which occurred on 24 September, with a value of ND (Table 4.1.4).

Indicator Bacteria

The California Department of Public Health (CDPH) developed the "Draft Guidance for Fresh Water Beaches," which describes bacteria levels that, if exceeded, may require posted warning signs in order to protect public health (CDPH 2011). The CDPH draft guideline for single sample maximum concentrations is: 10,000 most probable numbers (MPN) per 100 milliliters (ml) for total coliform, 235 MPN per 100 ml for E. coli, and 61 MPN per 100 ml for Enterococcus. In 2012, the United States Environmental Protection Agency (EPA) issued Clean Water Act (CWA) §304(a) Recreational Water Quality Criteria (RWQC) for States (EPA 2012). The RWQC recommends using two criteria for assessing water quality relating to fecal indicator bacteria: the geometric mean (GM) of the dataset and changing the single sample maximum (SSM) to a Statistical Threshold Value (STV) representing the 75^{th} percentile of an acceptable water-quality distribution. However, the EPA recommends using STV values as SSM values for potential recreational beach posting and those values are provided in this report for comparative purposes. It must be emphasized that these are draft guidelines and criteria, not adopted standards, and are therefore both subject to change (if it is determined that the guidelines and/or criteria are not accurate indicators).

Samples were collected during the monitoring season for diluted and undiluted analysis of E. coli and total coliform for comparative purposes and the results are included in Tables 4.1.2 through 4.1.4 and Figures 4.1.35 and 4.1.36. Samples collected for Enterococcus were undiluted only and results are included in Tables 4.1.2 through 4.1.4 and Figure 4.1.37. Sonoma Water submitted samples to the Sonoma County DHS Public Health Division Lab in Santa Rosa for bacteria analysis. E. coli and total coliform were analyzed using the Colilert method and Enterococcus was analyzed using the Enterolert method. Samples for all other constituents were submitted to Alpha Labs in Ukiah for analysis. Total Coliform and E. coli data presented in Figures 4.1.35 and 4.1.36 utilize undiluted sample results unless the reporting limit has been exceeded, at which point the diluted results are utilized.

In 2014 and more recently, staff at the NCRWQCB indicated that Enterococcus was not being utilized as a fecal indicator bacteria in freshwater environments due to evidence that Enterococcus colonies can be persistent in the water column and therefore its presence at a given freshwater site may not always be associated with a fecal source. Sonoma Water staff will continue to collect Enterococcus samples and record and report the data however, Enterococcus results will not be relied upon when coordinating with the NCRWQCB and Sonoma County DHS about potentially posting warning signs at freshwater beach sites or to

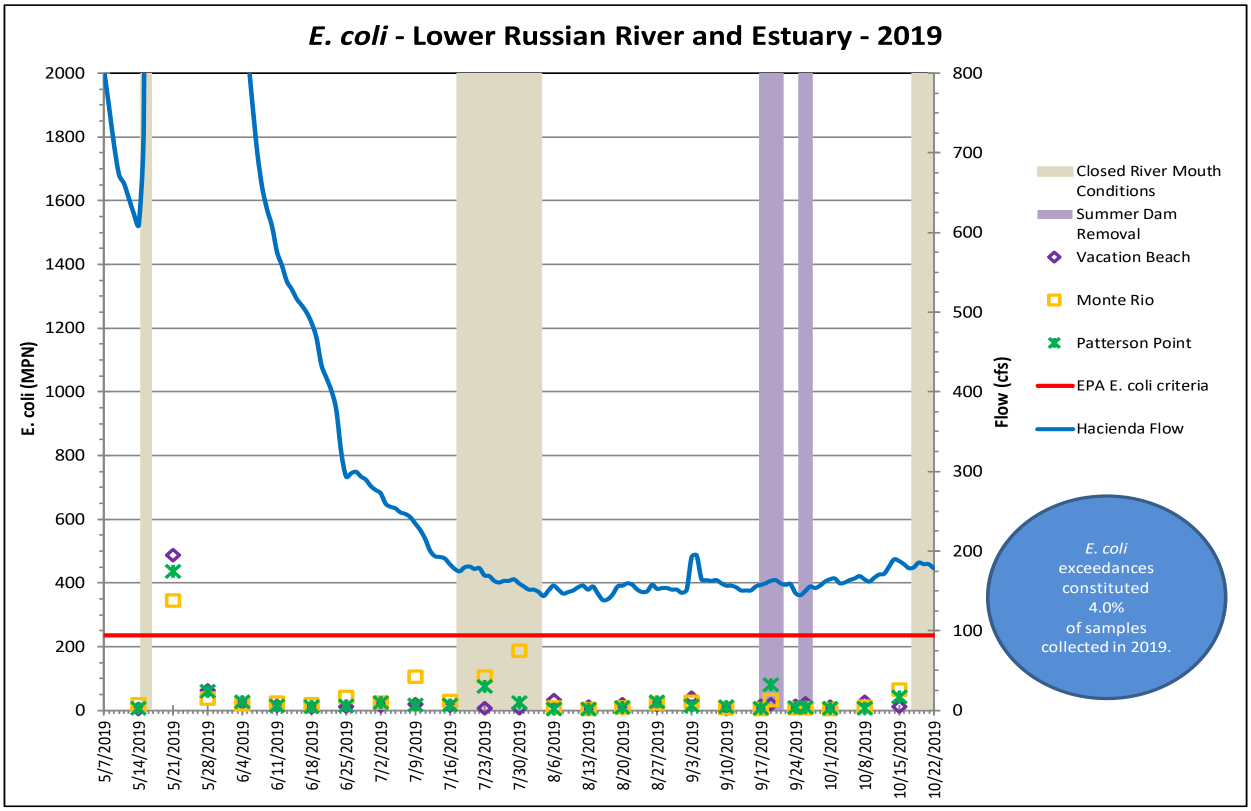


Figure 4.1.35. 2019 Russian River Grab Sampling Results for E. coli

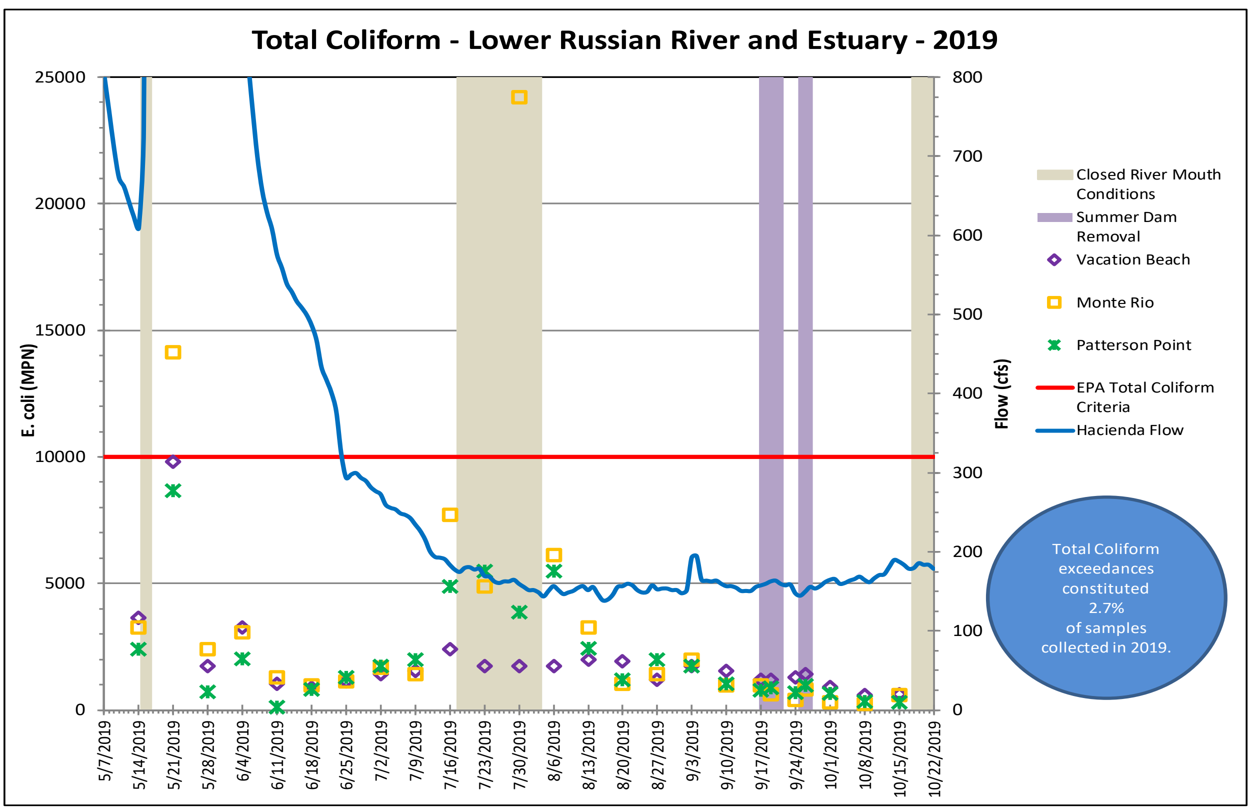


Figure 4.1.36. 2019 Russian River Grab Sampling Results for Total Coliform

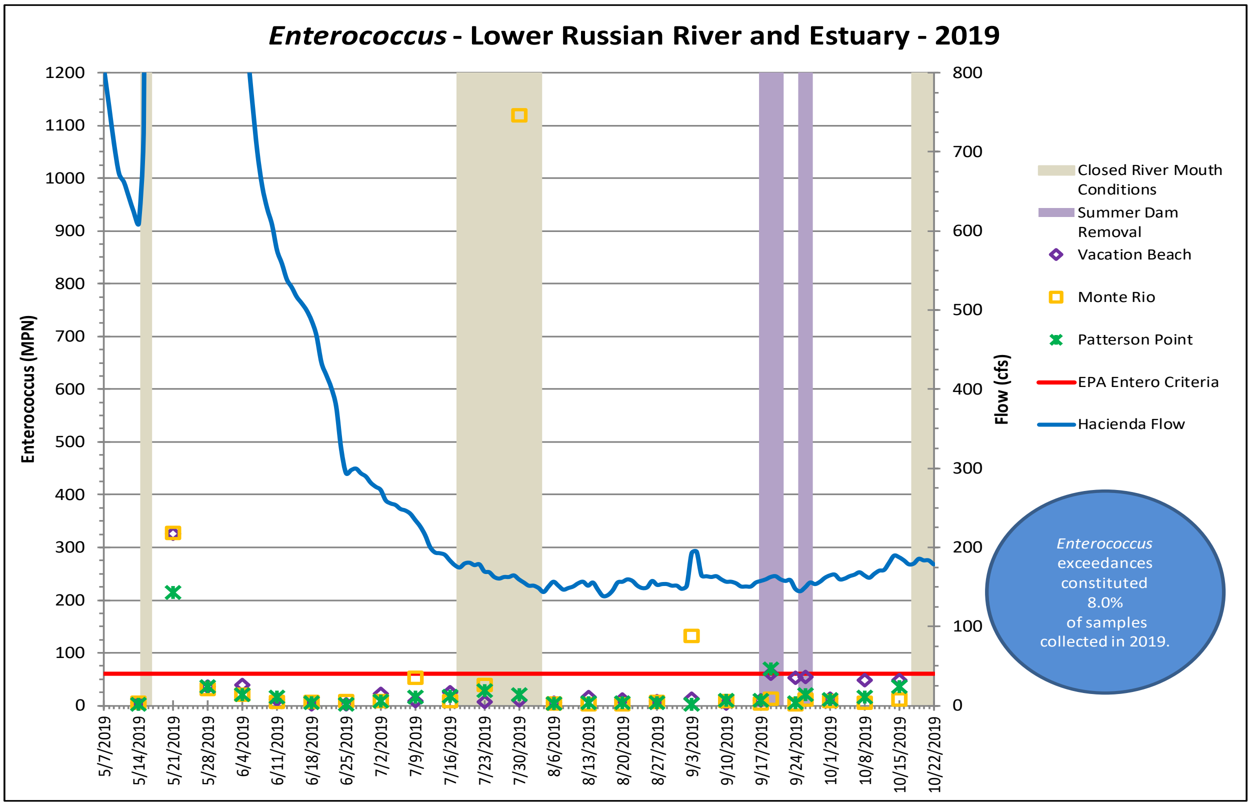


Figure 4.1.37. 2019 Russian River Grab Sampling Results for Enterococcus

discuss potential adaptive management actions including mechanical breaching of the sandbar to address potential threats to public health.

There were three (3) exceedances of the RWQC for E. coli during the 2019 monitoring season, representing 4.0% of the total samples collected (Figure 4.1.35). Each station exceeded the RWQC on 21 May during open conditions and elevated May storm flows of approximately 3060 cfs (Tables 4.1.2 through 4.1.4). Patterson Point had a value of 435.2 MPN, Monte Rio had a value of 344.8 MPN, and Vacation Beach had a value of 488.4 MPN. Summer dam removal may have had a minor effect on E. coli, as values were observed to slightly increase at Monte Rio and Patterson Point following removal of the Vacation Beach summer dam (Table 4.1.3). The extended closure in July may have also had an effect as values were observed to slightly increase during this same time period, however slightly elevated values were observed throughout July, which is also during the peak recreation season (Figure 4.1.35).

There were two exceedances of the RWQC for total coliform recorded at the Monte Rio station during the 2019 monitoring season, representing 2.7% of the total samples collected (Figure 4.1.36). High storm flows in May and the extended closure in July may have had an effect on total coliform as values were observed to increase during these events. These increases may have also been affected by increased recreational activity as they were observed during July, which is during the peak recreation season.

There were two exceedances of the recommended Enterococcus RWQC for fresh water beaches at Patterson Point, three at Monte Rio, and one at Vacation Beach representing 8.0%

of the total samples collected (Figure 4.1.37). High storm flows in May, estuary closure, and summer dam removal may have had an effect as values were observed to increase during these events (Figure 4.1.37).

Conclusions and Recommendations

Continuous Water Quality Monitoring Conclusions

Water quality conditions observed during the 2019 monitoring season were similar to conditions observed during previous monitoring seasons, and similar to the dynamic conditions associated with an estuarine river system. The differing physical properties associated with freshwater versus those of saltwater play a pivotal role in the stratification that is common in the Russian River Estuary. Since the saltwater is denser than the freshwater inflow, the saltwater layer is observed below the freshwater layer, and the slope of the temperature and density gradients is typically steepest at the halocline. While this relationship is a key player in what shapes the water quality conditions in the estuary, there are other influences at work in the estuary as well, including wind mixing, river inflow, tidal influence, shape and size of the river mouth, air temperatures, and others.

There were no beach management actions taken during the lagoon management period in 2019 since the mouth of the Estuary self-breached naturally after each closure. The barrier beach closed on 15 May for one (1) day before breaching naturally during high storm flows on 16 May. The barrier beach closed again for sixteen (16) days from 18 July to 3 August before breaching naturally. In addition, the barrier beach closed on 18 October and remained closed for four (4) days before breaching naturally on 22 October. The barrier beach closed for the last time of the calendar year on 21 November and remained closed for six (6) days before breaching naturally on 27 November.

Consequently, there was no opportunity for Sonoma Water staff to assess the availability of suitable aquatic habitat for rearing salmonids in comparison to closed and open Estuary conditions. Although Sonoma Water staff were not able to assess the merits of a lagoon outlet channel, staff were still able to collect data that provides a fuller understanding of salinity migration in the Upper Reach of the Estuary.

As freshwater flows in the Russian River decrease through spring, the salt layer typically migrates upstream. However, the degree of salinity migration can be highly variable depending on the orientation and aspect of the river mouth in relation to the barrier beach and jetty. The jetty can serve to mute the strength of the tidal cycle if the river mouth is oriented against the jetty.

In 2019, a late season storm significantly elevated flows during mid-May, resulting in mainstem Russian River flows decreasing later in the season compared to previous years, and especially the drought years of 2013 through 2015. Following the end of the drought, 2017 flows were observed to drop below 500 cfs in late-May and below 200 cfs in early July. In 2019, mainstem flows were observed to drop below 500 cfs in mid-June and below 200 cfs in mid-July. Whereas mainstem flows decreased below 200 cfs in mid-May during the drought years and early June in 2018.

Although salinity migration patterns in the upper reach of the Estuary were fairly similar to prior monitoring years, the Brown's Pool (RK 11.3) station was observed to remain entirely freshwater during the 2019 management period, similar to 2017 and 2018. Whereas the bottom of Brown's Pool became predominantly brackish during open and closed conditions throughout the 2016 monitoring season with concentrations as high as 6.5 ppt during the management period and 10.7 ppt in late-October (Martini-Lamb and Manning, 2017).

Brackish water had not been observed at Brown's Pool prior to the 2013 monitoring season, however Sonoma Water staff had only previously deployed a continuously monitoring sonde at this station in the 2011 season (Manning and Martini-Lamb, 2012). Even so, it is not unreasonable to expect salinity migration to periodically occur in this area, given the proximity of the Brown's Pool station to Moscow Road Bridge (RK 10.15), where brackish water has been observed to occur.

Monitoring conducted in the MBA at the bottom of the Patterson Point station in Villa Grande continued to show freshwater conditions with a maximum salinity value of approximately 0.2 ppt. Water is considered fresh at approximately 0.5 ppt. These results correspond with the data collected in the Upper Reach of the Estuary and the MBA since 2010 and further supports the theory that Brown's Riffle (RK 11.4) and the confluence of Austin Creek (RK 11.65) provide a significant hydrologic barrier to salinity migration in the mainstem Russian River.

Temperature, pH, and dissolved oxygen patterns during the 2019 monitoring season were also similar to those observed in previous monitoring years. While the Russian River Estuary is a dynamic estuarine system, the seasonal changes during the monitoring seasons have largely followed similar patterns each year since the implementation of the Biological Opinion (BO) in 2009.

To further illustrate the extent of salinity migration, a graphical representation of the maximum salinity levels recorded at various stations in the Russian River Estuary between 2009 and 2018 is being presented (Figure 4.1.38). The sondes chosen for this graph were situated in the lower portion of the water column at each station, where saline water would be expected to occur. This generally corresponds to approximately three-to-four-meter depths for the Mouth, Patty's Rock, and Sheephouse Creek stations, six-to-nine-meter depths at the Heron Rookery station, six-to-seven-meter depths at the Freezeout Creek station, eight to eleven meter depths at the Brown's Pool station, six to eight meter depths at Villa Grande, nine to eleven meters depth at Patterson Point, and one to two meters at the Monte Rio station. In the upper reaches of the Estuary and MBA, the sondes are located on the bottom of the river because the salt layer is typically thin when it occurs at these river locations. Excluding the depth variations, the graph depicts the decrease in salinity the further upstream in the Estuary and MBA the monitoring station is located.

The graph also illustrates the variable nature of salinity levels in the Upper Reach of the Estuary. For instance, in 2014 and 2016, the maximum salinity concentrations observed at

Brown's Pool were nearly identical at approximately 11 ppt, whereas in 2017, 2018, and 2019 the maximum salinity concentration was 0.2 ppt.

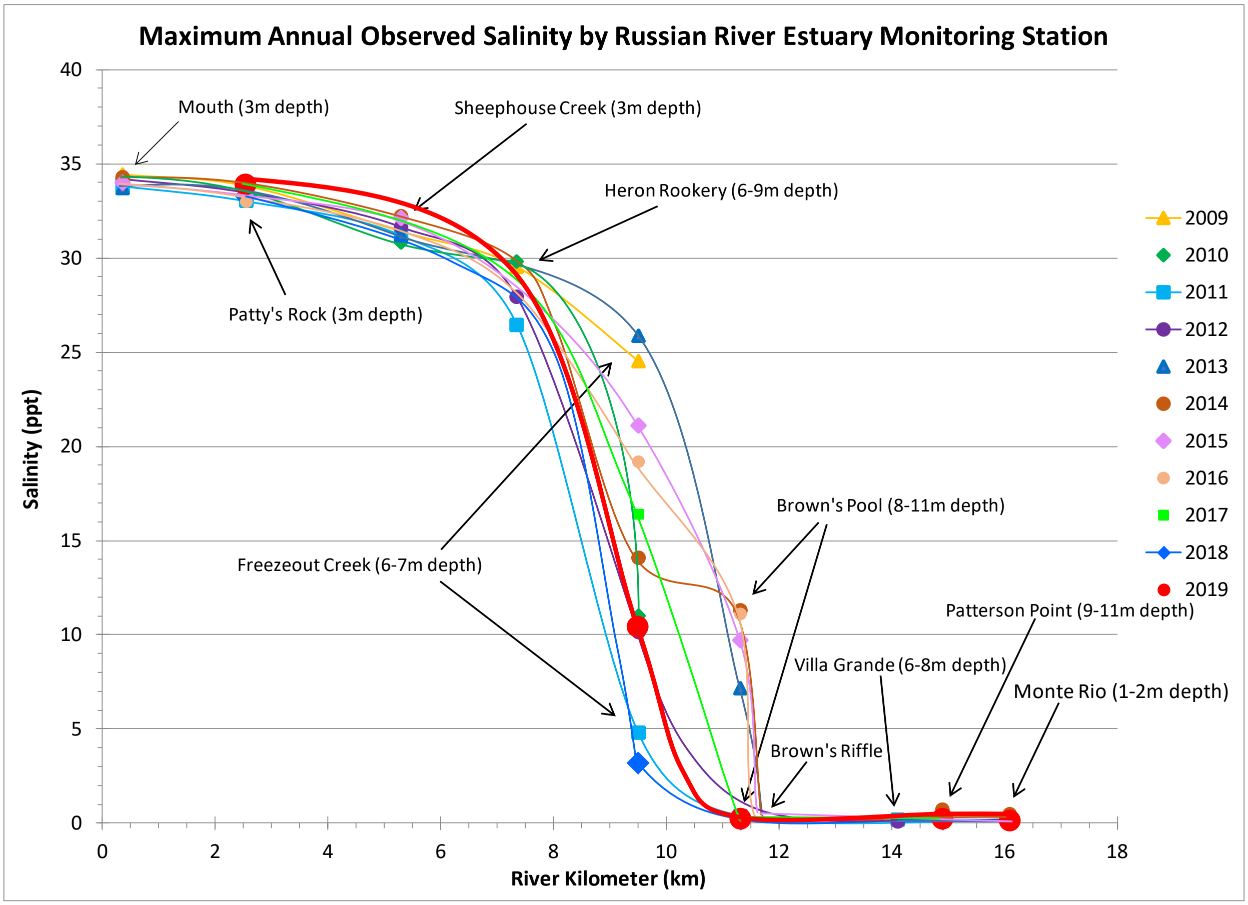


Figure 4.1.38. The maximum salinities at monitoring stations throughout the Russian River Estuary and Maximum Backwater Area between the years of 2009 and 2019.

Brown's Pool has been observed to have maximum salinity concentrations that range from lows of 0.2 ppt in 2017, 2018, and 2019, to a high of 11.3 ppt in 2014. Likewise, the maximum salinity concentrations observed at Freezeout Creek range from a low of 4.8 ppt in 2011 to a high of 25.9 ppt in 2013. In 2019, maximum salinity concentrations at Freezeout Creek were only 10.4 ppt, however this was recorded at the mid-depth sonde which typically has a lower concentration than the bottom sonde, which malfunctioned during the entire monitoring season.

Note that there are no elevated salinity levels recorded in the Maximum Backwater Area for any monitoring seasons. As was mentioned above, it is possible that saline water does not migrate past the riffle between Brown's Pool and the confluence of Austin Creek due to hydrologic and/or geologic conditions that serve to define a transition from the Russian River Estuary and the beginning of the Maximum Backwater Area.

Water Quality Grab Sampling Conclusions

The 2019 grab sampling effort in the Russian River Estuary continued to collect a robust set of data similar in effort to the 2012 through 2018 monitoring seasons. Additional focused sampling was conducted during summer dam removal in late September. Table 4.1.5 shows the total yearly number of sampling trips and the total number of samples collected within the freshwater portions of the Russian River Estuary and Maximum Backwater Area during each monitoring season since the implementation of the Biological Opinion in 2009.

Table 4.1.5. The total number of grab sampling trips per monitoring season and the total number of samples taken in the freshwater portion of the Russian River Estuary and Maximum Backwater Area per monitoring season. Note: duplicate and triplicate samples were counted as separate samples during the same sampling trip.

Estuary Monitoring Season	Total Number of Sampling Trips	Total Number of Samples
2009	7	7
2010	13	39
2011	13	52
2012	18	72-90
2013	33	98
2014	26-31	104-111
2015	26-27	104-106
2016	29-30	87-90
2017	26	75
2018	25	75
2019	25	75

The 2019 grab sampling effort observed Total Phosphorus exceedances in 85.3% of all samples collected (Table 4.1.6). This is not uncommon in the lower Russian River , and similar percentages of the samples analyzed for Total Phosphorus were in exceedance during previous monitoring seasons. Table 4.1.6 shows the percentage of samples that were in exceedance each season since 2009.

The Total Nitrogen and *Chlorophyll a* exceedances for samples taken during 2019 were also similar to percentages observed in previous monitoring years (Table 4.1.6). Year to year variability in the percentage of exceedances for these three constituents can be attributed in part to: the frequency and timing of storm events, fluctuating freshwater inflow rates, the frequency and timing of barrier beach closures, the strength of tidal cycles, summer dam removal, topography, relative location within the Estuary, and wind mixing.

Table 4.1.6. The percentages of freshwater samples taken that were in exceedance of U.S. EPA water quality criteria for Total Phosphorus, Total Nitrogen, and Chlorophyll a. Note; Chlorophyll a was not quantified below 0.01 mg/L in 2009, and as such, cannot be verified against the U.S. EPA criteria of 0.00178 mg/L. Also, the Total Nitrogen values in 2009 were not quantified sufficiently against the criteria to make comparisons. The U.S. EPA criteria for Total Nitrogen is 0.38 mg/L, and the criteria for Total Phosphorus is 0.02188 mg/L.

Estuary Monitoring Season	Percentage of Total Phosphorus Samples in Exceedance	Percentage of Total Nitrogen Samples in Exceedance	Percentage of Total *Chlorophyll a* Samples in Exceedance
2009	100	N/A	N/A
2010	84.6	15.4	18.0
2011	92.3	30.8	23.7
2012	61.5	6.9	11.5
2013	99.0	15.3	44.9
2014	100	14.4	23.1
2015	86.5	1.9	26.0
2016	83.9	8.1	39.1
2017	97.3	9.3	54.7
2018	93.3	5.3	36.6
2019	85.3	9.5	48.0

The percentage of E. coli exceedances since the implementation of the BO in 2009 until 2019 can be seen in Table 4.1.7. However, E. coli was not sampled for in 2010, with sampling being conducted for fecal coliforms instead. Samples collected in 2009 were analyzed using the multiple tube fermentation technique, whereas samples collected from 2011 through 2019 were analyzed using the Colilert Quanti-Tray method. Percentages for total coliform samples are not included prior to 2015, since values were not quantified above 1600 MPN for 2010 and a portion of 2011, or above >2419.6 MPN for 2012, 2013 and a portion of the 2014 season. Both levels are below CDPH Guidelines, therefore it is impossible to establish percent criteria exceedances for those monitoring seasons.

Table 4.1.7. The percentages of freshwater samples taken that were in exceedance of CDPH Guidelines for E. coli and Total Coliform for the sampling years 2009 through 2019. Note that for 2009, the analyzing method was multiple tube fermentation, and for 2011-2018 the method was Colilert Quanti-Tray.

Estuary Monitoring Season	Percentage of Total E. coli Samples in Exceedance	Percentage of Total Coliform Samples in Exceedance
2009	0	N/A
2010	N/A	N/A
2011	0	N/A
2012	0	N/A
2013	1.0	N/A
2014	6.3	N/A
2015	1.9	3.8
2016	2.2	0
2017	1.3	4.0
2018	1.3	0
2019	4.0	2.7

Data collected through the grab sampling effort in 2019 appear consistent with data collected between 2009 and 2018. Further analysis could elucidate any trends that may exist temporally or longitudinally through the Russian River Estuary and guide water quality monitoring efforts in the future.

Time series trend analyses of the grab sampling data collected under the Biological Opinion could prove useful in the future. Trend analyses could determine if there have been changes over time for any of the constituents collected under this project. Certain trend tests are used for non-parametric data analysis such as water quality data, including the Sen Slope test, the Kendall-Theil test, the Seasonal Kendall test, or a variety of other suitable statistical tests. Analyses of this nature require both time and expert knowledge of environmental statistical analysis. As such, they are difficult to run and outside the scope of this project at this time. In the future, allocating resources to analyses of this nature, on these data, would likely give a better understanding of the existence, or absence, of trends in the data.

4.2 Algae Sampling

Monitoring of periphytic and planktonic algae was conducted to document the algal response following Estuary closure; and establish baseline ecological data for algal populations representative of habitats available in the Russian River at Patterson Point. Monitoring for both was conducted as soon as river flows allowed a systematic investigation of abundance, cover, and successional processes. Data collected in 2020 is currently being analyzed and will be provided in a supplemental report.

4.3 Invertebrate Prey Monitoring, Salmonid Diet Analysis and Juvenile Steelhead Behavior

The Russian River Biological Opinion requires Sonoma Water to "monitor the effects of alternative water level management scenarios and resulting changes in depths and water quality (primarily salinity, dissolved oxygen concentration, temperature, and pH) on the productivity of invertebrates that would likely serve as the principal forage base of juvenile salmonids in the Russian River Estuary (NMFS 2008). Specifically, Sonoma Water is determining the temporal and spatial distribution, composition (species richness and diversity), and relative abundance of potential prey items for juvenile salmonids in the Estuary and evaluating invertebrate community response to changes in sandbar management strategies, inflow, estuarine water circulation patterns (stratification), and water quality. The monitoring of invertebrate productivity in the Estuary focuses primarily on epibenthic and benthic marine and aquatic arthropods within the classes Crustacea and Insecta, the primary invertebrate taxa that serve as prey for juvenile salmonids, especially steelhead (*Oncorhynchus mykiss*) that may be particularly characteristic of conditions unique to estuarine lagoons for which steelhead may be adapted in intermittent estuaries near the southern region of their distribution (Hayes and Kocik 2014). The monitoring effort will involve systematic sampling and analysis of zooplankton, epibenthic, and benthic invertebrate species" (NMFS 2008, page 254).

Commensurate with assessment of potential responses to Estuary conditions by the macroinvertebrate prey of juvenile salmonids, Sonoma Water is also monitoring juvenile salmonid diet composition and behavior. Based on the hypothesis that both diet and behavior of juvenile salmonids will vary as a function of increased water level and rearing space when the mouth of the Estuary is closed, the potentially differential effects of density-dependent interactions on diet composition and consumption rate are being compared between open and closed Estuary conditions. To facilitate the synthesis of this information with more precise information on juvenile salmonid exposure to variability in Estuary salinity and thermal regime, Sonoma Water is supporting hydroacoustic telemetry of their position, behavior, and residence as a function of Estuary conditions. The purpose of this effort is to determine for juvenile steelhead in the Estuary the variation under different Estuary open-closure conditions in: (1) the Estuary's water quality environment and the specific water quality conditions experienced by the juvenile steelhead; (2) their behavior in terms of estuarine habitat, reach occupancy and intra-estuarine movement patterns; (3) diet composition; (4) potential (modeled) and empirical growth. These will be used to refine parameters used in the Seghesio (2011) bioenergetics model to generate more empirically-based potential growth estimates during juvenile steelhead response to changing conditions in this intermittent Estuary.

Sonoma Water entered into an agreement with the University of Washington, School of Aquatic and Fishery Sciences' Wetland Ecosystem Team (UW-WET) to conduct studies of the ecological response of the Estuary to natural and alternative management actions associated with the opening and closure of the Estuary mouth. This component of the study is designed to evaluate how different natural and managed barrier beach conditions in the Estuary affect juvenile salmon foraging and their potential prey resources over different temporal and spatial scales. Systematic sampling is intended to capture the natural ecological responses (prey composition and consumption rate) of juvenile salmon and availability of their prey resources (insect, benthic and epibenthic macroinvertebrates, zooplankton) under naturally variable, seasonal changes in water level, salinity, temperature, and dissolved oxygen conditions. A second approach, event sampling, was originally proposed in 2009 to contrast juvenile salmonid foraging and prey availability changes over Estuary closure and re-opening events. The hydroacoustic telemetry component was particularly adaptable and targeted for the event sampling.

Based on prior data on the foraging of juvenile salmonids in the region's estuaries, the dominant prey of juvenile steelhead can be generally classified as invertebrate organisms that are epibenthic and benthic infauna. All of these prey sources are vulnerable to the variable conditions imposed by river mouth conditions, but taxa composition, relative abundance and production may vary as a function of both longitudinal axis (reach) of the estuary and cross-channel distribution. Another potential invertebrate component, pelagic zooplankton, has not appeared in juvenile salmon diets in either open or closed estuary conditions. Epibenthic, benthic, and zooplankton invertebrate sampling has been conducted monthly from May to October since 2009. Most of these sampling events were completed during open river mouth, tidal conditions in the estuary providing a robust baseline dataset. The composition and abundance of invertebrates was consistent among monthly sampling and among years indicating that the current dataset is adequate to characterize the invertebrate fauna of the estuary. The main gap in data is sampling during prolonged lagoon conditions in the estuary, which is the continuing focus of the on-going research. The methods and results presented in the following sections focus on the overall lessons of monitoring invertebrates in the Russian River Estuary through 2019.

Summary of Methods

As a result of greater focus on changes in epibenthic and benthic prey availability during estuary closures, Sonoma Water- UW-WET invertebrate monitoring protocols were revised in 2016 and were followed in 2019:

> *Monthly Estuary Surveys :*During years when no prolonged lagoon forms invertebrate surveys will be collected during May, June, and September. Under prolonged lagoon conditions surveys would be conducted monthly from May to October. This sampling schedule would be consistent with the Estuary fish seining schedule. There would be no change in the monthly number of epibenthic, benthic, and zooplankton invertebrate samples collected.
>
> *Mouth Closure Event Surveys:* Monitoring protocols will not change during estuary closure events. Samples would be collected approximately seven and 14 days after a river mouth closure and monthly during prolonged lagoon conditions.

Lab Processing: The focus of invertebrate processing in the lab would include the primary steelhead prey taxa (based on years' results, approximately 12-15 taxa). These dominant prey would be sorted and enumerated in epibenthic and benthic samples. Zooplankton are not an important prey group and samples would not be processed. All invertebrates from epibenthic, benthic, and zooplankton samples would be archived for further analysis if deemed important.

Sampling for fish diet and prey availability is designed to coincide with established Sonoma Water and other related sampling sites distributed in the lower, middle, and upper reaches of the Estuary during the Lagoon Management Period (May 15 to October 15). Since 2009, salmonid diet samples have been coincident with beach seining at 11 sites (Figure 4.3.1; modified from Largier and Behrens 2010) sampled for juvenile salmon by Sonoma Water – (1) Lower Reach: River Mouth, Penny's Point and Jenner Gulch; (2) Middle Reach: Patty's Rock, Bridgehaven and Willow Creek; and, (3) Upper Reach: Sheephouse Creek, Heron Rookery, Freezeout Bar, Moscow Bridge and Casini Ranch. These locations also overlap with sites established by water quality measurements for dissolved oxygen, temperature, and salinity.

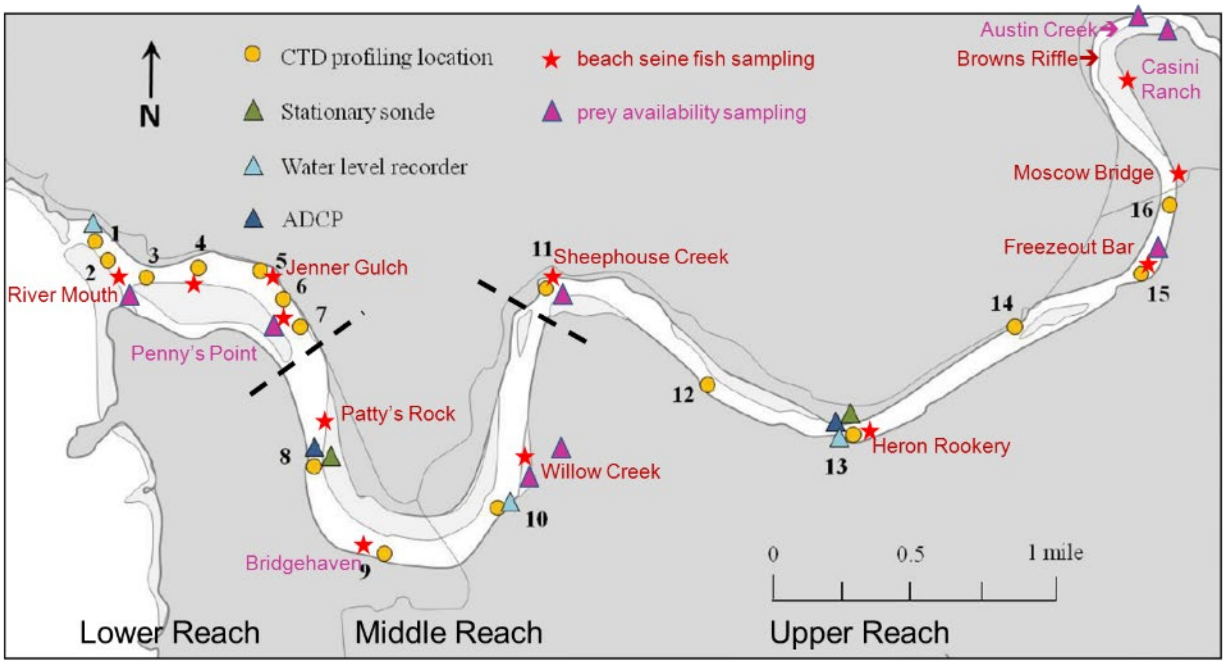


Figure 4.3.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (benthic infauna, epibenthos, zooplankton) in three reaches of the Russian River Estuary.

Prey resource availability sampling occurred at four sites distributed through the three estuarine reaches (Figure 4.3.1): Lower Reach—River Mouth and Penny Point; Middle Reach—Willow Creek; and Upper Reach—Freezeout Bar. Each of the sites includes three, lateral transects across the Estuary over which four sampling methods were deployed to sample availability of juvenile steelhead prey (Figures 4.3.2-4.3.7 for more specific locations by different sampling methods).

Figure 4.3.2 . Distribution of juvenile salmonid prey resource availability in three reaches of the Russian River Estuary.

Figure 4.3.3. Distribution of juvenile salmonid prey availability sampling transects and techniques at the River Mouth site in the Russian River Estuary.

Figure 4.3.4. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Penny Point site in the Russian River Estuary.

Figure 4.3.5. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Willow Creek site in the Russian River Estuary.

Figure 4.3.6. Distribution of juvenile salmonid prey availability sampling transects and techniques at the Freezeout Bar site in the Russian River Estuary.

Figure 4.3.7. Modification of sampling techniques during closed conditions for distribution of juvenile salmonid prey availability sampling transects and techniques at Willow Creek site in the Russian River Estuary. The grey area is the inundation of area during closed conditions.

Juvenile Salmon Diet Composition

Systematic sampling of the diets of five or more (n≥5) juvenile steelhead ≥55 mm FL are derived, when available, from the beach seine sampling during the lagoon management period between May 15 and October 15. All fish designated for diet analysis are handled, gastric lavaged and released according to the University of Washington animal care protocols.

Stomach lavage follows Foster (1977) and Light et al (1983). Diet contents are preserved in 10% formalin for later laboratory processing. Fork lengths and weights are taken from each fish. Each fish is scanned for a passive integrated transponder (PIT) tag and tagged if no previous PIT tag was detected.

Prey Resource Availability

Benthic infauna and epibenthos prey resource sampling are conducted once per month in the lagoon management period during open, tidal (baseline) conditions. If barrier beach conditions result in a closure, epibenthos and benthic infauna are sampled seven and 14 days after closure. Following an extended closure of 14 days or more, prey resource availability sampling of benthic infauna, epibenthos, and zooplankton begins at day 14 and continue every three weeks after until the Estuary opens.

Benthic Infauna

Replicate core samples (0.0024-m^2 PVC core inserted 10 cm in to the sediment) are taken at each transect of each site. The location of each core sample is consistent with each epibenthic sled and epibenthic net to shore sample, but no core samples are taken in between transects. This sample is repeated four times per transect (twelve times per site). Additional samples would be added along the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation (Figure 4.3.7). The sediment cores are preserved in 10% buffered formalin for laboratory analysis.

Epibenthos

Epibenthic organisms at the sediment-water interface are sampled with two methods: 1) epibenthic net (net to shore); and, 2) epibenthic (channel) sled. The epibenthic net is a 0.5-m x 0.25-m rectangular net, equipped with 106-μm Nitex mesh that is designed to ride along the surface of the Estuary bottom substrate. It is deployed 10 m from shore and then pulled along the bottom perpendicular back to shore by an individual onshore. This is replicated five times per site (once at each transect and then once between Transects 1 and 2 and also between Transects 2 and 3). The epibenthic sled is equipped with a 0.125-m^2 opening, 1-m long 500-μm Nitex mesh net towed behind the boat against the current. The sled is dropped from the bow of the boat and allowed to sink to the bottom. Then the boat tows the sled (in reverse) 10 m against the current and is retrieved back onto the boat. The sled is used to obtain three samples per transect (nine per site under open conditions). Additional samples would be added along the shoreward margin of the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation (Figure 4.3.7). Captured organisms are preserved in 10% buffered formalin for laboratory analysis.

Sample Processing and Analyses

Invertebrates found in the diets of steelhead and collected in the prey resource samples are identified to species level under a dissecting microscope, except for insects which are identified to family level. Any invertebrate collected during prey sampling and not found to be part of the steelhead diet is identified to order or family level. Each of the identified prey taxa are counted (for numerical composition) and weighed (for gravimetric [biomass] composition) and the frequency of occurrence. The state of total stomach content biomass is normalized by individual fish weight to provide an additional index of relative consumption rate ("instantaneous" ration), which is the total biomass of prey found in individual fish stomach contents relative to the biomass of the fish expressed as $g\ g^{-1}$. It is recognized that this is only a short-term index of consumption, and will vary by fish size, time of day and other factors influencing foraging behavior. If fish are captured under the same general conditions, this index can provide an indication of differences in feeding performance. Under some conditions, the instantaneous ration can be used to develop an estimate of daily ration that can be used in bioenergetic modeling of potential growth. For further details regarding methods for other calculated indices, see previous project annual reports.

Summary of Results

Estuary Conditions

Three invertebrate sampling events were conducted in 2019, coincident with monthly fish seine sampling, under open mouth conditions. Samples were collected on June 18, July 2, and October 8, 2019 (Figure 4.3.8). The Russian River estuary experienced only one significant mouth closure in 2019 during the Lagoon Management Period from July 18 to August 3 (Figure 4.3.8); however, samples were not collected during this closure period.

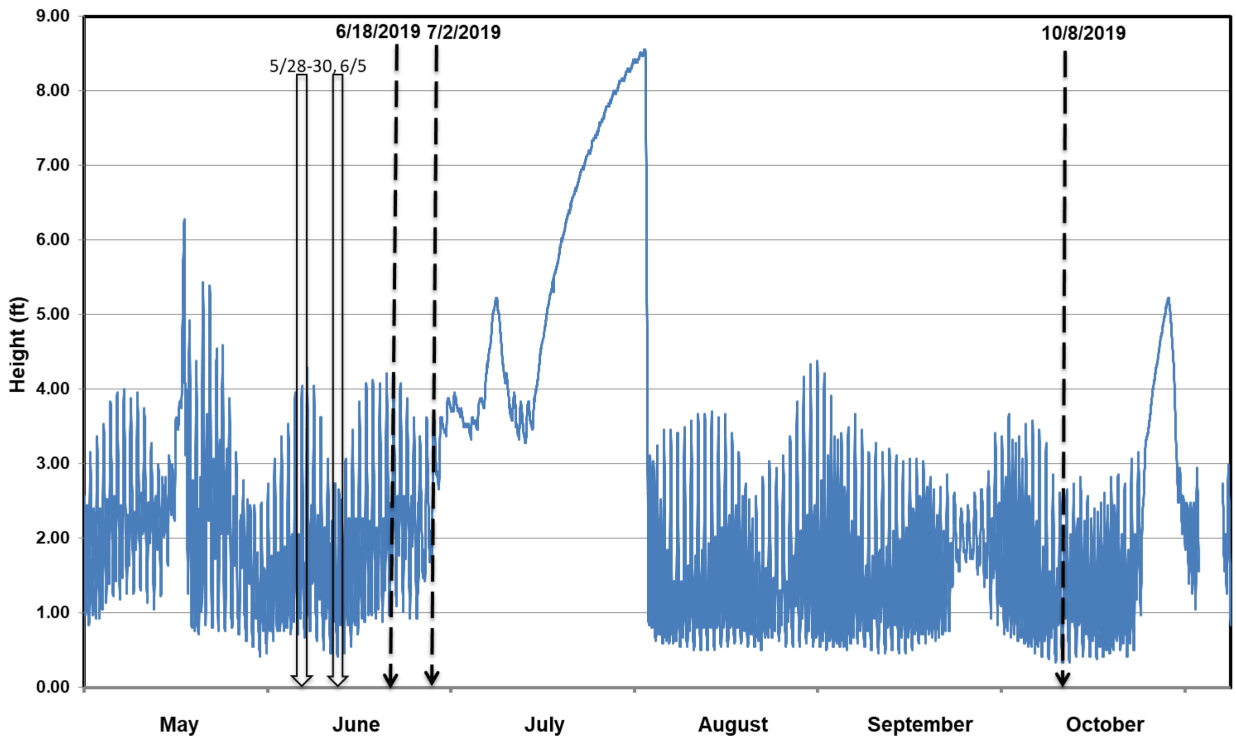


Figure 4.3.8. Dates of invertebrate samples (dashed vertical lines) and salmonid diet samples (open vertical lines) relative to Jenner Gauge water level (ft) at mouth of Russian River estuary, June and July, 2019.

Juvenile Steelhead Diet Composition

In 2019, 12 juvenile steelhead (63-172 mm FL) were sampled for diet composition in late May and early June and 21 juvenile Chinook salmon (83-134 mm FL) were sampled in late May (Figure 4.3.8). Only one of the steelhead originated from the lower reach (River Mouth) of the estuary, while all other fish were captured in the upper reach (Sheephouse Creek, Heron Rookery, Moscow Ridge, Casini Ranch). In contrast, nine (87-110 mm FL) of the juvenile Chinook were captured from the lower reach (River Mouth, Penny Point), most of the remainder (96-134 mm FL) originated from the middle reach (12, Bridgehaven), and one fish (83 mm FL) was retained from the upper reach (Freezeout Bar). All of these fish collections occurred during open estuary conditions.

Prey composition in the steelhead samples were relatively consistent with diet composition from the respective estuary reaches in previous study years since 2009. Among predominant prey in the steelhead diets (Figure 4.3.9), the gammarid amphipod *Eogammarus confervicolus* dominated (98% total IRI) in the lowest reach of the estuary (River Mouth) but Emphemoptera nymphs (19%-98% total IRI, increasing up-estuary) and Chironomid [biting midges/flies] larvae (35%-1% total IRI, decreasing up-estuary) also provided significant proportions of their diets. Lesser dietary contributions occurred from individual sites (e.g., Chironomidae adults and the gammarid amphipod *Americorophium spinicorne* at Heron Rookery, and Ephemeroptera [mayflies] adults at Moscow Bridge).

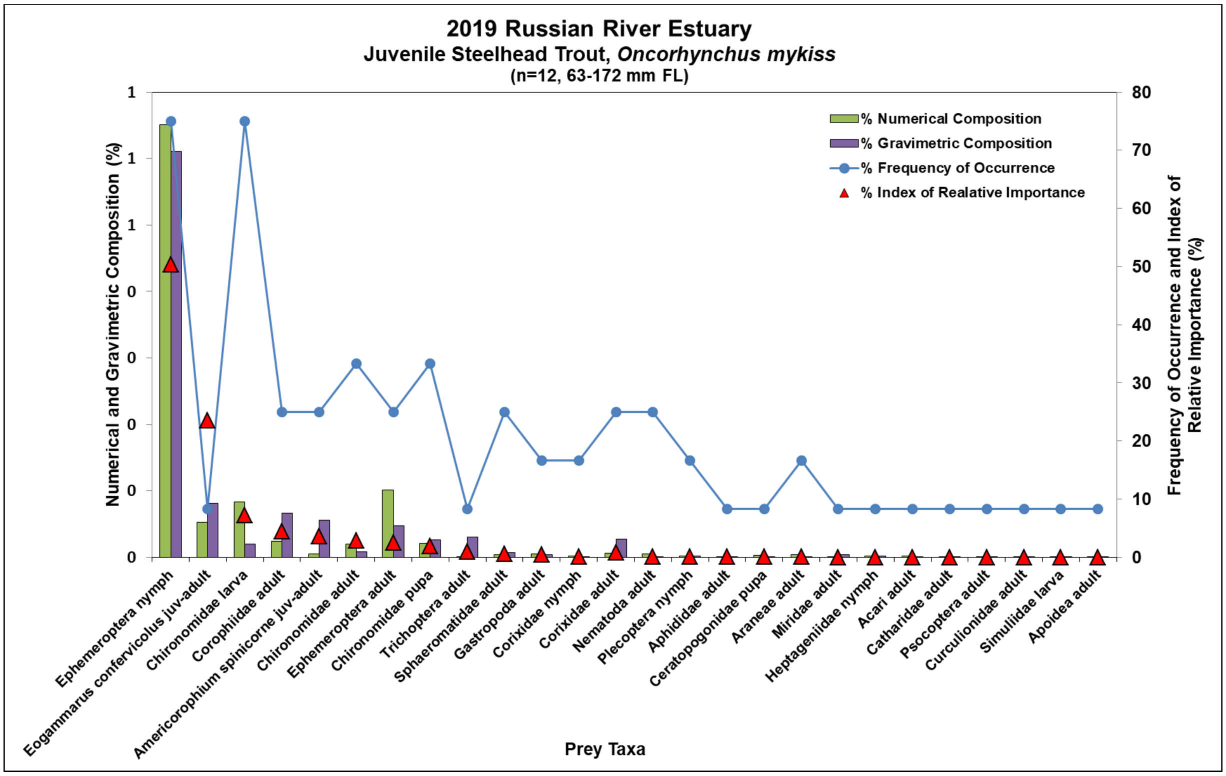


Figure 4.3.9. Composition and occurrence of prey taxa consumed by 12 juvenile steelhead in the Russian River estuary, late May-early June 2019.

Diet composition of juvenile Chinook salmon (Figure 4.3.10) was similarly composed (30% total IRI) of *Eogammarus confervicolus* at River Mouth but included a large contribution (39% total IRI) of unidentifiable fish larvae. In the Penny Point upper region of the River Mouth reach, the epibenthic amphipods and isopods (*Americorophium spinicorne*, *Americorophium stimpsoni*, *Gnorimosphaeroma insulare*) combined to compose ~75% of the total IRI. In contrast, the dominant (12 fish) component of the sample originating from Bridgehaven (2 sites) had consumed predominantly (60% total IRI) *Americorophium stimpsoni* but fish larvae fish larvae also composed 22% of the total IRI. One fish from the upper reach, at Freezeout Bar, had also consumed fish, *Ephemeroptera* nymph, and *Chironomid* pupae (29%, 29%, 20%, total IRI respectively).

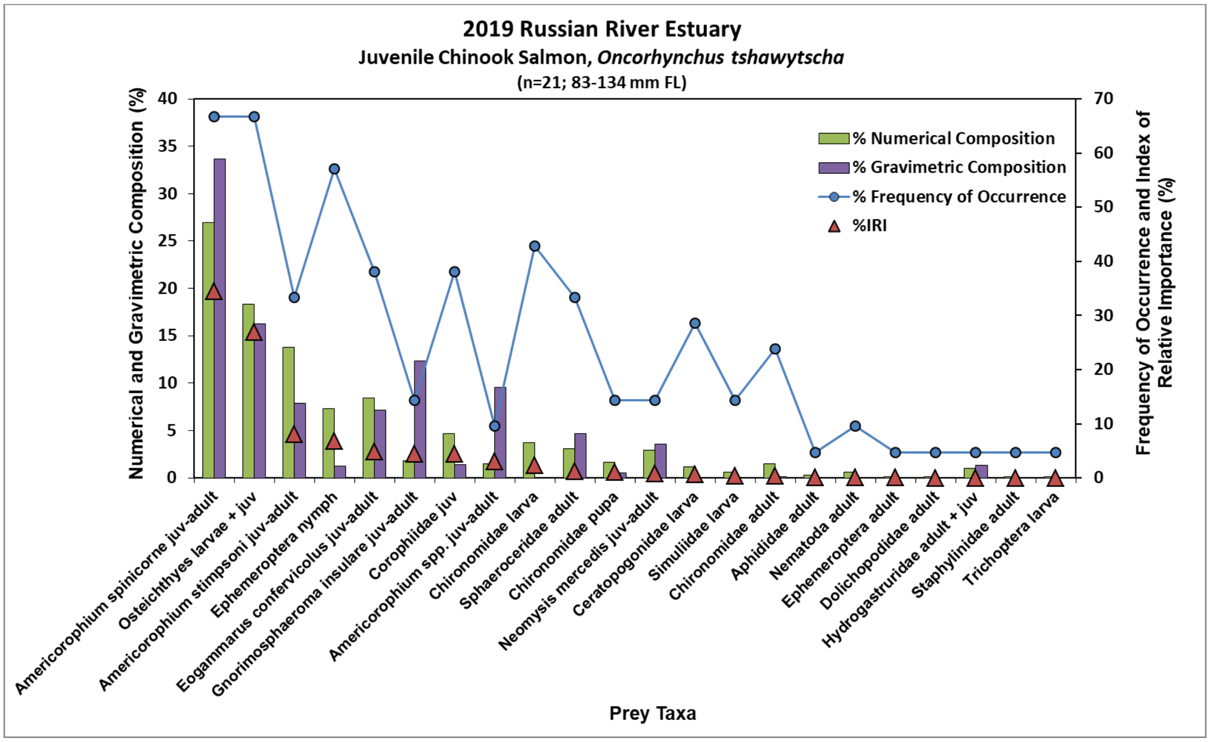


Figure 4.3.10. Composition and occurrence of prey taxa consumed by 21 juvenile Chinook salmon in the Russian River estuary, late May 2019.

Prey Availability

Juvenile steelhead and salmon prey represented in the littoral zone by the epibenthic net to shore samples were relatively comparable in composition and density between the 18 June and 2 July (Figures 4.3.11-4.3.12, 4.3.14), but more diverse and appreciable less dense on 8 October (Figures 4.3.13-4.3.14). Insect (Corixidae, water boatman) nymphs were the dominant taxa in June at the pre-dominantly freshwater Freezeout Bar site, and somewhat less dense at the brackish Willow Creek site (Figures 4.3.11 and 4.3.14). Gastropods were the only other prominent taxa at the brackish Penny Point and Willow Creek sites. In contrast, the more common steelhead/salmon prey (*Americorophium* spp., *Eogammarus confervicolus*, *Ceratopogonidae* larvae, Chironomid larvae and pupae, *Gnorimosphaeroma insulare, Neomysis mercidis*) occurred at much lower densities predominantly at the River Mouth and Penny Point sites, which are the most marine-influenced sample sites.

Prey taxa were distributed similarly, in relatively comparable densities between June 18 and July 2 sample dates prior to the estuary closure on July 18 (Figure4.3.8). Adult Corixidae and nymphs occurred in highest densities at Freezeout Bar. Gastropods were secondary, in the middle estuary reaches. As found in mid-June, and as in comparable sampling in previous years, common steelhead/salmon prey taxa such amphipods, isopods, mysids and insect larvae/pupae (Ceratopogonidae, Chironomidae) similarly represented the lower estuary sampling sites.

By the last sampling event on October 8, densities of epibenthic prey in the littoral zone had decreased appreciably but occurred somewhat more ubiquitously across the breadth of the estuary reaches (Figures 4.3.13 and 4.3.14). Among the more prevalent prey, early life history stages of corixid beetles and chironomid larvae were still prevalent at Freezeout Bar site, and Corophiidae amphipods were relatively abundant in lower estuary sites. Other steelhead/salmon prey *Gnorimosphaeroma insulare* were more ubiquitous across all sites. Other common prey (*Americorophium* spp., *Eogammarus confervicolus*, *Ceratopogonidae* larvae, Chironomid larvae and pupae, *Neomysis mercidis*) occurred broadly among River Mouth to Willow Creek sites in densities ≤2 m^{-2} or less.

Multivariate analysis (NMDS) of the taxa density composition among the four sites over the three sampling events (Figure 4.3.15) indicated significant (2D stress=0.14) but diffuse differences among sampling sites. Freezeout Bar and River Mouth sites are most dissimilar while River Mouth and Penny Point tended to have the most overlap, particularly during the June 18 sampling.

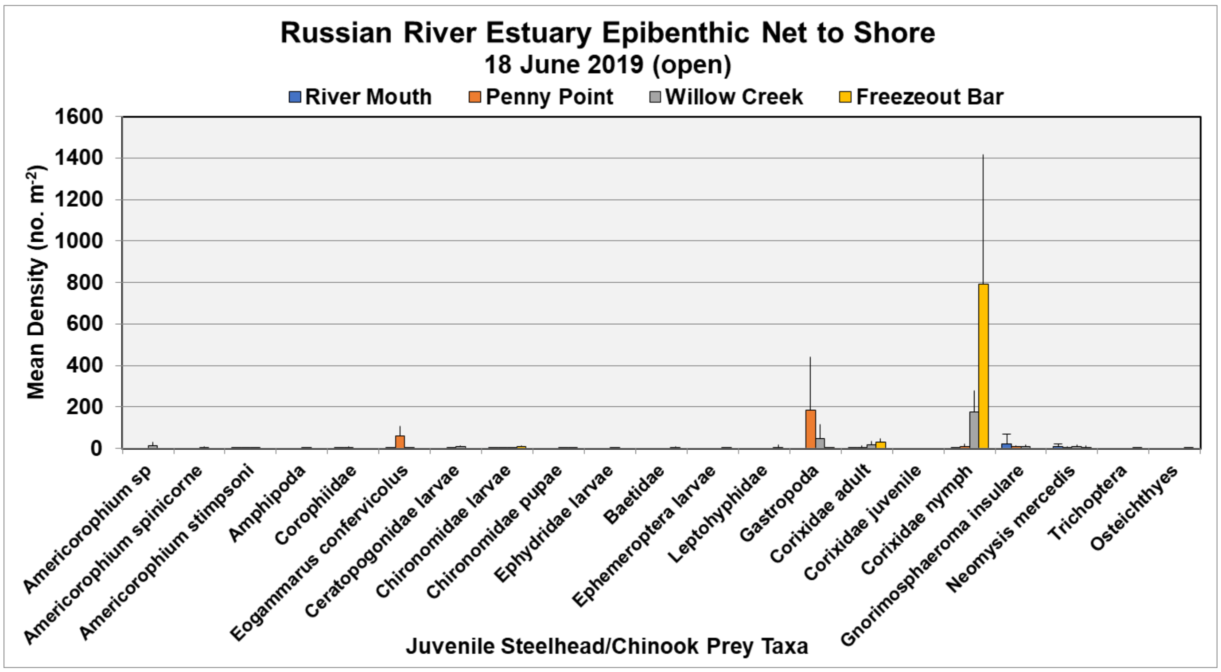


Figure 4.3.11. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic net to shore samples at four sites in the Russian River estuary, 18 June 2019.

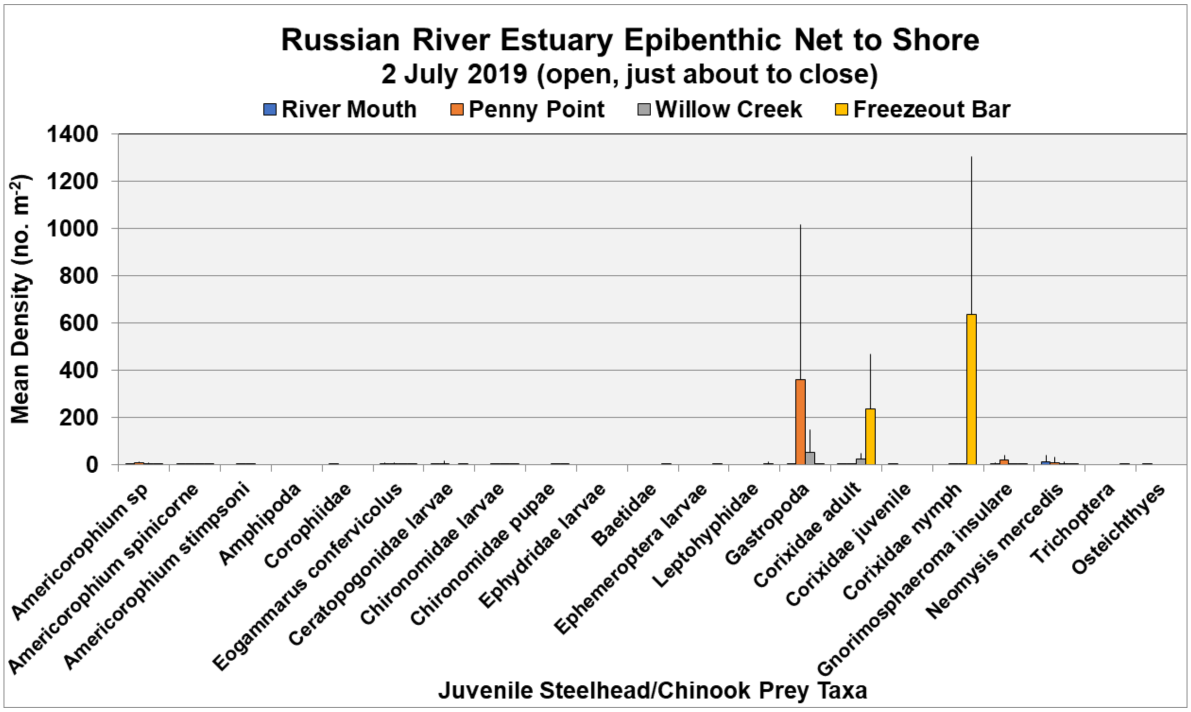


Figure 4.3.12. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic net to shore samples at four sites in the Russian River estuary, 2 July 2019.

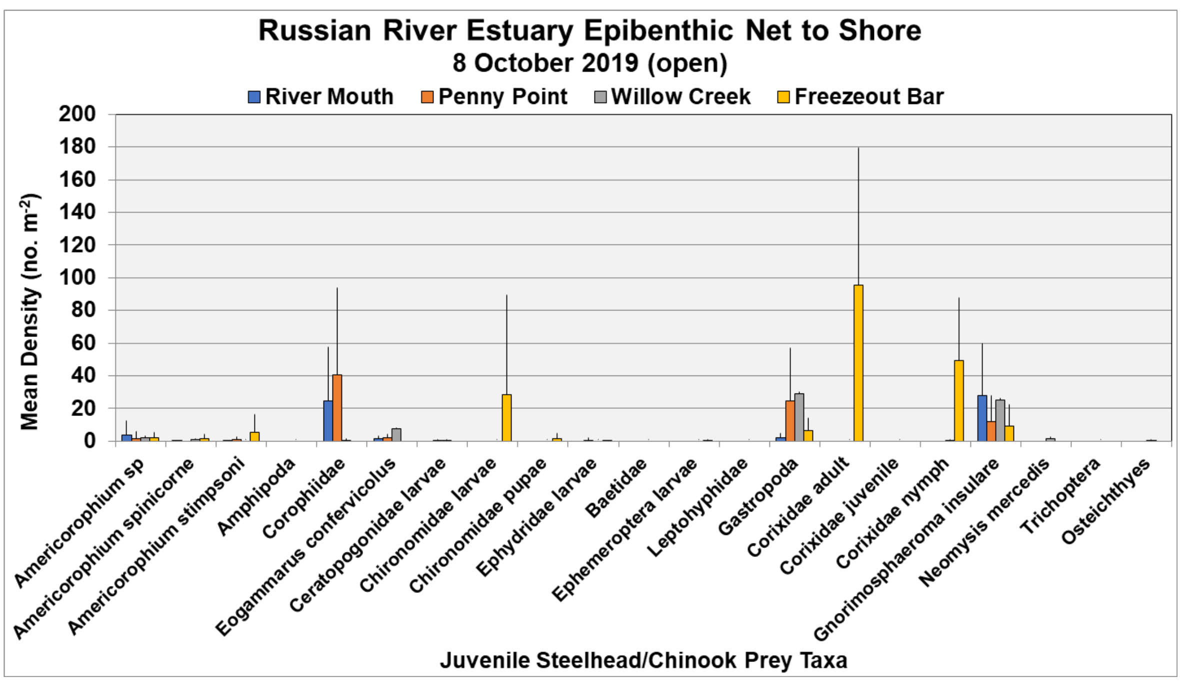


Figure 4.3.13. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic net to shore samples at four sites in the Russian River estuary, 8 October 2019.

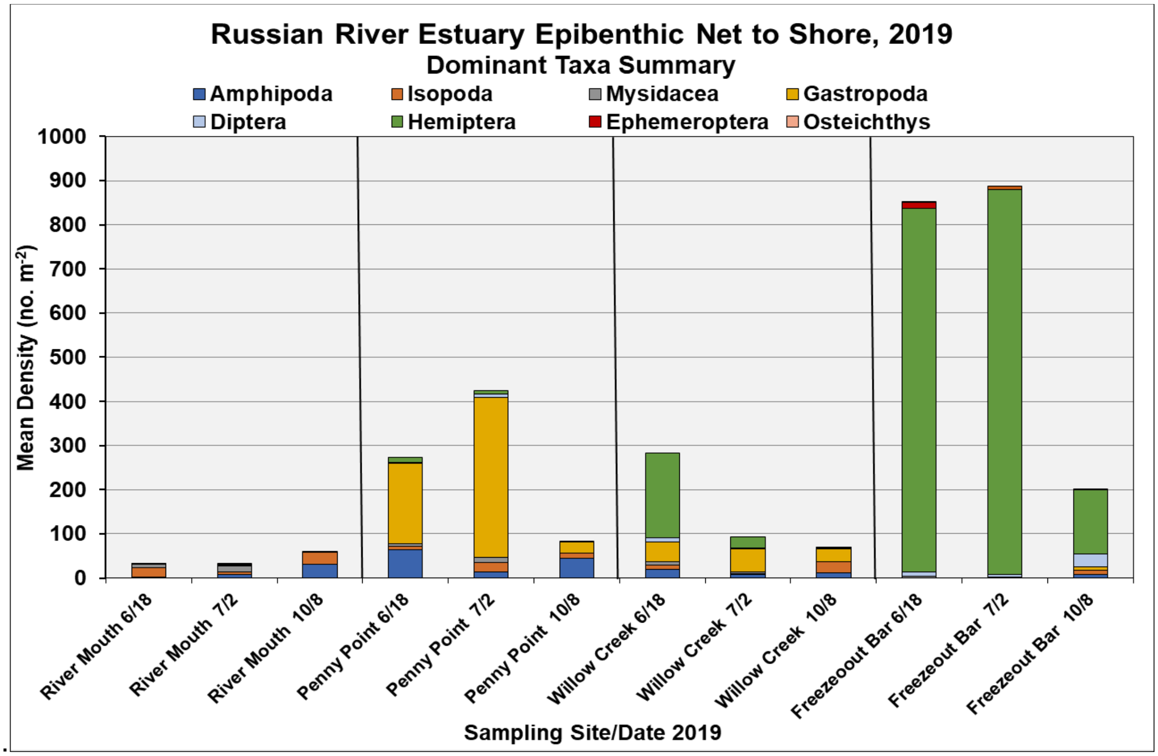


Figure 4.3.14. Cumulative mean density of epibenthic net to shore sampling during the three sampling periods at each of the four sampling sites in the Russian River estuary, 2019.

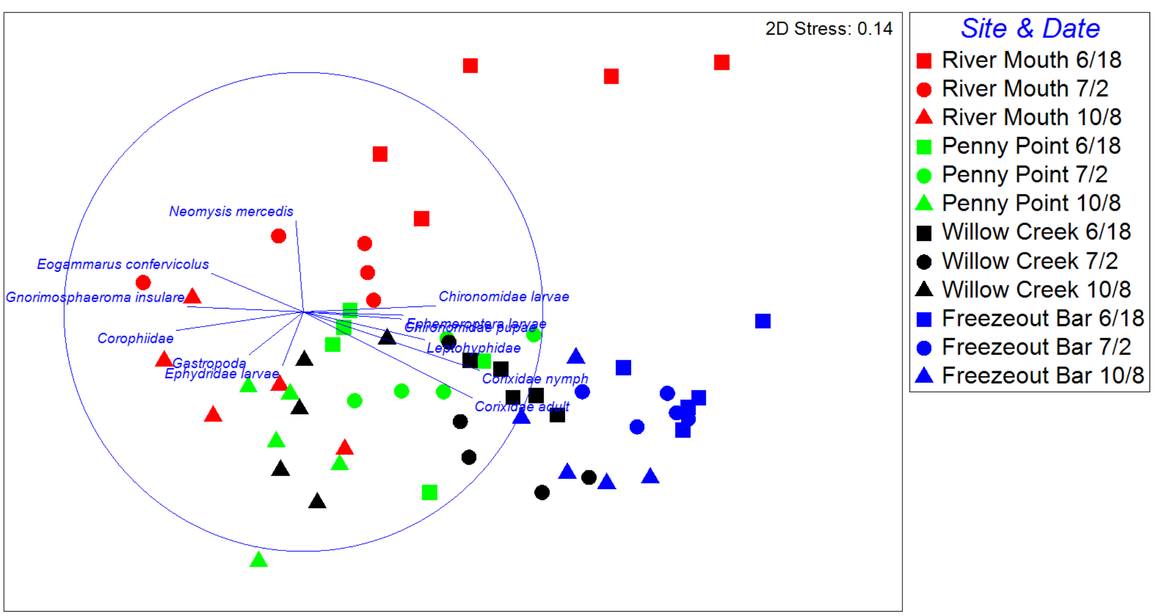


Figure 4.3.15. Multivariate analysis (NMDS) diagram of density composition of epibenthic net to shore macroinvertebrate prey of juvenile steelhead in the Russian River estuary, 2019.

The most distinguishing taxa of the River Mouth prey assemblage were *E. confervicolus*, *G. insulare*, Corophiidae, *N. mercedis*, Gastropoda and ephydrid (brine fly) larvae, although not as distinctly during the June 18 sampling (Figure 4.3.15). Conversely, prey taxa that distinguished the upper estuary sites were aquatic insect larvae, including nymph and adult corixid beetles, larvae and pupae chironomids, larval ephemeropterans, and Leptohyphidae (mayfly).

Epibenthic Sled

Other than a few exceptions, the epibenthic sled sampling analysis indicted similar general prey taxa distributions as documented in the epibenthic net to shore although densities were considerably higher during 18 June sampling compared to the 2 July and 8 October results (Figures 4.3.16-4.3.19). During all three sampling periods, the densest taxa were corixids collected at Freezeout Bar, particularly on 18 June. Although corixids were also most prominent in the 2 July and 8 October sampling, their densities were on the order of 141.0 m^{-2} – 338.4 m^{-2}. The only exceptions were the prominence of *N. mercedis* mysids at all sampling sites, particularly so at Willow Creek on 18 June, but also pervasively at all sites on 2 July (Figure 4.3.19). As observed in the epibenthic net to shore samples, prominent prey of juvenile salmonids such as Gammaridae, *Americorophium* spp., *Eogammarus confervicolus*, Corophiidae juveniles, and Chironomid larvae were comparatively less dense.

Multivariate analysis (NMDS) of the taxa density composition among epibenthic sled samples at the four sites over the three sampling events (Figure 4.3.20; 2D stress=0.16) indicated more distinct differentiation of the taxa in the lower estuary sites from the assemblages collected at Freezeout Bar. The primary indicators of this distinction were the occurrence of just *G. insulare*, Gammaridae and *E. confervicolus* at River Mouth, Penny Point and Willow Creek sites (Figure 4.3.20). The density composition of the assemblages at Penny Point and Willow Creek appeared to be more similar than the River Mouth assemblages.

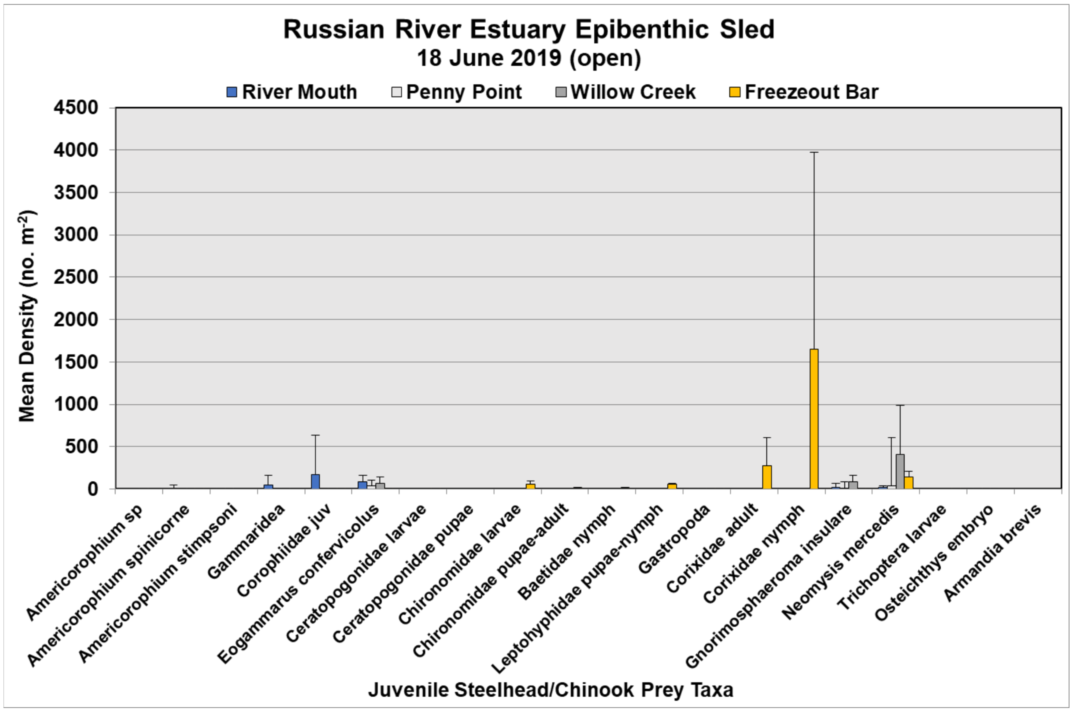


Figure 4.3.16. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic sled samples at four sites in the Russian River estuary, 18 June 2019.

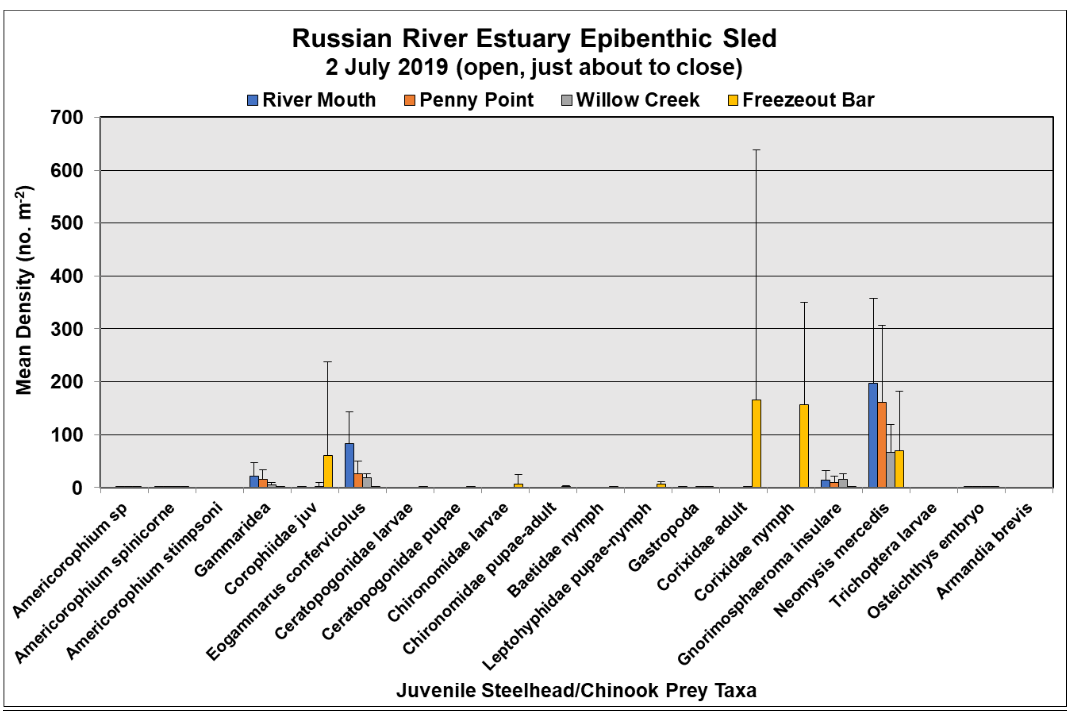


Figure 4.3.17. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic sled samples at four sites in the Russian River estuary, 2 July 2019.

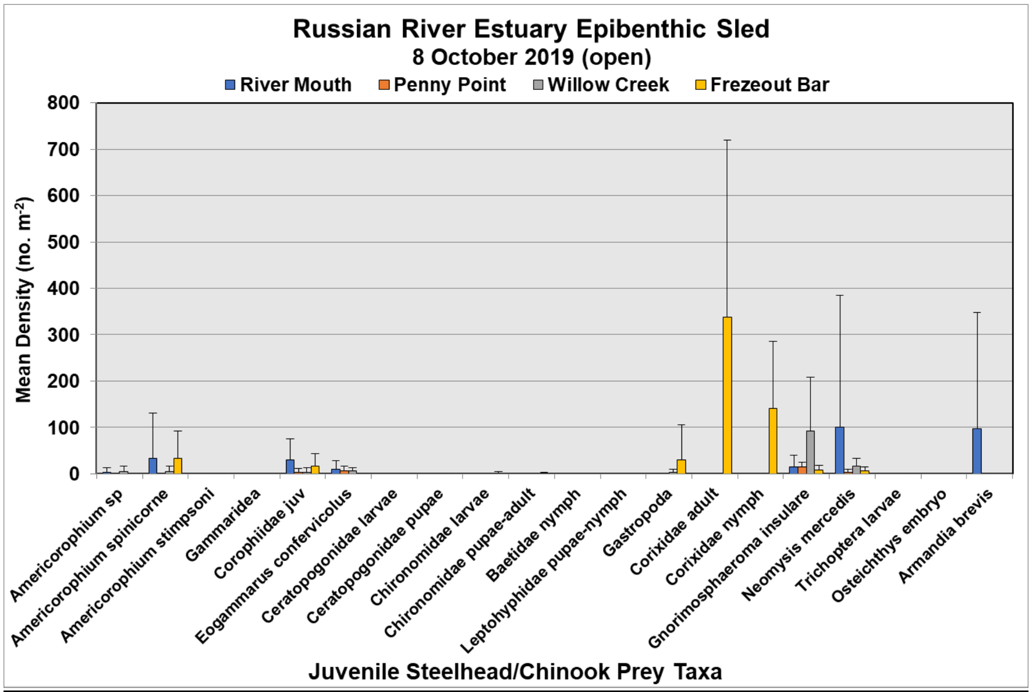


Figure 4.3.18. Mean density (± 1 s.d.) of epibenthic prey available to juvenile steelhead and Chinook salmon from epibenthic sled samples at four sites in the Russian River estuary, 8 October 2019.

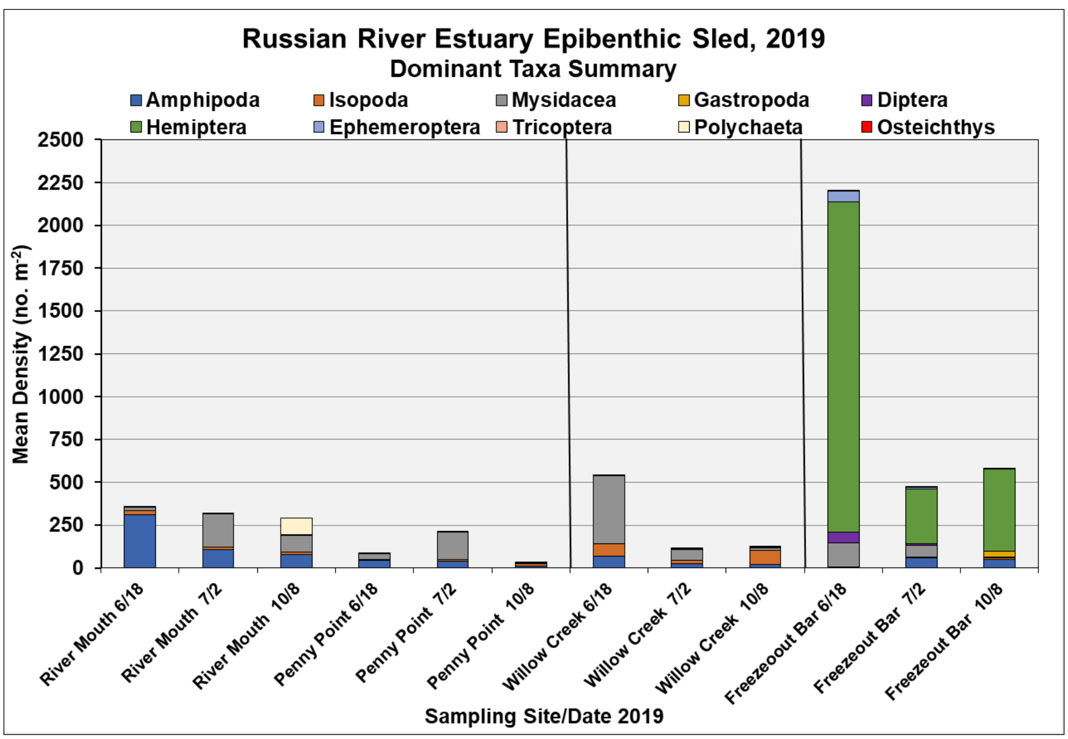


Figure 4.3.19. Cumulative mean density of epibenthic sled sampling during the three sampling periods at each of the four sampling sites in the Russian River estuary, 2019.

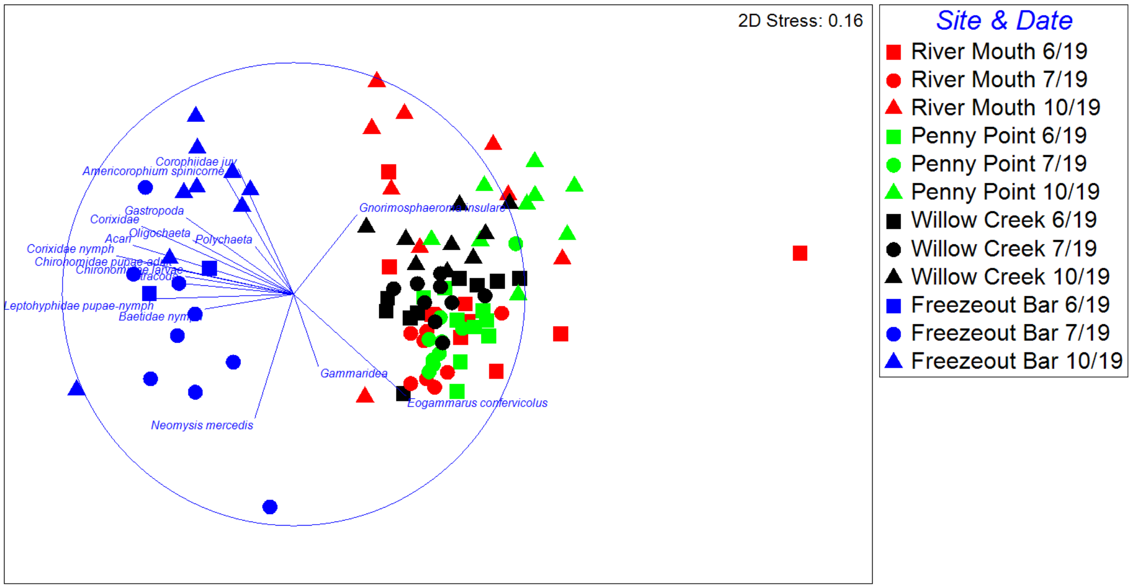


Figure 4.3.20. Multivariate analysis (NMDS) diagram of density composition of epibenthic sled macroinvertebrate prey of juvenile steelhead and Chinook from four sites over three sampling periods in the Russian River estuary, 2019.

Conclusions and Recommendations

There were no beach management actions taken during the lagoon management period in 2019. Samples were collected during open conditions in May, June, and September. Sampling results for juvenile steelhead diet composition and prey availability were consistent with results from previous years' efforts during the lagoon management period. The results presented here provide a summary of current understanding of juvenile steelhead diet composition and prey availability in the Russian River Estuary based on monitoring results from 2009 to 2019.

The diet composition of both juvenile steelhead and Chinook salmon in the Russian River estuary since 2009 has indicated that these juvenile salmons feed relatively specifically on a limited suite of epibenthic crustaceans and aquatic insects. While the diet composition of these two juvenile salmonids from the 2019 collections were somewhat restricted to May-June in the upper estuary (steelhead), or just May through diverse sites across all four reaches of the estuary (Chinook), their dominant prey composition was relatively consistent to results from prior years.

The diets of juvenile steelhead and Chinook salmon in the Russian River estuary tend to be dominated by free-living or tubicolus gammarid amphipods (*E. confervicolus*, *Americorophium* spp. (*A. spinicorne*; *A. stimpsoni*), the epibenthic isopod *G. insulare*, and aquatic stages of insects belonging to the hemipteran family Corixidae (water boatmen), Chironomidae (biting midges/flies), and Ephemeroptera (mayflies). All of these are aquatic prey; even the insects are predominantly the aquatic life history stages rather than flying adult stages. Less common prey taxa include Tricoptera (caddis flies) and dipteran insects (e.g., Sphaeromatidae) and *N. mercedis* mysids, which have appeared inconsistently in the diets of juvenile steelhead over the years of this study. The relative consistency of juvenile steelhead foraging on benthic/epibenthic prey provides some direction to the bioenergetic modeling of variability in their performance under variable seasonal, river flow, mouth opening, and other constraints on juvenile steelhead habitat (Broughton et al. 2017).

These taxa are commonly reported in the diets of juvenile steelhead (and Chinook salmon, in a few cases) sampled in other intermittent systems estuaries characteristic of Mediterranean regimes in the region (Needham 1940; Shapovalov and Taft 1954; Meyer et al*.* 1981; Martin 1995; Salamunovich and Ridenhour 1990; Zedonis 1992; Martin 1995; Bell et al. 2011; Ward 1914). While accounts of juvenile steelhead/Chinook foraging in these accounts is usually not directly comparable to the Seghesio (2011) and Matsubu et al. (2017)/Matsubu (2019), those from Pescadero Lagoon (Martin 1995), the Mattole River estuary (Zedonis 1992) and Waddell Creek (Shapovalov and Taft 1954) provide some comparisons.

Zedonis (1992) sampling in the Mattole River estuary lagoon described juvenile steelhead feeding predominantly on *Corophium* spp., isopods and tricopteran and ephemeropteran larvae in the lower lagoon. Although many of these invertebrates also occurred in the diets from the upper lagoon, gastropods and *N. mercedis* were also prevalent. Martin (1995) described dominant prey of juvenile steelhead in Pescadero Creek estuary under open conditions to be vary comparable to the Salmon River estuary accounts, dominated by *Corophium* spp., *E. confervicolus*, *N. mercedis*, *G. insulare*, and chironomid larvae and pupae. When the lagoon sandbar closed, the diet composition notably shifted to Odonata, Ephemeroptera, and Trichocornia insect stages. Shapovalov and Taft (1954) description of juvenile steelhead held in cages in the Waddell Creek lagoon included *E. confervicolus* as the predominant prey, complemented by *E. confervicolus* and *C. spinicorne*.

Prey densities in the Salmon River estuary were relatively comparable among the 2019 and prior years' results, implying a relatively consistent estuarine prey community available for juvenile steelhead despite some variability in the occurrence and duration of freshwater outflow and estuary closure events. There was no obvious gradient or differentiation in the composition and relative density distribution of prey among the independent epibenthic net to shore and channel sled samples. This would suggest that within a reach there was uniform or a relatively minor gradient of prey density distribution from their deeper channel to their shallower, marginal habitats. The only uncertainly inherent in these 2019 results were contrasts between open and closed estuary conditions. Both epibenthic net to shore and epibenthic sled indicate somewhat distinct invertebrate prey community composition between the River Mouth site assemblage and the Penny Point sampling site at the upper end of the Lower Reach, but often distinct prey assemblages between the upper estuary Freezeout Bay site versus the lower reach and assemblages at the Willow Creek site in the middle reach. Presumably salinity distribution is a likely determinant of these distinctions but cannot preclude the other influences of tidal exchange, substrate, or other factors. As indicated by prior reports and Matsubu (2019) and Matsubu et al. (2017) investigations of juvenile steelhead distribution and movement across the breadth of the estuary, the fish appear to volitionally respond to water level and temperature regime changes that would provide them variable access to different prey assemblages.

Unfortunately, there is little detailed/quantitative documentation of prey availability from other estuaries to results from the study of juvenile steelhead and Chinook salmon diets in the Russian River estuary. Perhaps the most relative documentation is that of Robinson (1993) that, although not synchronous with juvenile steelhead diet composition (e.g., Martin 1995), provides quantitative insight into timing, distribution, and some potentially explanatory correlates (particularly the potential influence of habitat factors, such as water quality and the role of *Potamogeton foliosus*). Based on benthic grab and Ekman dredge sampling, Robinson (1993) documented a macroinvertebrate assemblage relatively complementary to steelhead diet composition documented by Martin (1995). Relative densities were dominated by epibenthic *N. mercedis* (3400-5700/sample), *C. spinicorne* (329-2800; >10,000 in benthic sampling), *E.* (*ramellus*) *confervicolus*), *Chironomus* sp. (578-710), and *G. oregonense* (168-573). Many of the epibenthic taxa, especially *E. confervicolus*, were found to be specifically associated with the *P. foliosa* aquatic vegetation. As in the Russian River estuary, aquatic insect larvae and pupae (e.g., Hydrophliae, Baetidae) were also prominent in the upper Pescadero estuary lagoon, especially when the estuary was closed.

Of potential management implication is the question of food web/bioenergetic limitations for juvenile steelhead and salmon in the Russian River estuary, as potentially interpreted from our results under the current management plan. Relatable data from other intermittent estuaries is not directly comparable due to differing estuary management that influence the duration of estuary closures. In terms of fish performance, 2009-2019 results from the Russian River estuary would imply that the short-managed closure conditions are not deleterious to juvenile steelhead and Chinook salmon rearing in the estuary. Both the bioenergetic advantages and habitat expansion during somewhat extended estuary closures demonstrate or imply benefits to prey availability, consumption, bioenergetic conversion and growth (Broughton *et al.* 2017; Matsubu *et al.* 2017; Matsubu 2019). There are no clear assessments whether predation would be a major survival factor. Other estuaries with much more extended estuary closure periods are not directly comparable, but results from estuaries such as Scott Creek, where Bond *et al.* (2008) documented higher survival and twice the growth of estuary-reared steelhead, is suggested to be representative of many central California coastal streams.

4.4 Fish Sampling – Beach Seining

Sonoma Water has been fish sampling the Russian River Estuary since 2004 - prior to issuance of the Biological Opinion. An Estuary fish survey methods study was completed in 2003 (Cook 2004). To provide context to data collected in 2019, Sonoma Water presents and discusses previous years of data in this report. Although survey techniques have been similar since 2004, some survey locations and the sampling extensity changed in 2010 as required in the Biological Opinion. The distribution and abundance of fish in the Estuary are summarized below. In addition to steelhead, Coho Salmon, and Chinook salmon, the catch of several common species are described to help characterize conditions in the Estuary.

Methods

Study Area

The Estuary fisheries monitoring area included the tidally-influenced section of the Russian River and extended from the sandbar at the Pacific Ocean to Duncans Mills, located 9.8 km (6.1 mi) upstream from the coast (Figure 4.4.1).

Fish Sampling

A beach-deployed seine was used to sample fish species, including salmonids, and determine their relative abundances and distributions within the Estuary. The rectangular seine consisted of 5 mm (¼ inch) mesh netting with pull ropes attached to the four corners. Floats on the top and weights on the bottom positioned the net vertically in the water. From 2004 to 2006, a 30 m (100 ft) long by 3 m (10 ft) deep purse seine was used. From 2007 to 2014 a conventional seine 46 m (150 ft) long by 4 m (14 ft) deep was used. Then in 2015 a 46 m by 3 m seine with a 3 m square pocket located in the center of the net was employed. The seine was deployed with a boat to pull an end offshore and then around in a half-circle while the other end was held onshore. The net was then hauled onshore by hand. Fish were placed in aerated buckets for sorting, identification, and counting prior to release.

Salmonids were anesthetized with Alka-Seltzer tablets or MS-222 and then measured, weighed, and examined for general condition, including life stage (i.e., parr, smolt). All salmonids were scanned for passive integrated transponder (PIT) tags or other marks. Steelhead and Coho Salmon were identified as wild or hatchery stock by a clipped adipose fin. Hatchery Coho Salmon were no longer clipped after spring 2013 and were either marked with a coded wire tag or PIT tag. Unmarked juvenile steelhead caught in the Estuary greater than 60 mm fork length were surgically implanted with a PIT tag. Fish were allowed to recover in aerated buckets prior to release.

From 2004 to 2009, eight seining stations were located throughout the Estuary in a variety of habitats based on substrate type (i.e., mud, sand, and gravel), depth, tidal, and creek tributary influences. Three seine sets adjacent to each other were deployed at each station totaling 24 seine sets per sampling event.

Stations were surveyed approximately every 3 weeks from late May through September or October. Total annual seine pulls ranged from 96 to 168 sets.

Starting in 2010 fish seining sampling was doubled in effort with 300 sets completed for the season. Surveys were conducted monthly from May to October. Between 3 and 7 seine sets where deployed at 10 stations for a total of 50 sets for each sampling event. Twenty-five sets were in the lower and middle Estuary and 25 in the upper Estuary. Since 2014, seining was reduced to three events in May, June, and September if the river mouth condition remained open (tidal) during the Lagoon Management period (May 15 to October 15). If a

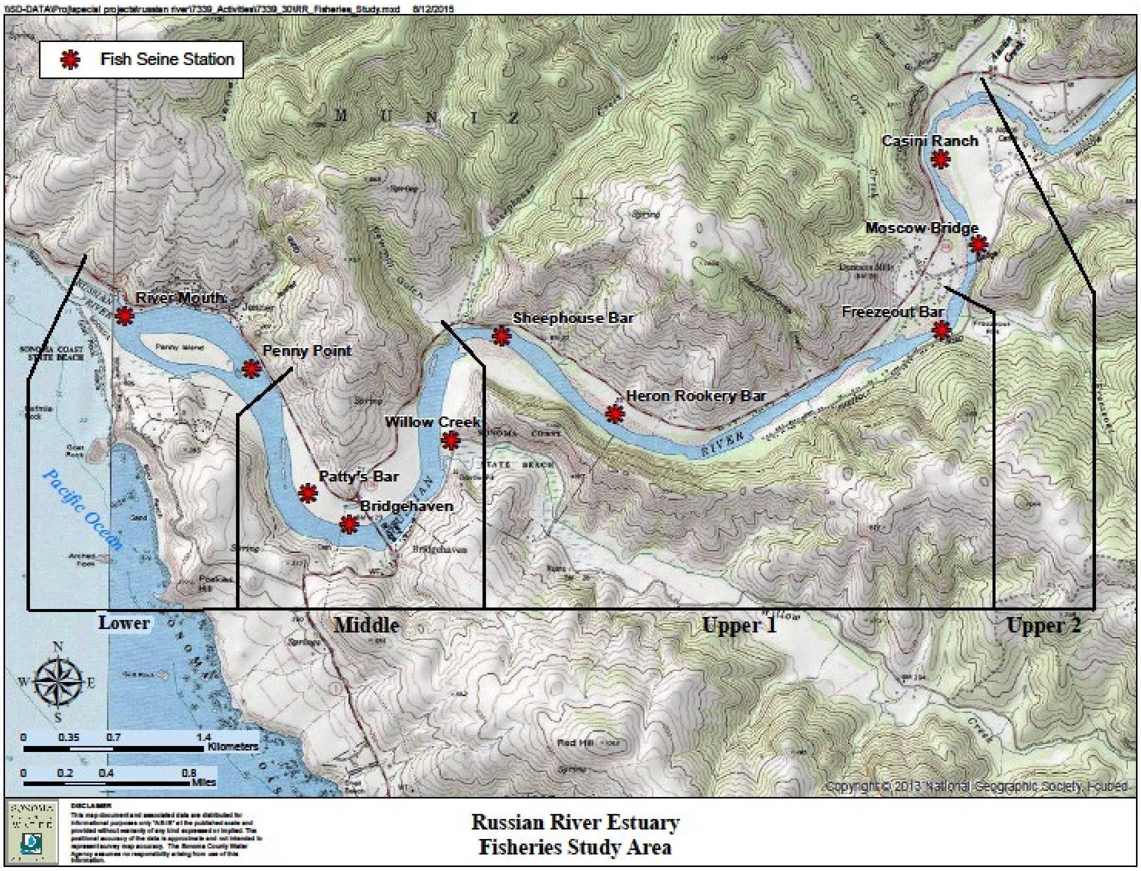


Figure 4.4.1. Russian River Estuary fisheries seining study reaches and sample sites, 2019.

prolonged closure occurred or a lagoon outlet channel was successfully installed forming a freshwater lagoon seine events occur monthly from May to June. In 2019, three seining events were completed in May, June, and September.

For data summary purposes the Estuary study area was divided into three reaches, including Lower, Middle, and Upper, which is consistent with study areas for water quality and invertebrate studies (Figure 4.4.1). For the fish seining study, the Upper Reach of the Estuary was divided into Upper1 and Upper2 sub-reaches to improve clarity on fish patterns. Fish seining stations were located in areas that could be sampled during open and closed river mouth conditions. Suitable seining sites are limited during closed mouth conditions due to flooded shorelines. Catch per unit effort (CPUE), defined as the number of fish captured per seine set (fish/set), was used to compare the relative abundance of fish among Estuary reaches and study years.

The habitat characteristics and locations of study reaches, fish seining stations, and number of monthly seining sets are below:

- Lower Estuary

  - River Mouth (7 seine sets): sandbar separating the Russian River from the Pacific Ocean, sandy substrate with a low to steep slope, high tidal influence.
  - Penny Point (3 seine sets): shallow water with a mud and gravel substrate, high tidal influence.

- Middle Estuary
  - Patty's Bar (3 seine sets): large gravel and sand bar with moderate slope, moderate tidal influence.
  - Bridgehaven (7 seine sets): large gravel and sand bar with moderate to steep slope, moderate tidal influence.
  - Willow Creek (5 seine sets): shallow waters near the confluence with Willow Creek, gravel and mud substrate, aquatic vegetation common, moderate tidal influence.

- Upper Estuary

  Upper1 Sub-Reach
  - Sheephouse Bar (5 seine sets): opposite shore from Sheephouse Creek, large bar with gravel substrate and moderate to steep slope, low to moderate tidal influence
  - Heron Rookery Bar (5 seine sets): gravel bank adjacent to deep water, low to moderate tidal influence.
  - Freezeout Bar (5 seine sets): opposite shore from Freezeout Creek, gravel substrate with a moderate slope, low tidal influence.

  Upper2 Sub-Reach
  - Moscow Bridge (5 seine sets): steep to moderate gravel/sand/mud bank adjacent to shallow to deep water, aquatic vegetation common, low tidal influence.

Casini Ranch (5 seine sets): moderate slope gravel/sand bank adjacent to shallow to deep water, upper end of Estuary at riffle, very low tidal influence.

Results

Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary for 2019 are summarized in Table 4.4.1. During the 15 years of study over 50 fish species were caught in the Estuary. In 2019, seine captures consisted of 14,379 fish comprised of 25 species.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity (Figure 4.4.2). In general, the influence of cold seawater from the ocean under open mouth conditions results in high salinity levels and cool temperatures in the Lower Reach transitioning to warmer freshwater in the Upper Reach from river inflows (Figure 4.4.3). The water column is usually stratified with freshwater flowing over the denser seawater.

Fish commonly found in the Lower Reach were marine and estuarine species including topsmelt (*Atherinops affinis*) surf smelt (*Hypomesus pretiosus*), and staghorn sculpin (*Leptocottus armatus*). The Middle Reach had a broad range of salinities and a diversity of fish tolerant of these conditions. Common fish in the Middle Reach included those found in the Lower Reach, and shiner surfperch (*Cymatogaster aggregata*) and bay pipefish (*Syngnathus leptorhynchus*). Freshwater dependent species, such as the Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), and Russian River tule perch (*Hysterocarpus traskii pomo*), were predominantly distributed in the Upper Reach. Anadromous fish, such as steelhead (*Oncorhynchus mykiss*) and American shad (*Alosa sapidissima*), which can tolerate a broad range of salinities, occurred throughout the Estuary. Habitat generalists, such as threespine stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper*), occurred in abundance in the Estuary, except within full strength seawater in the Lower Reach.

Steelhead

During 2019, a total of 43 steelhead were captured (Table 4.4.1) in 148 seine sets. These steelhead were all wild origin fish. The resulting CPUE was 0.29 fish/set (Figure 4.4.4). In comparison, during 2018, a total of 65 steelhead were captured in 150 seine sets for a CPUE of 0.43 fish/set. There has been an overall decline in steelhead abundance since 2008 when the CPUE was 1.32 fish/set. The seasonal abundance of steelhead captures varied annually in the Estuary (Figure 4.4.5). In 2019 juvenile steelhead were captured during the May and June surveys, but not during the September survey. The highest steelhead abundances are typically in June and August. During 2019, steelhead captures were similar during May and June at 0.43 and 0.44 fish/set, respectively. The highest capture abundance among all study years was in August at 4.3 fish/set and June at 4.2 fish/set in 2008. Since seining surveys began in 2004, steelhead appear to have a patchy distribution and vary in abundance in the Estuary (Figure 4.4.6). Overall years surveyed; captures were typically highest in the Upper Reach with a high of 6.9 fish/set in the Upper1 Sub-Reach in 2008.

Overall, there were few steelhead found in the Estuary in 2019, which limited the temporal and spatial evaluation of steelhead in the Estuary (Figure 4.4.7). The typical pattern observed in previous study years consisted of relatively large numbers of juveniles in the Upper Estuary in May and June, these fish found in the Middle Estuary in mid-summer, and then most steelhead found in the Lower Estuary in September. The pattern observed in 2019 consisted of parr steelhead in all reaches of the estuary in May and June and none observed in September.

Table 4.4.1. Total fish caught by beach seine in the Russian River Estuary, 2019. Each station was sampled monthly during May, June, and September for a total of 150 seine sets for all sites. Monthly seine sets per station are shown in parentheses.

Life History	Species	River Mouth (7)	Penny Point (3)	Patty's Bar (3)	Bridge-haven (7)	Willow Creek (5)	Sheep-house Bar (5)	Heron Rookery Bar (6)	Freezeout Bar (4)	Moscow Bridge (5)	Casini Ranch (5)	Total
Anadromous	American shad				1	2			181		39	223
	Chinook salmon	7	33	6	13	10	13		1			83
	Coho Salmon	13	3	1	2	4	6			1		30
	steelhead	10			4	9	3	6	1	6	4	43
Freshwater	bluegill								1	2	1	4
	cyprinid sp						1	2			2	5
	green sunfish										1	1
	hitch				1						1	2
	largemouth bass								4	1	2	7
	Russian River tule perch									6	2	8
	Sacramento pikeminnow						1	35	2	1	13	52
	Sacramento sucker		28	16	39	357	182	383	120	87	6	1218
	sculpin sp		3		2	4	7	1		1		18
	white catfish										2	2
Estuarine	bay pipefish	2		1	2	2	2					9
	shiner surfperch	10	2		2							14
	starry flounder	10	10	11	5	24	24	2	26	22	4	138
	staghorn sculpin	59	10	6	4							79
	surfperch sp				2							2
	topsmelt	254	215	151	386	135						1141
	surf smelt	2										2
Marine	northern anchovy				10200							10200
Habitat Generalists	prickly sculpin	7	256	165	50	13	29	1	2	2		525
	threespine stickleback	18	13	140	79	186	90	43			1	570
	Grand Total	392	573	497	10792	746	358	473	338	129	78	14376

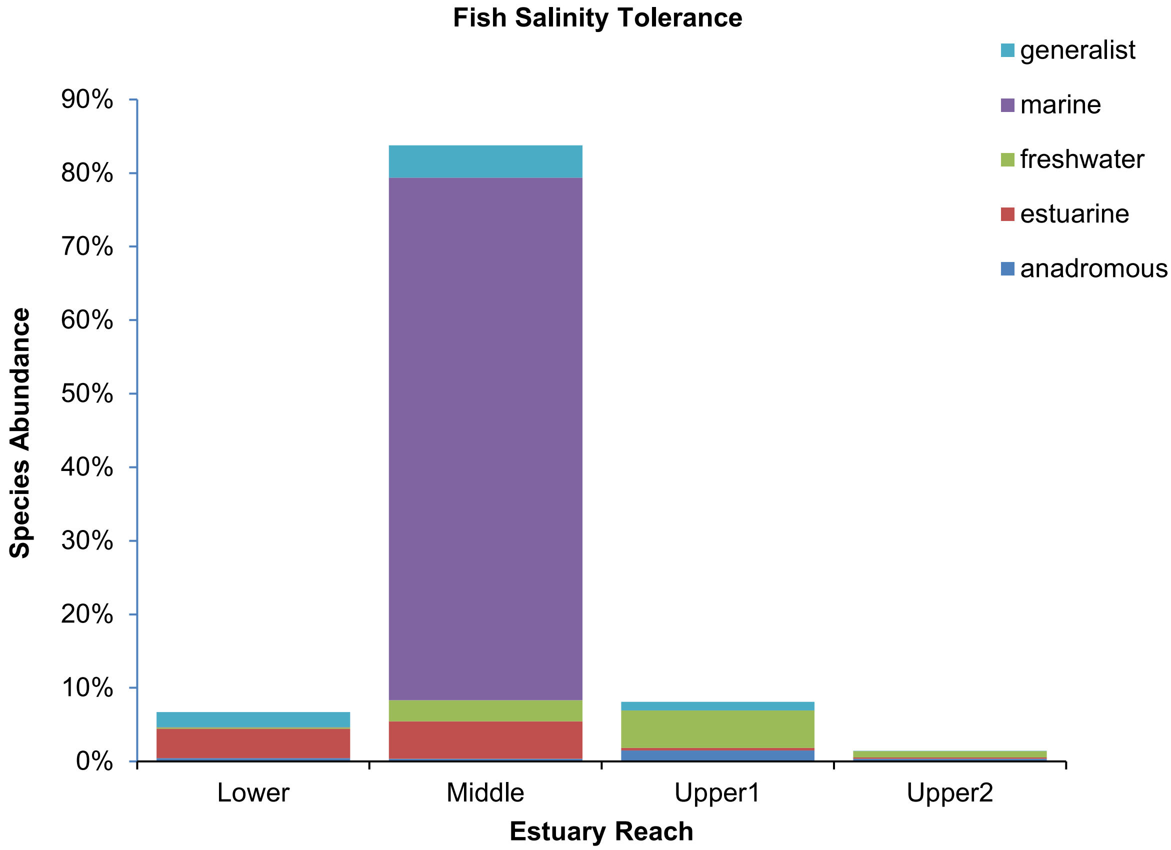


Figure 4.4.2. Distribution of fish in the Russian River Estuary based on salinity tolerance and life history, 2019. Data is from monthly seining during May, June, and September. Groups include: generalist species that occur in a broad range of habitats; species that are primarily anadromous; freshwater resident species; brackish-tolerant species that complete their lifecycle in estuaries; and species that are predominantly marine residents. See Table 4.4.1 for a list of species in each group.

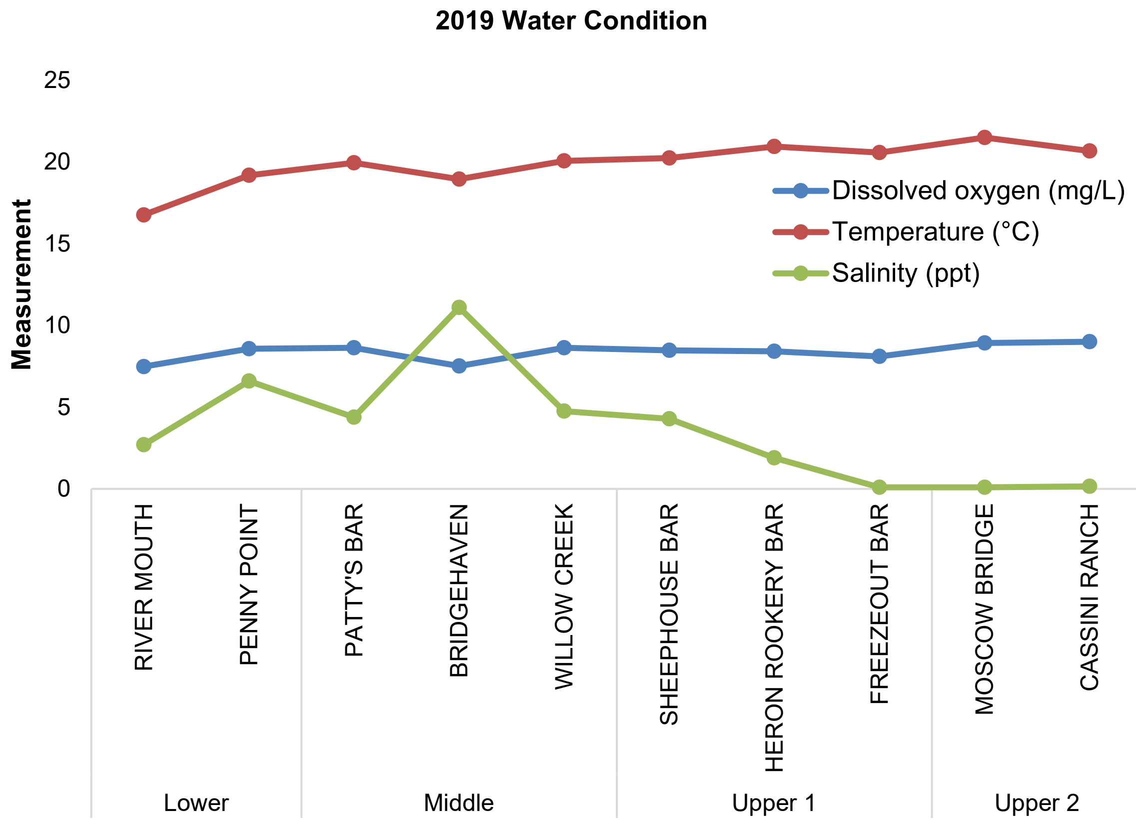


Figure 4.4.3. Generalized water conditions at fish seining stations in the Russian River Estuary, 2019. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May, June, and September during primarily open mouth conditions. Water measurements are salinity in parts per thousand (ppt), dissolved oxygen in milligrams per liter (mg/L), and temperature in Celsius (°C).

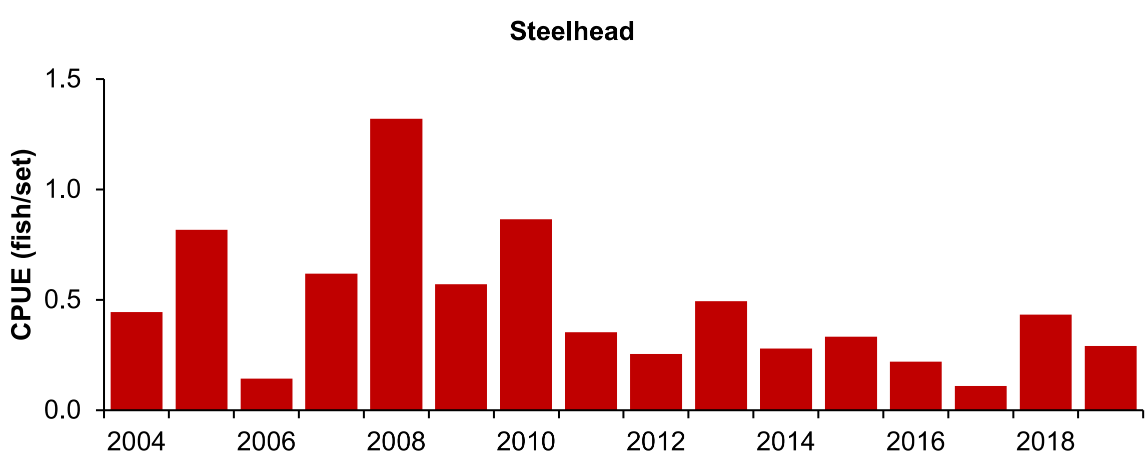


Figure 4.4.4. Annual abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2019. Samples are from 96 to 300 seine sets conducted yearly from May to October.

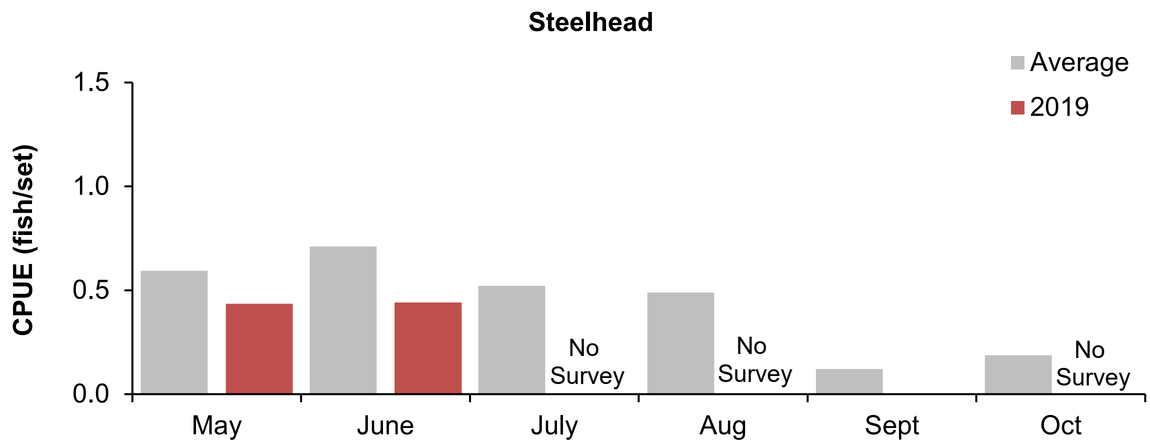


Figure 4.4.5. Seasonal abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2019. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010.

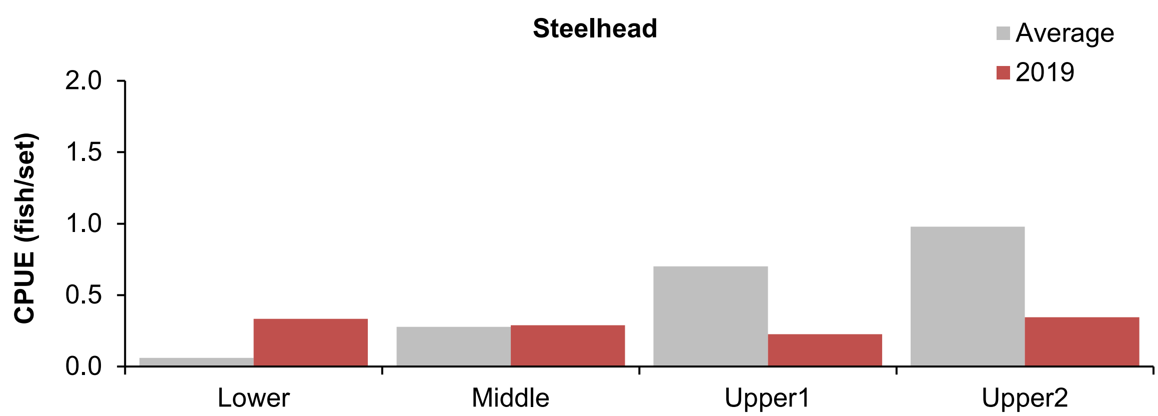


Figure 4.4.6. Distribution of juvenile steelhead in the Russian River Estuary, 2004-2019. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2019 were averaged.

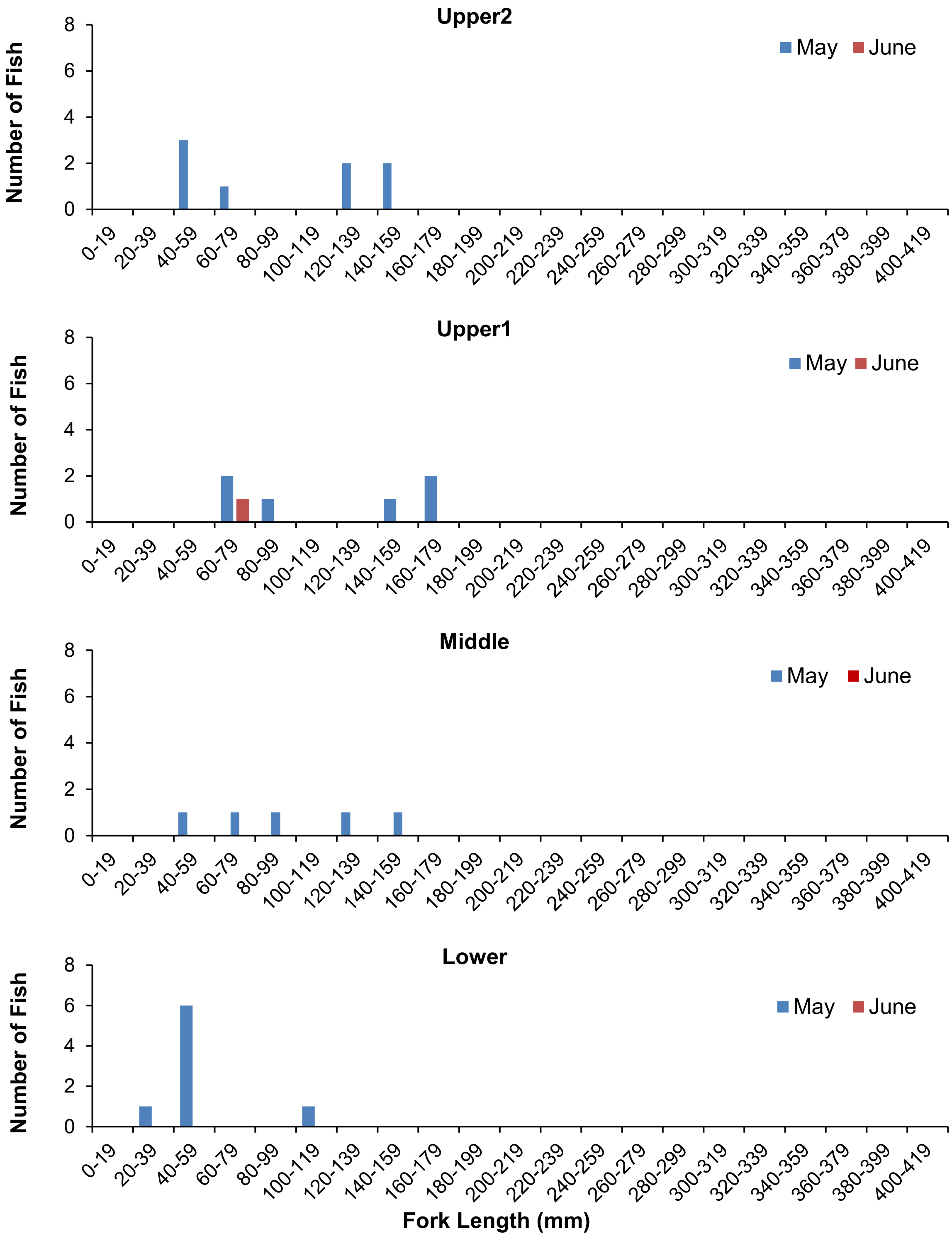


Figure 4.4.7. Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2019. Fish captures are grouped by Estuary reach and month.

Most juvenile steelhead captured in 2019 were age 0+ parr or age 1+ smolts and ranged in size from 40 mm to 180 mm fork length (Figure 4.4.8).

In 2019, 13 juvenile steelhead captured during Estuary seining surveys were implanted with PIT tags. In addition, 411 juvenile steelhead where PIT-tagged during downstream migrant trapping studies in the Russian River and tributaries upstream of the Estuary. There were no PIT-tagged steelhead recaptured in the Estuary during 2019 seining.

Chinook Salmon

A total of 83 Chinook salmon smolts were captured by beach seine in the Estuary during 2019 (Table 4.4.1). The abundance of smolts in the Estuary has varied since studies began in 2004 (Figure 4.4.9). The highest abundance of Chinook salmon smolts was in 2008 at 5.2 fish/set. The lowest abundance of Chinook smolts was in 2016 and 2018 at 0.3 fish/set. In 2019 the CPUE for Chinook was 0.56. Chinook salmon smolts are usually most abundant during May and June (Figure 4.4.10) and rarely encountered after July. Monthly smolt captures in 2019 were highest during May at 2.12 fish/set. Chinook salmon smolts were distributed throughout the Estuary with captures at most sample stations and reaches annually (Figure 4.4.11).

There were 1,086 Chinook smolts PIT-tagged at two (Dry Creek and mainstem Russian River) downstream migrant trap sites 2019. One of these smolts was recaptured in the Lower Reach of the Estuary. This fish was tagged in the Russian River at the Wohler-Mirabel downstream migrant trap near Forestville on May 14 and had a fork length of 91 mm. This smolt was recaptured in the Estuary 14 days later at the Penny Point and had grown 9 mm.

Coho Salmon

There have been relatively few Coho Salmon smolts captured in the Estuary during our beach seining surveys (Figure 4.4.12). The first Coho Salmon smolt captured in the Estuary was a single fish in 2006. In 2011 and 2015 there were marked increases in abundances of Coho smolts with a CPUE of 0.9 and 0.7 fish/set, respectively. During 2019 the total capture of Coho was 30 smolts at a CPUE of 0.20 fish/set. Two smolts were not marked and presumed wild. The remaining smolts were hatchery raised. Nearly all Coho Salmon smolts are captured by June and in 2019 smolts were captured in May and June (Figure 4.4.13). The spatial distribution of Coho smolts has varied annually (Figure 4.4.14). In 2019 Coho were captured in all reaches, with the highest abundance in the Lower Reach.

All Coho raised at the Don Clausen Hatchery are implanted with a coded wire tag and a portion are also implanted with a PIT tag. Six PIT tagged Coho were recaptured at in the Estuary. These fish were captured at the River Mouth on May 28, 2018. The history of these Coho is shown in Table 4.4.2. These fish were initially released in three different tributaries of the Russian River (Mill (tributary to Dry Creek), Dutch Bill, and Willow creeks). Two Coho parr were stocked in tributaries during the fall of 2018, were captured downstream migrant traps in the spring of 2019, and captured as smolts in the Estuary 19-24 days later. Two fish were released by the hatchery as parr during the fall and were not captured in downstream migrant traps. The remaining 2 fish were released by the hatchery in the spring of 2019.

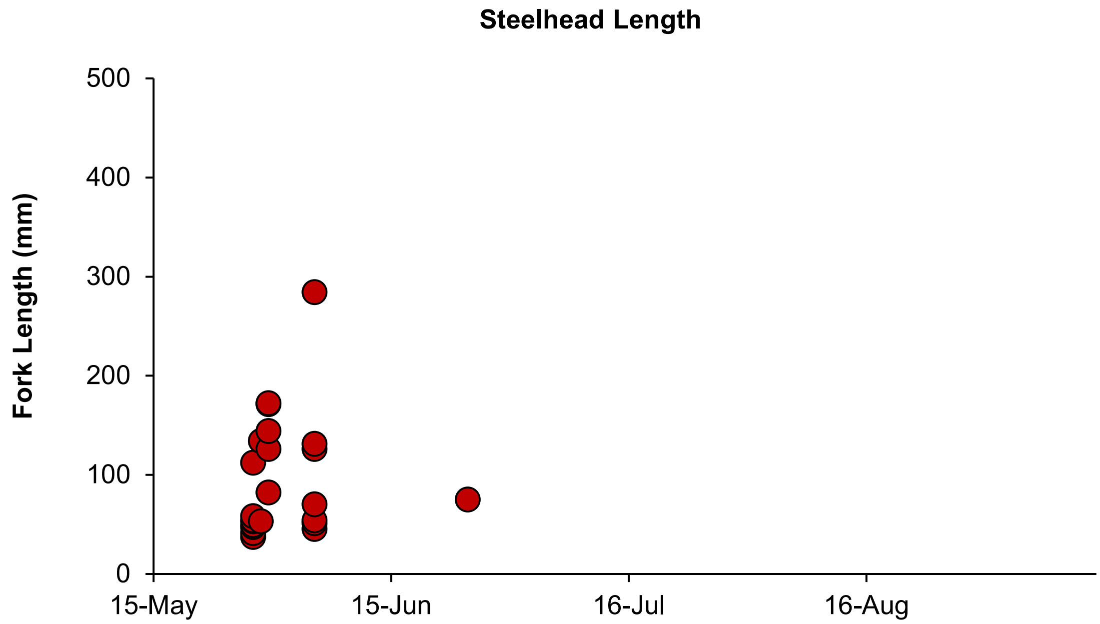


Figure 4.4.8. Juvenile steelhead sizes captured by beach seine in the Russian River Estuary, 2019.

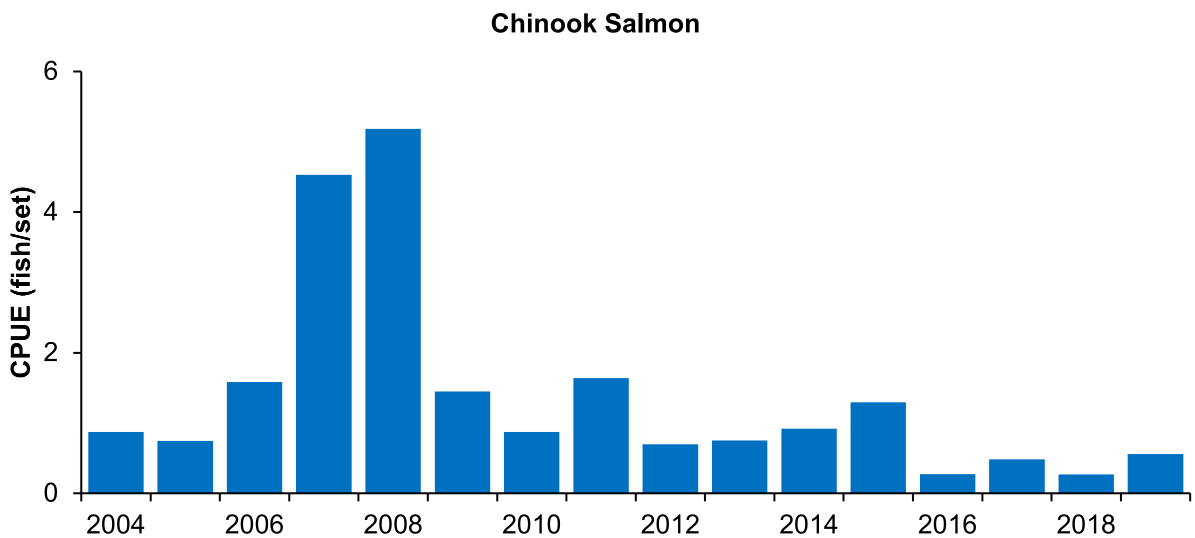


Figure 4.4.9. Annual abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2019. Samples are from 96 to 300 seine sets yearly from May to October.

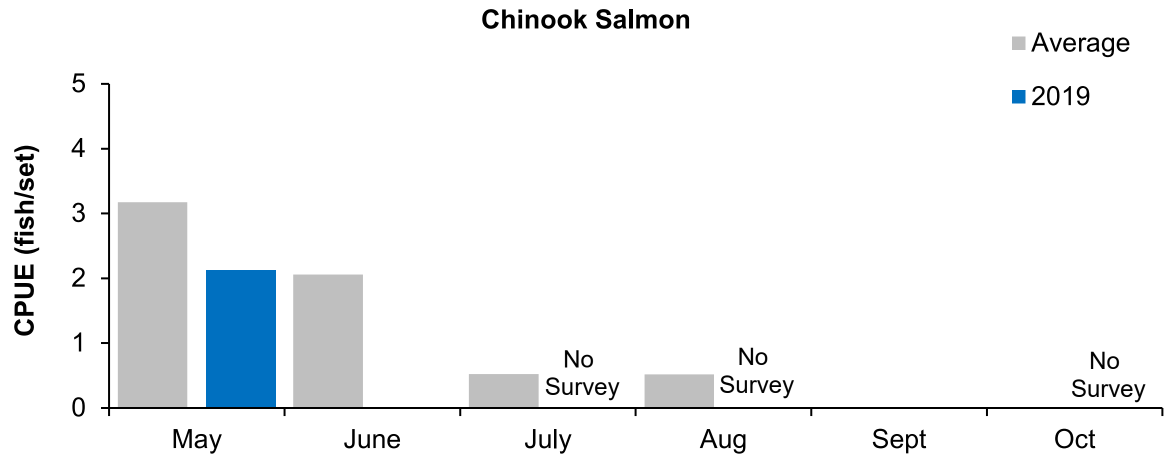


Figure 4.4.10. Seasonal abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2019. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2019 were averaged.

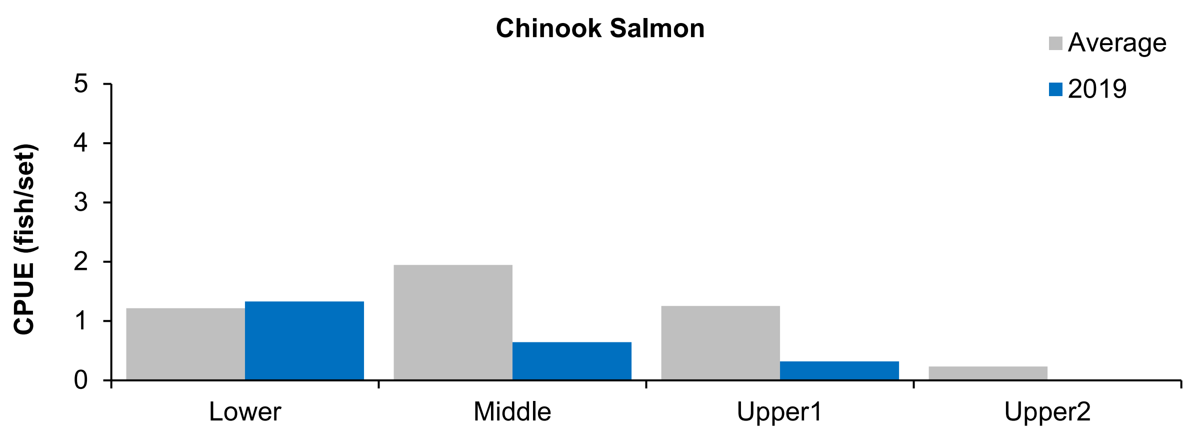


Figure 4.4.11. Spatial distribution of Chinook salmon smolts in the Russian River Estuary, 2004-2019. Fish were sampled by beach seine consisting of 96 to 300 sets annually. Data from 2004 to 2019 were averaged. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

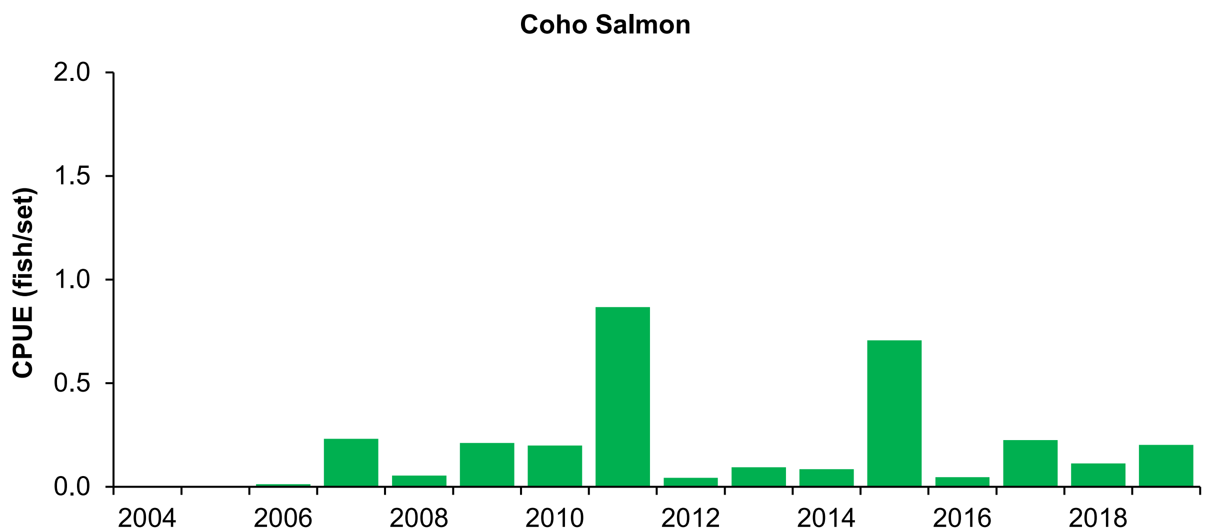


Figure 4.4.12. Annual abundance of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2019. Samples are from 96 to 300 seine sets yearly from May to October.

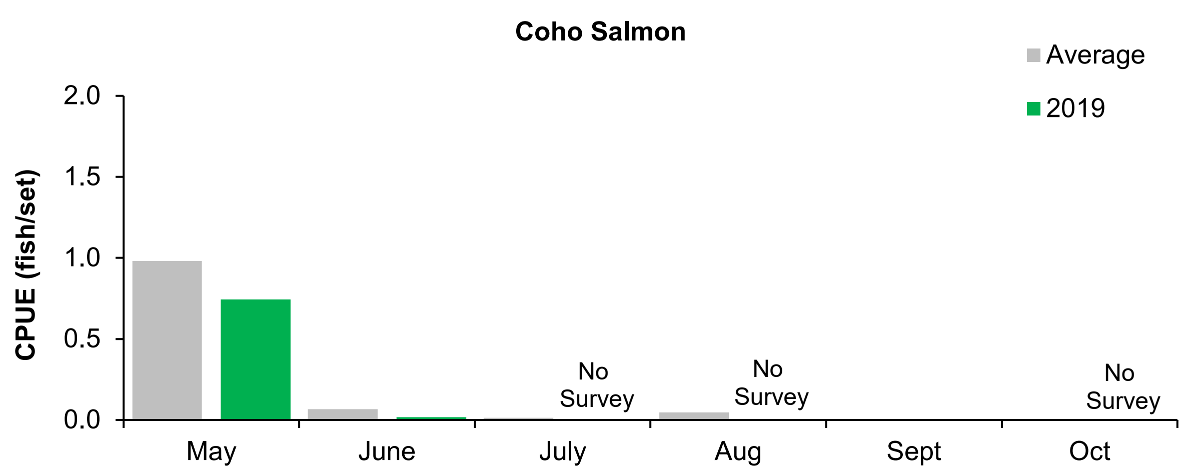


Figure 4.4.13. Seasonal abundance of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2019. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2019 were averaged.

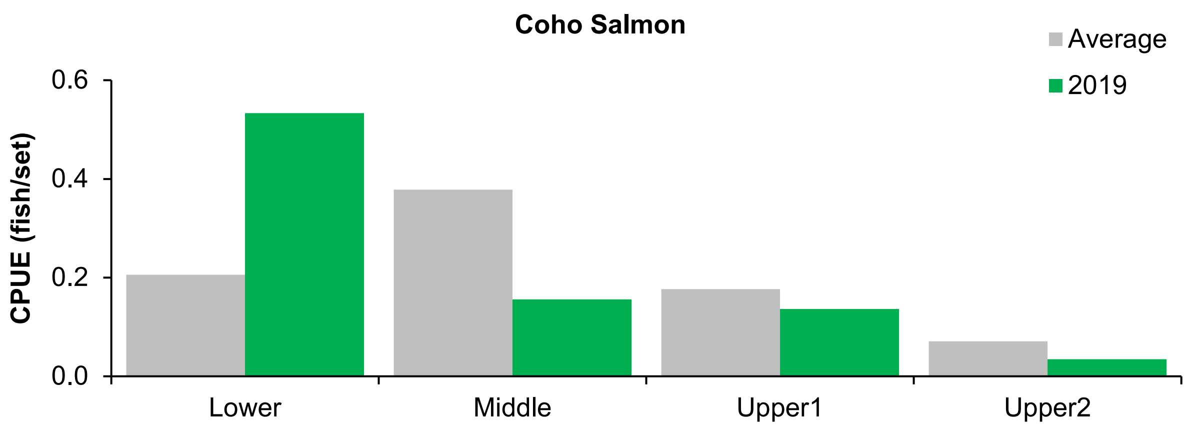


Figure 4.4.14. Spatial distribution of Coho Salmon smolts in the Russian River Estuary, 2004-2019. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2019 were averaged.

Table 4.4.2. Hatchery Coho Salmon detection sites and seasons captured in the Russian River Estuary in 2019. Coho were either stocked in creeks or captured at downstream migrant traps. Fish are from the Coho Salmon broodstock program at Warm Springs Fish Hatchery.

PIT Tag	Release/Capture Site	Date	Fork Length (mm)	Estuary Recapture Location	Recapture Date	Recapture Fork Length (mm)
3dd.003d354244	Willow Creek / Willow Creek DSMT	11/20/18 / 5/11/19	93 / 108	RIVER MOUTH	5/28/2019	123
3dd.003d357c4f	Dutch Bill Creek / Dutch Bill Creek DSMT	12/5/18 / 5/4/19	100 / 116	RIVER MOUTH	5/28/2019	137
3dd.003d3587d8	Redwood Creek (Atascadero)	12/7/18	98	RIVER MOUTH	5/28/2019	130
3dd.003d359a11	Green Valley Creek	3/7/19	95	RIVER MOUTH	5/28/2019	149
3dd.003d35670e	Dry Creek	4/23/19	120	RIVER MOUTH	5/28/2019	144
3dd.003d3549cb	Sheep House	11/28/19	96	RIVER MOUTH	5/28/2019	138

American Shad

American shad is an anadromous sportfish, native to the Atlantic coast. It was introduced to the Sacramento River in 1871 and within two decades was abundant locally and had established populations from Alaska to Mexico (Moyle 2002). Adults spend from 3 to 5 years in the ocean before migrating upstream to spawn in the main channels of rivers. Juveniles spend the first year or two rearing in rivers or estuaries. The abundance of American shad in the Estuary during 2019 was low at 1.51 fish/set (Figure 4.4.15). This low abundance may have been influenced by the reduced seining effort in 2019 where no surveys were conducted during July and August. Typically, juvenile American shad first appear in relatively large numbers in July and the catch usually peaks in August. Shad are typically distributed throughout the Estuary, although in 2019 they were found mostly in the upper two reaches (Figure 4.4.16).

Topsmelt

Topsmelt are one of the most abundant fish in California estuaries (Baxter et al. 1999) and can tolerate a broad range of salinities and temperatures but are seldom found in freshwater (Moyle 2002). They form schools and are often found near the water surface in shallow water. Sexual maturity is reached in 1 to 3 years and individuals can live as long as 7 to 8 years. Estuaries are used as nursery and spawning grounds and adults spawn in late spring to summer.

Topsmelt is a common fish in the Russian River Estuary. However, the abundance of topsmelt in the Estuary has varied substantially since 2004. There were peaks in abundance in 2006 and 2014 with a CPUE up to 17.9 and abundances below 0.3 fish/set in 2016 and 2017. (Figure 4.4.17). Also, the abundance of topsmelt in 2015 and 2016 may be an underestimate because no seining was conducted in July and August when the catch of topsmelt usually peaks. Topsmelt abundance in 2019 was above average at 7.7 fish/set. Topsmelt are mainly distributed in the Lower and Middle Reaches in the Estuary (Figure 4.4.18).

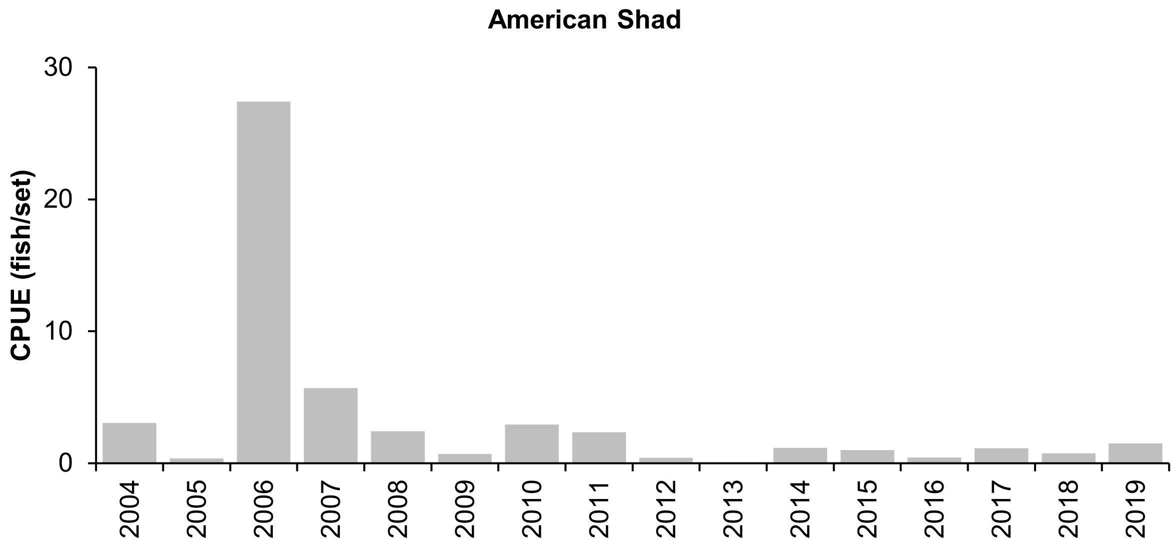


Figure 4.4.15. Annual abundance of juvenile American shad captured by beach seine in the Russian River Estuary, 2004-2019. Samples are from 96 to 300 seine sets yearly from May to October.

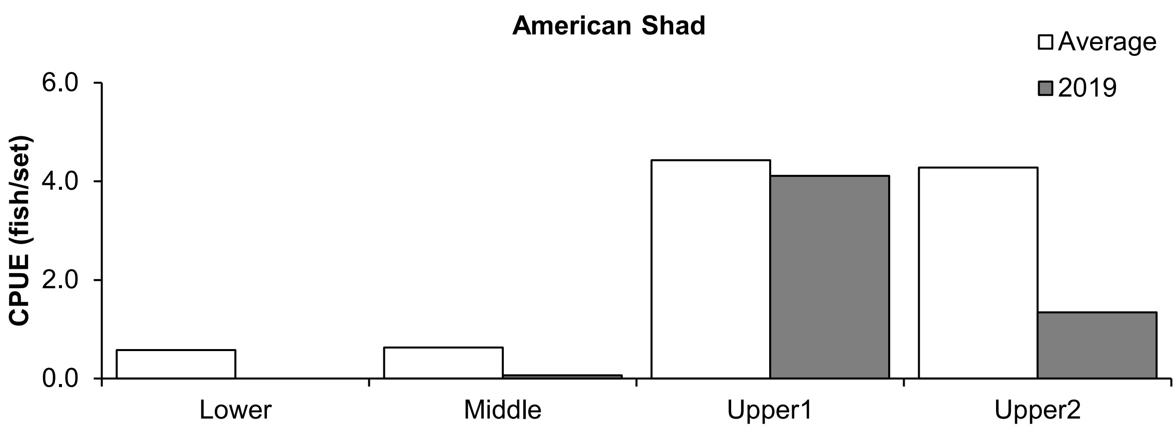


Figure 4.4.16. Spatial distribution of juvenile American shad in the Russian River Estuary, 2004-2019. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2019 were averaged.

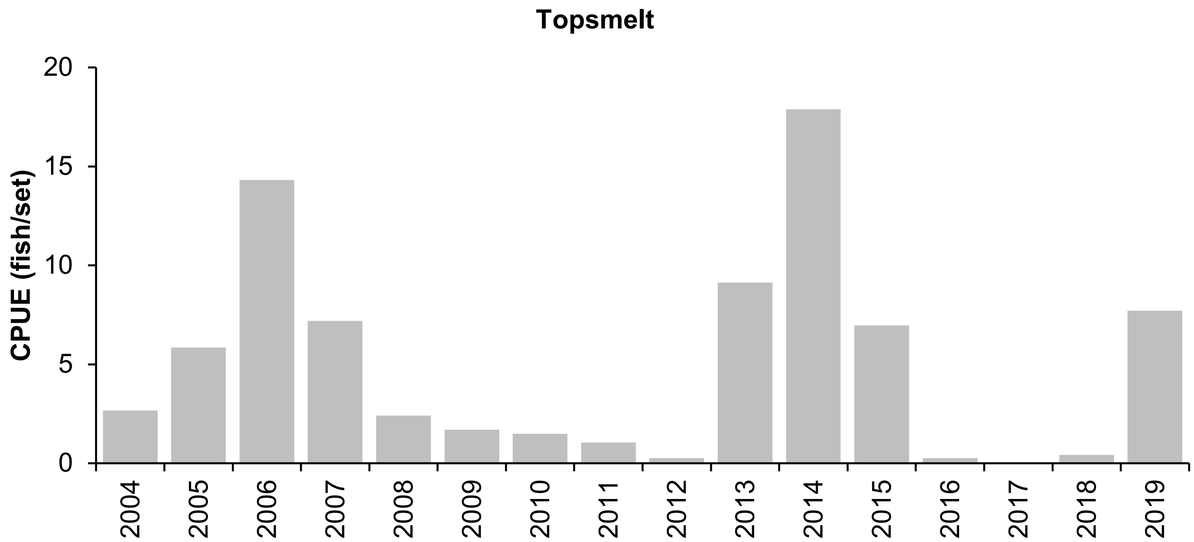


Figure 4.4.17. Annual abundance of topsmelt captured by beach seine in the Russian River Estuary, 2004- 2019. Samples are from 96 to 300 seine sets yearly from May to October.

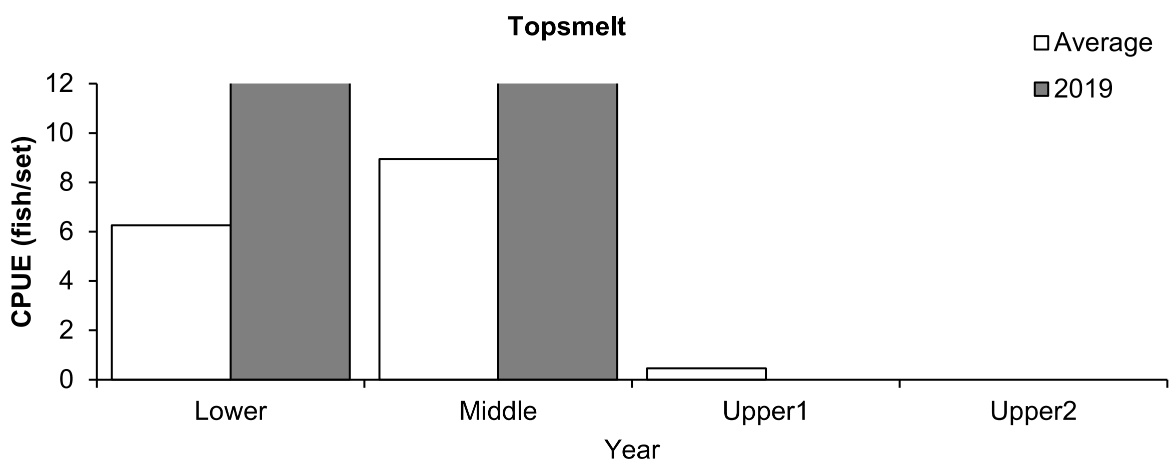


Figure 4.4.38. Spatial distribution of topsmelt in the Russian River Estuary, 2004-2019. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2019 were averaged.

Conclusions and Recommendations

Fish Sampling - Beach Seining

The results of Estuary fish surveys from 2004 to 2019 found over 50 fish species from marine, estuarine, and riverine origins. The distribution of species was strongly influenced by the salinity gradient in the Estuary that is typically cool seawater near the mouth of the Russian River and transitions to warmer freshwater at the upstream end. Exceptions to this distribution pattern were anadromous and generalist fish that occurred throughout the Estuary regardless of salinity levels. The 2019 fish studies contribute to the 16-year dataset of existing conditions and our knowledge of a tidal brackish system. This baseline data will be used to compare with a closed mouth lagoon system.

All three salmonid species in the Russian River watershed were detected in the Russian River Estuary at the parr and/or smolt life stages. The fluctuation in abundance of steelhead annually is likely attributed to the variability of adult spawner population size (i.e. cohort abundance), residence time of young steelhead before out-migration, and schooling behavior that affects susceptibility to capture by seining. In addition, a prolonged and severe drought that began in 2013 likely contributed to the low abundance of steelhead in the Russian River Estuary in 2019. It is worth noting that steelhead abundance was low in 2019 at the Mainstem Russian River (Mirabel), Mark West Creek, Dutch Bill Creek, and Austin Creek downstream migrant traps. It is likely that the majority of steelhead captured in the Estuary pass these downstream migrant traps on the way to the estuary. Low abundance at these trap sites suggest that fewer steelhead young-of-the-year entered the Estuary when compared to some years in the past.

Although beach seining is widely used in estuarine fish studies, beach seines are only effective near shore in relatively open water habitats free of large debris and obstructions that can foul or snag the net. Consequently, there is inherent bias in seine surveys (Steele et al. 2006). By design, our seining stations were located in areas with few underwater obstructions (i.e., large rocks, woody debris, etc.) and this likely influenced our assessment of fish abundance and habitat use. However, the spatial and temporal aspects of our sampling do allow quantitative comparisons among reaches and years.

4.5 Downstream Migrant Trapping

The Reasonable and Prudent Alternative (RPA) in the Russian River Biological Opinion requires Sonoma Water to provide information about the timing of downstream movements of juvenile steelhead into the Russian River Estuary, their relative abundance and the size/age structure of the population as related to the implementation of an adaptive management approach to promote formation of a perched freshwater lagoon. The sampling design implemented by Sonoma Water and described in this section specifically targets the detection and capture of anadromous salmonid young-of-the-year (YOY, age-0) and parr (≥age-1) (collectively referred to as juveniles) as well as smolts. In order to help accomplish the objectives listed above, Sonoma Water undertook fish capture and PIT-tagging activities at selected trapping sites upstream of the estuary (Figure 4.5.1):

- Mainstem Russian River at Mirabel
- Mark West Creek
- Dutch Bill Creek
- Austin Creek
- Dry Creek (capture only, included for broader sampling context)

Stationary PIT antenna arrays were operated in the following locations:

- Upstream end of the Russian River estuary in Duncans Mills (river km 10.46)
- Near the mouth of Austin Creek (river km 0.5)

Implementation of the monitoring activities described here are the result of a continually-evolving process of evaluating and improving on past monitoring approaches. Descriptions and data from other monitoring activities conducted in the estuary (e.g., water quality monitoring, beach seining) as well as fish trapping operations in Dry Creek and the Mirabel downstream migrant traps on the mainstem Russian are presented Russian River Biological Opinion Status and Data Report Year 2019-2020.

Methods

In 2019 Sonoma Water again relied on downstream migrant traps and stationary PIT antenna arrays at lower-basin trap sites to address the objectives in the RPA. Similar to 2010 through 2018, fish were physically captured at downstream migrant traps (rotary screw trap, funnel trap or pipe trap depending on the site), sampled for biological data and released. PIT tags were applied to a subset of age-0 steelhead captured at trap sites and fish were subject to detection at downstream PIT antenna arrays if they moved downstream into the estuary. The following sections describe the sampling methods and analyses conducted for data collected at each site.

Estuary/Lagoon PIT antenna systems

Typically, two antenna arrays with multiple flat plate antennas (antennas designed to lay flat on the stream bottom) are installed in the upper Russian River estuary near the town of Duncans Mills (river km 10.44, 10.46) to detect PIT-tagged fish entering the estuary (Figure 4.5.2). Generally, 12 antennas were operated continuously throughout the year. The orientation of the antennas consisted of 2 rows of antennas with one row slightly upstream of the other. Each row contained 6 antennas placed side by starting at the West river bank and extending out into the channel. Due to high winter flows the PIT antenna array was not operational until after the downstream migrant trapping season had concluded. The PIT antennas were reinstalled on September 20, 2019.

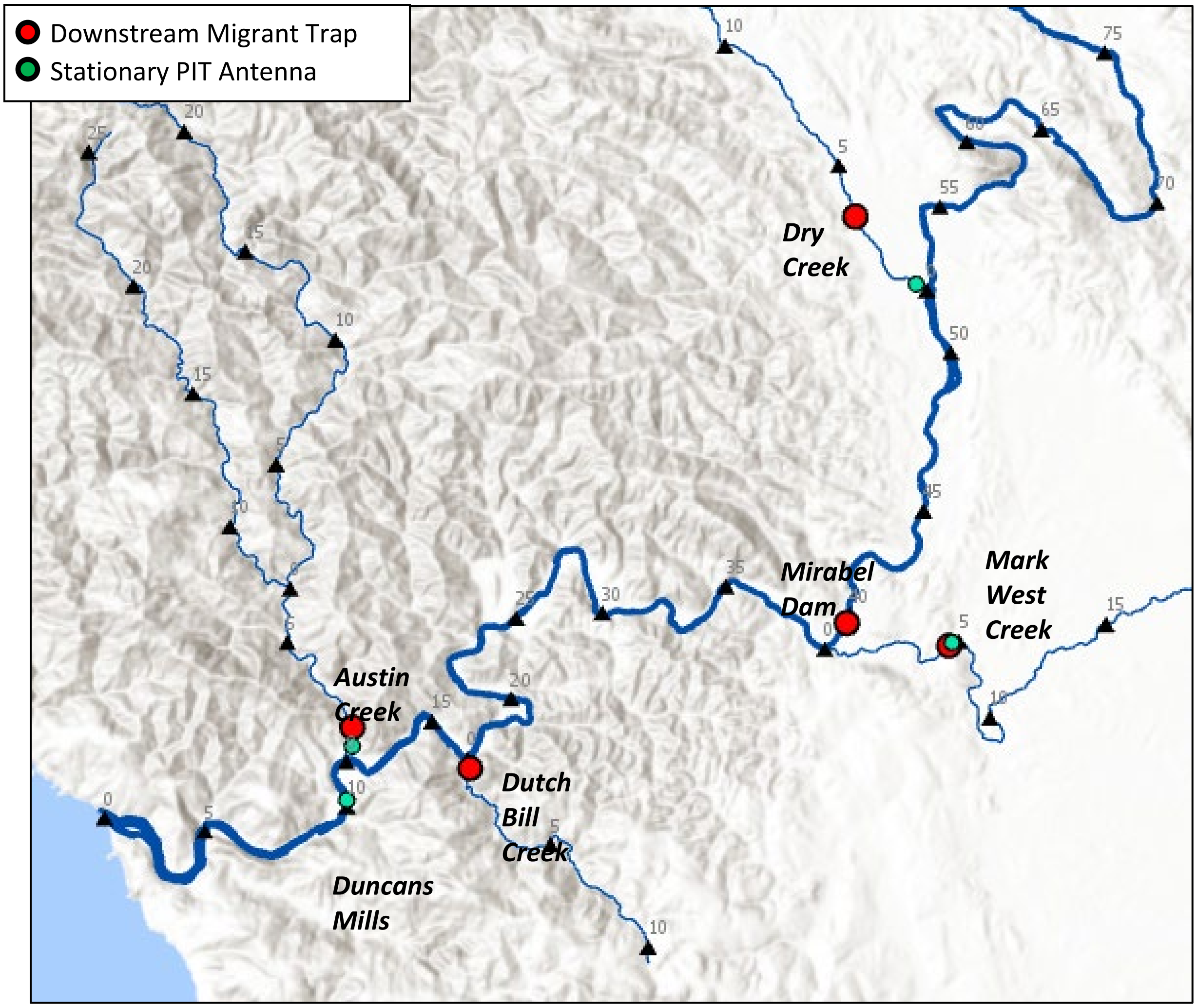


Figure 4.5.1. Map of downstream migrant detection sites in the lower Russian River, 2019. Numbered symbols along stream courses represent distance (km) from the mouth of each stream.

Figure 4.5.2. Flat plate antenna arrays at Duncans Mills (river km 10.44 and 10.46). Rectangles represent individual flat plate antennas.

Lower Russian River Fish Trapping and PIT tagging

Following consultation with NMFS and CDFW, Sonoma Water identified three lower Russian River tributaries (Mark West Creek, Dutch Bill Creek and Austin Creek, Figure 4.5.1) in which to operate fish traps as a way to supplement data collected from the Duncans Mills PIT antenna array and during sampling by beach seining throughout the estuary (Figure 4.5.1). Downstream migrant traps are also operated at the Mirabel inflatable dam. Sonoma Water operated three types of downstream migrant traps in 2019: rotary screw trap, funnel trap and pipe trap depending on the stream, water depth, and velocity (Figure 4.5.3). Fish traps were checked daily by Sonoma Water staff during the trapping season (March through July). Captured fish were enumerated and identified to species and life stage at all traps. All PIT-tagged fish were measured for fork length (±1 mm) and weighed (±0.1 g). Additionally, a subset of all non-PIT-tagged individuals were measured and weighed each day. PIT tags were implanted in a portion of the total number of steelhead YOY and parr captured that were ≥60 mm in fork length.

Mainstem Russian River at Mirabel and Dry Creek at Westside Road

Typically, two rotary screw traps (one 5 foot and one 8 foot) adjacent to one another are operated on the mainstem Russian River immediately downstream of Sonoma Water's inflatable dam site at Mirabel (approximately 38.7 km upstream of the river mouth in Jenner) (Table 4.5.1). Sonoma Water also operates a rotary screw trap at Dry Creek. The purpose of these trapping efforts was to fulfill a broader set of objectives in the Russian River Biological Opinion than what is described in the current section of this report.

Mark West Creek

A five-foot rotary screw trap was installed on Mark West Creek approximately 4.8 km upstream of the mouth on April 26. On June 6 the rotary screw trap was removed and replaced with a pipe trap because of low water velocities. The pipe trap was removed and all trapping operations were suspended on July 7 when fish captures dropped off rapidly (Table 4.5.1).

Dutch Bill Creek

A pipe trap was installed on Dutch Bill Creek adjacent to the park in downtown Monte Rio (approximately 0.3 km upstream of the creek mouth) on April 8. The funnel net was removed and replaced with a pipe trap on June 11 because of low water velocity. The pipe trap was fished until the completion of trapping operations on July 3 when stream flow in lower Dutch Bill Creek became disconnected (Table 4.5.1).

Austin Creek

A rotary screw trap was installed in Austin Creek on April 16. Due to low water velocity this trap was changed to a funnel trap June 5. The funnel trap consisted of wood-frame/plastic-mesh weir panels, a funnel net and a wooden live box. Trapping continued until July 3 when surface flow in lower Austin Creek was no longer contiguous and daily catches of steelhead dropped to zero (Table 4.5.1).

Mark West Creek: Rotary screw trap (fished 4/25-66) switched to pipe trap (fished 6/7-7/3).

Dutch Bill Creek: Funnel net (4/8-6/11) switched to a pipe trap (fished 6/12-7/3).

Austin Creek: Rotary screw trap (fished 4/16-6/5) switched to a funnel trap (fished 6/5-7/3).

Figure 4.5.3. Photographs of downstream migrant traps operated by Sonoma Water (Mark West, Dutch Bill, and Austin Creeks). See the Russian River Biological Opinion Status and Data Report year 2019-2020 for details regarding operation of the Mirabel and Dry Creek traps.

Steelhead parr were marked with PIT tags and released upstream of the trap in order to measure trap efficiency and estimate population size of fish passing the trap site. Sonoma Water operated a dual PIT antenna array approximately 0.2 km downstream of the funnel trap and approximately 0.5 km upstream from the mouth of Austin Creek in order to detect PIT-tagged steelhead moving out of Austin Creek. The PIT antenna array was located at the upstream extent of the area that can be inundated by the Russian River during closure of the barrier beach; therefore, it is likely that once fish passed the antenna array, they had effectively entered the estuary/lagoon (Figure 4.5.4). A second PIT tag antenna array located in the Russian River estuary at Duncans Mills (approximately 1.5 km downstream) is typically used to calculate antenna efficiency for the PIT antenna array located in Austin Creek. However, the Duncans Mills PIT antenna array was not operational for much of the downstream migrant trapping season due to damage from high river flows which occurred over the winter.

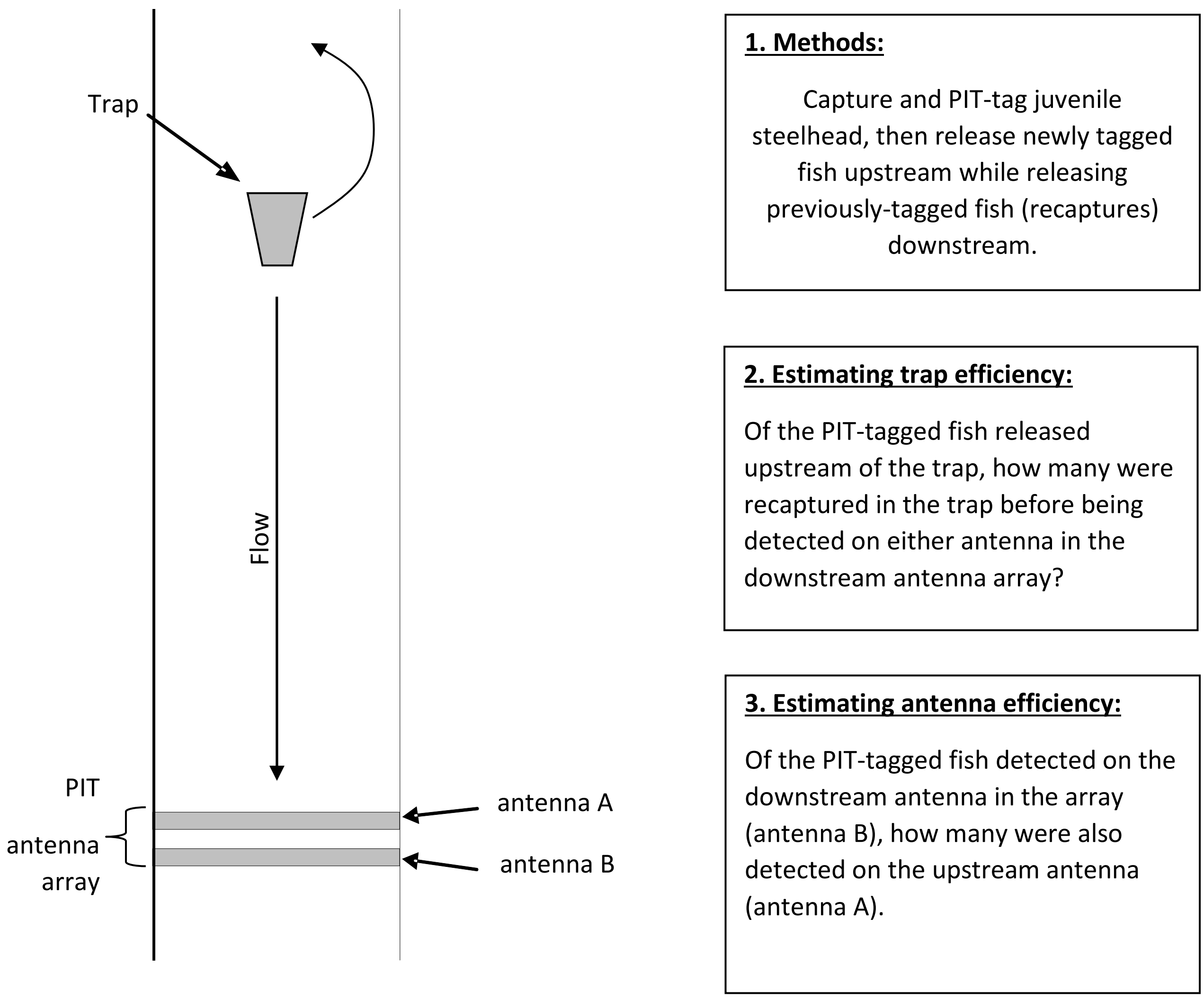


Figure 4.5.4. Diagram illustrating the relative location of the downstream migrant trap and PIT antenna array operated on Austin Creek and outline of how antenna efficiency was estimated.

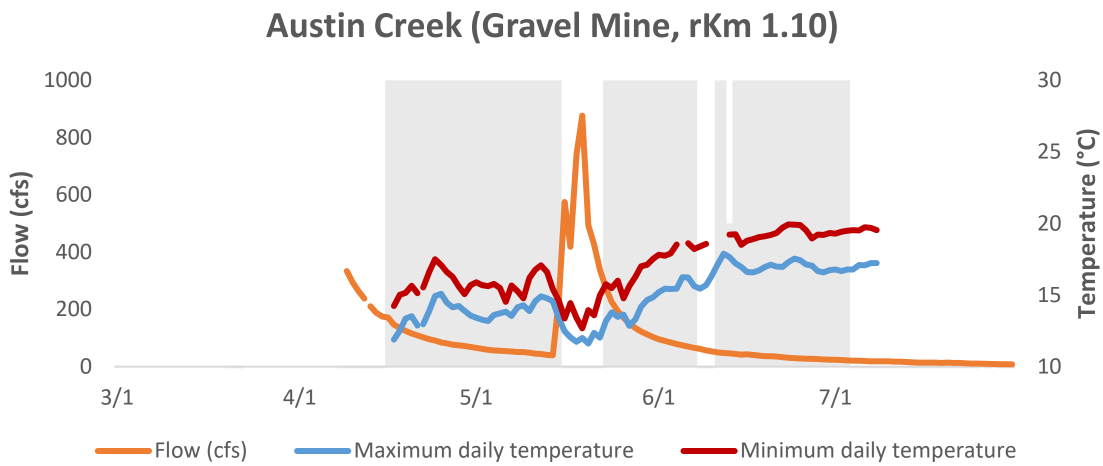
Table 4.5.1. Installation and removal dates, and total number of days fished for lower Russian River monitoring sites operated by Sonoma Water in 2019.

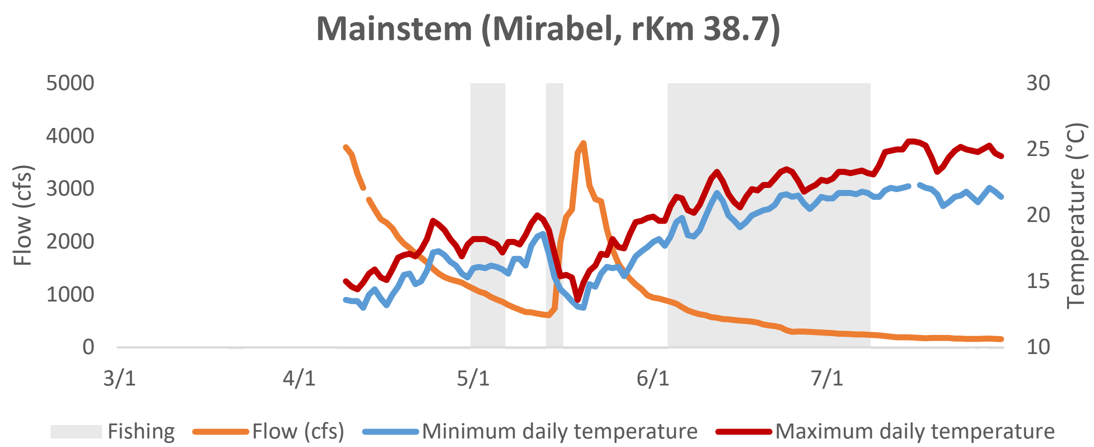
Monitoring site (gear type)	Installation date	Removal date	Number of days fished
Dry Creek (DSMT)	5/1	7/31	79
Mirabel (DSMT)	5/1	7/8	43
Mark West Creek (DSMT)	4/26	7/3	55
Dutch Bill Creek (DSMT)	4/8	7/3	77
Austin Creek (DSMT)	4/16	7/3	67
Duncans Mills (PIT antenna array)[1]	-	-	Not operational during 2019 DSMT season

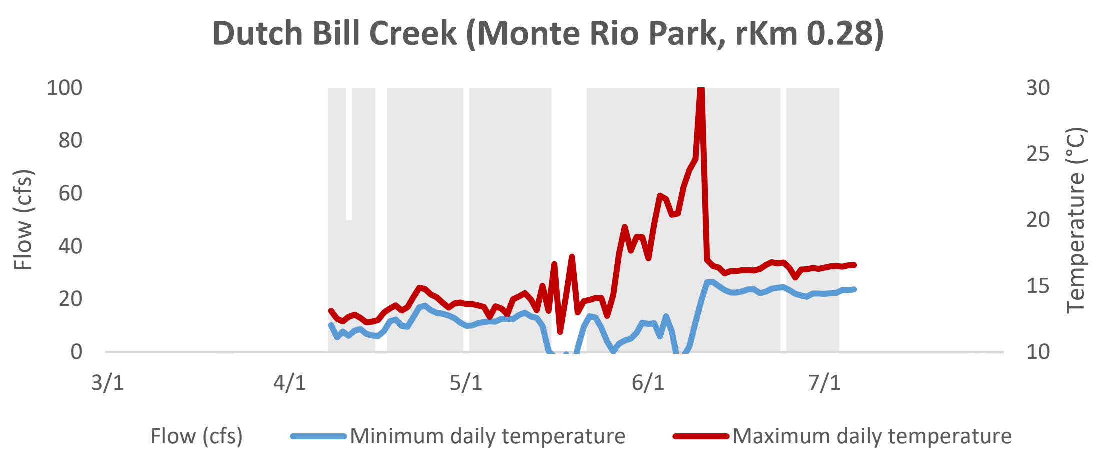
[1]See text for details on changes to PIT antenna array throughout the season.

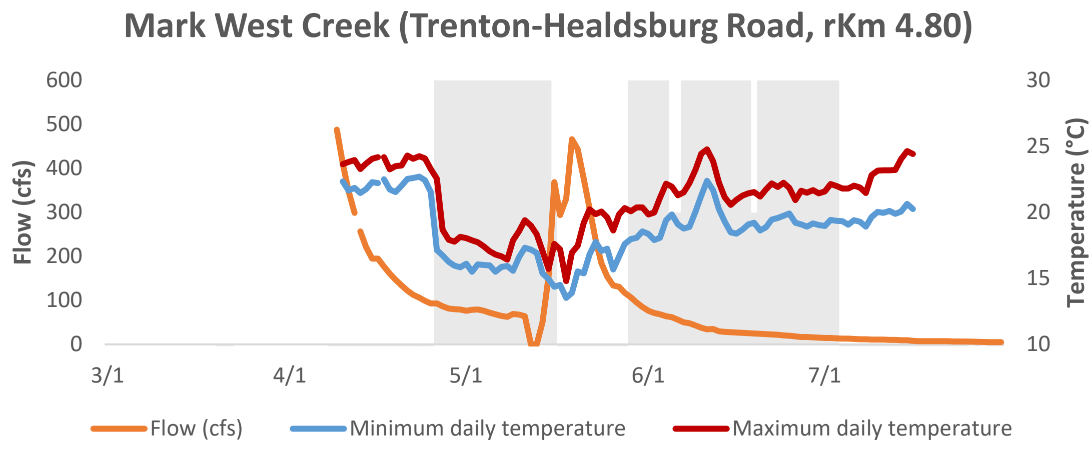
Results

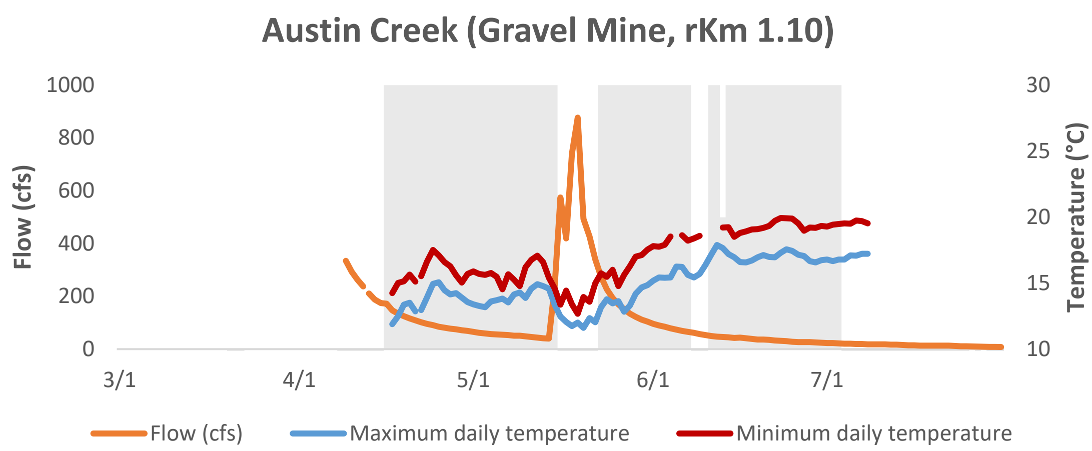
Stream flow largely dictates when downstream migrant traps can be installed (Figure 4.5.5). The sampling period most likely encompassed a high portion of the juvenile steelhead movement period but a substantial portion of the steelhead smolt migration period was likely missed due to the early run timing of steelhead smolts.


Austin Creek (Gravel Mine, rKm 1.10)
1000
800
600
400
200
0
Flow (cfs)
30
25
20
15
10
Temperature (°C)
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Maximum daily temperature
Minimum daily temperature


Mainstem (Mirabel, rKm 38.7)
5000
4000
3000
2000
1000
0
Flow (cfs)
30
25
20
15
10
Temperature (°C)
3/1
4/1
5/1
6/1
7/1
Fishing
Flow (cfs)
Minimum daily temperature
Maximum daily temperature


Dutch Bill Creek (Monte Rio Park, rKm 0.28)
100
80
60
40
20
0
Flow (cfs)
30
25
20
15
10
Temperature (°C)
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Minimum daily temperature
Maximum daily temperature





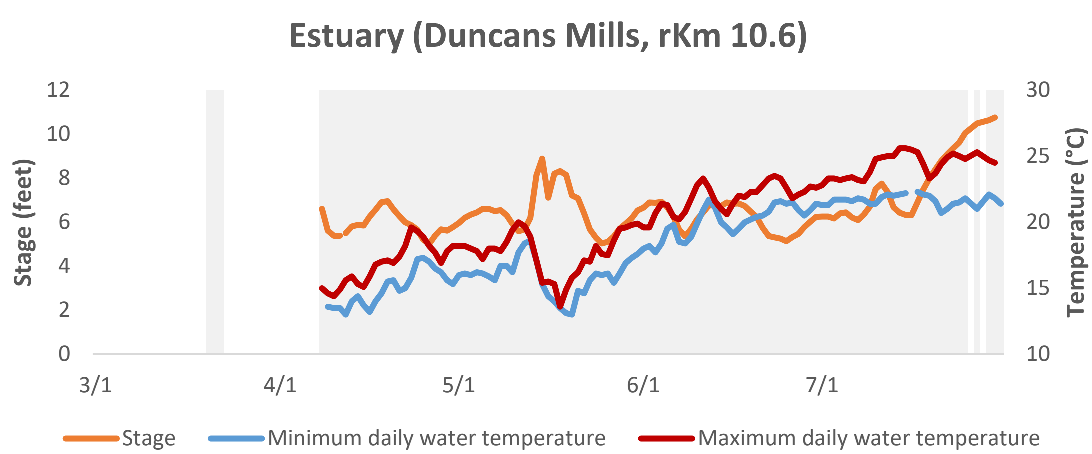
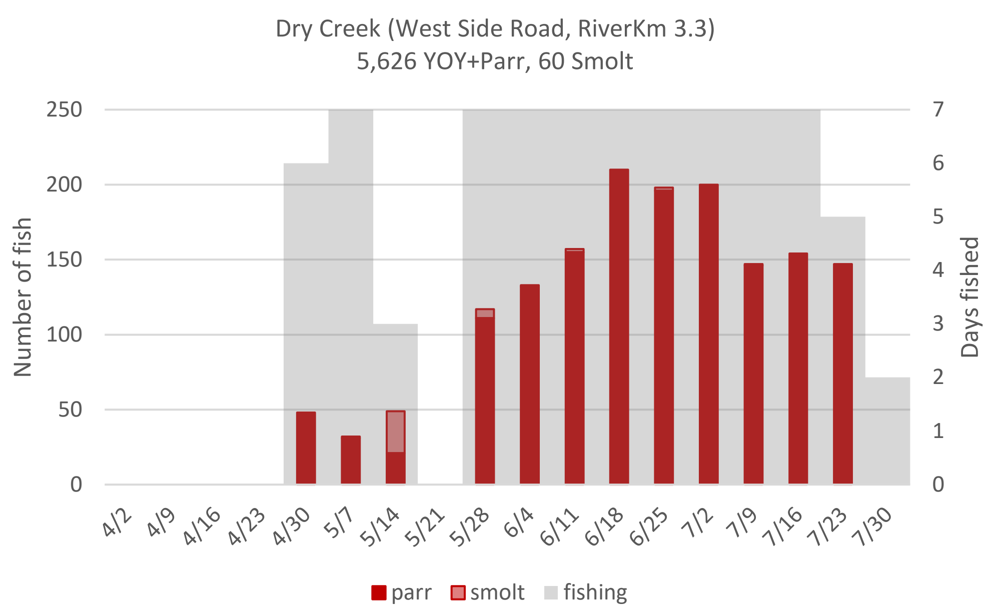


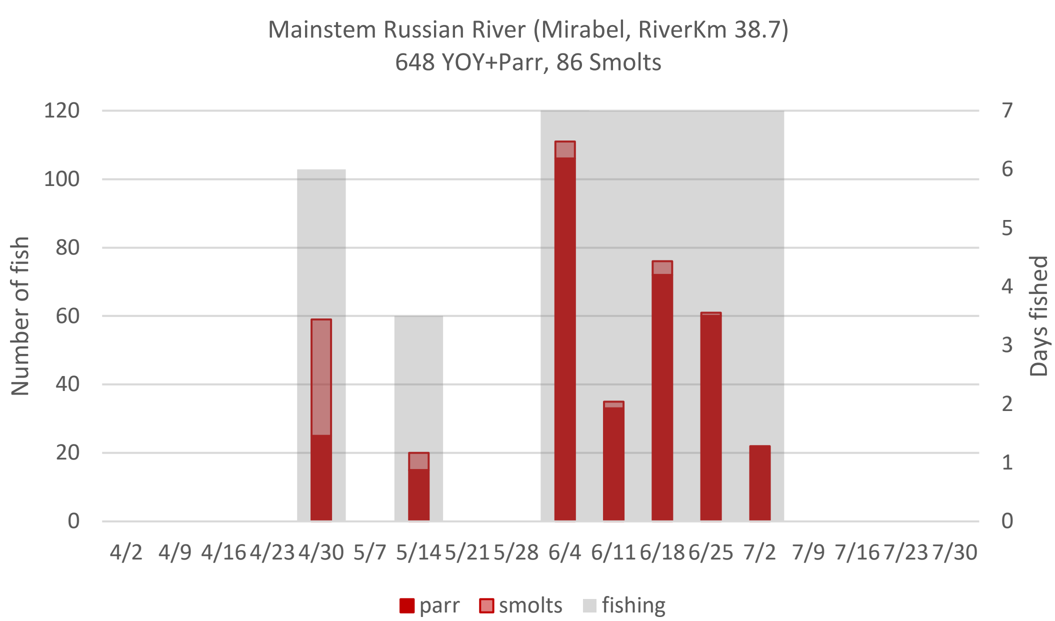
Figure 4.5.5. Environmental conditions at downstream migrant detection sites from March 1 to July 31. Gray shading indicates the proportion of each day that each facility was operated. Discharge data are from the USGS gage at Healdsburg (mainstem Russian, 11464000), the USGS gage at Trenton-Healdsburg Road (Mark West Creek, 11466800), a gage operated by CMAR on Dutch Bill Creek (data unavailable in 2019) and the USGS gauge at Cazadero (Austin Creek, 11467200). Stage (max daily) data for the estuary are from the USGS gage near Highway 1 (11467270). Temperature data are from the data loggers operated by Sonoma Water at each monitoring site.

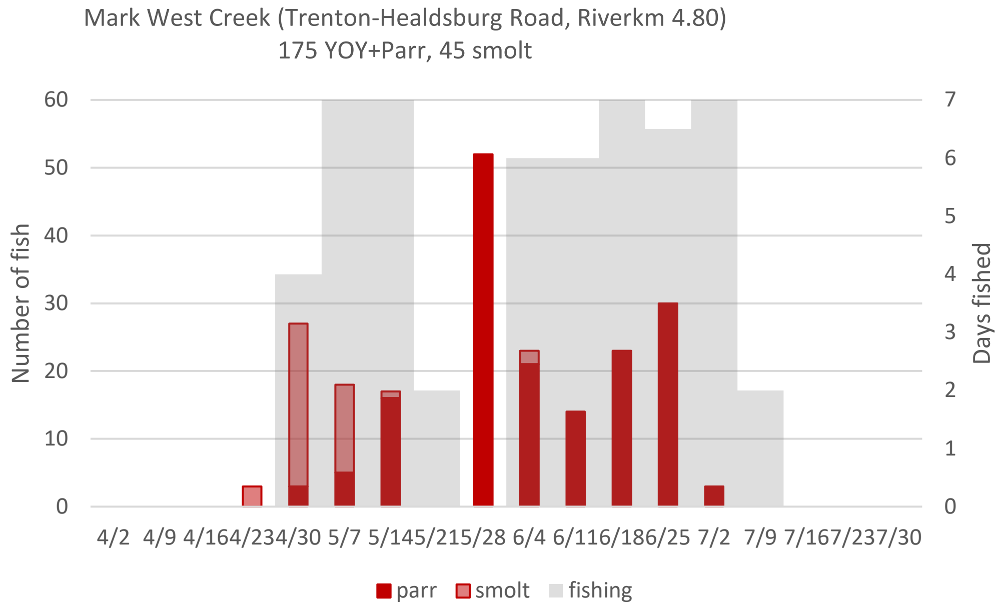
Estuary/Lagoon PIT antenna systems

Steelhead

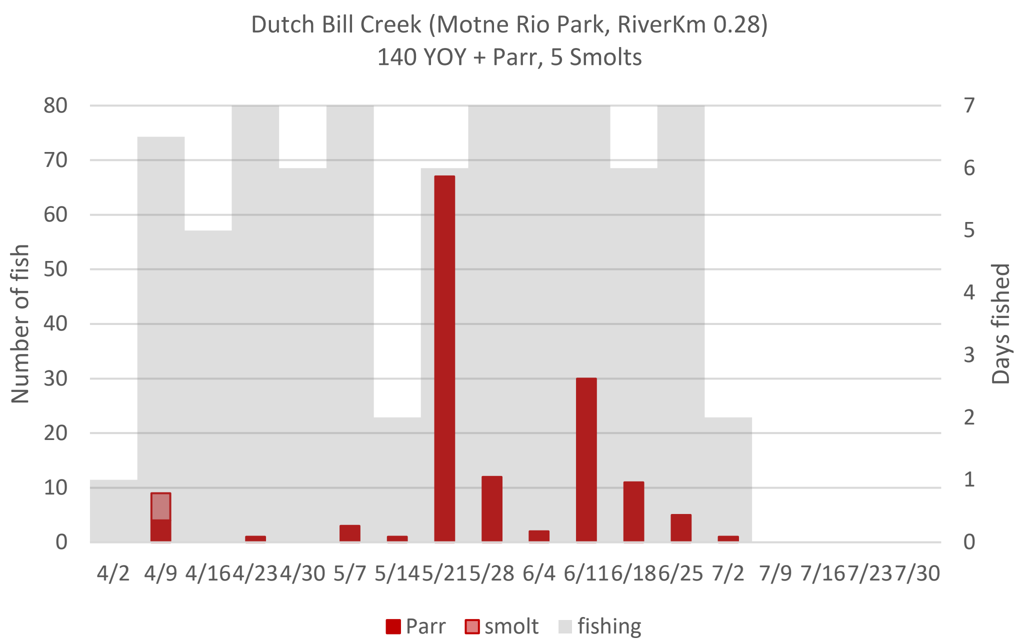
Steelhead were most frequently encountered at Dry Creek than any other trap. In total 5,608 YOY and parr, and 60 smolts were captured at the Dry Creek trap. In Austin Creek 397 YOY and parr and 6 smolts were captured. At Dutch Bill Creek 139 YOY and parr and 5 smolt steelhead were captured. At Mark West Creek 175 YOY and parr, and 44 smolts were captured. At the Mainstem Russian River trap 644 YOY and parr and 81 smolts were captured (Figure 4.5.6).







Mark West Creek (Trenton-Healdsburg Road, Riverkm 4.80)
175 YOY+Parr, 45 smolt
Number of fish
Days fished
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
parr
smolt
fishing



Dutch Bill Creek (Motne Rio Park, RiverKm 0.28)
140 YOY + Parr, 5 Smolts
Number of fish
Days fished
0
10
20
30
40
50
60
70
80
0
1
2
3
4
5
6
7
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
Parr
smolt
fishing

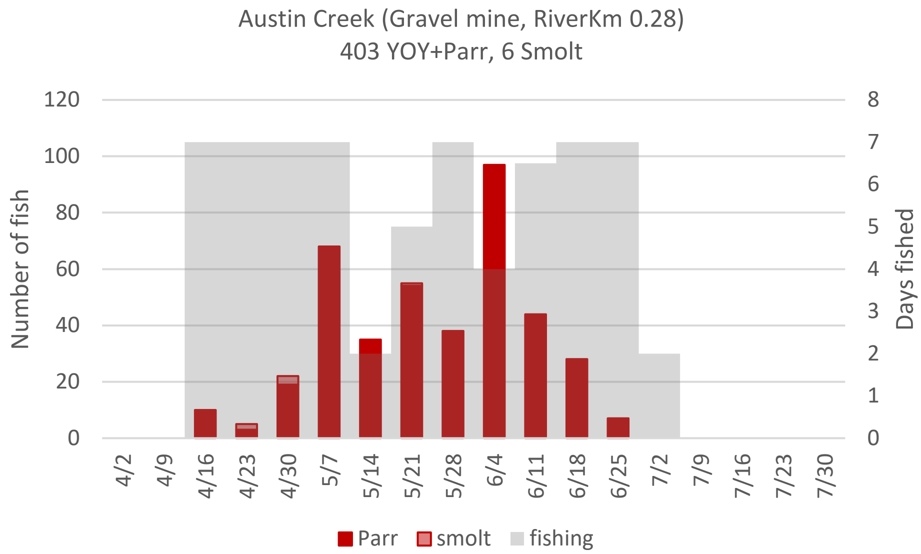


Figure 4.5.6. Weekly capture of steelhead by life stage at lower Russian River downstream migrant trapping sites, 2019. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.

In 2019 Sonoma Water had to rely on the Austin Creek PIT tag antenna for estimating the number of steelhead YOY and parr that entered the estuary because the Duncans Mills antenna at the head of the estuary was not operational. Of the 172 juvenile steelhead that were PIT-tagged in the Austin Creek downstream migrant trap, 78 (45.3%) were detected on the PIT antenna array at Austin Creek (Table 4.5.2 and Table 4.5.3). Reasons for non-detection include an unknown number of fish that simply did not move into the estuary as well as fish that moved into the tidal portion of the estuary but were not detected due to imperfect PIT antenna array detection efficiency at Austin Creek.

Table 4.5.2. Number of steelhead juveniles PIT-tagged at downstream migrant traps, 2009-2019 (N.T. indicates that tagging steelhead was not part of the protocol for that year, a dash indicates the trap was not operated).

Site	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Dry Creek	N.T.	N.T.	N.T.	N.T.	2,703	1,348	N.T.	N.T.	N.T.	N.T.	N.T.
Mainstem	5	96	99	315	100	101	-	-	1	63	40
Mark West Creek	-	-	-	43	135	18	19	546	49	62	125
Dutch Bill Creek	-	46	22	6	12	21	7	46	377	12	74
Austin Creek	-	996	500	1,636	1,749	590	107	1,205	359	780	172
Total	**5**	**1,138**	**621**	**2,000**	**4,699**	**2,078**	**133**	**1,797**	**791**	**917**	**411**

Table 4.5.3. The number of steelhead captured at downstream migrant traps, the number PIT tagged and the number detected on the Duncans Mills PIT tag detection systems before October 15, 2019.

Site	Number Captured	Number PIT-Tagged	Number (proportion) Detected at Duncans Mills
Mainstem	725	40	Duncans Mills Antenna not operational during 2019 DSMT season
Mark West Creek	219	125	
Dutch Bill Creek	144	74	
Austin Creek	403	172	
Total	**1,491**	**411**	

Over the course of the season, 403 steelhead were captured at Austin Creek of which 368 were YOY (206 of the 368 YOY were ≥60 mm, Figure 4.5.11). Although Sonoma Water applied PIT tags to 172 total individuals (YOY+parr), based on their size, 168 of these PIT tagged fish were estimated to be YOY. In total, 128 PIT-tagged steelhead YOY were released upstream of the trap and 7 were released downstream of the trap (Table 4.5.4). Because 53 of the 128 PIT-tagged YOY were detected on the PIT antenna array downstream of the trap in Austin Creek, at least 38% (53/138) moved downstream into the estuary/lagoon. Because of imperfect antenna detection efficiency, those minimum counts that were based only on PIT-tagged YOY were expanded to the entire population of YOY in the vicinity of the Austin Creek trap (both tagged and untagged) as follows.

Of the 71 PIT tagged individuals (YOY+parr) detected on the downstream antenna in the array (Lower Austin Creek antenna), 64 were also detected on the upstream antenna array (Austin Creek) resulting in an estimated antenna efficiency of 90% (64/71). In order to estimate the number of YOY out of the original 53 that actually moved downstream of the Austin Creek antenna array, this proportion was used to expand the detections to 68 (53/90%).

Of the 53 YOY detected on the downstream PIT antenna array that were also released upstream of the trap, 3 were recaptured in the trap resulting in a trap efficiency of 5.7%. Based on this trap efficiency the 368 steelhead YOY captured at the trap was expanded to a population estimate of 6,456. Using the percentage of emigrants from the PIT tagged population it is expected that 2,453 steelhead YOY (38% of the 6,456 steelhead YOY trap estimate) emigrated from Austin Creek to the estuary.

Table 4.5.4. PIT tag and trap capture metrics and values for young-of-year (YOY) steelhead in Austin Creek. Note that 2010 numbers differ from Martini-Lamb and Manning (2011) because they have been adjusted to only include YOY.

Metric	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number pit-tagged YOY released upstream of trap	765	324	1,356	0	214	101	1,132	244	713	128
Number pit-tagged YOY released downstream of trap	195	2	162	1,746	269	6	73	2	6	7
Number pit-tagged YOY detected on antenna array that were tagged in Austin creek	547	131	574	1,335	275	13	193	80	291	53
Number pit-tagged YOY released upstream & detected on antenna array	389	131	486	0	57	13	151	80	291	49
Number released upstream & recaptured in trap & detected on antenna	47	8	196	0	2	0	60	0	61	3
Estimated trap efficiency	**12.1%**	**6.1%**	**40.3%**	**N/A**	**N/A**	**N/A**	**39.7%**	**N/A**	**21.0%**	**5.7%**
Number YOY+parr detected on both antennas in array	241	93	85	399	129	34	76	52	60	64
Number YOY+parr detected on downstream antenna only	288	178	129	463	162	35	205	55	75	71
Estimated antenna efficiency	**83.6%**	**52.2%**	**65.9%[1]**	**86.2%[1]**	**79.6%[1]**	**97.1%**	**37.1%[1]**	**94.5%**	**80%[1]**	**90.1%**
Number YOY captured and pit-tagged	960	324	1,518	1,746	483	42	993	319	719	168
Total number of YOY captured (≥60 mm only)	2,617	453	2,341	4,216	541	42	2,427	319	2,056	368
Estimated number of pit-tagged YOY emigrants (≥60 mm only)	**632**	**251**	**759**	**1,549**	**325**	**32**	**520**	**55**	**93**	**138**
Estimated proportion of pit-tagged YOY that emigrated (≥60 mm only)	**65.8%**	**77.5%**	**50%**	**88.5%**	**67.3%**	**76.2%**	**46.0%**	**17.2%**	**40.5%**	**38%**
Estimated population size of YOY at trap	**21,628**	**7,426**	**5,804**	**N/A**	**N/A**	**N/A**	**6,113**	**N/A**	**9,791**	**6,456**
Estimated number of YOY in population that emigrated	**14,231**	**5,755**	**2,901**	**N/A**	**N/A**	**N/A**	**2,812**	**N/A**	**3,965**	**2,453**

[1]Efficiency is based on detections of PIT-tagged fish at Duncans Mills.

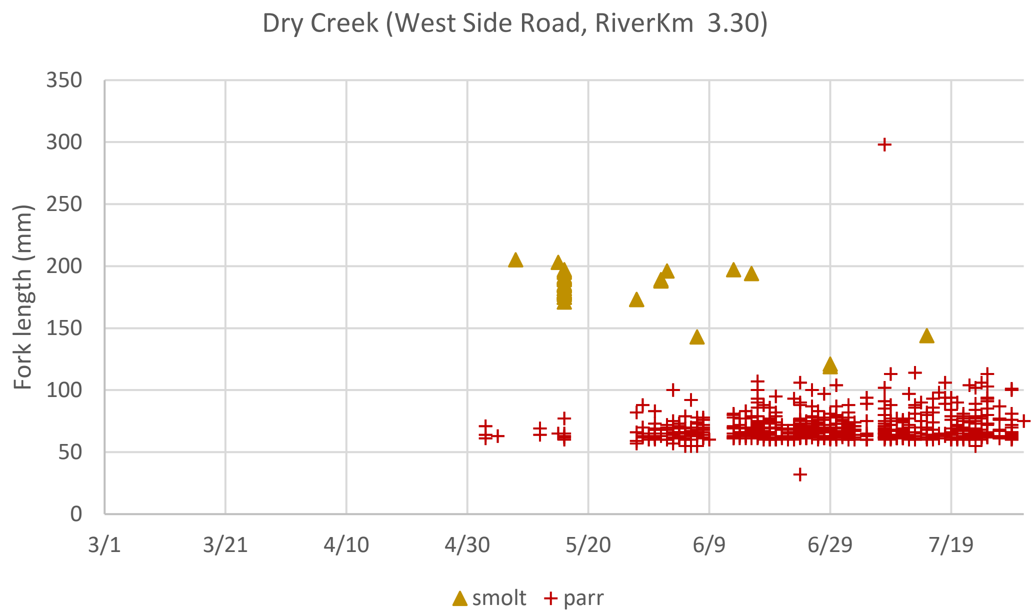
When compared to Austin and Dry Creeks fewer numbers of juvenile steelhead were captured at the mainstem Russian River, Mark West, and Dutch Bill Creeks (Figure 4.5.6) meaning that fewer numbers of juvenile steelhead were PIT-tagged at these locations (Table 4.5.3). Fork lengths of fish caught at these traps show at least 3-year classes with steelhead YOY present at each of the trapping locations (Figure 4.5.7). As in other years, the low number of steelhead smolts captured at the trap sites was likely due to a large portion of the smolt outmigration occurring before trap installation and the generally low trap efficiencies for steelhead smolts that is well-documented in the Russian River and elsewhere. The season total catches of steelhead have been variable over the course of this study (Figure 4.5.8 through Figure 4.5.11).

Coho

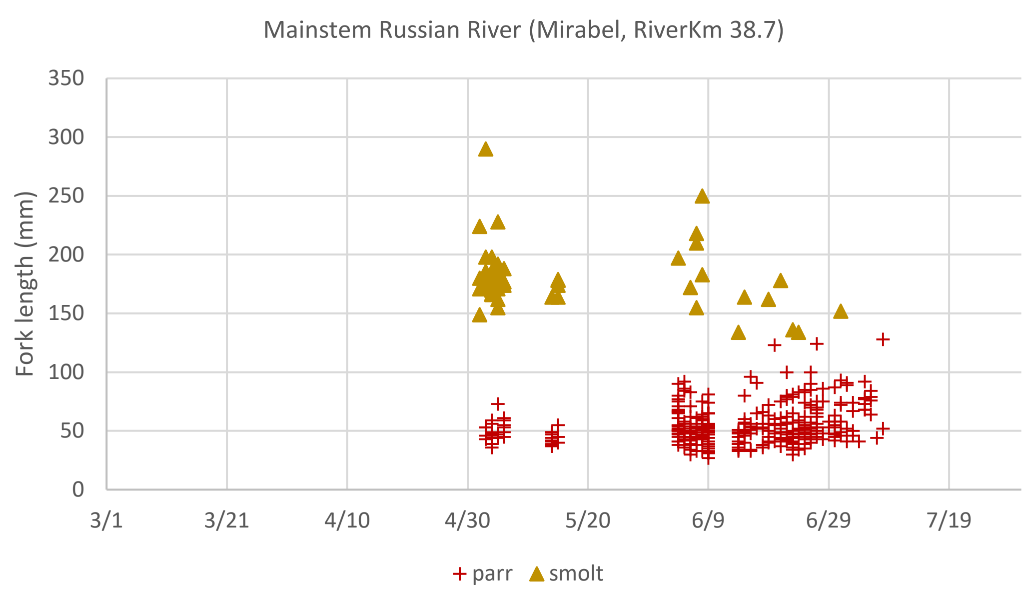
At Dry Creek 102 hatchery smolts, 8 wild smolts, 150 hatchery YOY, 627 YOY of unknown origin, and 8 wild YOY were detected at the trap (Figure 4.5.8 and Figure 4.5.12). At Mark West Creek, 273 hatchery smolts, 3 wild smolts, and 1 coho that did not have its life stage or origin recorded were captured (Figure 4.5.9 and Figure 4.5.12). A total of 325 hatchery smolts, 4 smolt of unknown origin, 12 wild smolts, 1 wild YOY were captured at the Dutch Bill Creek trap (Figure 4.5.10 and Figure 4.5.12). At Austin Creek, 26 hatchery smolts, 2 wild smolts, and 2 YOY of unknown origin, and 3 wild YOY were captured (Figure 4.5.11 and Figure 4.5.12). Based on length data collected at the lower Russian River traps, there were at least two age groups (YOY: age-0 and parr/smolt: ≥age-1) of coho captured (Figure 4.5.13).

Chinook

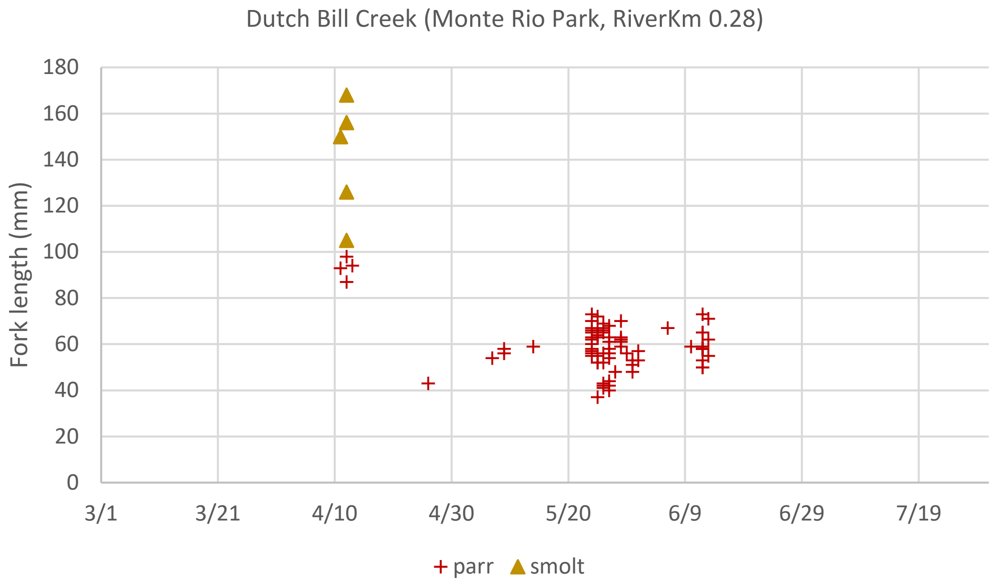
In 2019 relatively few Chinook smolts were captured in Austin Creek, Dutch Bill Creek, and Mark West Creek (15, 6, and 5 respectively). In the mainstem Russian River 2,661 Chinook smolts were captured (Figure 4.5.14 and Figure 4.5.15). Fork lengths of Chinook increases over the course of the trapping season (Figure 4.5.16). A total of 882 Chinook salmon smolts were marked with either PIT tags or fin clips and released upstream of the dam. Of these, 127 (14.4 percent) were recaptured. Based on the DARR estimator (Bjorkstedt 2005), mark-recapture estimate was 23,814 (+/- 6,861) juvenile Chinook salmon migrating past the trapping site during the mark-recapture study

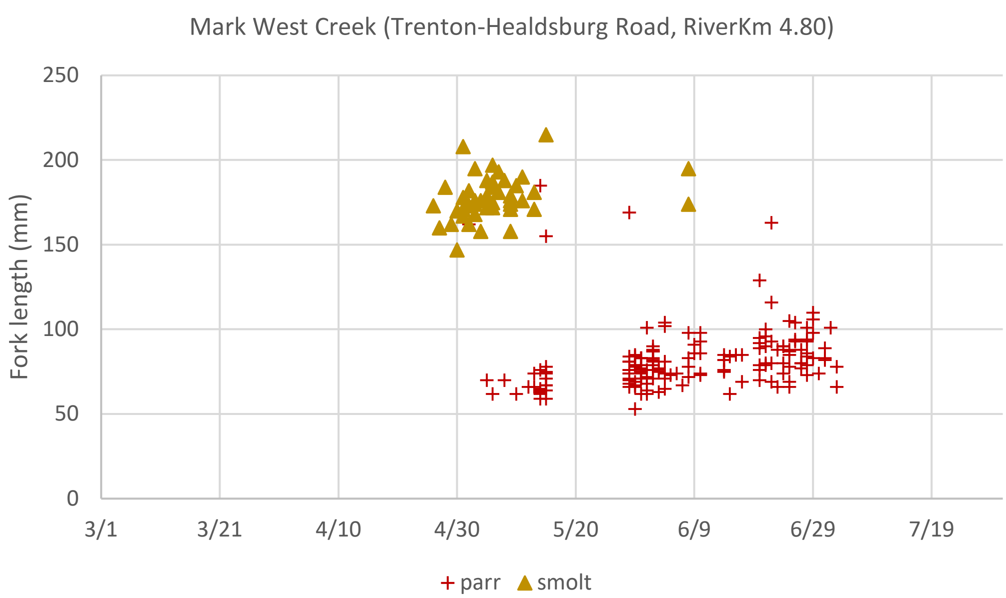


Dry Creek (West Side Road, RiverKm 3.30)
Fork length (mm)
350
300
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
smolt
parr



Mainstem Russian River (Mirabel, RiverKm 38.7)
Fork length (mm)
350
300
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
parr
smolt


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
Fork length (mm)
180
160
140
120
100
80
60
40
20
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
parr
smolt


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork length (mm)
250
200
150
100
50
0
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
parr
smolt

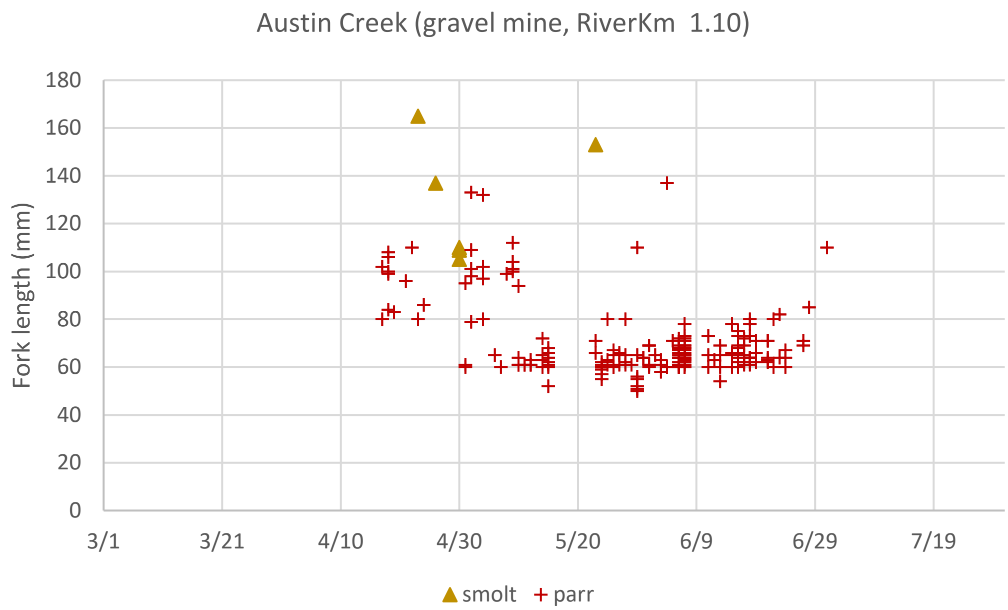
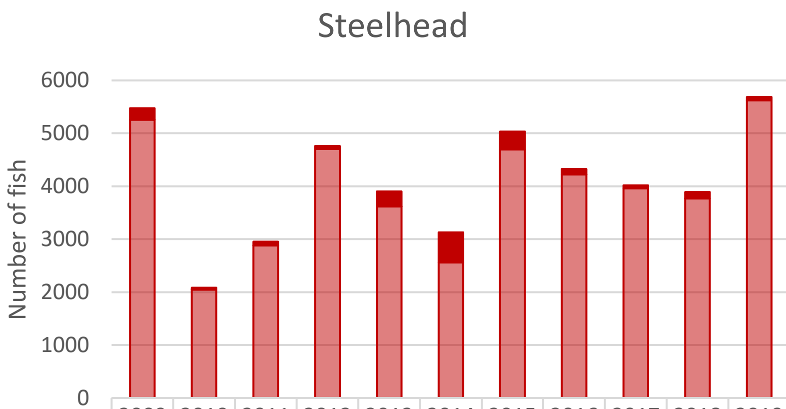
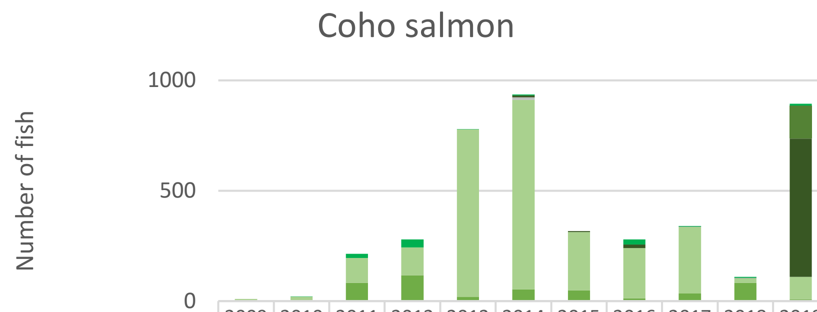


Figure 4.5.7. Weekly fork lengths of steelhead captured at lower Russian River downstream migrant trap sites, 2019.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Smolt	219	33	72	56	281	564	339	106	50	126	60
Parr	5258	2049	2879	4706	3619	2563	4696	4221	3966	3767	5626



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
YOY/parr-wild	0	2	18	35	1	4	0	22	3	5	8
YOY/parr-hatchery											150
YOY/parr-unknown	0	0	0	0	0	9	4	16	1	1	626
smolt-unknown	0	0	0	0	0	11	0	1	1	2	0
smolt-hatchery	7	19	113	127	760	858	264	227	301	19	102
smolt wild	3	1	83	117	19	54	49	13	35	83	8

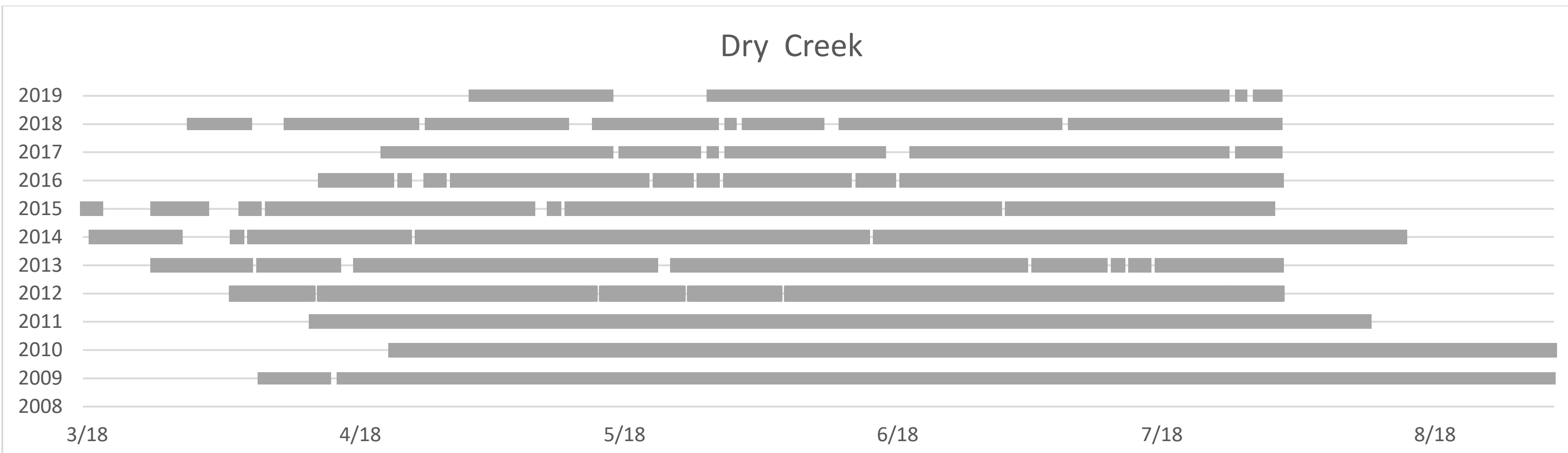
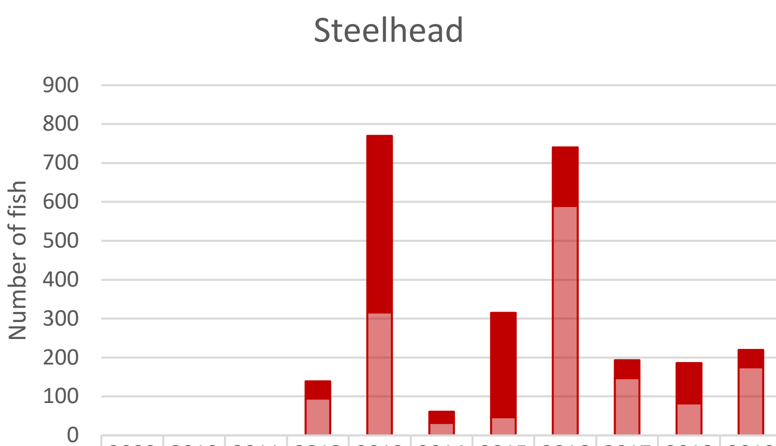
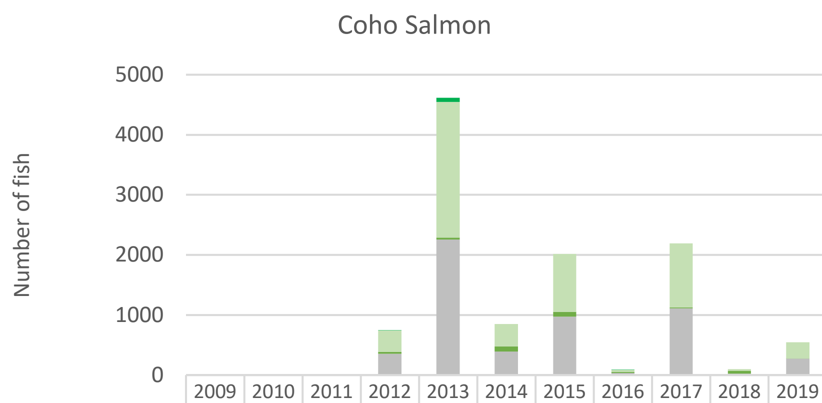


Figure 4.5.8. Number of steelhead and coho salmon captured by life stage and origin at the Dry Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2019.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Parr				44	454	29	268	150	46	104	45
smolt				95	316	32	47	590	147	82	175



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
YOY/Parr-wild	0	0	0	7	66	0	0	5	0	0	0
smolt-hatchery				357	2258	375	967	37	1065	23	273
smolt-wild				28	32	84	80	16	17	50	3
smolt-unknown	0	0	0	357	2258	393	971	37	1109	24	273

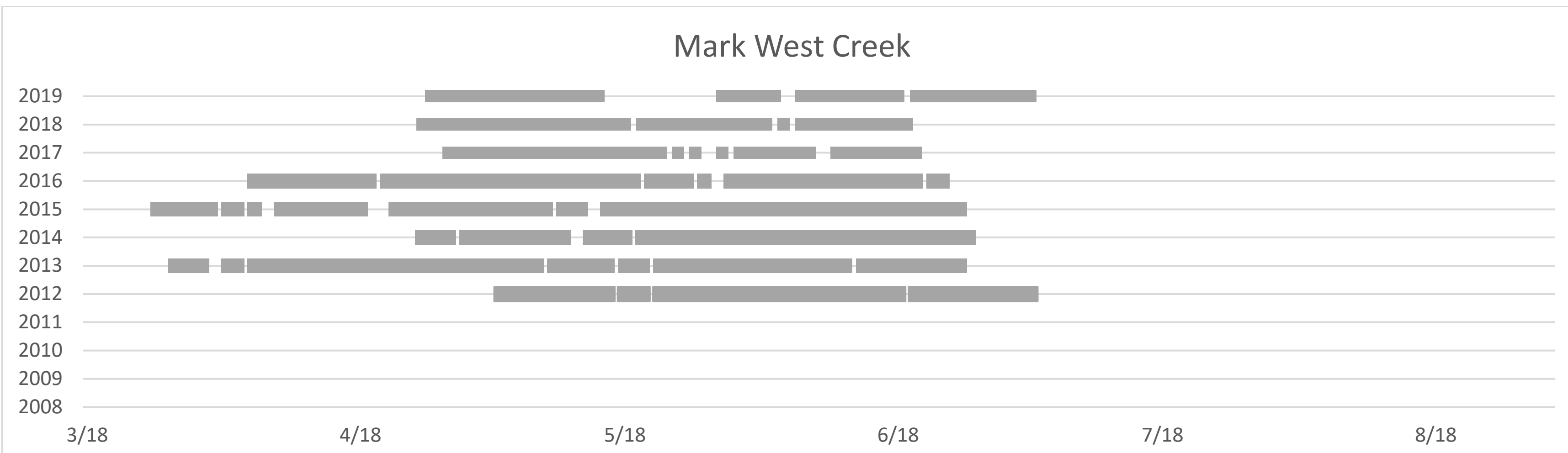
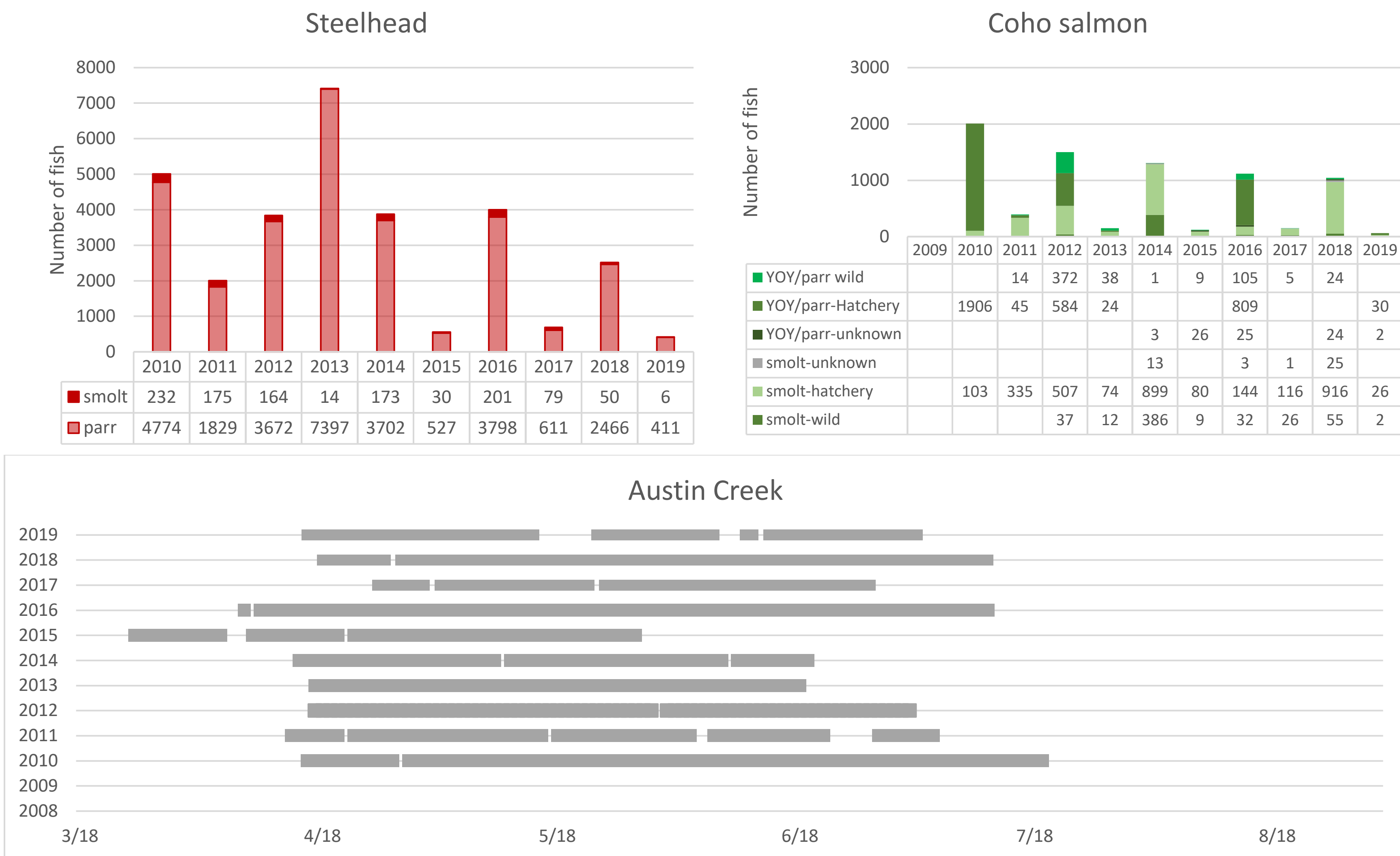


Figure 4.5.9. Number of steelhead and coho salmon captured by life stage and origin at the Mark West Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2019.

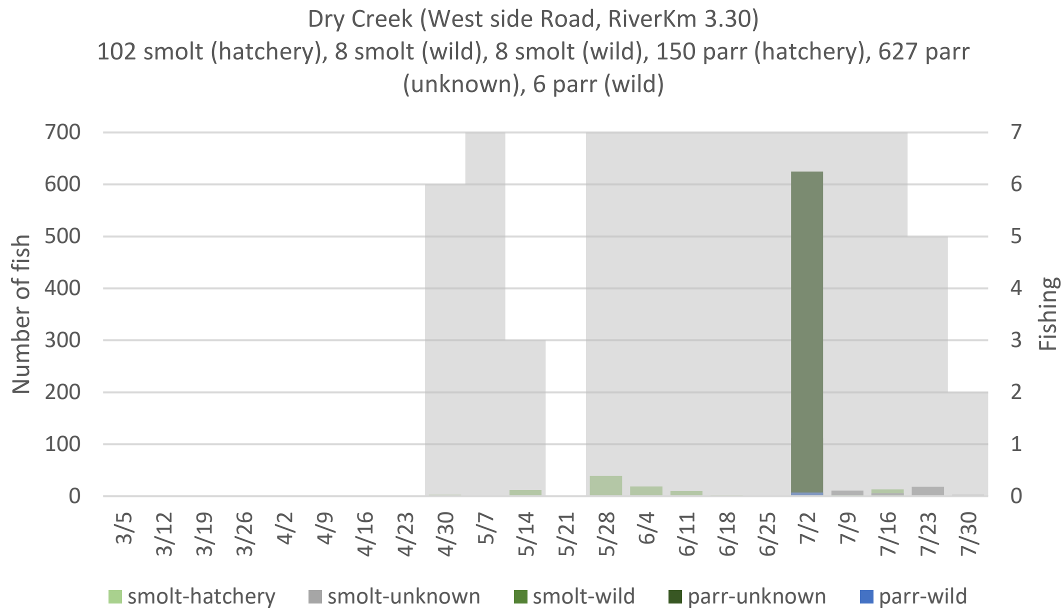
Figure 4.5.10. Number of steelhead and coho salmon captured by life stage and origin at the Dutch Bill Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2019.

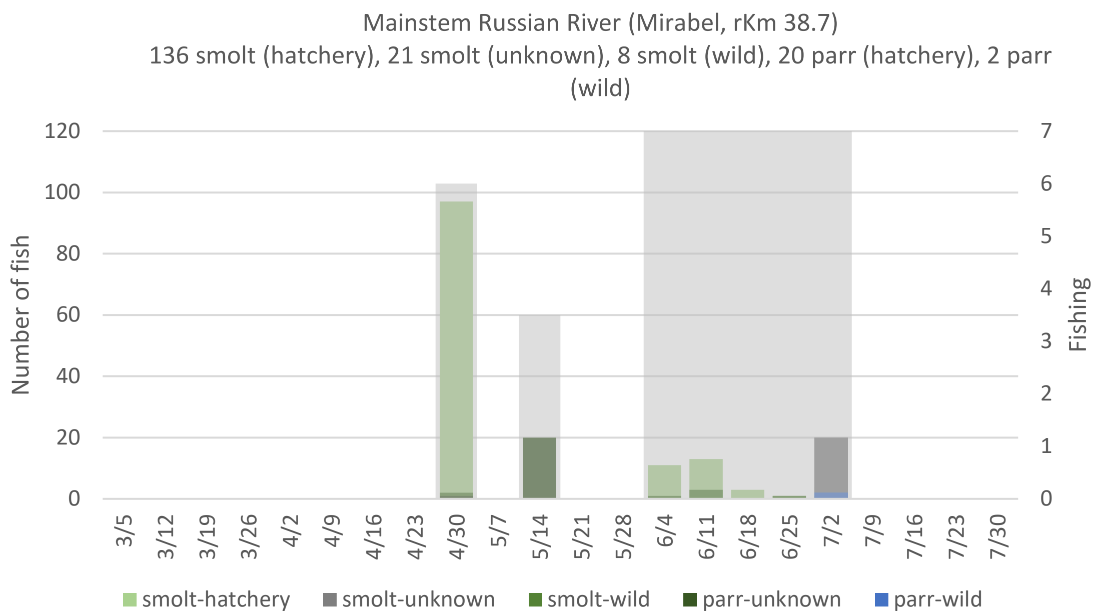


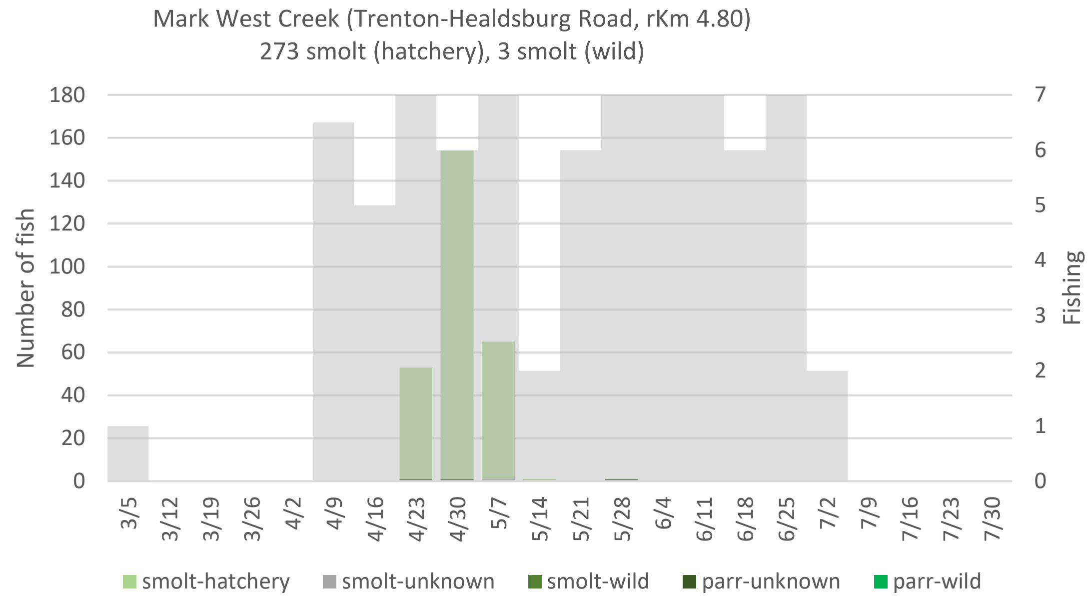
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
smolt	232	175	164	14	173	30	201	79	50	6
parr	4774	1829	3672	7397	3702	527	3798	611	2466	411

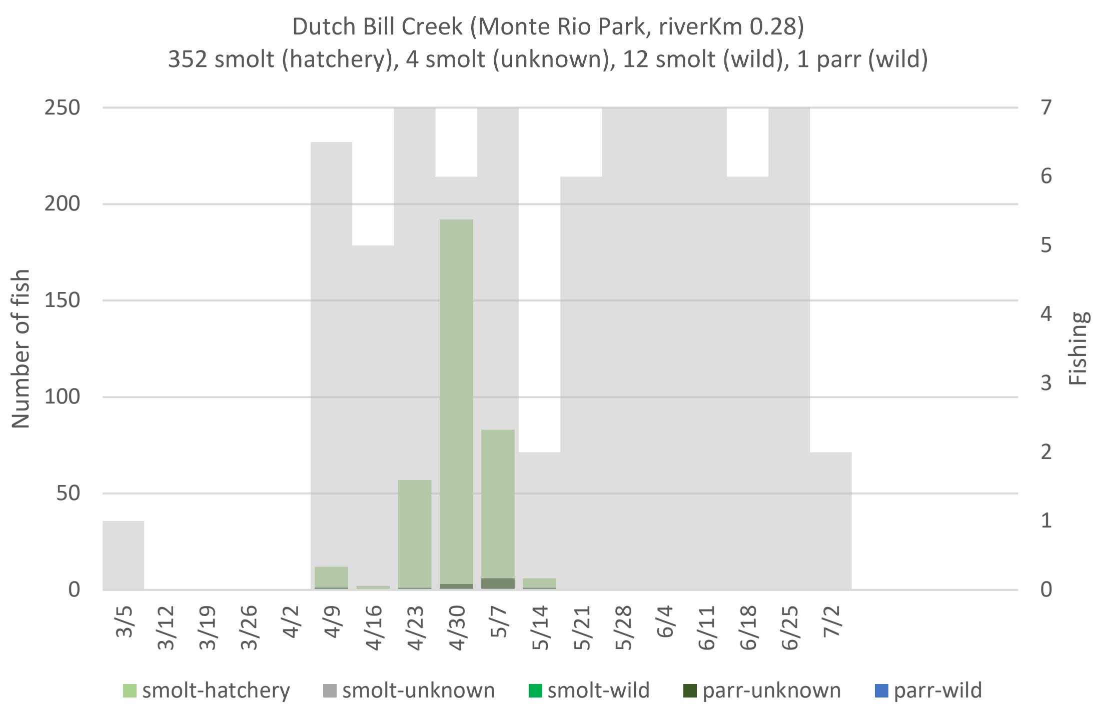
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
YOY/parr wild			14	372	38	1	9	105	5	24	
YOY/parr-Hatchery		1906	45	584	24			809			30
YOY/parr-unknown						3	26	25		24	2
smolt-unknown						13		3	1	25	
smolt-hatchery		103	335	507	74	899	80	144	116	916	26
smolt-wild				37	12	386	9	32	26	55	2

Figure 4.5.11. Number of steelhead and coho salmon captured by life stage and origin at the Austin Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2019.


Dry Creek (West side Road, RiverKm 3.30)
102 smolt (hatchery), 8 smolt (wild), 8 smolt (wild), 150 parr (hatchery), 627 parr (unknown), 6 parr (wild)
Number of fish
Fishing
0
100
200
300
400
500
600
700
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild


Mainstem Russian River (Mirabel, rKm 38.7)
136 smolt (hatchery), 21 smolt (unknown), 8 smolt (wild), 20 parr (hatchery), 2 parr (wild)
Number of fish
Fishing
0
20
40
60
80
100
120
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild


Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
273 smolt (hatchery), 3 smolt (wild)
Number of fish
Fishing
0
20
40
60
80
100
120
140
160
180
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild


Dutch Bill Creek (Monte Rio Park, riverKm 0.28)
352 smolt (hatchery), 4 smolt (unknown), 12 smolt (wild), 1 parr (wild)
Number of fish
Fishing
0
50
100
150
200
250
0
1
2
3
4
5
6
7
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
smolt-hatchery
smolt-unknown
smolt-wild
parr-unknown
parr-wild

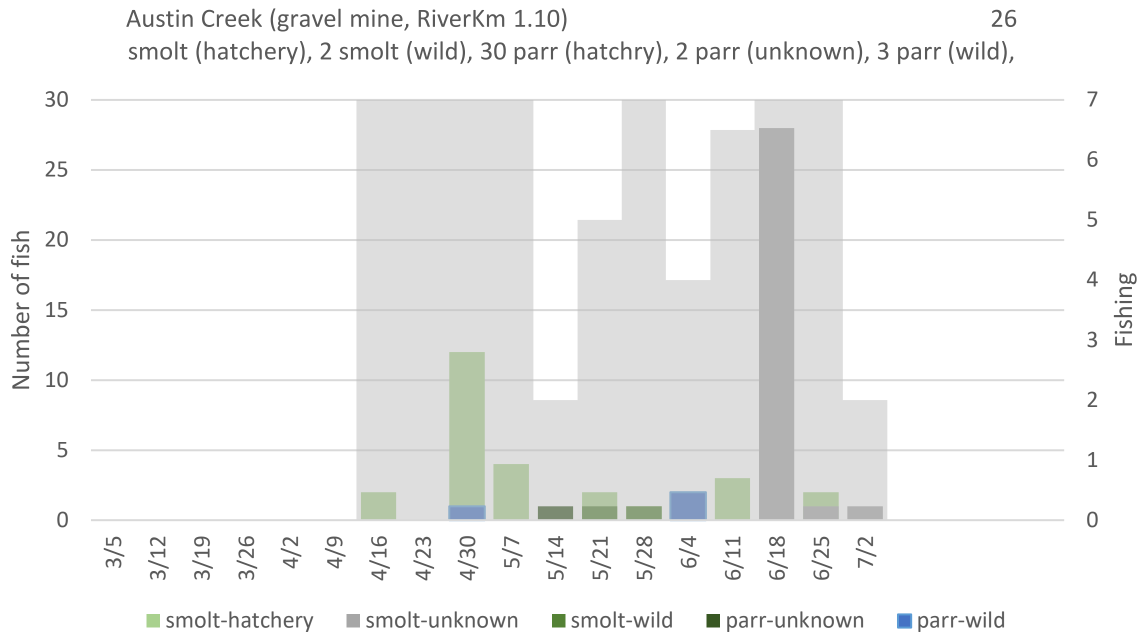
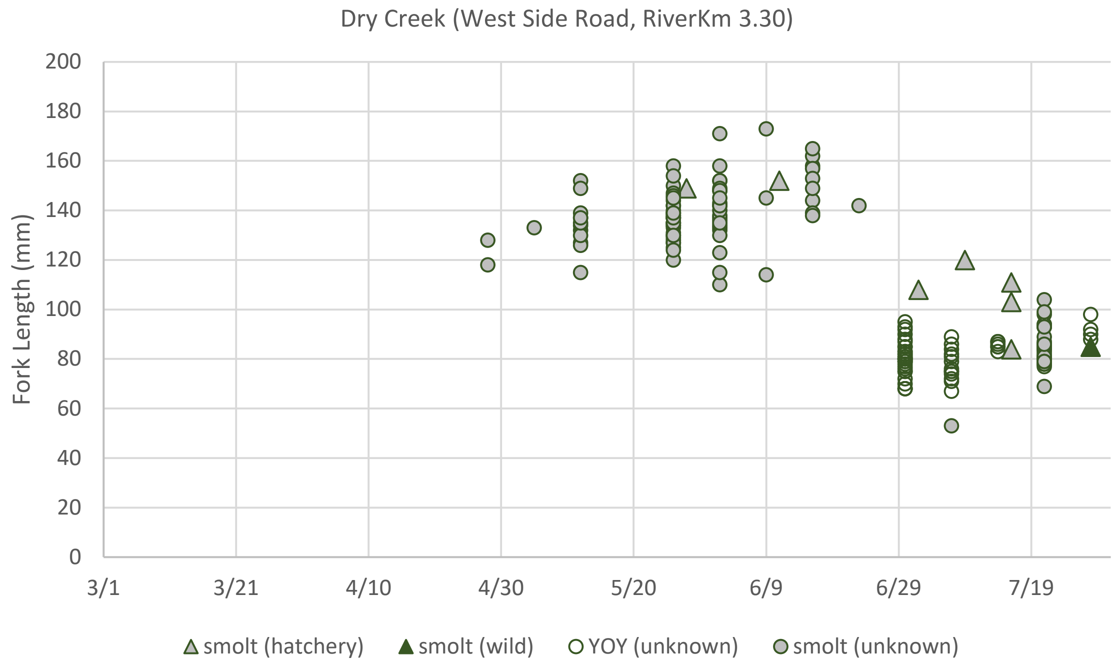
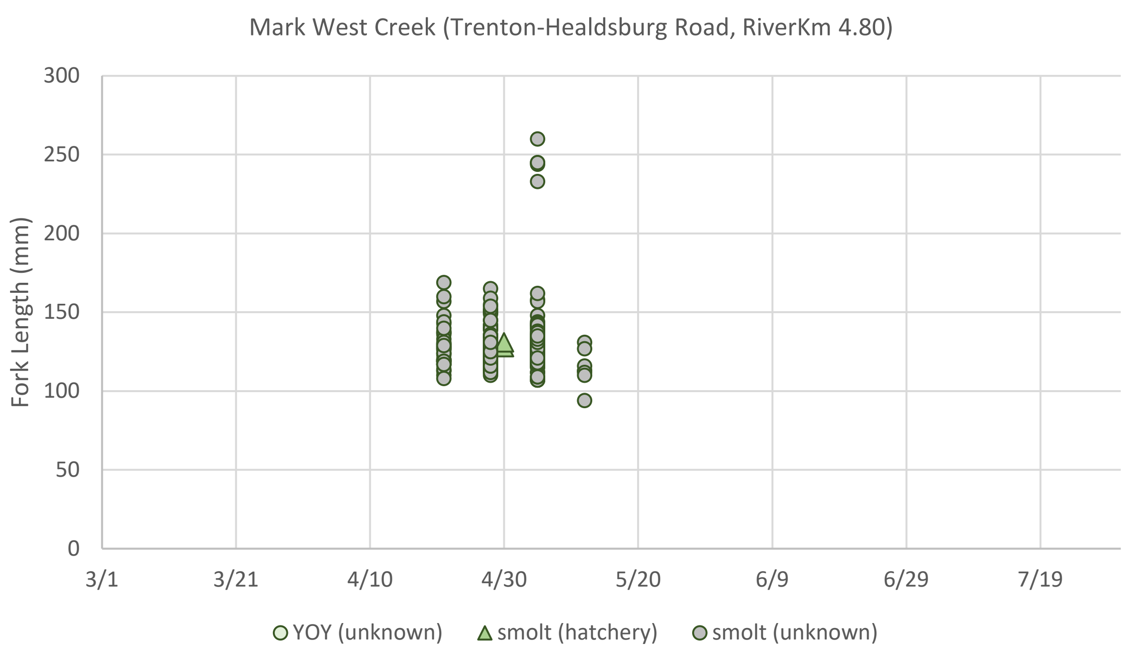
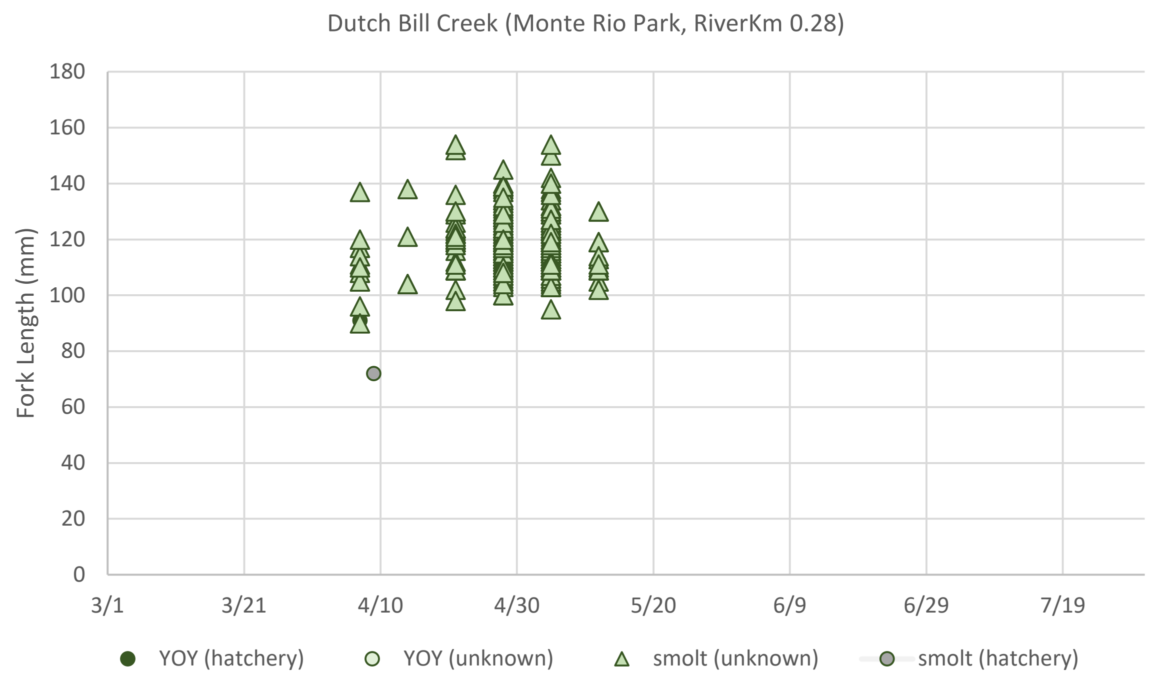
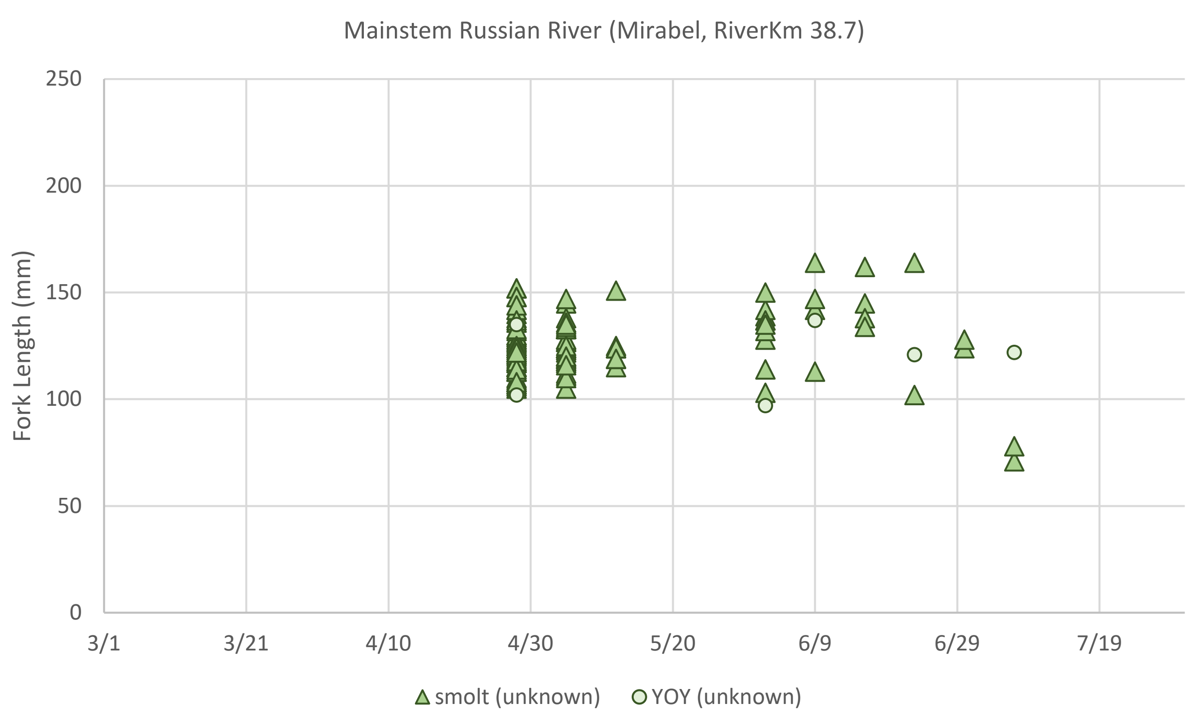


Figure 4.5.12. Weekly capture of coho salmon by life stage at lower Russian River downstream migrant trapping sites, 2019. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.


Dry Creek (West Side Road, RiverKm 3.30)
200
180
160
140
120
100
80
60
40
20
0
Fork Length (mm)
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
smolt (hatchery)
smolt (wild)
YOY (unknown)
smolt (unknown)


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
300
250
200
150
100
50
0
Fork Length (mm)
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
YOY (unknown)
smolt (hatchery)
smolt (unknown)


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
Fork Length (mm)
0
20
40
60
80
100
120
140
160
180
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
YOY (hatchery)
YOY (unknown)
smolt (unknown)
smolt (hatchery)


Mainstem Russian River (Mirabel, RiverKm 38.7)
Fork Length (mm)
0
50
100
150
200
250
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
smolt (unknown)
YOY (unknown)

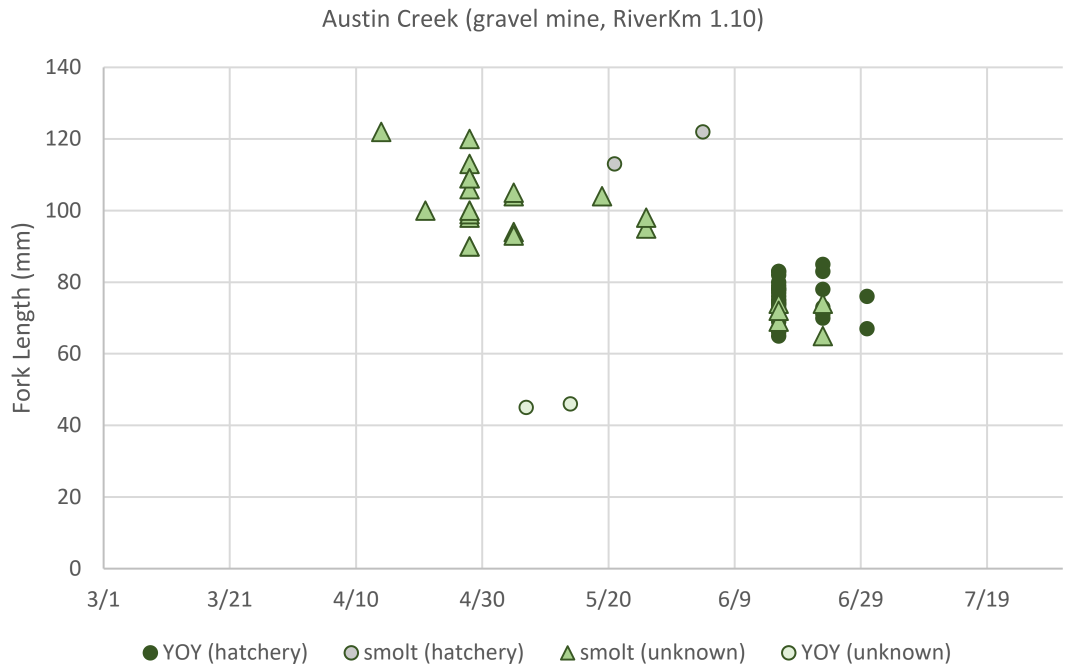


Figure 4.5.13. Weekly fork lengths of coho salmon captured at lower Russian River downstream migrant trap sites, 2019.

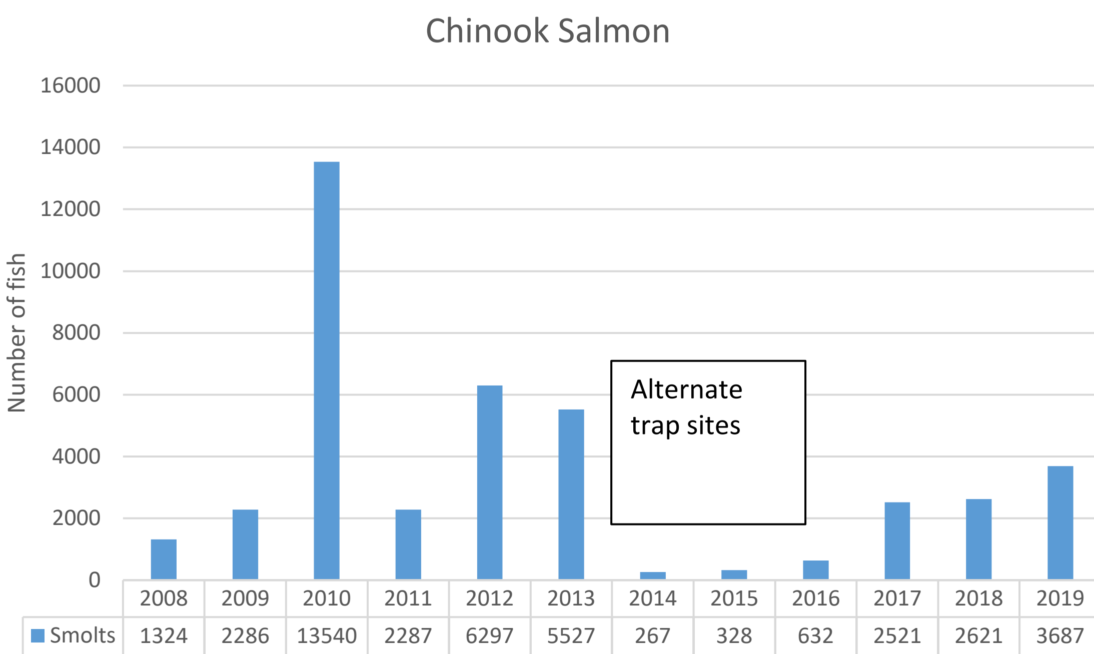


Figure 4.5.14. Number Chinook salmon smolts captured in the mainstem Russian River downstream migrant trap. In 2014 and 2015 the Mirabel dam was under construction and the mainstem Russian River trap was operated further upstream at Chalk Hill (river Km 69.82).

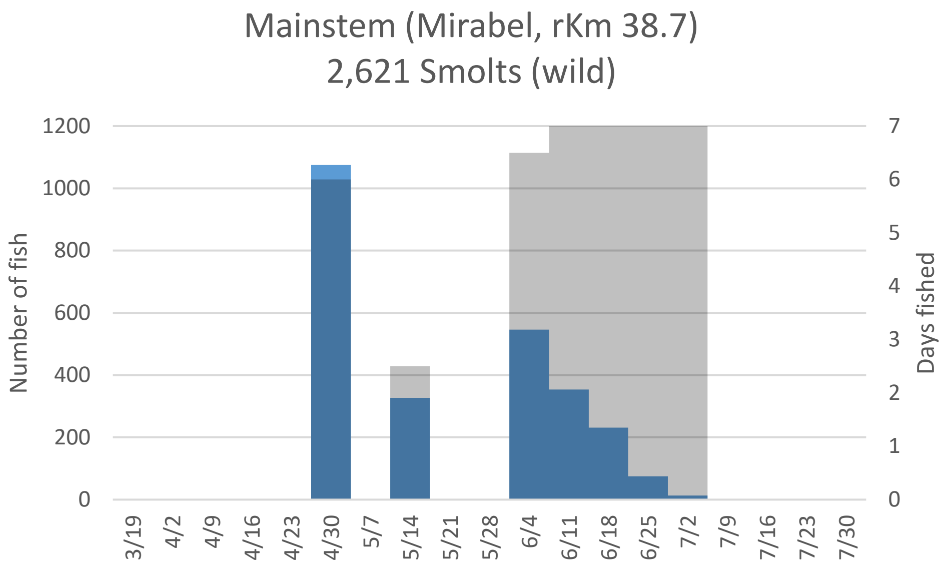


Figure 4.5.15. Weekly capture of Chinook salmon smolts at the Mirabel fish ladder on the mainstem Russian River, 2018. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.

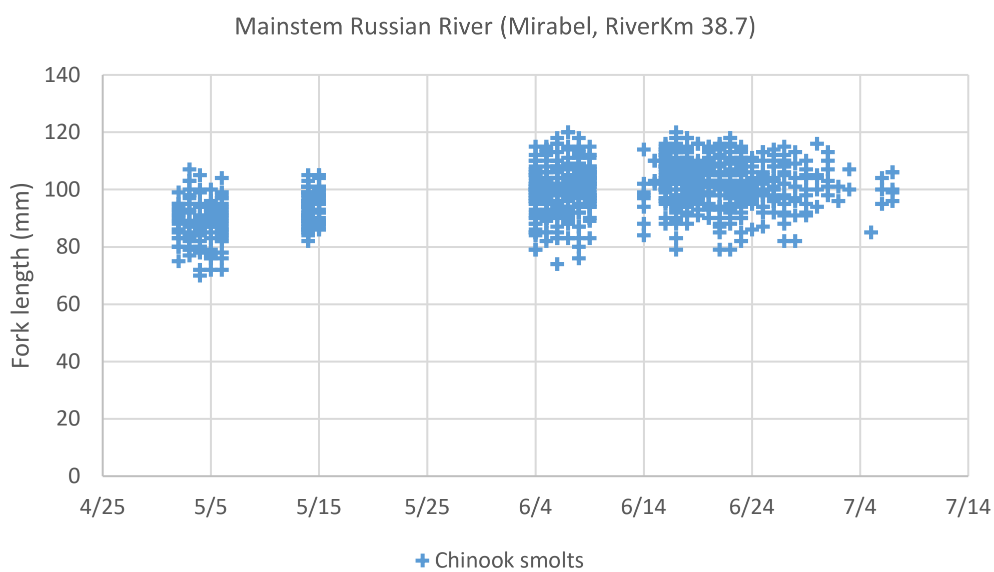


Figure 4.5.16. Weekly fork lengths of Chinook salmon captured at the Wohler Mirabel trap site on the mainstream Russian River downstream migrant trap sites, 2019.

Conclusions and Recommendations

Russian River Biological Opinion objectives regarding the timing of estuary entry are partially met by using PIT tag detections from the paired antenna array in lower Austin Creek where antenna efficiency estimates are possible and where fish moving past that array have effectively entered the estuary. In 2019, as in past years, many steelhead YOY were detected leaving Austin Creek and entering the estuary. This same pattern was not seen at the other tributary monitoring sites. Austin Creek has a large amount of spawning habitat in the lower portions of the creek, but this section of creek often becomes dry in the summer. More steelhead YOY may emigrate from Austin Creek when compared to our other sample sites because more Steelhead YOY may be produced in Austin Creek and opportunities to over summer in lower Austin Creek are limited.

In 2019, PIT tag detection at Austin Creek were relied upon to estimate the number of young-of-the-year that entered the estuary. In previous years, PIT tag antennas operated at Duncans Mills spanned much of the Russian River and provided detections of PIT tagged steelhead YOY immigrating from Austin Creek and other lower Russian River tributaries. However, the Duncans Mills PIT tag antenna array was damaged by high winter flows in early 2019 and was not operable during the 2019 outmigration season. As a result, detections at the Austin Creek were relied upon to estimate the number of steelhead young-of-the-year that entered the estuary. Detections of PIT tagged fish were not guaranteed because fish orientation (PIT tags must be perpendicular to the antenna for reliable detection), and multiple PIT-tagged fish in the detection field of the same antenna at the same time can effect detection probability. While these limitations result in decreased antenna efficiency they are not of concern as long as detection efficiency can be estimated for use in expanding the number of fish detected. A draw back to relying on the Austin Creek array as opposed to the Duncans Mills array is that fish emigrating from other trap sites (Mainstem Russian River, Mark West Creek, and Dutch Bill Creek) are not detected upon entering the estuary. It is likely that some PIT tagged steelhead YOY emigrating from the Mainstem Russian River, Mark West Creek, and Dutch Bill Creek would have been detected entering the estuary if it been possible to operate the Duncan's Mills PIT tag antenna in 2019. PIT-tagging steelhead YOY at upstream locations and detecting those individuals if and when they move into the estuary (along with beach seining in the estuary itself) remains the best option for addressing the fish monitoring objectives in the Russian River Biological Opinion at this time. The Duncans Mills antenna was repaired on September 20, 2019, and attempts continue to measure antenna efficiency so that expanded counts of PIT tagged individuals passing the antenna array can be constructed in future years.

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Chapter 5 Dry Creek Habitat Enhancement, Planning, and Monitoring

Introduction

The Biological Opinion contains a timeline that prescribes a series of projects to improve summer and winter rearing habitat for juvenile coho salmon and steelhead in Dry Creek (Figure 5.1). During the initial three years of implementation, 2008 to 2011, the Water Agency was charged with improving fish passage and habitat in selected tributaries to Dry Creek and the lower Russian River. The status of those efforts is described in previous reports (Martini-Lamb and Manning 2020). For the mainstem of Dry Creek, during this initial period, the Water Agency was directed to perform fisheries monitoring, develop a detailed adaptive management plan, and conduct feasibility studies for large-scale habitat enhancement and a potential water supply bypass pipeline. The pipeline feasibility study was completed in 2011 and is reported in Martini-Lamb and Manning 2011.

In 2012, the Water Agency began construction of the first phase of the Dry Creek Habitat Enhancement Demonstration Project. A second phase of the Dry Creek Habitat Enhancement Demonstration Project was constructed in 2013 with a third and final phase of the Demonstration Project constructed in 2014. The Dry Creek Habitat Enhancement Demonstration Project consists of a variety of habitat enhancement projects along a section of Dry Creek a little over one mile in length in the area centered around Lambert Bridge. Concurrently, the U.S. Army Corps of Engineers completed construction in 2013 of a habitat enhancement project on U.S. Army Corps of Engineers owned property just below Warm Springs Dam (Reach 15 area). In 2016, Sonoma Water began construction on the Dry Creek Habitat Enhancement Phase 2, Part 1 Project (centered approximately a mile upstream of the Demonstration Project) and the Dry Creek Habitat Enhancement Phase 3, Part 1 Project (centered in a lower reach area of Dry Creek just below the Westside Road Bridge crossing of Dry Creek). Construction activities for both the Phase 2, Part 1 and Phase 3, Part 1 projects were completed during the 2017 construction season. In 2018, Sonoma Water began construction of two sites (Corps of Engineers/Weinstock property site and Vala property site) of the Phase 2, Part 2 (Reach 14) habitat work. Also in 2018, the U.S. Army Corps of Engineers completed the Phase 3, Part 2 habitat work in Reach 4A. In 2019, Sonoma Water completed the remaining site (Gallo property) of the Phase 2, Part 2 habitat work in Reach 14. Phase 3, Part 3 (Reach 5) is expected to start in the 2020 construction season by Sonoma Water. Additional sites in reaches 1, 2, 4, 10, and 13 are in design for tentative construction at a future date.

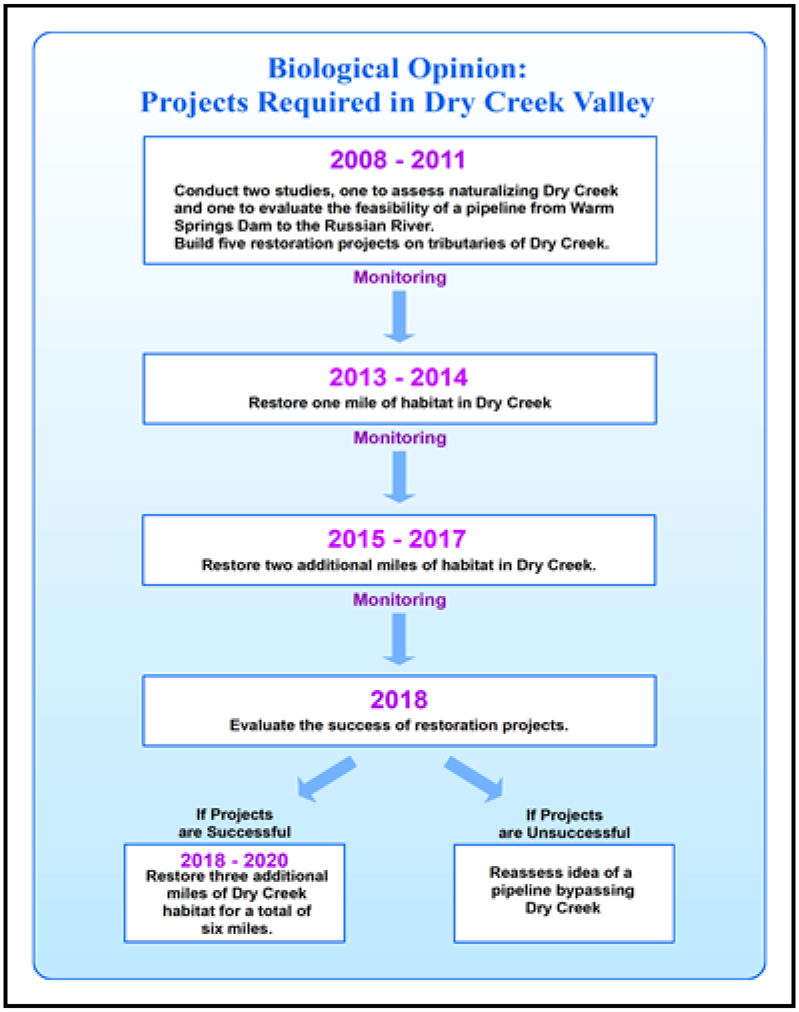


Figure 5.1. Timeline for implementation of Biological Opinion projects on Dry Creek.

2019 Habitat Enhancement Overview

In 2019 construction was completed in Reach 14 (Gallo property), completing Part 2 of Phase 2 construction. We conducted post-enhancement monitoring in the Gallo portion of Reach 14 as well as post-effective flow monitoring in previously completed reaches (Army Corps, Army Corps Reach 14, Weinstock, Truett Hurst, Farrow Wallace, Ferrari-Carano Olson, City of Healdsburg Yard, and Geyser Peak (Figure 5.2).

Of the number of habitat enhancement reaches implemented to date (13), monitoring data resulted in 8 reaches rated good-excellent, 4 rated fair, and 1 poor (Table 5.1). One reach previously rated fair was upgraded to good (Farrow Wallace) while two reaches were downgraded from good to fair (Truett Hurst) and good to poor (City of Healdsburg) ratings after subsequent monitoring in 2019.

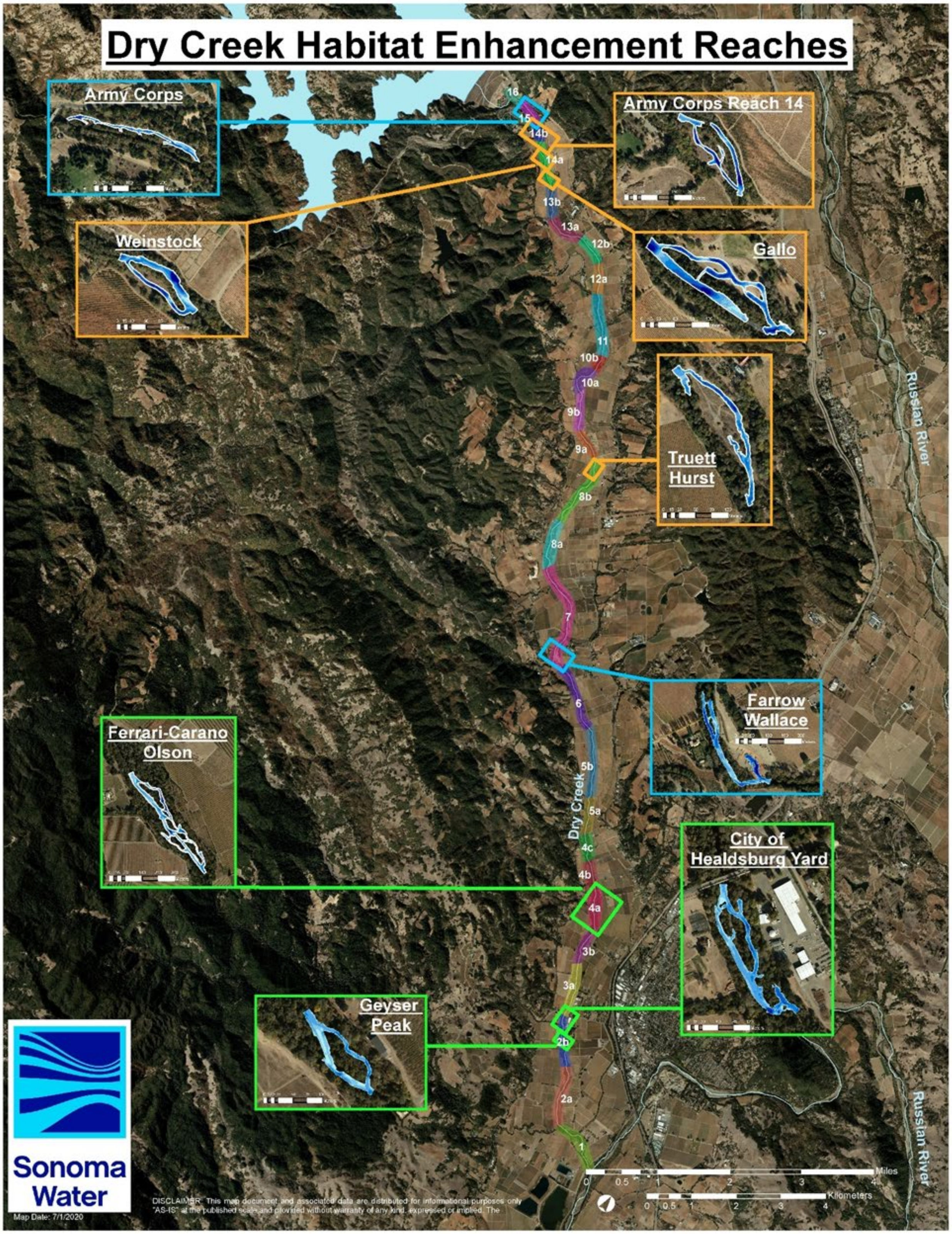


Figure 5.2. Location of Dry Creek habitat enhancement reaches monitored for effectiveness in 2019.

Table 5.1. Dry Creek enhancement reaches monitored, year(s) of post-effective flow effectiveness monitoring and effectiveness rating, and latest overall rating. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River).

Enhancement Reach	2015	2016	2017	2018	2019	Latest post-effective flow rating
Army Corps	Excellent	Excellent			Good	Good
Army Corps Reach 14					Good	Good
Weinstock					Good	Good
Truett Hurst			Poor	Good	Fair	Fair
Meyer			Fair	Fair		Fair
Carlson, Lonestar				Good		Good
Quivira		Excellent				Excellent
Van Alyea			Good			Good
Rued	Good					Good
Farrow Wallace			Fair		Good	Good
Ferrari-Carano, Olson					Fair	Fair
City of Healdsburg Yard				Good	Poor	Poor
Geyser Peak			Poor	Fair	Fair	Fair

Dry Creek Adaptive Management Plan

In 2014, an Adaptive Management Plan (AMP) to guide the process for evaluating habitat enhancement projects in Dry Creek was completed (Porter et al. 2014). Development of the Dry Creek AMP was facilitated by ESSA Technologies Ltd. (an independent consulting firm from Vancouver Canada) and it represented the culmination of a 3-year process including NMFS, CDFW, Sonoma Water, USACE, and Inter-Fluve (the design contractor for the initial phase of habitat enhancement). Enhancement projects were designed and implemented with the objective of addressing the lack of low water velocity areas with adequate cover and appropriate water depth that limit habitat suitability for juvenile salmonids in general and juvenile Coho Salmon in particular (NMFS 2008).

The Dry Creek AMP is based on the concept of adaptive management which involves synthesizing existing knowledge, exploring alternative actions, making explicit predictions of their outcomes, selecting one or more actions to implement, monitoring to see if the actual outcomes match those predicted, and then using these results to learn and adjust future management plans and policy (see Porter et al. 2014 and references therein). Sonoma Water's and USACE's level of compliance with the RPA for Dry Creek will involve examination of data from implementation, effectiveness and, to a lesser extent, validation monitoring. The process of combining monitoring data stems from first selecting a stream reach for enhancement then developing enhancement designs given geomorphic and landowner constraints. Once these designs are agreed to by parties to NMFS' Russian River Biological Opinion and enhancement projects are implemented, monitoring begins (Figure 5.3).

Prior to construction of a given enhancement project, but following reach selection and approval of construction design, pre-enhancement effectiveness monitoring is conducted. The objective of pre-enhancement monitoring is to rate existing habitat local to the intended enhancement project. Once construction of the project is complete, implementation monitoring is conducted to determine if the habitat enhancement was implemented according to the approved design. If it was, post-enhancement effectiveness monitoring is conducted following a geomorphically effective flow or within three years (whichever comes first). Validation monitoring aimed at assessing whether the habitat enhancement is achieving intended biological objectives is conducted after project implementation and can occur before, during or after post-enhancement effectiveness monitoring.

Enhancement project success is primarily based on the results of effectiveness monitoring and, in particular, post-enhancement effectiveness data. Importantly, however, implementation monitoring not only triggers post-enhancement effectiveness monitoring by addressing the question of whether the habitat enhancement was implemented according to the approved design, but it also builds a template for conducting that monitoring. Though less important for evaluating overall project success, validation monitoring can be key in tipping the overall project rating but only in a positive direction (Figure 5.3).

The specific quantitative data collected for effectiveness monitoring vary depending on aspects of the habitat being evaluated. Regardless, however, the aim is to evaluate habitat in light of those factors deemed in the RPA as most significantly impacting juvenile salmonid rearing habitat in Dry Creek (current velocity, depth, cover, habitat complexity). The RPA recognizes validation monitoring as being important given the complexity of major habitat enhancements and influences of uncontrollable factors such as major flood events. For both types of monitoring, the AMP lists “primary metrics” and outlines how data collection to evaluate against these metrics will occur (see Effectiveness Monitoring and Validation Monitoring sections). In some cases, data on “secondary metrics” which may inform habitat-related questions in Dry Creek as well as (potentially) beyond Dry Creek.

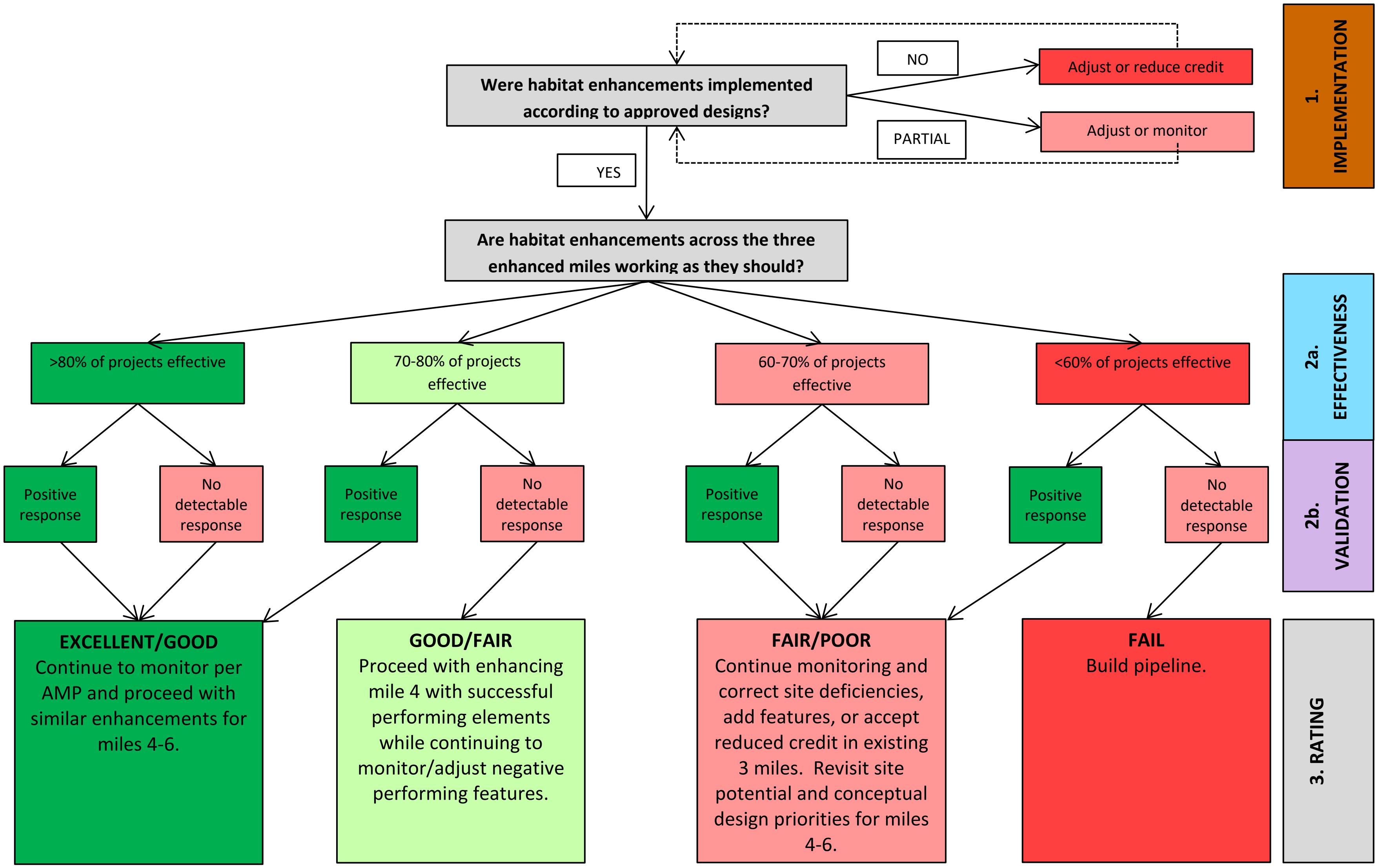


Figure 5.3. Process for determining course of action after the first three miles of Dry Creek have been enhanced. Ratings will be based on an objective evaluation in a step-wise phased monitoring approach which includes physical and biological quantitative measurements which lead to qualitative ratings (Porter et al. 2014).

Data Roll-up

Implementation monitoring is based solely on qualitative data at the habitat feature scale (i.e., was the feature installed in the approved location in the approved manner?) while effectiveness and validation monitoring are based on collecting quantitative data at one scale (i.e., the feature, site, enhancement reach scale) then qualitatively “rolling-up” those results to the next broader spatial scale (Figure 5.4).

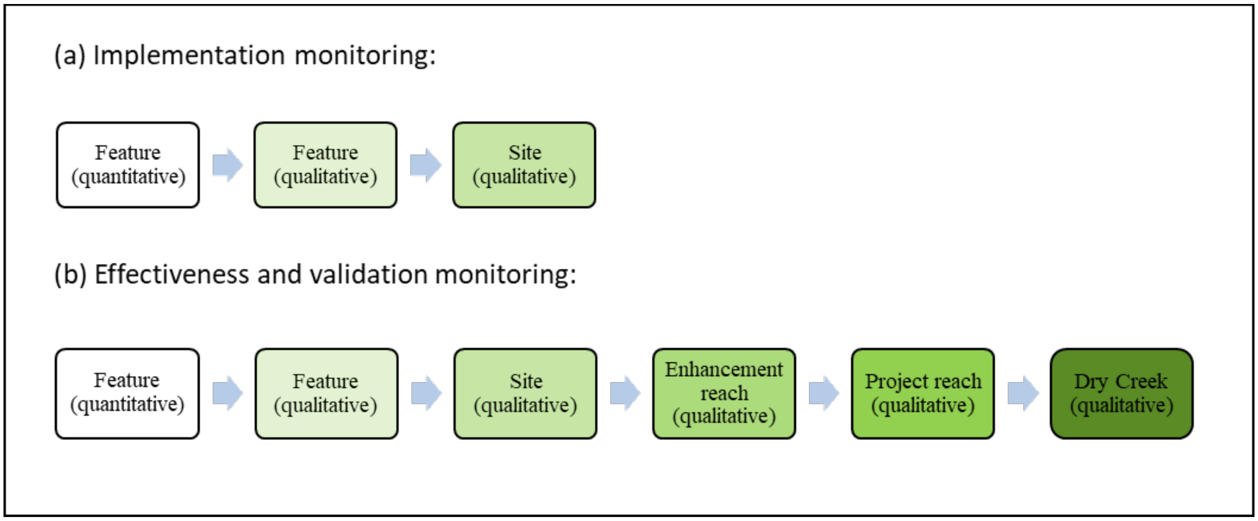


Figure 5.4. Illustration of the rollup concept for (a) implementation and (b) effectiveness and validation monitoring (from Porter et al. 2014).

In the sections that follow, definition of the following terms is necessary (from Porter et al. 2014):

- **Features:** Individually engineered elements (e.g., large woody debris accumulation, riffle, pool, side channel, alcove, boulder cluster, etc.) that will individually or in composite make up a habitat enhancement site (see definition for Site below). Features can in some cases represent complete habitat units (see definition for Habitat Unit below), while in other cases they represent only structural components within a habitat unit (e.g., large wood placement).
- **Site:** One or more engineered habitat features (see definition for Features above) that have been designed to work in combination to enhance a stream reach.
- **Enhancement reach:** A specified collection of enhancement sites (see definition for site above) that are implemented in close proximity to one another.
- **Project reach:** A specified collection of enhancement reaches (see definition for Enhancement Reach above).

The qualitative rating derived for a given group of features within a site, sites within an enhancement reach or enhancement reaches within a project reach represent the basis for overall rating of habitat enhancements. These overall ratings will influence crediting toward the total length of habitat enhanced in Dry Creek (Figure 5. 3).

- Excellent-Good: >80% rated Good or Excellent
- Fair-Poor: 60-80% rated Good or Excellent
- Fail: <60% rated Good or Excellent

5.1 Habitat Enhancement Implementation

Phase 2 and 3

Beyond the completion of the Demonstration Project (Reach 7) work and the USACE's Reach 15 work, Sonoma Water has continued to make progress towards the construction of the next two miles of habitat enhancement. These next two miles have been designated as Phase 2 and 3, with each of these phases to be constructed in parts. Figure 5.1.1 shows completed project areas (including the Demonstration Project and Reach 15), along with other areas in construction or under design. Construction of Phase 2, Part 1 (Reach 8) and Phase 3, Part 1 (Reach 2) was completed in 2017. Phase 2, Part 2 (Reach 14) construction started in 2018 and was completed in 2019. The construction management for Phase 2, Part 2 is being overseen by Sonoma Water. Phase 3, Part 2 (Reach 4a) was constructed in 2018 by the USACE.

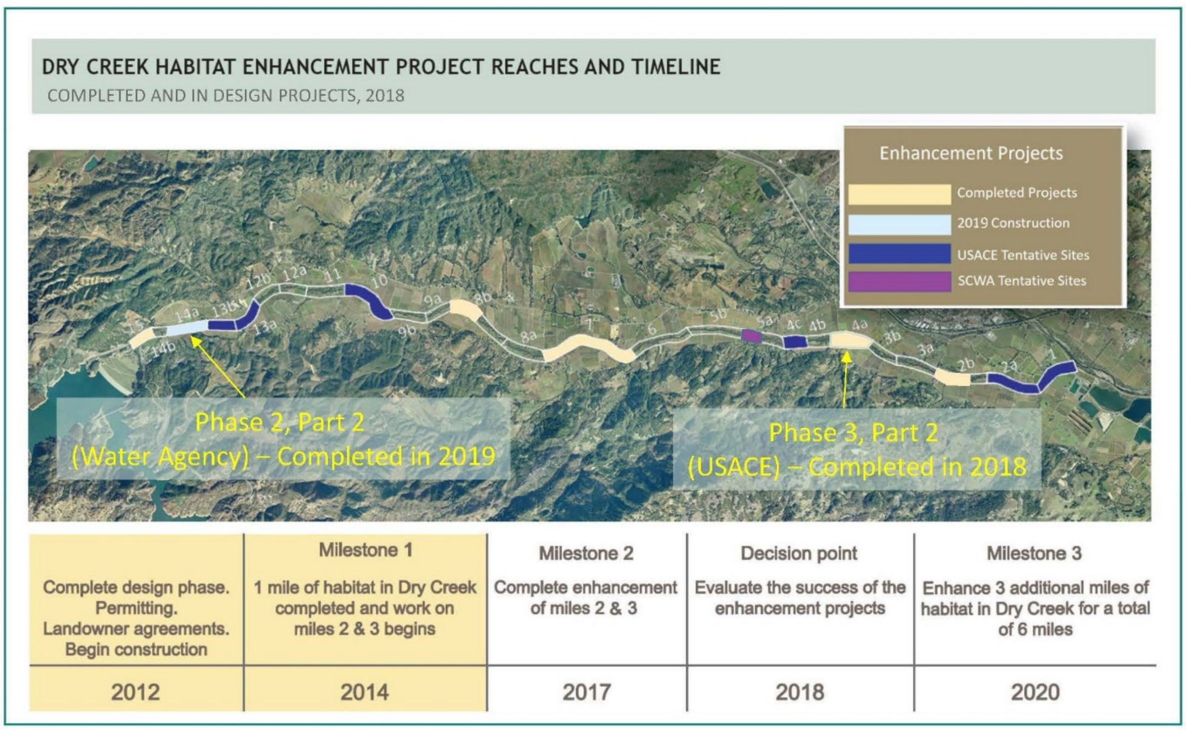


Figure 5.1.1. Dry Creek habitat projects constructed, constructed in 2018 and 2019, and tentatively planned for future construction.

Phase 2, Part 2

The Phase 2, Part 2 project area is along approximately 4,000 feet of Dry Creek in the Reach 14 area of Dry Creek just below Warm Springs Dam. This site originally consisted of five different sites, labeled Areas G, H, I, J, and K in the design drawings (Figure 5.1.2). Areas H and J were constructed during the 2018 construction season. Area G was constructed in 2019. Areas I and K unfortunately had to be dropped from the project because an agreement to construct the project could not be reached with the landowners of these two sites.

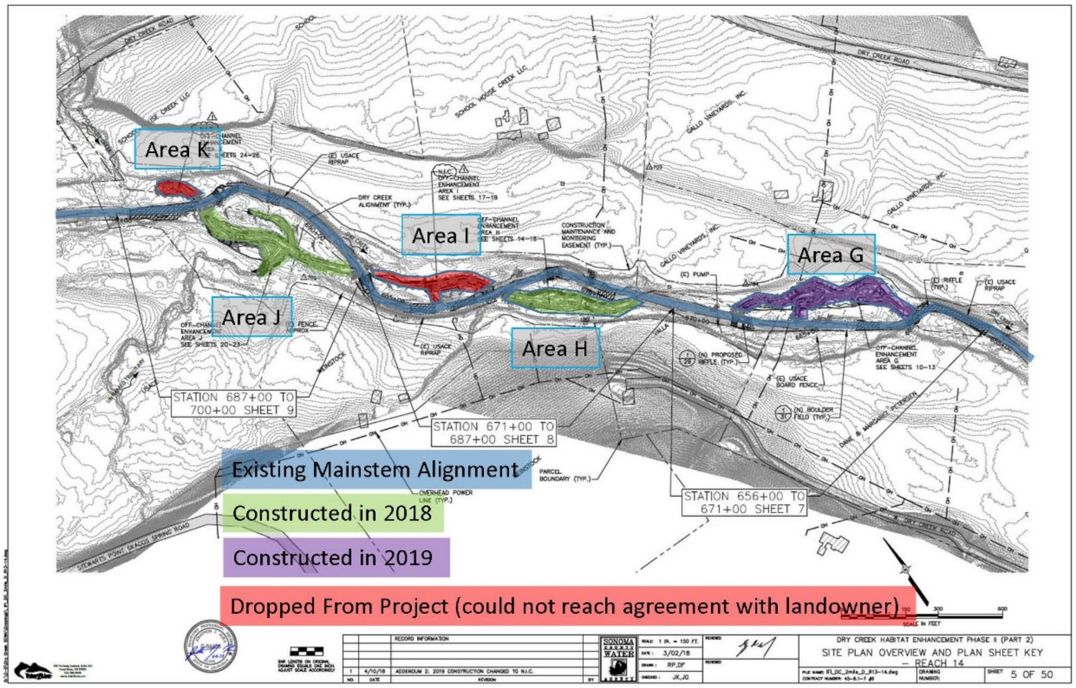


Figure 5.1.2. This figure shows the work area for the Dry Creek Habitat Enhancement Project, Phase 2, Part 2, constructed in 2018 and 2019.

Photo 5.1.1. Phase 2, Part 2, Area H approximately 9 months after construction. View is looking upstream at the inlet of Area H. June 26, 2019.

Photo 5.1.2. Phase 2, Part 2, Area H approximately 9 months after construction. View is looking upstream from the downstream end of the site. June 26, 2019.

Photo 5.1.3. Phase 2, Part 2, Area G. At start of construction. View is from the upper inlet location of the site and looking downstream where the new side-channel will be constructed. June 26, 2019.

Photo 5.1.4. Phase 2, Part 2, Area G. Driving vertical snags for the log structure at the upper inlet to the site. Note sheet pile in place isolating the turbid water of the work area from the mainstem of Dry Creek. July 31, 2019.

Photo 5.1.5. Phase 2, Part 2, Area G. Installation of boulder field in mainstem of Dry Creek. Note temporary bridge installed to keep excavator tracks out of the active flow while boulders are placed. July 22, 2019.

Photo 5.1.6. Phase 2, Part 2, Area G. Construction of new side channel is nearing completion. View is looking downstream from near the middle inlet. July 22, 2019.

Photo 5.1.7. Phase 2, Part 2, Area G. Construction of new side channel is complete. Installed willow cuttings have started to leaf out. View is looking upstream towards the upper inlet. December 11, 2019.

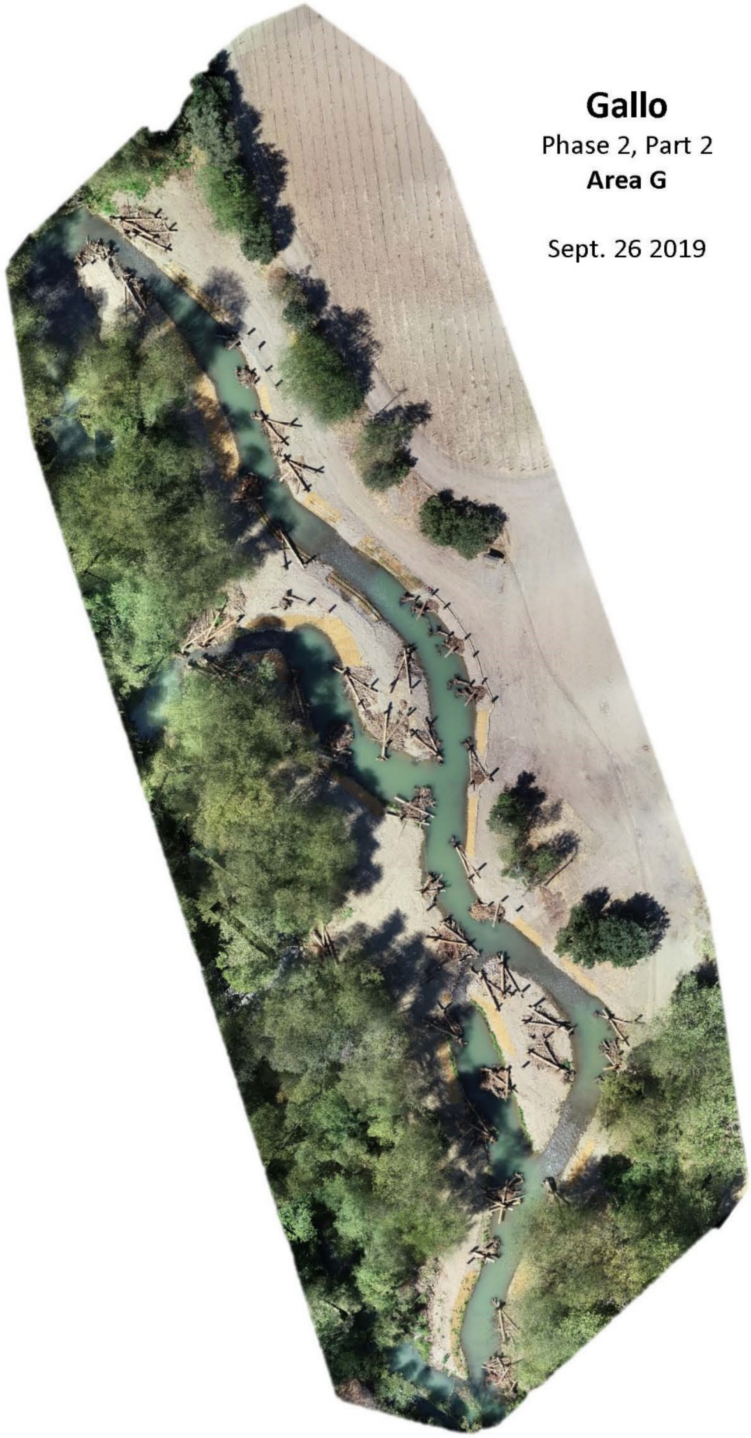


Photo 5.1.8. Phase 2, Part 2, Area G. Aerial view of the new side channel constructed in 2019. September 26, 2019.

5.2 Effectiveness monitoring

Performance Measures

Effectiveness monitoring focuses on the physical response of Dry Creek to habitat enhancements and determines “whether habitat enhancement is having the intended effect on physical habitat quality” in Dry Creek (NMFS 2008, pg. 266). NMFS (2008) concluded that sub-optimal water velocity, depth, and instream cover limit juvenile coho salmon and steelhead and suggested optimal values for water velocity depth, and cover as part of the Reasonable and Prudent Alternative (NMFS 2008). The Joint Monitoring Team, consisting of representatives from NMFS, CDFW, USACE, and the Water Agency, refined these values within the Dry Creek Adaptive Management Plan (AMP) (Porter et al. 2014) and developed primary performance metrics linked to the optimal values of water velocity, depth, and cover by which to evaluate the effectiveness of habitat features, sites, and reaches (Table 5.2.1). The Joint Monitoring Team also identified secondary performance metrics that help determine the effectiveness of habitat enhancements to influence non-target, ancillary conditions (e.g., water temperature, dissolved oxygen concentration). The AMP also suggested target flows to represent seasonal variation critical to each life stage (Porter et al. 2014).

Table 5.2.1. Primary and secondary performance measures from the Dry Creek Adaptive Management Plan.

Type of Performance Measure	Performance Measure	Life Stage	Spring Flow[1]	Summer Flow[2]	Winter Flow[3]
Primary	Velocity (ft/sec)	fry	0-0.5 ft/s	n/a	n/a
	Depth (ft)	fry	0.5-2.0 ft	n/a	n/a
	Velocity (ft/sec)	Summer/winter parr	0-0.5 ft/s	0-0.5 ft/s	0-0.5ft/s
	Depth (ft)	Summer/winter parr	2-4 ft	2-4 ft	2-4 ft
	Shelter value	Juvenile	≥80	≥80	≥80
	Pool: Riffle ratio	Juvenile	n/a	1:2 to 2:1	n/a
Secondary	Temperature (°C)	Juvenile	n/a	8-16° C	n/a
	Dissolved oxygen (mg/l)	Juvenile	n/a	6-10 mg/l	n/a
	Canopy (%)	Juvenile	80 %		
	Quiet water (< 0.5 ft/s) (%)	Juvenile	n/a	n/a	≥ 25%
	Off-channel access (off-ramps) (ft/sec)	Juvenile	Approx. 1.5 – 1.8 cm/s (Ucrit); Approx. 3.3 ft/s (burst speed)		
	Connectivity of habitats	Juvenile	Undefined		
	Substrate particle size (in.)	Adult	n/a	n/a	0.25-2.5 in.
	Depth (ft)	Adult	n/a	n/a	0.5-1.6 ft

[1] Target coho life stage during spring is newly emerged feeding fry which use shallower depths than would be preferred later in the summer and winter when fish would be larger. Target spring flow (discharge within the enhancement reach) is 200 cfs (approximately double the summer “base” flow).

[2] Target summer flow is 105 cfs

[3] Target winter flow is 1000 cfs

Spatial Scales

Data collection to evaluate the effectiveness of the Dry Creek Habitat Enhancement Project occurred across several increasingly broad spatial scales that nest within each other as they increase in size:

- Feature: Individually engineered elements (e.g., large woody debris accumulation, riffle, pool, side channel, alcove, boulder cluster).

- Habitat unit: A designation within a habitat classification system (e.g., Flosi et al. 2010) that allows stratification (based on natural patterns of variation) when attempting to quantify physical attributes of a stream.

- Site: An engineered portion of stream channel (e.g., side channel or alcove) constructed within an enhancement reach (see definition below), or a portion of stream channel adjacent to engineered portions of stream channel (e.g., a mainstem portion of channel adjacent to a constructed side channel). Sites typically contain several features and habitat units, but in some cases may contain no features and a single habitat unit (e.g., a mainstem portion of channel with no features adjacent to constructed side channel). Sites may also contain several features, but no habitat unit, such as floodplain sites that are dry during the summer.

- Enhancement reach: A collection of sites implemented in close proximity to one another.

- Project reach: A collection of enhancement reaches implemented during the same project phase

Quantitative and qualitative data collected at the feature and habitat unit-scale provide the basis to inform evaluation of progressively larger sites, enhancement reaches, and project reaches. This integration, or spatial rollup, allows a robust evaluation of individual project elements across multiple spatial scales.

Effectiveness Ratings

Within the AMP, the Joint Monitoring Team developed checklists to evaluate and rate the physical effectiveness of the Dry Creek Habitat Enhancement Project (See Porter et al [2014], pp. 40-45). The Joint Monitoring Team expanded existing checklists developed by Harris (2004) by incorporating additional quantitative metrics outlined in the RPA. The checklists integrate hydraulic (water depth and velocity) and shelter (shelter value, percent cover, shelter score) data to evaluate project performance relative to primary metrics (Table 5.2.1), and qualitative observations of features. The ratings of features and habitat units inform ratings of sites, enhancement reaches, and project reaches, which occur at increasingly broader spatial scales. Quantitative data collected to evaluate project performance support qualitative ratings that provide the basis for evaluating the overall effectiveness of habitat enhancement measures (see Methods, below). The qualitative ratings determine relative success of habitat enhancement measures within sites and habitat enhancement reaches, and determine potential future outcomes (management actions) (Table 5.2.2).

Table 5.2.2. Potential enhancement reach ratings, criteria, and future outcomes (actions). From Porter et al. 2014.

Rating	Objectives	Criteria	Unintended Effects	Future Outcome
Excellent-Good	Achieved all or most stated reach design objectives.	All or most sites/ enhancement reaches meet or exceed targeted values.(>80% of sites rated Good or Excellent)	None or minimal negative unintended effects. Unintended positive effects may outweigh failure to achieve a targeted value.	Continue to monitor according to adaptive management plan.
Fair-Poor	Partially achieved most reach design objectives, or objectives not achieved were beyond reach capacity	Some sites / enhancement reaches did not meet targeted values (60-80% of sites/ enhancement reaches rated Good or Excellent)	May have minor or major unintended negative effects that partially offset objectives or negates a targeted gain.	Develop and implement plans to correct site or metric deficiencies, add sites/features or reduce total project habitat credit. Step up monitoring on sites and features exhibiting negative performance.
Fail	Many sites achieved no goals; objectives not achieved were the fault of the feature; sites/feature may be completely gone.	Many sites/ enhancement reaches did not meet targeted values (<60% of sites/ enhancement reaches rated Good or Excellent).	Few positive effects and/or unintended negative effects may be degrading the habitat and outweigh achieved objectives.	Reduce total project habitat credit, and abandon use of failed features. Revisit site potential and conceptual design priorities

Methods

Performance Measures

Performance measure data collection focuses on data to assess the Dry Creek Habitat Enhancement Project against the primary performance measures of water depth (0.5-2 or 2-4 ft) and velocity (<0.5 ft/s), pool to riffle ratio, and amount of instream cover (shelter score) from the AMP (Porter et al. 2014) (Table 5.2.1). Depth, velocity, pool to riffle ratio, and shelter score also provide a means to directly assess against optimal habitat values suggested as part of the RPA in the BO (NMFS 2008). We collected data from April to September during summer baseflow conditions. Daily average discharge ranged from 110 to 135 cfs over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240]), and monitoring did not occur at discharges above 135 cfs to ensure accuracy and consistency when measuring depth and velocity, determining habitat types and evaluating cover.

Depth and velocity

The AMP suggested collecting water depth and velocity at points along transects placed within constructed backwaters and main channel portions of Dry Creek, and "habitat feature mapping" near selected habitat enhancements (logjams, boulder fields). Habitat feature mapping would result in two-dimensional depictions of depth and velocity around habitat features and allow quantification of optimal habitat area adjacent to features. Upon consultation with NMFS, and through field experimentation with several mapping and survey tools (auto-level, differential global positioning system, total station), Sonoma Water developed a robust habitat feature mapping method to characterize all portions of the Dry Creek channel, not just adjacent to enhancement features, obviating the need to collect cross-sectional data.

Field crews collected water depth and velocity at points across the streambed using handheld flow meters and a total station. At each point, we collected geographic location (latitude, longitude, elevation), and water depth and velocity by aiming the total station at a USGS topset rod fit with a survey prism and a flow meter (Figure 5.2.1). The technique allowed simultaneous collection of spatially accurate topographic and hydraulic data (water depth and velocity) that enabled comparison to future conditions. Field crews focused point collection on breaks in slope and breaks in water velocity, and at a minimum collected points at the top of each bank, water surface elevation, toe of bank, thalweg, and at least two points between toe of bank and thalweg.

We processed the data within a Geographic Information System (GIS) to create detailed maps of hydraulic conditions (water depth and velocity) to spatially characterize habitat conditions and quantify optimal fry and juvenile habitat. We processed spatial data to create raster (grid) based digital elevation models (DEMs) that classified hydraulic habitat conditions according to the primary metrics from the AMP (depth [0.5-2 ft or 2-4 ft], depending on life stage and velocity [<0.5 ft/s]) to identify the location of habitat falling within optimal depth, velocity, and depth and velocity ranges as polygons (Figure 5.2.2). Generating polygons within a GIS also allowed us to quantify the areas of optimal habitat.

Figure 5.2.1. Dry Creek effectiveness monitoring. At each data point, we collected geographic location (latitude, longitude, elevation), and water depth and velocity by aiming the total station at a USGS topset rod fit with a survey prism and a flow meter

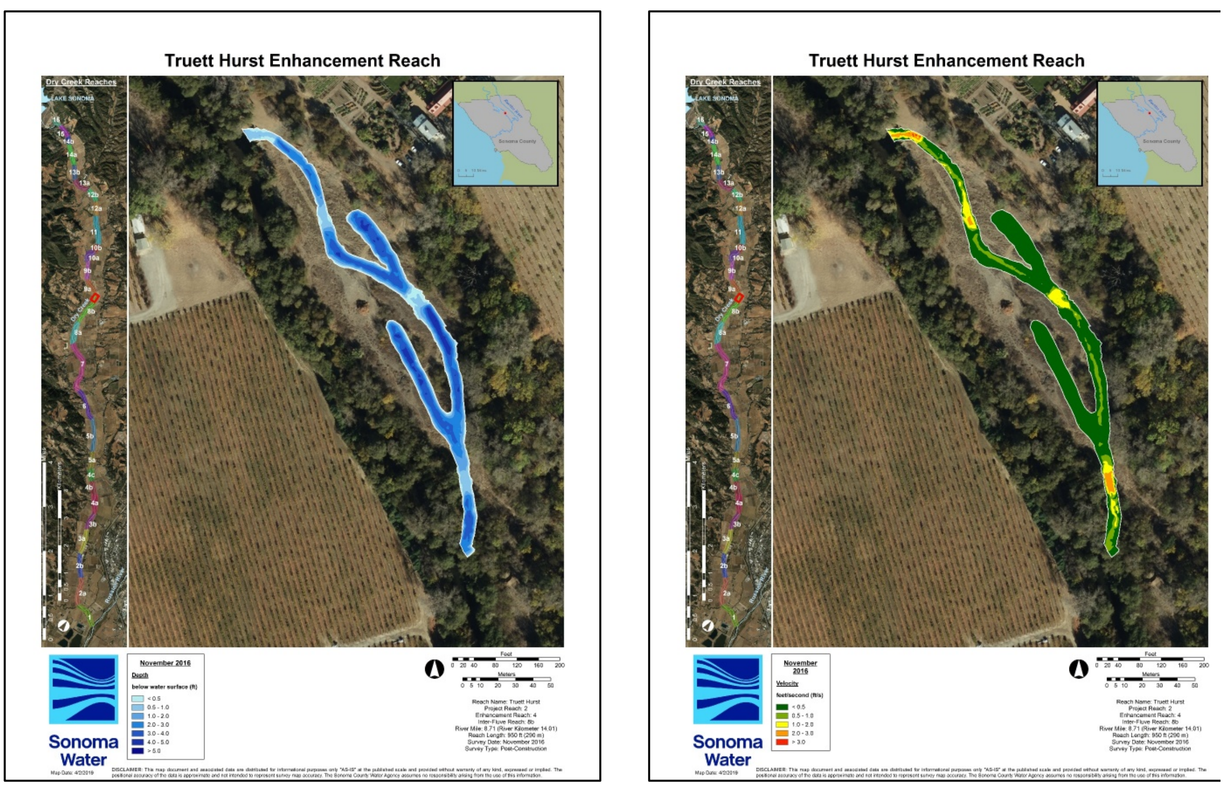


Figure 5.2.2. Digital elevation models (DEMs) created from spatially referenced depth and velocity points.

Habitat Types, Pool to Riffle Ratio, and Shelter Scores

We inventoried instream habitat units using descriptions from the California Salmonid Habitat Restoration Manual (Flosi et al. 2010). Differences in local channel gradient, water velocity, depth, and substrate size distinguish habitat types. Flosi et al. (2010) use four hierarchical levels to describe physical fish habitat, with each successive level providing greater detail. The most elementary descriptions (Levels 1 and 2) break stream channels into pool, riffle, or flatwater habitat types Successive levels differentiate habitat types by location within the stream channel (e.g., mid-channel pools, Level 3) or by cause or agent of formation (e.g., lateral-scour, log-formed pools, Level 4). In this survey, we inventoried habitat types to Level 2 and delineated upstream and downstream boundaries with nail spikes on the right and left bank. We surveyed the location of the nail spikes with a total station and processed the data within a GIS to create polygons of habitat types (Figure 5.2.3). After the inventory, we determined pool: riffle ratio to compare against the performance metric of 1:2 (0.5) to 2:1 (2.0) (Figure 5.2.3) (Porter et al. 2014).

Field crews determined the shelter value of individual habitat units within each enhancement site. Flosi et al. (2010) rates instream shelter by multiplying the complexity of available cover (0 = no shelter, 3 = highly complex shelter) by the overhead area occupied by that cover (0 = 0% of overhead area covered, 100 = 100% of overhead area covered) The maximum shelter value is 300 (3 [complexity of available cover within a habitat unit] * 100 [area of habitat unit covered]), with a score of ≥80 considered optimal within the AMP (Porter et al. 2014) (Figure 5.2.3).

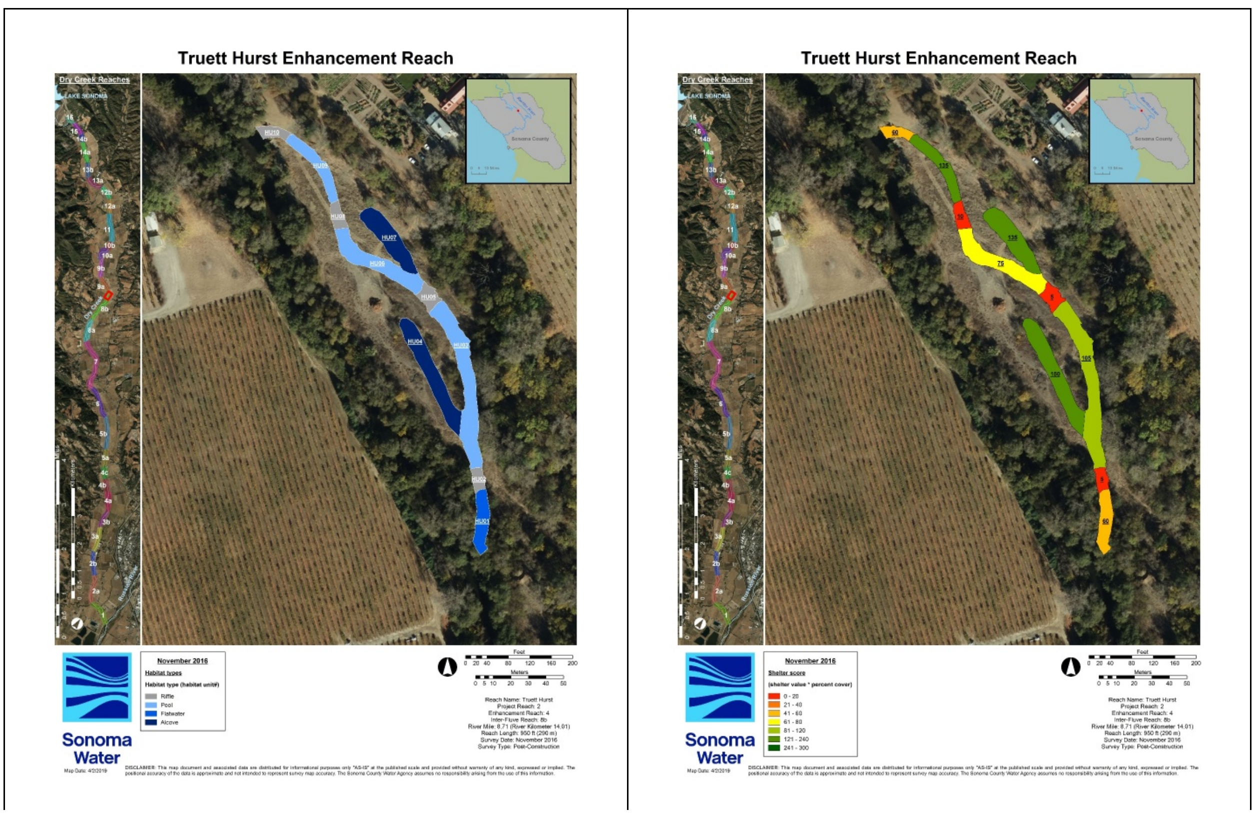


Figure 5.2.3. Example of inventoried habitat types and estimated shelter values within a Dry Creek habitat enhancement reach.

Effectiveness Ratings

We used modified monitoring checklists from the AMP to quantitatively and qualitatively evaluate enhancement features, habitat units, sites, and reaches. As noted above, the Joint Monitoring Team expanded checklists from Harris (2004) by incorporating quantitative metrics outlined in the RPA and to allow spatial rollup of the evaluation of project performance. The AMP included pre- and post-enhancement checklists for off-channel, in-channel, and areas along the bank for a total of six individual checklists (See Porter et al [2014], pp. 40-45). We modified off-channel and in-channel checklists to include bank areas, obviating the need for a bank stabilization checklist, and used the same checklists for pre-and post-enhancement, for a total of two individual checklists (Table 5.2.3 and Table 5.2.4). We standardized each checklist to ask the same number of questions, albeit with slightly different questions for off- and in-channel areas).

We retained the general order of the AMP checklist, but reclassified questions into spatially explicit data categories. The original AMP checklists ordered and grouped questions into several data categories (feature, depth/habitat, shelter, channel, velocity, and other) that included observations at multiple spatial scales (Table 5.2.3 and Table 5.2.4; see question 7: Current level II habitat type? [habitat unit scale]) and question 8: If an objective, did the feature create the targeted instream habitat type? [feature-scale]) are both in the depth/habitat category). We reclassified questions into data categories that evaluated enhancement features (feature data) or habitat units through hydraulic data and shelter data (habitat unit data) (Table 5.2.3 and Table 5.2.4). Grouping the questions facilitated the rollup from feature and habitat unit data into site and reach ratings.

Table 5.2.3. Off-channel effectiveness monitoring checklist showing original data category from the AMP (left column) and modified data category (right column).

ORIGINAL DATA CATEGORY	#	QUESTION	MODIFIED DATA CATEGORY
FEATURE	1.	LENGTH OF TARGETED TREATMENT (FT)	FEATURE DATA
	2.	WIDTH OF TARGETED TREATMENT: (FT)	FEATURE DATA
	3.	ESTIMATE AREA OF THE TARGETED FEATURE: (FT^2)	FEATURE DATA
	4.	STRUCTURAL CONDITION OF FEATURE: EXCL, GOOD, FAIR, POOR, FAIL	FEATURE DATA
	5a	ARE PROBLEMS WITH THE FEATURE VISIBLE?	FEATURE DATA
	5b	TYPES: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, OTH	FEATURE DATA
	6a	IS THE FEATURE STILL IN ITS ORIGINAL LOCATION?	FEATURE DATA
	6b	IS THE FEATURE STILL IN ITS ORIGINAL POSITION?	FEATURE DATA
	6c	IF YES: LBK, MDC, RBK, SPN, OTH	FEATURE DATA
	6d	IS THE FEATURE STILL IN ITS ORIGINAL ORIENTATON?	FEATURE DATA
	6e	IF YES: DNS, MUL, PRL, PRP, UPS, OTH	FEATURE DATA
DEPTH/HABITAT	7.	CURRENT LEVEL II HABITAT UNIT TYPE: FLT, POO, RIF, DRY, ALC, OTH	HABITAT UNIT (SHELTER) DATA
	8.	IF AN OBJECTIVE, DID THE FEATURE CREATE THE TARGETED INSTREAM HABITAT TYPE?	FEATURE DATA
	9.	WERE THERE ANY UNINTENDED EFFECTS BY THE FEATURE ON THE HABITAT TYPE? IF Y, COMMENT.	FEATURE DATA
	10.	MEAN WATER DEPTH IN HABITAT UNIT: FT	HABITAT UNIT (HYDRAULIC) DATA
	11a	MAXIMUM WATER DEPTH IN HABITAT UNIT: FT	HABITAT UNIT (HYDRAULIC) DATA
	11b	AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11c	AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11d	AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11e	% AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11f	% AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11g	% AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11h	IF AN OBJECTIVE, DID THE FEATURE INCREASE/DECREASE WATER DEPTH IN THE TREATMENT AREA?	FEATURE DATA
SHELTER	12a	TARGETED DEPTH OR RANGE (FT) IN HABITAT UNIT	HABITAT UNIT (SHELTER) DATA
	12b	ESTIMATE AREA OF FEATURE WITHIN TARGETED DEPTH OR RANGE FT^2:	FEATURE DATA
	13.	WERE THERE ANY UNINTENDED EFFECTS OF THE FEATURE ON THE WATER DEPTH? IF Y, COMMENT.	FEATURE DATA
	14.	INSTREAM SHELTER VALUE IN THE HABITAT UNIT: 0, 1, 2, 3	HABITAT UNIT (SHELTER) DATA
	15.	PERCENT OF HABITAT UNIT COVERED BY SHELTER: %	HABITAT UNIT (SHELTER) DATA
	16a	1ST DOMINANT COVER IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT (SHELTER) DATA
	16b	2ND DOMINANT IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT (SHELTER) DATA
	17a	IF AN OBJECTIVE, DID THE FEATURE INCREASE INSTREAM SHELTER RATING?	FEATURE DATA
	17b	A. CALCULATE THE SHELTER RATING FOR THE HABITAT UNIT: 0-300	HABITAT UNIT (SHELTER) DATA
	18a	LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L 6-20'	HABITAT UNIT (SHELTER) DATA
	18b	LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L >20'	HABITAT UNIT (SHELTER) DATA
	19a	IF AN OBJECTIVE, DID THE FEATURE INCREASE LWD COUNT IN THE HABITAT UNIT?	FEATURE DATA
	19b	LWD RECRUITMENT MECHANISMS IN HABITAT UNIT: ANC, EXC, EXH, INT, RPR, UNA, OTH	HABITAT UNIT (SHELTER) DATA
CHANNEL	20.	CURRENT STREAM CHANNEL PROBLEMS IN THE HABITAT UNIT: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH	HABITAT UNIT (SHELTER) DATA
	21a	IF AN OBJECTIVE, DID THE FEATURE LEAD TO THE TARGETED CHANNEL CONDITIONS?	FEATURE DATA
	21b	OVERALL OFFCHANNEL CONDITION (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH	FEATURE DATA
	21c	OUTLET CONDITIONS (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH	FEATURE DATA
	21d	INLET CONDITIONS (SITE): AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH	FEATURE DATA
	22.	WERE THERE ANY UNINTENDED EFFECTS ON THE STREAM CHANNEL AT THE FEATURE? IF Y, COMMENT.	FEATURE DATA
VELOCITY	23.	IF AN OBJECTIVE, DID THE FEATURE DECREASE/INCREASE VELOCITY IN THE TREATMENT AREA?	FEATURE DATA
	24.	TARGETED VELOCITY/RANGE IN THE HABITAT UNIT: (FT/SEC)	HABITAT UNIT (SHELTER) DATA
	25.	DID THE FEATURE ACHIEVE THE TARGETED VELOCITY?	FEATURE DATA
	26a	MEASURED MINIMUM VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT (HYDRAULIC) DATA
	26b	MEASURED MAX VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT (HYDRAULIC) DATA
	26c	MEASURED MEAN VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT (HYDRAULIC) DATA
	27.	AREA OF HABITAT UNIT WITHIN TARGETED VELOCITY: (FT^2)	HABITAT UNIT (HYDRAULIC) DATA
	28.	PERCENT OF HABITAT UNIT WITHIN TARGETED VELOCITY (SEE ABOVE): (%)	HABITAT UNIT (HYDRAULIC) DATA
	29.	WERE THERE ANY UNINTENDED EFFECTS OF FEATURE ON VELOCITY IF Y, COMMENT.	FEATURE DATA
OTHER	30a	1ST/2ND DOMINANT SUBSTRATE IN HABITAT UNIT: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT (SHELTER) DATA
	30b	2ND DOMINANT SUBSTRATE IN HABITAT UNIT: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT (SHELTER) DATA
	31.	IF AN OBJECTIVE, DID THE FEATURE ACHIEVE THE TARGETED SUBSTRATE COMPOSITION?	FEATURE DATA
	32.	% CANOPY MEASUREMENT:	HABITAT UNIT (SHELTER) DATA
	33.	PHOTOPOINT DATA COLLECTED: YES /NO	HABITAT UNIT (SHELTER) DATA
	34.	TEMPERATURE PROFILE: YES /NO	HABITAT UNIT (SHELTER) DATA
	35.	DISSOLVED OXYGEN PROFILE: YES/NO	HABITAT UNIT (SHELTER) DATA
RATING	36a	TOTAL HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36b	TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36c	TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36d	% HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36e	% HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36f	% HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	37.	DOES THIS FEATURE NEED: DEC, ENH, MNT, REP, NON, OTH	FEATURE DATA
	38.	ARE ADDITIONAL RESTORATION TREATMENTS RECOMMENDED AT THIS LOCATION?	FEATURE DATA

Table 5.2.4. In-channel effectiveness monitoring checklist showing original data category from the AMP (left column) and modified data category (right column).

ORIGINAL DATA CATEGORY	#	QUESTION	MODIFIED DATA CATEGORY
	1.	LENGTH OF TARGETED TREATMENT (FT)	FEATURE DATA
	2.	WIDTH OF TARGETED TREATMENT: (FT)	FEATURE DATA
	3.	ESTIMATE AREA OF THE TARGETED **FEATURE**: (FT^2)	FEATURE DATA
	4.	STRUCTURAL CONDITION OF **FEATURE**: EXCL, GOOD, FAIR, POOR, FAIL	FEATURE DATA
	5a	ARE PROBLEMS WITH THE **FEATURE** VISIBLE?	FEATURE DATA
FEATURE	5b	TYPES: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, OTH	FEATURE DATA
	6a	IS THE **FEATURE** STILL IN ITS ORIGINAL LOCATION?	FEATURE DATA
	6b	IS THE **FEATURE** STILL IN ITS ORIGINAL POSITION?	FEATURE DATA
	6c	IF YES: LBK, MDC, RBK, SPN, OTH	FEATURE DATA
	6d	IS THE **FEATURE** STILL IN ITS ORIGINAL ORIENTATON?	FEATURE DATA
	6e	IF YES: DNS, MUL, PRL, PRP, UPS, OTH	FEATURE DATA
	7.	CURRENT LEVEL II HABITAT TYPE: FLT, POO, RIF, DRY, ALC, OTH	HABITAT UNIT (SHELTER) DATA
	8.	IF AN OBJECTIVE, DID THE **FEATURE** CREATE THE TARGETED INSTREAM HABITAT TYPE?	FEATURE DATA
	9.	WERE THERE ANY UNINTENDED EFFECTS BY THE **FEATURE** ON THE HABITAT TYPE? IF Y, COMMENT.	FEATURE DATA
	10.	MEAN WATER DEPTH IN **HABITAT UNIT**: FT	HABITAT UNIT (HYDRAULIC) DATA
	11a	MAXIMUM WATER DEPTH IN **HABITAT UNIT**: FT	HABITAT UNIT (HYDRAULIC) DATA
DEPTH/HABITAT	11b	AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11c	AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11d	AREA OF **HABITAT UNIT** WITHIN 0.5-4.0 FT DEPTH: (FT2)	HABITAT UNIT (HYDRAULIC) DATA
	11e	% AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11f	% AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11g	% AREA OF **HABITAT** UNIT WITHIN 0.5-4.0 FT DEPTH	HABITAT UNIT (HYDRAULIC) DATA
	11h	IF AN OBJECTIVE, DID THE **FEATURE** INCREASE/DECREASE WATER DEPTH IN THE TREATMENT AREA?	FEATURE DATA
	12a	TARGETED DEPTH OR RANGE (FT) IN **HABITAT UNIT**	HABITAT UNIT (SHELTER) DATA
	12b	ESTIMATE AREA OF **FEATURE** WITHIN TARGETED DEPTH OR RANGE FT^2:	FEATURE DATA
	13.	WERE THERE ANY UNINTENDED EFFECTS OF THE **FEATURE** ON THE WATER DEPTH? IF Y, COMMENT.	FEATURE DATA
	14.	INSTREAM SHELTER VALUE IN THE **HABITAT UNIT**: 0, 1, 2, 3	HABITAT UNIT (SHELTER) DATA
	15.	PERCENT OF **HABITAT UNIT** COVERED BY SHELTER: %	HABITAT UNIT (SHELTER) DATA
	16a	1ST DOMINANT COVER IN **HABITAT UNI**T: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT (SHELTER) DATA
SHELTER	16b	2ND DOMINANT IN **HABITAT UNIT**: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT (SHELTER) DATA
	17a	IF AN OBJECTIVE, DID THE **FEATURE** INCREASE INSTREAM SHELTER RATING?	FEATURE DATA
	17b	A. CALCULATE THE SHELTER RATING FOR THE **HABITAT UNIT**: 0-300	HABITAT UNIT (SHELTER) DATA
	18a	LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L 6-20'	HABITAT UNIT (SHELTER) DATA
	18b	LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L >20'	HABITAT UNIT (SHELTER) DATA
	19a	IF AN OBJECTIVE, DID THE **FEATURE** INCREASE LWD COUNT IN THE **HABITAT UNIT**?	FEATURE DATA
	19b	LWD RECRUITMENT MECHANISMS IN **HABITAT UNIT**: ANC, EXC, EXH, INT, RPR, UNA, OTH	HABITAT UNIT (SHELTER) DATA
	20.	CURRENT STREAM CHANNEL PROBLEMS IN THE **HABITAT UNIT**: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH	HABITAT UNIT (SHELTER) DATA
CHANNEL	21a	IF AN OBJECTIVE, DID THE **FEATURE** LEAD TO THE TARGETED CHANNEL CONDITIONS?	FEATURE DATA
	21b	CONDITIONS AT THE **FEATURE**: AGG, FPD, GRC, INC, NAR, SIN, STB, TOG, WID, OTH	FEATURE DATA
	22.	WERE THERE ANY UNINTENDED EFFECTS ON THE STREAM CHANNEL AT THE **FEATURE**? IF Y, COMMENT.	FEATURE DATA
	23.	IF AN OBJECTIVE, DID THE **FEATURE** DECREASE/INCREASE VELOCITY IN THE TREATMENT AREA?	FEATURE DATA
	24.	TARGETED VELOCITY/RANGE IN THE **HABITAT UNIT**: (FT/SEC)	HABITAT UNIT (SHELTER) DATA
	25.	DID THE **FEATURE** ACHIEVE THE TARGETED VELOCITY?	FEATURE DATA
	26a	MEASURED MINIMUM VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT (HYDRAULIC) DATA
VELOCITY	26b	MEASURED MAX VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT (HYDRAULIC) DATA
	26c	MEASURED MEAN VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT (HYDRAULIC) DATA
	27.	AREA OF **HABITAT UNIT** WITHIN TARGETED VELOCITY: (FT^2)	HABITAT UNIT (HYDRAULIC) DATA
	28.	PERCENT OF **HABITAT UNIT** WITHIN TARGETED VELOCITY (SEE ABOVE): (%)	HABITAT UNIT (HYDRAULIC) DATA
	29.	WERE THERE ANY UNINTENDED EFFECTS OF **FEATURE** ON VELOCITY IF Y, COMMENT.	FEATURE DATA
	30a	1ST/2ND DOMINANT SUBSTRATE IN **HABITAT UNIT**: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT (SHELTER) DATA
	30b	2ND DOMINANT SUBSTRATE IN **HABITAT UNIT**: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT (SHELTER) DATA
	31.	IF AN OBJECTIVE, DID THE **FEATURE** ACHIEVE THE TARGETED SUBSTRATE COMPOSITION?	FEATURE DATA
OTHER	32.	% CANOPY MEASUREMENT:	HABITAT UNIT (SHELTER) DATA
	33.	PHOTOPOINT DATA COLLECTED: YES /NO	HABITAT UNIT (SHELTER) DATA
	34.	TEMPERATURE PROFILE: YES /NO	HABITAT UNIT (SHELTER) DATA
	35.	DISSOLVED OXYGEN PROFILE: YES/NO	HABITAT UNIT (SHELTER) DATA
	36a	TOTAL **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36b	TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36c	TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
RATING	36d	% **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36e	% **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	36f	% **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT (HYDRAULIC) DATA
	37.	DOES THIS **FEATURE** NEED: DEC, ENH, MNT, REP, NON, OTH	FEATURE DATA
	38.	ARE ADDITIONAL RESTORATION TREATMENTS RECOMMENDED AT THIS LOCATION?	FEATURE DATA

Feature Ratings

From the modified checklists, we reduced the number of questions used to rate each enhancement feature to focus on feature condition, function, and apparent effect on habitat. The modified checklists for off- and in-channel areas contain up to 30 questions in the feature data category, including questions with multiple parts (e.g., Question 21; Table 5.2.3 and Table 5.2.4). We reduced the list to 11 questions with each response assigned a numeric score (Table 5.2.5). The sum of the numeric scores for each feature (up to 15 points) corresponds to a qualitative rating ranging from excellent to fail. We used the reduced list to score and rate each feature, but still answered the full list of questions for each feature (see completed checklists in Appendices). The full list provides ancillary qualitative information beyond the reduced list, but the reduced list directly evaluates feature condition, function, and effect on habitat, and is more efficient given the number of features in the Dry Creek Habitat Enhancement Project (>500 as of August 2019) and the number of feature data questions in the original and modified AMP checklists.

Habitat Unit Ratings

We also reduced the number of questions used to rate habitat units to focus on area of hydraulic habitat and shelter data and to directly evaluate performance relative to primary performance measures (Table 5.2.6). The modified checklists for off- and in-channel areas each contain 40 habitat unit data questions, including questions with multiple parts (e.g., Question 16; Table 5.2.3 and Table 5.2.4). The reduced list of habitat unit data questions includes shelter value, percent overhead cover, and the calculated shelter score, with each response assigned a numeric score (Table 5.2.6). The reduced list of habitat unit data questions also includes the percent area of a habitat unit within optimal depth (0.5–2.0 ft; 2.0–4.0 ft) and velocity (≤0.5 ft/s) ranges, both singly and in combination, as specified in the BO and AMP, each assigned a numeric score (Table 5.2.6). The sum of the numeric scores for habitat units (up to 35 points) determines a qualitative rating ranging from excellent to fail. As with feature data, we still answered the full list of questions for each habitat unit (see completed checklists in Appendix 5.1). But, the reduced list directly evaluates habitat unit shelter and hydraulic habitat, which are primary performance measures in the AMP, and is more efficient given the number of habitat units evaluated for the Dry Creek Habitat Enhancement Project (>700 as of August 2019) and the number of habitat unit data questions in the original and modified AMP checklists.

Table 5.2.5. Feature data questions used to rate each enhancement feature, the highest numerical score assigned to each response, and the qualitative rating assigned to the range of quantitative ratings.

Question #	Question	Highest possible score
4.	Structural condition of feature[a]	5
5a	Are problems with the feature visible?[b]	1
6a	Is the feature still in its original location?[c]	1
6b	Is the feature still in its original position?[c]	1
6d	Is the feature still in its original orientation?[c]	1
8.	Did the feature create the targeted instream habitat type?[c]	1
9.	Were there any unintended effects by the feature on the habitat type?[b]	1
17a	Did the feature increase instream shelter rating?[c]	1
19a	Did the feature increase LWD count in the habitat unit?[c]	1
21a	Did the feature lead to the targeted channel conditions?[c]	1
25.	Did the feature achieve the targeted velocity?[c]	1
Feature quantitative rating	**(sum of above)**	**15**
Feature qualitative rating: Excellent (≥12), Good (≥9), Fair (≥6), Poor (≥3), Fail (<3)		**Excellent**

[a]Excellent = 5 points; Good = 4 point; Fair = 3 points; Poor = 2 points; Fail = 1 point
[b]Yes = 0 points; No = 1 point
[c]Yes = 1 point; No = 0 points

Table 5.2.6. Habitat unit data questions used to rate each habitat unit, the highest numerical score assigned to each response, and the qualitative rating assigned to the range of quantitative ratings.

Question #	Question	Highest possible score
11e	% Area of **habitat unit** within 0.5 -2.0 ft depth[a]	4
11f	% Area of **habitat unit** within 2.0 -4.0 ft depth[a]	4
14.	Instream shelter value in the **habitat unit**: 0, 1, 2, 3[b]	5
15.	Percent of **habitat unit** covered by shelter: %[c]	5
17b	a. Calculate the shelter rating for the **habitat unit**: 0-300[d]	5
28.	Percent of **habitat unit** within targeted velocity (see above): (%)[a]	4
36e	% **habitat unit** area where < 0.5 f/s; 0.5 to 2 ft and shelter criteria overlap[a]	4
36f	% **habitat unit** area where < 0.5 f/s; 2 to 4 ft and shelter criteria overlap[a]	4
Habitat unit quantitative rating (out of 35)	**(sum of above)**	**35**
Habitat unit qualitative rating: Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)		**Excellent**

[a]≥40% = 4 points; ≥30% = 3 points; ≥20% = 2 points; ≥10% = 1 point, ; ≥5% = 0 points
[b]3 = 5 points; 2 = 4 points, 1 = 3 points, 0 = 0 points
[c]≥80% = 5 points; ≥60% = 4 points; ≥40% = 3 points; ≥20% = 2 points; ≥10% = 1 point; <10% = 0 points
[d]≥140 = 5 points; ≥100 = 4 points; ≥80 = 3 points; ≥60 = 2 points; ≥40 = 1 point; <40 = 0 points

Site and Enhancement Reach Ratings

Data collected at the feature and habitat unit scale provide the basis to evaluate and rate sites and enhancement reaches (Table 5.2.7). The sum of the site average feature and site average habitat unit ratings determines the site quantitative rating (up to 50 points), which is converted to a site qualitative rating, ranging from excellent to fail, similar to ratings for features and habitat units. Following the upward progression of spatial scales, the average of all sites within an enhancement reach determines the enhancement reach quantitative and qualitative ratings (Table 5.2.7).

Table 5.2.7. Spatial roll-up of site average feature and habitat unit ratings into site and enhancement reach rating using an enhancement reach with three sites as an example. The sum of the site average feature and habitat unit ratings determine the site quantitative and qualitative rating. The average of site ratings determines the enhancement reach quantitative and qualitative rating.

	Site number	**1**	**2**	**3**
Site average feature rating	Site average feature quantitative rating[a]	15	15	15
	Site average feature qualitative rating[a]	Excellent	Excellent	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	35	35	35
	Site average qualitative rating[b]	Excellent	Excellent	Excellent
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	50	50	50
	Site qualitative rating[c]:	Excellent	Excellent	Excellent
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	50		
	Enhancement reach qualitative rating[c]:	Excellent		

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

Monitoring Frequency

The AMP recommended monitoring sites at three different time periods: prior to enhancement (pre-enhancement), just after enhancement (post-enhancement), and following a geomorphically effective flow (post-effective flow) (Porter et al. 2014). Pre-enhancement surveys include depth, velocity, habitat type and shelter value, but do not include feature data, as feature installation occurs during construction. Accordingly, pre-enhancement site and enhancement reach ratings do not include feature ratings. Post-enhancement surveys occur after construction and include quantitative ratings and qualitative ratings of all spatial scales (feature, habitat unit, site, and enhancement reach). The AMP also recommends collecting data after a geomorphically effective flow (the flow [discharge] responsible for transporting the largest volume of sediment in a river or stream over the long-term). In the absence of a geomorphically effective discharge, the AMP recommends collecting data within three years after construction (Porter et al. 2014). Inter-Fluve (2013) found that the geomorphically effective flow in Dry Creek occurred at a return period of less than one year (i.e., annually or sub-annually). Following this, post-effective flow surveys typically occurred the following spring or summer after construction. After the initial post-effective flow survey, Sonoma Water surveys each site every three years.

We also added a post-repair monitoring time-period. The AMP recommends future outcomes (actions) for enhancement reaches receiving low ratings (fair to fail) that range from corrective action (repair or modification) to a reduction in potential habitat credit, to abandonment of features, sites, or enhancement reaches (Table 5.2.2). If Sonoma Water repaired or modified a site, we conducted post-repair effectiveness monitoring shortly after repairs or modifications. We added post-repair to the monitoring frequency categories to differentiate from post-enhancement monitoring that occurs after a site is newly constructed. We will include this category as necessary in future monitoring reports.

Results

During the summer and fall 2019, Sonoma Water effectiveness monitored nine enhancement reaches totaling nearly 600,000 ft^2 on mainstem Dry Creek, side channels, and alcoves (Table 5.2.8, Figure 5.2.4). Fields crews collected over 28,000 depth and velocity points, evaluated 488 features for their condition, and evaluated 187 habitat units for their hydraulic (depth and velocity) and shelter characteristics. The monitored enhancement reaches stretch from Reach 2b (as defined by Inter-Fluve 2012, River Mile [RM] 1.67) to Reach 15 (RM 13.29) (Figure 5.2.4). We monitored and rated the post-enhancement condition of one newly constructed enhancement reach (Gallo; see Post-enhancement results below), and monitored and rated eight enhancement reaches post-effective flow (Army Corps, Army Corps Reach 14, Weinstock, Truett-Hurst, Farrow Wallace, Ferrari-Carano, Olson, Meyer, City of Healdsburg Yard, and Geyser Peak; see Post-effective flow results below). Sonoma Water constructed the Army Corps Reach 14, Weinstock, and Ferrari-Carano, Olson enhancement reaches in 2018 and this is the first post-effective flow effectiveness monitoring survey for both enhancement reaches. The results below summarize effectiveness monitoring results for post-enhancement and post-effective flow time periods by enhancement reach. We did not conduct any pre-enhancement or post-repair monitoring. Each summary describes the amount of habitat monitored within each main and side channel area, the area and percent of the enhancement reach meeting depth and velocity criteria, habitat types, shelter scores, and pool to riffle ratio. We also summarize the feature and habitat unit ratings that inform the site ratings, and the roll-up of site ratings into the enhancement reach rating.

Table 5.2.8. Dry Creek enhancement reaches monitored in 2019, type of monitoring conducted, and area of aquatic habitat monitored. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River) (-- indicates monitoring not conducted).

Enhancement Reach	Pre-enhancement (ft^2)	Post-enhancement (ft^2)	Post-effective Flow (ft^2)	Post-repair (ft^2)
Army Corps	--		28,207	--
Army Corps Reach 14	--	--	74,541	--
Weinstock	--	--	46,140	--
Gallo	--	78,841		--
Truett Hurst	--	--	81,137	--
Farrow, Wallace	--		73,824	--
Ferrari-Carano Olson	--	--	110,660	--
City of Healdsburg Yard	--	--	59,426	--
Geyser Peak	--	--	42,954	--
TOTAL (ft^2)		**78,841**	**516,890**	
GRAND TOTAL (ft^2)	**595,731**			

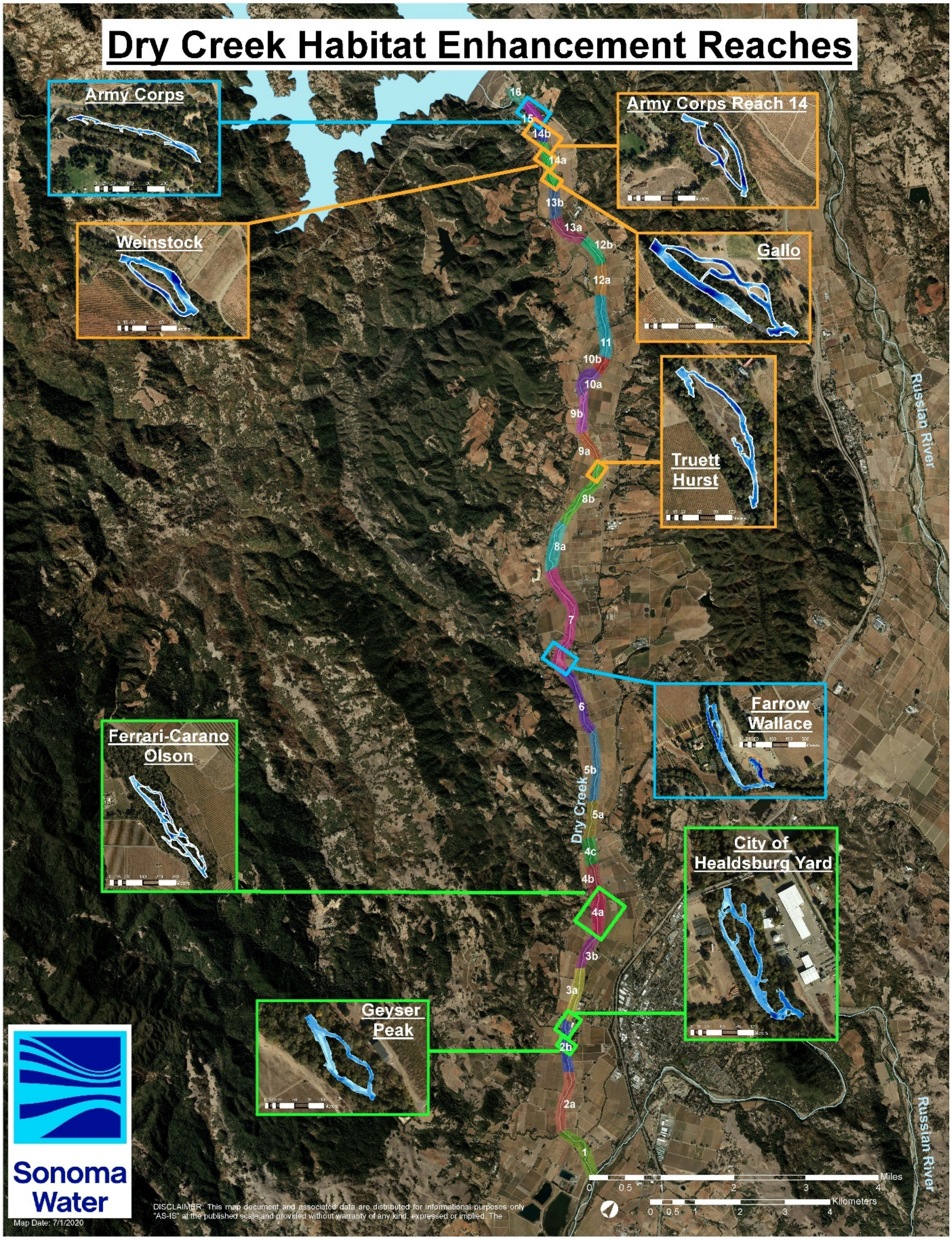


Figure 5.2.4. Location of Dry Creek habitat enhancement reaches monitored in 2019.

Post-enhancement

Gallo Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Gallo enhancement reach in September 2019. Previous effectiveness monitoring surveys occurred in June 2018 (pre-enhancement), receiving a fair rating. The enhanced reach encompassed 78,841 ft^2 within main- and off-channel areas of Dry Creek with 33% of the total area meeting optimal depth and velocity criteria (Table 5.2.9, Figure 5.2.5,). The monitoring characterized 34,281 ft^2 of side channel area, of which 44% met optimal depth and velocity criteria, compared with 44,560 ft^2 and 25% for the main channel area. Seventeen habitat units composed the enhancement reach, with a pool to riffle ratio of 9:7 (1.29) and average shelter score of 75 (Table 5.2.10, Figure 5.2.6, Figure 5.2.7). Eight habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised two enhancement sites (one main-channel, one side channel; Table 5.2.11, Figure 5.2.8), with excellent site average feature ratings, and fair average habitat unit ratings (Figure 5.2.9, Figure 5.2.10). Enhancement sites received fair to good ratings (Figure 5.2.11). Overall, the Gallo enhancement reach received a good effectiveness monitoring rating (Figure 5.2.12; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.9. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Gallo enhancement reach, September 2019.

Gallo Post-enhancement September 2019	Wetted area (ft^2)	Optimal depth (ft^2): 0.5 – 2.0 ft	Optimal depth (ft^2): 2.0 – 4.0 ft	Optimal depth (ft^2): Total	Optimal velocity (ft^2): < 0.5 ft/s	Optimal habitat (ft^2): 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2): 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2): Total
Main channel area	44,560	17,445	14,701	32,146	19,052	5,542	5,679	11,221
Side channel area	34,281	12,531	11,961	24,492	22,276	6,857	8,160	15,017
Total area	**78,841**	**29,976**	**26,662**	**56,637**	**41,328**	**12,399**	**13,839**	**26,238**
Main channel % of wetted area	57%	39%	33%	72%	43%	12%	13%	25%
Side channel % of wetted area	43%	37%	35%	71%	65%	20%	24%	44%
Total % of wetted area	**100%**	**38%**	**34%**	**72%**	**52%**	**16%**	**18%**	**33%**

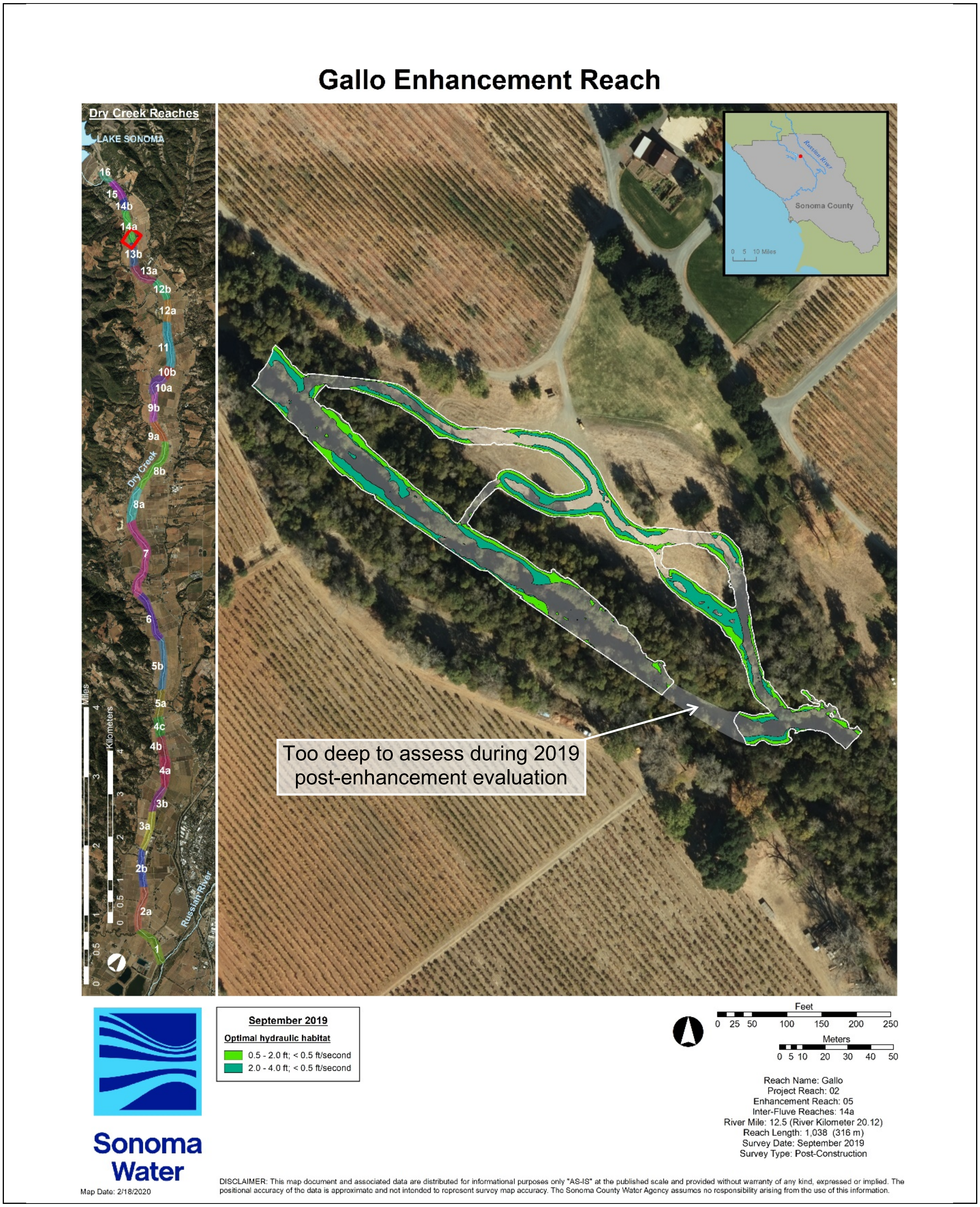


Figure 5.2.5. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Gallo enhancement reach, September 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.10. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Gallo enhancement reach, Post-enhancement September 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	20	40
HU02	Pool	3	50	150
HU03	Alcove	1	25	25
HU04	Riffle	3	50	150
HU05	Pool	3	25	75
HU06	Riffle	2	20	40
HU07	Pool	2	15	30
HU08	Pool	3	30	90
HU09	Riffle	3	30	90
HU10	Pool	3	30	90
HU11	Riffle	1	5	5
HU12	Pool	3	30	90
HU13	Riffle	3	60	180
HU14	Riffle	3	30	90
HU15	Riffle	1	10	10
HU16	Pool	3	20	60
HU17	Riffle	3	20	60
Pool: riffle	**9:7 (1.29)**			**Avg = 75**

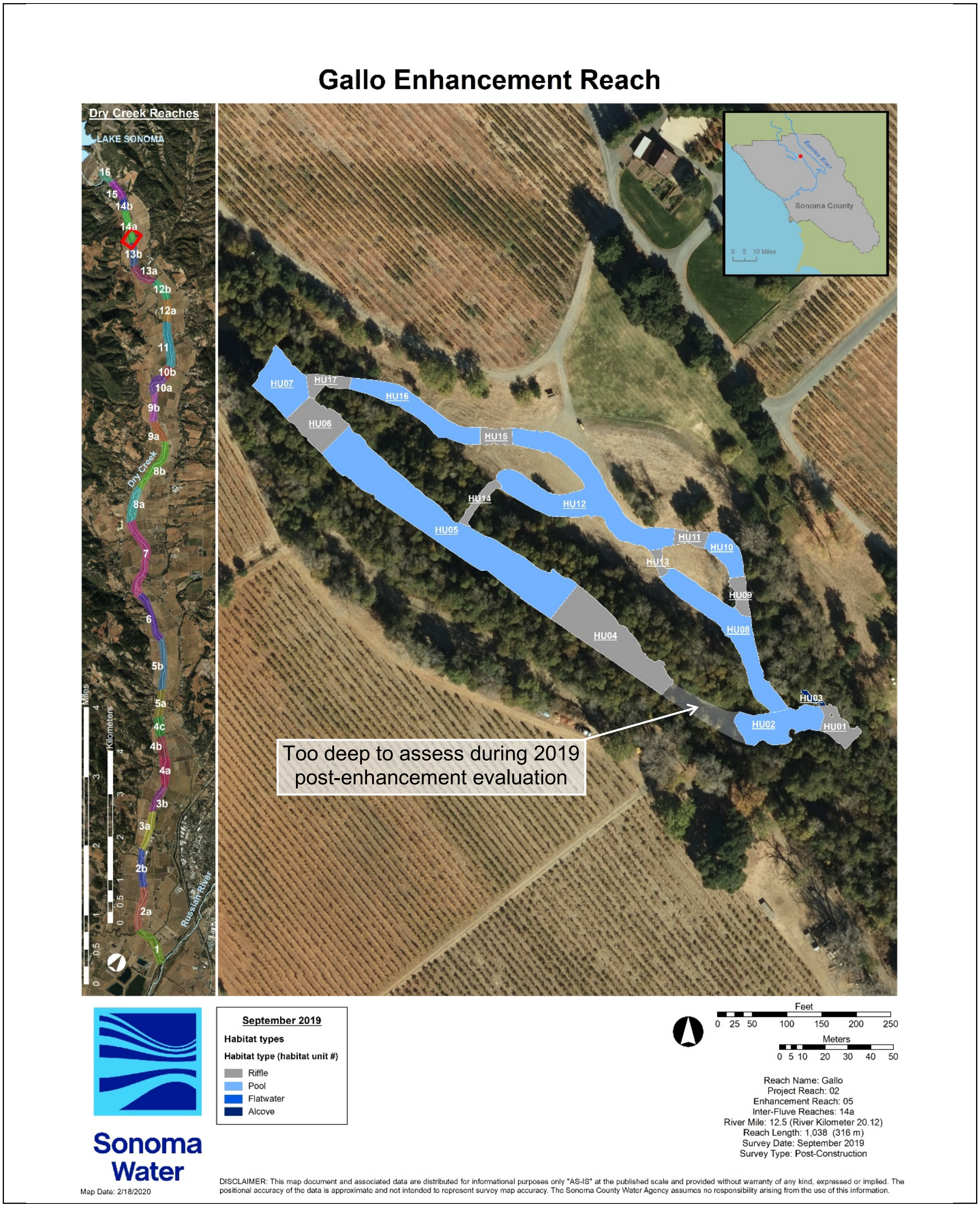


Figure 5.2.6. Habitat unit number and type within the Gallo enhancement reach, September 2019.

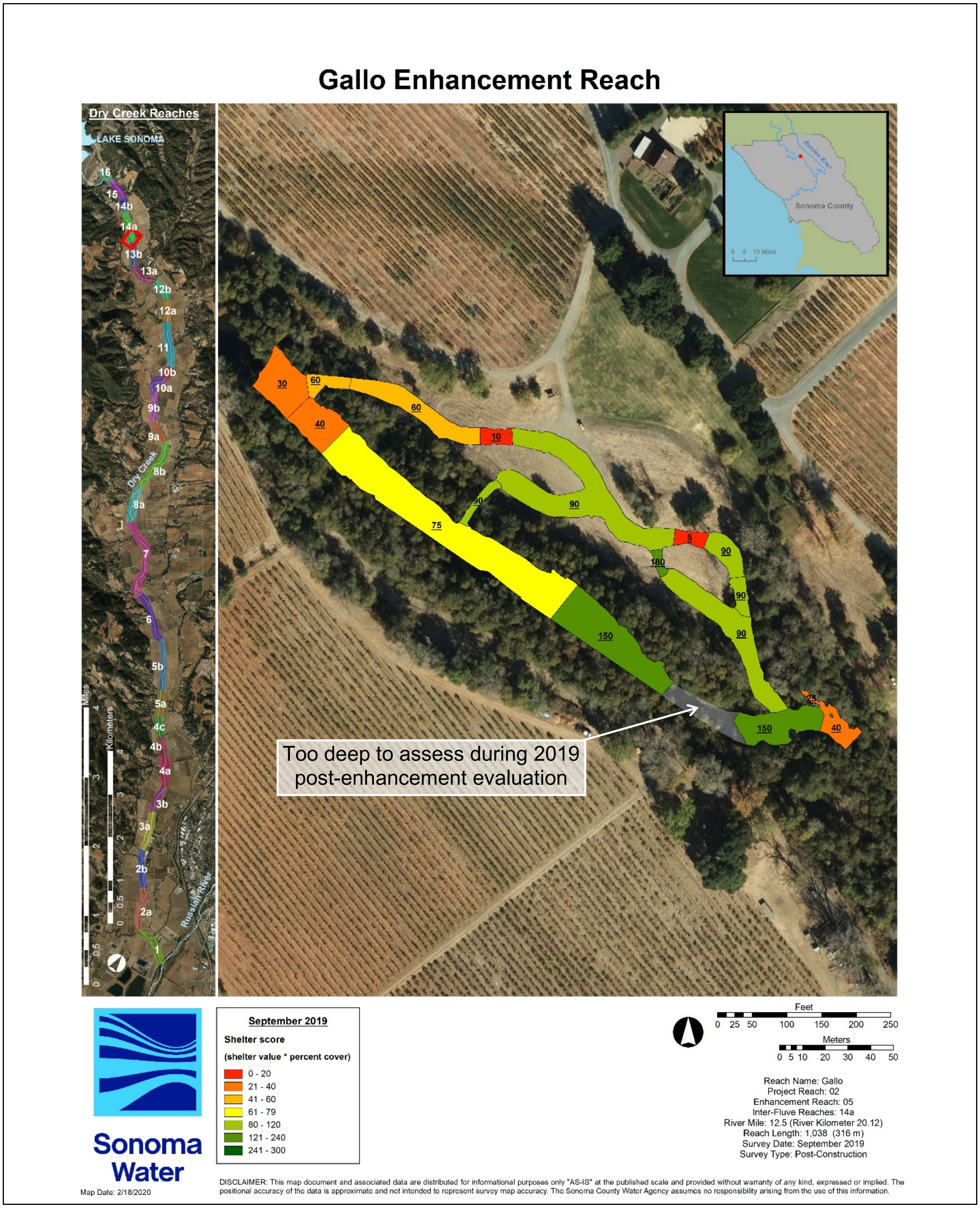


Figure 5.2.7. Habitat unit shelter scores within the Gallo enhancement reach, September 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.11. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Gallo enhancement reach, September 2019.

Site number		**1**	**2**		
Site type		Main channel	Side channel		
Site average feature rating	Site average feature quantitative rating[a]	14	14		
	Site average feature qualitative rating[a]	Excellent	Excellent		
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	17	16		
	Site average qualitative rating[b]	Fair	Fair		
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	31	29		
	Site qualitative rating[c]	Good	Fair		
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	30			
	Enhancement reach qualitative rating[c]:	Good			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

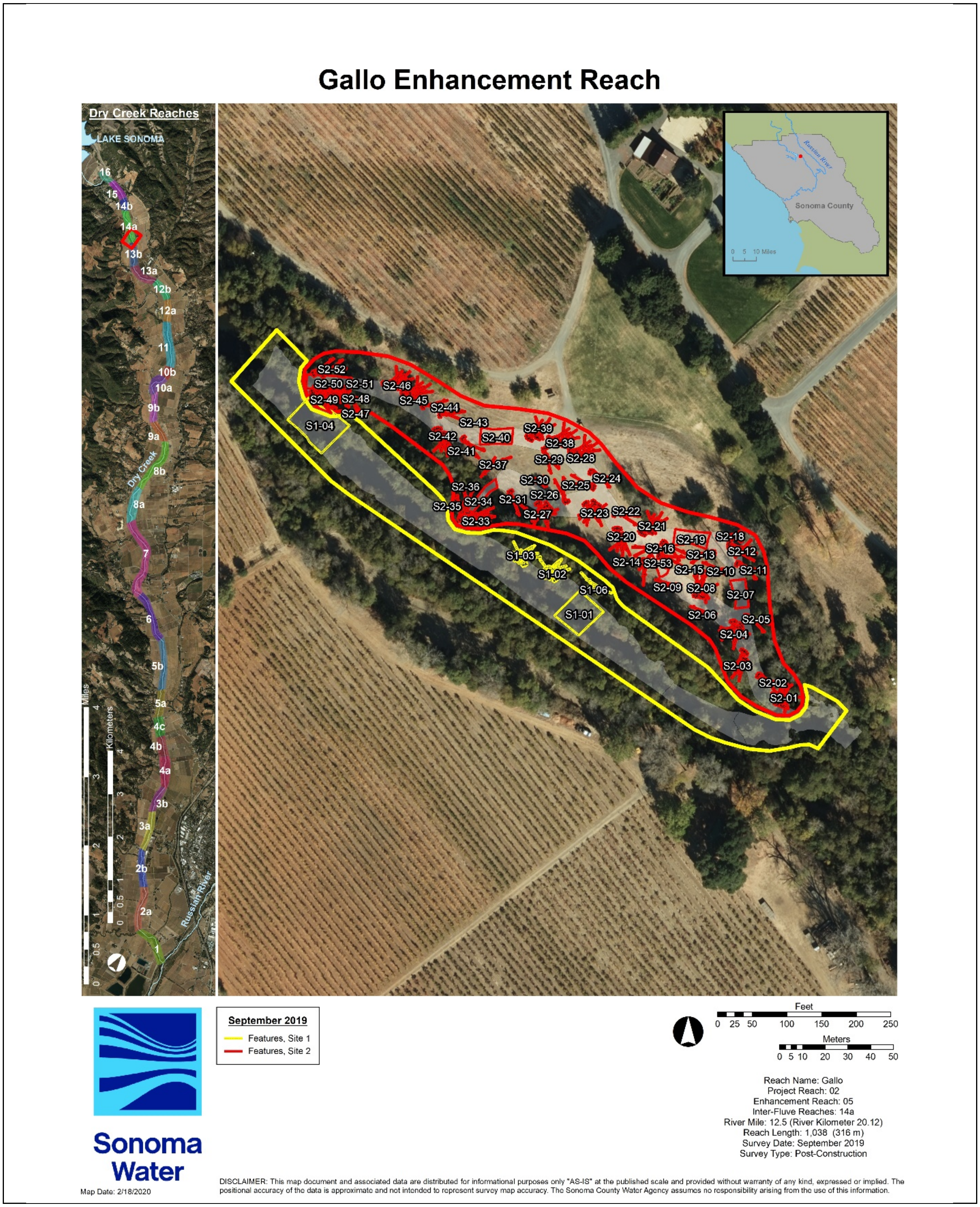


Figure 5.2.8. Enhancement sites and features within the Gallo enhancement reach, September 2019.

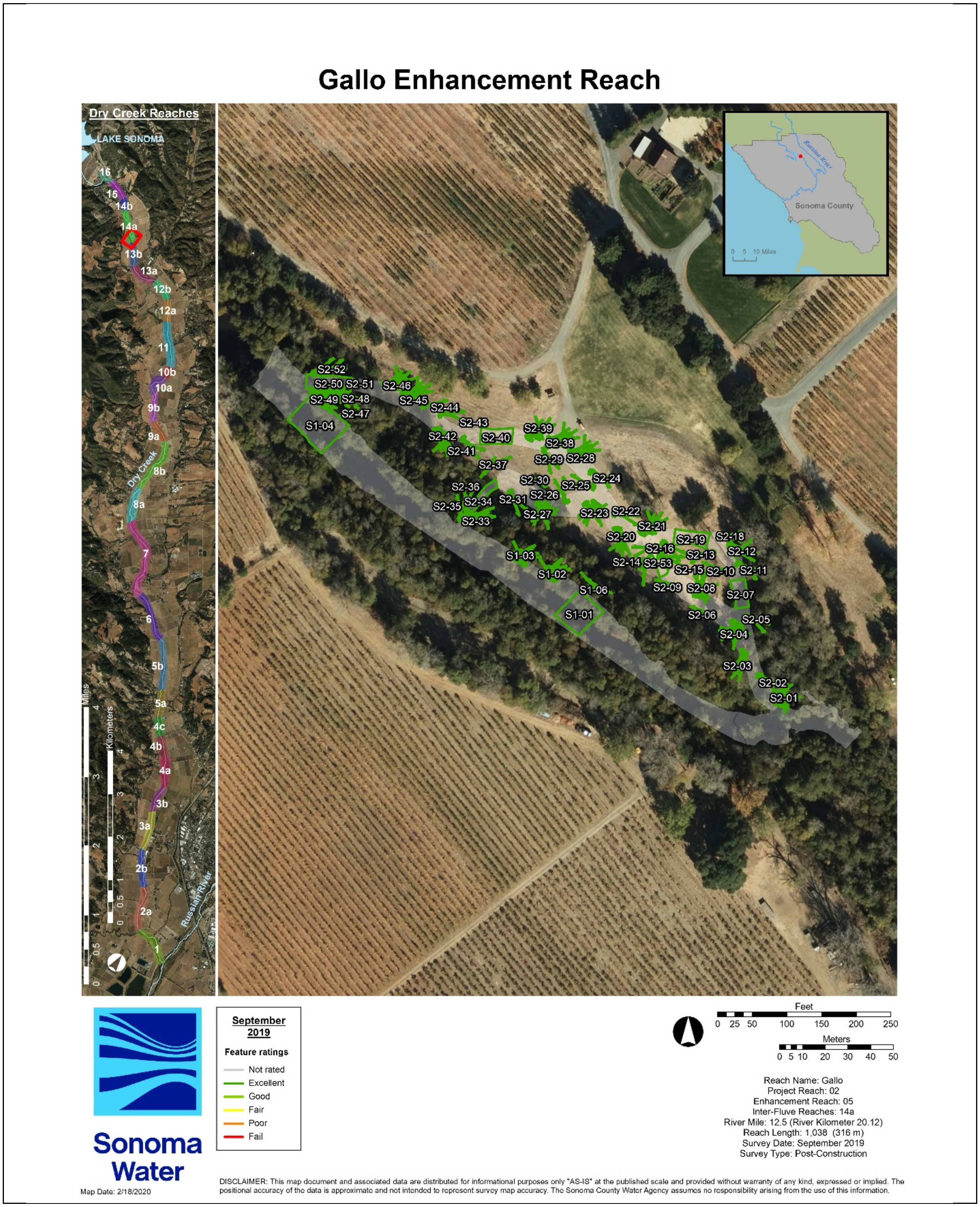


Figure 5.2.9. Feature ratings for the Gallo enhancement reach, September 2019.

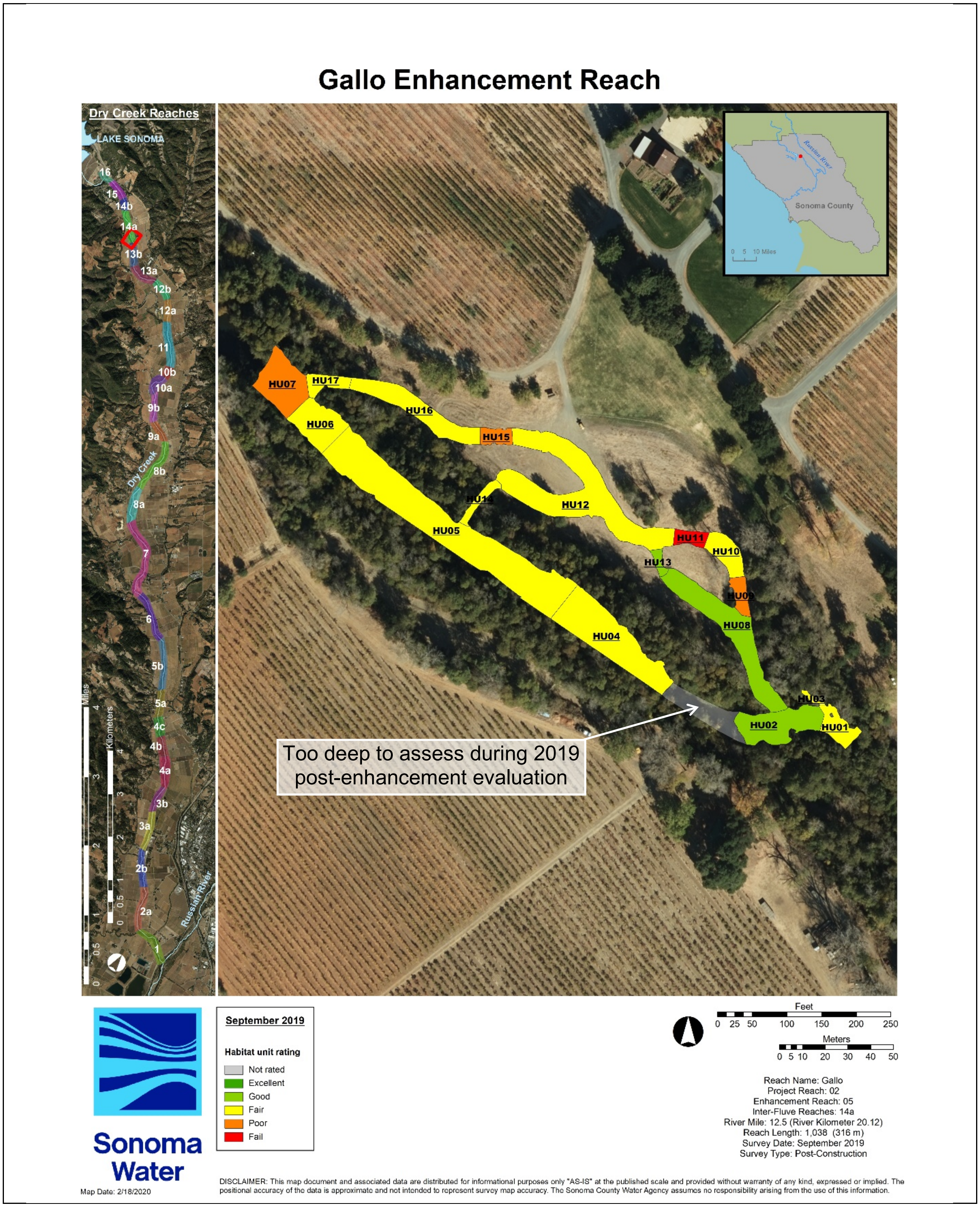


Figure 5.2.10. Habitat unit ratings for the Gallo enhancement reach, September 2019.

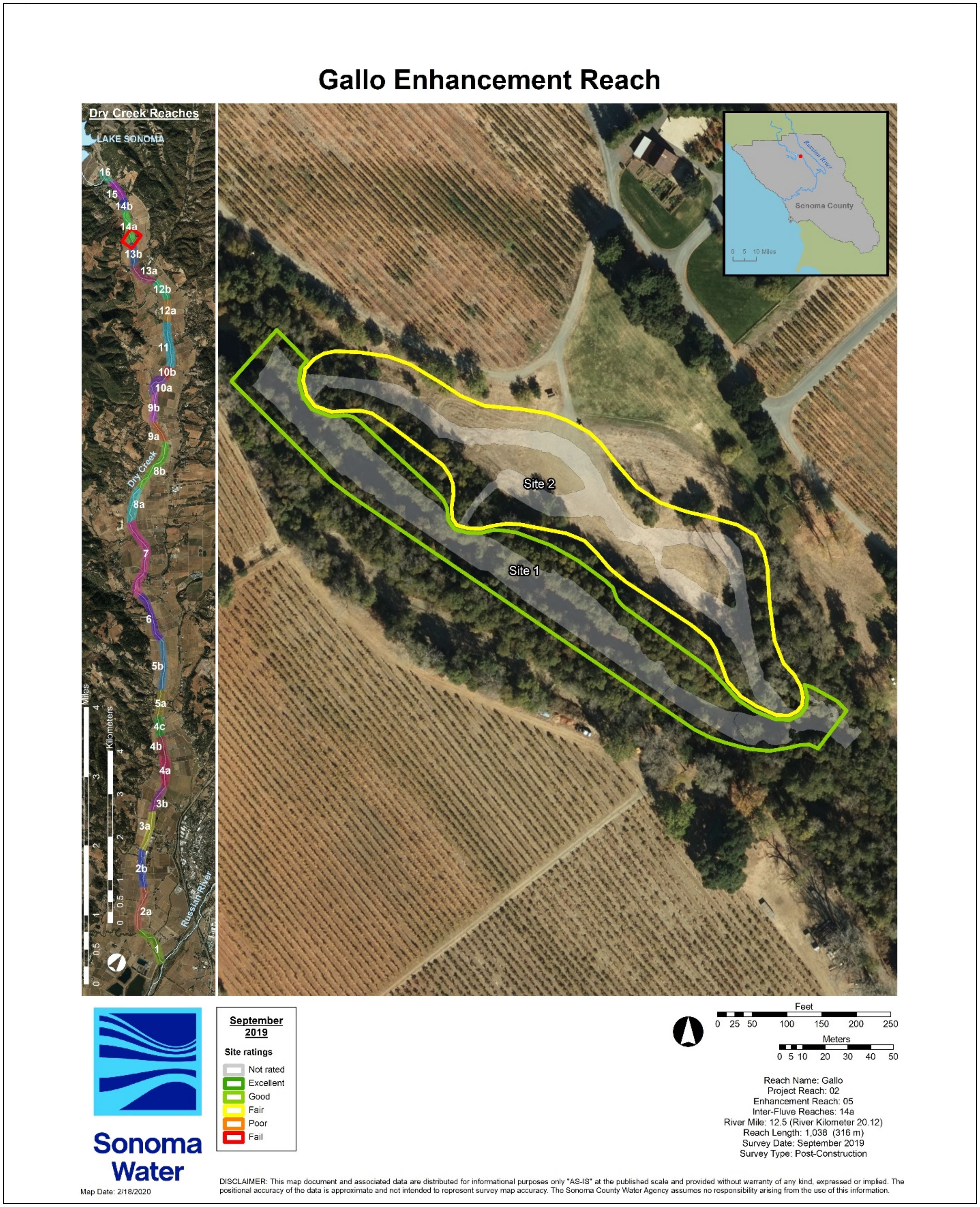


Figure 5.2.11. Post enhancement site ratings for the Gallo enhancement reach, September 2019.

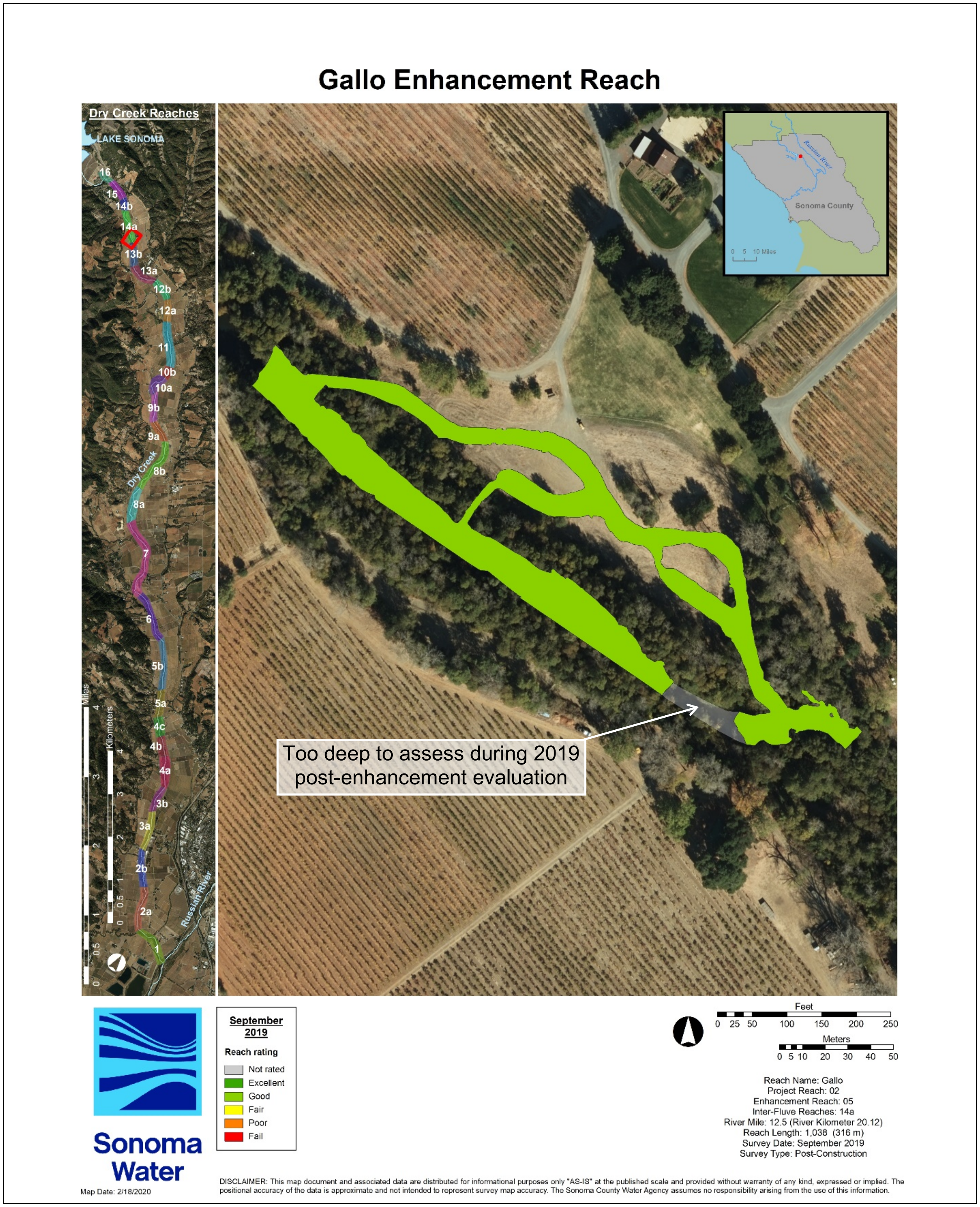


Figure 5.2.12. Post-enhancement reach rating for the Gallo enhancement reach, September 2019.

Post-effective Flow

Summary

Sonoma Water monitored the post-effective flow conditions of the Army Corps, Army Corps Reach 14, Weinstock, Truett Hurst, Farrow Wallace, Ferrari-Carano-Olson, City of Healdsburg Yard, Geyser Peak enhancement reaches in 2019 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 535,005 ft^2 within main- and off-channel areas, with 28% of the total area meeting optimal depth and velocity criteria (Table 5.2.12). Monitoring examined 160,898 ft^2 of off-channel area, of which 44% met optimal depth and criteria, compared with 369,107 ft^2 and 21% in the main channel. Crews observed 171 habitat units across all enhancement reaches with a total pool to riffle ratio of 70:44 (1.59) and a total average shelter score of 72 (Table 5.2.13). Average alcove shelter score (97, n = 13) and average pool shelter score (95, n = 70) exceeded the optimum shelter score of 80, followed by flatwaters (52, n = 44), and riffles (44, n = 48). Post-effective flow, the Army Corps, Weinstock, Truett Hurst, and Geyser Peak enhancement reaches rated good, and Army Corps Reach 14, Farrow Wallace, Ferrari-Carano, Olson, and City of Healdsburg Yard rated fair (Table 5.2.14; see below for individual enhancement reach summaries and Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.12. Post-effective flow areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement surveyed in 2019.

Dry Creek Post-effective Flow 2019	**Wetted area (ft^2)**	**Optimal depth (ft^2) 0.5 – 2.0 ft**	**Optimal depth (ft^2) 2.0 – 4.0 ft**	**Optimal depth (ft^2) Total**	**Optimal velocity (ft^2) < 0.5 ft/s**	**Optimal habitat (ft^2) 0.5 – 2.0 ft < 0.5 ft/s**	**Optimal habitat (ft^2) 2.0 – 4.0 ft < 0.5 ft/s**	**Optimal habitat (ft^2) Total**
Main channel area	360,764	92,689	95,395	288,084	124,414	48,220	27,156	75,376
Off channel area	156,125	73,757	42,223	115,980	99,112	47,305	21,805	69,110
Total area	516,890	266,446	137,619	404,064	223,526	95,526	48,961	144,486
Main channel % of wetted area	70%	53%	26%	80%	34%	13%	8%	21%
Off channel % of wetted area	30%	47%	27%	74%	63%	30%	14%	44%
Total % of wetted area	**100%**	52%	27%	78%	43%	18%	9%	28%

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.13. Post-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches surveyed in 2019, Post-effective flow.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	44	48
Pool	70	95
Flatwater	44	52
Alcove	13	97
Pool: riffle	**70:44 (1.59)**	**Avg: 72**

Reach ratings

Table 5.2.14. Post-enhancement ratings for Dry Creek enhancement reaches surveyed in 2019.

Enhancement Reach	Post-effective Flow Rating
Army Corps	Good
Army Corps Reach 14	Good
Weinstock	Good
Truett Hurst	Fair
Farrow, Wallace	Good
Ferrari-Carano Olson	Fair
City of Healdsburg Yard	Poor
Geyser Peak	Fair

Army Corps Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Army Corps enhancement reach in October 2019. Previous effectiveness monitoring surveys occurred in November 2015 (post-effective flow) and September 2016 (post-effective flow) receiving an excellent rating in both instances (Table 5.2.41). The monitored area encompassed 28,207 ft^2 within a side channel, with 71% of the total area meeting optimal depth and velocity criteria (Table 5.2.15, Figure 5.2.13). Eighteen habitat units composed the enhancement reach, with a pool to riffle ratio of 7:2 (3.50) and average shelter score of 102 (Table 5.2.16, Figure 5.2.14, Figure 5.2.15). Nine habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised six enhancement sites (all side channel sites, including connections to the main channel; Table 5.2.17, Figure 5.2.16), with excellent site average feature ratings, and fair to good site average habitat unit ratings (Table 5.2.17, Figure 5.2.17, Figure 5.2.18). Enhancement sites received fair to good ratings (Table 5.2.17, Figure 5.2.19). Overall, the Army Corps enhancement reach received a good effectiveness monitoring rating (Table 5.2.17, Figure 5.2.20 ; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.15. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Army Corps enhancement reach, October 2019.

USACE reach 15 Post-effective flow October 2019	Wetted area (ft^2)	Optimal depth (ft^2): 0.5 – 2.0 ft	Optimal depth (ft^2): 2.0 – 4.0 ft	Optimal depth (ft^2): Total	Optimal velocity (ft^2): < 0.5 ft/s	Optimal habitat (ft^2): 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2): 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2): Total
Side channel area	28,207	17,137	4,107	21,244	26,976	16,019	4,105	20,125
Side channel % of area	100%	61%	15%	75%	96%	57%	15%	71%

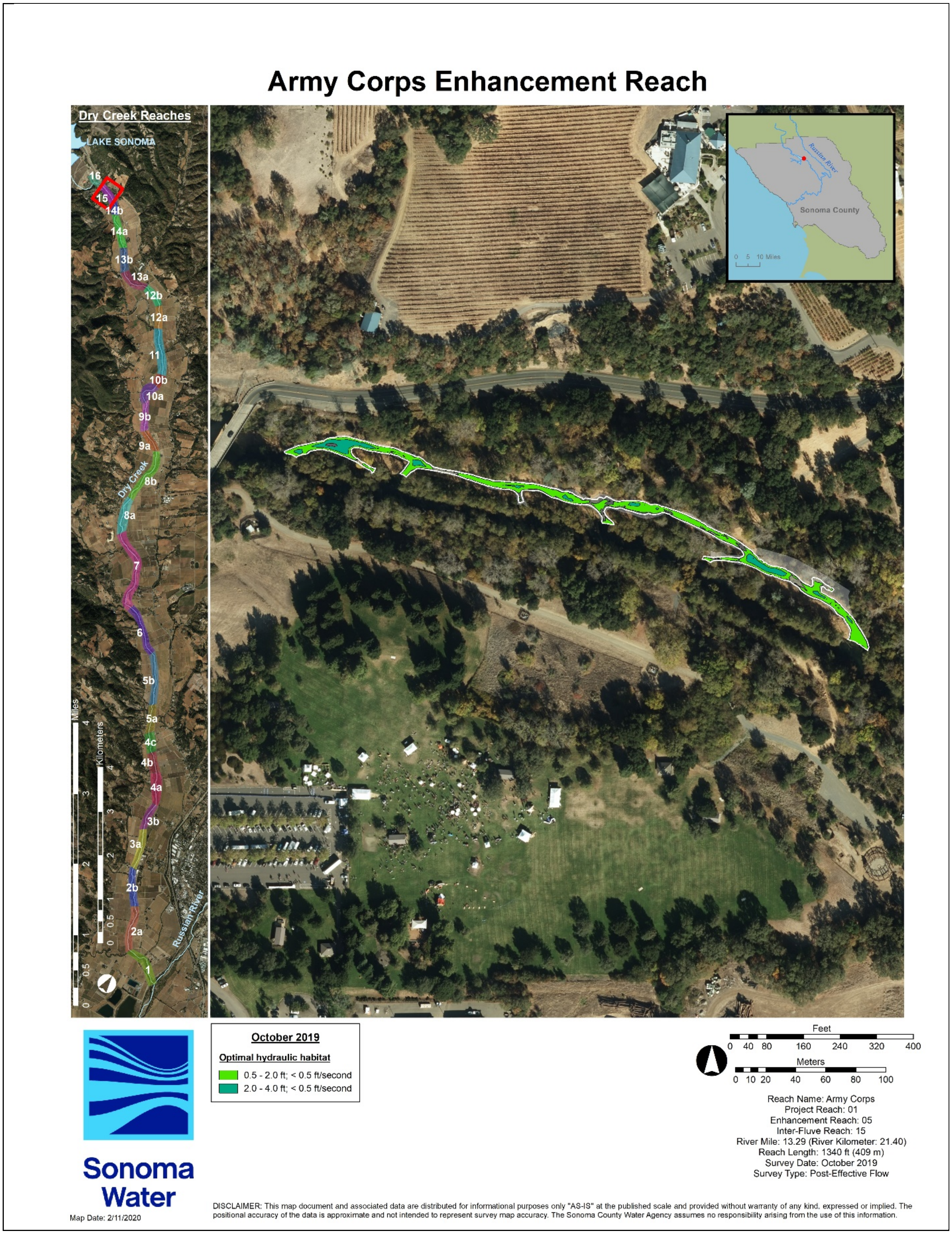


Figure 5.2.13. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Army Corps enhancement reach, October 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.16. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Army Corps enhancement reach, Post-effective flow, October 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	50	150
HU02	Pool	2	30	60
HU03	Alcove	3	60	180
HU04	Riffle	1	5	5
HU05	Pool	3	65	195
HU06	Flatwater	2	15	30
HU07	Flatwater	3	35	105
HU08	Pool	3	65	195
HU09	Flatwater	1	15	15
HU10	Pool	3	45	135
HU11	Flatwater	1	25	25
HU12	Riffle	2	30	60
HU13	Pool	3	60	180
HU14	Flatwater	2	35	70
HU15	Flatwater	1	30	30
HU16	Flatwater	1	25	25
HU17	Pool	3	45	135
HU18	Pool	3	80	240
Pool: riffle	**7: 2 (3.50)**			**Avg = 102**

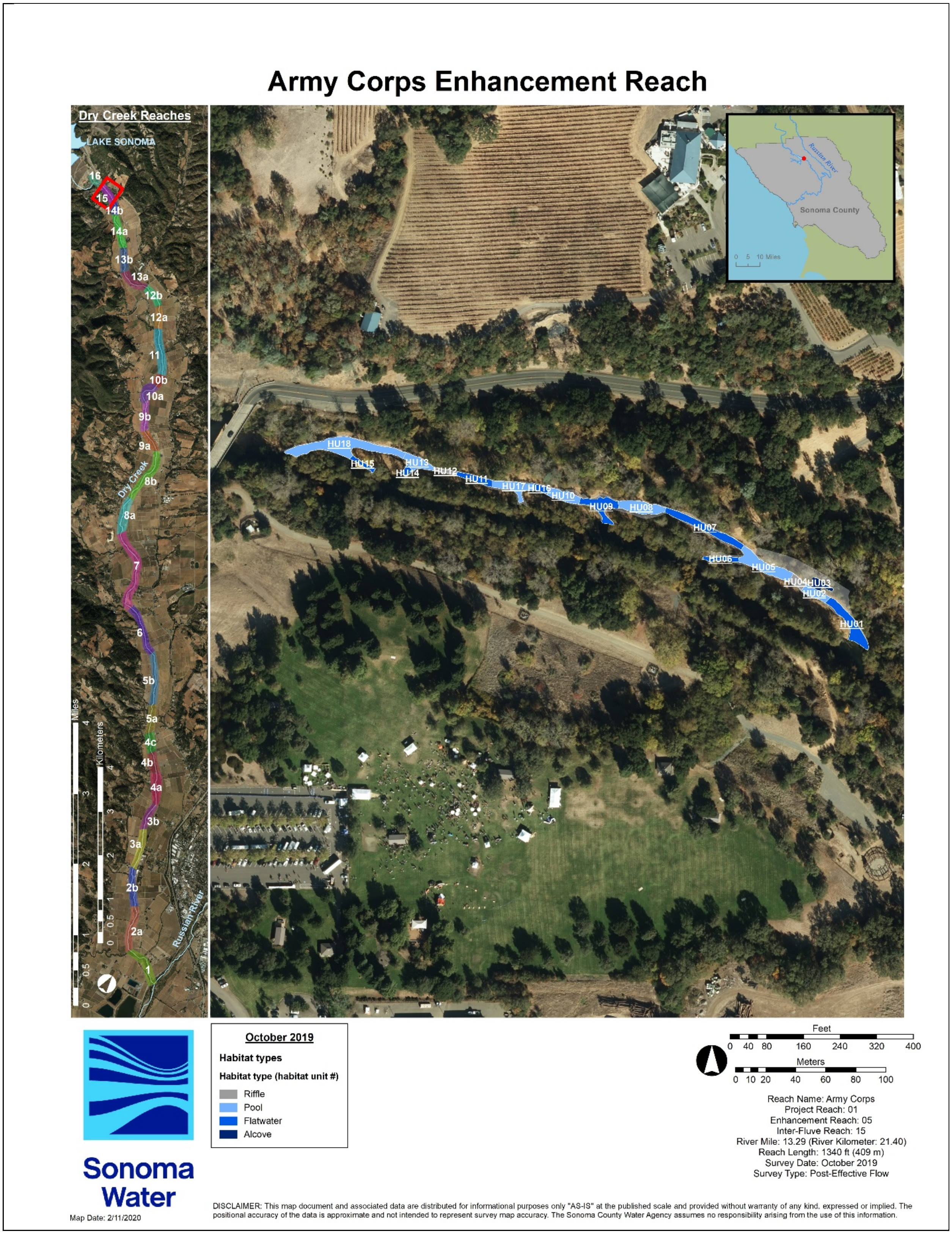


Figure 5.2.14. Habitat unit number and type within the Army Corps enhancement reach, October 2019.

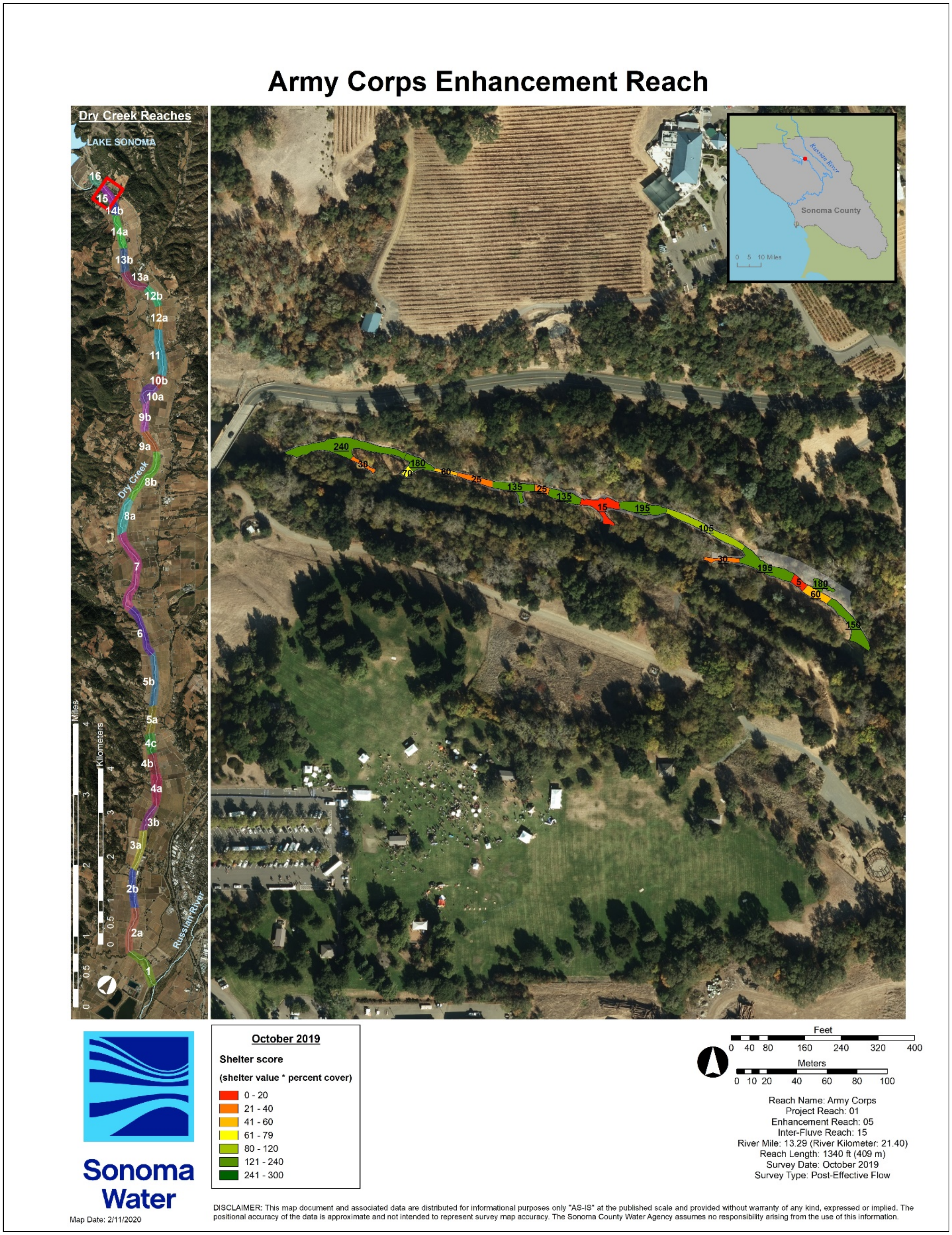


Figure 5.2.15. Habitat unit shelter scores within the Army Corps enhancement reach, October 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.17. Post-enhancement average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Army Corps enhancement reach, October 2019.

Site number		**1**	**2**	**3**	**4**	**5**	**6**
Site type		Side channel	Side channel	Side channel	Side channel	Side channel	Side channel
Site average feature rating	Site average feature quantitative rating[a]	13	14	13	13	13	13
	Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	25	26	16	19	22	23
	Site average qualitative rating[b]	Good	Good	Fair	Fair	Good	Good
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	38	39	29	32	35	36
	Site qualitative rating[c]	Good	Good	Fair	Good	Good	Good
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	35					
	Enhancement reach qualitative rating[c]:	Good					

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

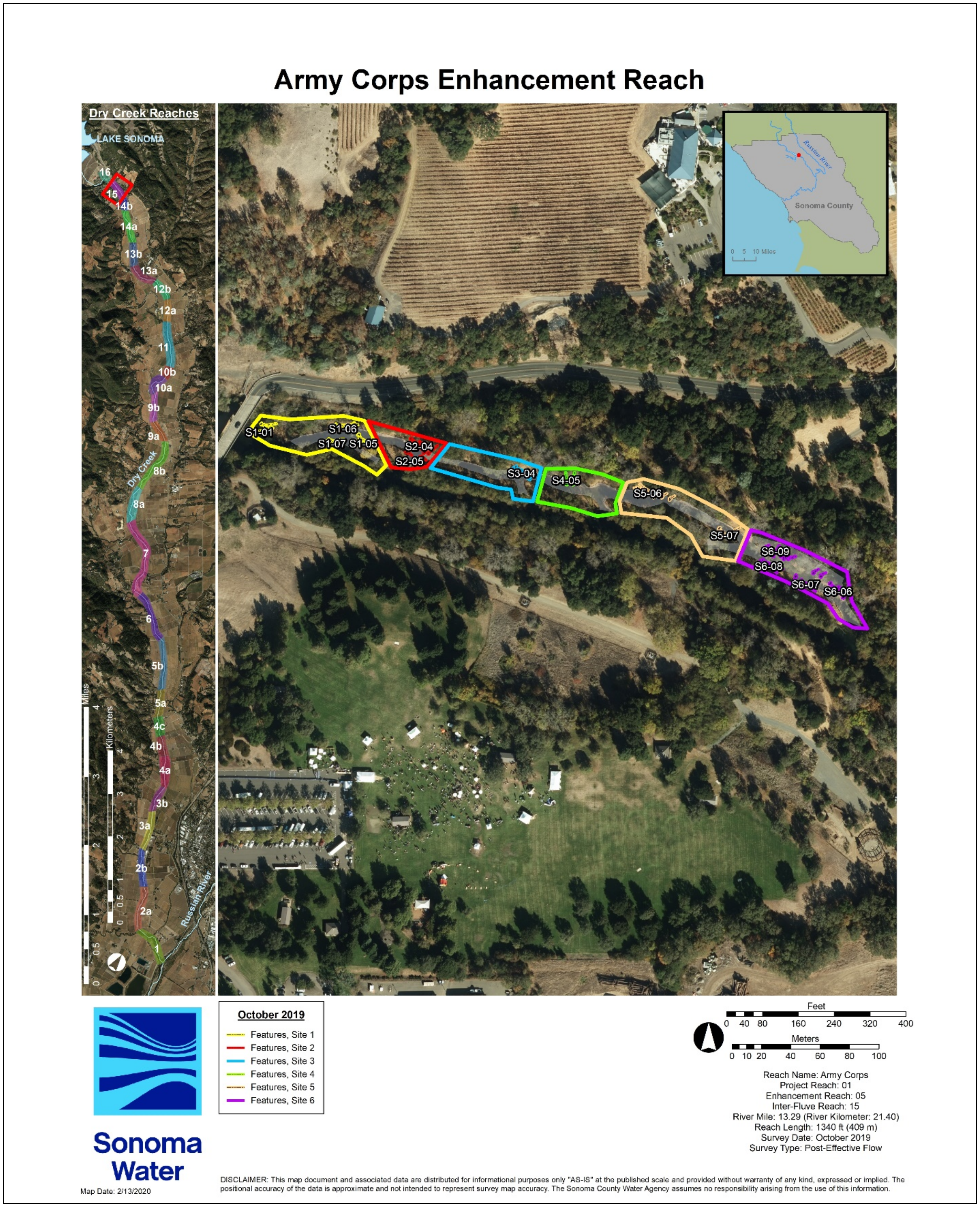


Figure 5.2.16. Enhancement sites and features within the Army Corps enhancement reach, October 2019.

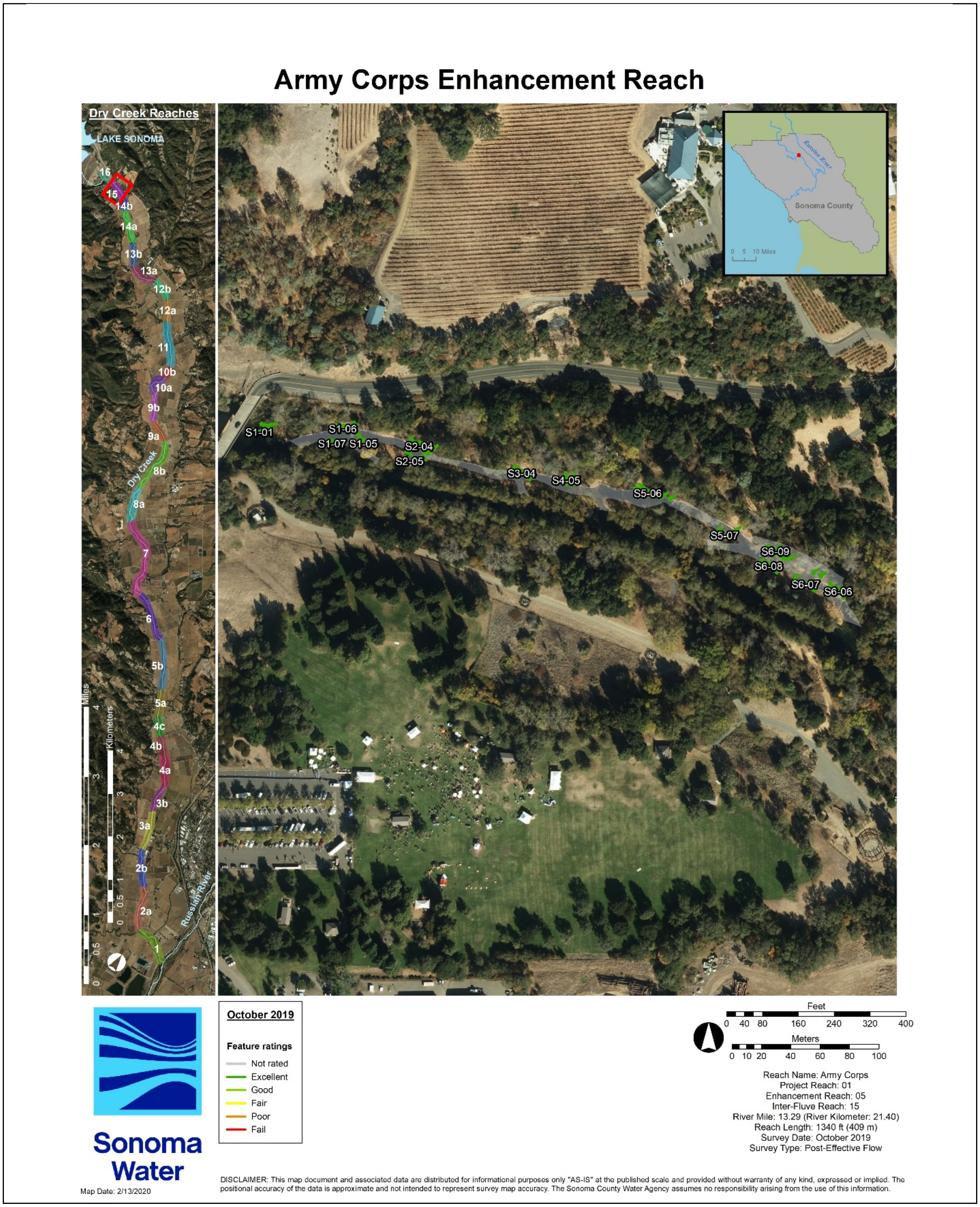


Figure 5.2.17. Post-effective flow feature ratings within the Army Corps enhancement reach, October 2019.

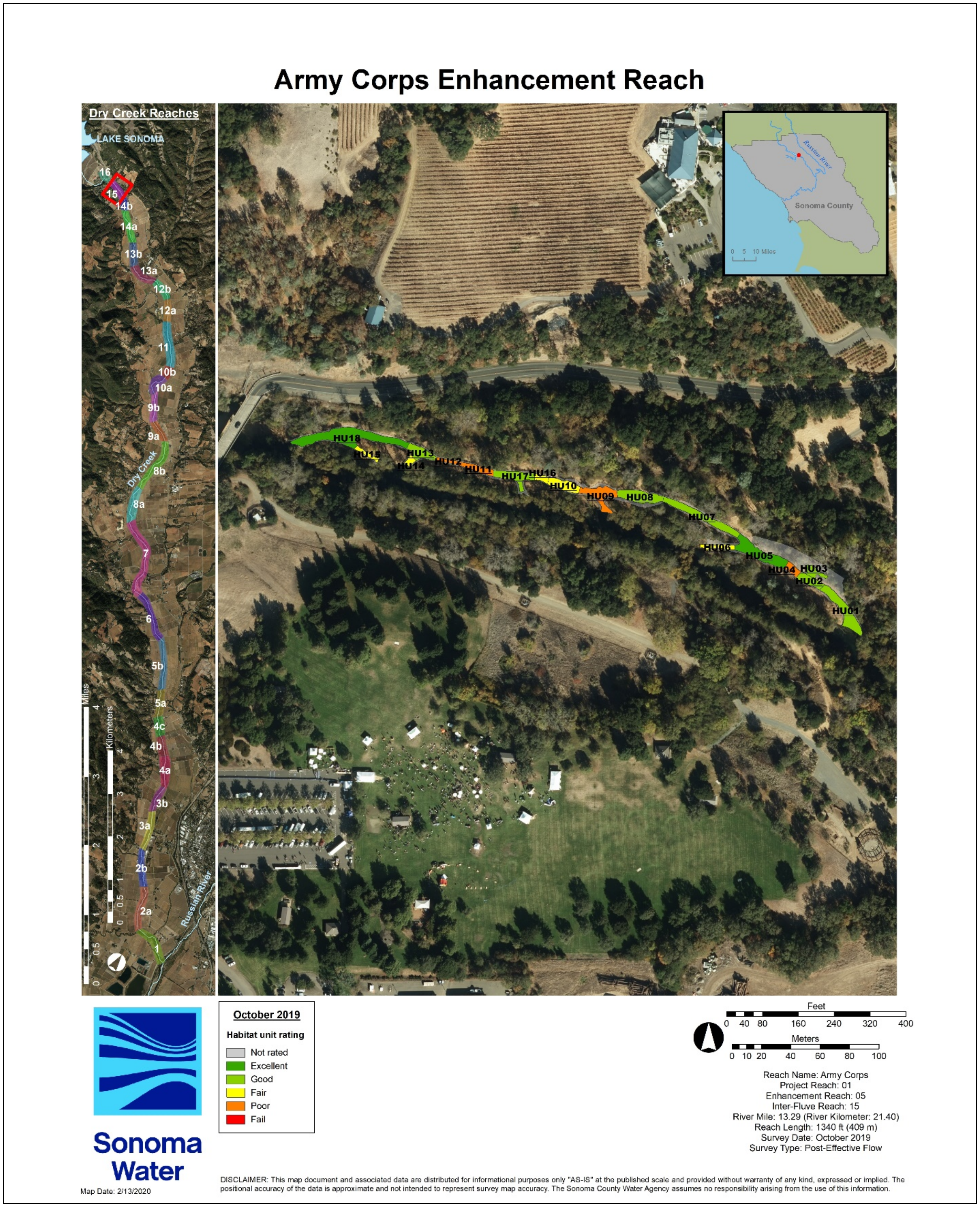


Figure 5.2.18. Habitat unit ratings within the Army Corps enhancement reach, October 2019.

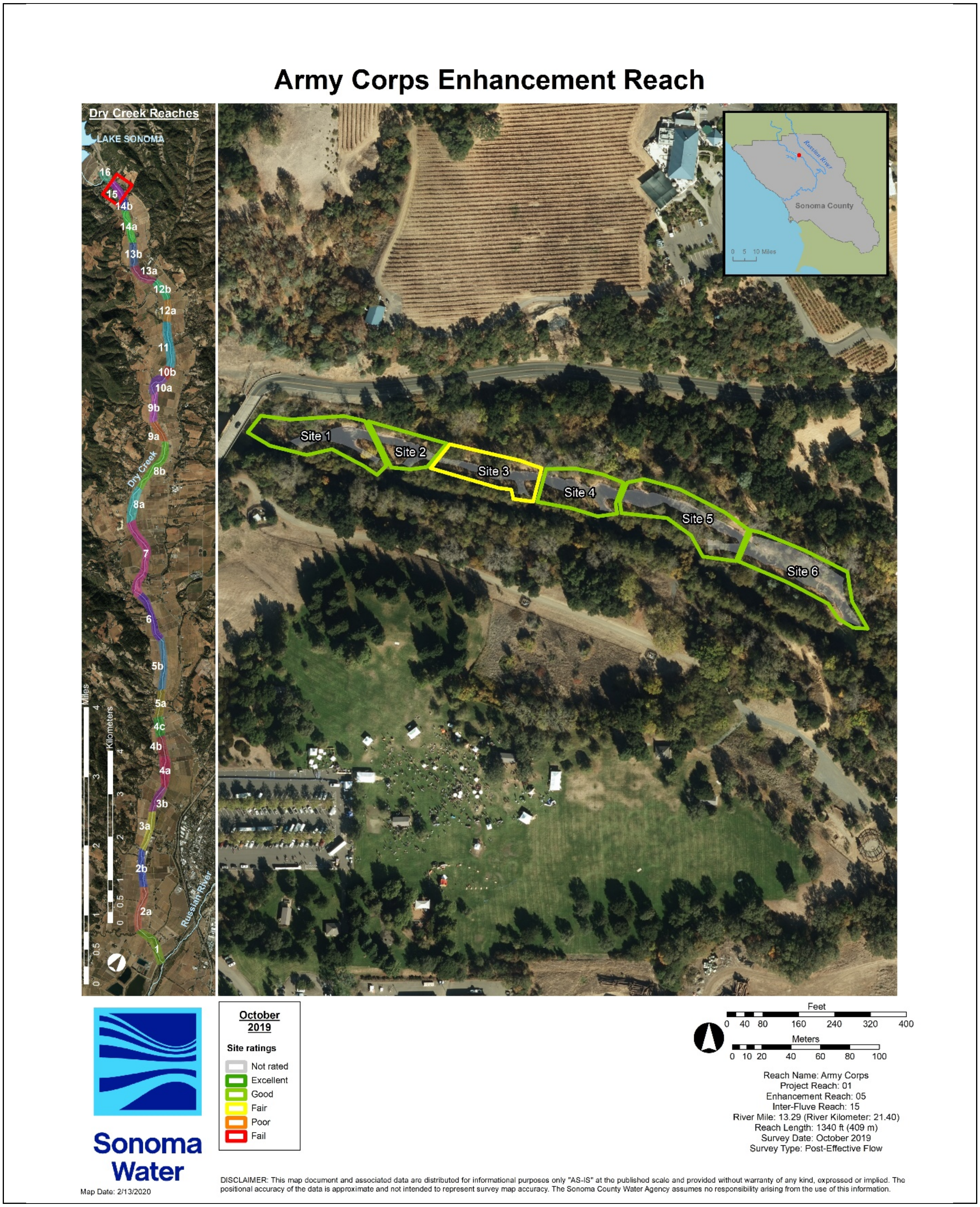


Figure 5.2.19. Post-effective flow site ratings for the Army Corps enhancement reach, October 2019.

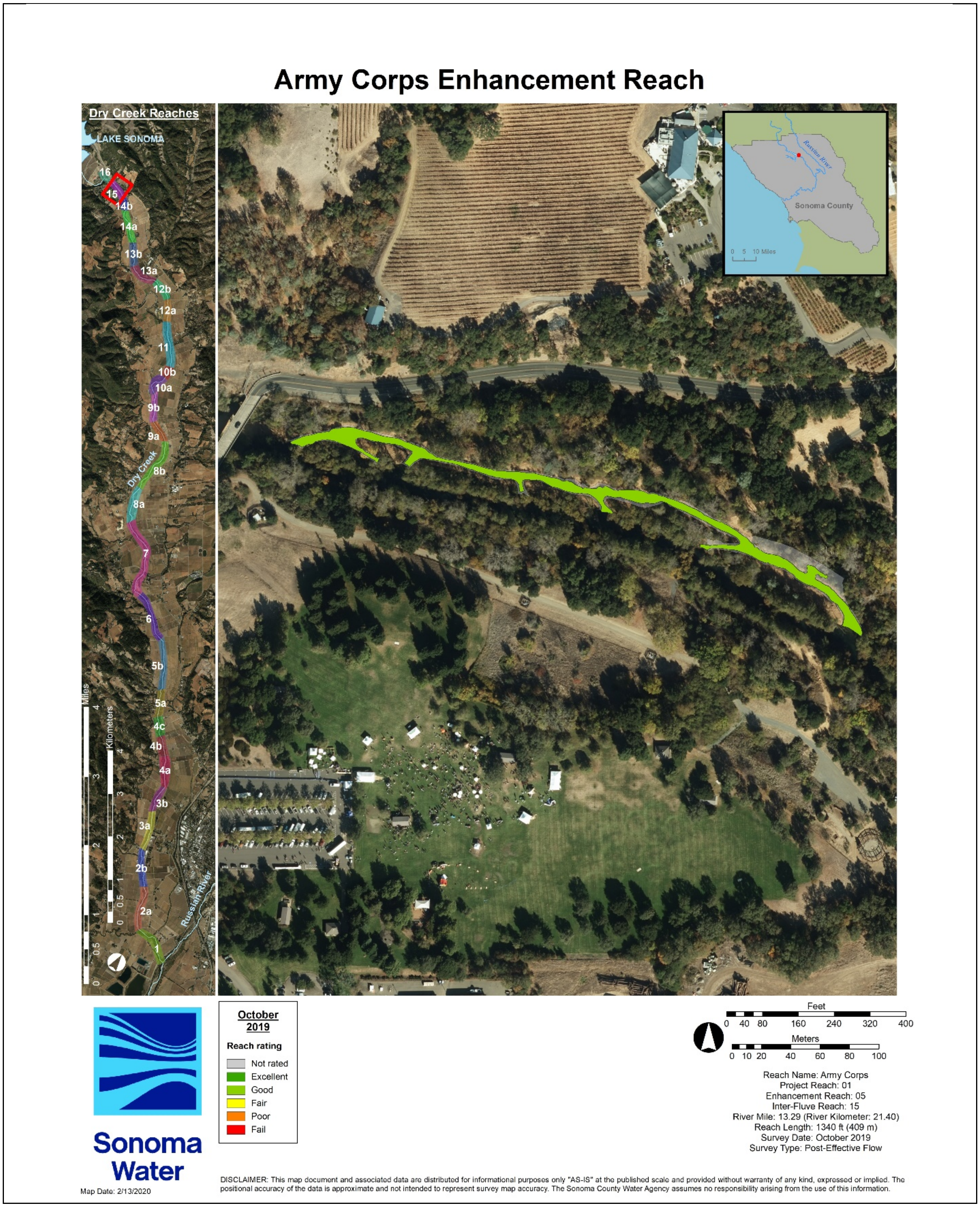


Figure 5.2.20. Post-effective flow reach rating for the Army Corps enhancement reach, October 2019.

Army Corps Reach 14 Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Army Corps Reach 14 enhancement reach in September 2019. Previous effectiveness monitoring surveys occurred in May 2018 (pre-enhancement) and October 2018 (post-enhancement) receiving fair and good ratings, respectively. The enhanced reach encompassed 74,571 ft^2 within main- and off-channel areas of Dry Creek with 29% of the total area meeting optimal depth and velocity criteria (Table 5.2.18, Figure 5.2.21). The monitoring characterized 3,121 ft^2 of side channel alcove area and 25,220 ft^2 of side channel area, of which 81% and 40% met optimal depth and velocity criteria, compared with 46,201 ft^2 and 19% for the main channel area. Eighteen habitat units composed the enhancement reach, with a pool to riffle ratio of 10:7 (1.43) and average shelter score of 76 (Table 5.2.19, Figure 5.2.22, Figure 5.2.23). Eight habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised four enhancement sites (one main-channel, one side channel, two alcoves; Table 5.2.20, Figure 5.2.24), with good to excellent site average feature ratings (site 1 contained no features and received no rating), and fair to good site average habitat unit ratings (Table 5.2.20, Figure 5.2.25, Figure 5.2.26). Enhancement sites received good to excellent ratings (Table 5.2.20, Figure 5.2.27). Overall, the Army Corps Reach 14 enhancement reach received a good effectiveness monitoring rating (Table 5.2.20, Figure 5.2.28; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.18. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Army Corps Reach 14 enhancement reach, September 2019.

Army Corps Reach 14 Post-effective flow September 2019	**Wetted area (ft^2)**	**Optimal depth (ft^2): 0.5 – 2.0 ft**	**Optimal depth (ft^2): 2.0 – 4.0 ft**	**Optimal depth (ft^2): Total**	**Optimal velocity (ft^2): < 0.5 ft/s**	**Optimal habitat (ft^2): 0.5 – 2.0 ft < 0.5 ft/s**	**Optimal habitat (ft^2): 2.0 – 4.0 ft < 0.5 ft/s**	**Optimal habitat (ft^2): Total**
Main channel area	46,201	22,142	12,171	34,313	16,975	5,444	3,330	8,774
Side channel alcove area	3,121	1,807	725	2,532	3,121	1,807	725	2,532
Side channel area	25,220	8,396	10,330	18,725	15,182	4,910	5,116	10,026
Total area	**74,541**	**32,345**	**23,225**	**55,570**	**35,278**	**12,161**	**9,170**	**21,332**
Main channel % of wetted area	62%	48%	26%	74%	37%	12%	7%	19%
Side channel alcove % of wetted area	4%	58%	23%	81%	100%	58%	23%	81%
Side channel % of wetted area	34%	33%	41%	74%	60%	19%	20%	40%
Total % of wetted area	**100%**	**43%**	**31%**	**75%**	**47%**	**16%**	**12%**	**29%**

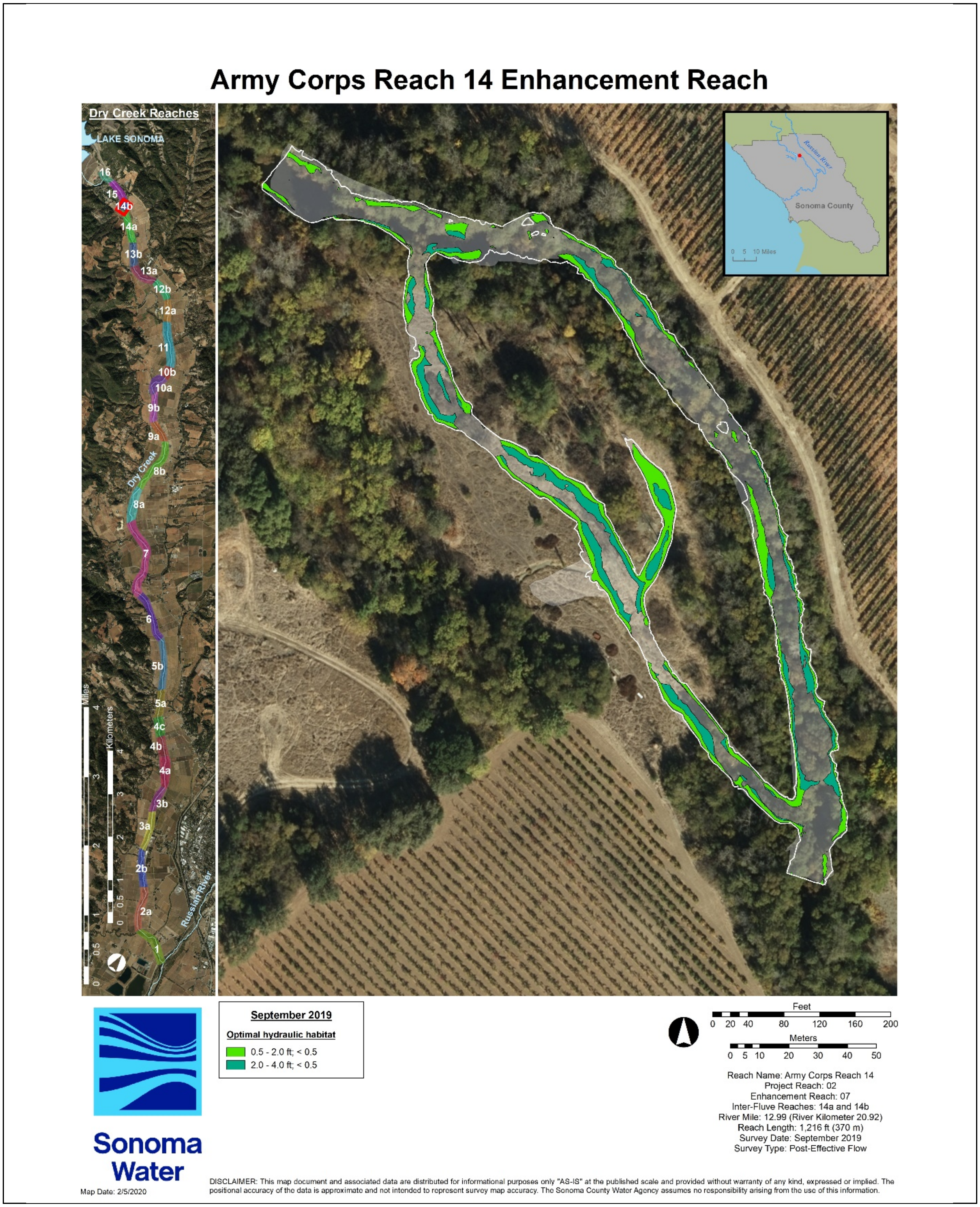


Figure 5.2.21. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Army Corps Reach 14 enhancement reach, September 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.19. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Army Corps Reach 14 enhancement reach, Post-effective flow, September 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	10	20
HU02	Pool	3	20	60
HU03	Pool	3	10	30
HU04	Riffle	3	15	45
HU05	Pool	3	30	90
HU06	Riffle	3	45	135
HU07	Pool	3	15	45
HU08	Pool	2	25	50
HU09	Riffle	2	15	30
HU10	Pool	3	40	120
HU11	Pool	3	50	150
HU12	Riffle	3	10	30
HU13	Pool	3	40	120
HU15	Riffle	0	0	0
HU16	Pool	3	40	120
HU17	Pool	3	30	90
HU18	Riffle	3	50	150
Pool: riffle	**10:7 (1.43)**			**Avg = 76**

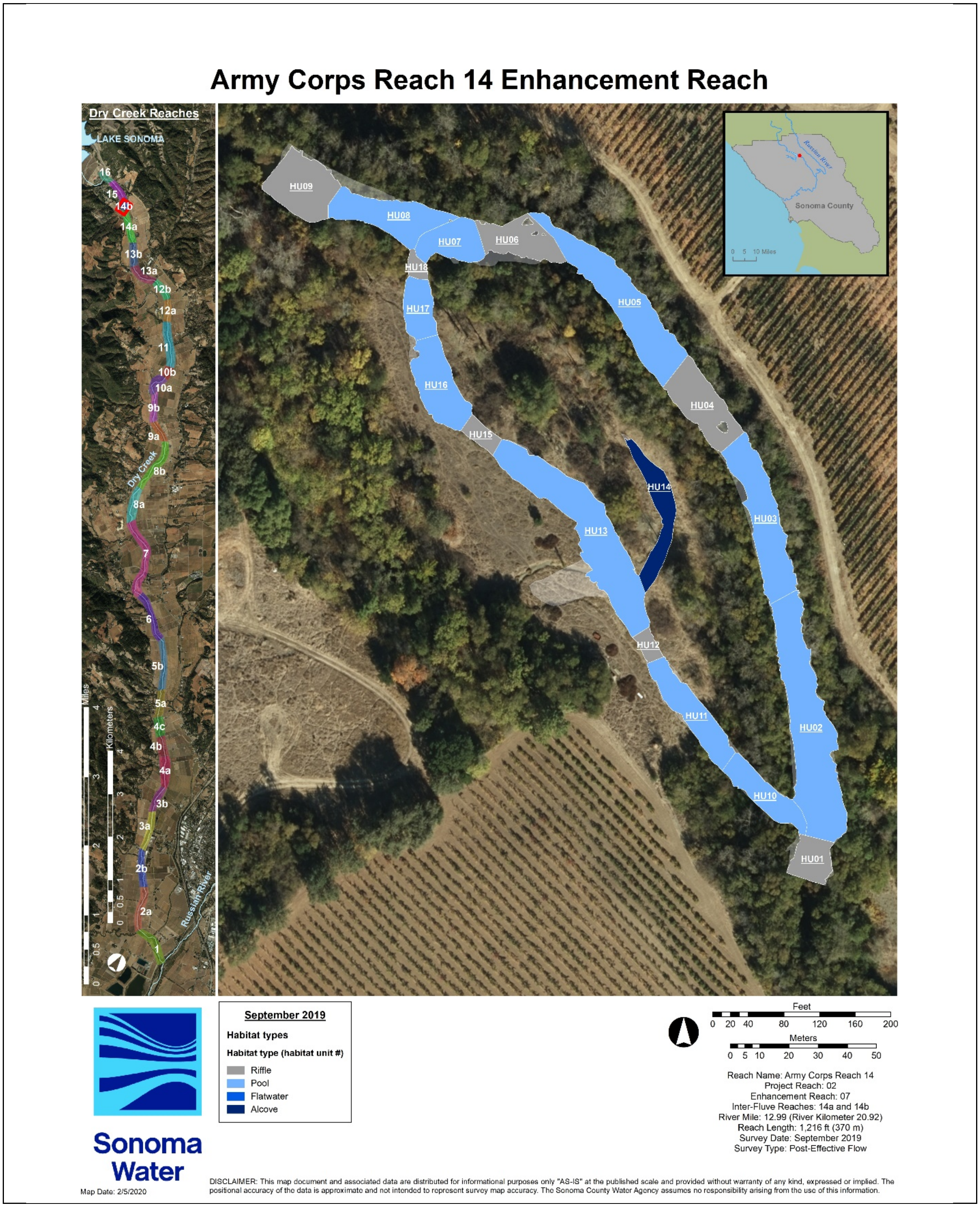


Figure 5.2.22. Habitat unit number and type within the Army Corps Reach 14 enhancement reach, September 2019.

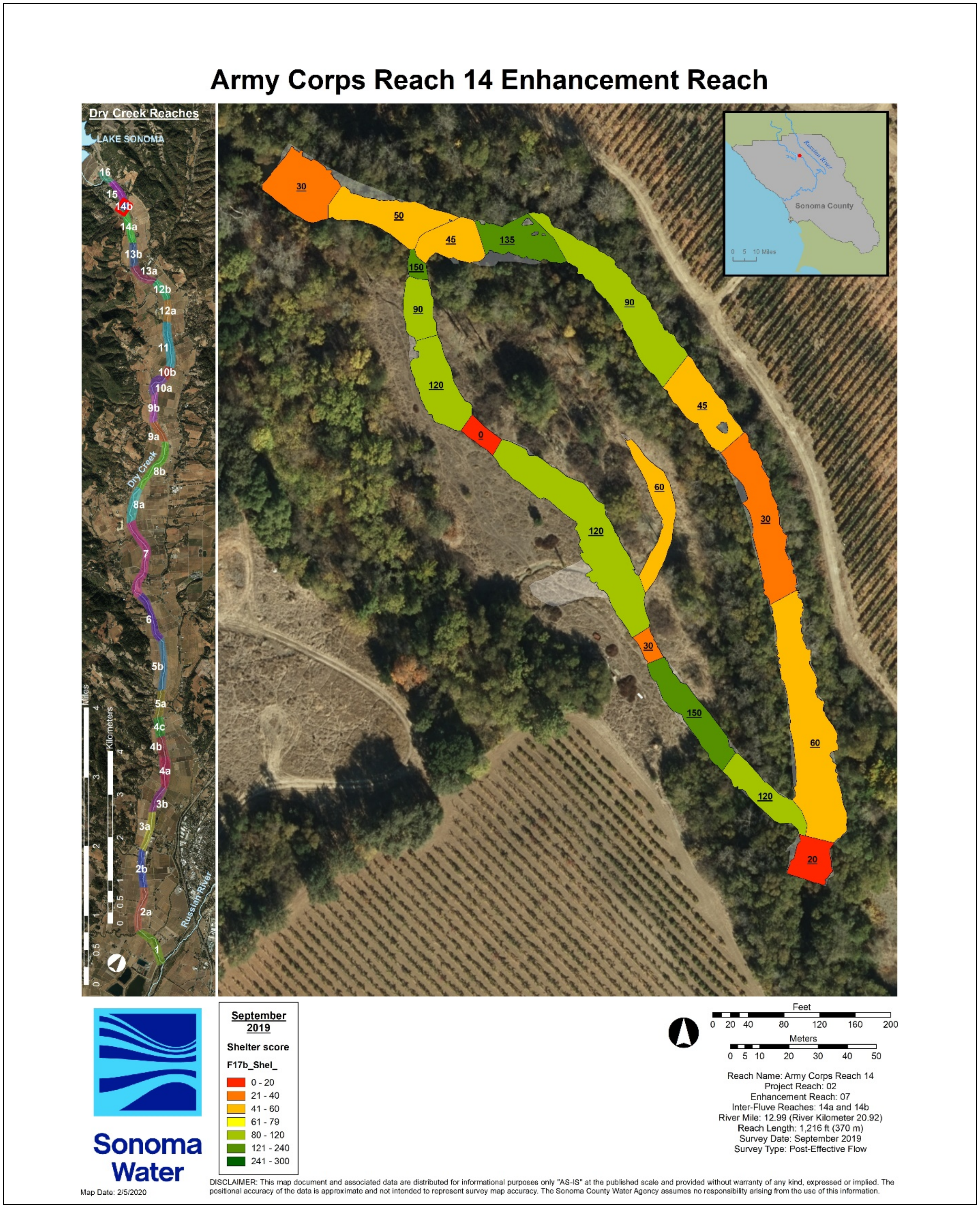


Figure 5.2.23. Habitat unit shelter scores within the Army Corps Reach 14 enhancement reach, September 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.20. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Army Corps Reach 14 enhancement reach, September 2019.

Site number		**1**	**2**	**3**	**4**
Site type		Main channel	Side channel	Alcove	Alcove
Site average feature rating	Site average feature quantitative rating[a]	0	14	14	9
	Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	Good
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	16	17	25	22
	Site average qualitative rating[b]	Fair	Fair	Good	Good
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)	16[b]	31[c]	39[c]	31[c]
	Site qualitative rating	Fair[b]	Good[c]	Good[c]	Good[c]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	29			
	Enhancement reach qualitative rating[d]:	Good			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[c]out of 46; Excellent (>=37), Good (>=28), Fair (>=19), Poor (>=9), Fail (<9)

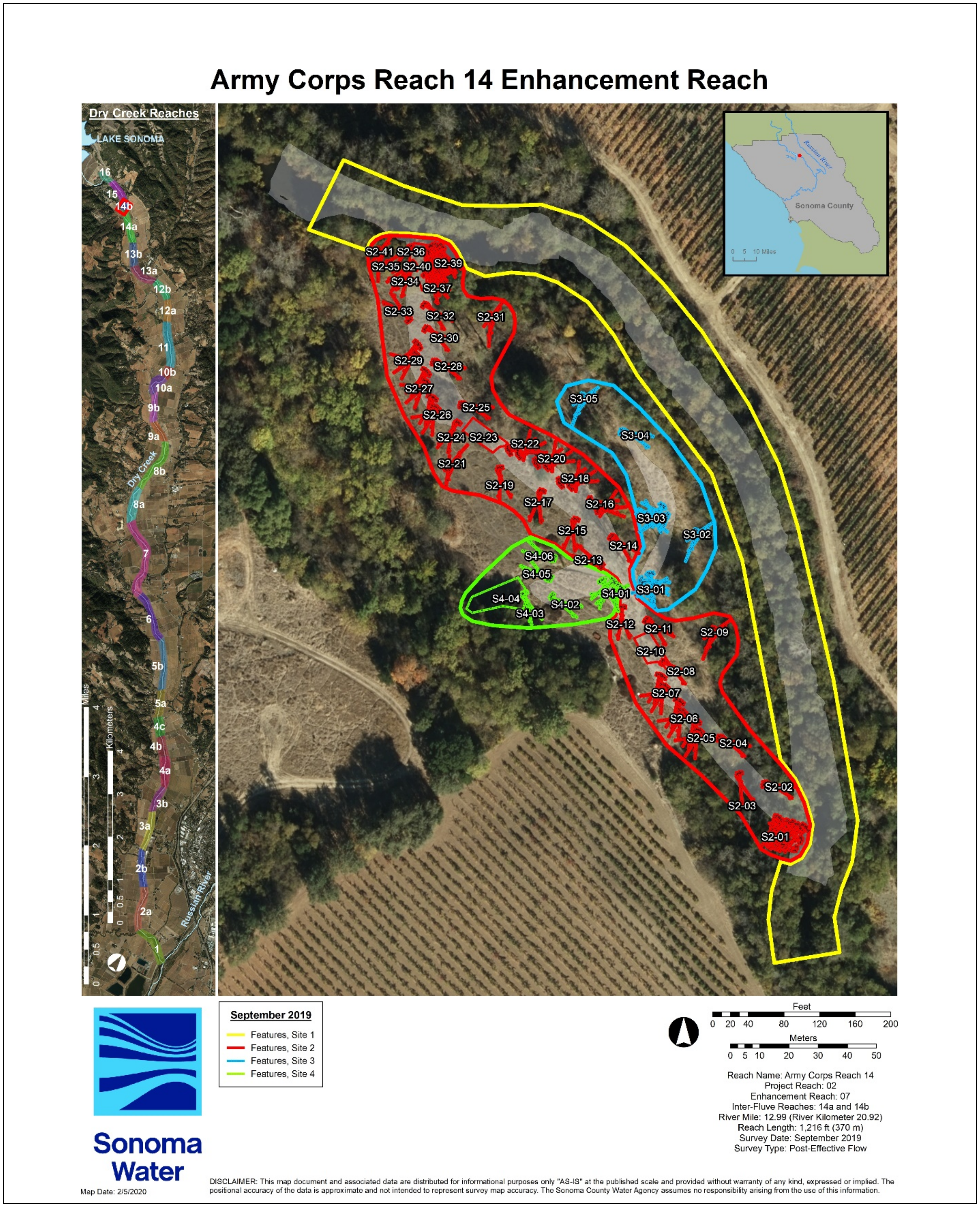


Figure 5.2.24. Enhancement sites and features within the Army Corps Reach 14 enhancement reach, September 2019.

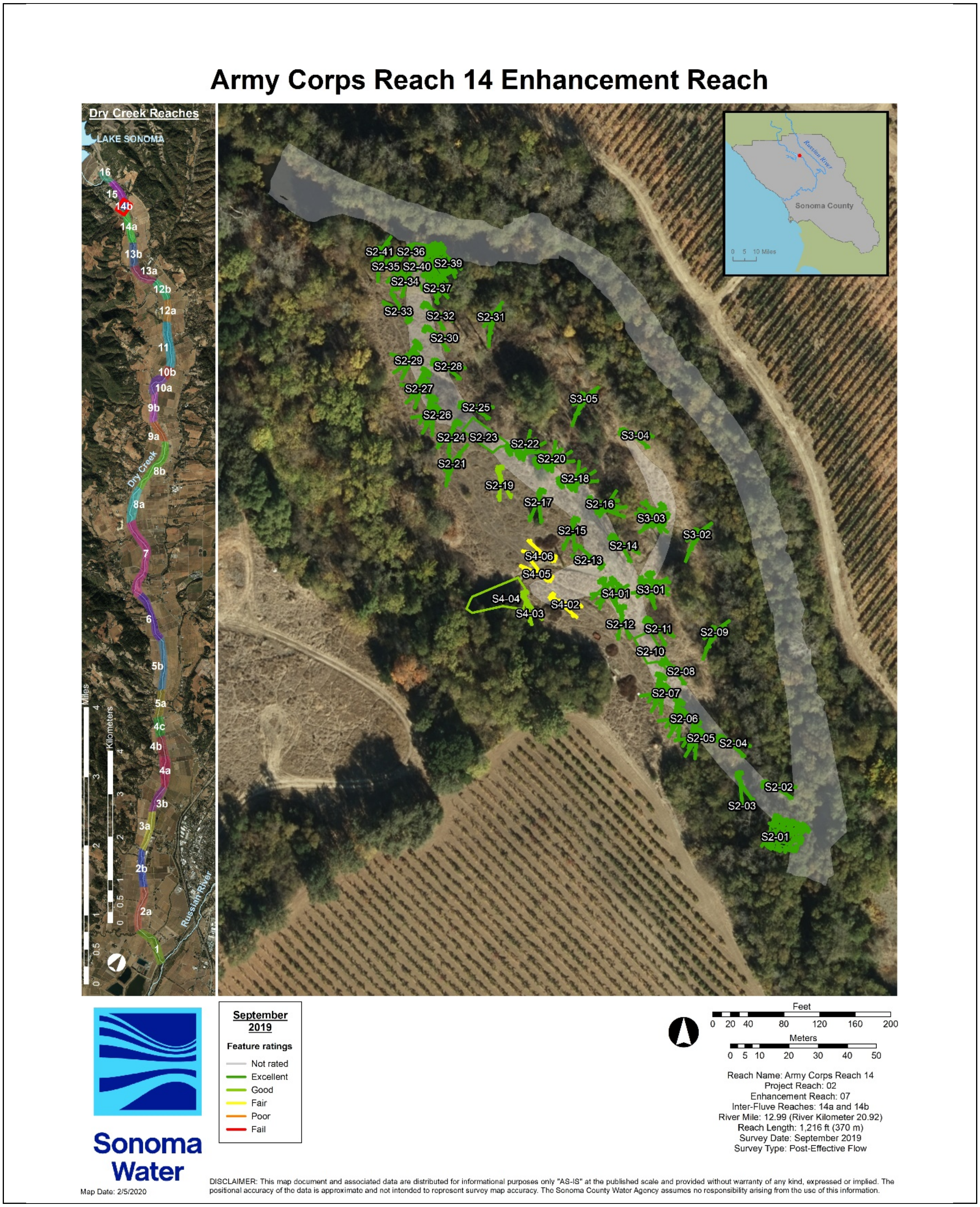


Figure 5.2.25. Feature ratings for the Army Corps Reach 14 enhancement reach, September 2019.

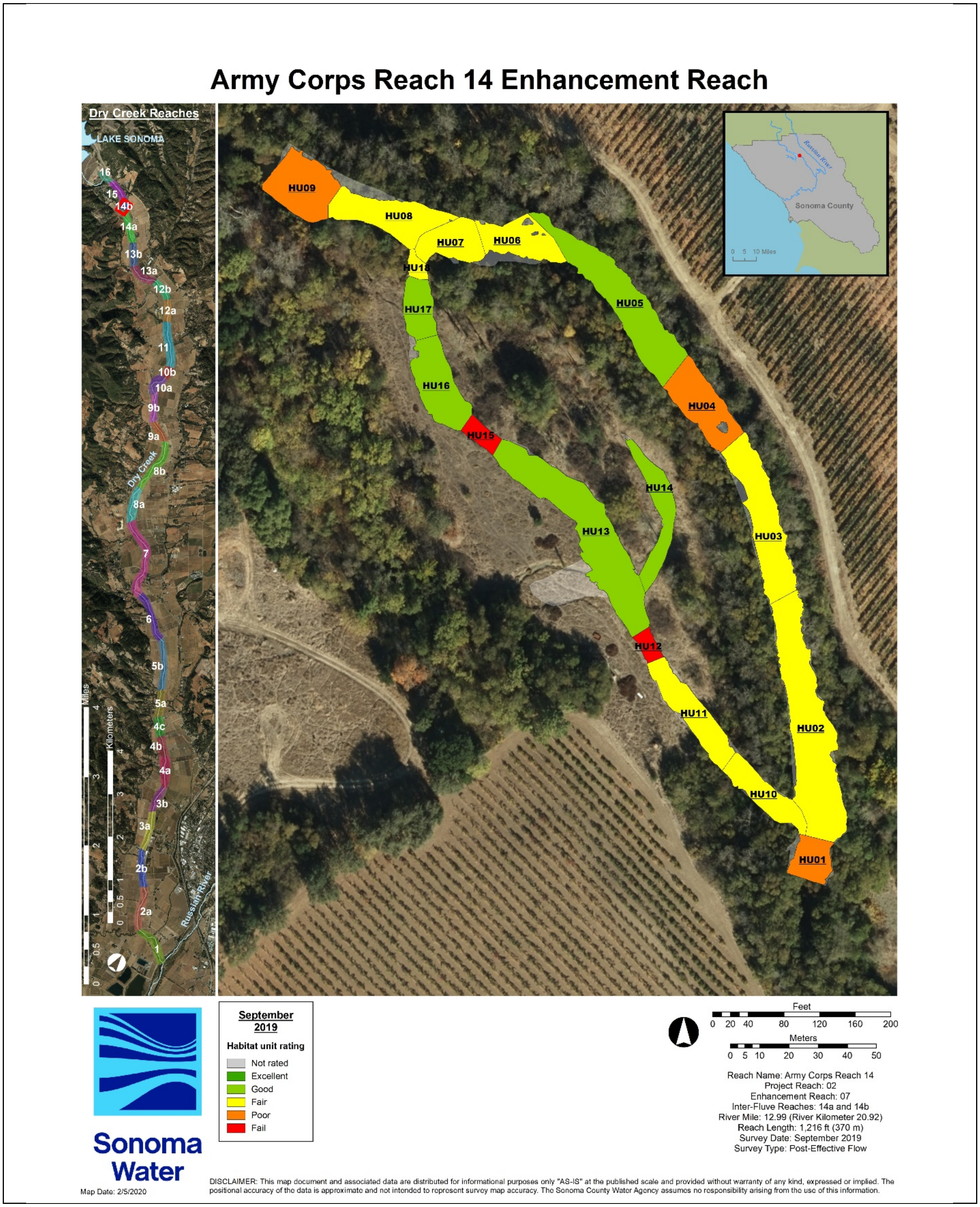


Figure 5.2.26. Habitat unit ratings for the Army Corps Reach 14 enhancement reach, September 2019.

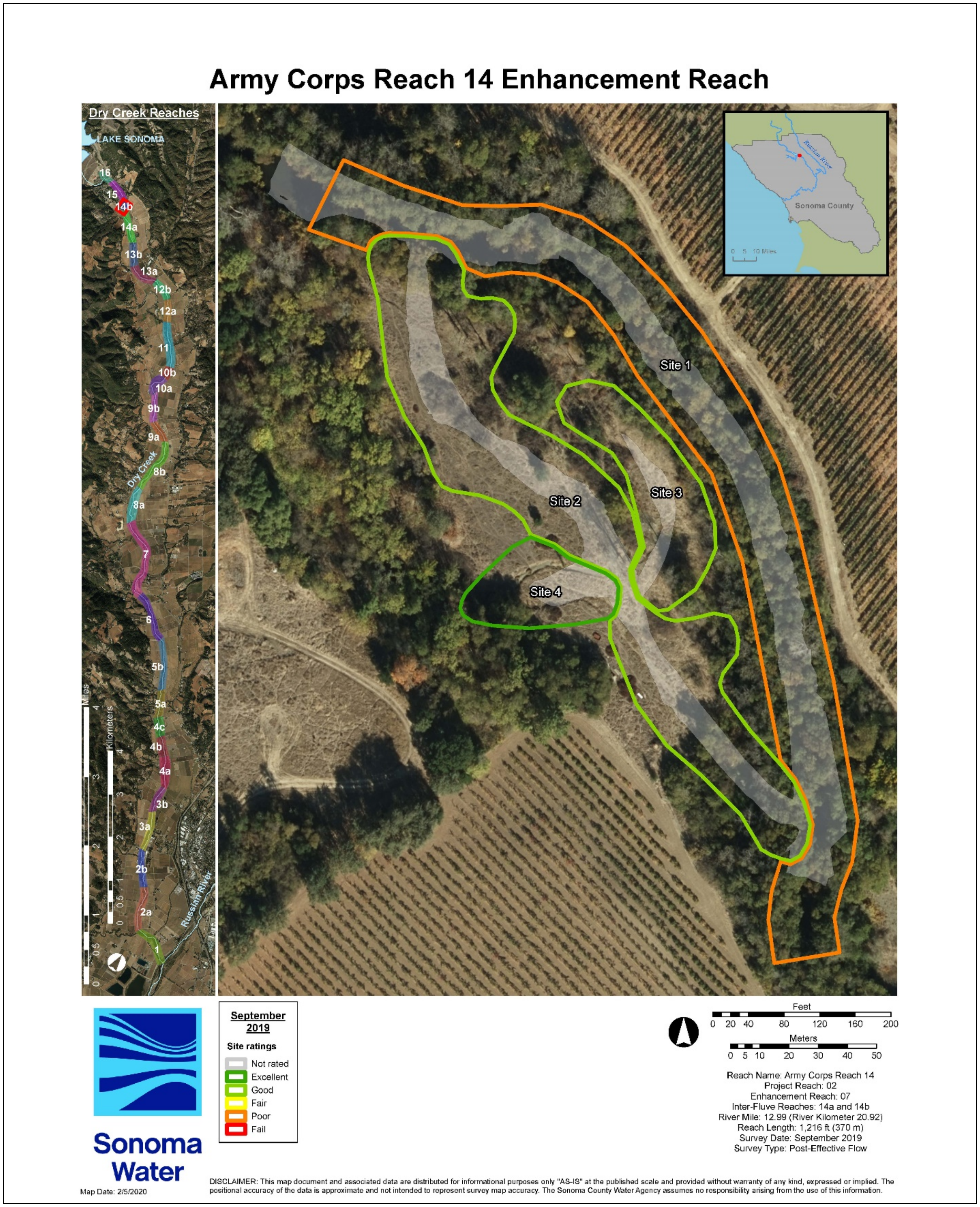


Figure 5.2.27. Post enhancement site ratings for the Army Corps Reach 14 enhancement reach, September 2019.

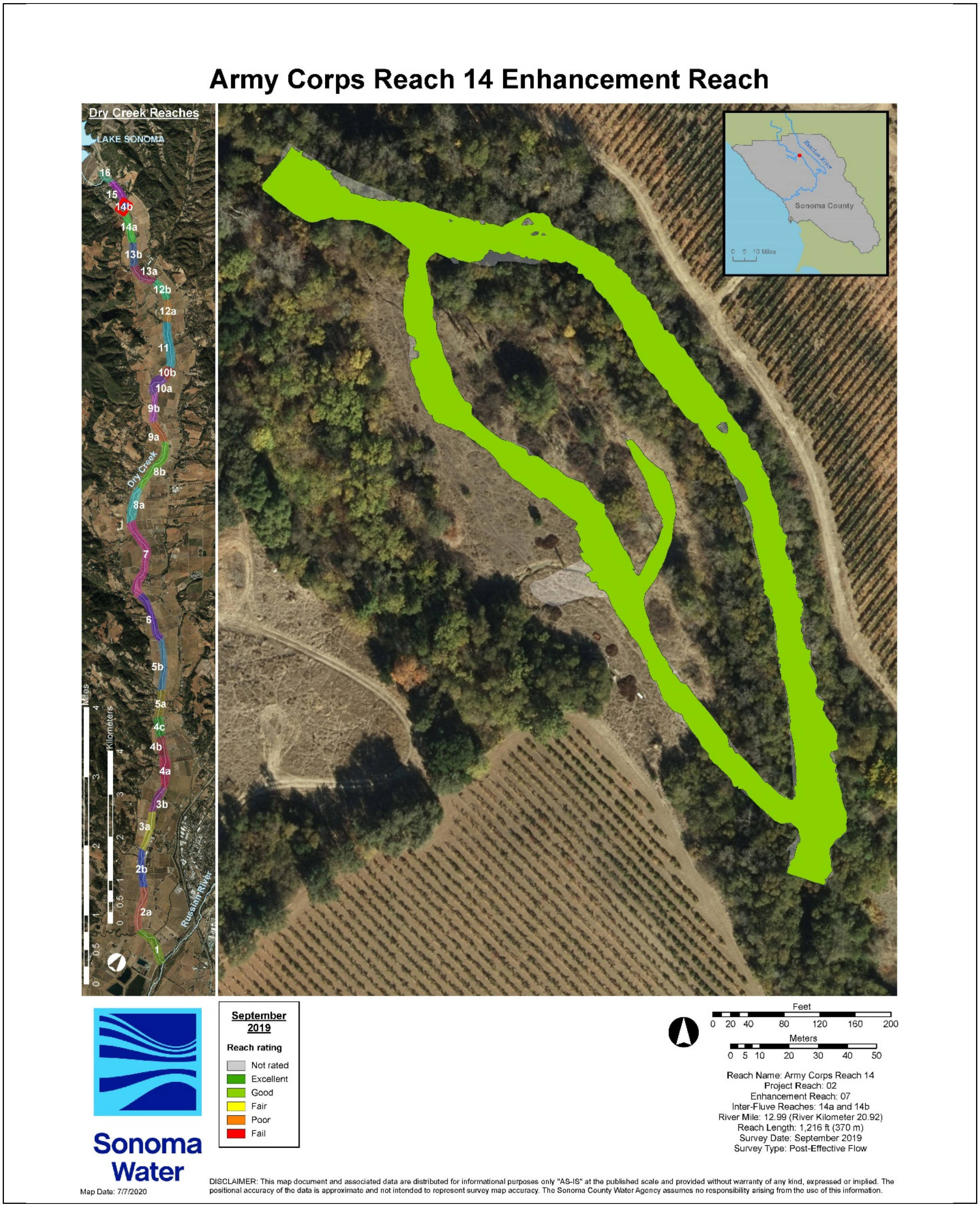


Figure 5.2.28. Post-effective flow reach rating for the Army Corps Reach 14 enhancement reach, September 2019.

Weinstock Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Weinstock enhancement reach in September 2019. Previous effectiveness monitoring surveys occurred in July 2018 (pre-enhancement) and October 2018 (post-enhancement) receiving fair and good ratings, respectively. The enhanced reach encompassed 46,140 ft^2 within main- and off-channel areas of Dry Creek with 27% of the total area meeting optimal depth and velocity criteria (Table 5.2.21, Figure 5.2.29). The monitoring characterized 34,734 ft^2 of main channel area, and 11,406 ft^2 of side channel area, of which 28% and 25% met optimal depth and velocity criteria, respectively. Thirteen habitat units composed the enhancement reach, with a pool to riffle ratio of 8:3 (2.67) and average shelter score of 75 (Table 5.2.22, Figure 5.2.30, Figure 5.2.31). Six habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised two enhancement sites (one main-channel, one side channel; Table 5.2.23, Figure 5.2.32), with excellent site average feature ratings, and fair site average habitat unit ratings (Table 5.2.23, Figure 5.2.33, Figure 5.2.34). Enhancement sites received fair to good ratings (Table 5.2.23, Figure 5.2.35). Overall, the Weinstock enhancement reach received a good effectiveness monitoring rating (Table 5.2.23, Figure 5.2.36; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.21. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Weinstock enhancement reach, September 2019.

Weinstock Post-effective flow September 2019	Wetted area (ft^2)	Optimal depth (ft^2): 0.5 – 2.0 ft	Optimal depth (ft^2): 2.0 – 4.0 ft	Optimal depth (ft^2): Total	Optimal velocity (ft^2): < 0.5 ft/s	Optimal habitat (ft^2): 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2): 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2): Total
Main channel area	34,734	14,437	11,841	26,278	15,474	5,102	4,504	9,605
Side channel area	11,406	6,711	3,132	9,843	3,924	1,823	1,039	2,862
Total area	**46,140**	**21,148**	**14,973**	**36,121**	**19,398**	**6,924**	**5,543**	**12,467**
Main channel % of wetted area	75%	42%	34%	76%	45%	15%	13%	28%
Side channel % of wetted area	25%	59%	27%	86%	34%	16%	9%	25%
Total % of wetted area	**100%**	**46%**	**32%**	**78%**	**42%**	**15%**	**12%**	**27%**

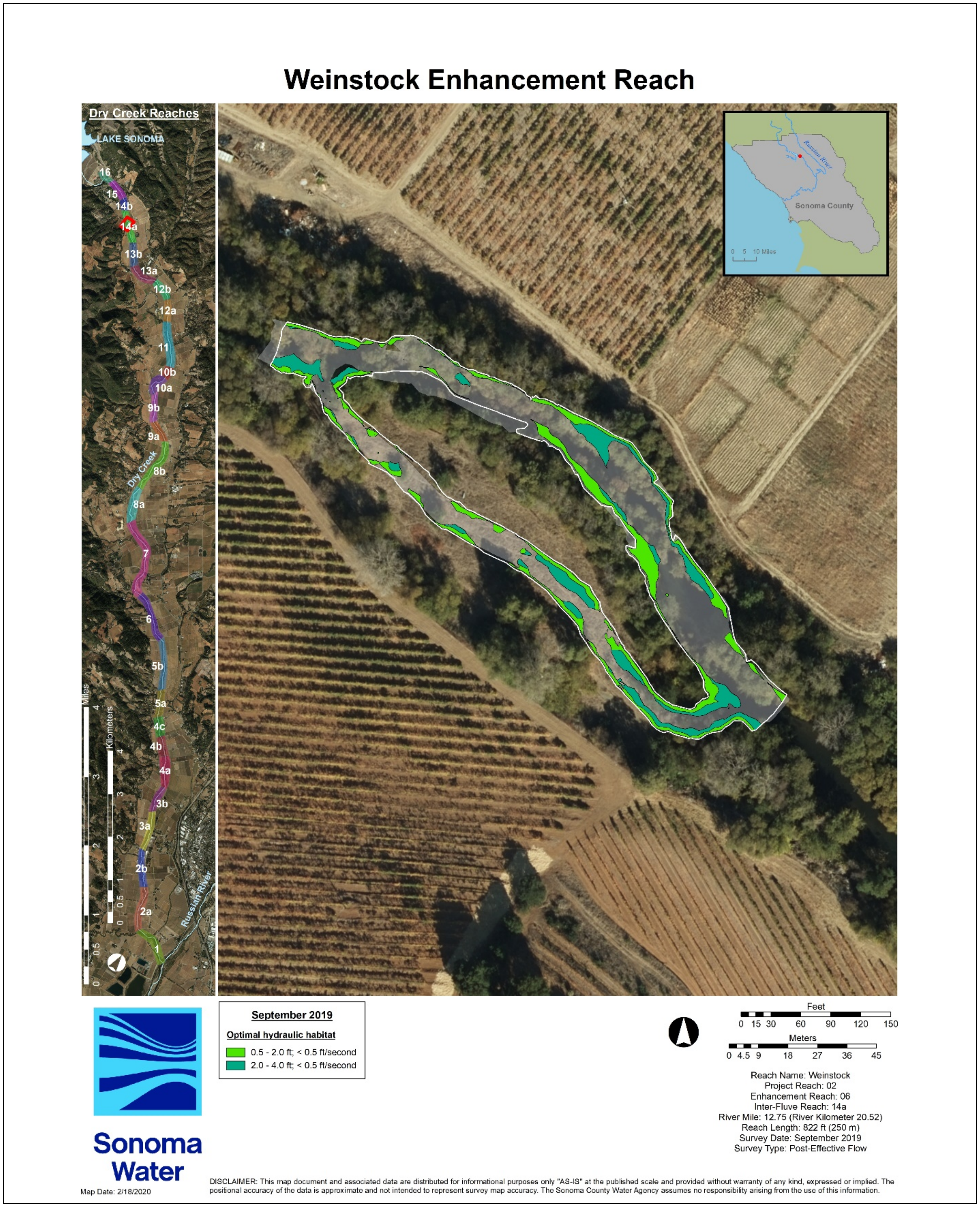


Figure 5.2.29. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Weinstock enhancement reach, September 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.22. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Weinstock enhancement reach, Post-effective flow, September 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	35	105
HU02	Flatwater	2	25	50
HU03	Pool	3	20	60
HU04	Riffle	2	15	30
HU05	Pool	3	20	60
HU06	Riffle	2	20	40
HU07	Pool	3	40	120
HU08	Flatwater	3	25	75
HU09	Pool	3	30	90
HU10	Pool	3	30	90
HU11	Pool	3	30	90
HU12	Riffle	3	15	45
HU13	Pool	3	40	120
Pool: riffle	**8:3 (2.67)**			**Avg = 75**

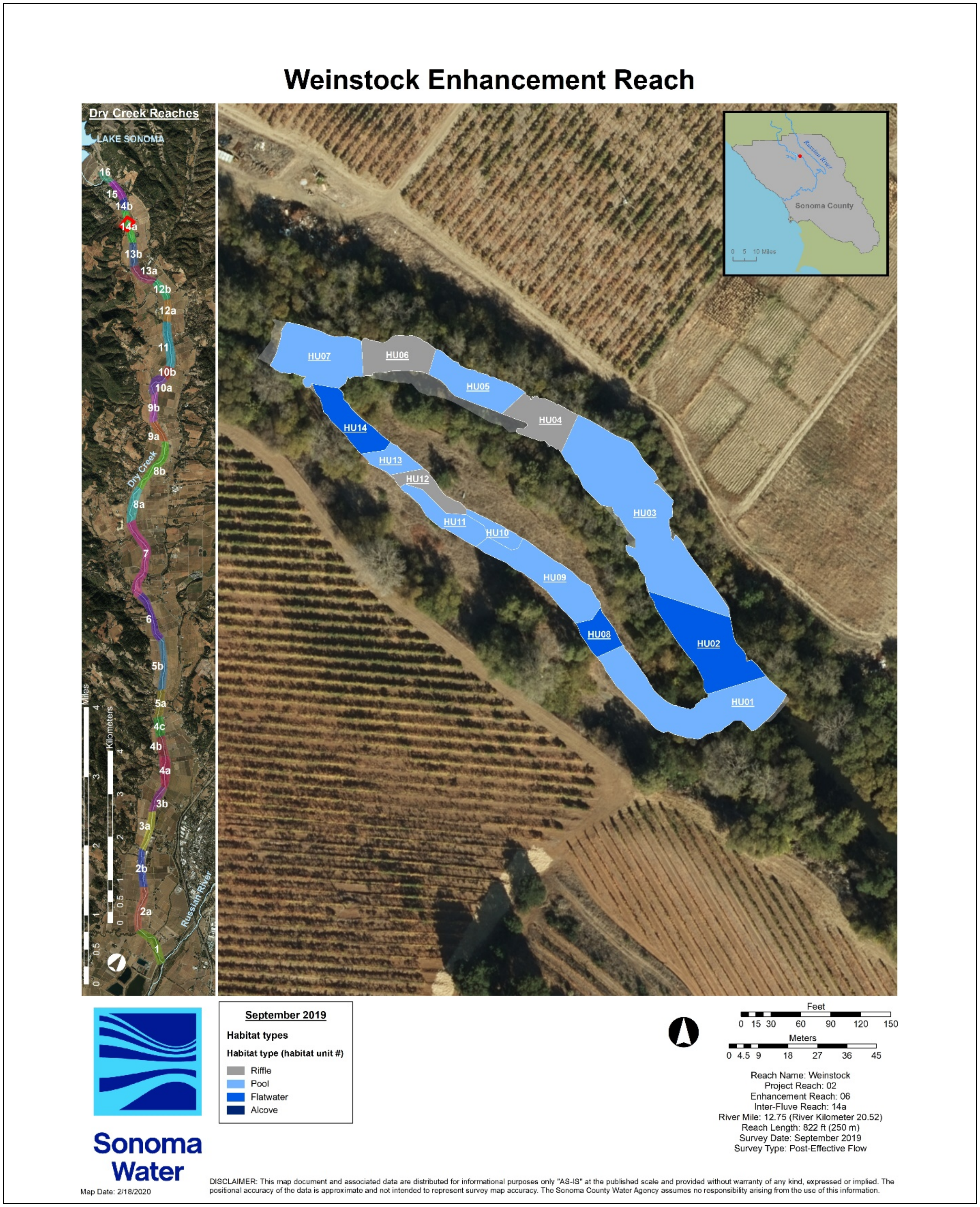


Figure 5.2.30. Habitat unit number and type within the Weinstock enhancement reach, September 2019.

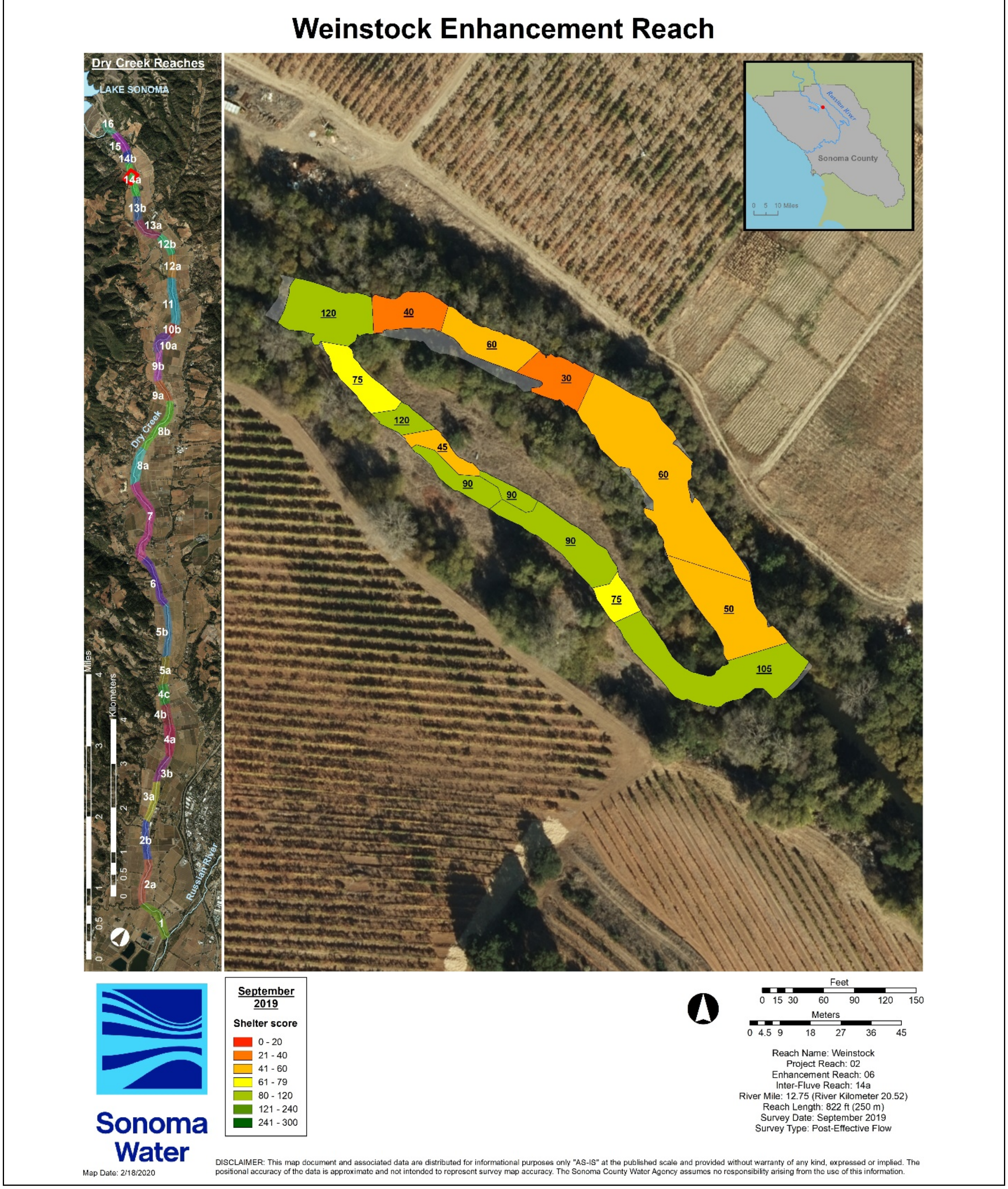


Figure 5.2.31. Habitat unit shelter scores within the Weinstock enhancement reach, September 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.23. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Weinstock enhancement reach, September 2019.

Site number		1	2		
Site type		Main channel	Side channel		
Site average feature rating	Site average feature quantitative rating[a]	13	13		
	Site average feature qualitative rating[a]	Excellent	Excellent		
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	18	17		
	Site average qualitative rating[b]	Fair	Fair		
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	31	30		
	Site qualitative rating[c]	Good	Fair		
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	31			
	Enhancement reach qualitative rating[c]:	Good			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

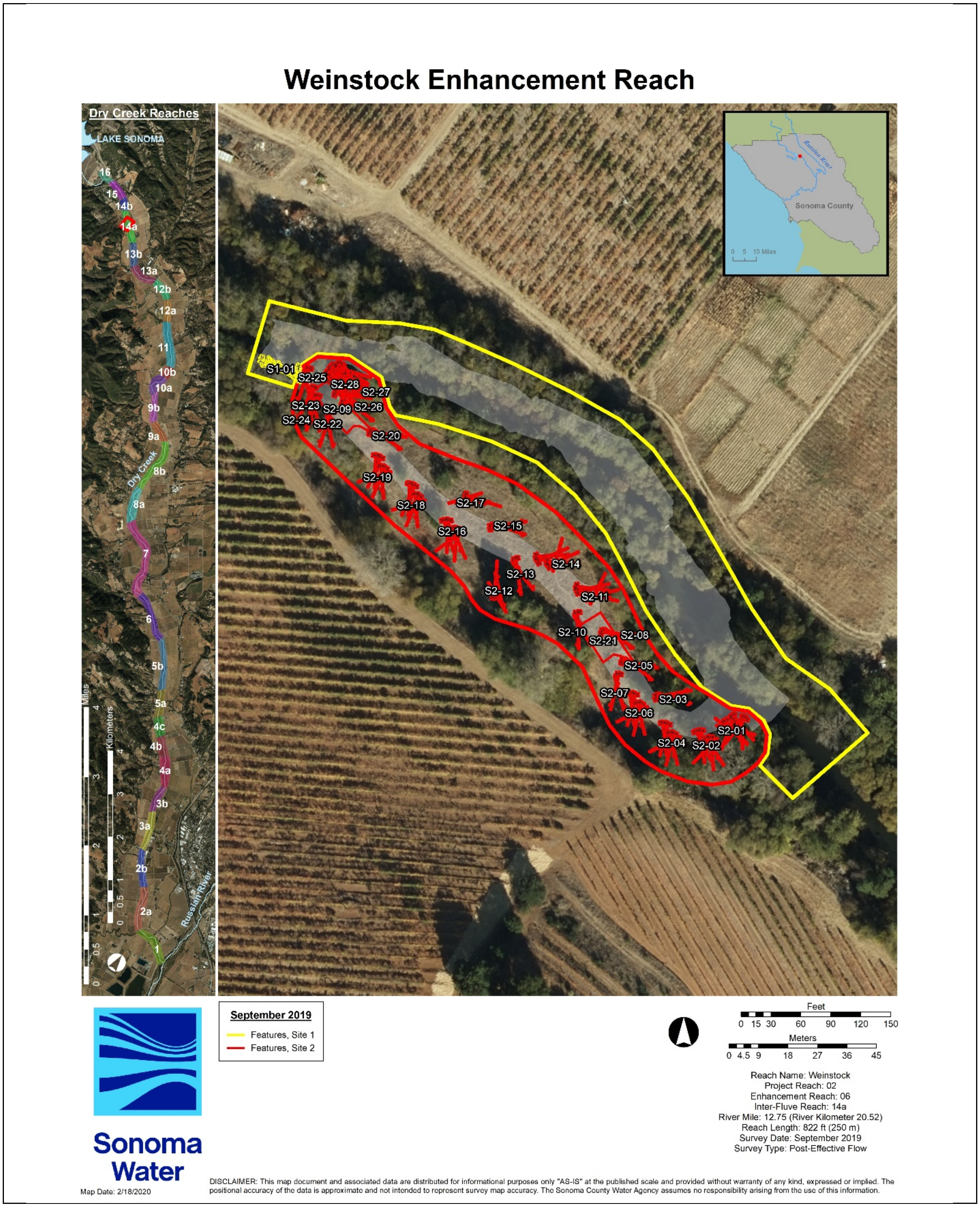


Figure 5.2.32. Enhancement sites and features within the Weinstock enhancement reach, September 2019.

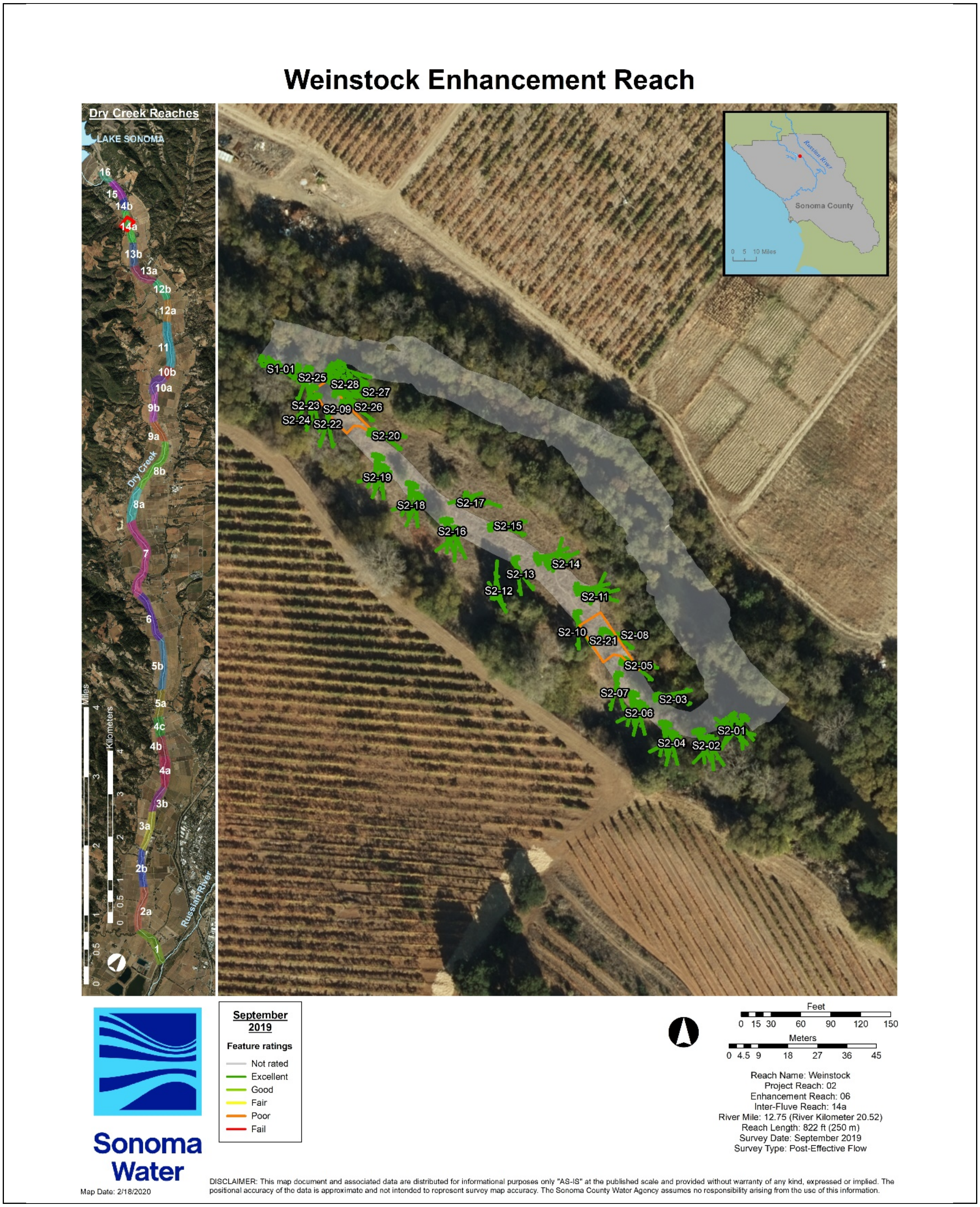


Figure 5.2.33. Feature ratings for the Weinstock enhancement reach, September 2019.

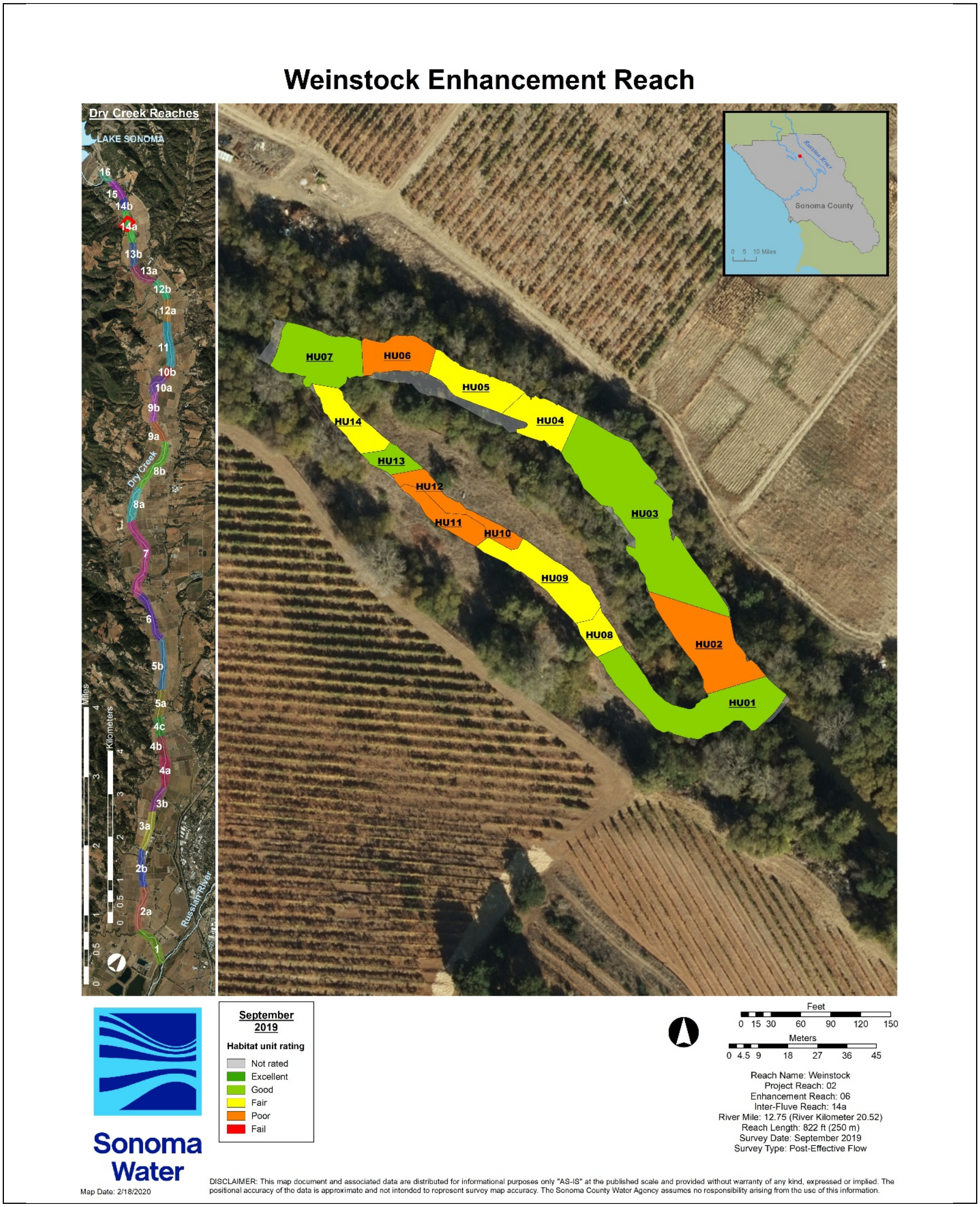


Figure 5.2.34. Habitat unit ratings for the Weinstock enhancement reach, September 2019.

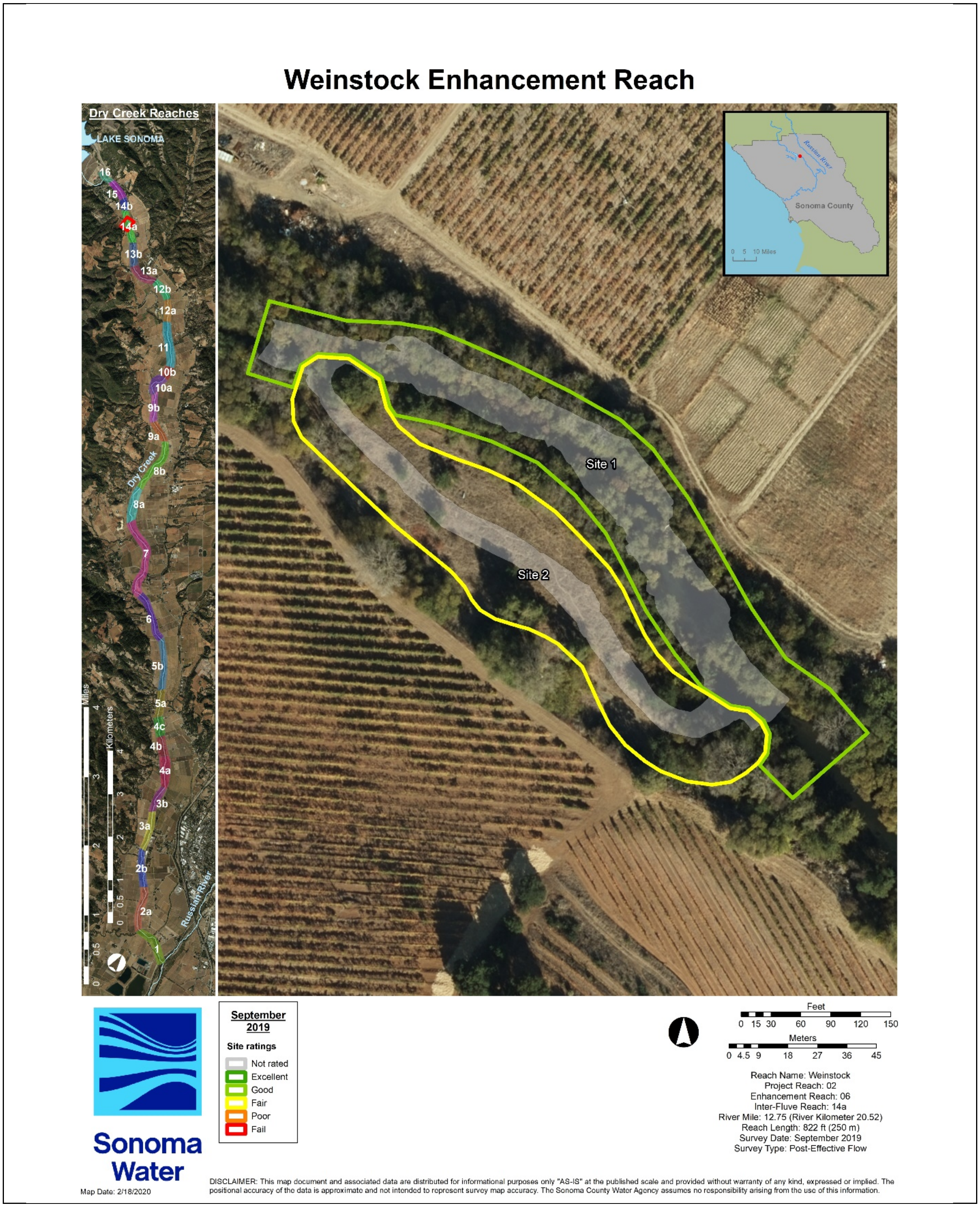


Figure 5.2.35. Post effective flow site ratings for the Weinstock enhancement reach, September 2019.

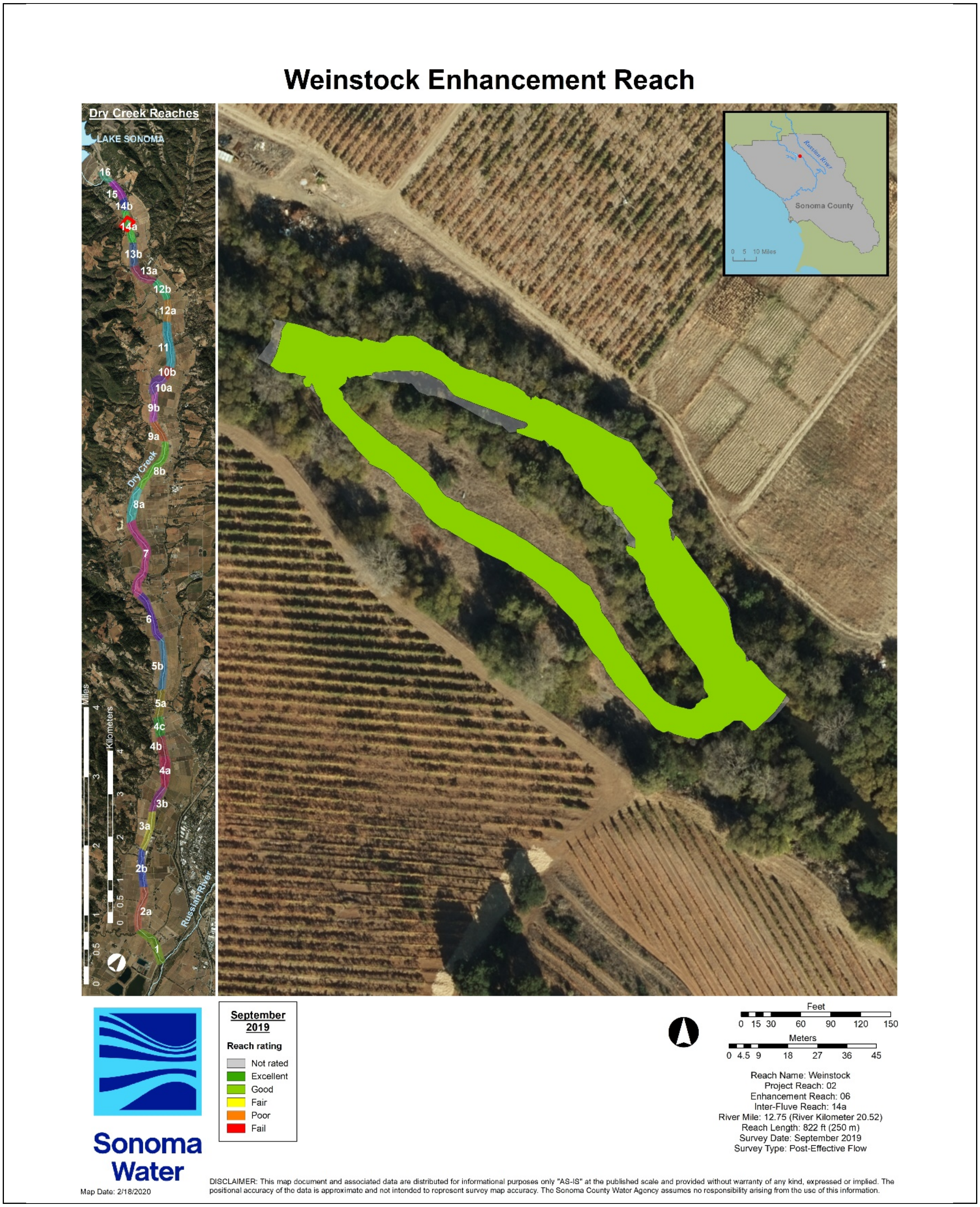


Figure 5.2.36. Post-effective flow reach rating for the Weinstock enhancement reach, September 2019.

Truett Hurst Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Truett Hurst enhancement reach in August 2019. Sonoma Water originally constructed the Truett Hurst enhancement reach in November 2016, but aggradation caused by large storms in winter 2016/2017 led to a poor effectiveness monitoring rating in July 2017 and subsequent repairs in summer 2017. Crews monitored again in October 2017 and the enhancement reach received a good post-repair rating (see 2018 report for results). Sonoma Water monitored the post effective flow, post-repair habitat condition in August 2018 with the enhancement reach receiving a good effectiveness monitoring rating (see 2019 report [with 2018 data] for results).

The 2019 monitored area encompassed 81,137 ft^2 within main and off channel areas with 31% of the total area meeting optimal depth and velocity criteria (Table 5.2.24, Figure 5.2.37). The monitored area included 16,572 ft^2 of side channel and 6,324 ft^2 of side channel alcove area, of which 44% and 36%, respectively met optimal depth and velocity criteria, compared with 58,831 ft^2 and 26% for the main channel area. Thirty six habitat units composed the enhancement reach post-effective flow 2019, with a pool to riffle ratio of 15:10 (1.50) and an average shelter score of 69 (Table 5.2.25, Figure 5.2.38, Figure 5.2.39). Thirteen habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised five enhancement sites (one main channel, a side channel, two alcoves, and a bank site; Table 5.2.26, Figure 5.2.40) that received fair to excellent site average feature ratings (we did not rate enhancement site 1 as it contained no features), and fair site average habitat unit ratings (Table 5.2.26, Figure 5.2.41, Figure 5.2.42). Enhancement site ratings ranged from fair to good, with the main channel site (site 1) receiving a fair rating, the two alcove sites receiving fair ratings, and the side-channel and bank sites receiving good ratings (Table 5.2.26, Figure 5.2.43). Overall, the Truett Hurst enhancement reach received a fair effectiveness monitoring rating for 2019 (Table 5.2.26, Figure 5.2.44; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.24. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, August 2019.

Truett Hurst Post-effective flow August 2019	Wetted area (ft^2)	Optimal depth (ft^2): 0.5 – 2.0 ft	Optimal depth (ft^2): 2.0 – 4.0 ft	Optimal depth (ft^2): Total	Optimal velocity (ft^2): < 0.5 ft/s	Optimal habitat (ft^2): 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2): 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2): Total
Main channel area	58,331	33,091	17,611	50,702	20,262	8,993	6,281	15,274
Side channel area	16,572	9,039	1,784	10,823	10,928	5,849	1,488	7,337
Side channel alcove area	6,234	3,321	39	3,360	4,159	2,199	33	2,233
Total area	**81,137**	**45,451**	**19,435**	**64,885**	**35,348**	**17,041**	**7,802**	**24,844**
Main channel % of wetted area	72%	57%	30%	87%	35%	15%	11%	26%
Side channel % of wetted area	20%	55%	11%	65%	66%	35%	9%	44%
Side channel alcove area % of wetted area	8%	53%	1%	54%	67%	35%	1%	36%
Total % of wetted area	**100%**	**56%**	**24%**	**80%**	**44%**	**21%**	**10%**	**31%**

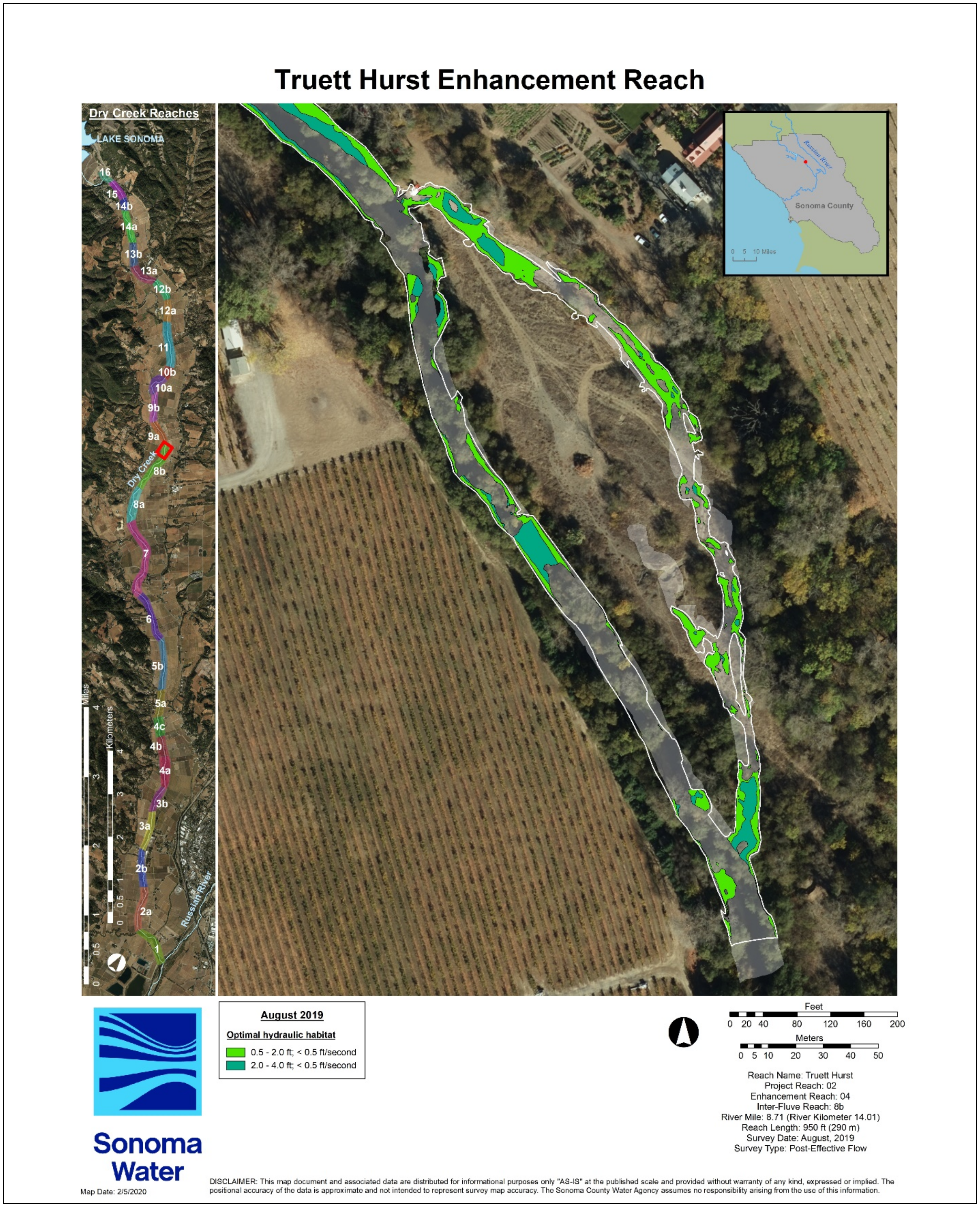


Figure 5.2.37. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, August 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.25. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, Post-effective flow, August 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	10	30
HU02	Pool	3	25	75
HU03	Riffle	1	5	5
HU04	Flatwater	2	15	30
HU05	Riffle	2	20	40
HU06	Pool	3	45	135
HU07	Flatwater	3	20	60
HU08	Riffle	3	25	75
HU09	Flatwater	2	30	60
HU10	Pool	3	30	90
HU11	Riffle	3	40	120
HU12	Pool	2	15	30
HU13	Flatwater	2	15	30
HU14	Pool	3	25	75
HU15	Riffle	1	10	10
HU16	Pool	3	35	105
HU17	Flatwater	3	30	90
HU18	Riffle	1	15	15
HU19	Pool	3	40	120
HU20	Flatwater	1	5	5
HU21	Alcove	3	40	120
HU22	Pool	3	45	135
HU23	Riffle	2	40	80
HU24	Flatwater	3	70	210
HU25	Pool	3	30	90
HU26	Riffle	2	20	40
HU27	Pool	3	20	60
HU28	Pool	3	10	30
HU29	Pool	3	20	60
HU30	Riffle	3	10	30
HU31	Pool	3	10	30
HU32	Flatwater	3	35	105
HU33	Flatwater	3	35	105
HU34	Riffle	3	10	30
HU35	Pool	3	20	60
HU36	Pool	3	30	90
Pool: riffle	**15:10 (1.50)**			**Avg = 69**

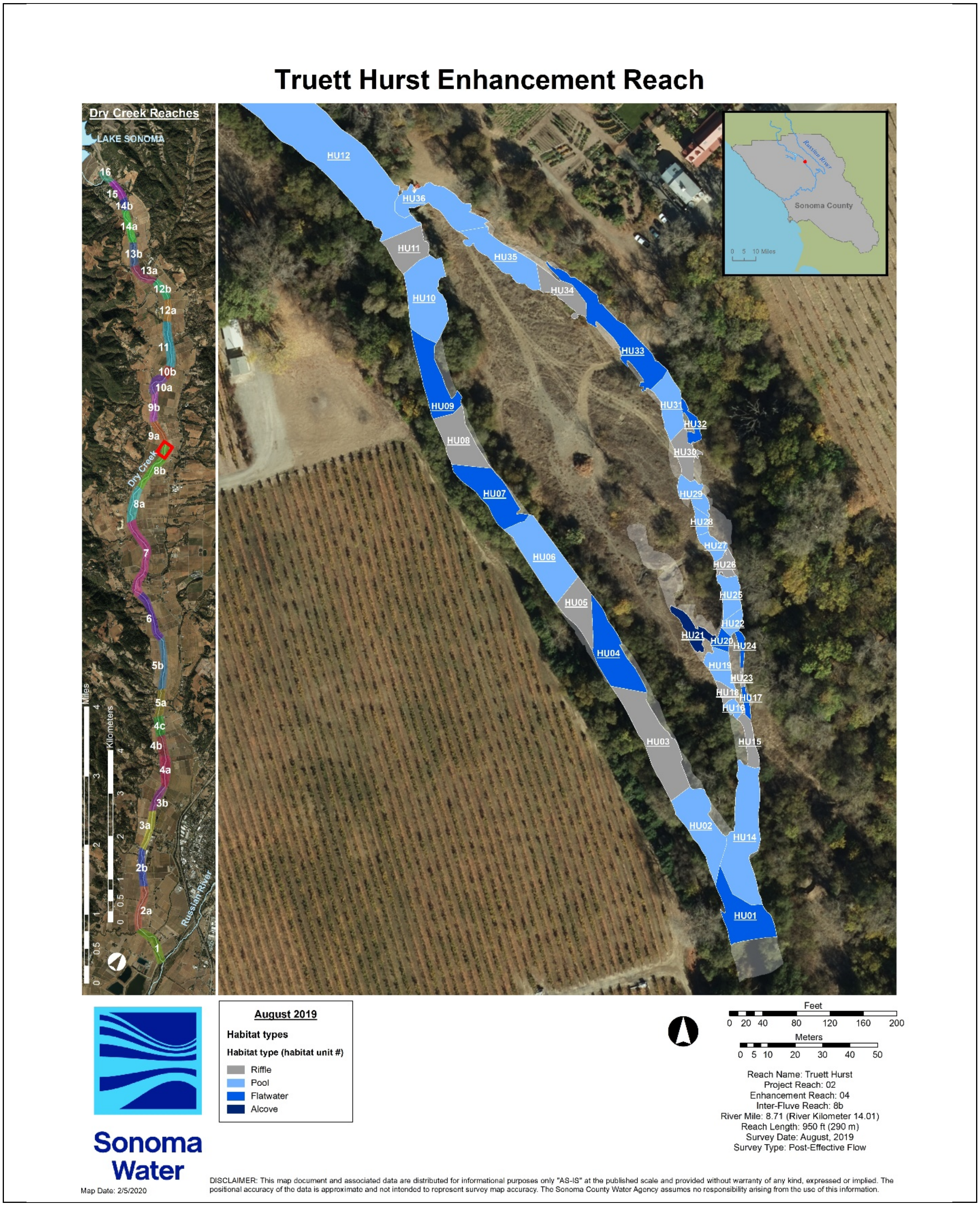


Figure 5.2.38. Habitat unit number and type within the Truett Hurst enhancement reach, August 2019.

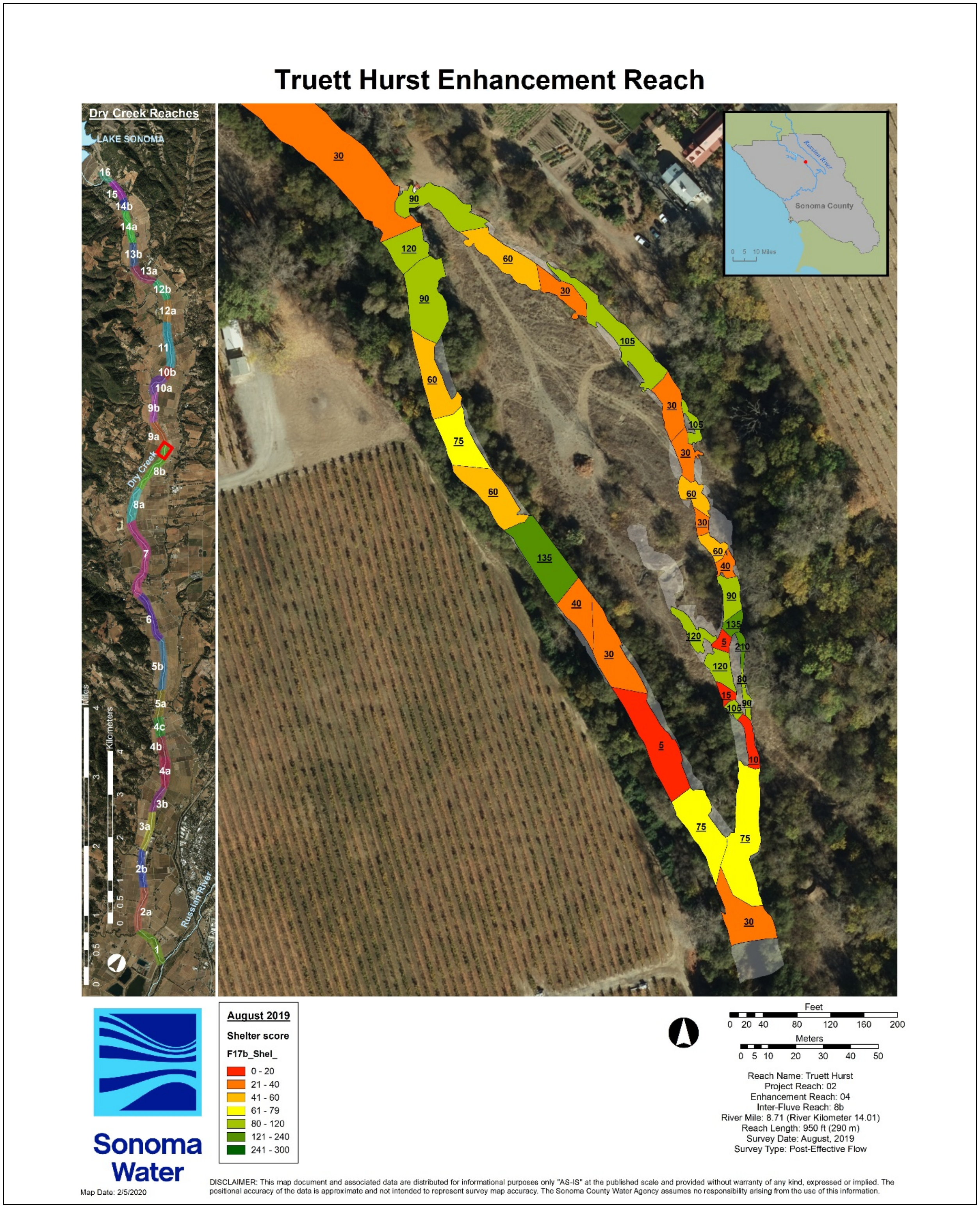


Figure 5.2.39. Habitat unit shelter scores within the Truett Hurst enhancement reach, August 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.26. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Truett Hurst enhancement reach, August 2019.

Site number		1	2	3	4	5
Site type		Main channel	Side channel	Alcove	Alcove	Bank
Site average feature rating	Site average feature quantitative rating[a]	0	12	6	11	12
	Site average feature qualitative rating[a]	Not rated	Excellent	Fair	Good	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	15	18	19	16	21
	Site average qualitative rating[b]	Fair	Fair	Fair	Fair	Fair
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	15[b]	30[c]	25[c]	27[c]	33[c]
	Site qualitative rating	Fair[b]	Good[c]	Fair[c]	Fair[c]	Good[c]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating[d]	26				
	Enhancement reach qualitative rating[d]:	Fair				

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 47; Excellent (>=38), Good (>=28), Fair (>=19), Poor (>=9), Fail (<9)

Truett Hurst Enhancement Reach

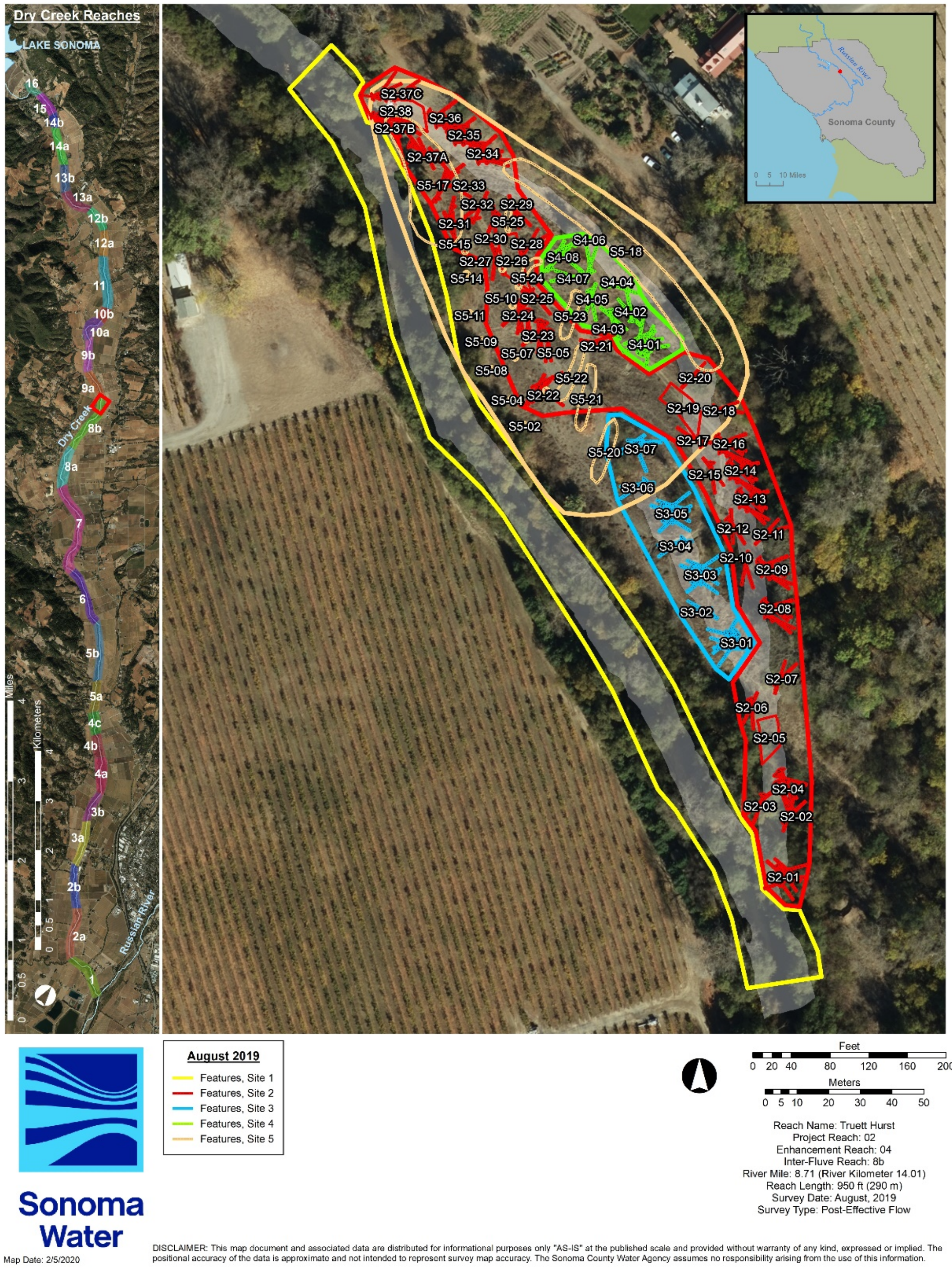


Figure 5.2.40. Enhancement sites and features within the Truett Hurst enhancement reach, August 2019.

Truett Hurst Enhancement Reach

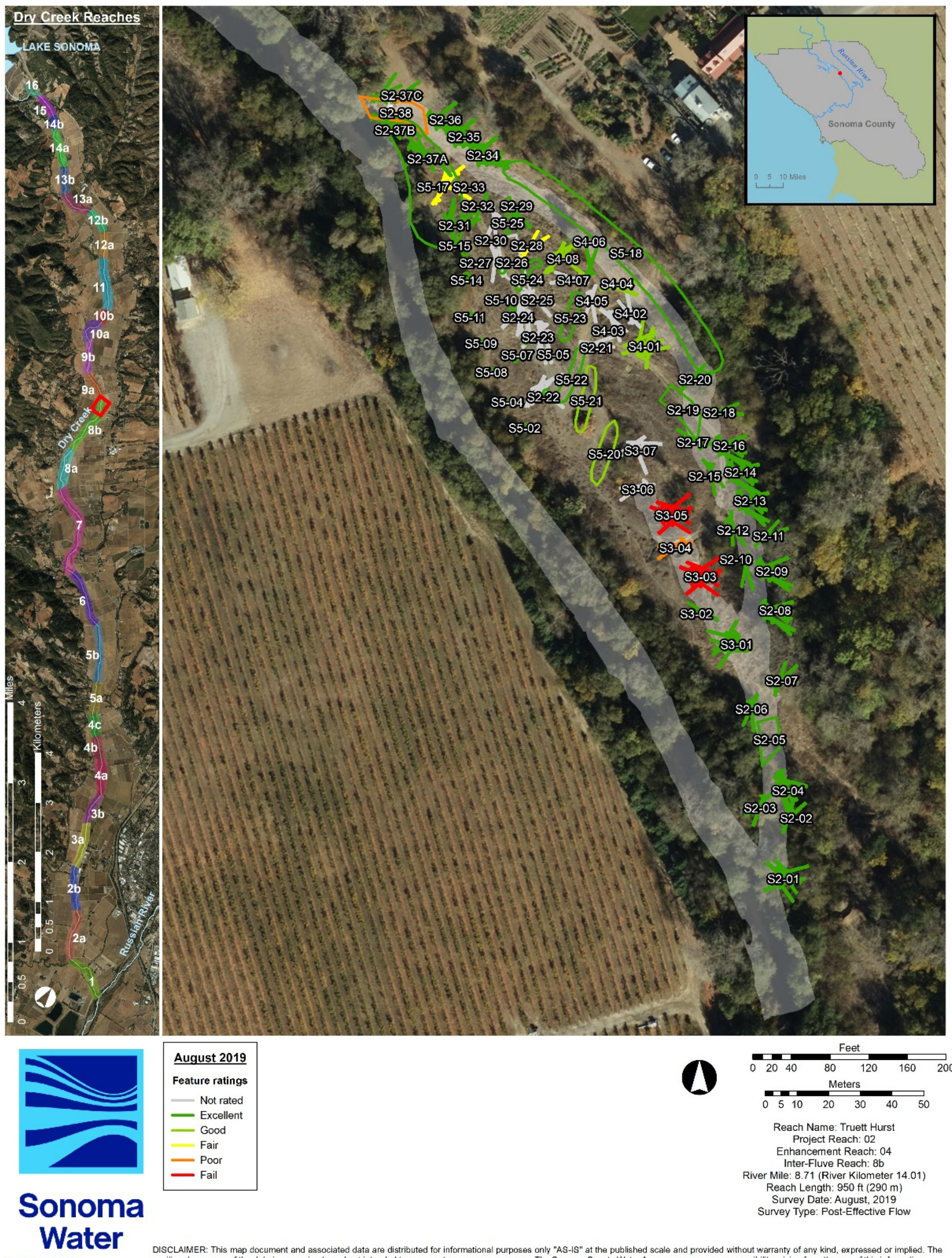


Figure 5.2.41. Feature ratings for the Truett Hurst enhancement reach, August 2019.

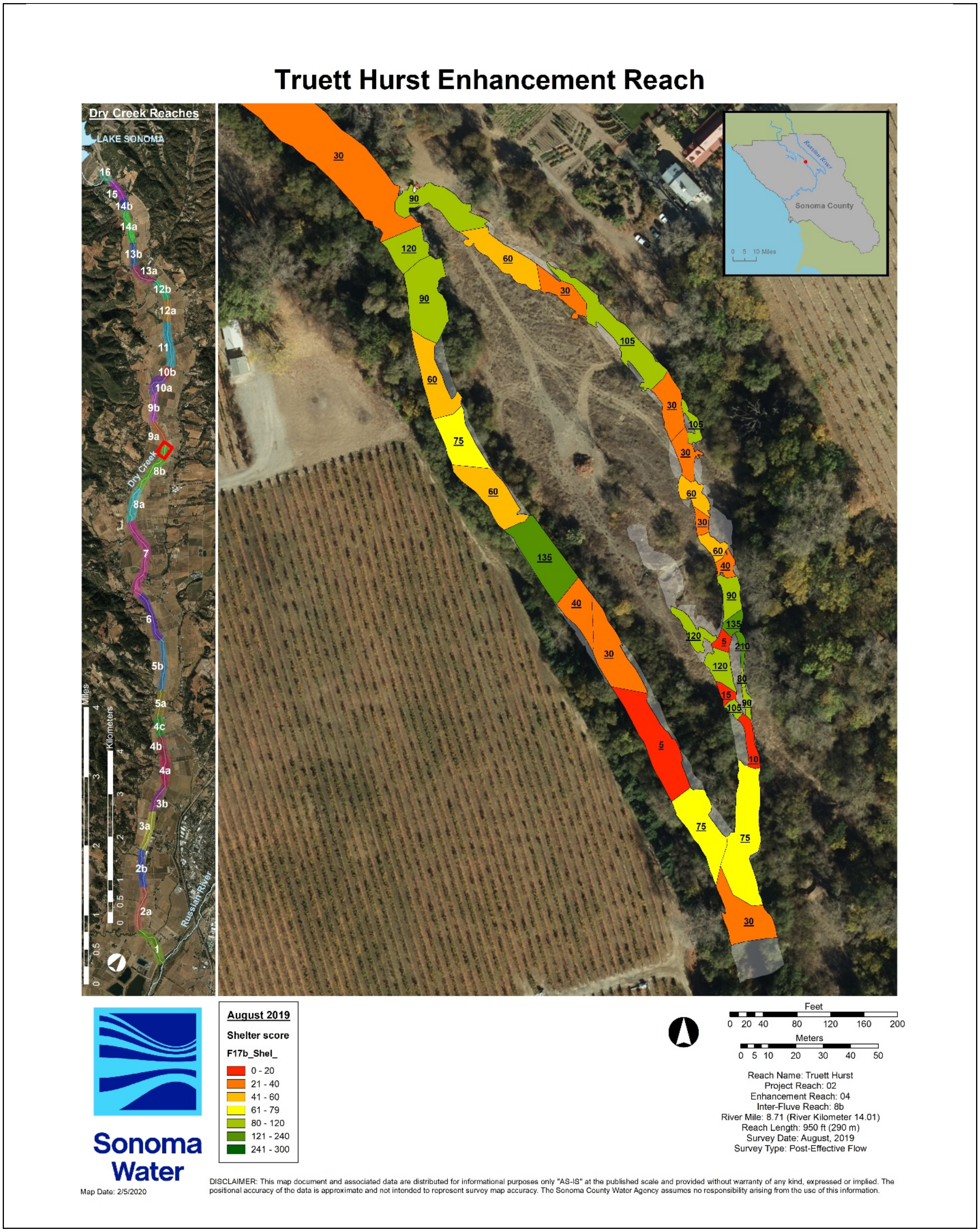


Figure 5.2.42. Habitat unit ratings for the Truett Hurst enhancement reach, August 2019.

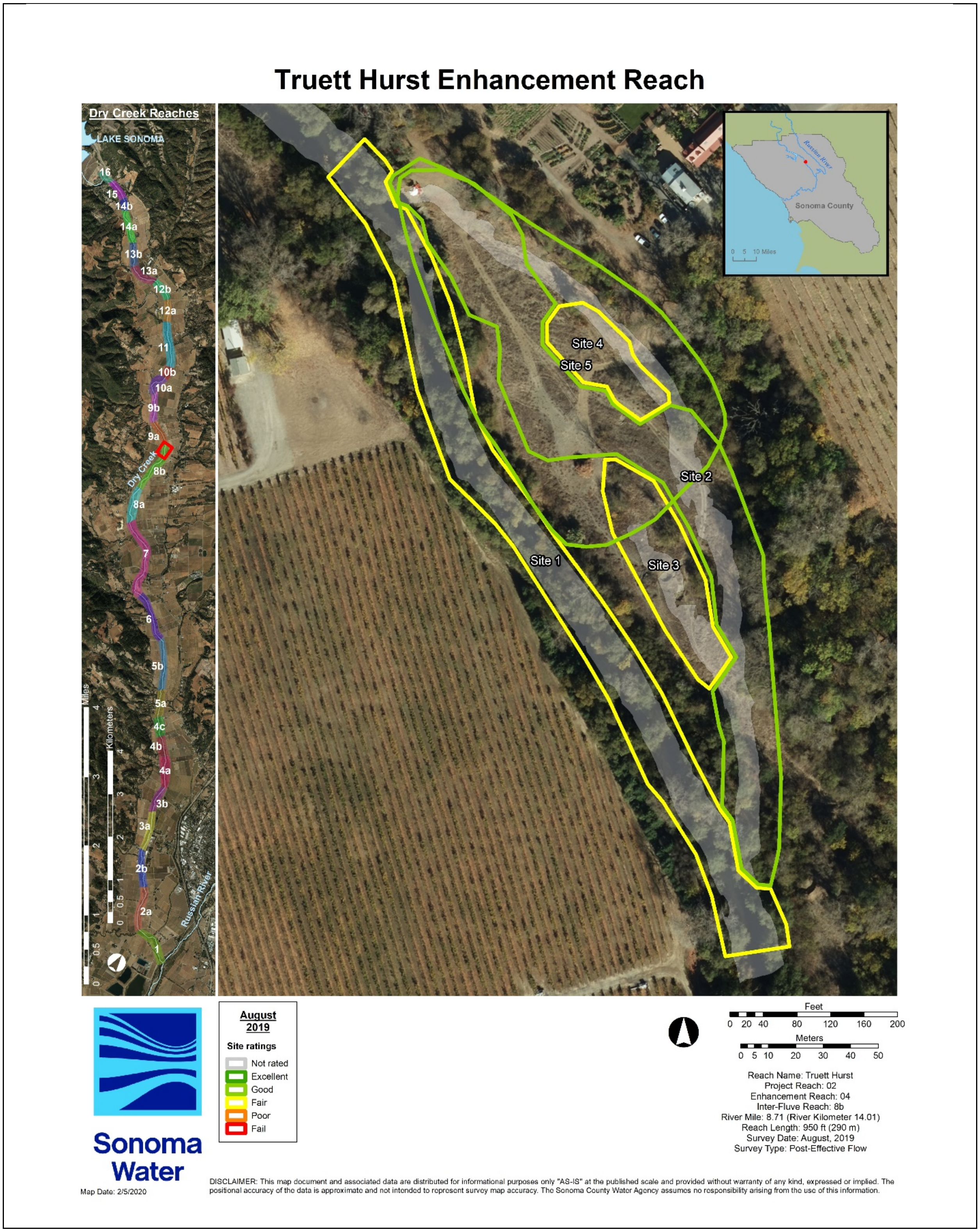


Figure 5.2.43. Post-effective flow site ratings for the Truett Hurst enhancement reach, August 2019.

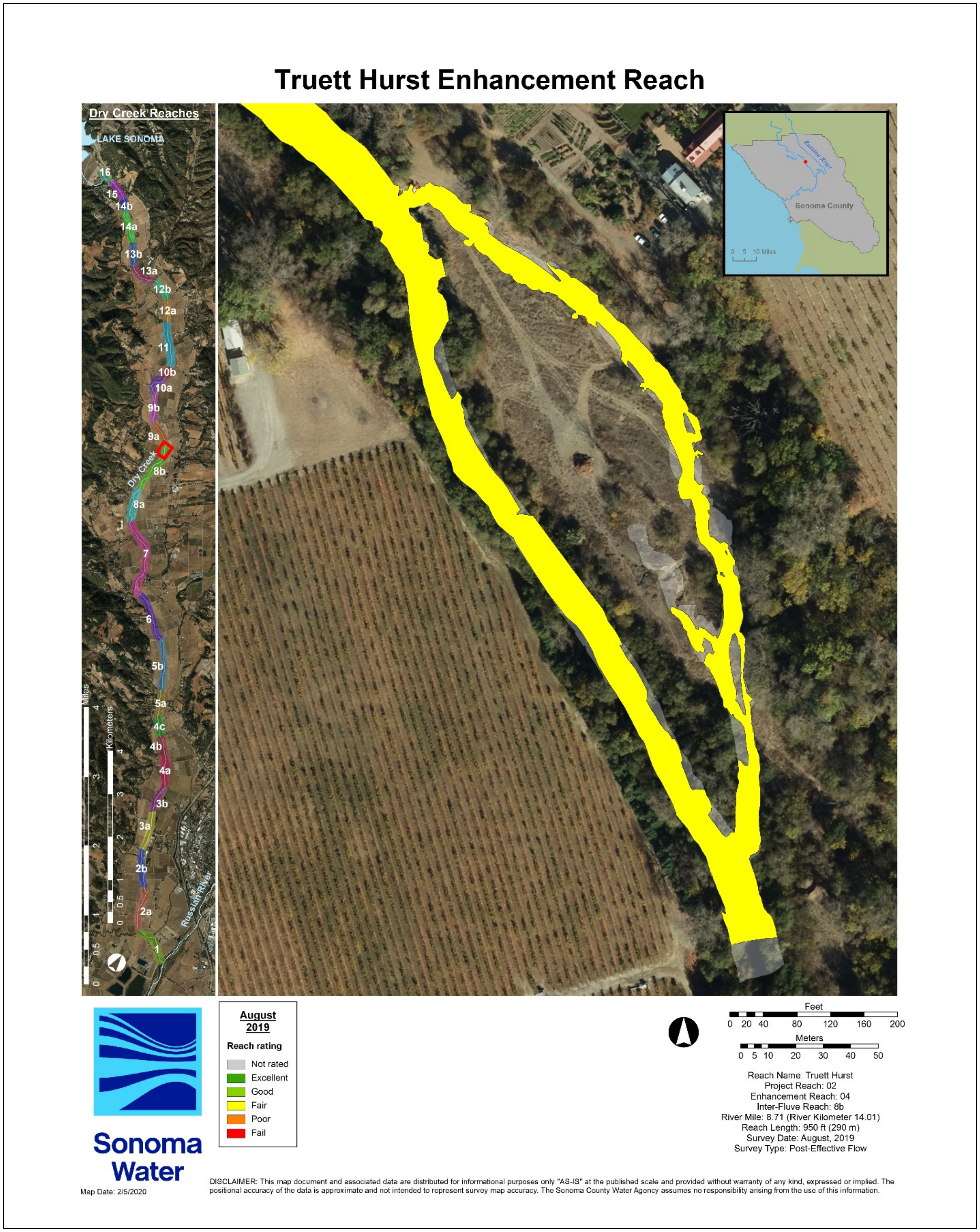


Figure 5.2.44. Post-effective flow reach rating for the Truett Hurst enhancement reach, August 2019.

Farrow Wallace Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Farrow, Wallace enhancement reach in November 2019. Previous effectiveness monitoring surveys occurred in August 2015 (post-effective flow) and August 2017 (post-effective flow) receiving good and fair ratings, respectively. The 2019 monitored area encompassed 73,824 ft^2 within main- and off-channel areas of Dry Creek with 33% of the total area meeting optimal depth and velocity criteria (Table 5.2.27, Figure 5.2.45). The monitoring characterized 15,821 ft^2 of main channel alcove area and 10,711 ft^2 of side channel area, of which 54% and 71% met optimal depth and velocity criteria, compared with 47,292 ft^2 and 17% for the main channel area. Seventeen habitat units composed the enhancement reach, with a pool to riffle ratio of 6:4 (1.50) and average shelter score of 84 (Table 5.2.28, Figure 5.2.46, Figure 5.2.47). Nine habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised seven enhancement sites (four main-channel sites, one alcove, one side channel, one bank site; Table 5.2.29, Figure 5.2.48), with good to excellent site average feature ratings (we did not rate enhancement site 1 as it contained no features), and poor to good site average habitat unit ratings (we did not rate site 4 as it contained no aquatic habitat; Table 5.2.29, Figure 5.2.49, Figure 5.2.50). Enhancement sites received fair to excellent ratings (Table 5.2.29, Figure 5.2.51). Overall, the Farrow, Wallace enhancement reach received a good effectiveness monitoring rating (Table 5.2.29, Figure 5.2.52; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.27. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Farrow, Wallace enhancement reach, November 2019.

Farrow, Wallace Post-effective flow November 2019	Wetted area (ft^2)	Optimal depth (ft^2) 0.5 – 2.0 ft	Optimal depth (ft^2) 2.0 – 4.0 ft	Optimal depth (ft^2) Total	Optimal velocity (ft^2) < 0.5 ft/s	Optimal habitat (ft^2) 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2) 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2) Total
Main channel area	47,292	25,257	13,813	39,070	12,252	4,267	3,667	7,934
Main channel alcove area	15,821	5,517	6,531	12,048	11,521	4,296	4,297	8,593
Side channel area	10,711	5,142	3,485	8,628	9,697	4,575	3,061	7,636
Total area	73,824	35,917	23,829	59,746	33,470	13,138	11,025	24,163
Main channel % of wetted area	64%	53%	29%	83%	26%	9%	8%	17%
Main channel alcove % of wetted area	21%	35%	41%	76%	73%	27%	27%	54%
Side channel % of wetted area	15%	48%	33%	81%	91%	43%	29%	71%
Total % of wetted area	**100%**	49%	32%	81%	45%	18%	15%	33%

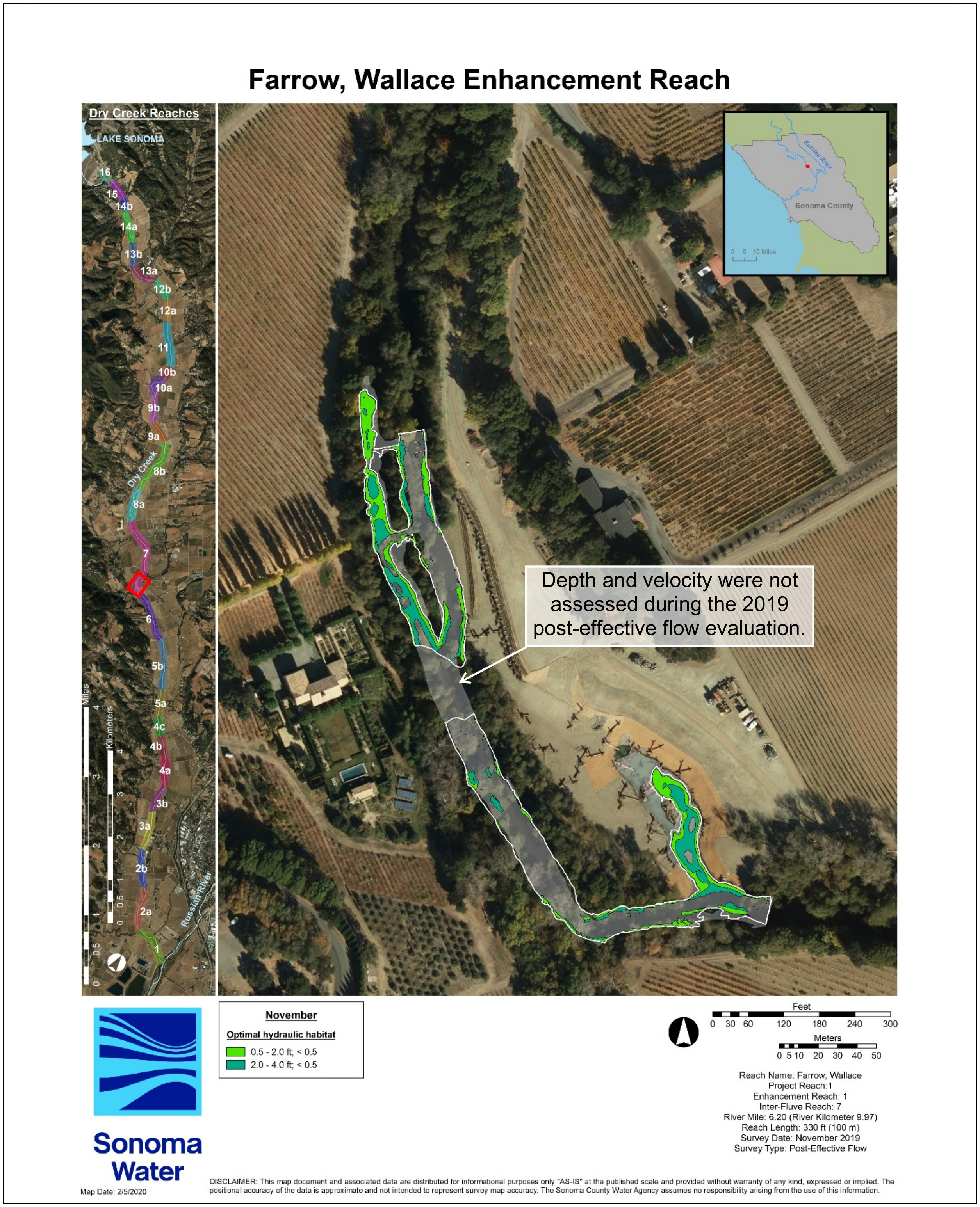


Figure 5.2.45. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Farrow, Wallace enhancement reach, November 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.28. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Farrow, Wallace enhancement reach, Post-effective flow, November 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	35	105
HU02	Alcove	3	65	195
HU03	Flatwater	2	30	60
HU04	Pool	2	20	40
HU05	Riffle	1	10	10
HU06	Flatwater	1	10	10
HU07	Pool	3	40	120
HU08	Riffle	0	50	0
HU09	Pool	3	50	150
HU10	Riffle	2	20	40
HU11	Pool	3	30	90
HU12	Flatwater	2	20	40
HU13	Riffle	3	75	225
HU14	Alcove	2	45	90
HU15	Flatwater	2	15	30
HU16	Flatwater	2	40	80
HU17	Pool	3	50	150
Pool: riffle	**6:4 (1.50)**			**Avg = 84**

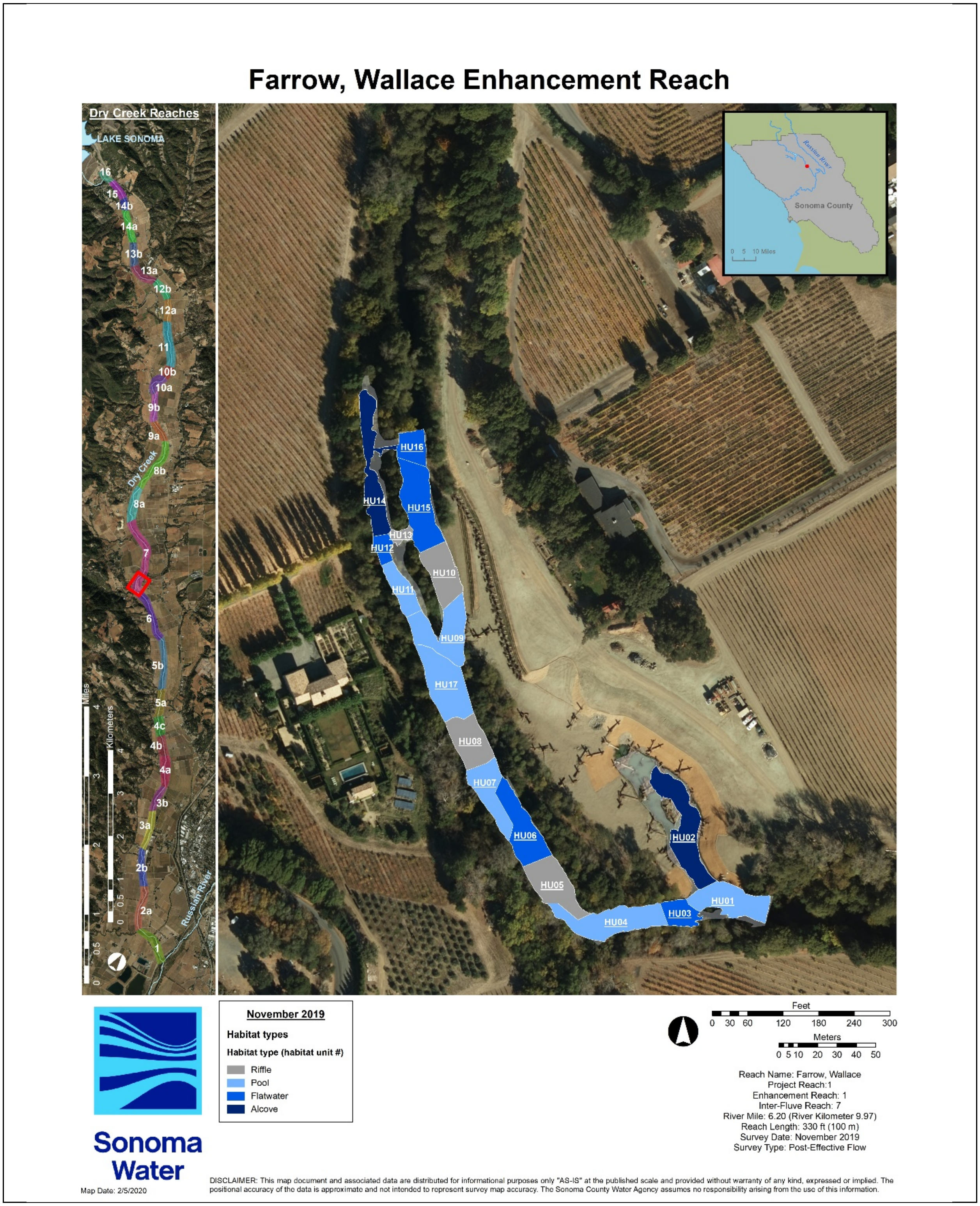


Figure 5.2.46. Habitat unit number and type within the Farrow, Wallace enhancement reach, November 2019.

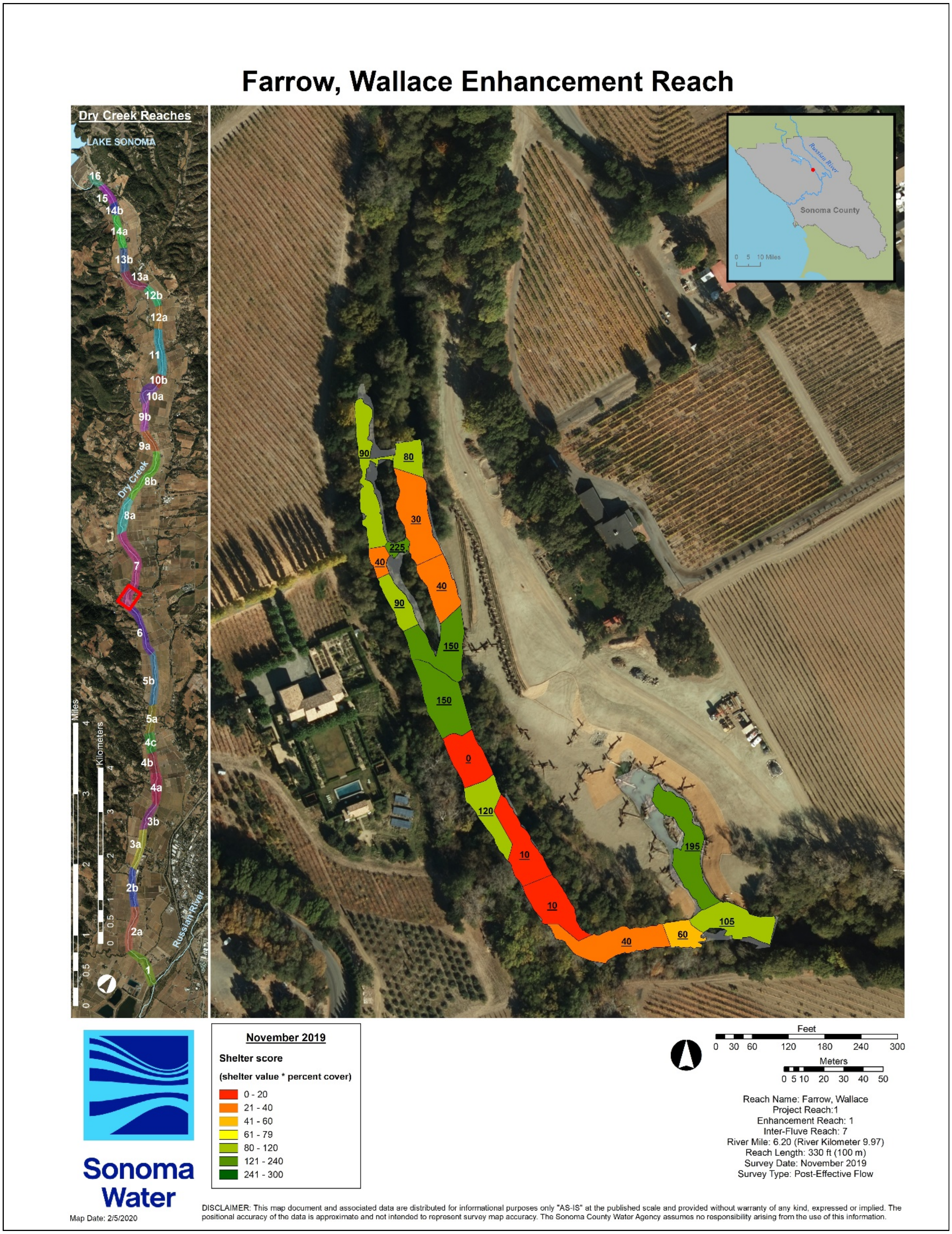


Figure 5.2.47. Habitat unit shelter scores within the Farrow, Wallace enhancement reach, November 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.29. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Farrow, Wallace enhancement reach, November 2019.

Site number		1	2	3	4	5	6	7
Site type		Alcove	Main chan	Main chan	Bank	Main chan	Side chan	Main chan
Site average feature rating	Site average feature quantitative rating[a]	11	0	13	13	13	11	13
	Site average feature qualitative rating[a]	Good	Not rated	Excellent	Excellent	Excellent	Good	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	25	13	19	0	21	25	7
	Site average qualitative rating[b]	Good	Poor	Fair	Not rated	Good	Good	Poor
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)	36[c]	13[b]	32[c]	13[a]	34[c]	36[c]	20[c]
	Site qualitative rating	Good[c]	Poor[b]	Good[c]	Excellent[a]	Good[c]	Good[c]	Fair[c]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	26						
	Enhancement reach qualitative rating[d]:	Good						

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 43; Excellent (>=34), Good (>=26), Fair (>=17), Poor (>=9), Fail (<9)

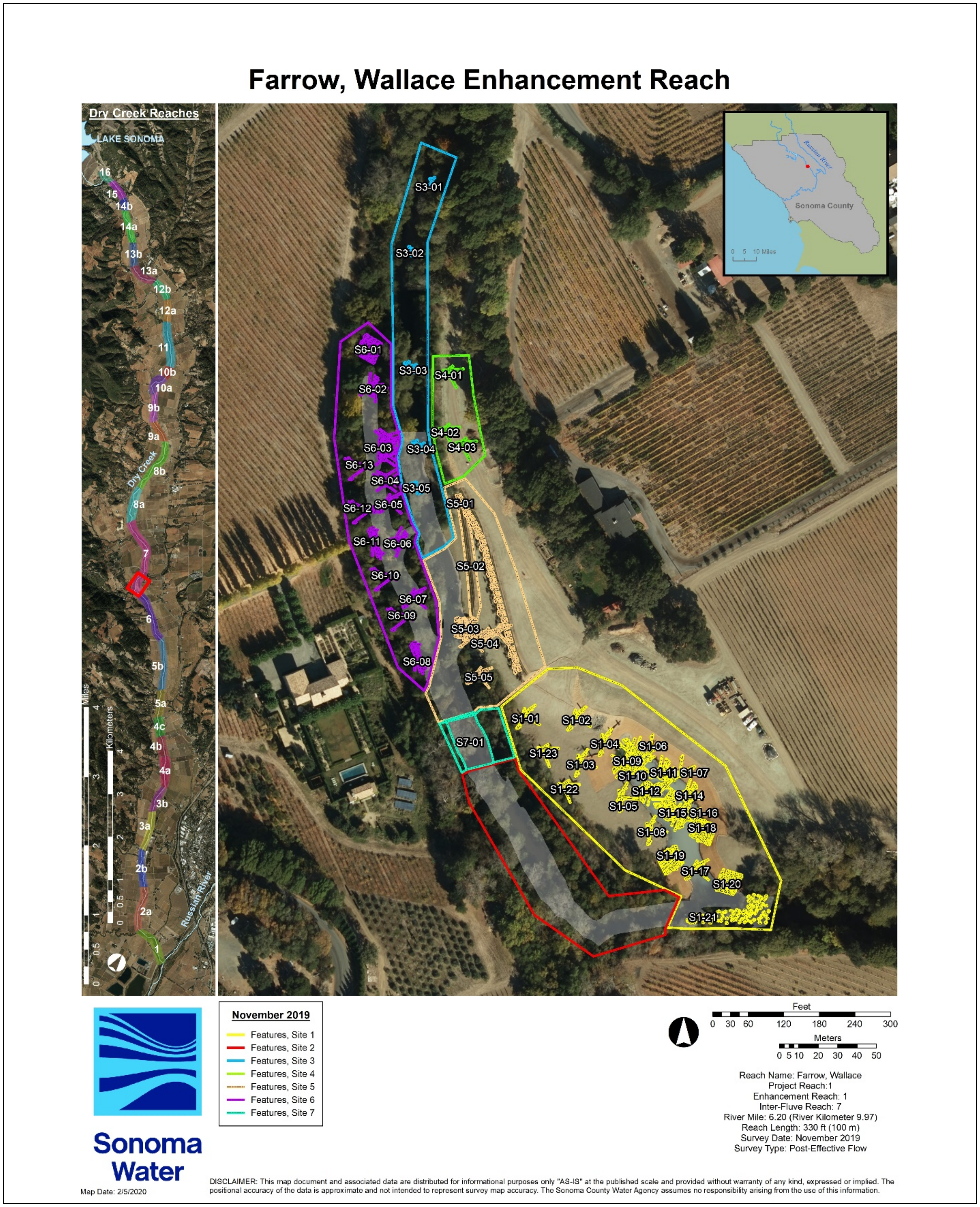


Figure 5.2.48. Enhancement sites and features within the Farrow, Wallace enhancement reach, November 2019.

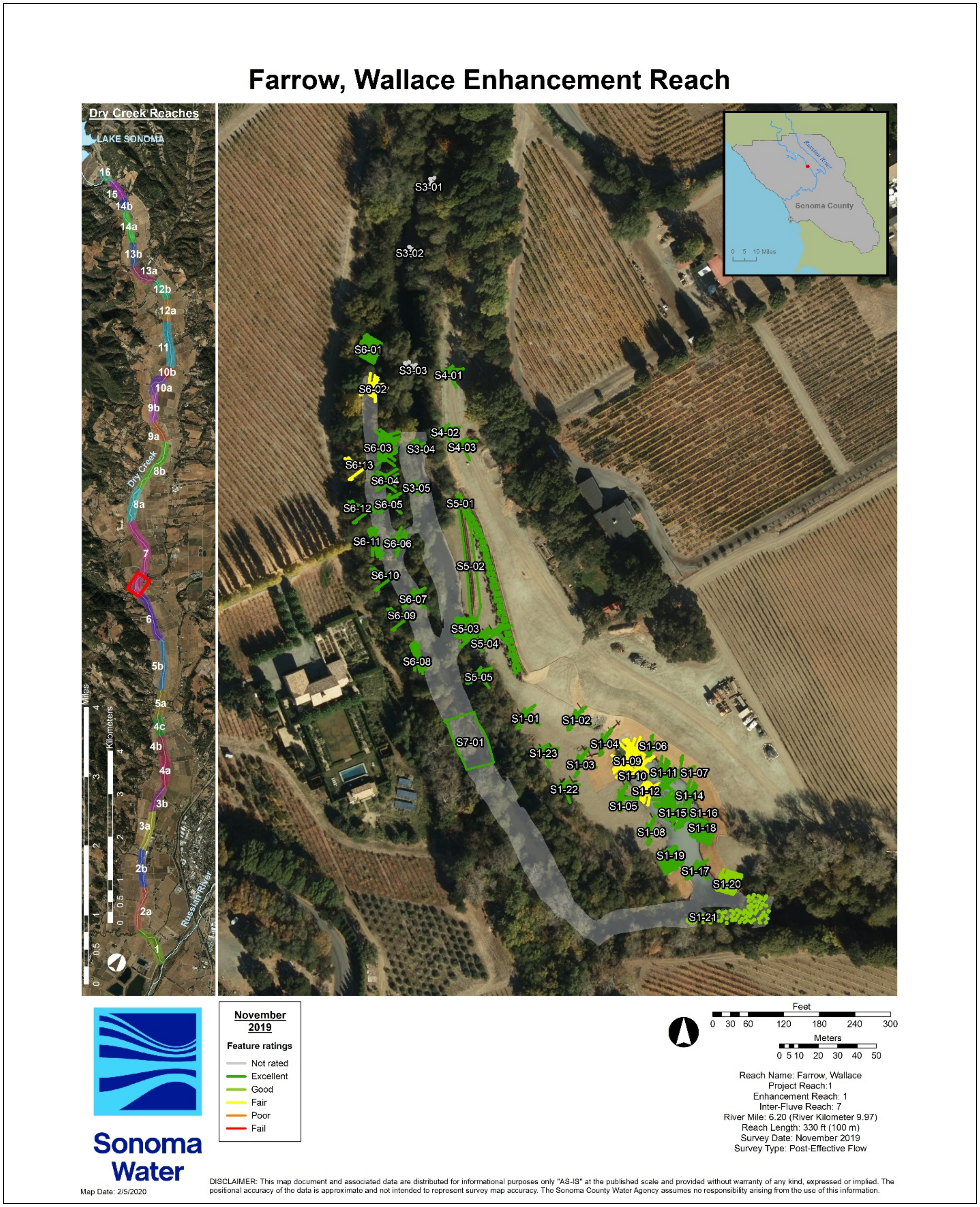


Figure 5.2.49. Feature ratings for the Farrow, Wallace enhancement reach, November 2019.

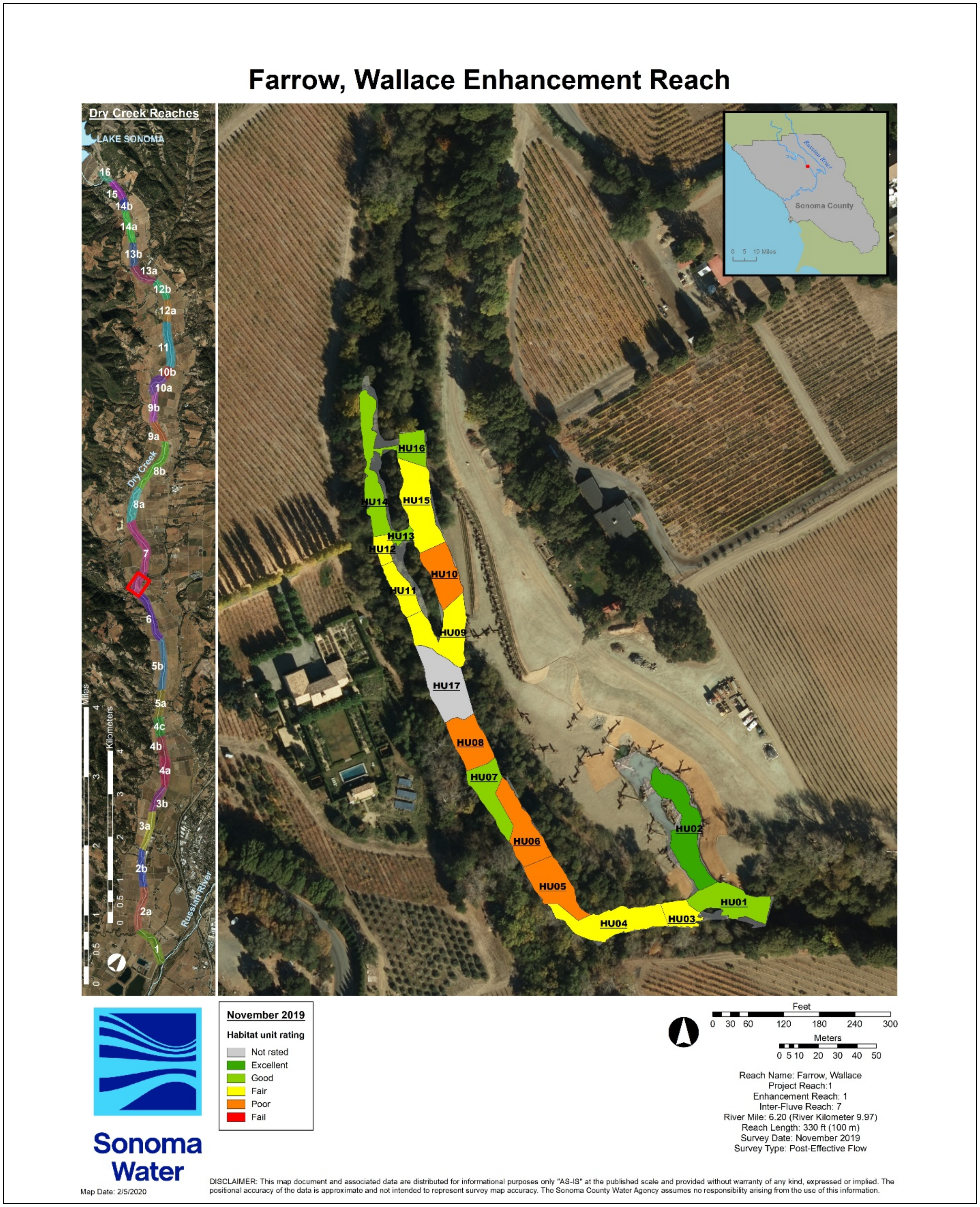


Figure 5.2.50. Habitat unit ratings for the Farrow, Wallace enhancement reach, November 2019.

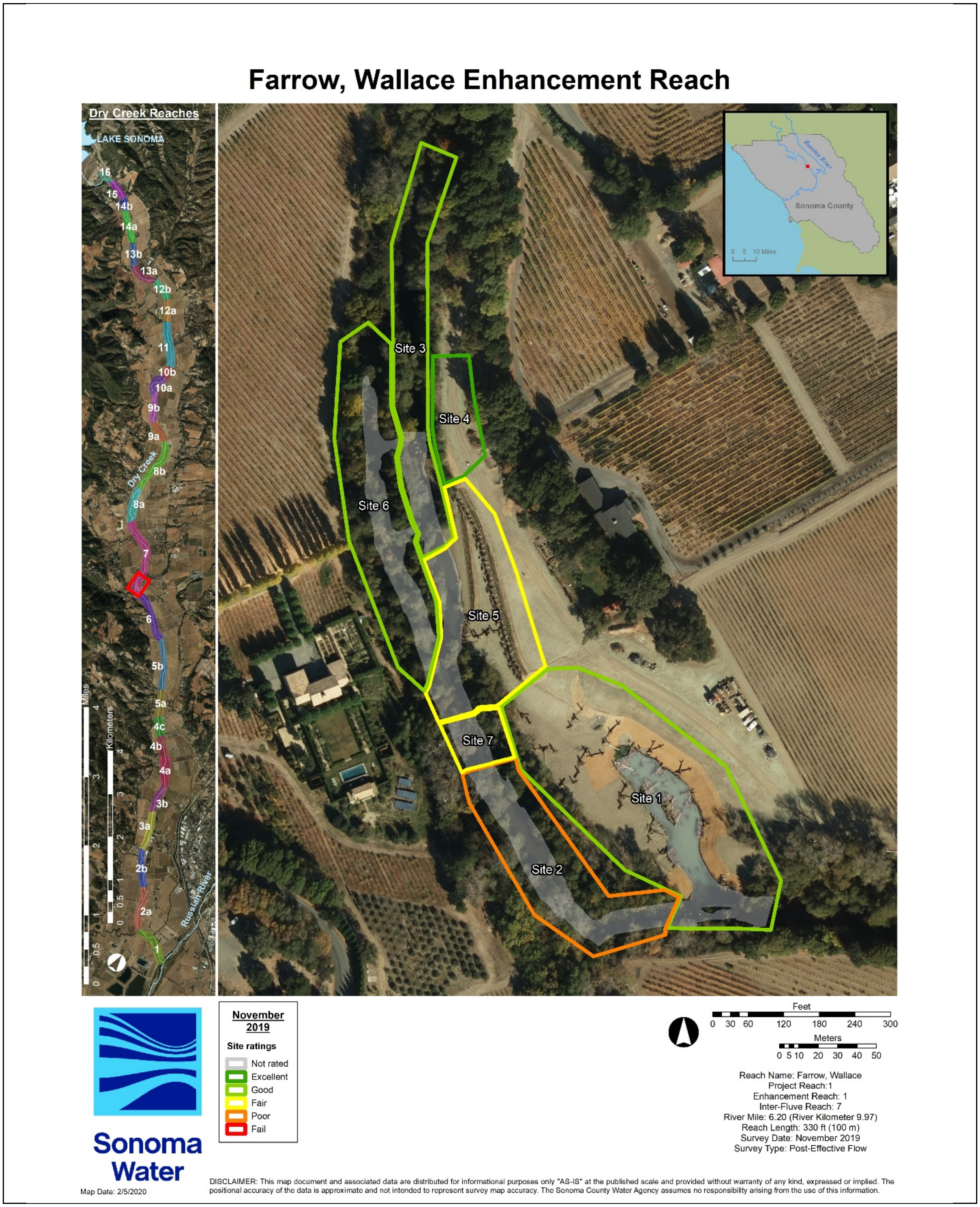


Figure 5.2.51. Post-effective flow site ratings for the Farrow, Wallace enhancement reach, November 2019.

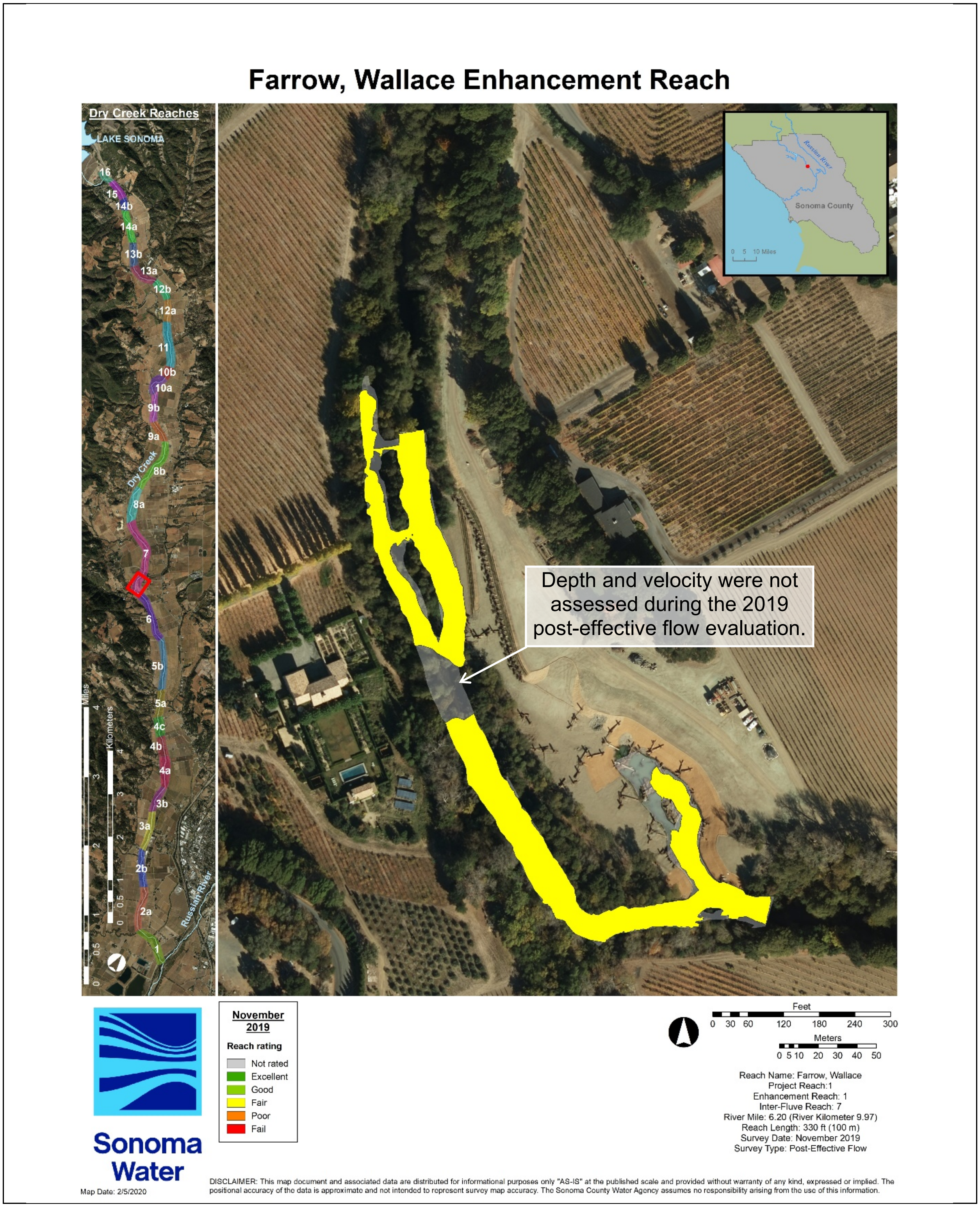


Figure 5.2.52. Post-effective flow reach rating for the Farrow, Wallace enhancement reach, November 2019.

Ferrari-Carano, Olson Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Ferrari-Carano, Olson enhancement reach in June 2019. Previous effectiveness monitoring surveys occurred in May 2018 (pre-enhancement) and October 2018 (post-enhancement) receiving fair and good enhancement reach ratings, respectively. The post-effective flow 2019 enhancement reach encompassed 110,660 ft^2 within main and off channel areas with 23% of the total area meeting optimum depth and velocity criteria (Table 5.2.30, Figure 5.2.53). The enhancement initially added 63,666 ft^2 of side channel in May 2018 (reported as 83,833 ft^2 in 2019 report and revised in this report), but aggradation caused by storms in winter 2018/2019 reduced off channel area to 53,142 ft^2. The enhancement also included 87,361 ft^2 of main channel in May 2018 (reported as 67,194 ft^2 in 2019 report and revised in this report), but aggradation by storms in winter 2018/2019 reduced off channel area to 53,142 ft^2 in 2019 (Table 5.2.30). Sediment aggraded in the upper portion of the upstream most side channel, within the main channel, and in a side channel near the downstream end of the enhancement reach (Figure 5.2.53). Monitoring found that 28% of the remaining off-channel area and 18% of the main channel area met optimal depth and velocity criteria (Table 5.2.30, Figure 5.2.53). Thirty-nine habitat units composed the enhancement reach post-effective flow, with a pool to riffle ratio of 17:10 (1.70) and an average shelter score of 60 (Table 5.2.31, Figure 5.2.54, Figure 5.2.55). Sixteen habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel, two side channels) that received poor to fair site average feature ratings and poor to fair site average habitat unit ratings (Table 5.2.32, Figure FO 56, Figure 5.2.57, Figure 5.2.58). Sites 1 and 2 partially aggraded, burying some enhancement features, while Site 3 almost completely aggraded, burying nearly all enhancement features, leading to fair, fair, and poor site ratings (Table 5.2.32, Figure 5.2.59). Overall, the Ferrari-Carano, Olson enhancement reach received a fair enhancement reach rating (Figure 5.2.60) (See Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.30. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Ferrari-Carano, Olson enhancement reach, June 2019.

Ferrari-Carano, Olson Post-effective flow June 2019	Wetted area (ft^2)	Optimal depth (ft^2) 0.5 – 2.0 ft	Optimal depth (ft^2) 2.0 – 4.0 ft	Optimal depth (ft^2) Total	Optimal velocity (ft^2) < 0.5 ft/s	Optimal habitat (ft^2) 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2) 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2) Total
Main channel area	57,518	27,641	14,415	42,056	21,612	8,118	2,247	10,364
Side channel area	53,142	24,016	18,338	42,353	23,365	8,824	6,168	14,992
Total area	110,660	51,656	32,753	84,409	44,977	16,942	8,414	25,356
Main channel % of wetted area	52%	48%	25%	73%	38%	14%	4%	18%
Side channel % of wetted area	48%	45%	35%	80%	44%	17%	12%	28%
Total % of wetted area	**100%**	**47%**	**30%**	**76%**	**41%**	**15%**	**8%**	**23%**

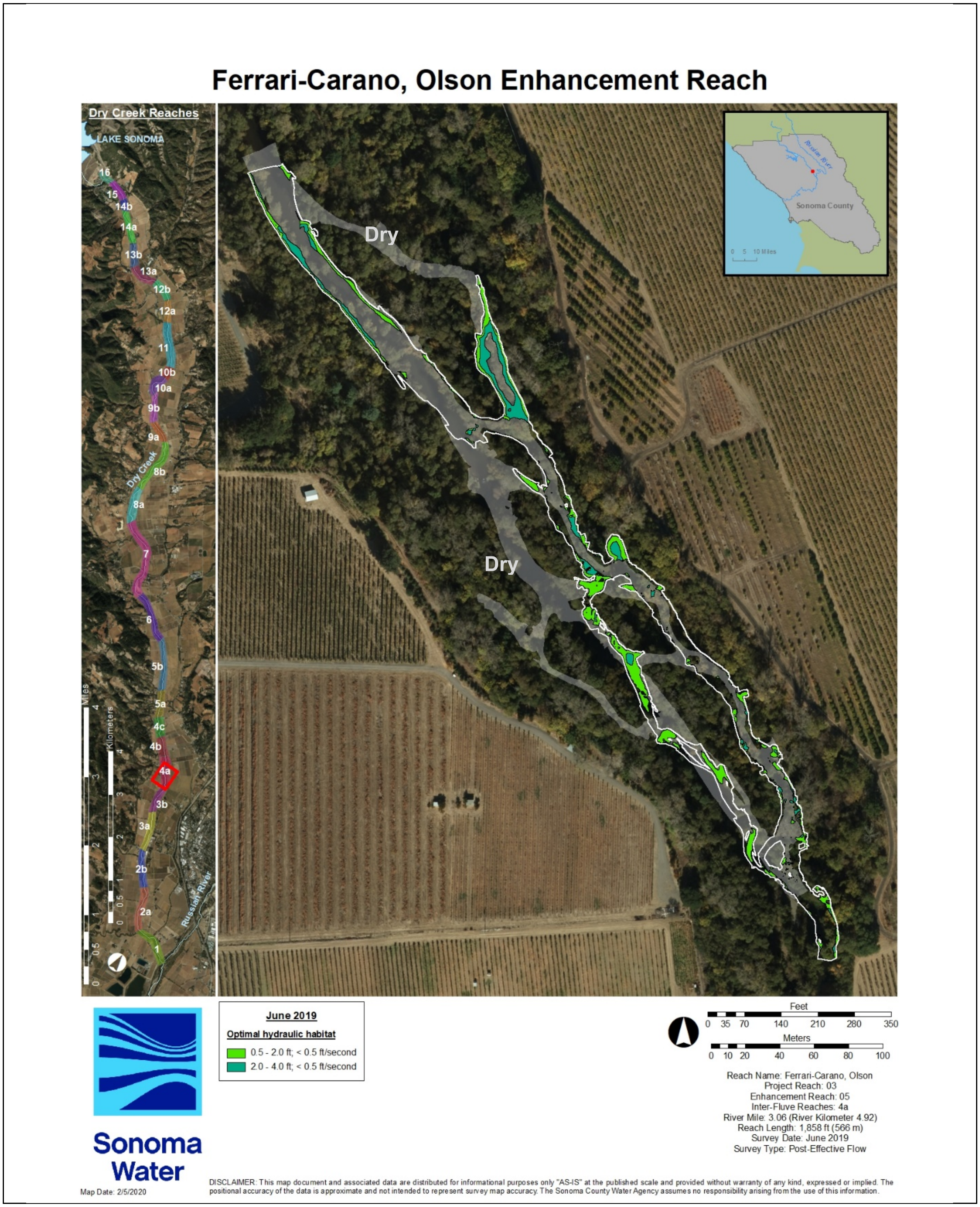


Figure 5.2.53. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Ferrari-Carano, Olson enhancement reach, June 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.31. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Ferrari-Carano, Olson enhancement reach, Post-effective flow, June 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU00	Pool	3	65	195
HU01	Flatwater	3	40	120
HU02	Alcove	1	15	15
HU03	Riffle	3	30	90
HU04	Pool	2	40	80
HU05	Pool	3	35	105
HU06	Flatwater	2	15	30
HU07	Pool	3	40	120
HU08	Pool	3	15	45
HU09	Riffle	3	20	60
HU10	Pool	3	30	90
HU11	Flatwater	1	10	10
HU12	Pool	3	30	90
HU13	Pool	3	15	45
HU14	Pool	3	30	90
HU15	Alcove	3	60	180
HU16	Flatwater	3	15	45
HU17	Alcove	0	0	0
HU18	Riffle	0	0	0
HU19	Pool	3	20	60
HU20	Alcove	3	25	75
HU21	Riffle	1	15	15
HU22	Pool	3	15	45
HU23	Flatwater	2	10	20
HU24	Riffle	0	0	0
HU25	Pool	3	40	120
HU26	Riffle	1	5	5
HU27	Pool	2	40	80
HU28	Riffle	1	10	10
HU29	Flatwater	1	5	5
HU30	Pool	3	35	105
HU31	Riffle	0	0	0
HU32	Flatwater	1	10	10
HU33	Pool	3	15	45
HU34	Pool	3	35	105
HU35	Riffle	2	40	80
HU36	Pool	2	15	30
HU37	Riffle	3	50	150
HU38	Flatwater	2	10	20
HU39	Alcove	1	5	5
Pool: riffle	**17:10 (1.70)**			**Avg = 60**

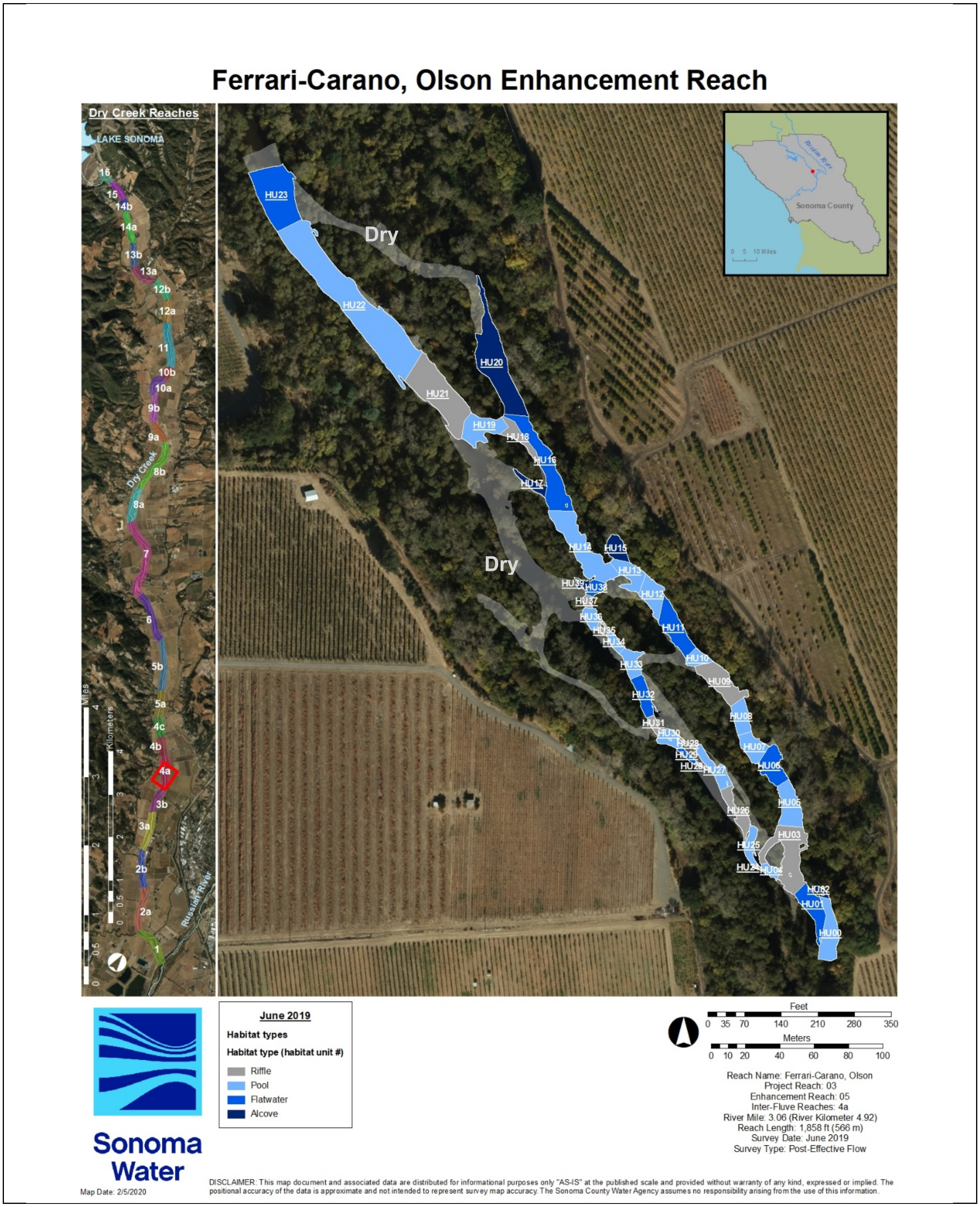


Figure 5.2.54. Habitat unit number and type within the Ferrari-Carano, Olson enhancement reach, June 2019.

Ferrari-Carano, Olson Enhancement Reach

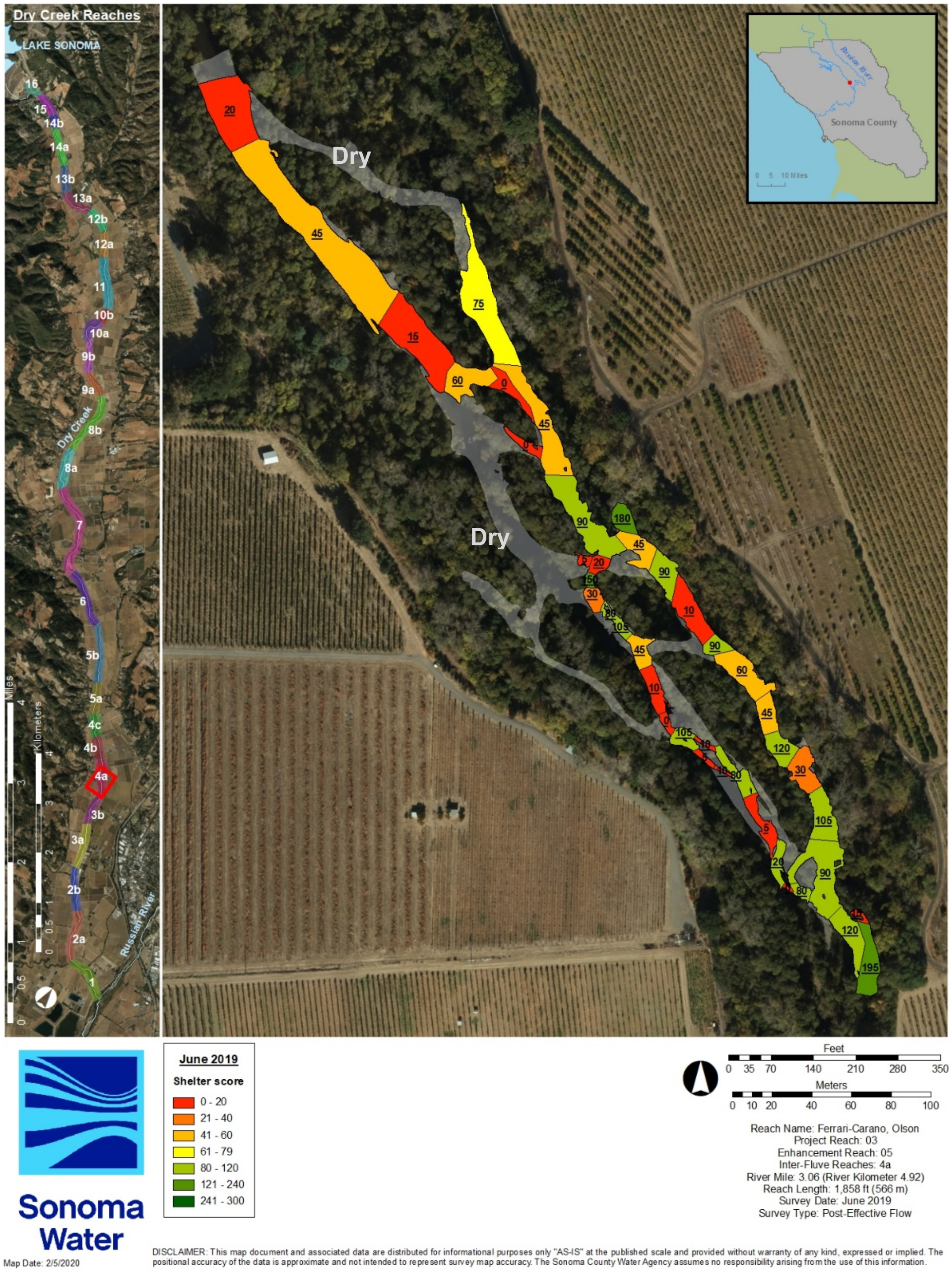


Figure 5.2.55. Habitat unit shelter scores within the Ferrari-Carano, Olson enhancement reach, June 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.32. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Ferrari-Carano, Olson enhancement reach, June 2019.

Site number		**1**	**2**	**3**	
Site type		Main channel	Side channel	Side channel	
Site average feature rating	Site average feature quantitative rating[a]	6	8	5	
	Site average feature qualitative rating[a]	Poor	Fair	Poor	
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	14	17	10	
	Site average qualitative rating[b]	Fair	Fair	Poor	
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	20	26	15	
	Site qualitative rating[c]	Fair	Fair	Poor	
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	20			
	Enhancement reach qualitative rating[c]:	Fair			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

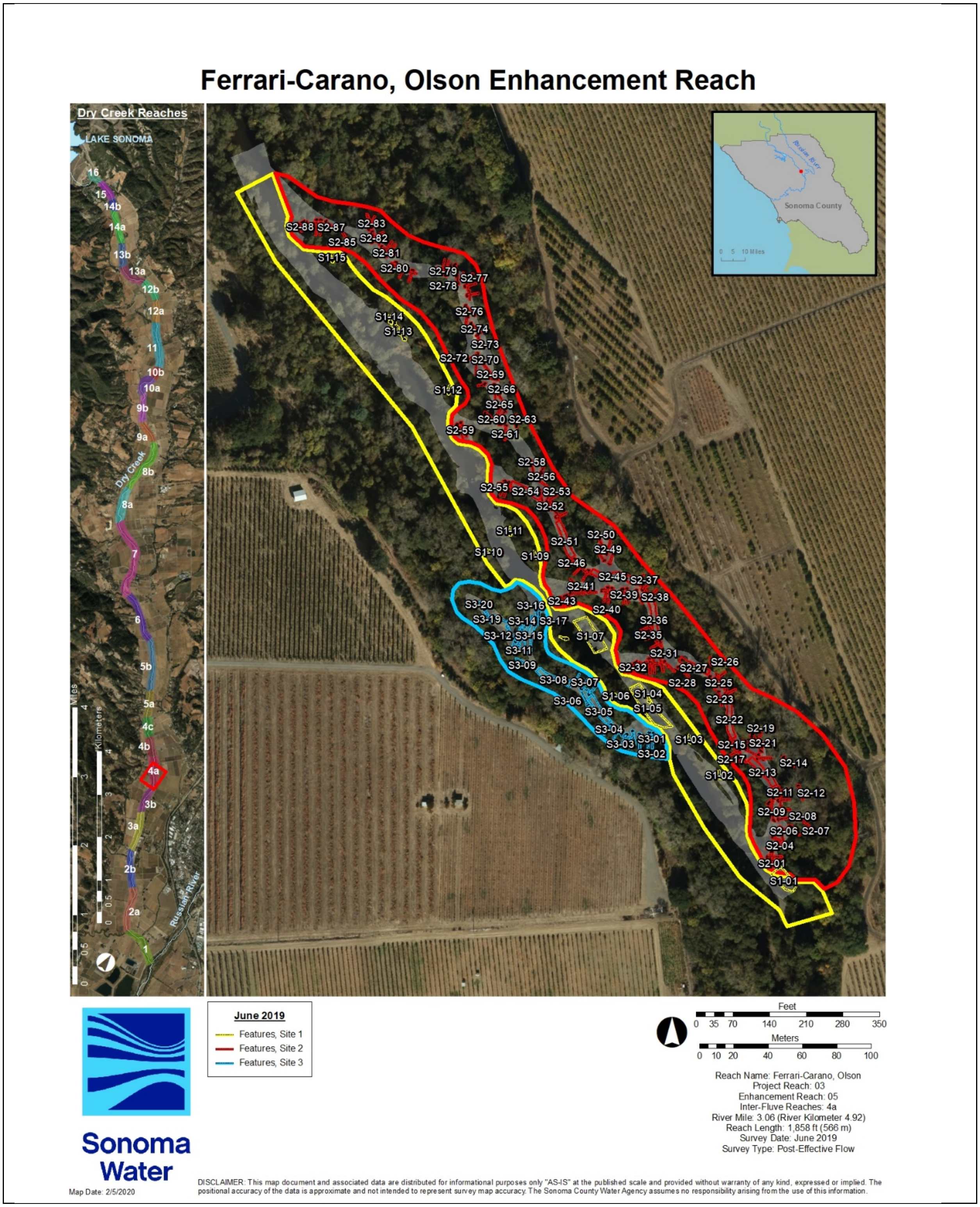


Figure 5.2.56. Enhancement sites and features within the Ferrari-Carano, Olson enhancement reach.

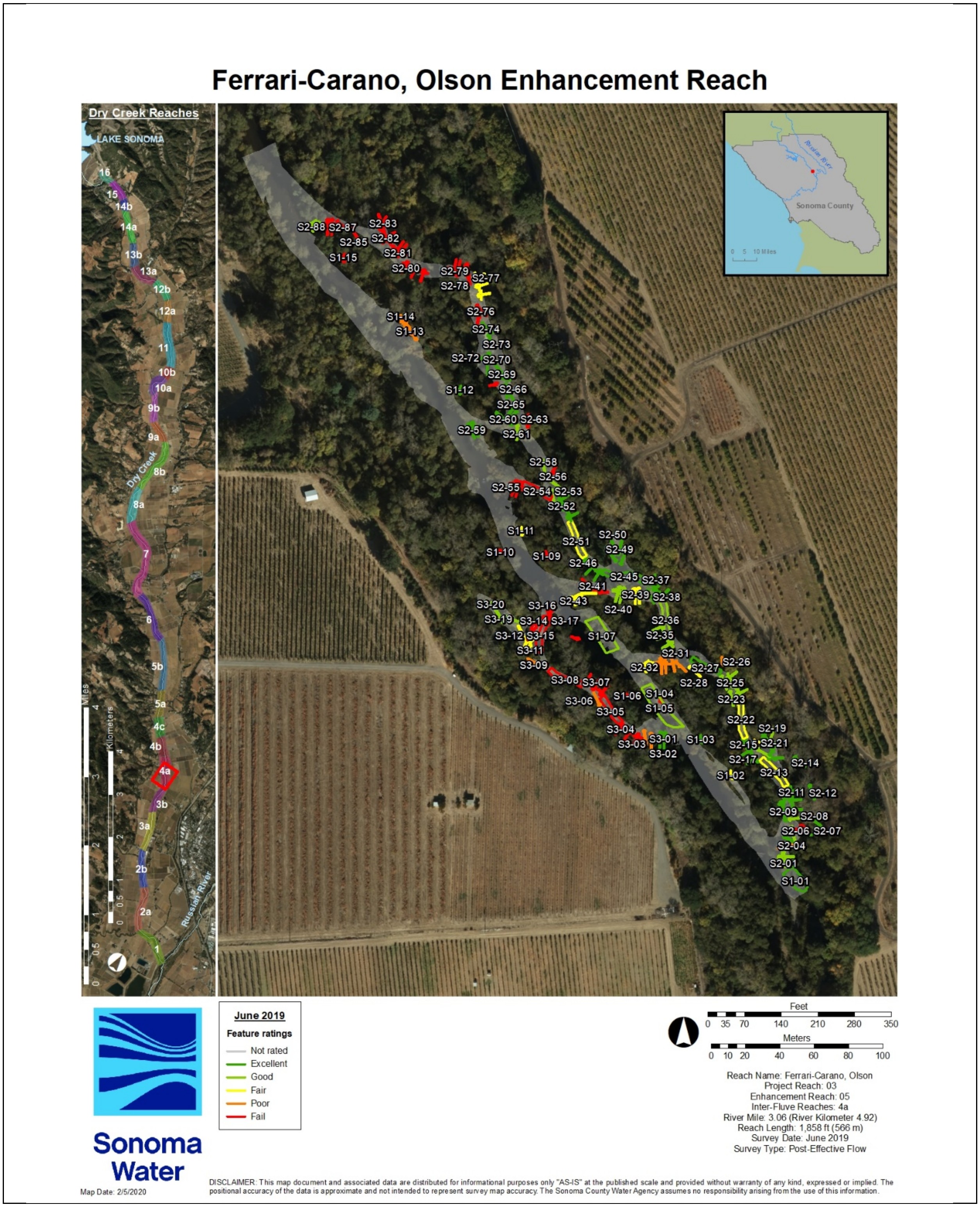


Figure 5.2.57. Feature ratings for the Ferrari-Carano, Olson enhancement reach, June 2019.

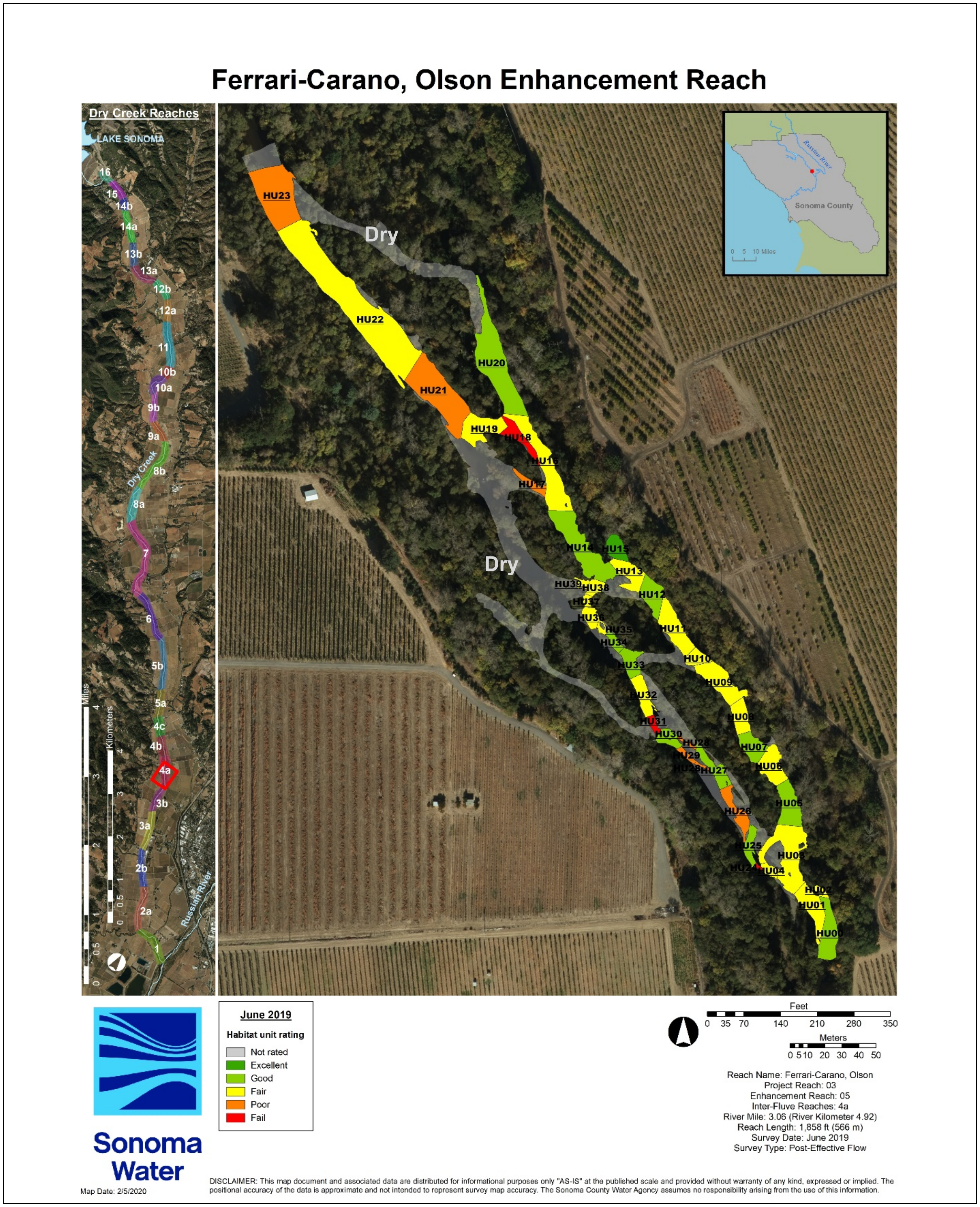


Figure 5.2.58. Habitat unit ratings for the Ferrari-Carano, Olson enhancement reach June 2019.

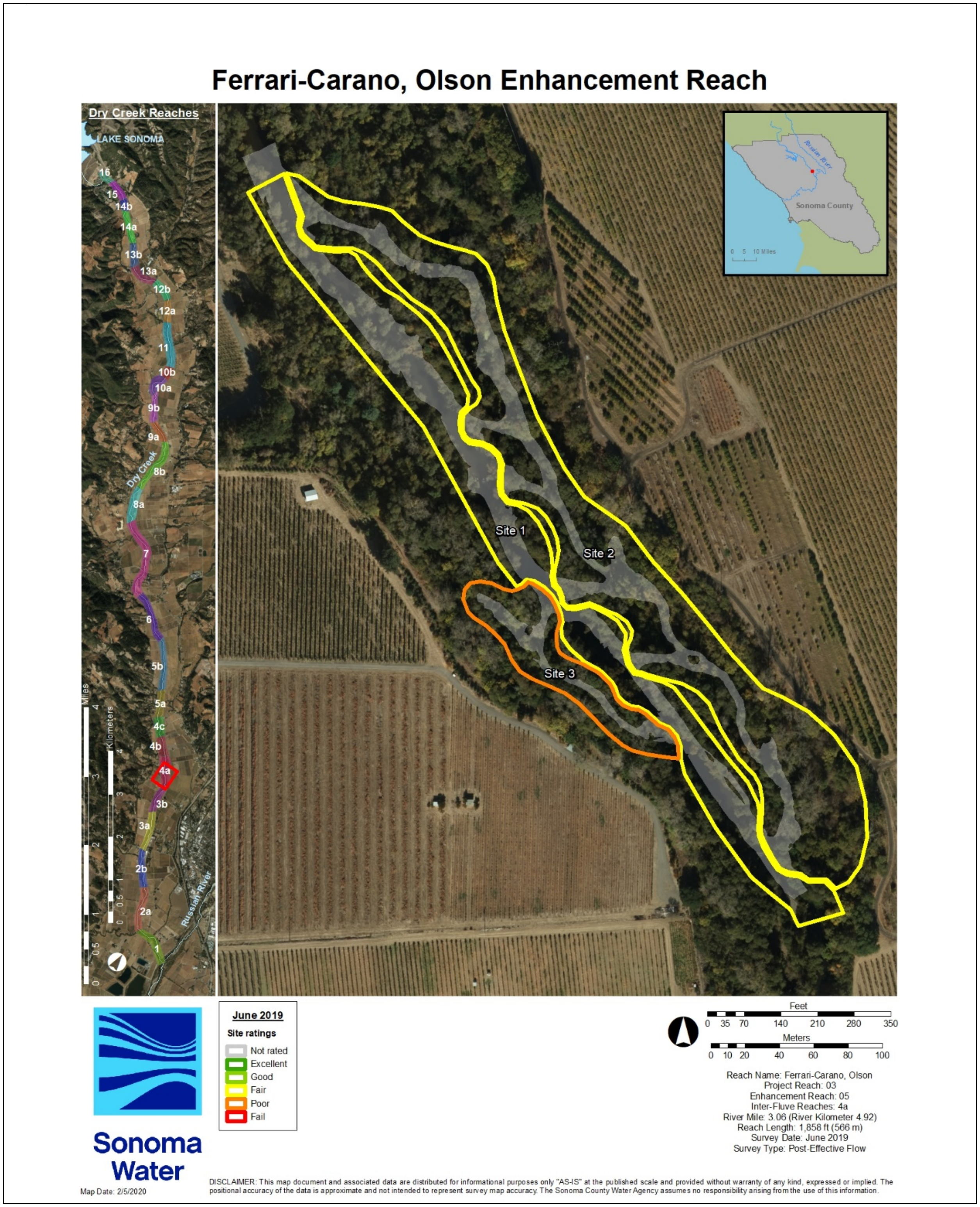


Figure 5.2.59. Enhancement site ratings for the Ferrari-Carano, Olson enhancement reach, June 2019.

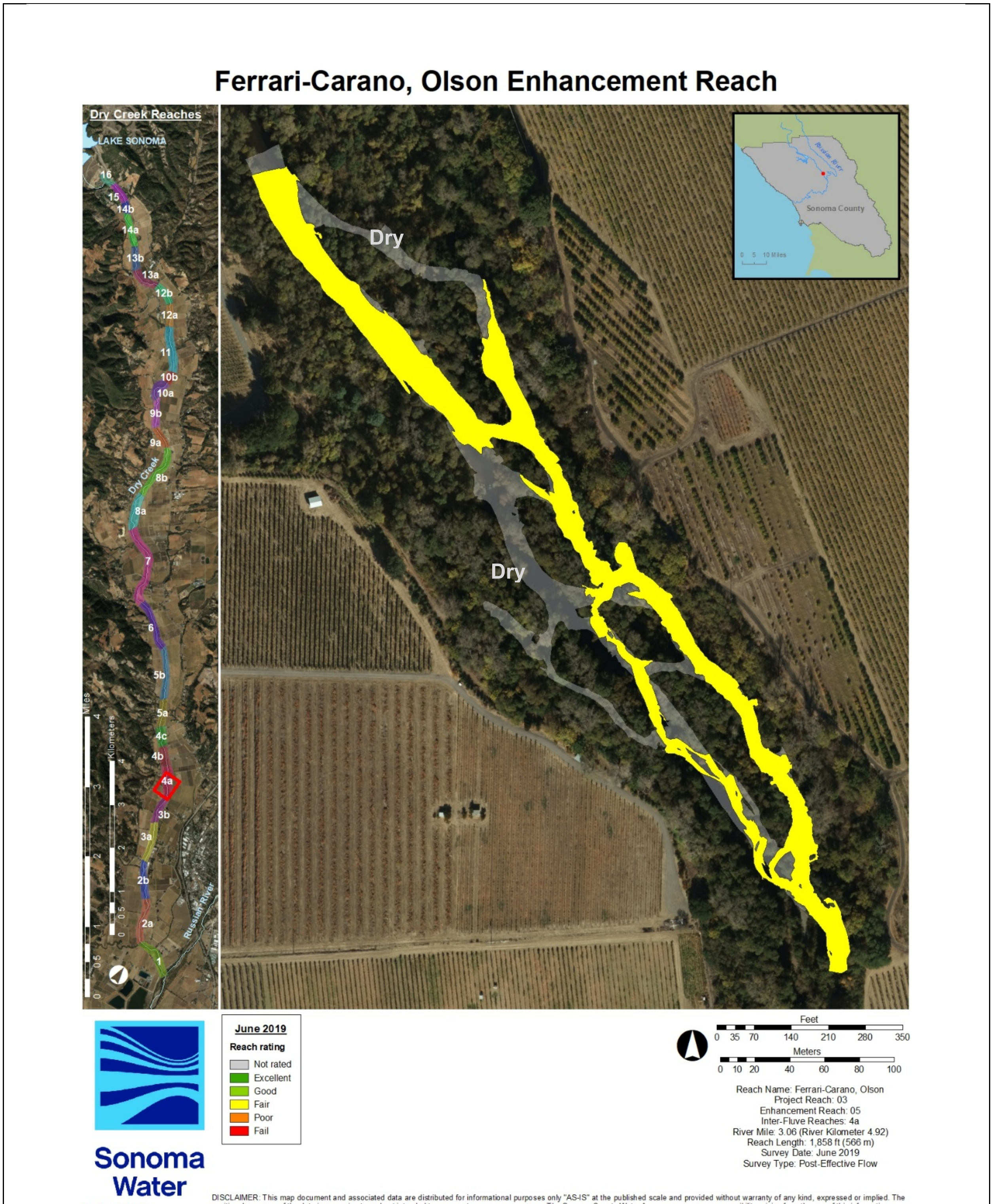


Figure 5.2.60. Enhancement reach rating for the Ferrari-Carano, Olson enhancement reach, June 2019.

City of Healdsburg Yard Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the City of Healdsburg enhancement reach in July 2019. Previous effectiveness monitoring surveys occurred in June 2017 (pre-enhancement; enhancement reach rating: fair), September 2017 (post-enhancement; enhancement reach rating: good), and October 2018 (post-effective flow; enhancement reach rating: good). The enhancement initially added 15,717 ft^2 of side channel area in September 2017 that expanded to 19,409 ft^2 in October 2018, was well as 2,318 ft^2 of side channel alcove area in September 2017 that remained stable through October 2018 (2,378 ft^2). But, similar to 2016/2017, large storms in winter 2018/2019 caused aggradation, reducing side channel area to 1,513 ft^2 (a 93 % reduction in area from 2018), and completely filling the side channel alcove. As, such the storms substantially reduced off channel area while main channel area increased (50,330 ft^2 [2017], 45,128 ft^2 [2018], 54,727 ft^2 [2019]) and main channel alcove area slightly decreased (5,007 ft^2 [2017], 3,936 ft^2 [2018], 3,186 ft^2 [2019]). Post- effective flow 2019, the enhanced reach encompassed 59,426 ft^2 within main- and off-channel areas of Dry Creek with 16% of the total area meeting optimal depth and velocity criteria, compared with 70,852 ft^2 and 32% post-effective flow 2018 (Table 5.2.33, Figure 5.2.61). The monitoring characterized 3,186 ft^2 of main channel alcove area and 1,513 ft^2 of side channel area, of which 74%, and 77% met optimal depth and velocity criteria, compared with 54,727 ft^2 and 11% for the main channel area. Nineteen habitat units composed the enhancement reach, with a pool to riffle ratio of 5:5 (1.00) and average shelter score of 57 (Table 5.2.34, Figure 5.2.62, Figure 5.2.63). Seven habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised five enhancement sites (one main-channel, two alcoves, one side channel, and a bank site; Table 5.2.35, Figure 5.2.64), with fail to poor site average feature ratings in the main channel, side channel, and alcove sites, and excellent for the bank site (Table 5.2.35, Figure 5.2.65). Site average habitat unit ratings ranged from fail to good for all sites (Table 5.2.35, Figure 5.2.66). Main channel, side channel, alcove enhancement sites received fail to fair ratings while the bank site received a good rating (Figure 5.2.67). Overall, the City of Healdsburg Yard enhancement reach received a poor effectiveness monitoring rating (Figure 5.2.68; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.33. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the City of Healdsburg Yard enhancement reach, July 2019.

City of Healdsburg Yard Post-effective flow July 2019	Wetted area (ft^2)	Optimal depth (ft^2) 0.5 – 2.0 ft	Optimal depth (ft^2) 2.0 – 4.0 ft	Optimal depth (ft^2) Total	Optimal velocity (ft^2) < 0.5 ft/s	Optimal habitat (ft^2) 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2) 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2) Total
Main channel area	54,727	35,457	10,376	45,833	11,276	5,313	687	6,000
Main channel alcove area	3,186	1,513	981	2,494	3,028	1,417	936	2,352
Side channel area	1,513	952	109	1,061	1,513	952	109	1,061
Total area	**59,426**	**37,922**	**11,467**	**49,388**	**15,817**	**7,682**	**1,732**	**9,413**
Main channel % of wetted area	92%	65%	19%	84%	21%	10%	1%	11%
Main channel alcove % of wetted area	5%	47%	31%	78%	95%	44%	29%	74%
Side channel % of wetted area	3%	63%	7%	70%	100%	63%	7%	70%
Total % of wetted area	**100%**	**64%**	**19%**	**83%**	**27%**	**13%**	**3%**	**16%**

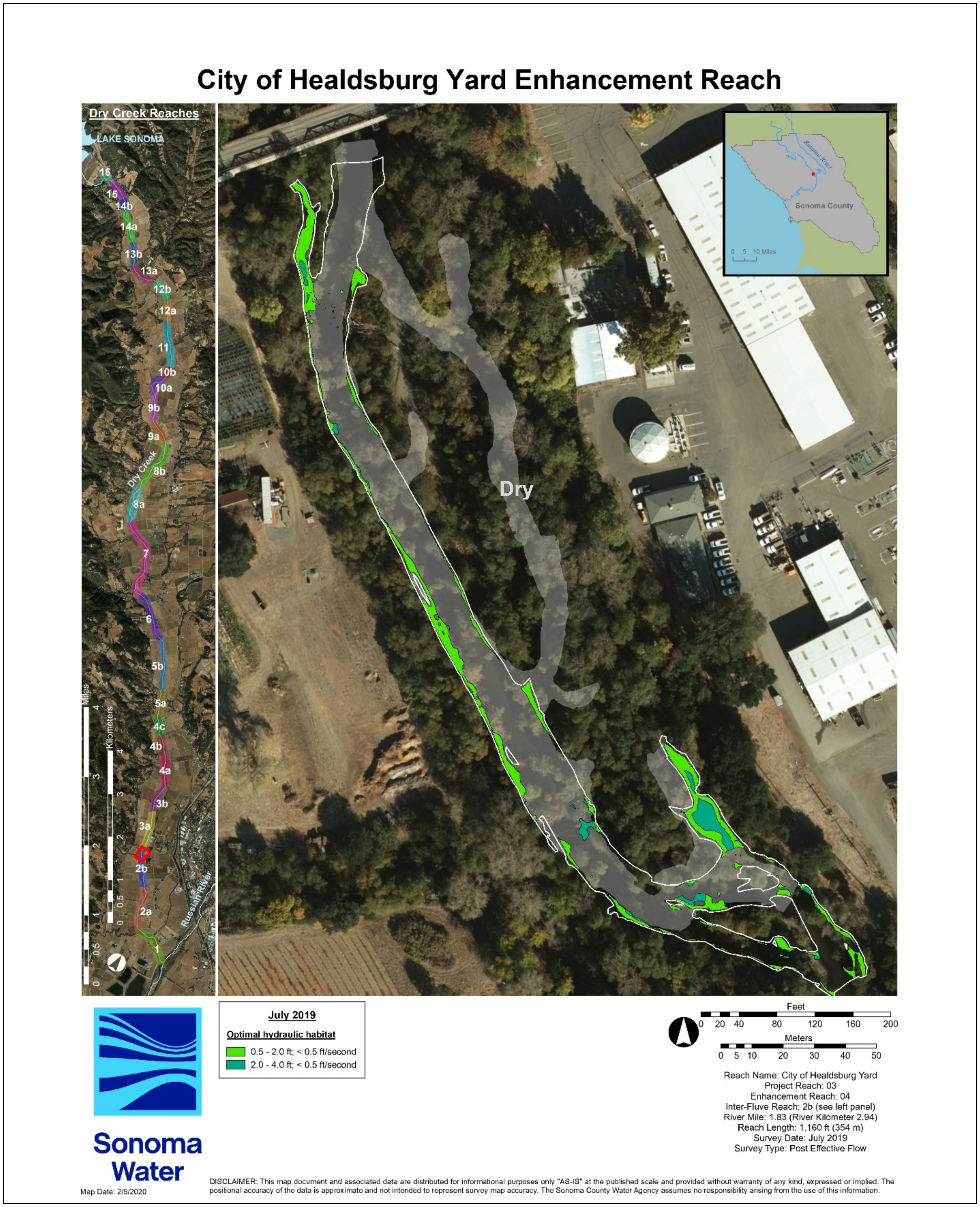


Figure 5.2.61. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the City of Healdsburg Yard enhancement reach, July 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.34. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the City of Healdsburg Yard enhancement reach, Post-effective flow, July 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	30	90
HU02	Riffle	1	20	20
HU03	Flatwater	3	20	60
HU04	Riffle	0	0	0
HU05	Flatwater	1	5	5
HU06	Pool	2	30	60
HU07	Flatwater	2	40	80
HU08	Riffle	3	30	90
HU09	Flatwater	2	25	50
HU10	Pool	3	35	105
HU11	Riffle	1	5	5
HU12	Alcove	3	40	120
HU13	Flatwater	1	15	15
HU14	Flatwater	3	15	45
HU15	Flatwater	3	10	30
HU16	Flatwater	3	35	105
HU17	Pool	3	60	180
HU18	Riffle	1	5	5
HU19	Pool	1	10	10
Pool: riffle	**5:5 (1.00)**			**Avg = 57**

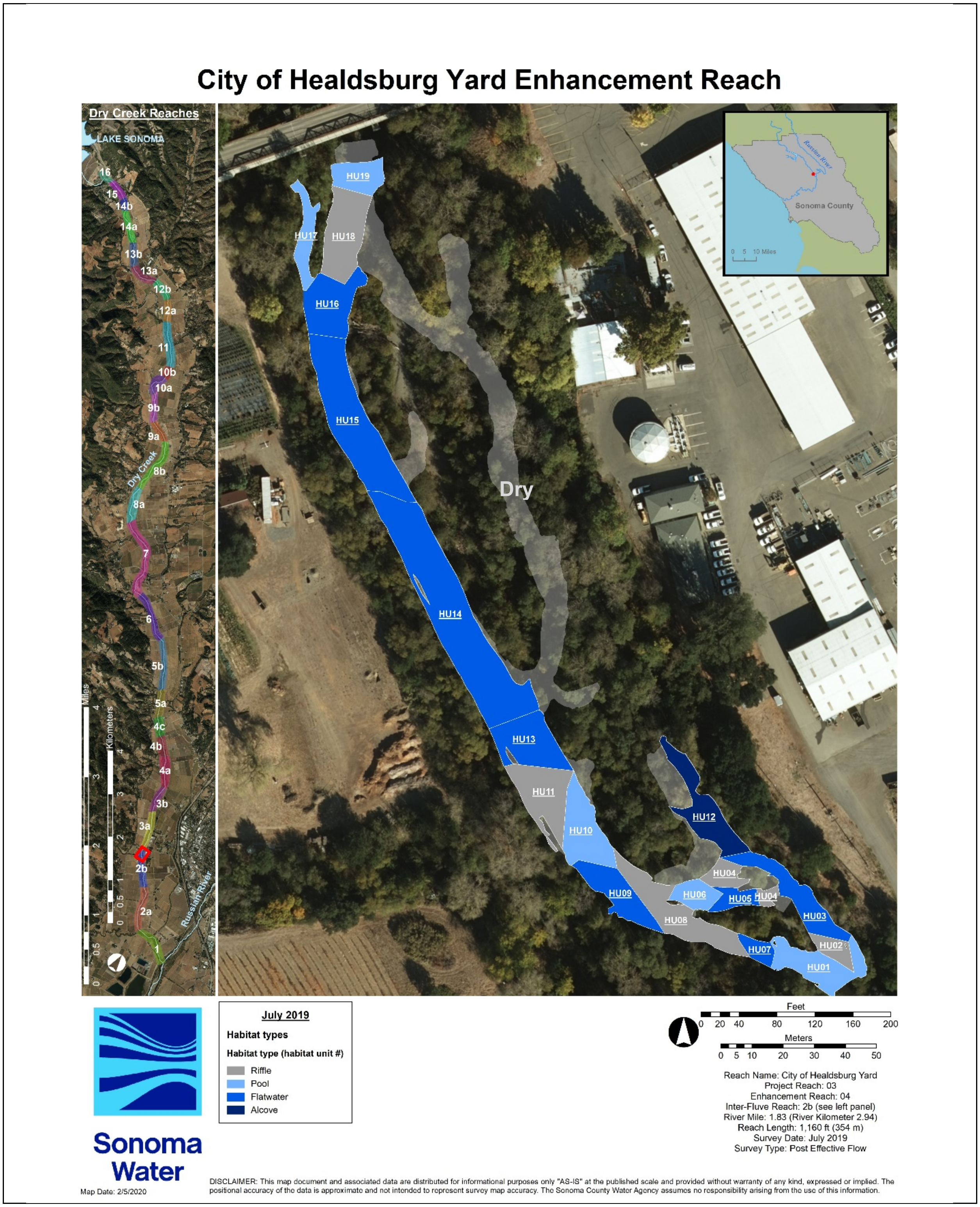


Figure 5.2.62. Habitat unit number and type within the City of Healdsburg Yard enhancement reach, July 2019.

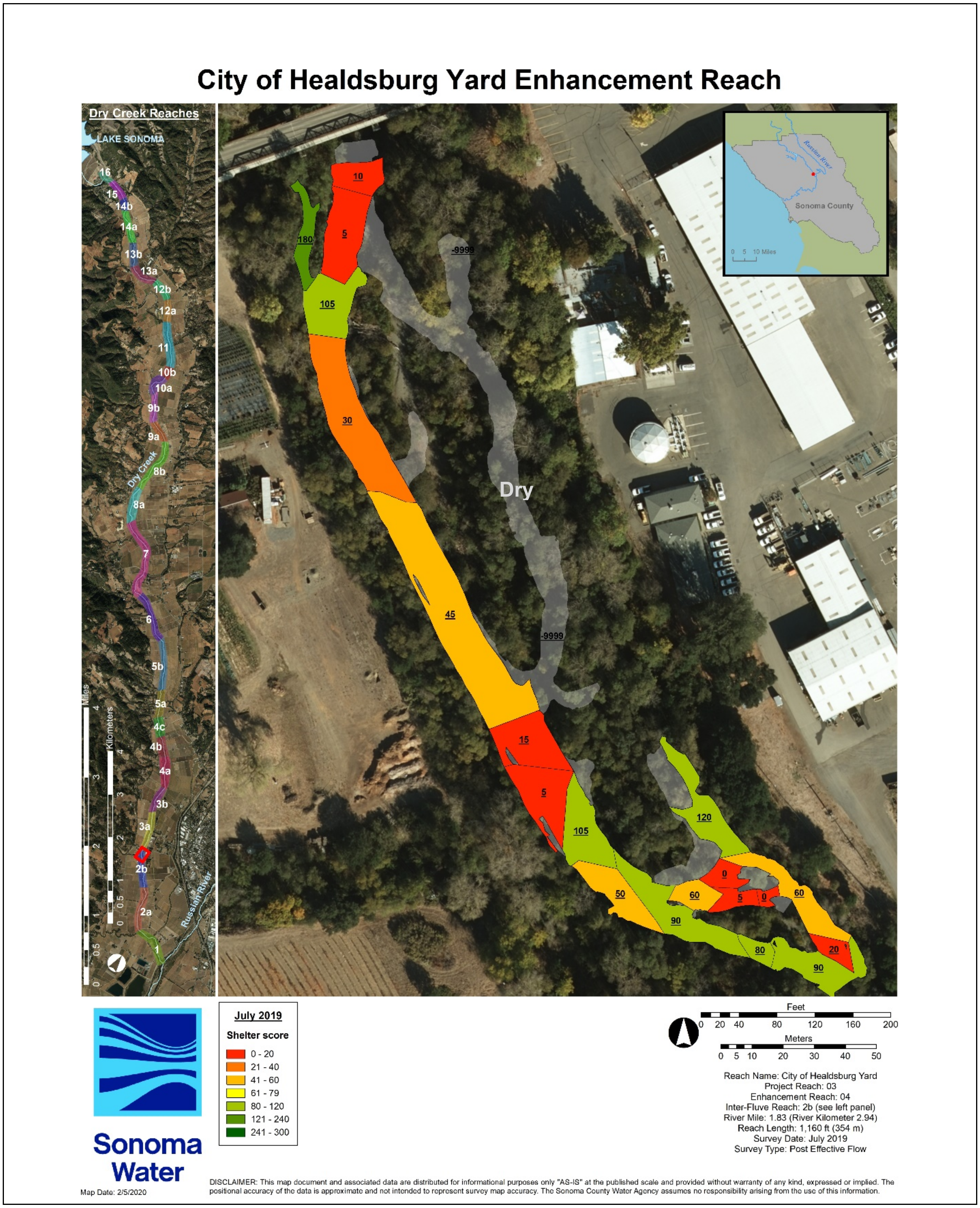


Figure 5.2.63. Habitat unit shelter scores within the City of Healdsburg Yard enhancement reach, July 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.35. Post-enhancement average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the City of Healdsburg Yard enhancement reach, July 2019.

Site number		**1**	**2**	**3**	**4**	**5**
Site type		Main channel	Alcove	Side channel	Alcove	Bank
Site average feature rating	Site average feature quantitative rating[a]	6	6	2	3	13
	Site average feature qualitative rating[a]	Poor	Poor	Fail	Fail	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	14	23	6	0	26
	Site average qualitative rating[b]	Poor	Good	Fail	Fail	Good
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	19	28	8	3	39
	Site qualitative rating[c]	Poor	Fair	Fail	Fail	Good
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	20				
	Enhancement reach qualitative rating[c]:	Poor				

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)

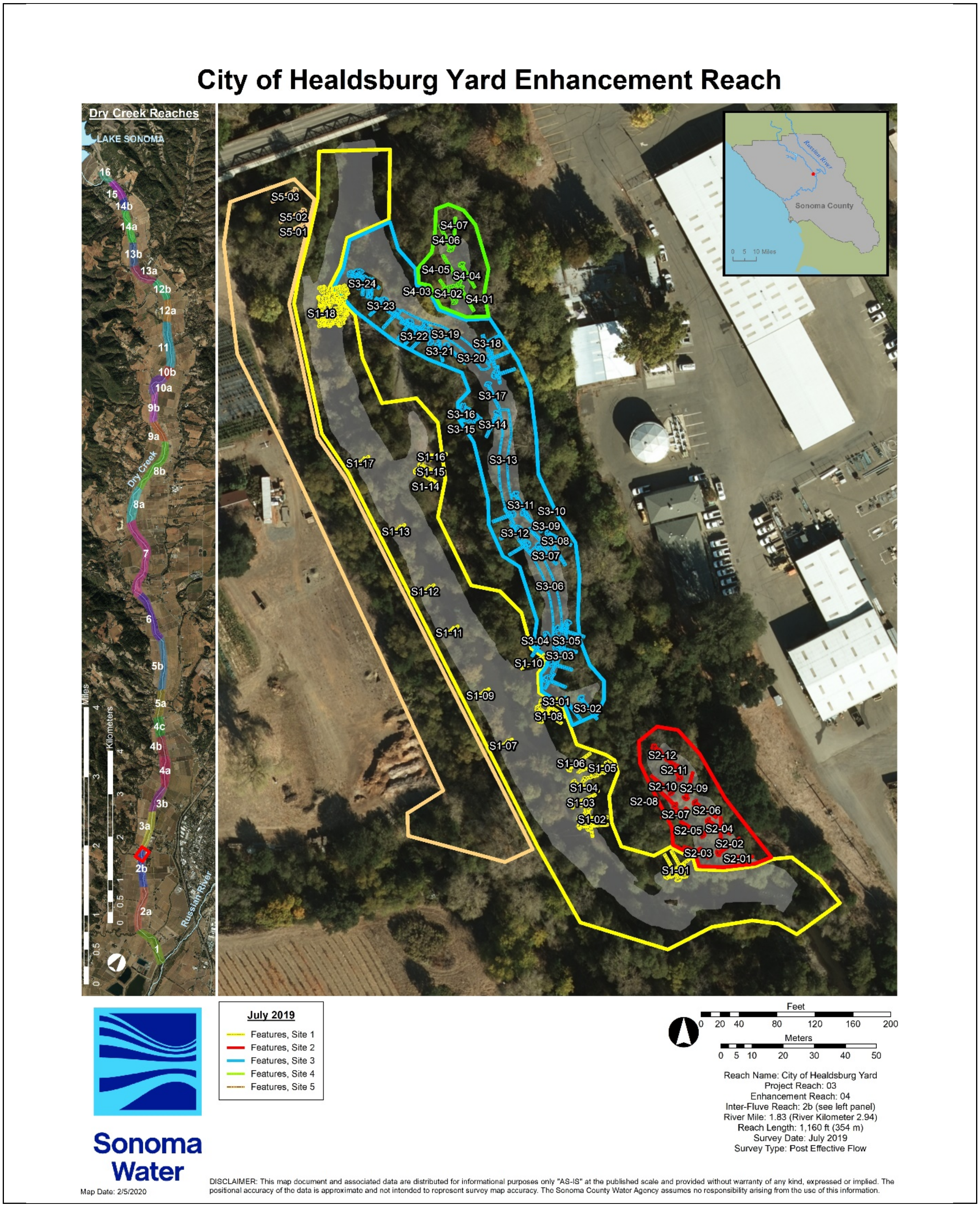


Figure 5.2.64. Enhancement sites and features within the City of Healdsburg Yard enhancement reach, July 2019.

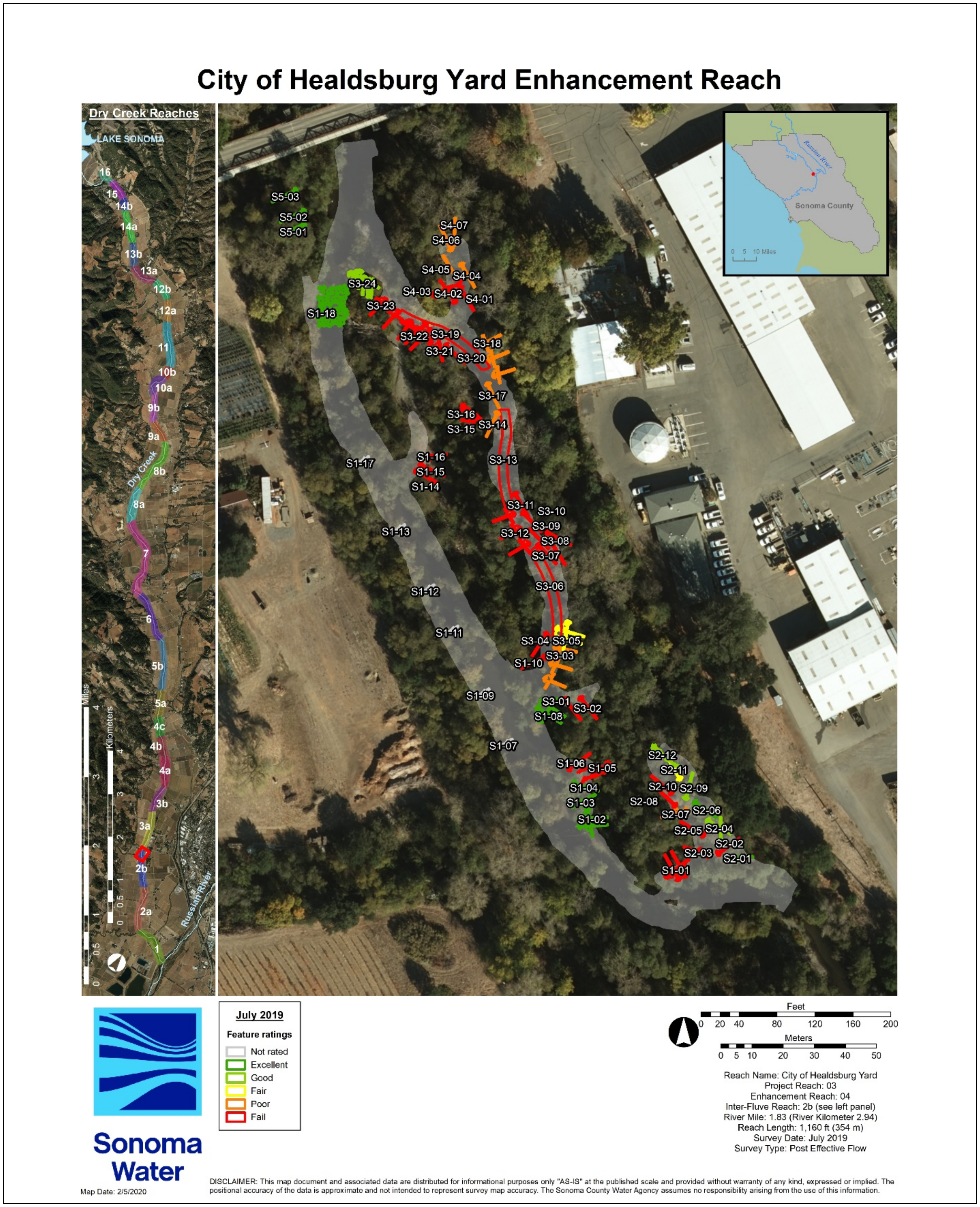


Figure 5.2.65. Feature ratings for the City of Healdsburg Yard enhancement reach, July 2019.

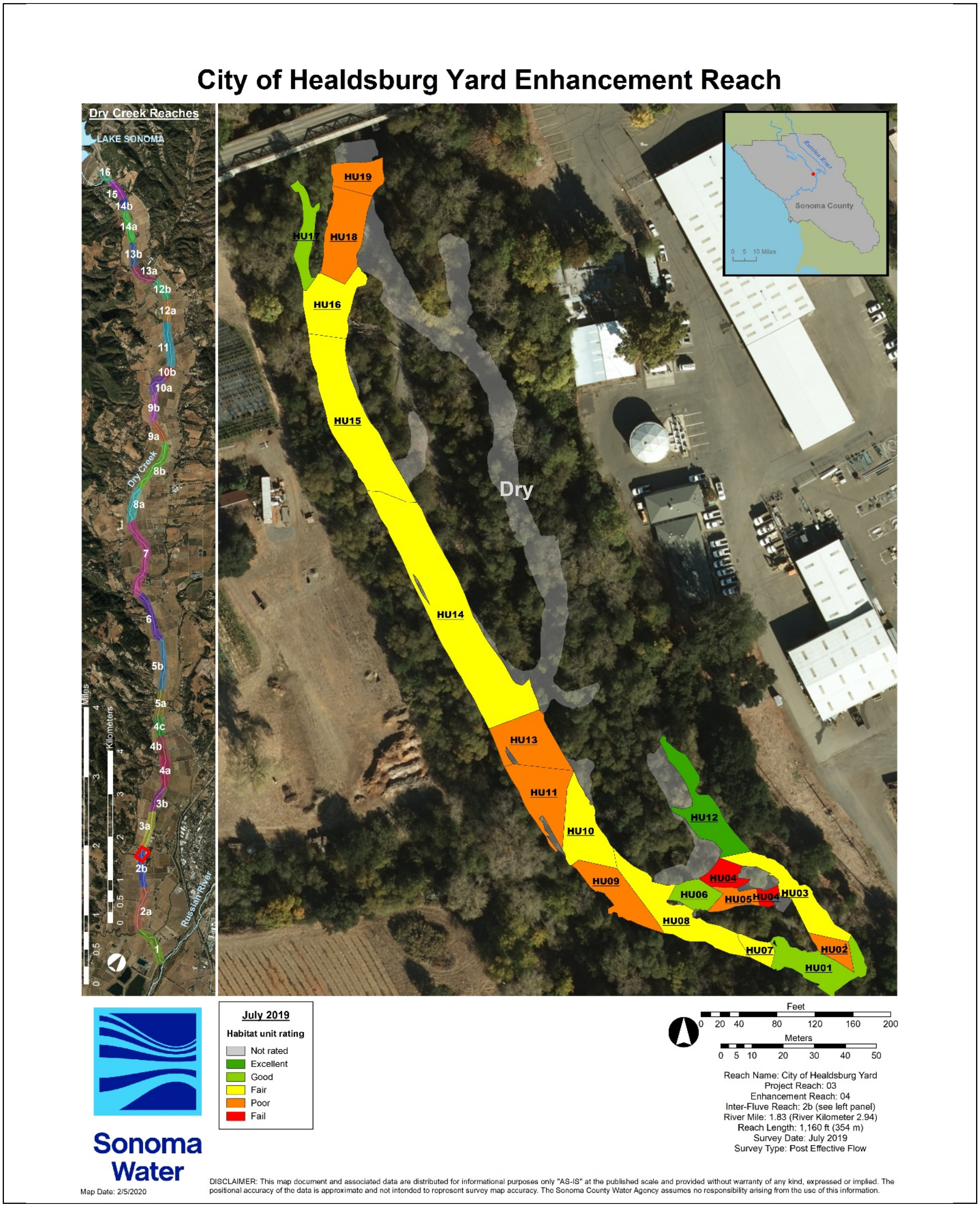


Figure 5.2.66. Habitat unit ratings for the City of Healdsburg Yard enhancement reach, July 2019.

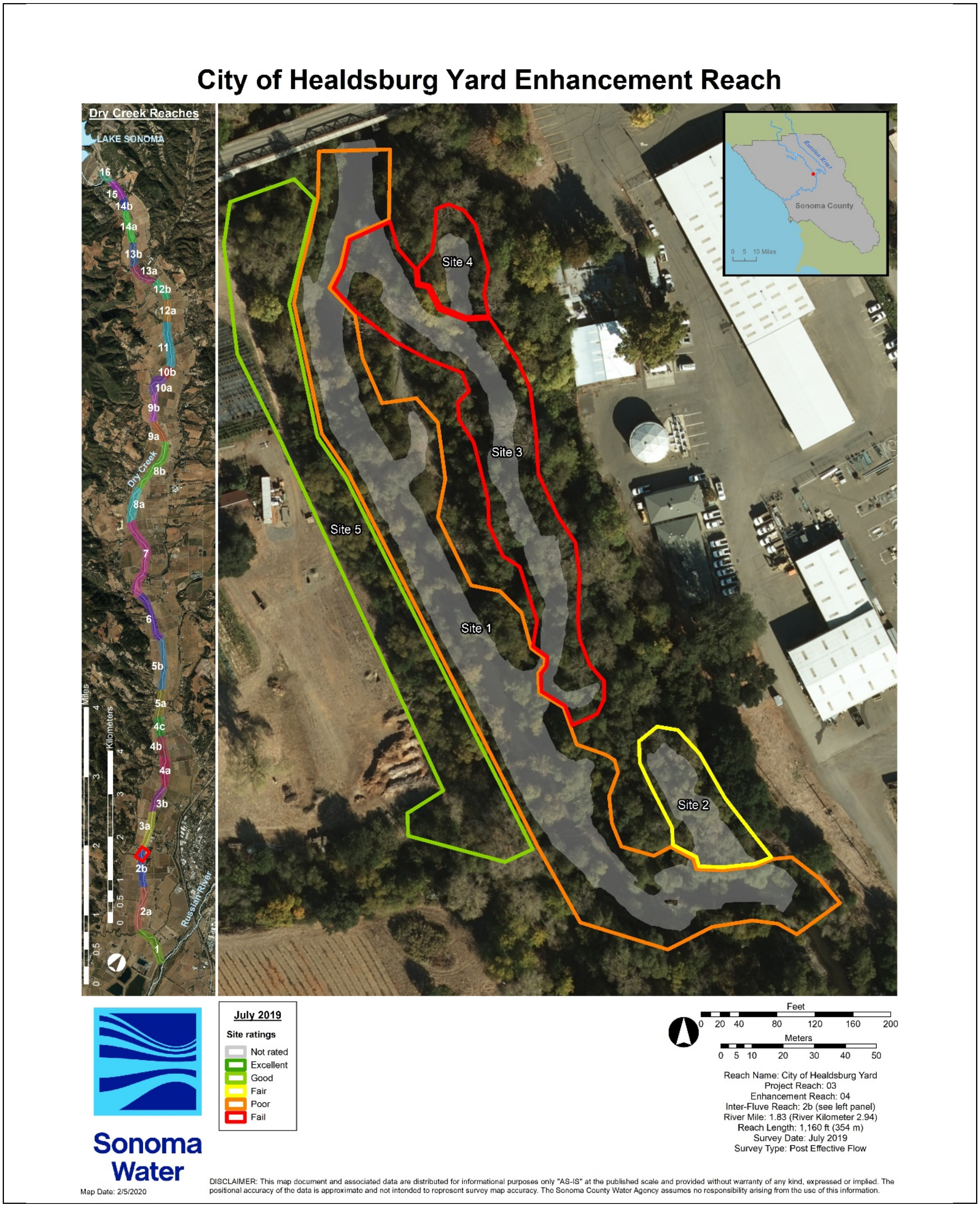


Figure 5.2.67. Post enhancement site ratings for the City of Healdsburg Yard enhancement reach, July 2019.

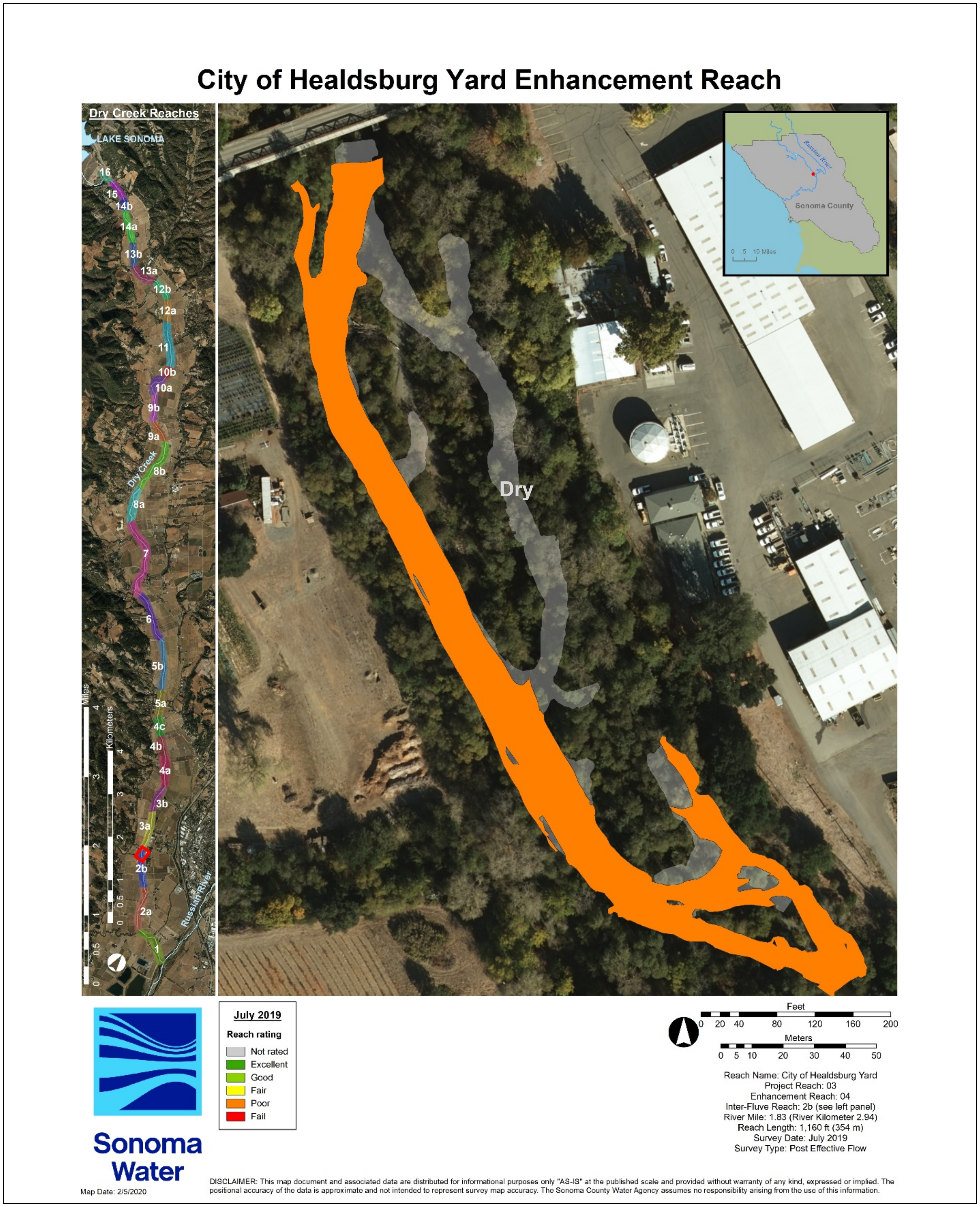


Figure 5.2.68. Post-enhancement reach rating for the City of Healdsburg Yard enhancement reach, July 2019.

Geyser Peak Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Geyser Peak enhancement reach in July 2019. Sonoma Water originally constructed the Geyser Peak enhancement reach in October 2016, adding 8,244 ft^2 of side-channel. Aggradation caused by large storms in winter 2016/2017 reduced side channel area to 0 ft^2, leading to a fail effectiveness monitoring rating in July 2017 and repairs in summer 2017. The repair re-excavated 8,721 ft^2 and crews monitored again in October 2017 giving the enhancement reach a fair post-repair rating (see 2018 report for results). Sonoma Water subsequently monitored the post-effective flow condition in July 2018, finding that side channel area expanded slightly to 9,588 ft^2, and giving the enhancement reach a fair effectiveness monitoring rating (see 2019 report for results). But, similar to 2016/2017, aggradation caused by large storms in winter 2018/2019 reduced side channel area to 0 ft^2 in July 2019. Main channel area increased from 2018 (26,170 ft^2) to 2019 (42,954 ft^2) likely due to an increase in habitat at the downstream end of the enhancement reach.

In 2019, 15% of total habitat area met optimal depth and velocity criteria, mainly along the channel margins (Table 5.2.36, Figure 5.2.69). Nine habitat units made up the enhancement reach, with a pool to riffle ratio of 2:3 (0.67) and an average shelter score of 79 (Table 5.2.37, Figure 5.2.70, Figure 5.2.71). Six habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised four enhancement sites (one main channel and two side channel sites, and one bank site) that received fail to excellent site average feature ratings, and fail to good site average habitat unit ratings (Table 5.2.38, Figure 5.2.72, Figure 5.2.73, Figure 5.2.74). Site 4 (bank) included features installed above water surface elevation, but no aquatic habitat. As such, site 4 did not receive a site average habitat unit rating. Site 2 (side channel) completely aggraded from July 2018 to July 2019, burying nearly all features and aquatic habitat, leading to fail site average feature and site average habitat unit ratings. Enhancement site ratings ranged from fail (site 2) to fair (site 1) to good (sites 3 and 4) to fair (site 2) to good site 4 (Table 5.2.38, Figure 5.2.75). Overall, the Geyser Peak enhancement reach received a fair effectiveness monitoring score in July 2019 (Table 5.2.38, Figure 5.2.76; see Appendix 5.1 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.36. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, July 2019.

Geyser Peak Post-effective flow July 2019	Wetted area (ft^2)	Optimal depth (ft^2) 0.5 – 2.0 ft	Optimal depth (ft^2) 2.0 – 4.0 ft	Optimal depth (ft^2) Total	Optimal velocity (ft^2) < 0.5 ft/s	Optimal habitat (ft^2) 0.5 – 2.0 ft < 0.5 ft/s	Optimal habitat (ft^2) 2.0 – 4.0 ft < 0.5 ft/s	Optimal habitat (ft^2) Total
Main channel area	42,954	27,633	7,656	35,289	12,013	5,271	1,208	6,479
Side channel area	0	0	0	0	0	0	0	0
Total area	**42,954**	**27,633**	**7,656**	**35,289**	**12,013**	**5,271**	**1,208**	**6,479**
Main channel % of wetted area	100%	64%	18%	82%	28%	12%	3%	15%
Side channel % of wetted area	0	0	0	0	0	0	0	0
Total % of wetted area	**100%**	**64%**	**18%**	**82%**	**28%**	**12%**	**3%**	**15%**

Figure 5.2.69. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Geyser Peak enhancement reach, July 2019.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.37. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Geyser Peak enhancement reach, Post-effective flow, July 2019.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	3	35	105
HU02	Alcove	3	30	90
HU03	Pool	2	40	80
HU04	Alcove	2	65	130
HU05	Flatwater	1	10	10
HU06	Riffle	2	35	70
HU07	Flatwater	2	20	40
HU08	Riffle	2	50	100
HU09	Pool	3	30	90
Pool: riffle	**2:3 (0.67)**			**Avg = 79**

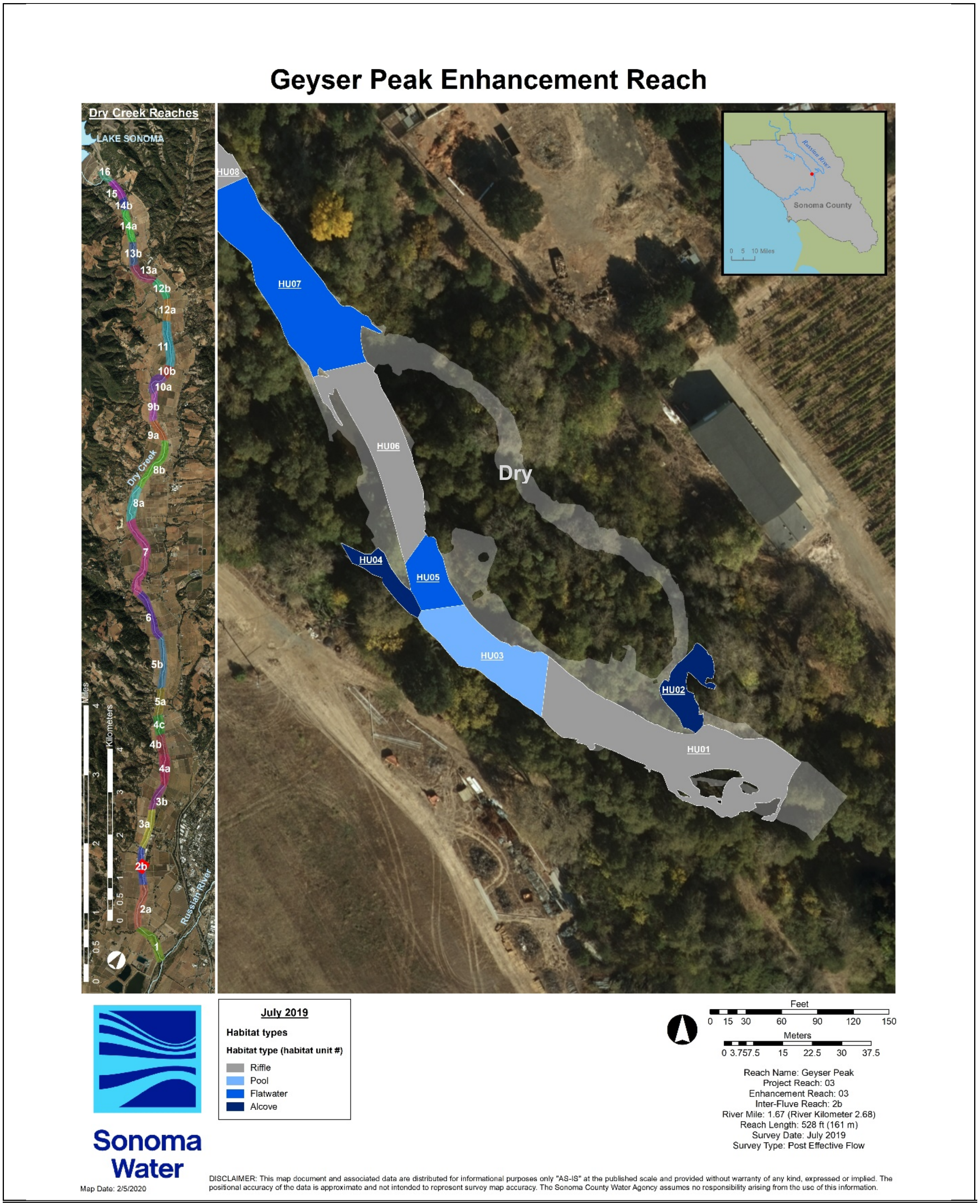


Figure 5.2.70. Habitat unit number and type within the Geyser Peak enhancement reach, July 2019.

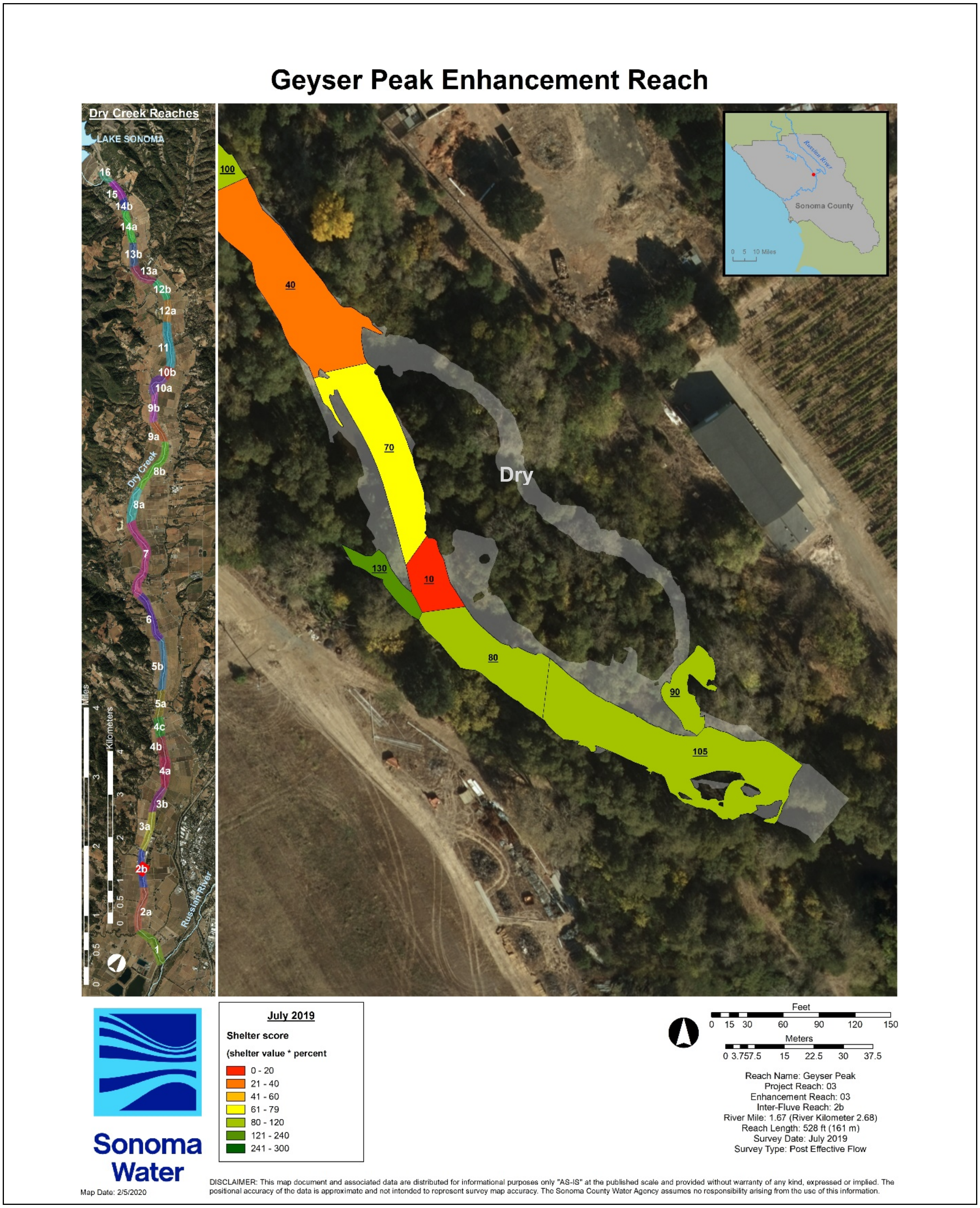


Figure 5.2.71. Habitat unit shelter scores within the Geyser Peak enhancement reach, July 2019.

Feature, habitat unit, site, and reach ratings

Table 5.2.38. Post-effective flow average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Geyser Peak enhancement reach, July 2019.

Site number		1	2	3	4
Site type		Main channel	Side channel	Side channel	Bank
Site average feature rating	Site average feature quantitative rating[a]	6	3	12	11
	Site average feature qualitative rating[a]	Poor	Fail	Excellent	Good
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	16	0	24	0
	Site average qualitative rating[b]	Fair	Fail	Good	Not rated
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	22[c]	3[c]	36[c]	11[a]
	Site qualitative rating[c]	Fair[c]	Fail[c]	Good[c]	Good[a]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	18			
	Enhancement reach qualitative rating[d]:	Fair			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=50), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 42; Excellent (>=33), Good (>=25), Fair (>=17), Poor (>=8), Fail (<8)

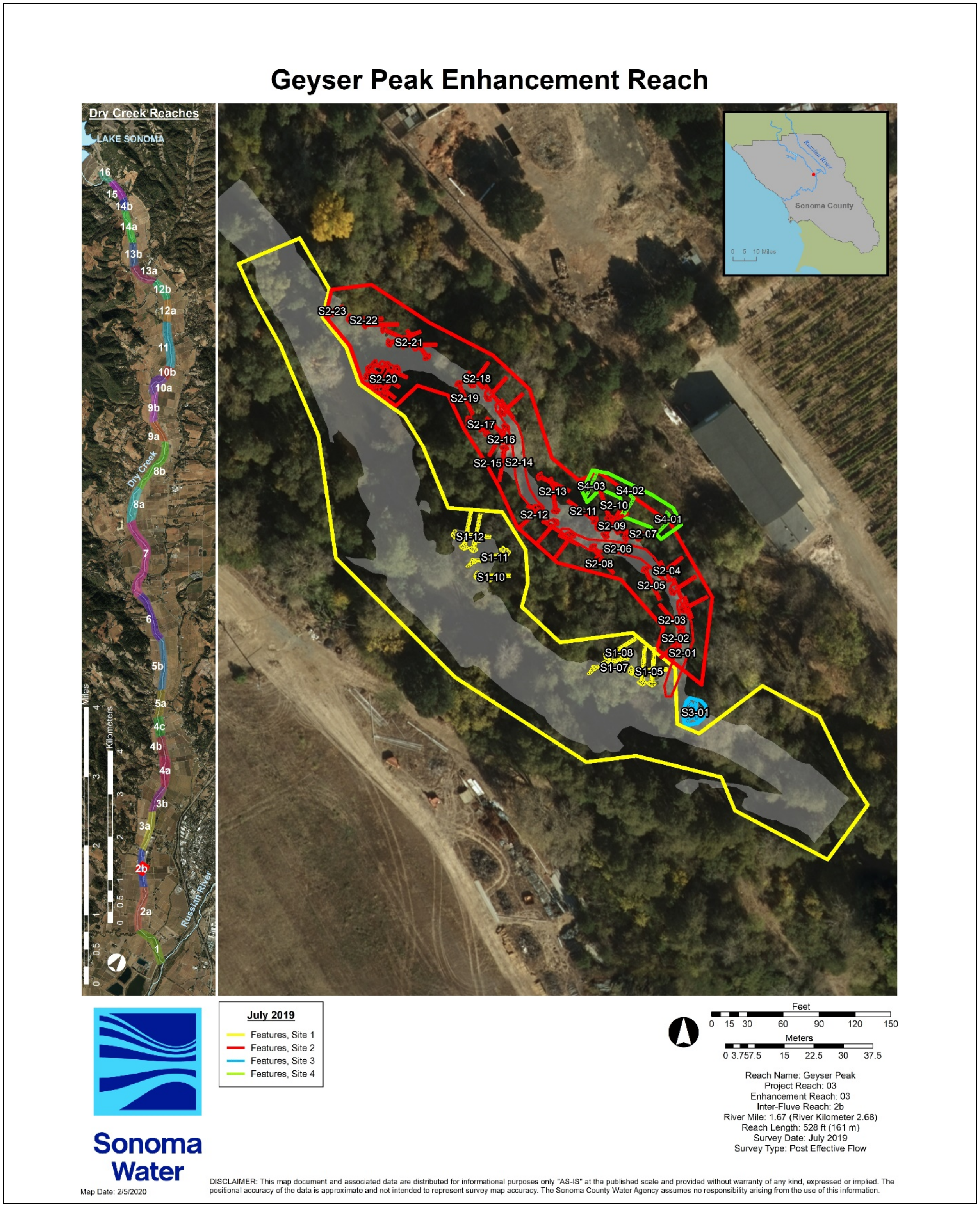


Figure 5.2.72. Enhancement sites and features within the Geyser Peak enhancement reach, July 2019.

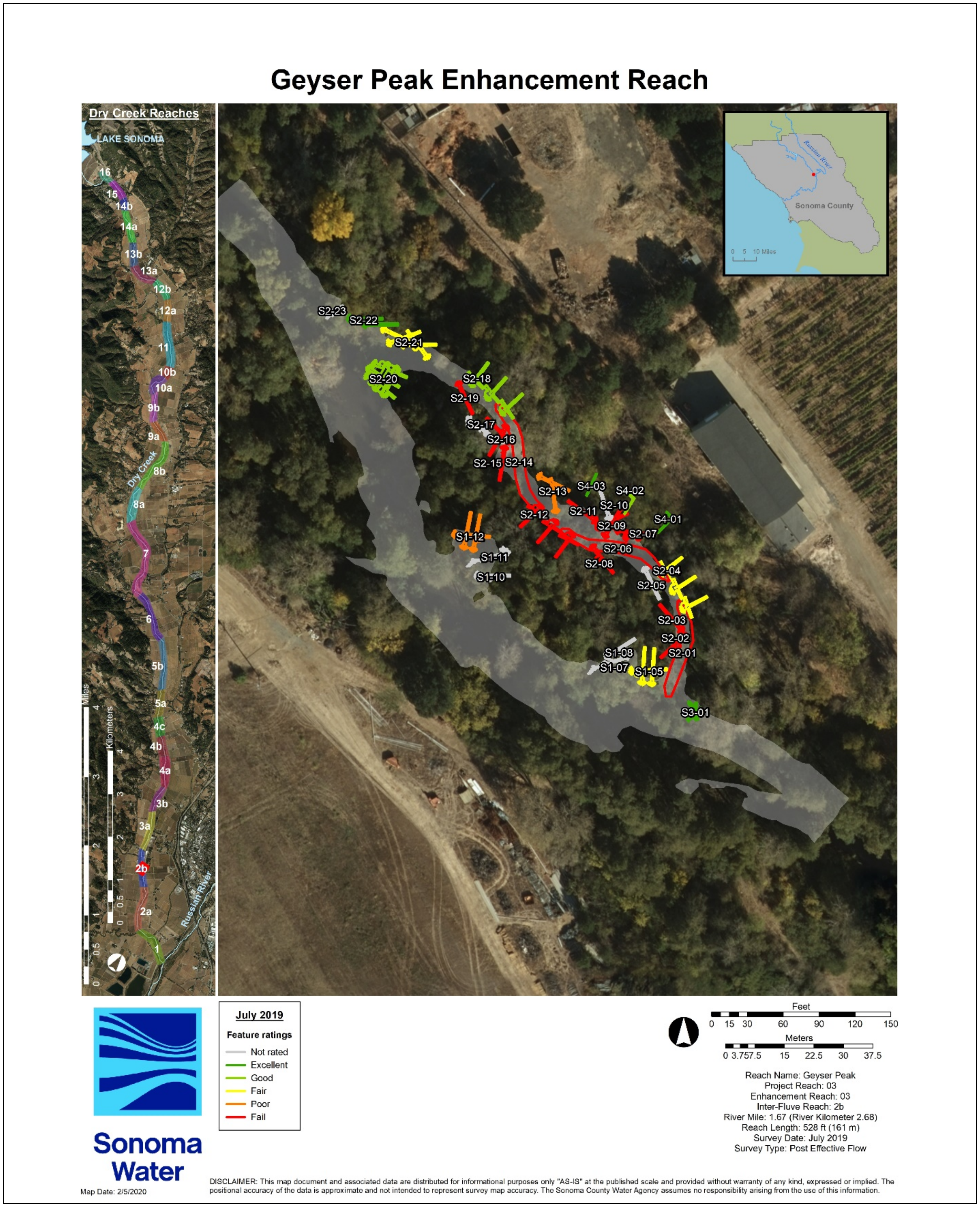


Figure 5.2.73. Feature ratings for the Geyser Peak enhancement reach, July 2019.

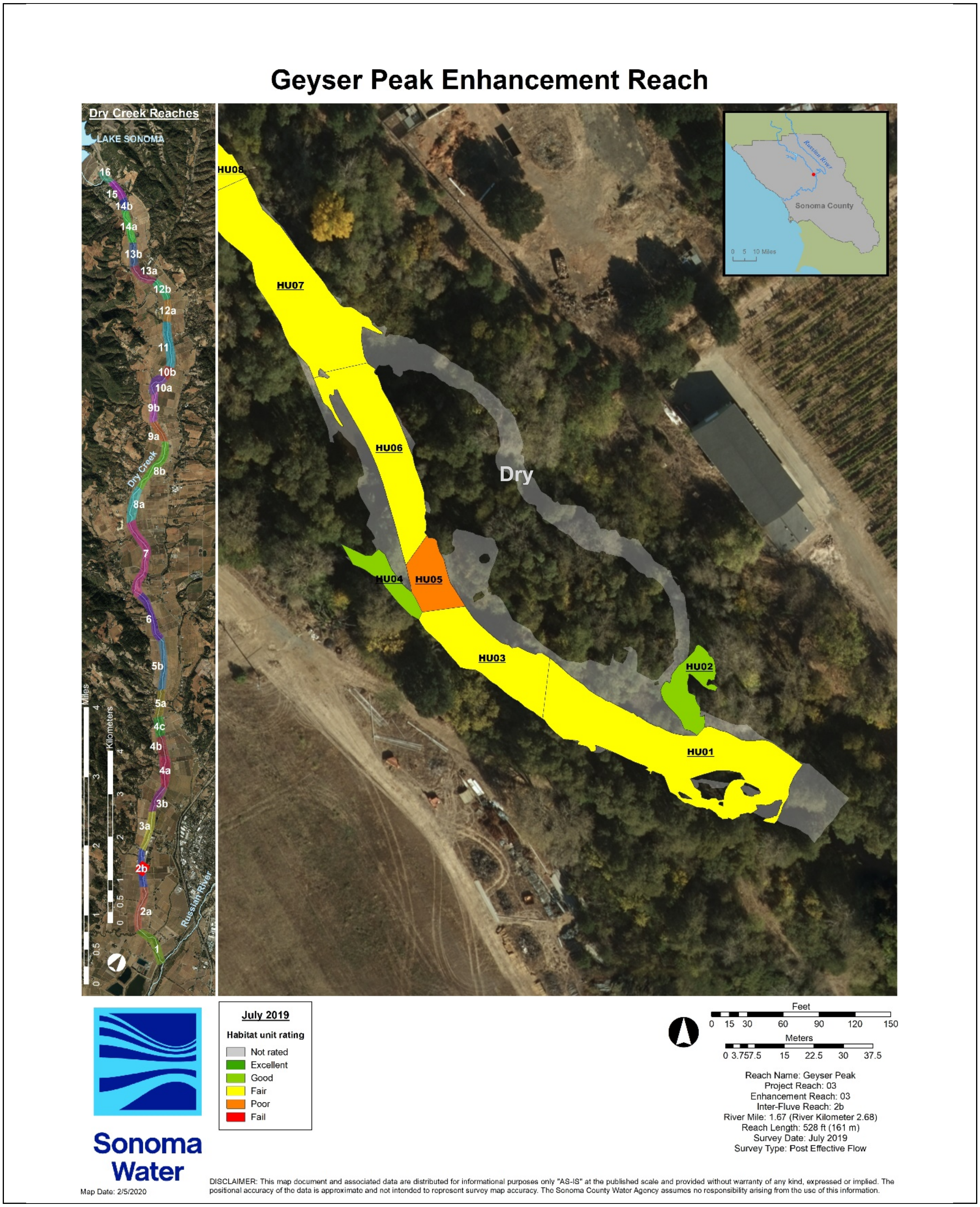


Figure 5.2.74. Post-effective flow habitat unit rating for the Geyser Peak enhancement reach, July 2019.

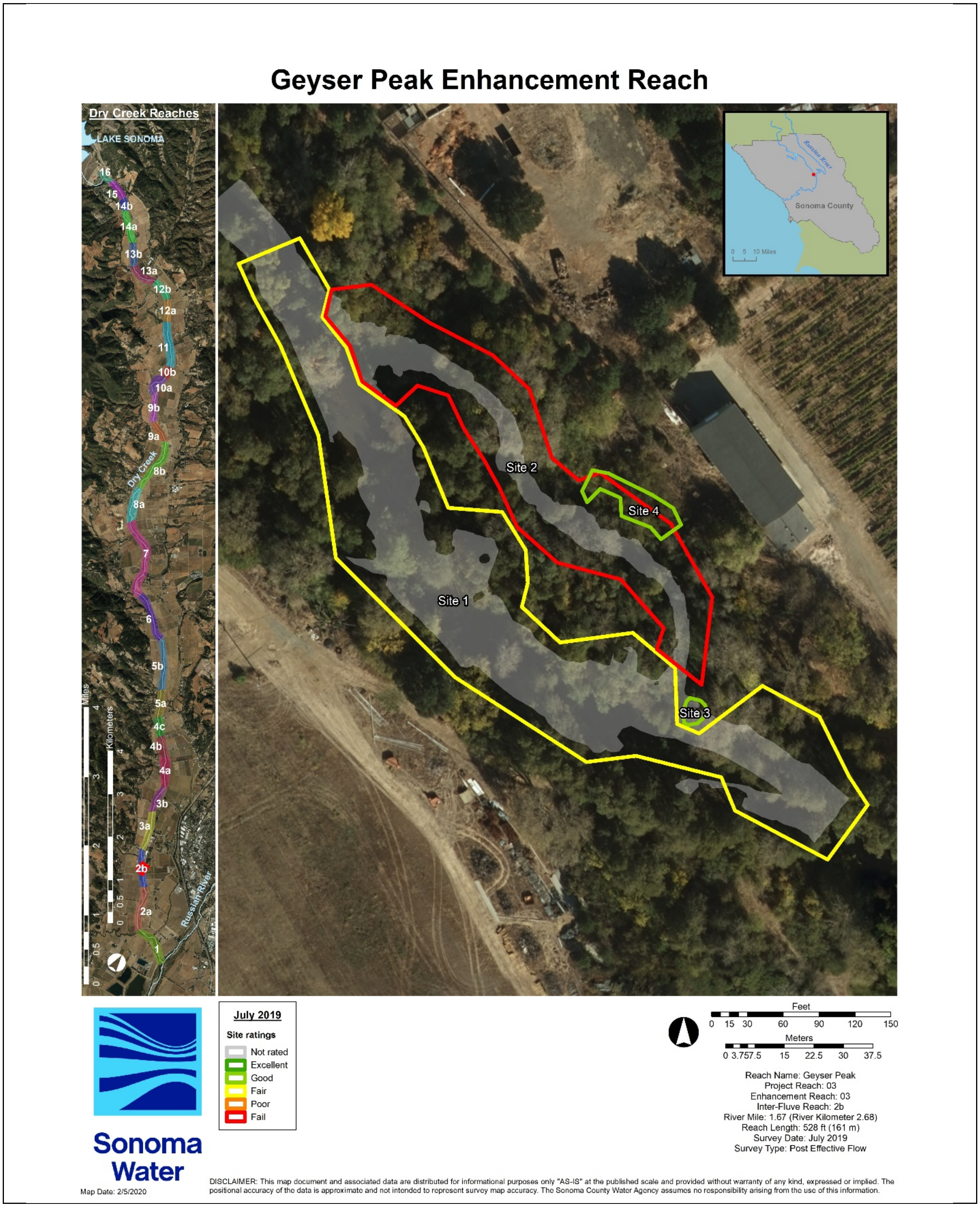


Figure 5.2.75. Post-effective flow site ratings for the Geyser Peak enhancement reach, July 2019.

Figure 5.2.76. Post-effective flow reach rating for the Geyser Peak enhancement reach, July 2019.

Discussion

Summary

Effectiveness monitoring in 2019 showed a decrease in the percent of optimal depth and velocity area from post-enhancement (33%) to post-effective flow (28%), and average shelter scores also slightly decreased from post-enhancement (75) to post-effective flow (72), both less than the optimal shelter value of 80 (Table 5.2.39). Observed pool to riffle ratio remained within 1:2 to 2:1 (0.50 to 2.00) during post-enhancement and post-effective flow effectiveness monitoring surveys.

Table 5.2.39. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.

Monitoring time-period	% optimal depth and velocity	Average shelter score	Pool to riffle ratio
Post-enhancement	33%	75	9:7 (0.78)
Post-effective Flow	28%	72	70:44 (1.59)

Depth and Velocity

Effectiveness monitoring data from all monitoring time periods in 2019 showed substantial differences in the amount of optimal depth and velocity habitat between main and off-channel areas, and between habitat types (Figure 5.2.77). Overall, 29% of main and off-channel area supported optimal depth and velocity, compared with 21% in main channel areas, and 44% in off-channel areas. Alcoves supported the greatest area of optimal depth and velocity, regardless of channel location (main and off-channel [71%], main channel [76%], off-channel [69%]), followed by pools (main and off-channel [36%], main channel [29%], off-channel [47%]). The percentage of optimal depth and velocity in flatwaters and riffles remained consistently lower than alcoves or pools across all channel areas. Inter-Fluve (2010) recorded similar observations for flatwaters during pre-enhancement habitat surveys in 2010, prompting recommendations to construct low velocity habitats, such as alcoves and side channels, as a primary strategy to enhance Dry Creek. Riffles typically have higher water velocity and shallow depths at low flows, and by character do not support the optimal depth and velocity conditions recommended by the BO or the AMP, but still perform important ecological roles, such as nutrient retention and food production.

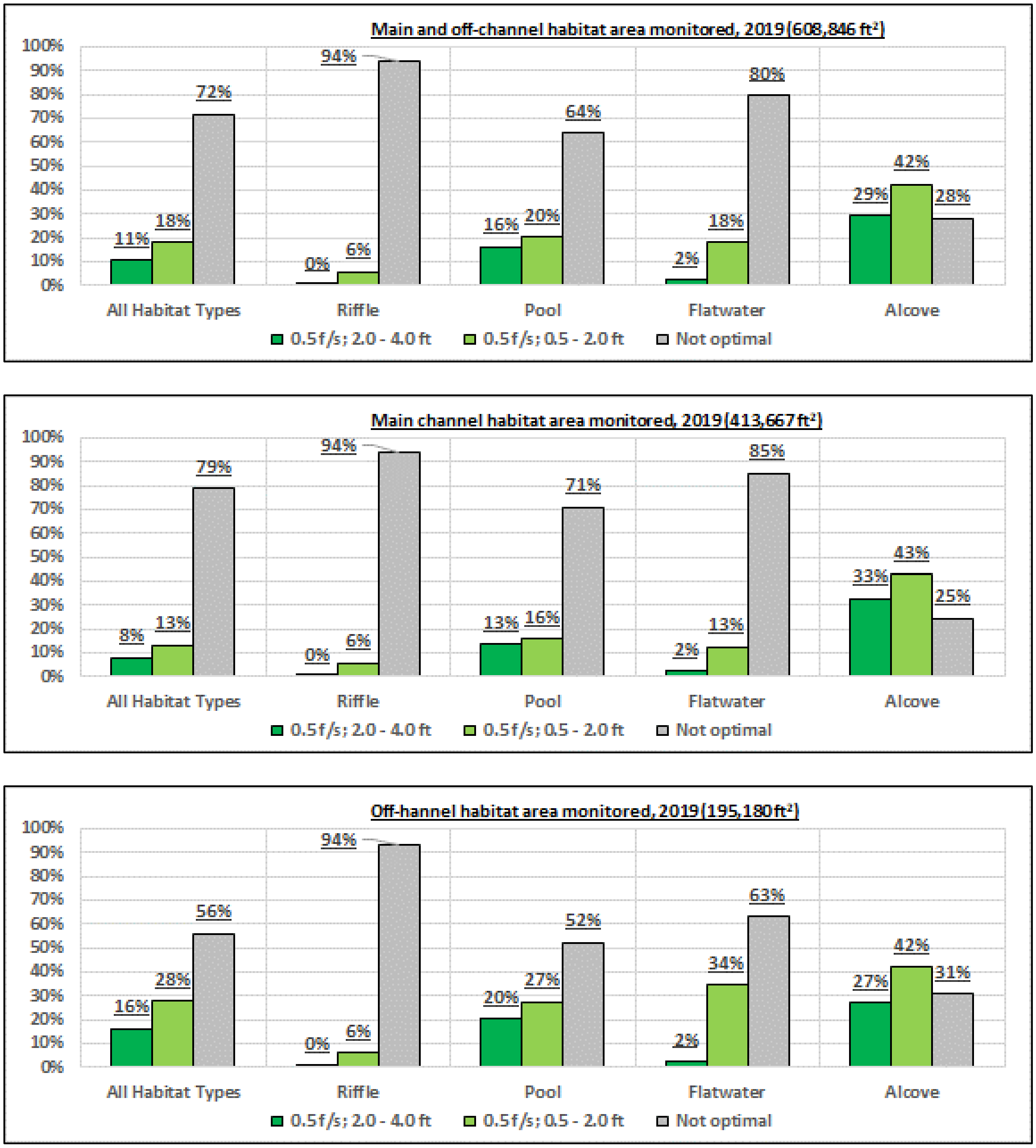


Figure 5.2.77. Percentages of optimal depth and velocity within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.

Habitat Types, Pool to Riffle Ratio, and Shelter Scores

Effectiveness monitoring data from all monitoring time periods in 2019 did show differences in average shelter score between main and off-channel areas, and differences between habitat types (Figure 5.2.78). Overall, main and off-channel areas supported an average shelter score of 72, compared with 64 in main channel areas, and 82 in off-channel areas. Pools supported the highest average shelter score in main and off-channel areas (94), followed by alcoves (92,) and also in off-channel areas (101), again followed by alcoves (89). Alcoves supported the highest average shelter score in main channel areas (96), followed by pools (87). As with the percentage of optimal depth and velocity, average shelter score in flatwaters and riffles remained consistently lower than alcoves and pools across all channel locations. The results reinforce depth and velocity observations (above) that side-channels and alcoves are effective at providing habitat conditions recommended in the RRBO and in the AMP.

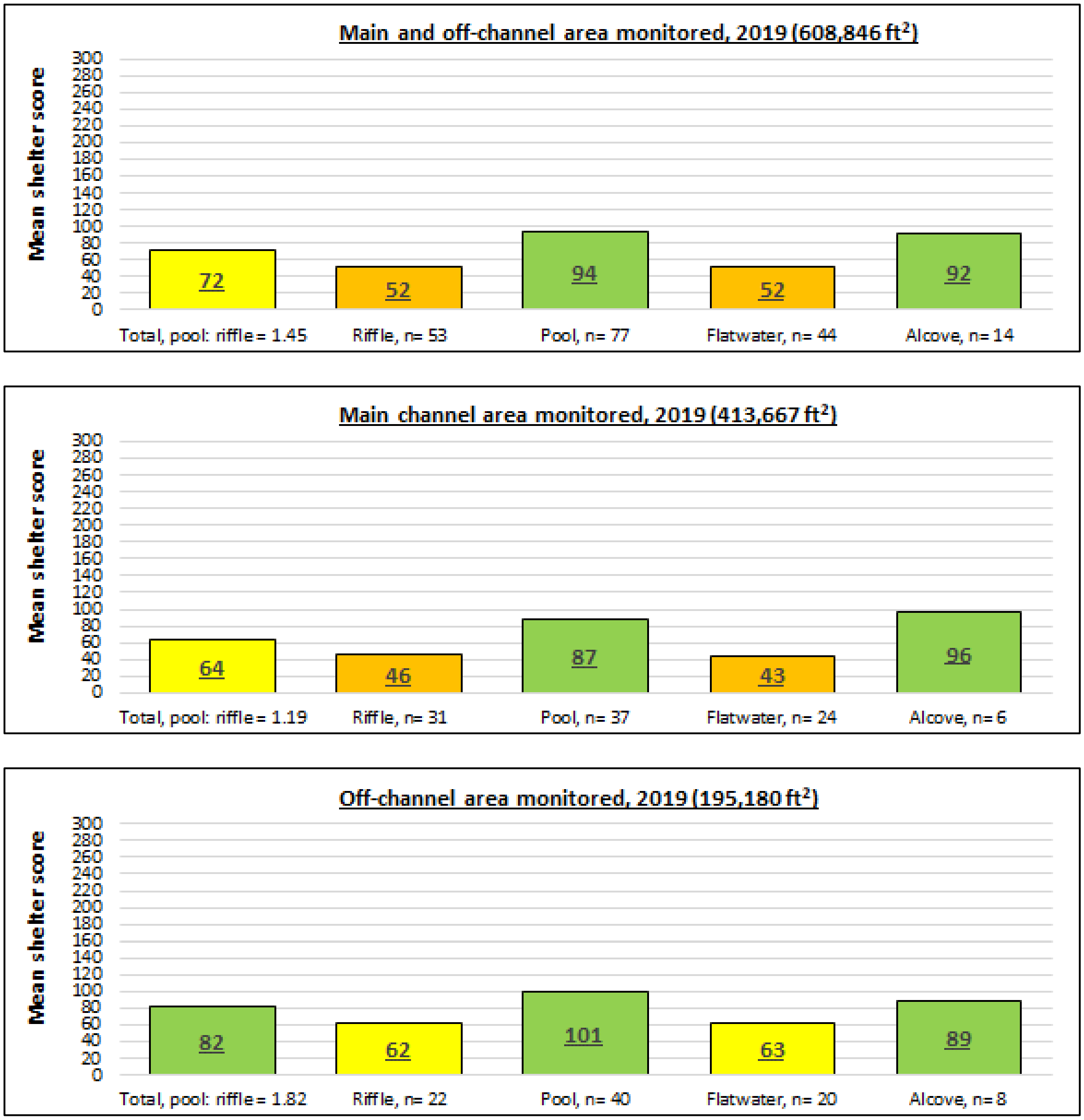


Figure 5.2.78. Average shelter scores within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.

Reach Ratings

Enhancement reach ratings from 2019 effectiveness monitoring vary according to monitoring time period (Table 5.2.40). The Gallo enhancement reach received a fair pre-enhancement rating in 2018 and received a good post-enhancement rating in 2019. Pre-enhancement ratings of Army Corps reach 14, Weinstock and Ferrari-Carano, Olson enhancement reaches improved from fair to good post-enhancement in 2018, then received good, good, and fair ratings post-effective flow in 2019, respectively.

Table 5.2.40. Dry Creek enhancement reaches monitored in 2019 and reach ratings for each monitoring time period. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River) (-- indicates monitoring not conducted).

Enhancement Reach	Pre-enhancement	Post-enhancement	Post-effective Flow	Post-repair
Army Corps	--	--	Good	--
Army Corps Reach 14	--	--	Good	--
Weinstock	--	--	Good	--
Gallo	--	Good	--	--
Truett Hurst	--	--	Fair	--
Farrow, Wallace	--	--	Good	--
Ferrari-Carano Olson	--	--	Fair	--
City of Healdsburg Yard	--	--	Poor	--
Geyser Peak	--	--	Fair	--

Conclusion

Qualitative ratings describe the relative success of habitat enhancement measures within enhancement sites and enhancement reaches and determine potential future outcomes. Post-effective flow enhancement reach ratings occur after exposure to at least one effective flow and likely reflect restored habitat conditions more accurately than post-enhancement ratings determined just after construction. As such, the ratings that determine management actions should likely be the most recent post-effective flow ratings. The latest post-effective flow ratings, as of 2019, show one excellent rating, seven good ratings, four fair ratings, and one poor rating (Table 5.2.41). With 60% to 80% of ratings either good or excellent, the AMP suggests developing and implementing plans to correct site or metric deficiencies, adding sites/features, and increasing monitoring of sites and features exhibiting negative performance (Table 5.2.2). Sonoma Water is currently implementing the above suggestions, and will continue to monitor habitat units, features, sites, and enhancement reaches according the AMP. Any future actions will be guided by monitoring data.

Table 5.2.41. Dry Creek enhancement reaches monitored, year(s) of post-effective flow effectiveness monitoring and effectiveness rating, and latest post effective flow effectiveness monitoring score. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River).

Enhancement Reach	2015	2016	2017	2018	2019	Latest post-effective flow rating
Army Corps	Excellent	Excellent			Good	Good
Army Corps Reach 14					Good	Good
Weinstock					Good	Good
Truett Hurst			Poor	Good	Fair	Fair
Meyer			Fair	Fair		Fair
Carlson, Lonestar				Good		Good
Quivira		Excellent				Excellent
Van Alyea			Good			Good
Rued	Good					Good
Farrow Wallace			Fair		Good	Good
Ferrari-Carano, Olson					Fair	Fair
City of Healdsburg Yard				Good	Poor	Poor
Geyser Peak			Poor	Fair	Fair	Fair

5.3 Validation Monitoring

Part of the Adaptive Management Plan (AMP) for validating the effectiveness of habitat enhancement in mainstem Dry Creek calls for a multiscale monitoring approach in both space and time (Porter et al. 2014). The current section of this report focuses on the results of validation monitoring for juvenile and smolt salmonid populations in mainstem Dry Creek in 2019. These data are part of an ongoing pre-construction (baseline) monitoring effort begun in 2008 and outlined in the Reasonable and Prudent Alternative section of NMFS' Russian River Biological Opinion. Validation monitoring data collected in newly constructed habitats are reported as well as continued efforts to monitor trends in juvenile and smolt abundance at the reach and watershed scale.

In the Russian River Biological Opinion status and data report year 2009-10 (Manning and Martini-Lamb 2011), Sonoma Water outlined six possible metrics that could be considered for validation monitoring of juvenile salmonids with respect to eventual habitat enhancements in the mainstem Dry Creek: habitat use, abundance (density), size, survival, growth and fidelity (Table 5.3.1). In 2009-2010, a major focus of validation monitoring in Dry Creek was on evaluating the feasibility of sampling methods to accurately estimate each of those metrics while simultaneously attempting to understand how limitations in sampling approaches may affect our ability to validate project success. These same validation metrics and associated limitations and uncertainties have been discussed in the context of the results of those evaluations and are incorporated into the Dry Creek AMP (Porter et al. 2014). The methods currently employed for validation monitoring in Dry Creek are largely based on the outcome of that work (Manning and Martini-Lamb 2011; Martini-Lamb and Manning 2011).

Table 5.3.1. Proposed target life stages, validation metrics, spatiotemporal scale and monitoring tools for validation monitoring in Dry Creek.

Spatial scale	Target life stage	Target metric(s)	Temporal scale	Primary monitoring tools
Site/feature	Juvenile (non-smolt)	Habitat use, abundance (density), size, growth	Post-construction	Snorkeling, electrofishing, PIT tags and antennas
Reach	Juvenile (non-smolt)	Abundance (density), size, survival, growth, fidelity	Pre-construction (baseline) vs. post-construction	Electrofishing, PIT tags and antennas
Mainstem Dry Creek	Smolt	Abundance	Ongoing to capture long-term trend	Downstream migrant trap, PIT antennas

Methods

In order for juvenile Coho Salmon to take advantage of the habitat enhancements created in Dry Creek, fish will need to come from somewhere and although there is a substantial population of juvenile steelhead that rear in mainstem Dry Creek, Coho are extremely scarce. Therefore, our strategy for juvenile Coho validation monitoring must rely on hatchery releases coupled with visual observations of Coho in the backwaters during snorkel surveys and observations on PIT antennas within habitat enhancement sites. Because of this, much of our juvenile salmonid monitoring has been focused on steelhead. However, in 2019 we conducted a juvenile Coho Salmon release trial in Dry Creek to evaluate how extending the hatchery rearing phase in a natural environment would impact the behavior of Coho Salmon post-release.

In order to address use of newly created habitat by juvenile steelhead at the site and feature scale, sampling consisted of PIT-tagging in the summer, operation of stationary PIT antennas starting in July through the following June in some locations and snorkeling in summer. We also conducted mark-recapture electrofishing in enhancement areas to estimate juvenile population density where possible. To better isolate how data collected at the site-scale indicate the effect of habitat enhancement, we also conducted backpack electrofishing in stream sections (reach-scale) that were not enhanced. Finally, we continued to operate a downstream migrant trap seasonally in lower Dry Creek to assess trends in smolt production over time. Broad-scale efforts that are part of the Coastal Monitoring Program (CMP) now being implemented in the Russian River provide a framework for placing our results in the context of watershed-scale patterns in those population metrics identified in Fish Bulletin 180 (the guiding document for California Coastal Salmonid Monitoring Program implementation, Adams et al. 2011).

Evaluation of juvenile Coho Salmon releases

On July 3, 2019, approximately 2,000 PIT-tagged juvenile Coho were released into Dry Creek as part of the Russian River Coho Salmon recovery program and as a way to evaluate use of constructed side channels by juvenile Coho. We released PIT-tagged individuals in three constructed side channels and one alcove. Two of these sites were newly constructed (Army Corps Reach 14 and Ferrari-Carano Olson) and one was originally constructed in 2016 (Truett Hurst) (Figure 5.3.3). A fourth release site was an alcove within the Ferrari-Carano Olson enhancement area created when the upstream flow from the mainstem was blocked by sediment aggradation during storms of the previous winter.

In the alcove site we conducted a trial where a portion of the PIT tagged Coho were held in cages suspended in the water column and another group was held in the alcove behind a mesh block net, restricting their movement out of the alcove (Figure 5.3.1). A total of 505 Coho juveniles were placed into one of two cages measuring 8’ x 4’ x 2’ constructed out of PVC pipe and 1/4” Vexar mesh, approximately 250 juveniles in each cage. Each cage was equipped with a food release box and fish were fed approximately 100g of hatchery rations dispensed over a 12 hour period every 48 hours. In addition to the juveniles released into and held in the cages, 250 PIT tagged Coho were released directly into the alcove behind the block net. Fish from both cages were released into the alcove, behind the block net, on July 15. A subsample of 20 fish from each cage were anesthetized, measured and weighed at the time of the release. The block net at the mouth of the alcove was removed on July 18. Stationary antennas were placed just upstream of the alcove (rkm 5.31), just downstream of the alcove (rkm 5.29) and at the downstream end of the constructed channel (rkm 5.00) to detect the movements of tagged Coho that were released in the constructed channel and the adjacent alcove (Figure 5.3.1). In addition, stationary PIT antennas were also located at the inlet and outlet of the Truett Hurst side channel (rkm 14.30 and 14.05) and outlet and midway upstream from the outlet in the Army Corps Reach 14 side channel (rkm 20.99 and 21.05).

Figure 5.3.1. Location of Coho Salmon cage release trial in Ferrari-Carano, Olson habitat enhancement. PIT antennas are depicted in yellow ovals, block net location depicted by black line and cage location (2 cages) depicted by purple square.

Habitat utilization

Snorkel surveys

Snorkel surveys of juvenile salmonids in the Dry Creek habitat enhancement areas were not conducted in 2019. Turbidity was too high to effectively survey the habitat enhancement sites (Figure 5.3.2).

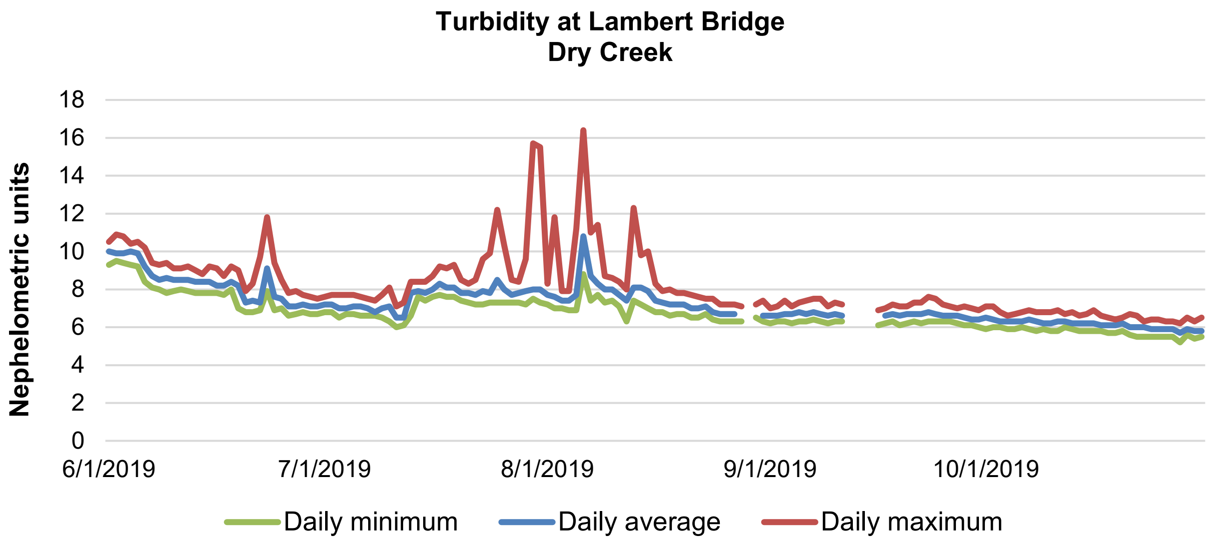


Figure 5.3.2. Turbidity at Lambert Bridge USGS stream **gage number 11465240.**

PIT antennas

Similar to previous years, we operated PIT antennas in constructed habitat enhancements: Truett-Hurst side channel (one antenna at rkm 14.05, and a second antenna at rkm 14.30), Gallo side channel (rkm 20.40), Weinstock side channel (rkm 20.72) and Army Corps Reach 14 side channel (one antenna at rkm 20.99, and a second antenna at rkm 21.05) (Figure 5.3.3, Figure 5.3.4). Although antennas did not necessarily span the wetted width of channels, they did cover the majority of the wetted width. The source of PIT-tagged fish included: (1) PIT-tagged juvenile Coho that were released from Warm Springs Hatchery into Dry Creek; (2) wild (natural-origin) juvenile steelhead that were PIT-tagged during mainstem Dry Creek electrofishing surveys; (3) adult anadromous salmonids that had been previously PIT-tagged as juveniles.

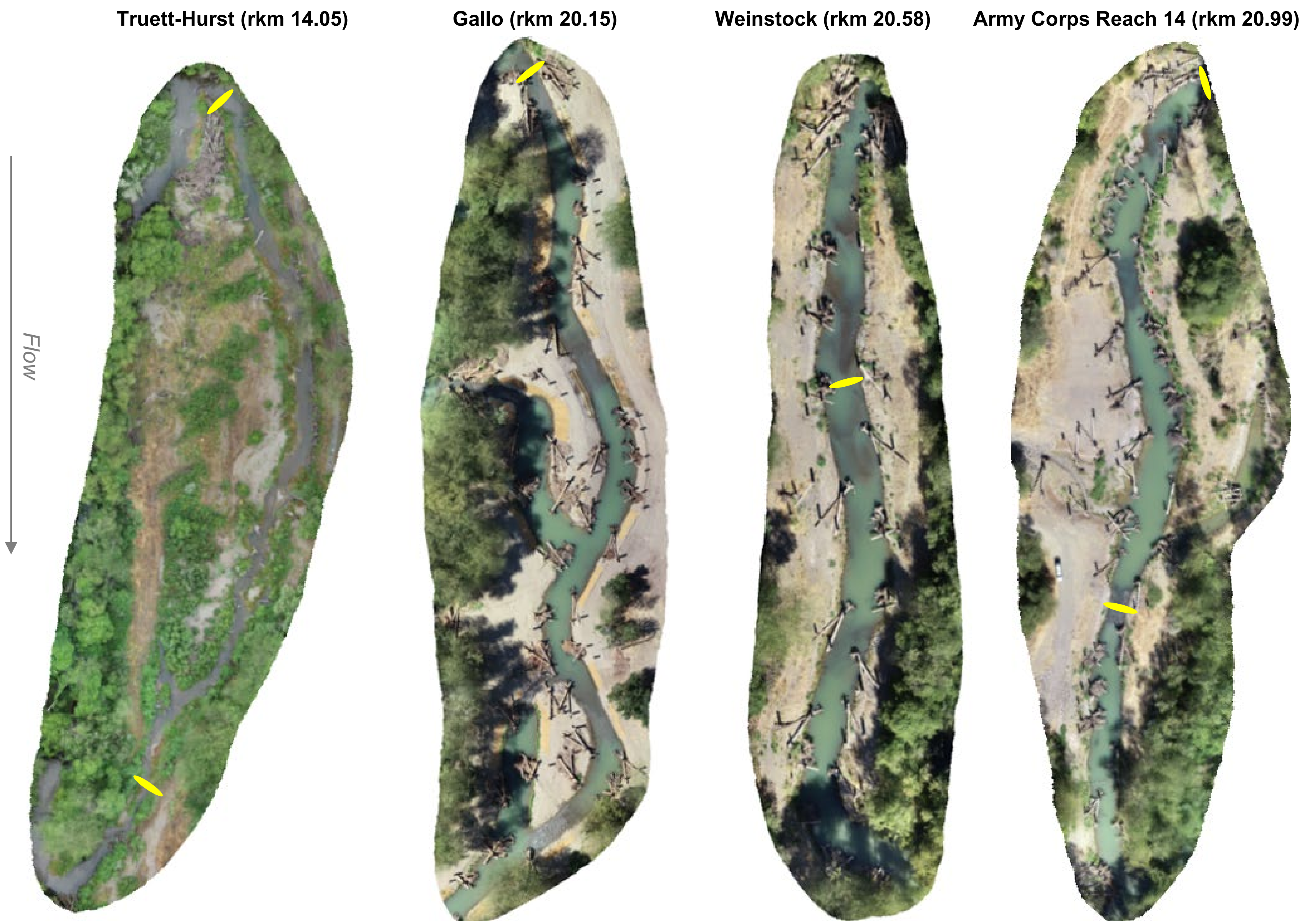


Figure 5.3.3. Approximate location of PIT antennas (yellow ovals) in Dry Creek habitat enhancements.

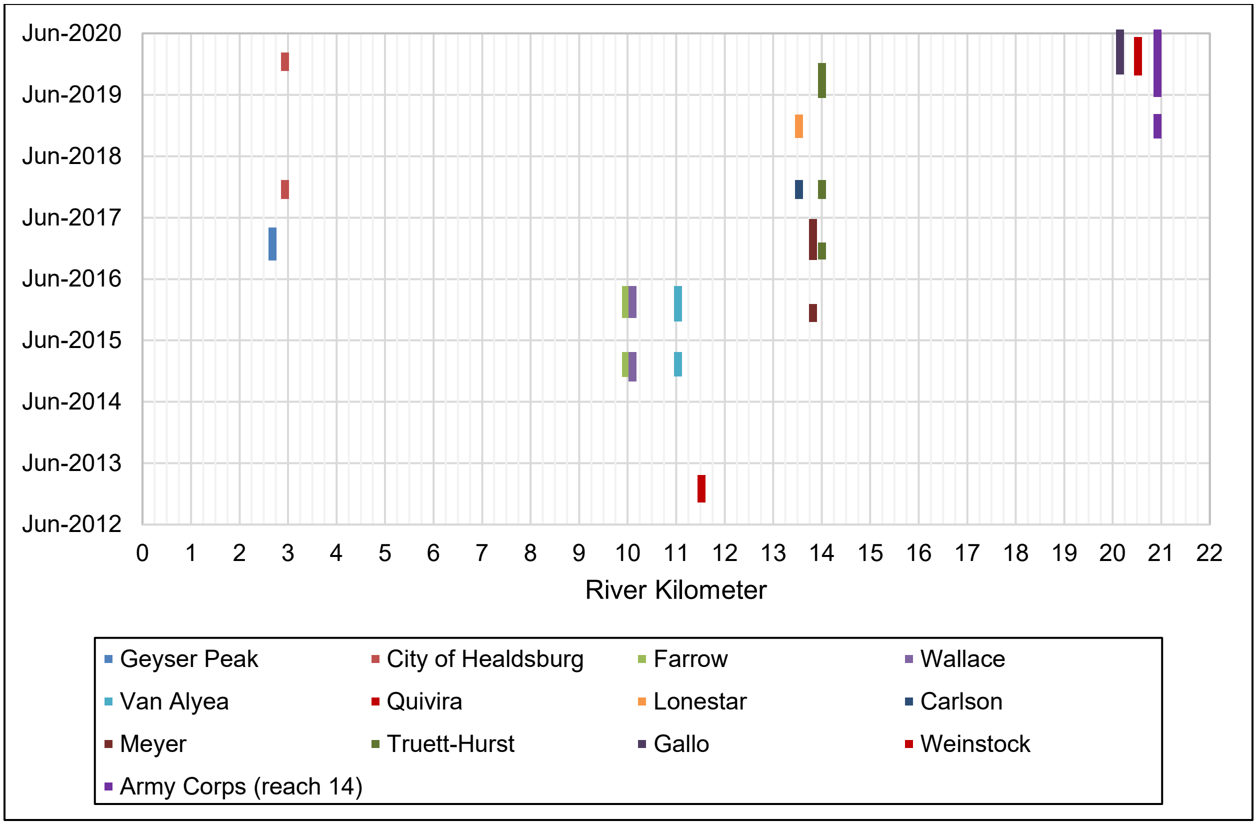


Figure 5.3.4. Dates of PIT antenna operation in Dry Creek habitat enhancement sites, November 2012 to June 2020.

Late summer population density

Site-scale sampling

We conducted sampling to estimate population density in the Truett Hurst constructed side channel (rkm 14.01) on August 13, 2019. Unlike in previous years we used block nets to temporarily close two sections of the side channel for sampling. Multiple electrofishing passes were conducted through each section on the same day. In order to estimate local population abundance, all fish captured on each pass was counted and temporarily "removed" from the stream section by holding them in live wells while subsequent passes were conducted. We used the Petersen mark-recapture model in Program MARK (White and Burnham 1999) to estimate end-of-summer abundance ($\widehat{N}$). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the site.

Reach-scale sampling

The Biological Opinion as well as the primary literature (e.g., Roni 2005) acknowledge the problem of biological monitoring that is too limited in time and space to accurately detect changes in population that may result from artificial habitat enhancements as opposed to other factors. To overcome this we sought to place our results in a broader context. From 2015 to 2018, Sonoma Water employed a reach-based approach that relied on the spatially-balanced random sampling framework afforded by the generalized random tessellation stratified (GRTS) framework outlined for CMP implementation (Adams et al. 2011). Sampling reaches in this manner over time should allow us to place our results in a broader spatial context thereby facilitating more accurate validation of the effectiveness of habitat enhancement measures in Dry Creek (Figure 5.3.5). In 2019 we reduced the number of sampling reaches from nine to three: one section in each of the geomorphically-based reach designations identified by Inter-Fluve (2011). Sampling was conducted with a single pass through the entire stream section on day 1 (the marking event) followed by a second pass two days later (the recapture event). Individuals captured on day 1 were PIT-tagged, released near their capture location and subject to recapture on day 2. From these paired sampling events, we used the Petersen mark-recapture model in Program MARK (White and Burnham 1999) to estimate end-of-summer abundance ($\widehat{N}$). Provided recapture probability, mortality and the proportion of fish leaving the section between the marking and recapture events was the same for the marked group as it was for the unmarked group, the abundance estimates from the paired mark and recapture events in early autumn will be unbiased (White et al. 1982). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the site.

Stream sections (sub-reaches) were typically longer (average 850 feet, range 750 - 1050 feet) than sites sampled during site-scale sampling.

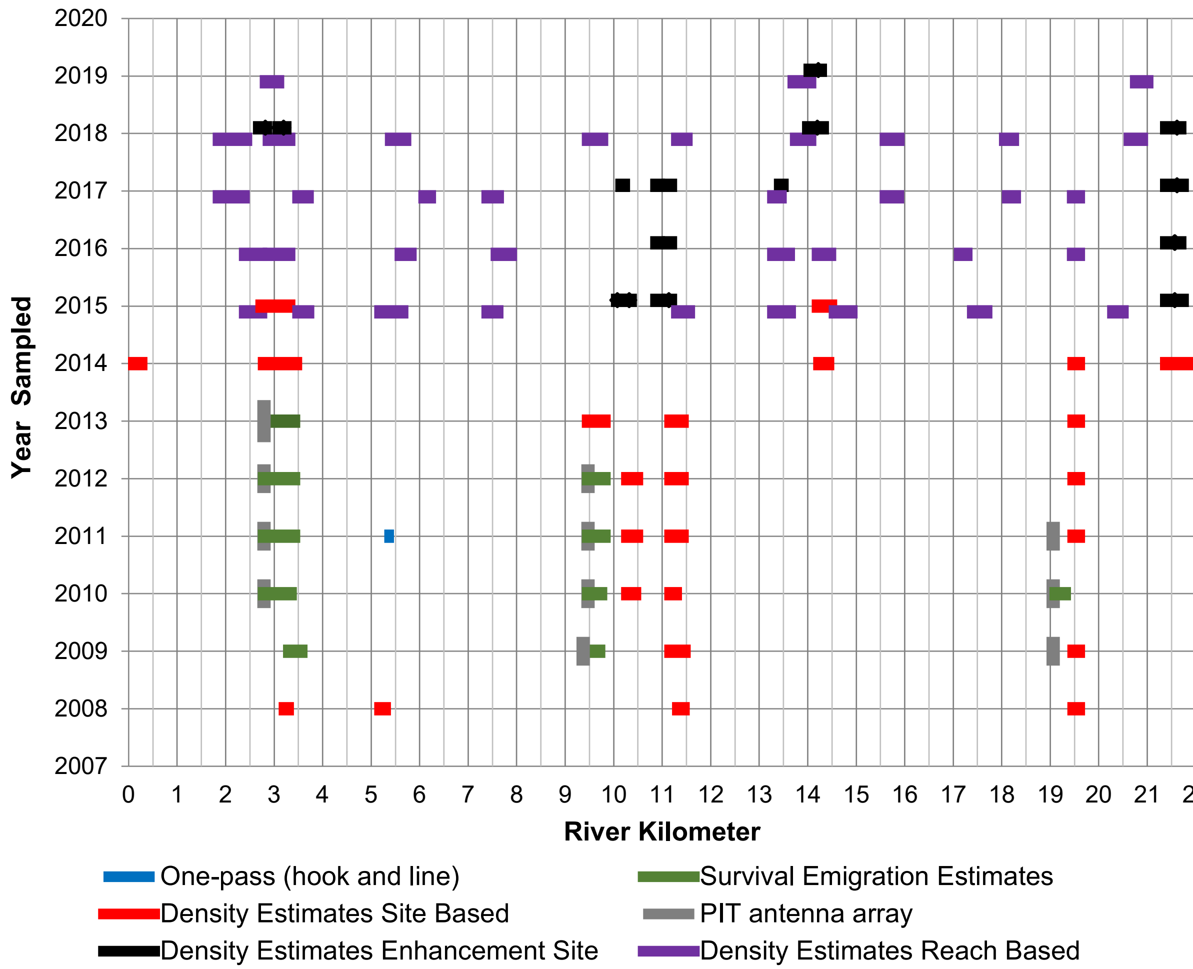


Figure 5.3.5. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in mainstem Dry Creek, 2008-2019. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass depletion or Petersen model) and reach-scale data collected in 2009 were analyzed with the core-sampling approach (see Manning and Martini-Lamb 2011 for details) while reach scale data collected in 2011-13 were analyzed with the multistate model using program MARK (White and Burnham 1999) to estimate survival and emigration.

Smolt abundance

A rotary screw trap with a 1.5 m diameter cone was anchored to the Westside Road bridge, located 3.3 km upstream from the confluence of Dry Creek and the Russian River. Wood-frame mesh panels were installed adjacent to the rotary screw trap in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap.

Fish handling methods and protocols were similar to those used in previous years (see Manning and Martini-Lamb 2011). Fish captured in the trap were identified to species and enumerated. A subsample of each species was anesthetized and measured for fork length each day, and a subsample of salmonid species was weighed each week. With the exception of up to 50 Chinook Salmon smolts each day, all fish were released downstream of the first riffle located downstream of the trap.

Each day, up to 50 Chinook smolts (≥60 mm) were marked and released upstream of the trap for the purpose of estimating trap efficiency and constructing a population estimate. Both fin clips and PIT tags were used to mark fish. PIT-tagged fish provided the potential to evaluate migration mortality and migration time as fish were detected at downstream monitoring sites (i.e., Duncans Mills PIT antenna array). Marked fish (fin-clipped or PIT-tagged) that were recaptured in the trap were noted and released downstream (the lengths and weights of recaptured fish were not recorded a second time). The population estimate of Chinook Salmon smolts produced in the Dry Creek watershed upstream of the trap were based on recapture rates of PIT tagged fish only. The abundance estimate of Chinook smolts reported in 2019 applies to the period the trap was operated (April 30-July 31).

Results

Evaluation of juvenile Coho Salmon releases

Of the 763 PIT tagged Coho Salmon released in the Ferrari-Carano Olson alcove (either in cages or free swimming) 35 fish were detected at four constructed side channels (excluding the release location) in the following fall and winter.

Table 5.3.2. Release and detection information for PIT tagged juvenile (age-0+) Coho Salmon released in the Ferrari-Carano Olson enhancement site, Dry Creek, summer 2019. Note that individuals that were detected at more than one detection site are counted more than once.

Release Site	Release Number	Detect Site	Detect Number (%)	Median Days[1] (0.1, 0.9 percentile)
Ferrari-Carano Olson cages	505	USGS (rkm 0.36)	21 (4.1%)	5 (1, 31)
		Ferrari-Carano Olson (rkm 5.31-5.0)	297 (58.8%)	1 (0, 3)
		Truett Hurst (rkm 14.3-14.05)	12 (2.4%)	32.5 (15, 115.7)
		Gallo (rkm 20.4)	1 (0.2%)	134 (na)
		Weinstock (rkm 20.72)	2 (0.4%)	139.5 (134.3, 144.7)
		Army Corps 14 (rkm 20.99)	1 (0.2%)	146 (na)
Ferrari-Carano Olson alcove	258	USGS (rkm 0.36)	14 (5.4%)	10.5 (1.3, 22.9)[2]
		Ferrari-Carano Olson (rkm 5.31-5.0)	172 (66.7%)	1 (0, 2.8)[3]
		Truett Hurst (rkm 14.3-14.05)	6 (2.3%)	17 (7.5, 76)
		Gallo (rkm 20.4)	2 (0.8%)	136.5 (132.1, 140.9)
		Weinstock (rkm 20.72)	1 (0.4%)	142 (na)
		Army Corps 14 (rkm 20.99)	2 (0.8%)	92 (52, 132)
Ferrari-Carano Olson constructed channel	247	USGS (rkm 0.36)	56 (22.7%)	1 (0, 25.5)
		Ferrari-Carano Olson (rkm 5.31-5.0) [4]	103 (41.7%)	1 (0, 12.6)
		Truett Hurst (rkm 14.3-14.05)	4 (1.6%)	7 (7, 42)
		Weinstock (rkm 20.72)	2 (0.8%)	183.5(181.5, 185.5)
		Army Corps 14 (rkm 20.99)	2 (0.8%)	183.5(181.5, 185.5)
Total	**1,010**	**Combined**	**698 (69.1%)**	**N/A**

[1] Refers to number of days between release date and first detection date at the detection site
[2] Excludes detection date of 2 fish that escaped from the alcove prior to release date
[3] Excludes detection date of 19 fish that escaped from the alcove prior to release date
[4] Includes detections at rotary screw trap located at rkm 3.30 to include fish leaving the downstream end of the constructed side channel as the antenna was nonoperational until July 17.

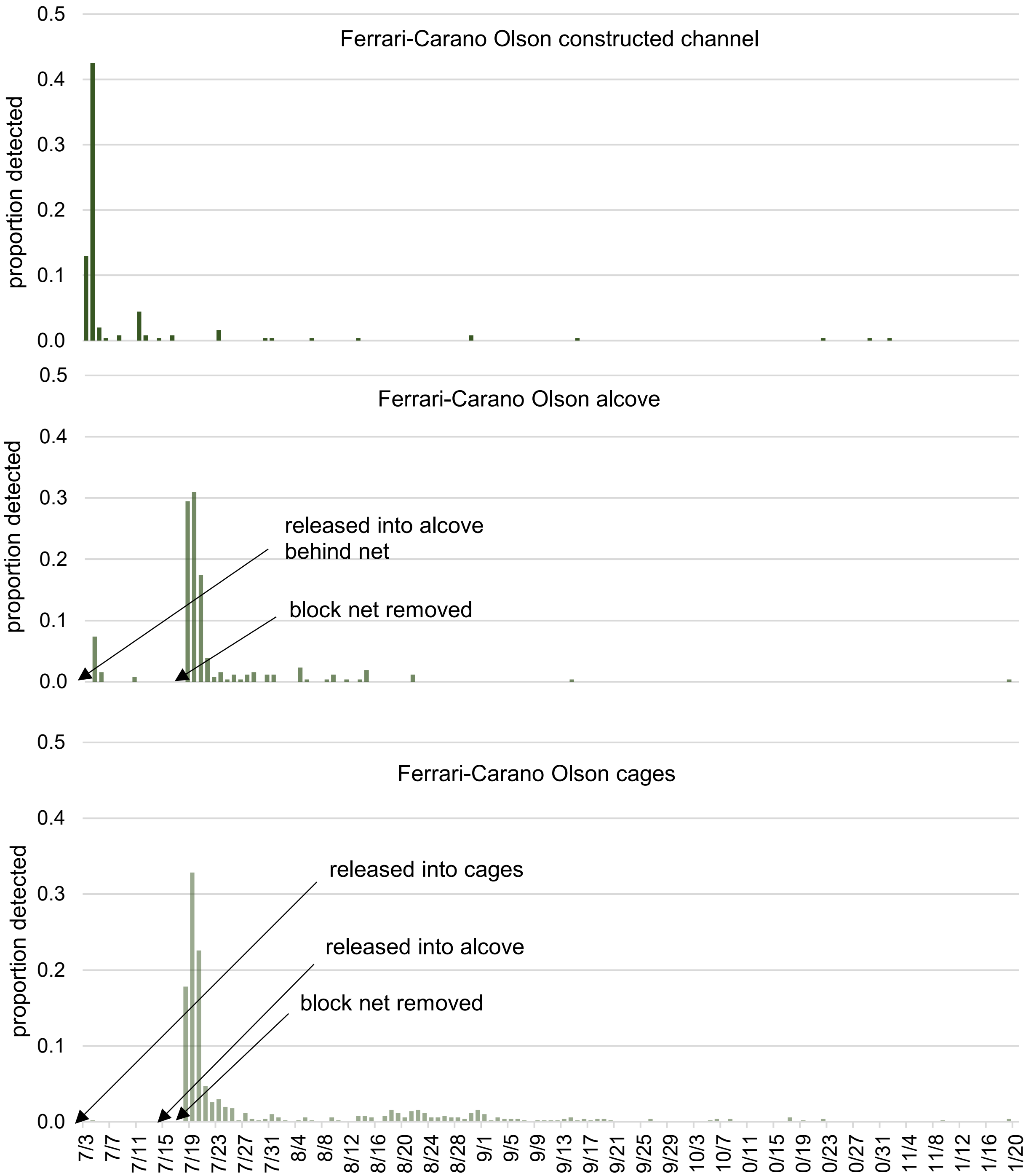


Figure 5.3.6 Proportion of juvenile Coho released into two constructed, unblocked side channels (see text for description) that were later detected leaving (most likely) the side channel of release.

Habitat utilization

PIT antenna

Of the 708 juvenile steelhead that were PIT-tagged in 2019 during electrofishing surveys, 505 were captured in the main channel and 203 were captured in the Truett-Hurst side channel

(Table 5.3.3). Of the 505 fish tagged in the main channel, 174 (35%) were detected on PIT antennas in one or more enhancement sites. Most of these detections (166) were from fish that were tagged within 2 km of the enhancement site (Figure 5.3.7 - Figure 5.3.10). Of the 160 individuals tagged in the upstream-most 2 km of the main channel of Dry Creek, 24 (15%) were detected entering at least 2 of the side channels. Of those 24, 10 were detected entering all three side channels. From these data, it is reasonable to conclude that a significant portion of all juveniles are making use of these enhanced off-channel habitats during the winter, but, not surprisingly, the highest use is by fish residing in close proximity to the habitat enhancements.

In addition to juvenile salmonid detections in the habitat enhancements, we also documented use by adult salmonids. We documented 54 unique, PIT-tagged adults during the 2019-2020 adult migration season. Twenty-eight of those individuals entered at least 1 of the side channels that we monitored with PIT antennas: 3 in Truett Hurst, 25 in Gallo, 22 in Weinstock, and 14 in Army Corps reach 14. Twelve individuals entered all three of the side channels in the upstream-most 1 km of Dry Creek nearest the dam.

Table 5.3.3 Number of juvenile steelhead PIT-tagged during Dry Creek electrofishing surveys in summer 2019 and subsequent number detected (and percent of total tagged in that reach) on PIT antennas in habitat enhancement side channels, summer 2019 through spring 2020.

Reach	Lower (rkm)	Upper (rkm)	Number tagged (summer 2019)	Detected at Truett-Hurst	Detected at Gallo	Detected at Weinstock	Detected at Army Corps Reach 14
Lower	**0.00**	**5.27**	**0**	**0**	**0**	**0**	**0**
Middle	**5.27**	**17.71**	**548**	**189 (34%)**	**3 (0.6%)**	**2 (0.4%)**	**7 (1%)**
Main channel	*13.72*	*14.04*	*345*	*67 (19%)*	*0 (0%)*	*1 (0.3%)*	*4 (1%)*
Truett-Hurst	*14.01*	*14.30*	*203*	*122 (60%)*	*3 (2%)*	*1 (0.5%)*	*3 (2%)*
Upper	**17.71**	**22.00**	**160**	**3 (2%)**	**5 (3%)**	**20 (13%)**	**74 (46%)**
Main channel	*20.55*	*20.99*	*160*	*3 (2%)*	*5 (3%)*	*20 (13%)*	*74 (46%)*
		Totals	**708**	**192 (27%)**	**8 (1%)**	**22 (3%)**	**81 (11%)**

Truett-Hurst side channel

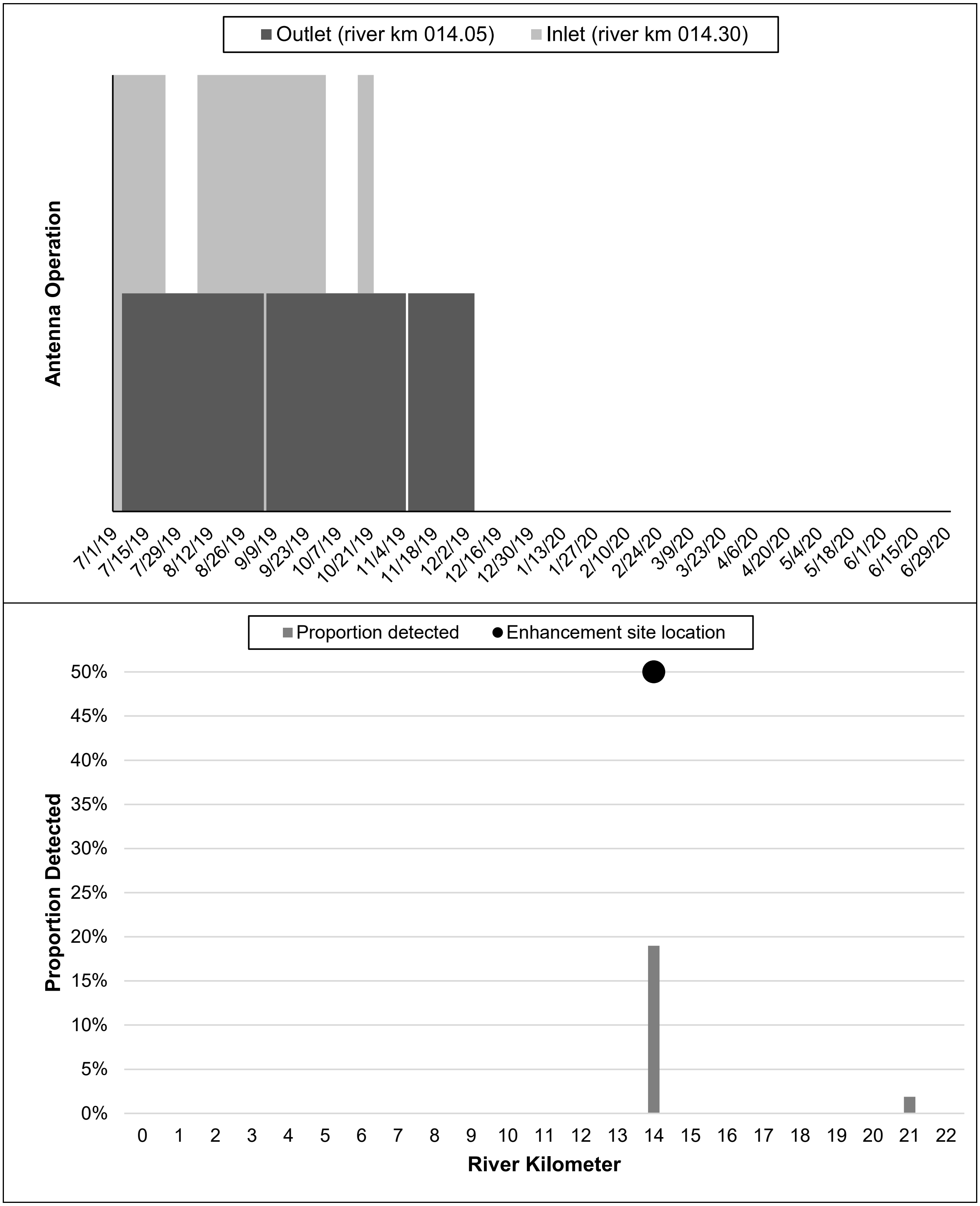


Figure 5.3.7. Period of antenna operation (upper panel) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek at a given river km that were later detected in the habitat enhancement (lower panel).

Gallo side channel

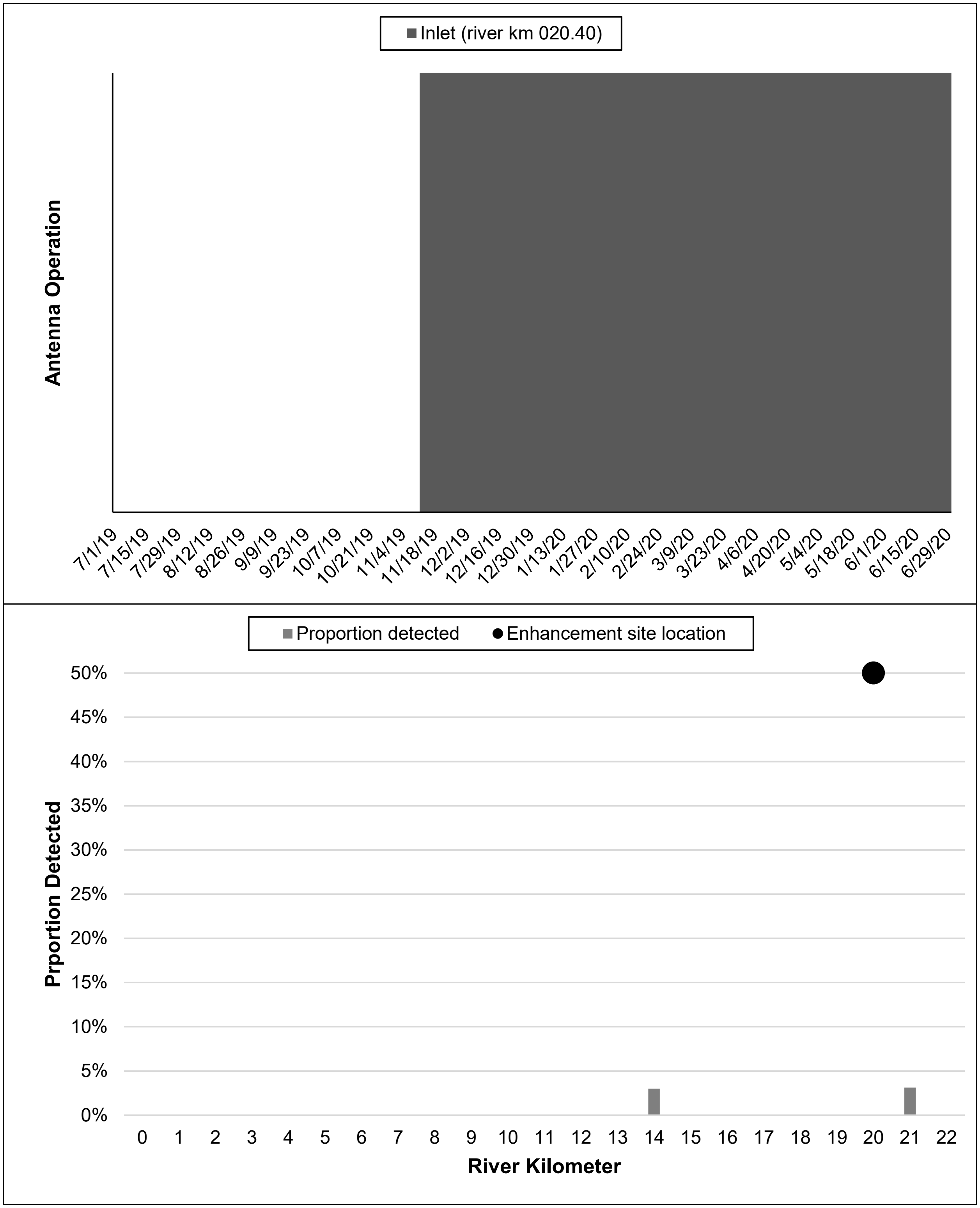


Figure 5.3.8. Period of antenna operation (upper panel) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek at a given river km that were later detected in the habitat enhancement (lower panel).

Weinstock Side Channel

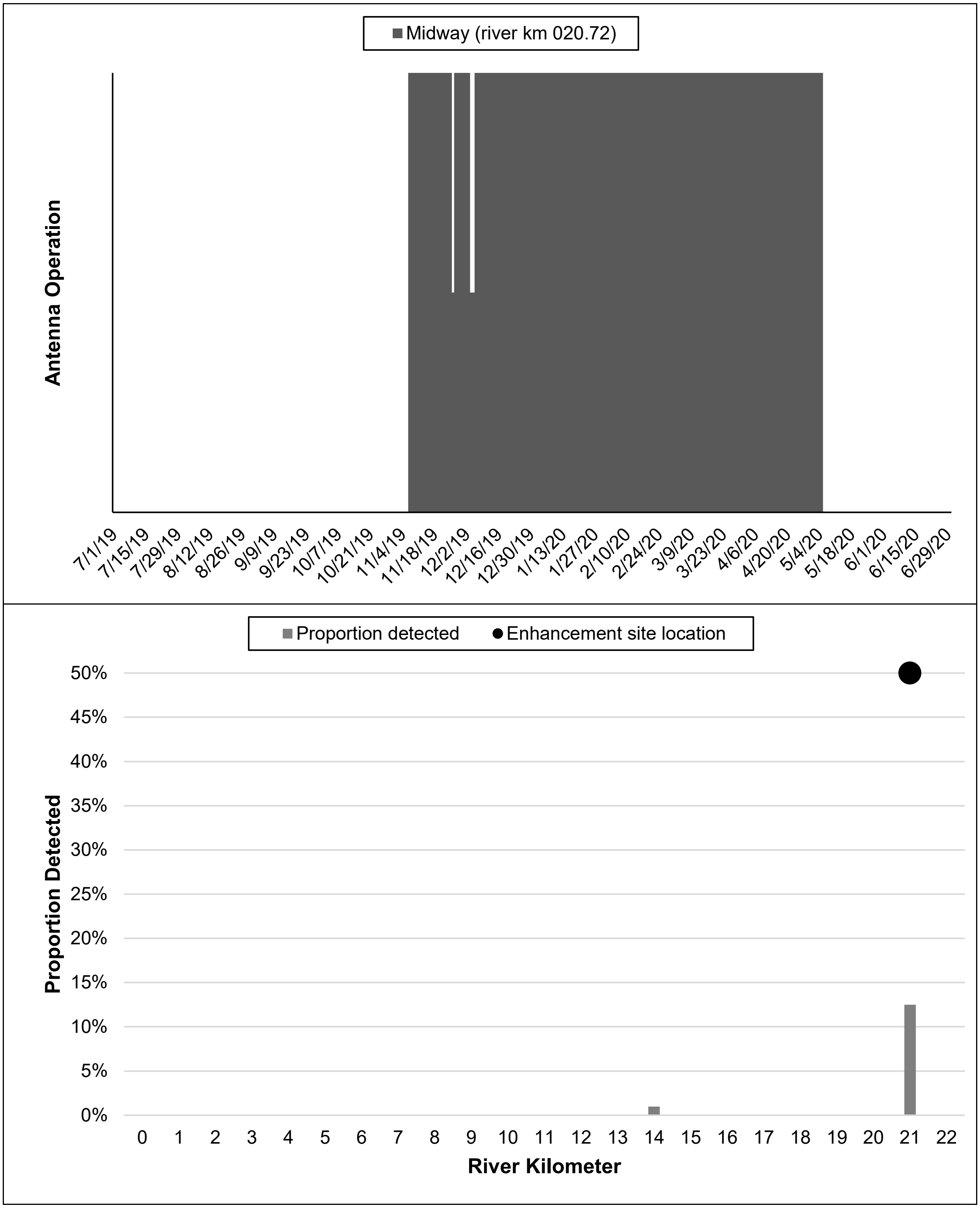


Figure 5.3.9. Period of antenna operation (upper panel) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek at a given river km that were later detected in the habitat enhancement (lower panel).

Army Corps (Reach 14) Side Channel

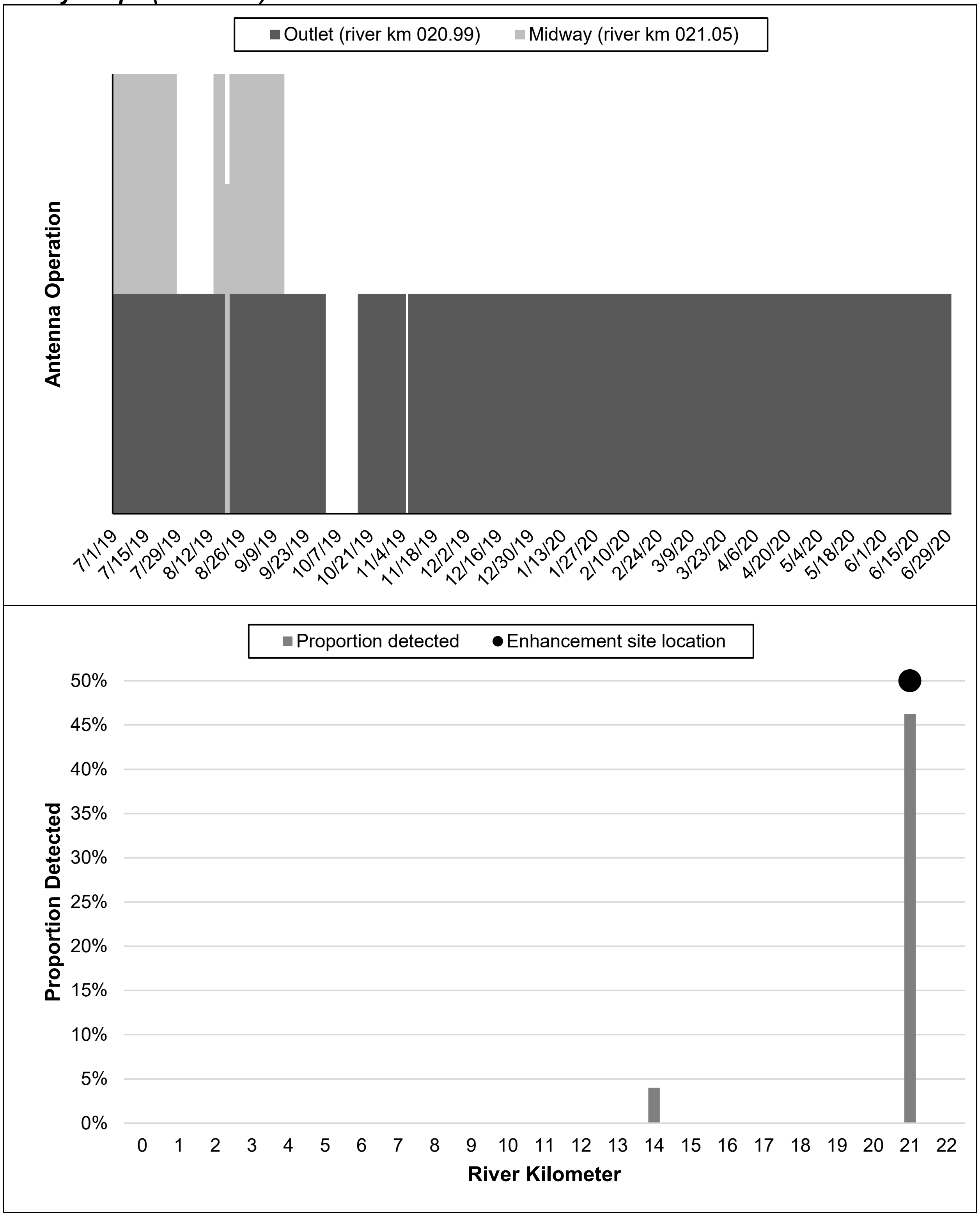


Figure 5.3.10. Period of antenna operation (upper panel) and proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek at a given river km that were later detected in the habitat enhancement (lower panel).

Late summer population density

Site-scale sampling

The estimated density of juvenile steelhead in the Truett Hurst side channel (0.68 fish*m^{-2}, rkm 14.01) was greater than the density estimates obtained from the previous year sample of the same side channel (0.36 fish*m^{-2}). While we did not capture enough Coho to generate a density estimate, we did capture a total of 8 hatchery origin Coho Salmon YOY during electrofishing sampling in the Truett Hurst side channel.

Reach-scale sampling

The average density of juvenile steelhead in mainstem sections was 0.32 fish*m^{-2} (range 0.19 fish*m^{-2} to 0.51 fish*m^{-2}). When averaged for all sites within a year, densities in 2019 were 0.14 fish*m^{-2} higher than the eleven year average from 2008-2018 (Figure 5.3.11). The average population density for enhanced sites was greater than for un-enhanced sites (Figure 5.3.11).

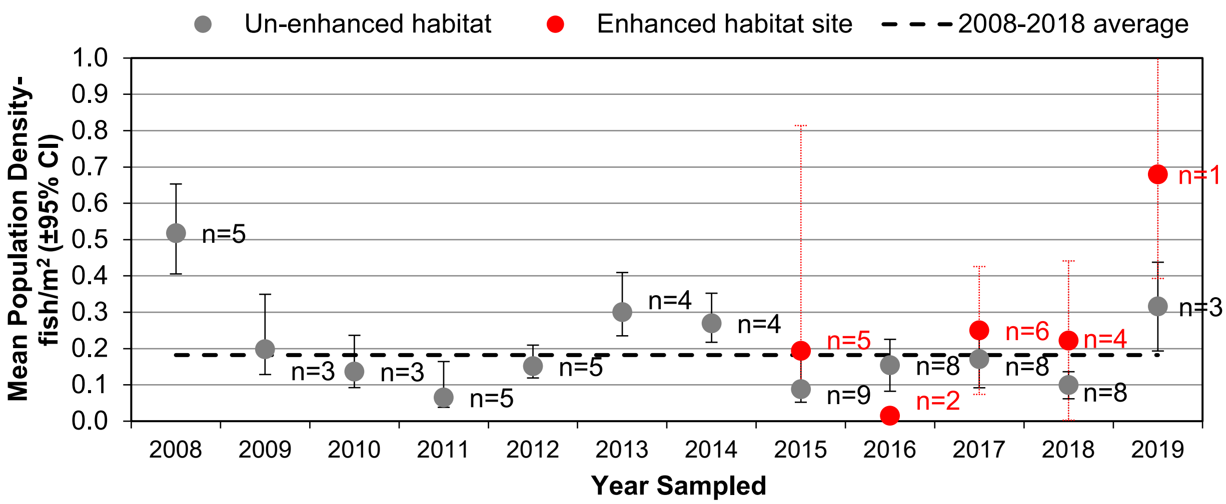


Figure 5.3.11. Mean juvenile steelhead density among all sites sampled within a year in mainstem Dry Creek, 2008-2019. "n" refers to the number of sites sampled per year.

Smolt abundance

We installed the rotary screw trap on April 30 (Figure 5.3.12). Except for brief periods when trapping was suspended because of high debris loading in the trap from high winds, the trap was checked daily during operation until it was removed on July 31.

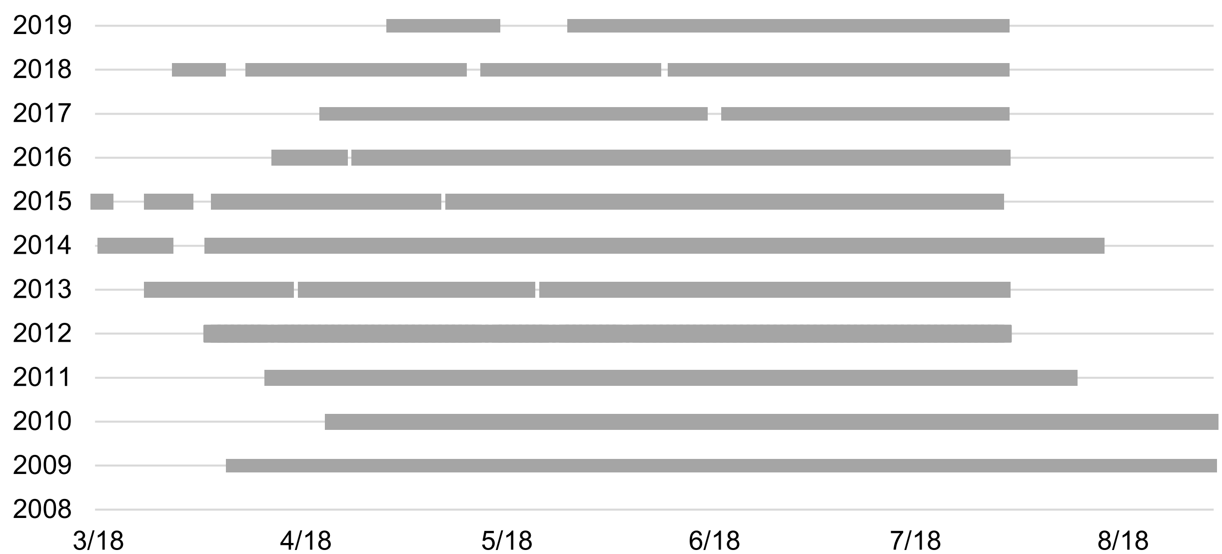


Figure 5.3.12. Begin and end dates and data gaps (spaces in lines) for operation of the Dry Creek downstream migrant trap, 2009-2019.

The peak capture of Chinook Salmon smolts (243) occurred during the week of 6/11 (Figure 5.3.13). Based on the estimated average weekly capture efficiency (range: 3% to 6%), the resulting population size of Chinook smolts passing the Dry Creek trap between April 30 and June 25 was 17,665 (±95% CI: 5,661, Figure 5.3.14). This is the smallest population estimate since we began trapping Dry Creek in 2009.

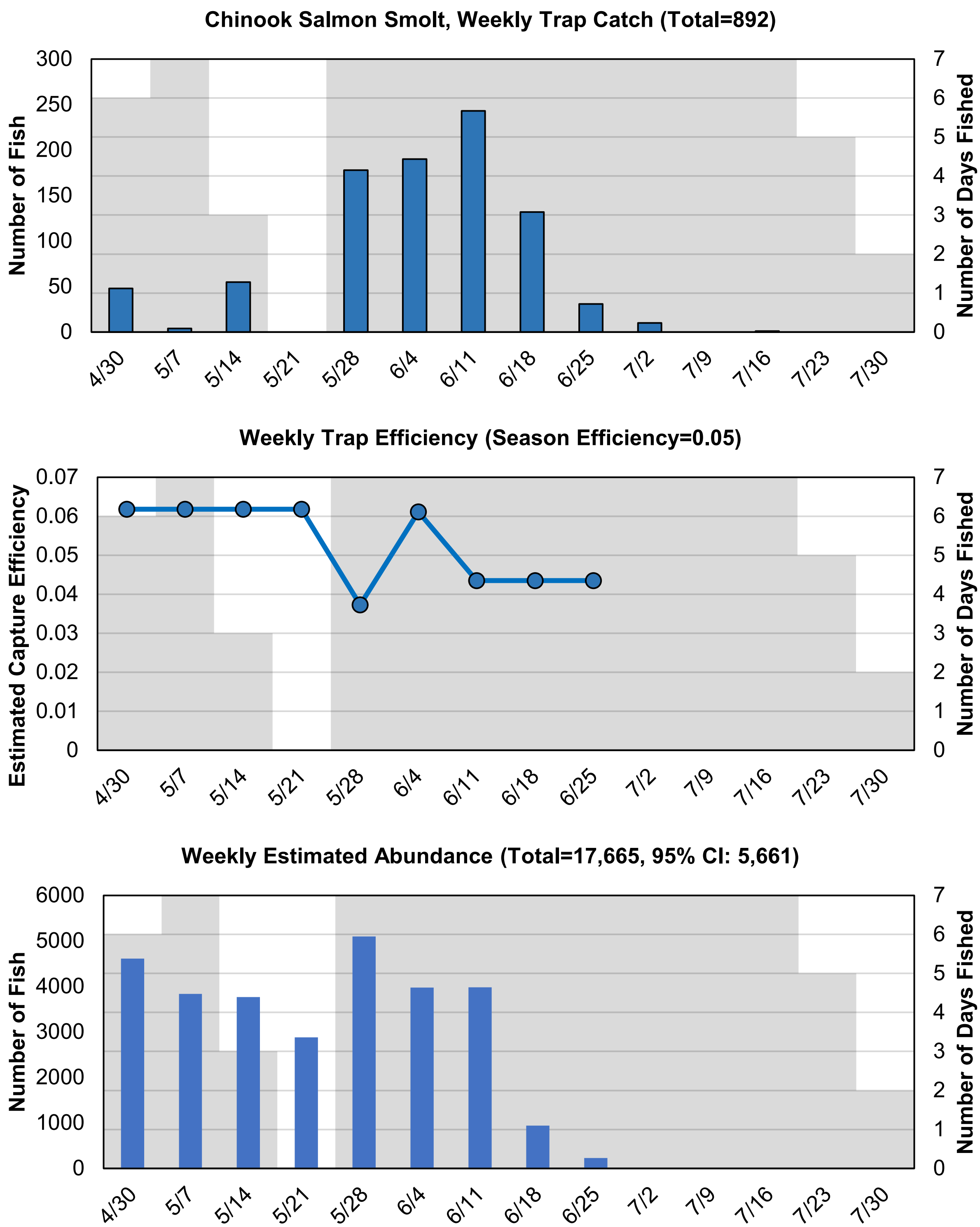


Figure 5.3.13. Weekly trap catch (upper panel), estimated average weekly capture efficiency (middle panel) and population estimate of Chinook Salmon smolts in the Dry Creek rotary screw trap (lower panel), 2019. Estimates are from DARR (Bjorkstedt 2005). The number of days each week the trap was fished is represented by the shaded area.

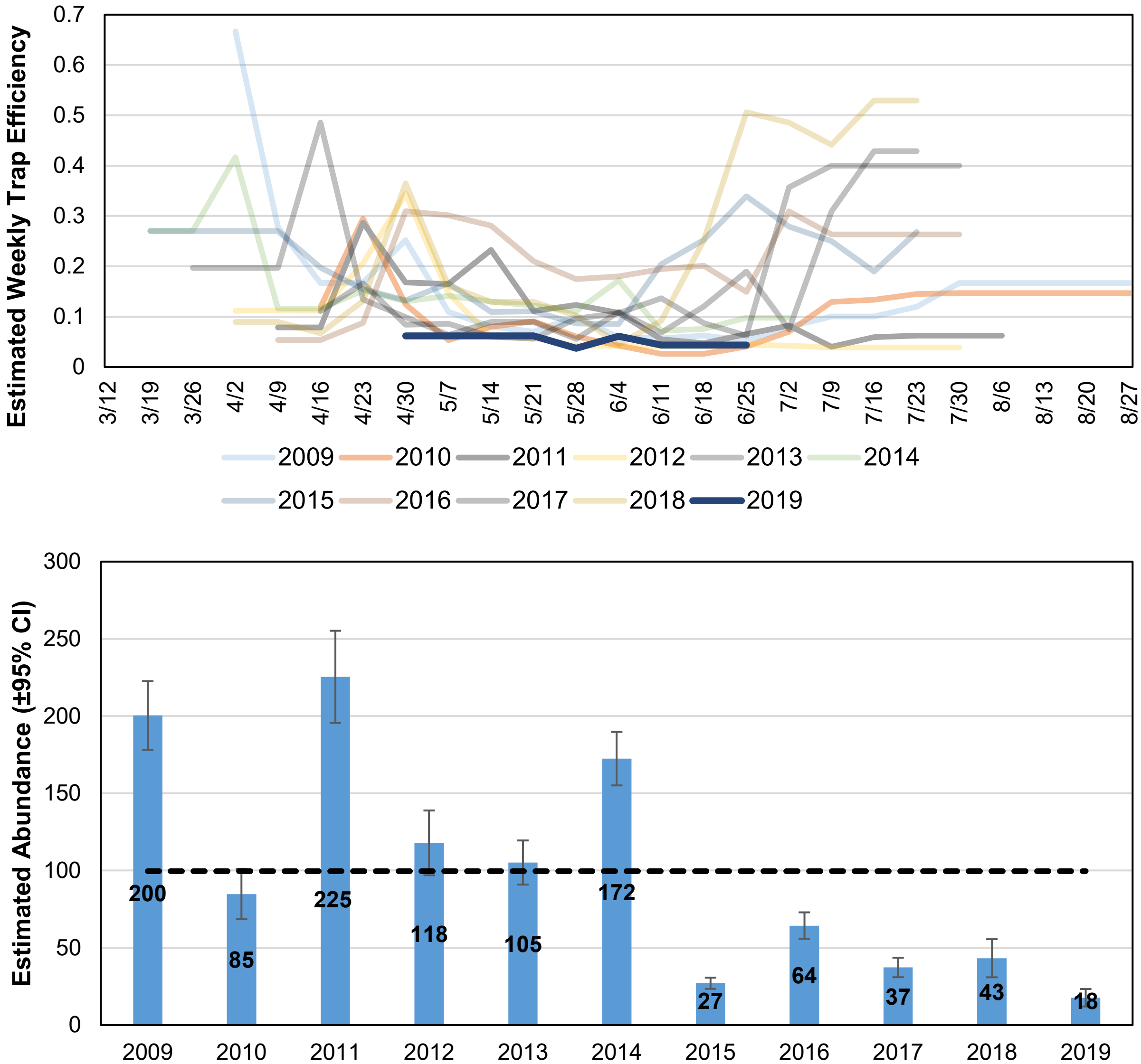
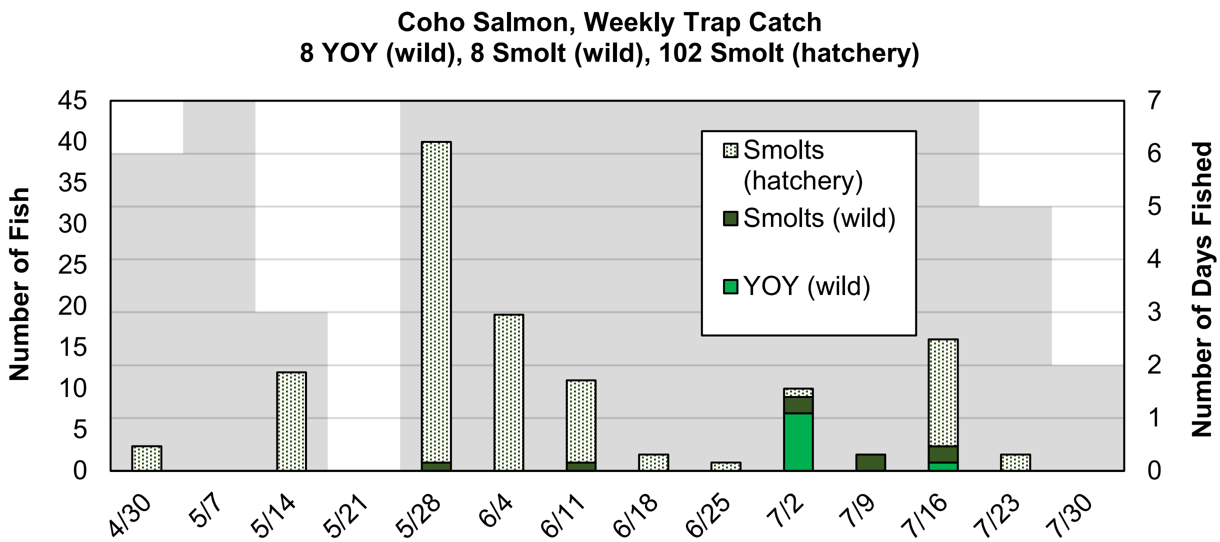


Figure 5.3.14. Estimated average weekly capture efficiency (upper panel) and population estimate of Chinook Salmon smolts (x1000) produced from the Dry Creek watershed upstream of Westside Road smolt trap site (rkm=3.3) (lower panel), 2009-2019. Dashed line is the eleven year average abundance for all years combined.

Coho Salmon were the least abundant of the three salmonid species captured. Hatchery smolts dominated the catch with a total of 118 individuals captured. Steelhead parr capture was highest in June (Figure 5.3.15).



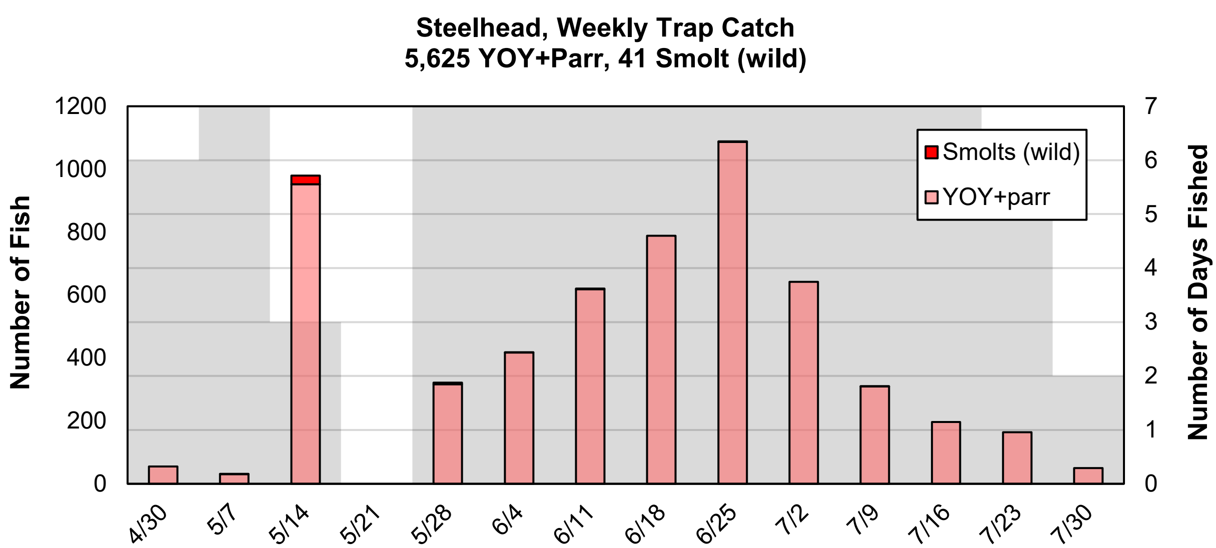


Figure 5.3.15. Weekly trap catch of juvenile Coho Salmon and steelhead in the Dry Creek rotary screw trap, 2019.

Coho smolt trap catch for the season was relatively low and similar to the catch in 2018 (Figure 5.3.16). Steelhead smolt and YOY/parr captures (41 and 5,625) were also similar to totals from previous years.

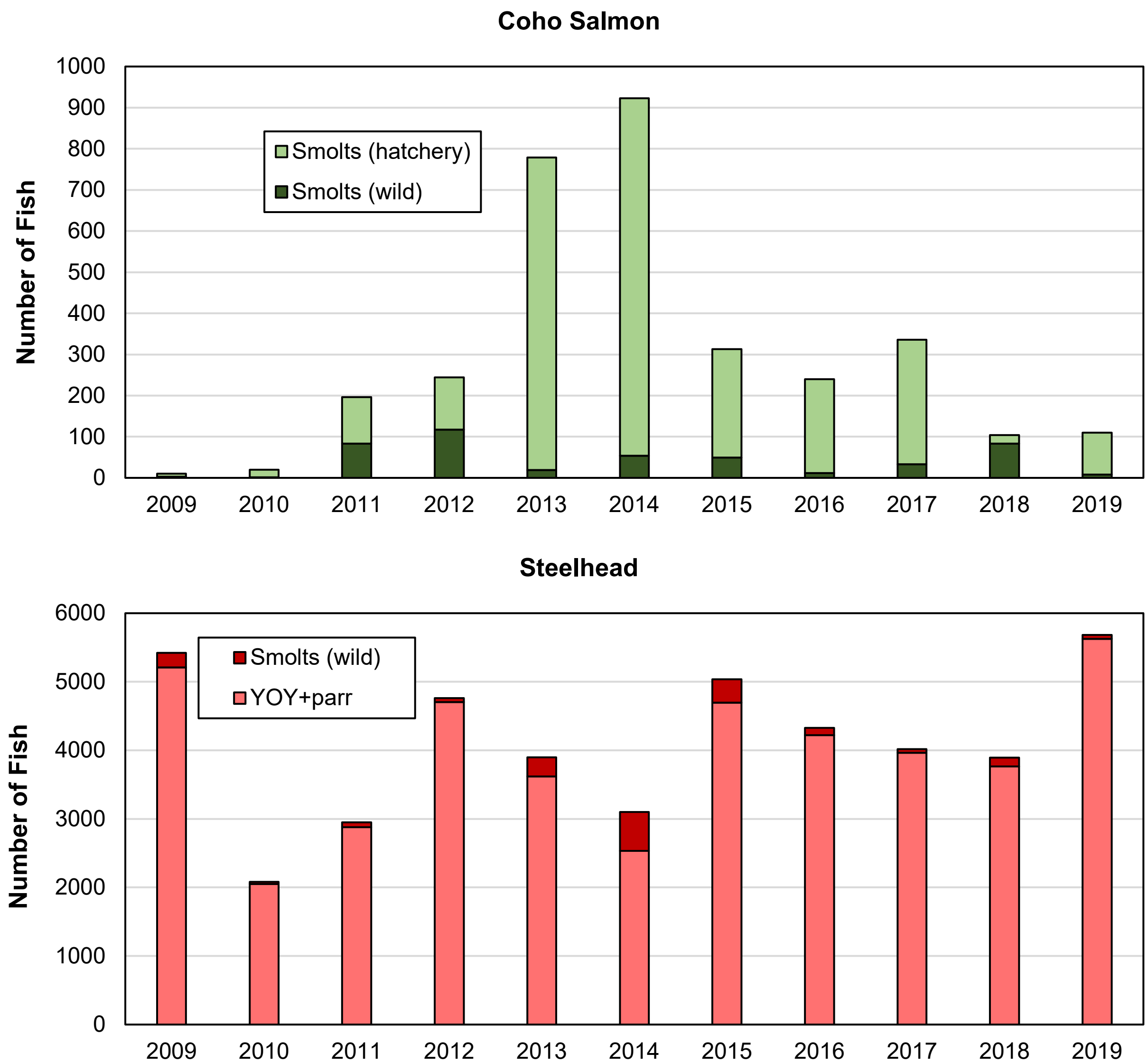


Figure 5.3.16. Trends in trap catch for Coho smolts and steelhead smolts and parr, 2009-2019.

Weekly sizes of all salmonids captured at the Dry Creek trap increased over the course of the trapping season in 2019 (Figure 5.3.17).

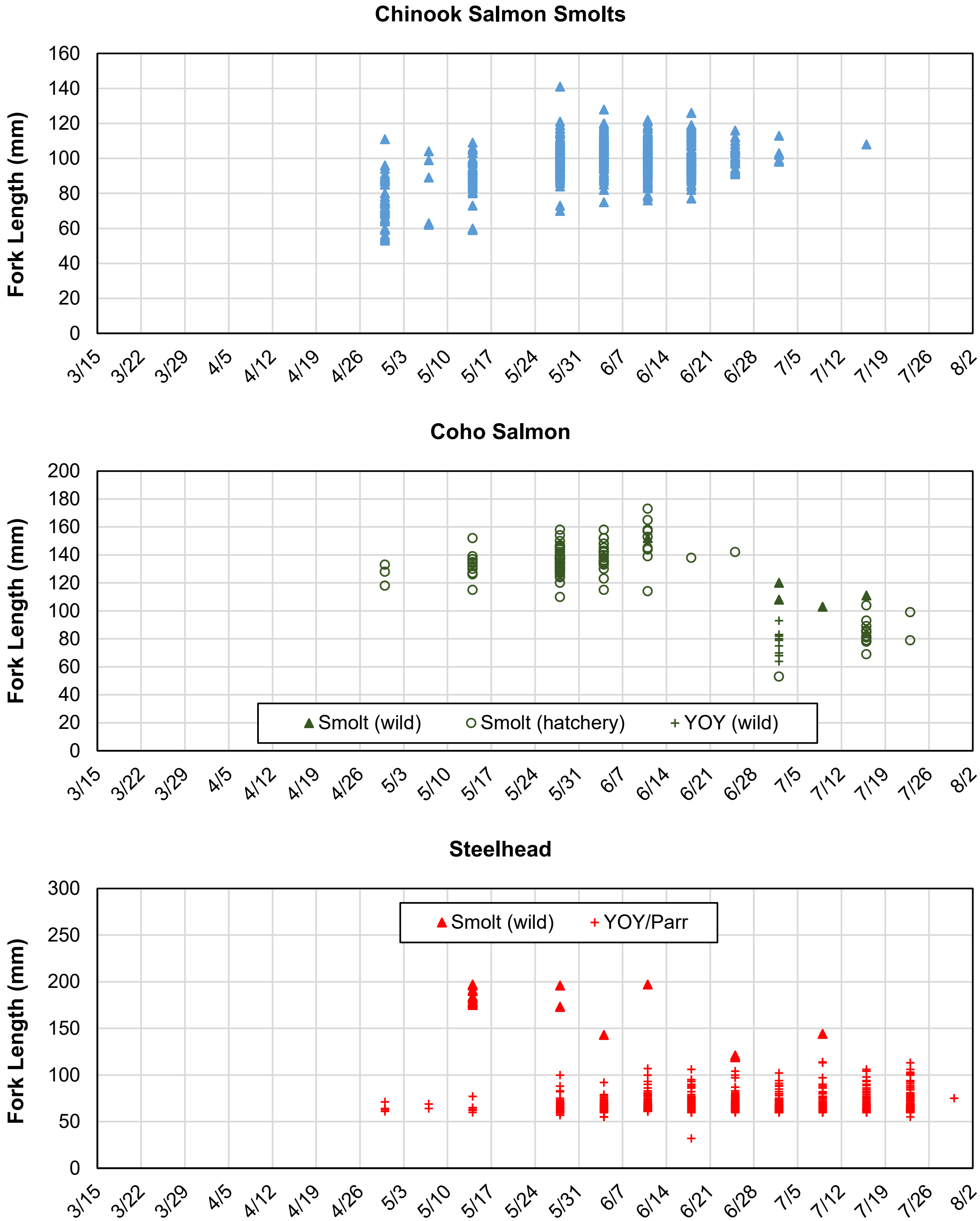


Figure 5.3.17. Fork lengths of juvenile salmonids captured in the Dry Creek rotary screw trap by week, 2019.

Conclusions and Recommendations

Based on validation monitoring conducted in 2019, there is clear evidence that juvenile salmonids are utilizing habitat enhancements in Dry Creek (Table 5.3.4). Although habitat utilization by adult salmonids is not a primary metric, presence of all three species in constructed off-channel habitats suggests that benefits are likely accrued to life stages other than juveniles.

Table 5.3.4. Outcomes from validation monitoring conducted in 2019 in Dry Creek habitat enhancements.

Metric	Life stage	Species	River km	Name	Habitat Type	Method	Season	Outcome
habitat use	juvenile	Coho Salmon	5.00	Ferrari-Carano Olson	EMC[1]	PIT ant	sum/fall	present
			14.01	Truett Hurst	SC[2]	Efish /PIT ant	sum/fall	present
			20.40	Gallo	SC	PIT ant	fall/win	present
			20.72	Weinstock	SC	PIT ant	fall/win	present
			20.99	Army Corps reach 14	SC	PIT ant	sum/fall/ win	present
		steelhead	5.00	Ferrari-Carano Olson	EMC	PIT ant	sum/fall	present
			14.01	Truett Hurst	SC	PIT ant	sum/fall	present
			20.40	Gallo	SC	PIT ant	fall/win	present
			20.72	Weinstock	SC	PIT ant	fall/win	present
			20.99	Army Corps reach 14	SC	PIT ant	sum/fall/ win	present
	adult	Coho Salmon	5.00	Ferrari-Carano Olson	EMC	PIT ant	fall/win	present
			14.01	Truett Hurst	SC	PIT ant	fall/win	present
			20.40	Gallo	SC	PIT ant	fall/win	present
			20.72	Weinstock	SC	PIT ant	fall/win	present
			20.99	Army Corps reach 14	SC	PIT ant	fall/win	present
		steelhead	5.00	Ferrari-Carano Olson	EMC	PIT ant	fall/win	present
			20.40	Gallo	SC	PIT ant	fall/win	present
			20.72	Weinstock	SC	PIT ant	fall/win	present
			20.99	Army Corps reach 14	SC	PIT ant	fall/win	present
		Chinook Salmon	5.00	Ferrari-Carano Olson	EMC	PIT ant	fall/win	present
			20.40	Gallo	SC	PIT ant	fall/win	present
			20.72	Weinstock	SC	PIT ant	fall/win	present
			20.99	Army Corps reach 14	SC	PIT ant	fall/win	present
density (fish * m^{-2})	juvenile	steelhead	14.01	Truett Hurst	SC	efish	sum/fall	0.68 $^{-2}$

[1]EMC=enhanced main channel; [2]SC=side channel

Our method of validating fish use in the late fall and winter through the use of PIT antennas in off-channel habitat continues to provide evidence that constructed habitats are utilized by juvenile steelhead and Coho Salmon in the winter. Confining hatchery Coho juveniles to in-stream enclosures prior to being released at large in off-channel habitats decreased the proportion of fish fleeing the release site indicating that this may be an effective way to overcome the apparent flight response that has been shown in other streams by the Russian River Coho Salmon Broodstock Program. We will continue to refine this approach in an effort to increase the opportunity for hatchery Coho to rear in enhanced habitats within Dry Creek.

Trap efficiency, trap catch, and the resulting population estimate of Chinook smolts in the Dry Creek downstream migrant trap were lower in 2019 than in previous years. The reason for low trap efficiency is unknown. However, a possible explanation for the low catch and population estimate is that environmental conditions, mainly high flow in February- April, that was unfavorable for survival of Chinook redds and fry in 2019 (Figure 5.3.17).

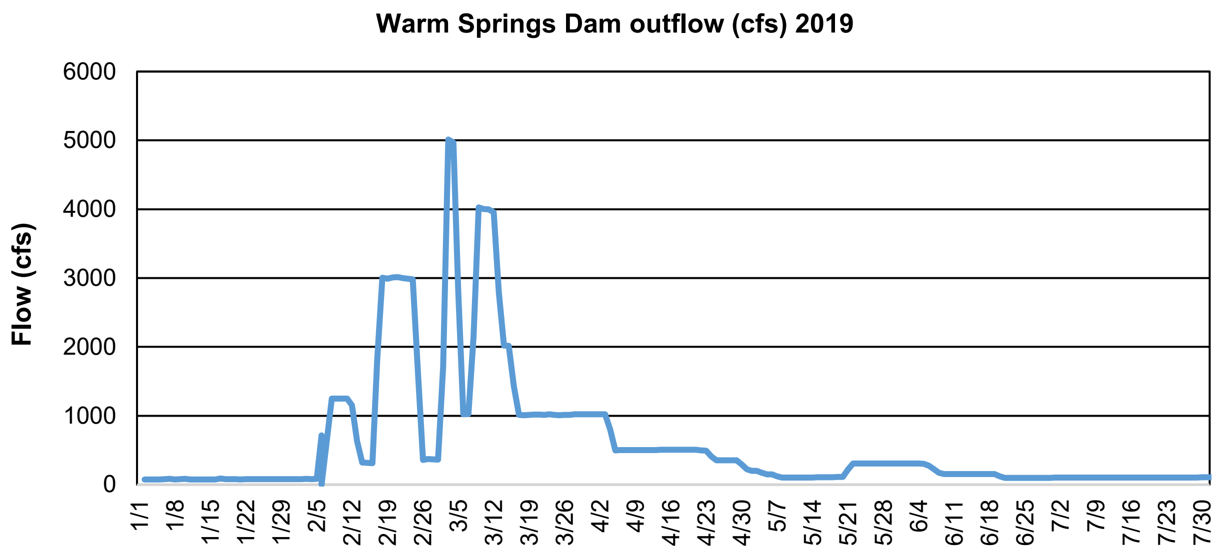


Figure 5.3.18. Outflow from the Warm Springs Dam in 2019.

Steelhead density in the Truett Hurst constructed side channel was near double that observed in previous years and overall densities in the main channel were higher than average. Considering trap catches for steelhead were also higher than in recent years, it appears steelhead spawning success and recruitment was not negatively impacted by higher flows in February and March. Unfortunately, poor visibility due to high turbidity made it impossible for us to effectively observe fish via snorkel surveys in other off-channel habitats and these features are largely too deep to sample with a backpack electrofisher.

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Chapter 6 Tributary Habitat Enhancements

Tributary Habitat Enhancement

One component of the reasonable and prudent alternative (RPA) identified in the Biological Opinion is the enhancement of salmonid rearing habitats in tributaries to Dry Creek and the Russian River. A total of ten potential tributary enhancement projects are listed in the Biological Opinion with the requirement that the Water Agency implement at least five of these projects by the end of year 3 of the 15 year period covered by the Russian River Biological Opinion. The five projects that the Water Agency completed were 1) Grape Creek Habitat Improvement Project; 2) Willow Creek Fish Passage Enhancement Project; 3) Crane Creek Fish Passage Project; 4) Grape Creek Fish Passage Project; and 5) Mill Creek Fish Passage Project.

Grape Creek Habitat Improvement

Phase 1

The Grape Creek Phase 1 portion of the project consisted of installing 8 complex log and boulder structures along a 1,200-foot reach of Grape Creek upstream of the Wine Creek Road Crossing (Figure 6. 1 and Figure 6. 2). Implementation of this work took place in July and August of 2009. All areas where vegetation was disturbed by heavy equipment were replanted with native plants prescribed by restoration staff from the RCD. Additional plantings were also installed per the request of the California Department of Fish and Wildlife, and permission of the landowner, in areas outside the active construction area in an effort to eventually expand the width of the riparian area. A total of 248 native trees and shrubs were planted along this reach of the project.

Figure 6. 1. Grape Creek – Phase 1. In-Stream Large Woody Debris Structure Example (2009 post construction).

Figure 6. 2. Grape Creek – Phase 1. In-Stream Large Woody Debris Structure Example. December 2014 winter flows.


Figure 6. 3. Grape Creek – Phase 1. February 2012.


Figure 6. 4. Grape Creek – Phase 1. December 2014.

Phase 2

The Grape Creek Phase 2 portion of the project consisted of installing 9 complex log and boulder structures and 2 bank layback areas along a 700 foot reach of Grape Creek upstream of the West Dry Creek Road Crossing (Figure 6. 5). Implementation of this work took place over two construction seasons, in 2009 and 2010. Construction began in early October 2009 and was cut short due to rain. Revegetation took place in January 2010. In February 2010, portions of one structure (Site 5) were removed as an emergency measure to avoid bank erosion on the opposite bank as a result of the structure's movement during high flows. Construction resumed in late August 2010, with heavy equipment work completed in the first week of September, and final touches placed on erosion control in early October. The remaining vegetation was installed in early 2011 when the soil is sufficiently moist.

Figure 6. 5. Grape Creek – Phase 2. Large Woody Debris and Bank Layback Example.

Figure 6. 6. Grape Creek – Phase 2. February 2012.

Figure 6. 7. Grape Creek – Phase 2. December 2014.

Willow Creek Fish Passage Enhancement Project

Willow Creek is a tributary to the lower Russian River that once supported an abundant subpopulation of coho salmon. The creek continues to support significant potential spawning and rearing habitat; however, access to that habitat is blocked by impassable road culverts and a shallow braided channel that passes through forested wetland. To implement the Willow Creek Fish Passage Enhancement Project, the Water Agency contributed $100,000 in funding to Trout Unlimited towards the removal of a complete barrier in Willow Creek. On October 19, 2010, the Water Agency's Board of Directors approved the funding agreement with Trout Unlimited for the Willow Creek Fish Passage Enhancement Project. The $100,000 in funding was provided by the Water Agency to Trout Unlimited on January 26, 2011. During the summer of 2011, construction was completed for the Willow Creek Fish Passage Enhancement Project (Figure 6. 8 and Figure 6. 9).

Figure 6. 8. Willow Creek Bridge Installation. September 2011.

Figure 6. 9. Willow Creek Bridge Installation. September 2011.

Crane Creek Fish Passage Project

The Water Agency originally intended to implement the Mill Creek Fish Passage Project. The Mill Creek Fish Passage Project required landowner permission from two property owners in order to design and construct the project. One of the property owners was willing to enter into an agreement to allow the project to move forward; however, the second landowner gave multiple indications that they would allow the project to move forward, but ultimately failed to ever sign any access agreements to allow project design to move forward. Multiple attempts at obtaining the necessary permissions from this landowner were made by the Sotoyome Resource Conservation District and the National Marine Fisheries Service. Still seeing no progress with this landowner, the Water Agency directed the Sotoyome Resource Conservation District in December 2010 to abandon its efforts on the Mill Creek Fish Passage Project and instead implement the Crane Creek Fish Passage Access Project (Figure 6. 10 and Figure 6. 11). The Crane Creek Fish Passage Access Project consists of the removal of a barrier to fish passage caused by a bedrock outcropping at the lower end of Crane Creek near its confluence with Dry Creek. The proposed project design developed by Prunuske Chatham, Inc., consisted of creating a series of step pools through the bedrock outcropping to create sufficient depth and flow to allow fish passage (Figure 6. 12). Design approval was obtained from National Marine Fisheries Service and the landowners in September of 2011. Construction began on October 1, 2011 and was completed on October 18, 2011.

Figure 6. 10. Crane Creek Fish Passage Access Project. Bedrock outcropping.

Figure 6. 11. Crane Creek Fish Passage Access Project. Chiseling pools in bedrock outcropping.

Figure 6. 12. Crane Creek Fish Passage Access Project. Expanded pools in bedrock outcropping (February 2012).

Grape Creek Fish Passage Project

The Grape Creek Fish Passage Project consists of the modification of a concrete box culvert where Grape Creek flows under West Dry Creek Road (Figure 6. 13). As part of the permit review and design approval process, the National Marine Fisheries Service noted that the project design did not meet their maximum allowable 0.5-foot drop height for barrier passage. In October 2010, the Water Agency proposed re-designing the project to cut into the culvert bottom instead of placing curbs on top of the culvert bottom in order to meet the 0.5-foot maximum drop height requirement. Because the culvert-bottom is a structural portion of the bridge and culvert, cutting into the culvert bottom substantially increases the design complexity and costs of implementing the project. Between October 2010 and March 2011, the Water Agency coordinated with the Sonoma County Department of Public Works on the proposed re-design of the project. In April 2011, National Marine Fisheries Service indicated that the proposed re-design provided by the Sonoma County Department of Public Works was acceptable. Because of the increased complexity and cost, the revised project design was required to be put out to bid as a general construction contract, which required detailed project drawings and construction specifications. The Water Agency worked with a consultant through the Sotoyome Resource Conservation District to prepare the project construction drawings and specifications. Construction of the Grape Creek Fish Passage Project was completed in October of 2012 (Figure 6. 14 and Figure 6. 15).

Figure 6. 13. Grape Creek Fish Passage Project – Flat culvert invert proposed for modification.

Figure 6. 14. Grape Creek Fish Passage Project – Newly Constructed October 2012.

Figure 6. 15. Grape Creek Fish Passage Project – First Flows November-December 2012.

Mill Creek Fish Passage Project

The Water Agency had been working towards the construction of the Wallace Creek Fish Passage Project, which would have consisted of the modification of a concrete box culvert where Wallace Creek flows under Mill Creek Road. Engineering designs were completed and the National Marine Fisheries Service had approved those engineering designs for the project. The County of Sonoma Permit and Resource Management Department had submitted permit applications and coordinated site visits with California Department of Fish and Wildlife, National Marine Fisheries Service, U.S. Army Corps of Engineers, and the North Coast Regional Water Quality Control Board. Unfortunately, the Water Agency was been unable to secure the necessary landowner permissions from two of the three landowners in the project area. Because of the inability to secure the necessary landowner permission for the project, the Water Agency abandoned efforts to construct the Wallace Creek Fish Passage Project and began working with the National Marine Fisheries Service on an alternative as a substitute for the Wallace Creek Fish Passage Project.

The National Marine Fisheries Service continued to work with the landowners regarding the Mill Creek Fish Passage Enhancement Project and ultimately identified a larger scale project that the landowners agreed to allow move forward on their properties. In April of 2015, the National Marine Fisheries Service acknowledged that a proposal by the Water Agency to provide $200,000 in funding towards the construction of this larger Mill Creek Fish Passage Enhancement Project would meet the intent of the Russian River Biological Opinion and would be considered as the completion of the fifth and final tributary enhancement project required under the Russian River Biological Opinion. The Mill Creek Fish Passage Enhancement Project is a high-value project that would restore coho salmon access into 11.2 miles of upper Mill Creek. The initial estimate for the Mill Creek Fish Passage Enhancement Project described in the Russian River biological Opinion estimated the cost of the project at $100,000 to $200,000; however, recent estimates placed the costs closer to $1,500,000. The Water Agency agreed to provide $200,000 towards the project costs, which was consistent with the original estimates in the Russian River Biological Opinion. The remaining funding for the project came from NOAA grant funding and California Department of Fish and Wildlife Fisheries Restoration Grant Program funding. The project, which was constructed in the summer of 2016, provides fish passage past a rock and mortar sill that was a barrier for fish passage under most flow conditions. The Mill Creek Fish Passage Enhancement Project was constructed in 2016. See Appendix 6-1 for a February 20, 2020 Final Report from Trout Unlimited providing detailed post-construction documentation for the Mill Creek Passage Project.

Figure 6. 16. Mill Creek Fish Passage Project. Existing passage barrier in Mill Creek. December 2009.

Figure 6. 17. Mill Creek Fish Passage Project. Showing completed new bypass channel and roughened ramp on downstream side of the passage barrier in Mill Creek. October 2016.

CHAPTER 7 Coho Salmon Broodstock Program Enhancement

NMFS' Russian River Biological Opinion compels the USACE to continue operation of a conservation hatchery to provide a source of genetically appropriate juvenile Coho Salmon to release into the Russian River watershed. The hatchery program is instrumental to Russian River Coho population recovery and Coho releases are widely recognized as the main reason the Russian River population was not extirpated. The Biological Opinion and Consistency Determination obligate Sonoma Water to provide hatchery support by increasing the production of Coho smolts. This support has primarily been in the form of funding for fish-rearing tanks, purchase of PIT tags, and technical staff to assist with hatchery operations including PIT-tagging of hatchery-reared juveniles. Sonoma Water has also contributed a significant amount of information through direct data collection, financial and staff support to partner entities, and consistent participation on the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP) Technical Advisory Committee (TAC).

In addition to hatchery operations, USACE must also conduct annual monitoring of the distribution and survival of stocked juvenile salmon and the subsequent return of adult Coho to the Russian River. Much of the Coho monitoring in the Russian is implemented by CSG with base funding from USACE. However, Sonoma Water has and will continue to make significant contributions to the collection of monitoring data to allow evaluation of program success. These contributions include data collected at Sonoma Water operated fish monitoring sites (i.e., downstream migrant traps and stationary PIT antenna arrays) as well as assistance to CSG in conducting studies to identify population bottlenecks (e.g., low flow studies) and inform solutions to overcoming those bottlenecks (e.g., Russian River Coho Water Resources Partnership).

The technical aspects of Coho Salmon population recovery are complex, and it is often difficult to evaluate recovery strategies and program success in light of the host of factors operating at a variety of scales to shape Coho populations. The RRCSCBP TAC is a multi-partner effort involving USACE, CDFW, NMFS, CSG, and Sonoma Water. The TAC provides invaluable advice to ensure genetically sound broodstock management, and it develops annual plans for hatchery Coho releases with the primary objective of balancing survival of early life stages in the wild against the risk of artificial selection from releasing older life stages that are reared in the hatchery for a longer period of time. Many of the innovative monitoring methods spearheaded by CSG and Sonoma Water feedback to inform these plans while at the same time providing metrics of program success such as tributary-specific smolt production and numbers of adult returns (see CSG data reports 2004 through present) – both of which have been identified as key metrics in state and federal recovery plans.

A component that has been lacking until recently is a better understanding of the broader context in which salmonid demographic processes operate. In 2013, Sonoma Water and CSG began implementing CDFW's Coastal Monitoring Program (CMP, Adams et al. 1980). The broad-scale metrics from this coastwide effort have and will continue to inform Coho Salmon recovery in the Russian River watershed and elsewhere by helping to decouple those factors that are largely outside our control (e.g., marine survival) from in-watershed recovery efforts.

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CHAPTER 8 Adult Salmonid Returns

8.1 Adult Salmonid Escapement

Since 2000, Sonoma Water has been operating video cameras in the east and west fish ladders to assess the adult Chinook salmon run passing the Mirabel inflatable dam (rkm 39).

Methods

A digital camera and lighting system was installed in the east and west Mirabel fish ladders. Individuals were counted as moving upstream once they exited the upstream end of the camera's view. For each adult salmonid observed, the reviewer recorded the species, date, and time of upstream passage. During periods of low visibility it was not always possible to identify fish to species although identification as an adult salmonid was usually possible. Adult salmonids that could not be identified to species were lumped into a general category called "unknown salmonid." Unknown salmonids were then partitioned into species by taking the proportion of each species positively identified in the ladder on a given day and multiplying the number of unknown salmonids on that same day by these proportions. On days when no salmonids could be identified to species, an average proportion from adjacent days was used to assign species for the unidentified salmonids on that day.

Results

In 2019, the Mirabel fish ladder cameras were in operation from September 1 to December 2, 2019 (Figure 8.1.1). With a few exceptions these cameras were operated 24 hours/day after installation until they were removed (Figure 8.1.2).

Chinook Salmon

For the 2019 video monitoring season, 922 adult Chinook Salmon were observed passing the Mirabel fish counting station (including "unknown salmonids" prorated as Chinook) (Table 8.1.1). A total of 44 fish were categorized as an "unknown salmonid" (i.e., they possessed the general body shape of an adult salmonid, but could not be identified to species). Of these 44 unknown salmonids 37 were partitioned to Chinook Salmon.

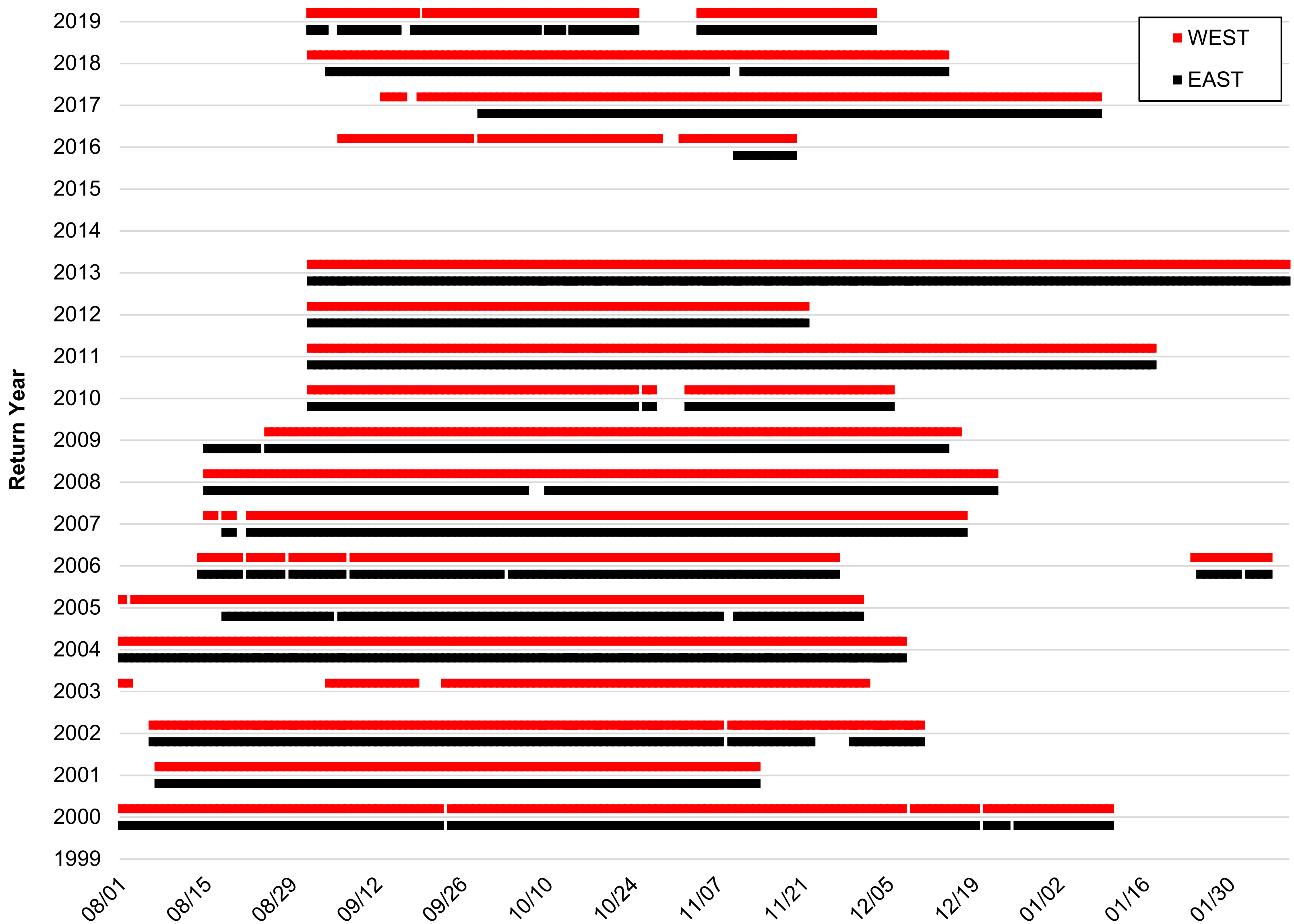

Figure 8.1.1. Period of operation by adult salmonid return year of video counting station at the Mirabel dam.

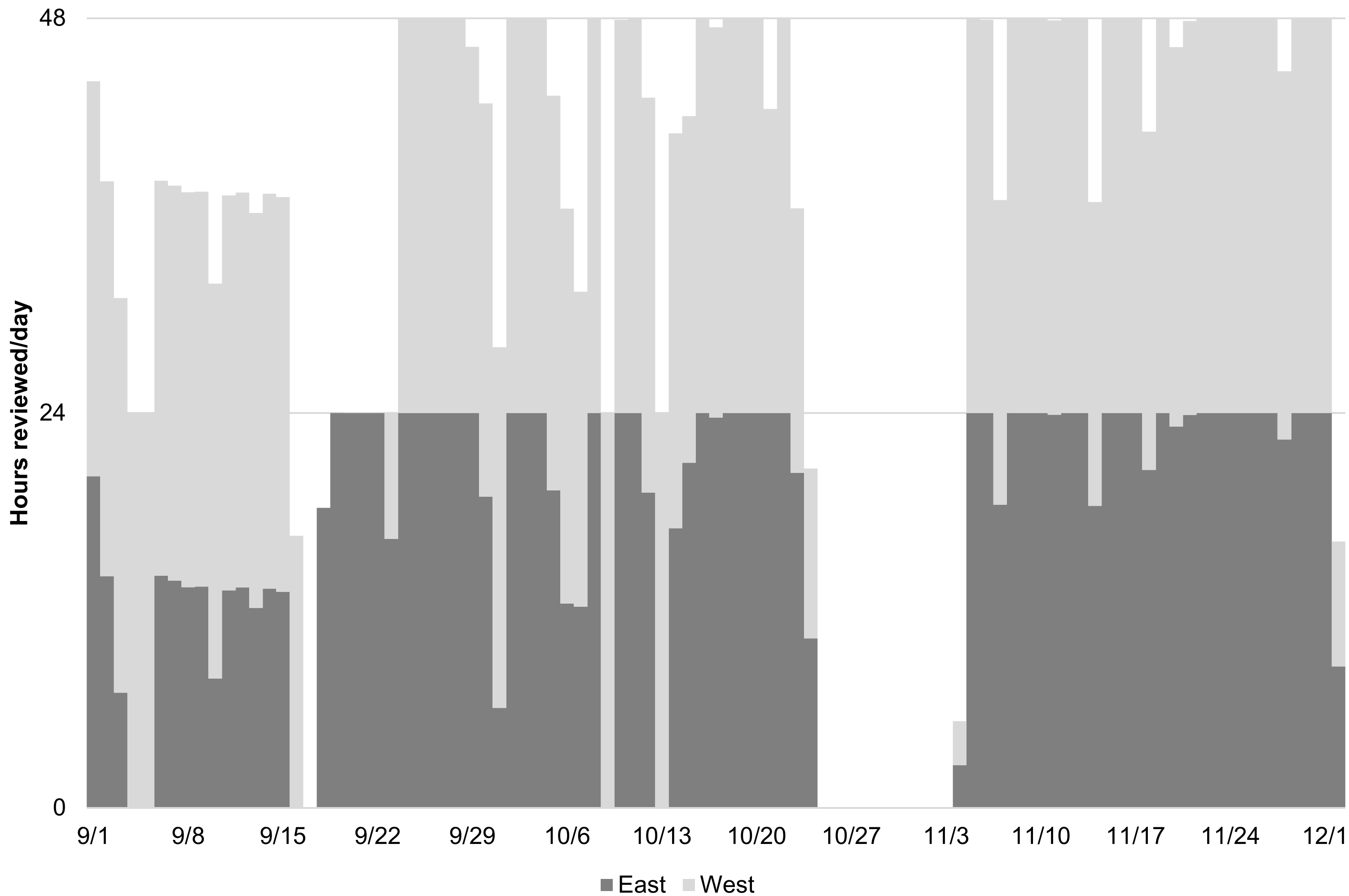

Figure 8.1.2. Number of hours/per day that the west and east fish ladder cameras were in operation at the Mirabel dam in 2019.

Table 8.1.1. Weekly count of adult Chinook salmon at the Mirabel dam fish ladders, 2000-2019. Dashes indicate that no sampling occurred during that week.

Week	2000	2001	2002	2003	2004	2005	2006*	2007	2008	2009	2010	2011	2012	2013	2014**	2015**	2016***	2017	2018	2019
15-Aug	0	0	1	--	0	0	0	0	0	0	--	--	--	--	Not Operated	Not Operated	--	--	--	--
22-Aug	1	0	8	--	0	1	1	0	0	0	--	--	--	--			--	--	--	--
29-Aug	0	3	7	2	1	4	0	0	1	0	0	0	0	1			--	--	2	0
5-Sep	9	1	18	7	1	4	0	0	0	0	0	0	1	1			0	--	0	0
12-Sep	36	7	19	20	3	14	3	0	2	0	0	0	2	2			0	0	1	0
19-Sep	25	12	65	23	8	14	4	1	17	0	3	1	0	1			0	3	4	4
26-Sep	50	17	1223	181	16	31	8	4	84	0	1	158	70	17			8	2	37	43
3-Oct	31	240	113	146	42	27	317	10	126	78	669	534	51	44			32	91	77	29
10-Oct	115	51	628	515	52	112	87	39	82	562	896	390	551	4			291	50	47	26
17-Oct	81	10	272	232	651	556	532	26	13	177	153	1070	1886	8			392	125	158	52
24-Oct	465	300	153	532	2287	309	114	106	22	285	280	273	996	27			131	81	50	2
31-Oct	64	661	505	2969	185	613	1531	250	511	135	94	223	1654	315			56	612	68	22
7-Nov	23	81	2337	1289	1189	699	298	429	174	335	169	90	619	731			50	366	60	170
14-Nov	182	--	20	47	221	127	459	154	15	38	43	120	851	1063			103	508	145	110
21-Nov	201	--	37	95	57	63	53	96	24	129	113	266	50	179			--	71	461	333
28-Nov	110	--	14	45	60	33	--	425	19	24	76	6	--	99			--	82	66	131
5-Dec	19	--	53	--	16	--	--	476	18	9	5	1	--	172			--	24	38	--
12-Dec	15	--	--	--	--	--	--	4	8	28	--	2	--	125			--	24	6	--
19-Dec	17	--	--	--	--	--	--	--	13	--	--	10	--	73			--	16	--	--
26-Dec	1	--	--	--	--	--	--	--	--	--	--	16	--	32			--	27	--	--
2-Jan	0	--	--	--	--	--	--	--	--	--	--	2	--	53			--	11	--	--
9-Jan	0	--	--	--	--	--	--	--	--	--	--	10	--	58			--	--	--	--
16-Jan	--	--	--	--	--	--	--	--	--	--	--	1	--	28			--	--	--	--
23-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	73			--	--	--	--
30-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	36			--	--	--	--
6-Feb	--	--	--	--	--	--	--	--	--	--	--	--	--	10			--	--	--	--
Total	**1,445**	**1,383**	**5,474**	**6,103**	**4,788**	**2,607**	**3,407**	**2,021**	**1,129**	**1,800**	**2,502**	**3,173**	**6,730**	**3,152**	**--**	**--**	**1,062**	**2,093**	**1,219**	**922**

*Video cameras were reinstalled and operated from 4/1-6/27/2007 but no Chinook were observed.

**Video cameras not operated in 2014 and 2015 because the site was under construction in order to construct the new fish screens and ladder.

***Typically 1 camera is operated in both fish ladders but in 2016 a video camera was only operated in the east ladder for the final 10 days of the season.

Coho Salmon

During the monitoring period for the 2019 return year, we observed 92 adult Coho Salmon. These images were reviewed by fisheries biologist from Sonoma Water and California Sea Grant (CSG). Because of the timing of camera operations, which are tied to dam operations, and the location of these monitoring sites upstream of significant amounts of Coho habitat in the basin, these counts are not the best indicator of adult Coho returns to the basin. Instead, we suggest the basinwide redd survey estimate of 104 (95% CI: 72-136) as the most comprehensive and accurate indicator of all adult Coho (hatchery- and natural-origin) returning to the Russian River basin in 2019-20 (Sonoma Water and CSG 2020) . This estimate is based on spawner surveys in the Coho stratum of the Russian River Coastal Monitoring Program sample frame (see Adams et al. 2011 for details).

Steelhead

Based on hatchery returns, steelhead migrate and spawn in the Russian River primarily between December and March; however, we removed the Mirabel cameras in December and there is significant portion of the steelhead run occurs after December. In total, 35 steelhead were observed migrating through the Mirabel Fish ladder between September 1, 2019 and December 2, 2019.

Conclusions and Recommendations

In 2019 we were able to successfully operate video cameras in both fish ladders for the duration of the Chinook migration, but this was not without some difficulty. There was a significant data loss in late October and early November when a software malfunction overwrote data. In 2016 Sonoma Water decided that it is unsafe to supply 110-volt power to the east side video camera and lights by routing the cable underwater along the stream bottom. There appeared to be few alternative ways to supply power to east side of the river. In 2019 we relied on deep cycle batteries to supply power to the lights on the east side of the river. This required frequent battery changes. In addition to the difficulties supplying power to the east side Chinook continued to spend an unusually long time in front of the west video camera in 2019. Frequently there were many Chinook milling in front of the camera. These fish would move upstream out of view of the camera and then drop back downstream out of the view of the camera. When many fish were exhibiting this behavior at the same time double counting became a possibility. The reviewers had to watch the video at a slower speed, which made the review process more laborious.

The Mirabel video system continues to provide useful data on the Russian River Chinook run. We recommend continuing to operate the camera system in future years.

8.2 Chinook Salmon Spawning Ground Surveys

Although not an explicit requirement of the Biological Opinion, Sonoma Water performs spawning ground surveys for Chinook Salmon in the mainstem Russian River and Dry Creek. This effort compliments the required video monitoring of adult fish migration and has been stipulated in temporary D1610 flow change orders issued by the State Water Resources Control Board to satisfy the Biological Opinion (see Pursue Changes to D1610 flow chapter of this report). Sonoma Water began conducting Chinook Salmon spawning surveys in fall 2002 to address concerns that reduced water supply releases from Coyote Valley Dam (Lake Mendocino) may affect migrating and spawning Chinook Salmon (Cook 2003). Spawner surveys in Dry Creek began in 2003.

Background information on the natural history of Chinook Salmon in the Russian River is presented in the 2011 Russian River Biological Opinion annual report (SCWA 2011). The primary objectives of the spawning ground surveys are to (1) characterize the distribution and relative abundance of Chinook Salmon spawning sites, and (2) compare annual results with findings from previous study years.

Methods

Chinook Salmon redd (spawning nest) surveys are conducted annually in the Russian River during fall. Typically, the upper Russian River basin and Dry Creek are surveyed (Figure 8.2.1). The study area includes approximately 114 km of the Russian River mainstem from Riverfront Park (40 rkm), located south of Healdsburg, upstream to the confluences of the East and West Forks of the Russian River (154 rkm) near Ukiah. River kilometer (rkm) is the meandering stream distance from the Pacific Ocean upstream along the Russian River mainstem and for Dry Creek the distance from the confluence with the Russian River upstream. In 2003, the study area was expanded to include 22 rkm of Dry Creek below Warm Springs Dam at Lake Sonoma to the Russian River confluence.

The Chinook Salmon spawning ground study consists of a single-pass survey during the estimated peak of Chinook Salmon fall spawning. A crew of two biologists in kayaks visually search for redds along the streambed. Riffles with several redds are inspected on foot. The locations of redds are recorded using a global positioning system (GPS).

Surveys may be cancelled or postponed if increased turbidity from heavy rainfall and subsequent high flows obscure the detection of redds. Spawner surveys were curtailed or cancelled during 2005, 2010, 2014, 2015, 2017, and 2019 along the Russian River. During high flows surveys are often possible in Dry Creek due to regulated, clear water releases from Lake Sonoma. Also, increases in turbid water releases from Coyote Dam at Lake Mendocino since around 2011 have prevented an accurate count of redds in Ukiah and Canyon study reaches.

Results

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek. However, no Chinook spawning surveys were conducted in the Russian River in 2019 due to high turbidity. Salmon spawning surveys were completed in Dry Creek on

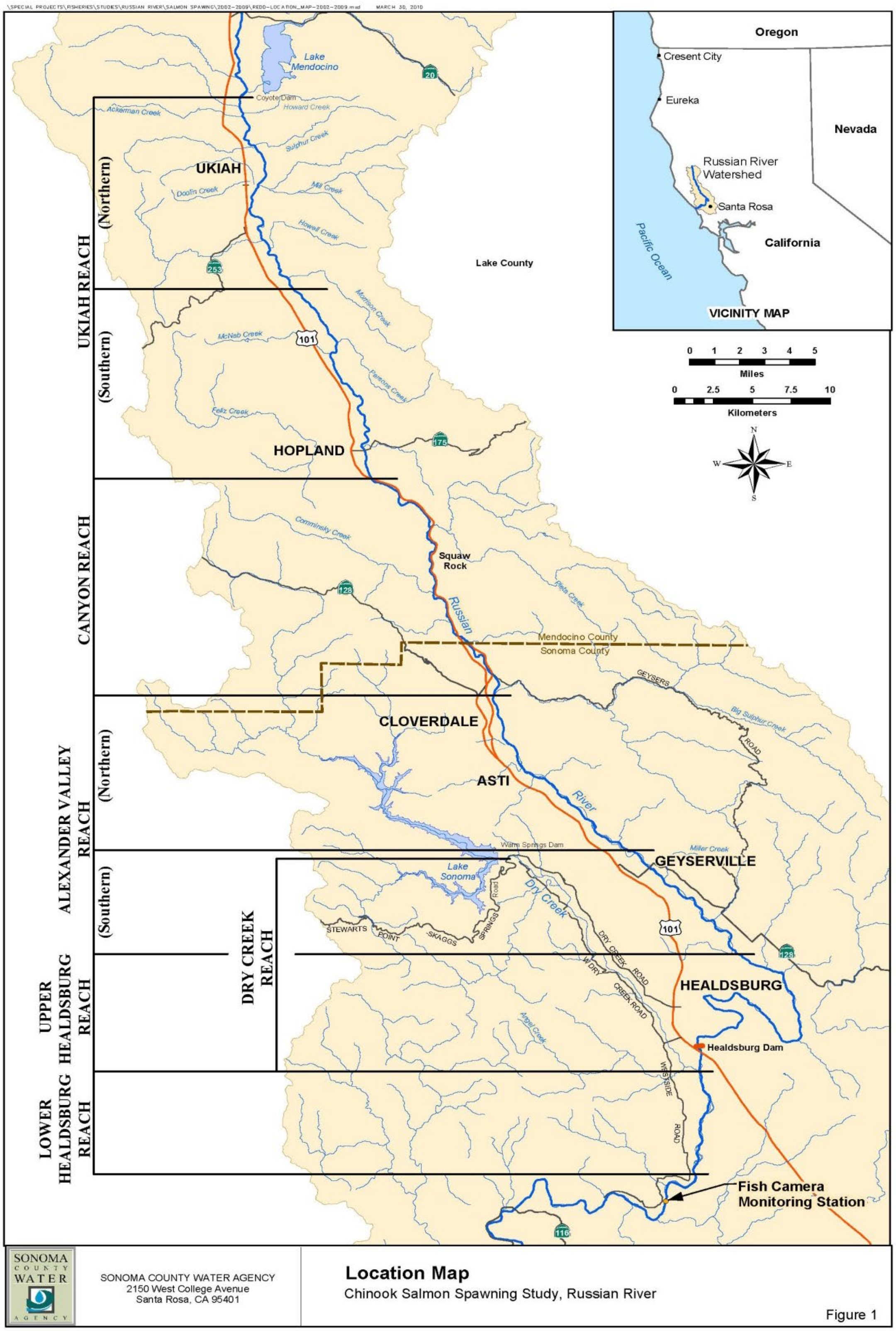

Figure 8.2.1. Chinook salmon spawning survey reaches. Only Dry Creek reaches were surveyed in 2019.

November 19, 2019. Water released from Lake Sonoma at the headwaters of Dry Creek improved water clarity. A total of 15 Chinook redds were detected in Dry Creek (Table 8.2.1). This is the lowest count of redds since surveys began in 2003. The second lowest count was 79 in 2015. The highest count of redds was 362 in 2012. There has been a marked decrease in redd observations in Dry Creek since 2013.

Conclusions and Recommendations

Dry Creek typically produces one-quarter to nearly one-half of all Chinook redds detected during spawner surveys compared to the Russian River. The below normal number of redds found in the Dry Creek in fall 2019 suggests that Chinook spawning activity in the upper Russian River was likely far below typical activity as well. The abundance of Chinook Salmon redds have shown a sharp decline in the past three years. Although there are many factors that could be driving this trend, it is likely that several years of severe drought in the region is a major contributor.

Table 8.2.1. Chinook salmon redd abundances at Dry Creek, 2003-2019. Redd counts are from a single pass survey conducted during the peak of fall spawning activity. *Survey either not completed or incomplete.

Year	Dry Creek
2003	256
2004	342
2005	*
2006	201
2007	228
2008	27
2009	223
2010	269
2011	229
2012	362
2013	325
2014	*
2015	79
2016	90
2017	112
2018	86
2019	15

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CHAPTER 9 Synthesis

Introduction

Sonoma Water has collected a variety of fish and water quality monitoring data relevant to fulfilling the overall monitoring objectives in the Reasonable and Prudent Alternative (RPA) of the Russian River Biological Opinion. Those efforts have been detailed in portions of this report leading to this chapter. The objectives specific to this synthesis chapter are to illustrate the spatial and temporal extent of monitoring activities in the basin.

As in previous years of RPA implementation, we collected fish and related environmental data from a broad spatial and temporal extent in the Russian River Basin (Figure 9.1 and Figure 9.2). We collected juvenile and smolt data from multiple locations in Dry Creek, Mark West Creek, Dutch Bill Creek, Austin Creek, and the Russian River estuary. We opportunistically conducted Chinook spawner surveys on the 22 km of stream length in mainstem Dry Creek downstream of Warm Springs Dam. High turbidity in the mainstem Russian River prevented surveys for adult salmonids. Juvenile salmonids were sampled throughout the watershed using a variety of techniques. In the mainstem Russian, juvenile salmonids were sampled using beach seining at 10 fixed locations in the estuary and passive integrated transponder (PIT) antenna arrays operated near the upstream extent of the tidal portion of the estuary in Duncans Mills and at Sonoma Water's Mirabel inflatable dam. Downstream migrant trapping for smolts and juveniles and video monitoring of upstream migrating adults also occurred at the Mirabel dam. In tributaries of the lower river, juvenile salmonids were sampled using downstream migrant traps on Mark West Creek at Trenton-Healdsburg Road, Austin Creek at the gravel mine and Dutch Bill Creek in Monte Rio. PIT antennas were operated in conjunction with downstream migrant trap sites on Austin Creek and Dutch Bill Creek. In Dry Creek, juvenile salmonids were sampled using a downstream migrant trap and backpack electrofishing. PIT antennas were operated in at the mouth of mainstem Dry Creek and constructed off-channel habitat sites in Dry Creek. Complementary data on water quality were collected by means of continuously-recording data sondes at multiple sites in the mainstem Russian and throughout the estuary/lagoon. Water quality grab samples including algae samples were collected at additional sites in mainstem Russian River. Details regarding the specifics of water quality and fisheries monitoring activities are covered in individual chapters of this report.

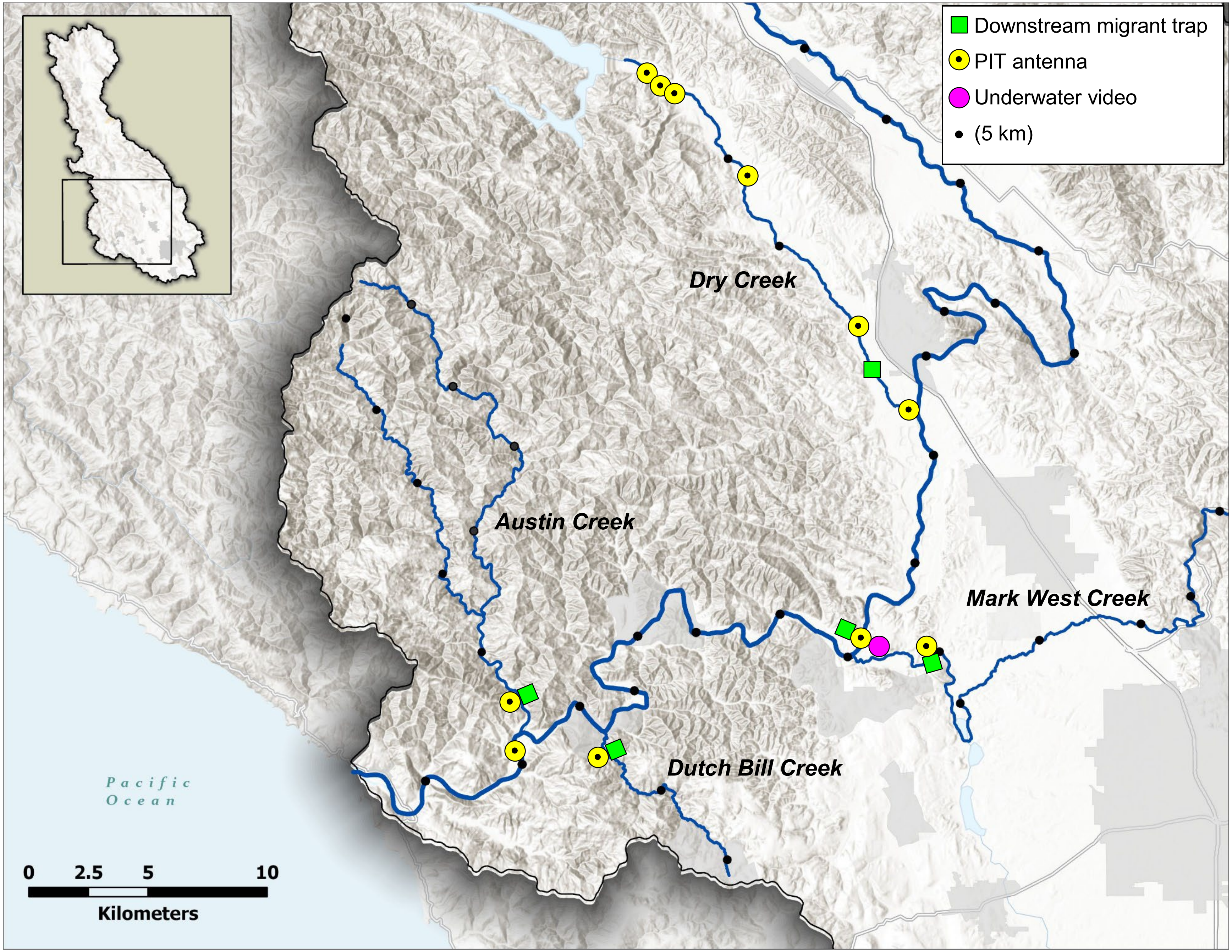

Figure 9.1. Spatial extent of fisheries monitoring related to the Russian River Biological Opinion, 2019.

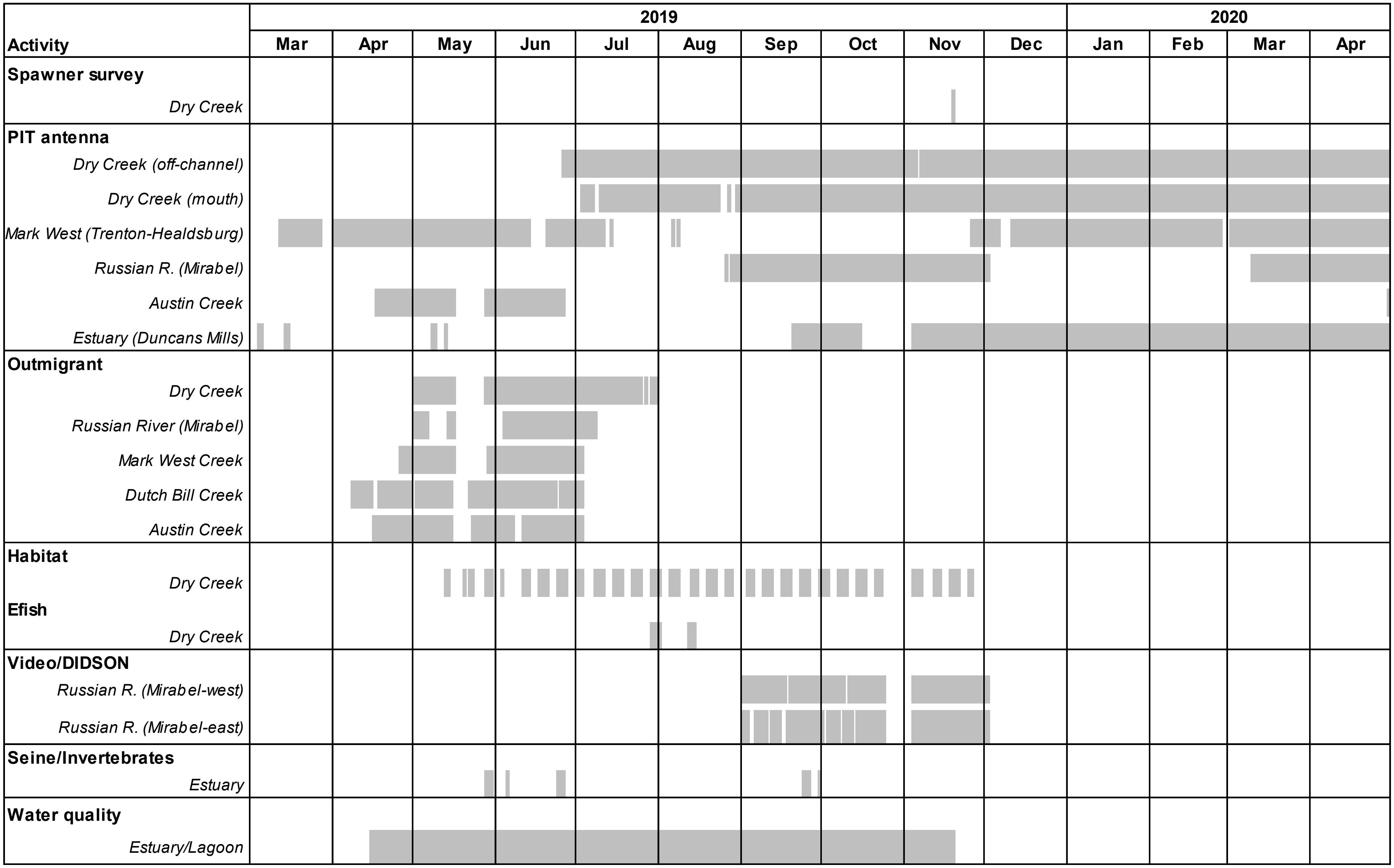

Figure 9.2. Temporal extent of fish and water quality monitoring related to the Russian River Biological Opinion, spring 2019-early spring 2020.

In the sections that follow, we summarize indicators of juvenile and smolt salmonids based on data from tributary and mainstem sites sampled in 2019 into early 2020. Sonoma Water used PIT tags and fin-clipping as primary tools for characterizing fish population abundance. As described in other sections of this report and reports from prior years, PIT-tagged fish were detected during beach seining sampling in the estuary, at downstream migrant traps, and stationary PIT-tag antennas located throughout the system (Figure 9.1).

Abundance

Combined juvenile steelhead downstream migrant trap (DSMT) catch at Dry Creek, Dutch Bill Creek and Austin Creek was similar to 2018 with an increase at Dry Creek and a decrease at Austin Creek (Figure 9.3). Juvenile steelhead density from backpack electrofishing on mainstem Dry Creek showed an increase relative to recent years (Figure 9.4) and the Dry Creek Chinook smolt estimate in Dry Creek was again low compared to 2010-2014 and even lower than 2018 (Figure 9.4). Chinook smolt estimates were once again possible at Mirabel due to improved conditions for trap operation compared to recent years – the 2018 and 2019 Chinook smolt estimates were nearly identical to Dry Creek. Captures of wild Coho smolts were low everywhere as has been the case since we began monitoring (Figure 9.4). The increase in the number of Coho YOY captured in the Dry Creek trap in 2019, however, suggests that there may have been some Coho spawning in mainstem Dry Creek and/or newly-created off-channel habitats. Relative to previous years, adult steelhead returns to Russian River hatcheries were significantly lower than in 2018-19 (Figure 9.5) and the adult Chinook run continued to be disappointingly low. The 2019-20 adult Coho estimate was lower than in the previous two seasons but overall numbers remain encouraging.

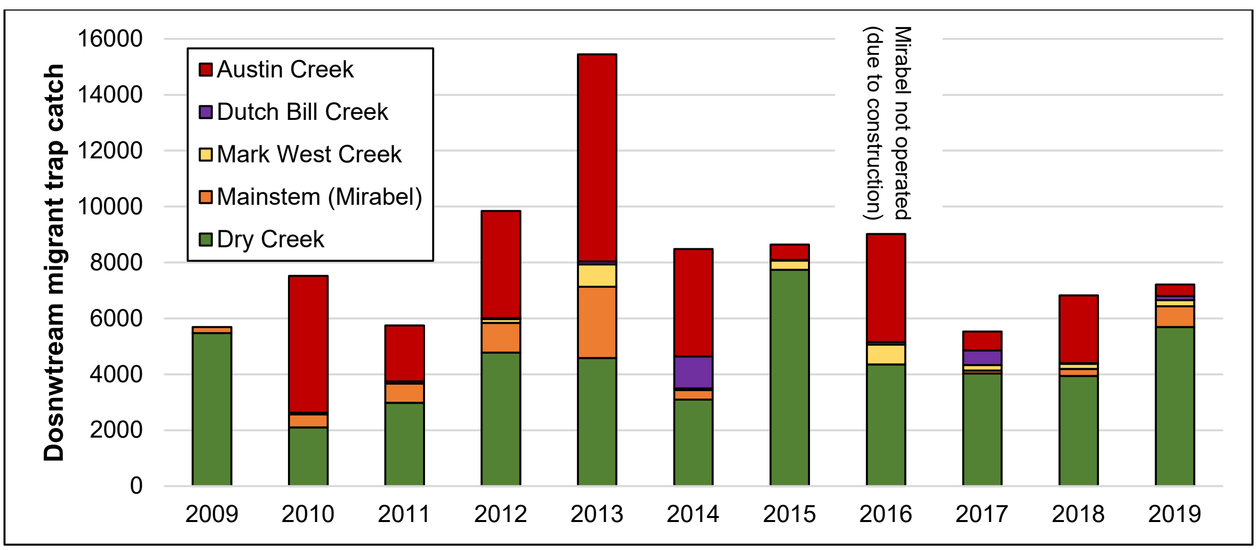

Figure 9.3. Number of juvenile steelhead (YOY and smolt combined) captured at downstream migrant traps operated by Sonoma Water, 2009-2019.

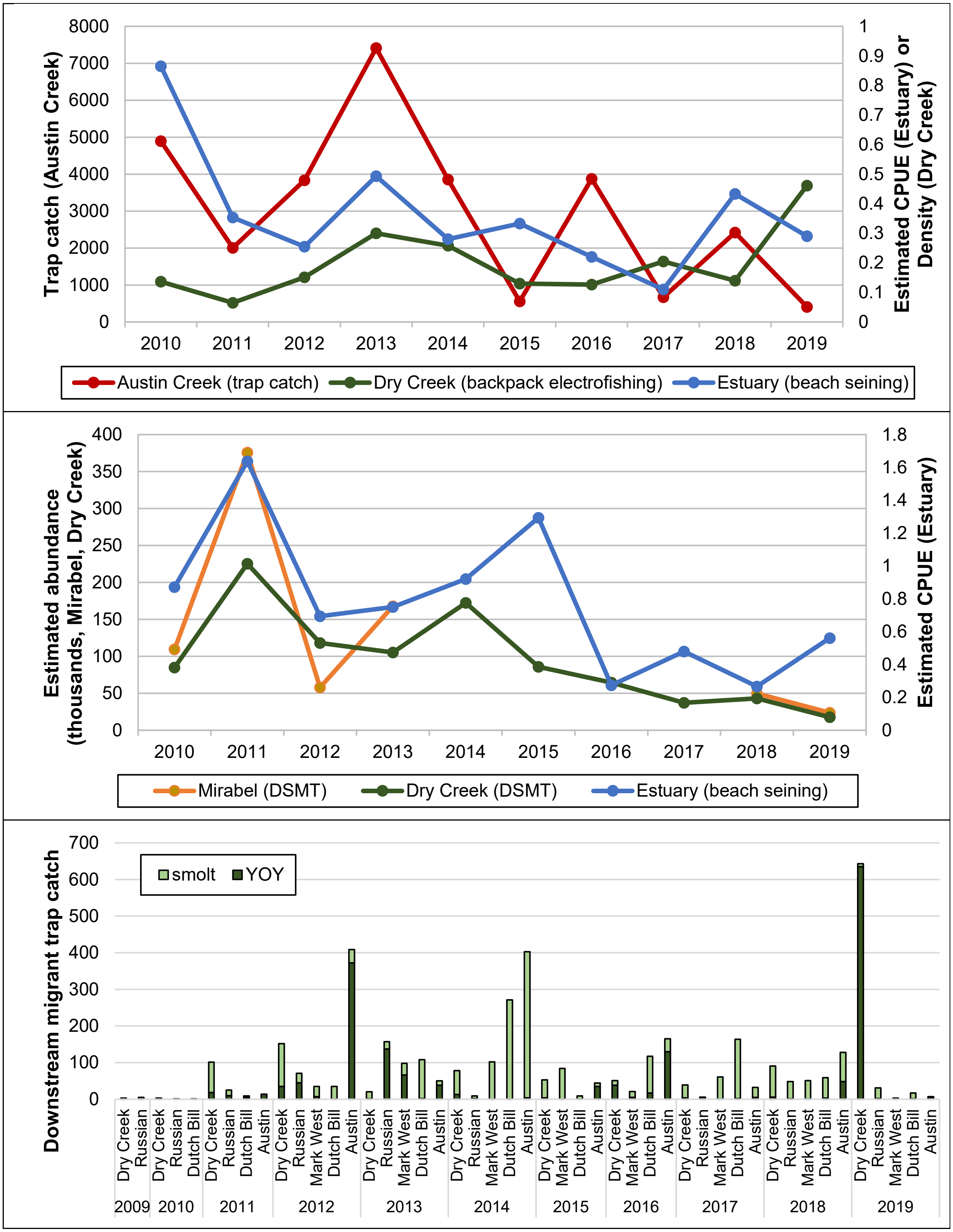

Figure 9.4. Indicators of trends in natural-origin juvenile steelhead (top panel), Chinook smolts (middle panel) and Coho smolt/YOY (lower panel) based on monitoring conducted by Sonoma Water, 2009-2019.

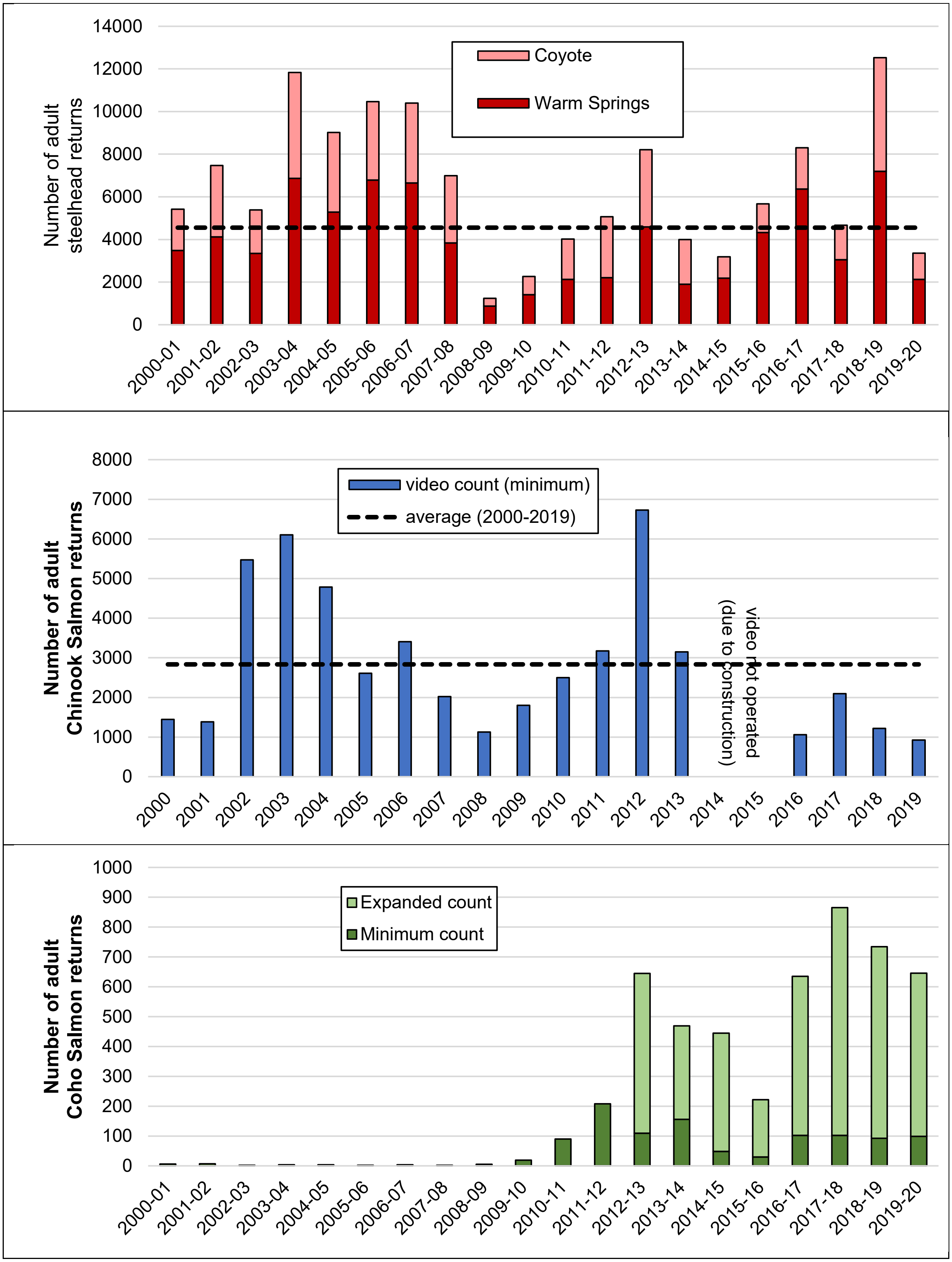

Figure 9.5. Indicators of adult steelhead (counted at Russian River hatcheries), adult Chinook (based on video counts at Wohler-Mirabel) and Coho Salmon returns (CA Sea Grant).

Conclusions and Recommendations

In 2019, Sonoma Water continued to implement monitoring approaches that are beginning to show that they are serving the important need to understand the context in which salmon and steelhead populations in the Russian are being affected by RPA implementation as opposed to environmental conditions or other factors outside our control. The degree to which various measures of population abundance track each other (e.g., Figure 9.4) suggests that despite the many challenges of monitoring in a watershed the size of the Russian, monitoring that goes beyond what is required in the RPA (e.g., PIT monitoring) is paying dividends in terms of informing a broader context. Continuation of California Coastal Monitoring Program (Adams et al. 2011) implementation throughout the watershed begun in 2013 by Sonoma Water and UC/CA Sea Grant is further assisting in providing that context.

References

Adams, P. B., and coauthors. 2011. California coastal salmonid population monitoring strategy design and methods. CA Department of Fish and Game, Sacramento, CA. 82 p.