Russian River Biological Opinion Status and Data Report

Year 2022 – 2023

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Sonoma Water

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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 fourteenth report for year 2022-2023. 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 – 2022

Meetings

The Public Policy Facilitating Committee (PPFC) held a virtual webinar on Wednesday, April 6, 2022. The online meeting will take place from 4-6:30 p.m. via Zoom.
The meeting included presentations and updates on:

- Status of Russian River Instream Flow Changes
- Responding to Changes in Russian River Watershed Hydrology
- Drought and Fisheries Monitoring
- Warm Springs Hatchery and Coyote Valley Fish
- Dry Creek Habitat Enhancement Project
- Biological Assessment Update and allowed for questions and answers from attendees.

[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

The meeting was advertised in the Healdsburg Tribune, a press release was issued and notices were sent out to approximately 800 individuals and agencies. The PPFC meeting was also promoted on Sonoma Water's website and through its social media channels.

No community meetings, events or tours were held in 2022.

Other Outreach

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

Free Media –In 2022, press releases were issued on the community meeting regarding the Dry Creek and the Public Policy Facilitating Committee meeting and on changes in river flows due to the need to maintain water levels in Lake Mendocino.

Electronic Media – Sonoma Water updated its Biological Opinion webpage, including links on new documents and meetings. Email alerts to interested stakeholders regarding activities in the estuary were issued 20 times in 2022.

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.

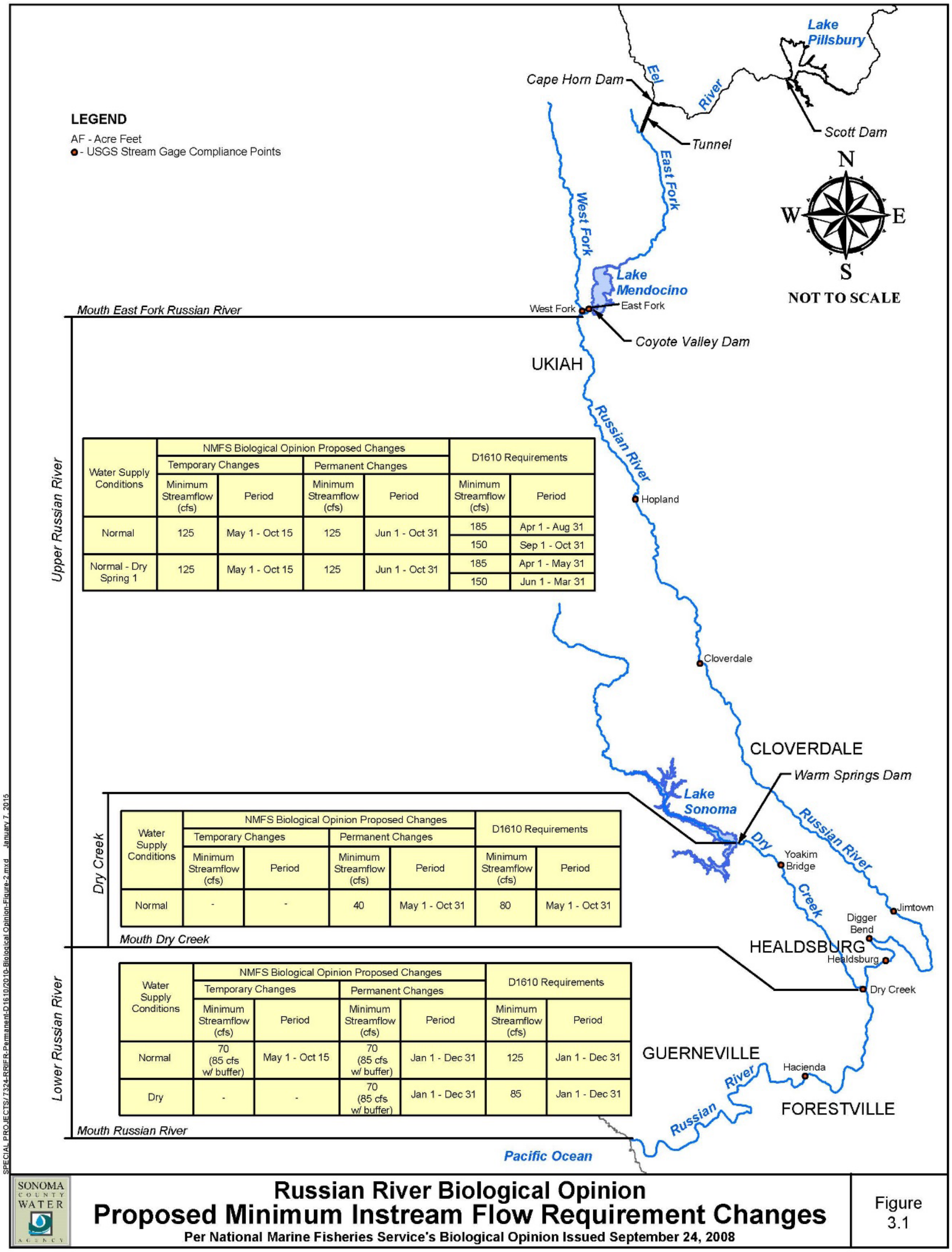
Summary Status

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 and updating data sets in 2022.

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				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	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				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period
Normal	-	-	40	May 1 - Oct 31	80	May 1 - Oct 31

Lower Russian River

Water Supply Conditions	NMFS Biological Opinion Proposed Changes				D1610 Requirements	
	Temporary Changes		Permanent Changes			
	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	Period	Minimum Streamflow (cfs)	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 multiple Temporary Urgency Change (TUCP) packages to the SWRCB in 2022 due to ongoing drought conditions and issues related to Pacific Gas and Electric's (PG&E) Potter Valley Project. The Water Agency submitted a TUCP to the SWRCB on November 17, 2021, due to drought conditions, severely low storage levels in Lake Mendocino, and a hydrologic index for establishing minimum instream flows not aligning with the watershed conditions (Appendix A-1). The requested temporary change was implementation of an alternative hydrologic index based on Lake Mendocino storage values in lieu of the Decision 1610 hydrologic index based on cumulative Lake Pillsbury inflow. The alternative hydrologic index based on Lake Mendocino would then be used to determine which minimum instream flow requirements would apply to the upper Russian River. No changes in this TUCP were requested for how minimum instream flow requirements were determined for Dry Creek or the lower Russian River (from its confluence with Dry Creek to the Pacific Ocean. The SWRCB issued an Order approving the Water Agency's TUCP on December 10, 2021 (Appendix A-2).

The SWRCB's Order made the following changes to the Water Agency's permits until June 9, 2022: 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) was to be established using a hydrologic index based on water storage in Lake Mendocino and defined in the December 10, 2021, Order (Appendix A-2, Terms and Condition 1).

The December 10, 2021, 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; continuation of ongoing water quality monitoring at existing USGS sonde sites on the Russian River; additional consultation with the North Coast Water Quality Control Board by April 22, 2022, to discuss whether additional water quality monitoring should be required; reporting on hydrologic conditions of the Russian River system; weekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates; reporting of water conservation measures and water savings being implemented by Sonoma Water's Water Shortage Contingency Plans (WSCP) and the WSCPs fo this contractors and other wholesale customers.

Reports to fulfill the terms of the December 10, 2021, Order were prepared and submitted to the SWRCB and are provided in Appendices A-3 to A-4.

The Water Agency filed a TUCP (Appendix A-5) on May 25, 2022, requesting temporary reductions to the Russian River instream flow requirements to address the ongoing severe drought conditions in the Russian River watershed and the extreme low storage conditions in Lake Mendocino and Lake Sonoma, and to avoid potential violations of the Incidental Take Statement contained in the 2008 National Marine Fisheries Service (NMFS) Biological Opinion. Lake Mendocino and Lake Sonoma were at or near their lowers levels for this time of year since filling in 1959 and 1986, respectively. The SWRCB issued an Order approving the TUCP on June 17, 2022, (Appendix A-6) establishing that minimum instream flow requirements would be set to *Critical* water supply classification of 25 cfs in the upper Russian River and 35 cfs in the lower Russian River, and that the minimum instream flow requirement will be implemented as a 5-day running average of average daily stream flow measurements with instantaneous minimum instream flows being no less than 10 cfs below the minimum (Appendix A-6). The June 17, 2022, Order included terms and conditions that required: fisheries and water quality monitoring to monitor habitat and water quality conditions and hydrologic connectivity in the Russian River; preparation and implementation of a water quality monitoring plan; weekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates; reporting on hydrologic conditions of the Russian River system;ramping rates associated with reductions in flow under the Order in the East Fork Russian River below Lake Mendocino; and submission of a schedule of milestones and completion dates for activities necessary for SWRCB consideration of and potential action on pending petitions to permanently change the Water Agency's water right permits. The June 17, 2022, Order also included a condition that Sonoma Water submit weekly reports of daily average release rates and characterization of releases from Lake Mendocino and Lake Sonoma to the SWRCB.

Water quality and fishery monitoring reports to fulfill the terms of the June 17, 2022, Order were prepared and submitted to the SWRCB and are provided in Appendix A-7 and Appendix A-8. Water quality monitoring in the Russian River Estuary is further discussed in Chapter 4.

Sonoma Water filed a TUCP on October 31, 2022, due to the ongoing drought conditions and the exacerbated disconnection of the current index, Lake Pillsbury inflow in the Eel River, and Russian River watershed conditions. (Appendix A-9). The TUCP requested implementation of a hydrologic index based on Lake Mendocino storage values in lieu of the Decision 1610 hydrologic index based on cumulative Lake Pillsbury inflow.

The SWRCB issued an Order approving the Water Agency's TUCP on December 14, 2022 (Appendix A-10). The Order established that minimum instream flow requirements for the upper Russian River, lower Russian River, and Dry Creek would be based on a hydrologic index based on water storage in Lake Mendocino (Appendix A-10, Terms and Conditions 1) from December 14, 2022, to April 15, 2023. The Order included several terms and conditions, including: requirements for fisheries habitat monitoring and regular consultation with NMFS and CDFW regarding fisheries conditions; ramping raptes for changes in releases from Lake Mendocino during *Dry* or *Critical* conditions; coordination with CDFW regarding time and level of temporary and period flow increases from Lake Mendocino during hatchery steelhead smolt releases and from Lake Mendocino and Lake Sonoma during the end of steelhead spawning season; continuation of ongoing water quality monitoring at existing USGS sonde sites on the Russian River; additional consultation with the North Coast Water Quality Control Board by April 21, 2023, to discuss whether additional water quality monitoring should be required; biweekly consultation meetings with NMFS, CDFW, and the North Coast Regional Water Quality Control Board for fishery and water quality conditions updates during *Dry* or *Critical* conditions; reporting on hydrologic conditions of the Russian River system; and reporting of status of implementation of Sonoma Water and its contractors and other wholesale customer's WSCPs; and continuing to conduct activities described in the Plannign and Management Terms of the March 21, 2022 Memorandum of Understanding Concerning Lake Mendocino Storage Planning and Russian River Management. The December 14, 2022, Order also included a condition that Sonoma Water submit weekly reports of daily average release rates and characterization of releases from Lake Mendocino and Lake Sonoma to the SWRCB. The December 14, 2022, Order also included a term and condition for consultation with NMFS and CDFW when releases were to be reduced under the Order to protect against stranding of fish.

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 Water. 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 state and federal agencies. Estuary management for 2022 was discussed at a meeting on March 24, 2022, that included representatives from NMFS and CDFW, as well as Sonoma Water, the North Coast Regional Water Quality Control Board, and ESA. A draft of the 2022 plan was provided to the Estuary Management Team on March 25, 2022, for review. Comments on the draft plan from these representatives informed the revision of the draft plan to create the final plan.

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 2022 and provided to NMFS and CDFW. The April and May 2022 topographic surveys were cancelled due to the presence of neonate (less than 1 week old) harbor seals at the mouth of the Russian River. 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. A summary of beach topography changes in 2022 is provided in Attachment R, Physical Process during the 2022 Management Period in the Russian River Estuary Adaptive Management Plan 2023 (ESA, 2023).

2022 Beach and River Mouth Conditions

A barrier beach formed 11 times in 2022 (Table 4.0.1). Eight river mouth closures ended in self-breaches and Sonoma Water conducted water level management activities during three closures. The Russian River mouth was closed to the ocean for a total of 78 days (or 21%) in 2022.

Table 4.0.1. Summary of Russian River mouth closures in 2022. Three beach management activities were conducted in 2022.

Closure Date	Beach Management Date	No. Days Closed	Activity Time[1]	Water Elevation (ft)[2]	Beach Management Activity[3]	Excavated Volume (CY)[4]
18-Feb	18-Feb	0	None	4.68	None	0
27-Feb	3-Mar	4	10:52am-12:54pm	6.95	Pilot Channel	618
6-Mar	8-Mar	2	None	5.3	None	0
14-Mar	21-Mar	7	None 10:28am-11:55am	7.3	Pilot Channel	580
28-Mar	70-Apr	10	None	8.0	None	0
10-Apr	14-Apr	4	None	4.6	None	0
22-Apr	23-Apr	1	None	6.8	None	0
6-May	12-May	6	None	7.0	None	0
21-Oct	15-Nov	25	9:51am-11:13am	5.9	None	0
25-Nov	4-Dec	9	None	5.9	None	0
26-Dec	27-Dec	1	None	8.9	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 in feet (NGVD29).

[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 volumes 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 Figure1 for the entire 2022 lagoon management season (ESA, 2023).The lagoon water level time series (Figure 1) 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 where the river mouth was open and estuary water surface elevations were mainly dominated by tidal flows (ESA, 2023). A third year of drought conditions occurred in 2022, which resulted in drier watershed conditions and river flows. Peak flows in the 2022 Water Year reached 20,400 cubic feet per second (cfs) at Hacienda Bridge but occurred toward the beginning of the wet season in late 2021, leaving much of 2022 with dry conditions. Dry spring and summer conditions meant that flows dipped below 100 cfs at Hacienda Bridge by mid-May and were less than 100 cfs for about half of June and all of July and August, before recovering in mid-September.

The winter of 2021-2022 experienced early seasonal rain in November and December (peaking at 20,400 cfs in November 2021 at the USGS Hacienda Bridge station; ESA, 2023). The final strong rainfall event of the season occurred in late December 2021, peaking at a maximum flow of 8,840 cfs on December 25, 2021, before gradually decreasing to around 170 cfs in mid-March 2022. Accordingly, closure events occurred after mid-March, with the estuary water level reaching as high as 8 feet NGVD on April 7, 2022. During spring closure events, wave overtopping occurred within a few days of closure, caused by waves of 5-6 feet height. The first major closure event, where estuary water levels reached as high as 7.5 feet NGVD, ended by an artificial breach on March 21. Two partial closure events occurred during this season in late April, where the inlet was relatively narrow near the jetty. These partial closure events occurred a few days after waves arrived from the southwest (April 13 to April 19), which might have caused sediment accumulation after they passed through the jetty groin.

During the period from mid-May to mid-October the estuary was subjected to relatively low riverine flows (inflows smaller than 100 cfs) and relatively small incoming waves (significant wave heights smaller than 5 feet; ESA, 2023). Accordingly, the estuary mouth was not significantly accreted by incoming waves nor eroded by stream flows. The only noticeable tidal attenuation occurred as a partial mouth closure during the first half of June. The mouth never fully closed during this event, and flows were naturally forming an outlet channel along and through the jetty groin. This event started with the mouth already located near the jetty and southwest waves penetrating through the gap in the jetty groin. The waves appear to have caused accretion of the mouth, and outflows also appeared to be split into two channels (one along the face of the jetty groin, and another flowing through the gap in the jetty groin). A similar event was observed in June 2021, under similar conditions. In both cases, it appeared that both wave transmission and outflow of estuary water occurred through the gap in the jetty groin. In both cases, discharge to the lagoon was low, and southwesterly waves were present. In both cases, waves were long period swell with periods larger than 12 seconds, though wave heights were larger during the 2021 event. From early June to mid-June, the river inflows increased from 45 cfs to 140 cfs, which eventually led to erosion and opening of the mouth. (ESA, 2023).

During the post-management season, the estuary was significantly affected by inflows reaching as high as 1,920 cfs on December 12, 2022, and 6,530 cfs on December 28, 2022, with the nearshore waves reaching as high as 10.2 feet on October 31 and 18.9 feet on December 27. This season included one long closure event from mid-October to mid-November and short/partial closure events in late November and early December. The initiation of closure for the October-November event coincided with a period of neap tides and low period swell waves coming from the northwest. During this event, inflows were relatively low, ranging from 68 cfs (October 19) to 171 cfs (November 9). During this closure event the river mouth was subjected to relatively large waves reaching heights of 10 feet mainly coming from west, causing overtopping on October 29, November 7, and November 14, which can be observed as the increases in estuary water level time series on October 29 and November 7. This closure event ended by an artificial breach on November 15 (ESA, 2023).

Appendix R of the 2023 Russian River Estuary Adaptive Beach Management Plan (ESA, 2023) offers lessons learned based on 2022 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, 2023 for fuller context:

- As observed in similarly dry years from 2012 to 2015, 2018, 2020and 2021, peak 2022 winter flows of less than 40,000 cfs limited the inlet's northward excursion, and the inlet remained near the groin for the entire management period.
- In prior annual monitoring reviews, it was noted that dry years usually were associated with stable or growing conditions for the beach berm north of the jetty groin. Conditions in 2021 and 2022 have shown that while the beach crest was stable, the beach profile experienced a net movement landward. In both years, the entire profile moved landward, suggesting that the process is driven by wave overtopping of the beach berm (rather than just erosion of the beach face).
- As with observations in 2020 and 2021, the gap in the jetty groin was again observed to allow swash from southern swell waves to penetrate through the jetty and deposit sand in the inlet. This wave energy may have deposited sand in the mouth of the inlet and contributed to the early June 2022 partial closure event. During the partial closure event, outflows were also observed to split into two channels, one passing along the face of the jetty groin, and another passing through the gap. This flow split (and possibly the rock in the jetty groin gap acting as a grade control) may have acted to slow outflows and limit the vertical scouring that is normally observed to end partial closure events in prior years.

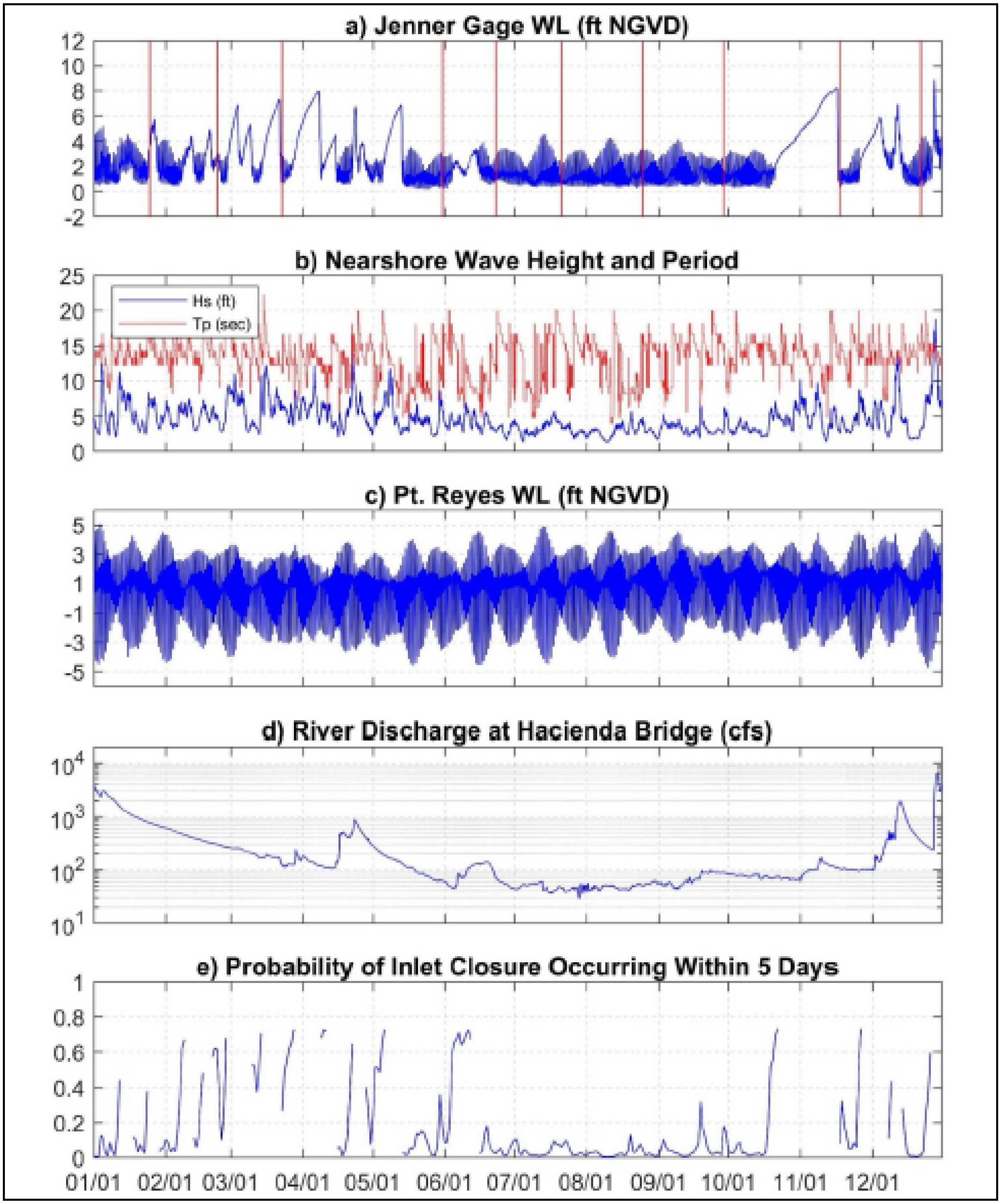


Figure 4.0.1. Estuary, Ocean, and River Conditions Compared with Closure Probability, 2022.

Artificial Breaching

There were 11 mouth closures in 2022; none occurred during the lagoon management season. Three beach management activities were conducted by Sonoma Water in 2022, all outside the lagoon management season. More information about the wave and water level conditions during these closures are available in Appendix R of the 2023 Russian River Estuary Adaptive Beach Management Plan (ESA, 2023).

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 (https://ourcoastourfuture.org/case-studies/). Sonoma Water plans 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.

Conclusions and Recommendations

A barrier beach formed 11 times in 2022. Eight river mouth closures ended in self-breaches and Sonoma Water conducted three water level management activities outside the lagoon management season (Table 1). The Russian River mouth was closed to the ocean for a total of 78 days (or 21%) in 2022.

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 did not experience any closures during the 2022 management period, which runs from 15 May to 15 October.

There were several closures that occurred prior to the management period including a closure that occurred for six (6) days from 6 May to 12 May before self-breaching shortly before the management period began.

Three (3) closures also occurred after the management period ended, including a closure that occurred for twenty-five (25) days from 21 October to 15 November before self-breaching.

Methods

Continuous Multi-Parameter Monitoring

Water quality was monitored using YSI Series 6600 multi-parameter datasondes and YSI EXO2 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.

Five (5) stations were established for continuous water quality monitoring, including three stations in the mainstem Estuary and two tributary stations (Figure 4.1.1). The first 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 (Willow Creek Station), which flows into the middle reach of the Estuary upstream of Patty's Rock. The second mainstem station was located in the upper reach of the Estuary downstream of Freezeout Creek (Freezeout Creek Station). The third mainstem station was located in the upper reach of the Estuary 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. However, no data were recorded at the Austin Creek station due to equipment malfunction.

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 (Figure 4.1.1). 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.

Mainstem Estuary monitoring stations up to Brown's Pool were comprised of a concrete anchor attached to a steel cable suspended from the surface by a large buoy (Figure 4.1.2).

The Patty's Rock, Freezeout Creek, and Brown's Pool stations had a vertical array of two datasondes to collect water quality profiles (Figure 4.1.2). The Patty's Rock station, located in the middle reach of the Estuary, is predominantly saline and had a sonde placed near the surface at approximately 1 meter depth (~1-2m), and at the mid-depth (~4-5m) portion of the water column. The Freezeout Creek station 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 mid-depth (~3-4m) and bottom (~6-7m) portions of the water column. Similarly, the Brown's Pool station in the upper reach of the Estuary had sondes placed at the mid-depth (~4-5m) and bottom (~10-11m) portions of the water column.

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.

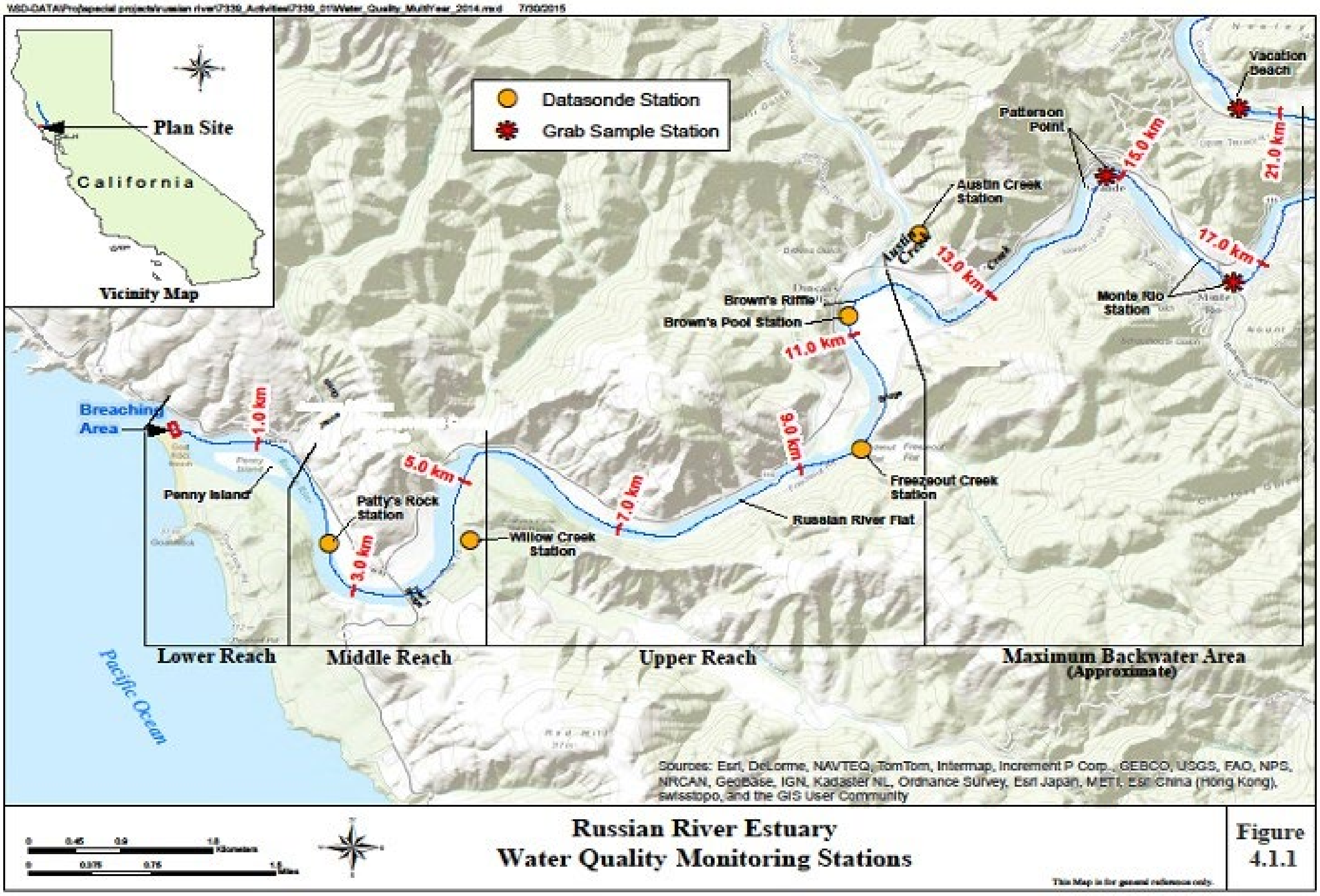


Figure 4.1.1. 2022 Russian River Estuary Water Quality Monitoring Stations

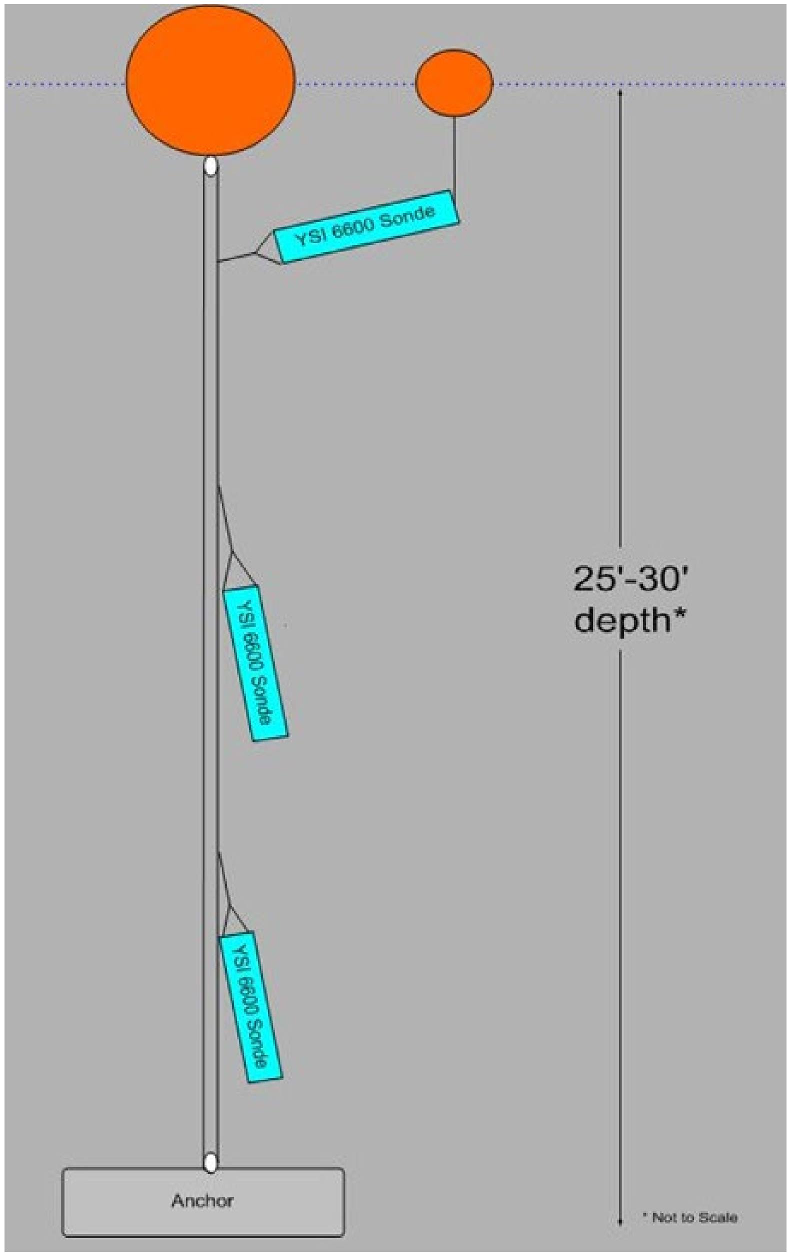


Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.

The monitoring stations in Austin Creek and Willow Creek consisted of one datasonde suspended at approximately mid-depth (~0-2m during open conditions) in the thalweg at each respective site.

The Patty's Rock station was deployed from August to November. The Freezeout Creek and Brown's Pool stations were deployed from June to November. The Austin Creek sonde was deployed from June to October, however no data was recorded due to equipment malfunction. The Willow Creek sonde was deployed year-round.

Grab Sample Collection

In 2022, 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 2022 grab sampling effort represented the ninth 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 19 April to 18 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. Sampling results for other nutrient components, dissolved and total organic carbon, and total dissolved solids are included; however, an analysis and discussion of these constituents is not included in this report.

Results

Water quality conditions in 2022 were similar to trends observed in sampling from 2004 to 2021. 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 4.1.18.

Although gaps exist in the 2022 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.

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.

In the upper reach, the Estuary typically begins to transition from predominantly saline conditions to brackish and freshwater conditions in the Heron Rookery area, located downstream from the town of Duncans Mills. Further upstream, the Freezeout Creek area 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 upper extent of the upper reach of the estuary is located in the Brown's Pool area where conditions are predominantly freshwater habitat with periodic salinity migration creating brackish conditions at depth. This area is located next to Casini Ranch just downstream of the confluence with Austin Creek and what is considered the beginning of the MBA. The Austin Creek station is located in the MBA in freshwater habitat that can become inundated during high tides, barrier beach closures, perched conditions, and lagoon formation.

Table 4.1.1. Russian River Estuary 2022 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						
August 9, 2022 - November 3, 2022						
Min	12.2	1.4	6.0	70.5	7.4	15.4
Mean	14.7	1.5	9.4	111.7	8.0	29.5
Max	**18.8**	**1.7**	**16.2**	**187.7**	**8.5**	**31.9**
Mid-Depth						
August 9, 2022 - November 3, 2022						
Min	11.9	4.2	0.6	7.4	7.2	17.4
Mean	13.8	4.7	7.4	86.9	7.9	31.1
Max	**16.4**	**4.9**	**13.3**	**158.9**	**8.3**	**32.3**
Willow Creek						
Mid-Depth						
January 11, 2022 - December 31, 2022						
Min	3.9	0.0	0.1	1.1	6.3	0.1
Mean	15.2	0.8	7.8	83.9	7.6	12.5
Max	**25.7**	**2.8**	**16.4**	**200.7**	**8.7**	**27.9**
Freezeout Creek						
Mid-Depth						
July 6, 2022 - September 27, 2022						
Min	18.9	3.5	0.0	0.0	7.6	0.1
Mean	22.1	3.7	6.9	79.8	8.5	0.9
Max	**24.6**	**3.9**	**13.7**	**163.5**	**9.2**	**4.4**
Bottom						
June 8, 2022 - November 3, 2022						
Min	13.5	6.0	0.1	0.8	5.4	0.1
Mean	20.3	6.4	0.6	6.5	6.8	3.1
Max	**24.1**	**7.1**	**11.2**	**131.9**	**9.2**	**7.8**
Brown's Pool						
Mid-Depth						
June 8, 2022 - November 3, 2022						
Min	12.6	4.6	0.0	0.0	7.1	0.1
Mean	20.1	4.8	5.4	60.3	7.7	0.1
Max	**24.1**	**5.0**	**9.3**	**107.9**	**8.5**	**0.3**
Bottom						
June 8, 2022 - November 3, 2022						
Min	14.9	10.6	0.1	0.6	6.0	0.1
Mean	15.6	10.8	0.5	5.4	6.7	0.9
Max	**19.2**	**11.0**	**7.5**	**75.9**	**8.0**	**1.7**

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 to 2 meters, 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 15.4 to 31.9 ppt at the Patty's Rock surface sonde with a mean salinity value of 29.5 ppt (Table 4.1.1).

The mid-depth sonde at the Patty's Rock station was suspended at a depth of approximately 4 to 5 meters, and also experienced fluctuations in salinity concentrations, though to a lesser degree and frequency than the surface sonde. Concentrations ranged from 17.4 to 32.3 ppt at the Patty's Rock mid-depth sonde with a mean salinity value of 31.1 ppt (Table 4.1.1).

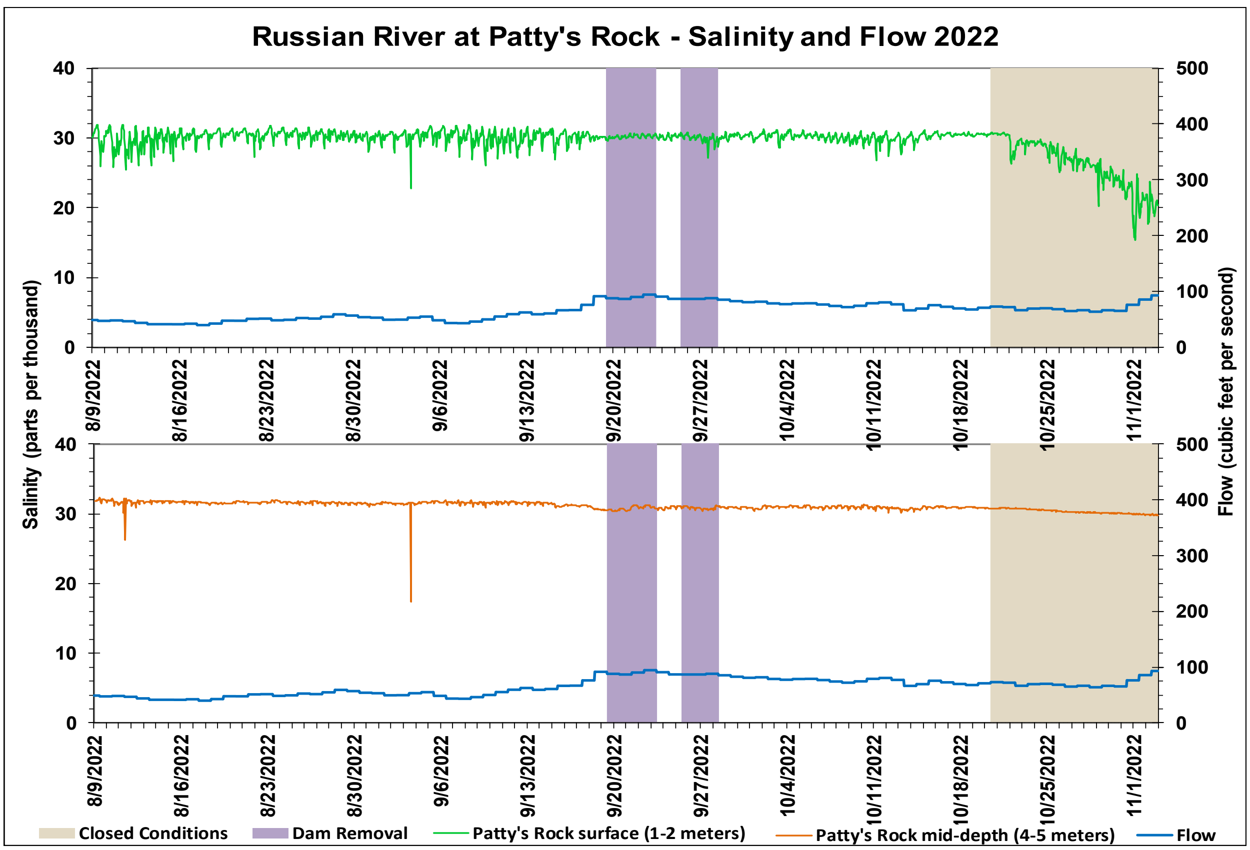


Figure 4.1.3. 2022 Russian River at Patty's Rock Salinity and Flow Graph

The Estuary did not experience any closures during the 2022 management period, which runs from May 15 to October 15 (Figure 4.1.3). However, there was a closure before the management period in early May, as well as an extended closure after the management period from 21 October to 15 November. 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 typically 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.

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. Salinity concentrations at Willow Creek were observed to fluctuate significantly at times during open barrier beach conditions in late spring and early summer, with concentrations generally declining during closed conditions (Figure 4.1.4). Salinity concentrations were generally observed to remain brackish to saline during barrier beach closures. The mean salinity concentration observed at the Willow Creek station was 12.5 ppt, with a minimum concentration of 0.1 ppt, and a maximum concentration of 27.9 ppt (Table 4.1.1).

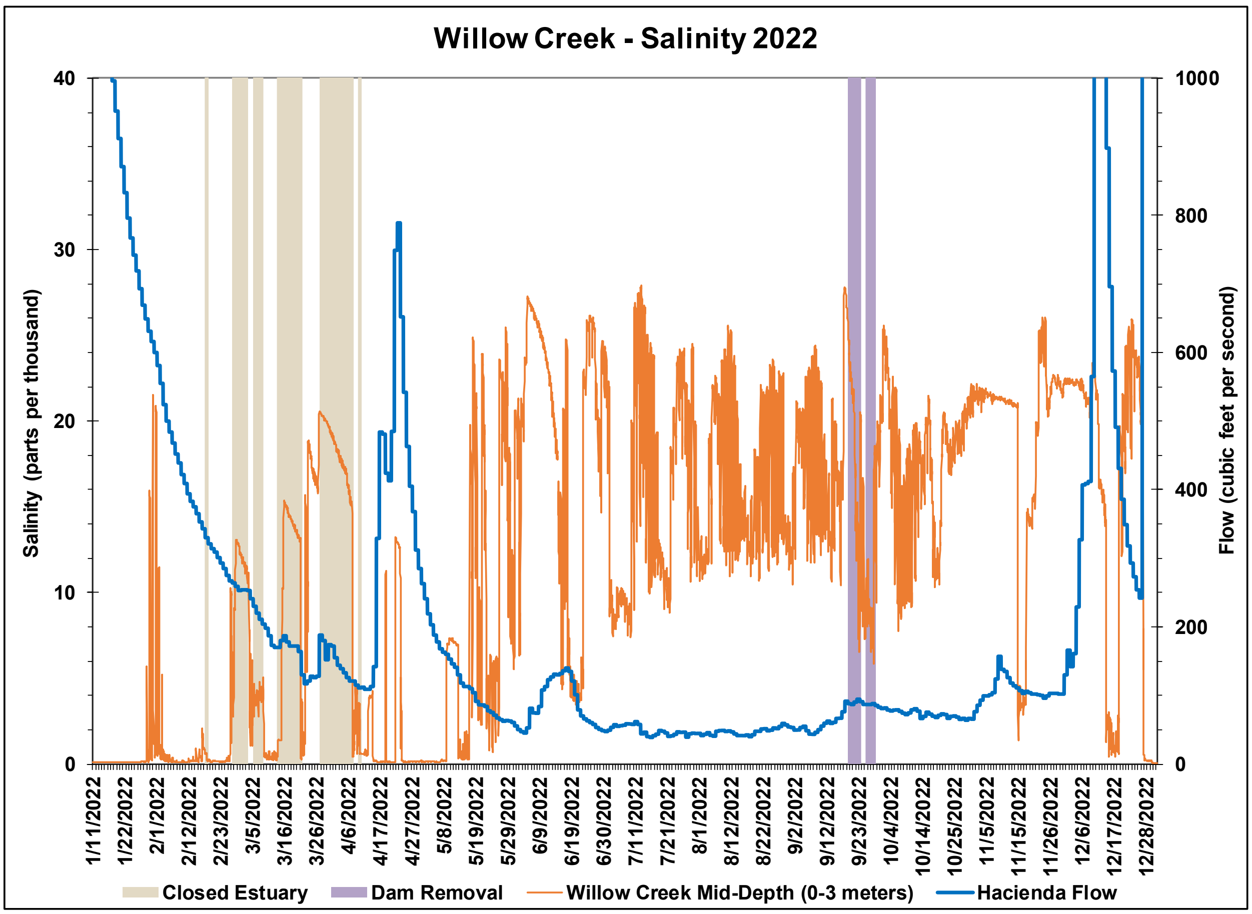


Figure 4.1.4. 2022 Willow Creek Salinity and Russian River Flow Graph

Upper Reach Salinity

Two stations were monitored in the upper reach in 2022; Freezeout Creek and Brown's Pool. Both stations included a bottom sonde and a mid-depth sonde. 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 fresh to brackish habitat in spring that became freshwater during open conditions from late September through the end of the monitoring season (Figure 4.1.5). The mid-depth sonde at Freezeout Creek had a mean salinity concentration of 0.9 ppt, and salinity levels that ranged from 0.1 to 4.4 ppt (Table 4.1.1). The bottom sonde at Freezeout Creek had a mean salinity concentration of 3.1 ppt, and salinity levels that ranged from 0.1 to 7.8 ppt.

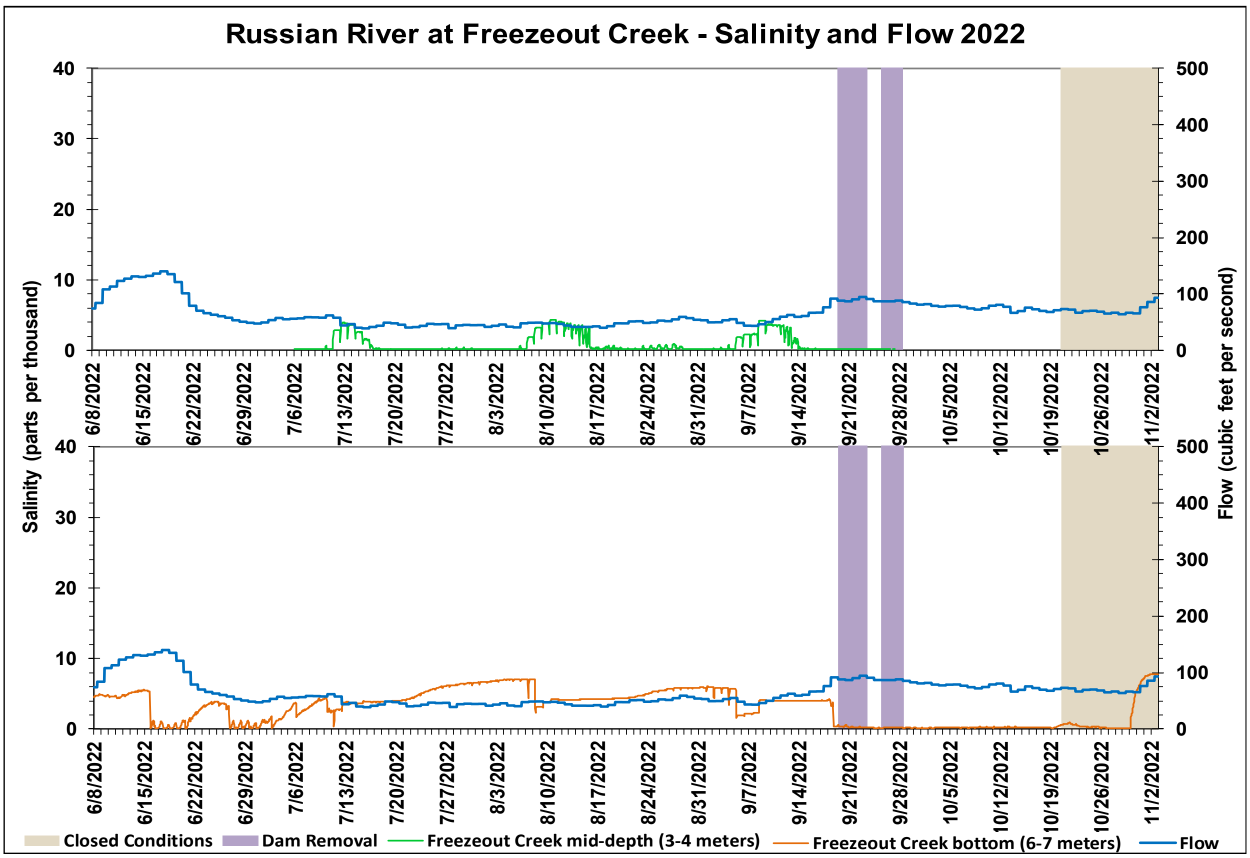


Figure 4.1.5. 2022 Russian River at Freezeout Creek Salinity and Flow Graph

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 experienced slightly elevated salinity levels at the bottom sonde that generally remained below 2 ppt, and otherwise remained predominantly freshwater habitat during the 2022 monitoring season (Figure 4.1.6). The mid-depth sonde at Brown's Pool had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.3 ppt (Table 4.1.1). The bottom sonde at Brown's Pool had a mean salinity concentration of 0.9 ppt, and salinity levels that ranged from 0.1 to 1.7 ppt.

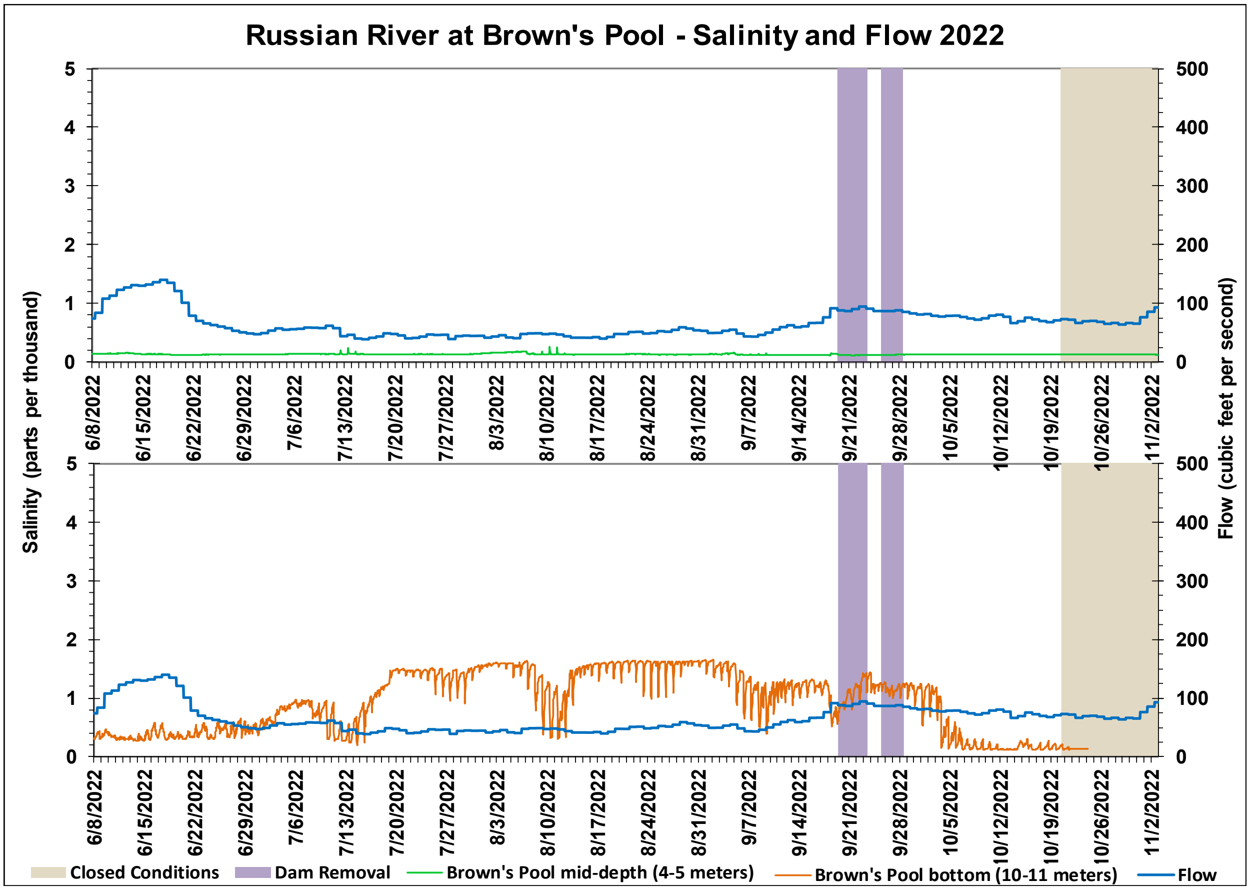


Figure 4.1.6. 2022 Russian River at Brown's Pool Salinity and Flow Graph

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 4.1.7 through 4.1.10). 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 4.1.7). 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 warmer dry months of summer and fall, 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 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 18.8°C (Table 4.1.1). Whereas, the mid-depth sonde was located primarily in saltwater and had a maximum temperature of 16.4°C. Maximum temperatures at the surface sonde were observed in saline water during open barrier beach conditions in August. Maximum temperatures at the mid-depth sonde were observed in saline water during open barrier beach conditions in August (Figures 4.1.7 and 4.1.3). The Patty's Rock surface sonde had a mean temperature of 14.7 °C and a minimum temperature of 12.2 °C. The mid-depth sonde had a mean temperature of 13.8 °C and a minimum temperature of 11.9 °C.

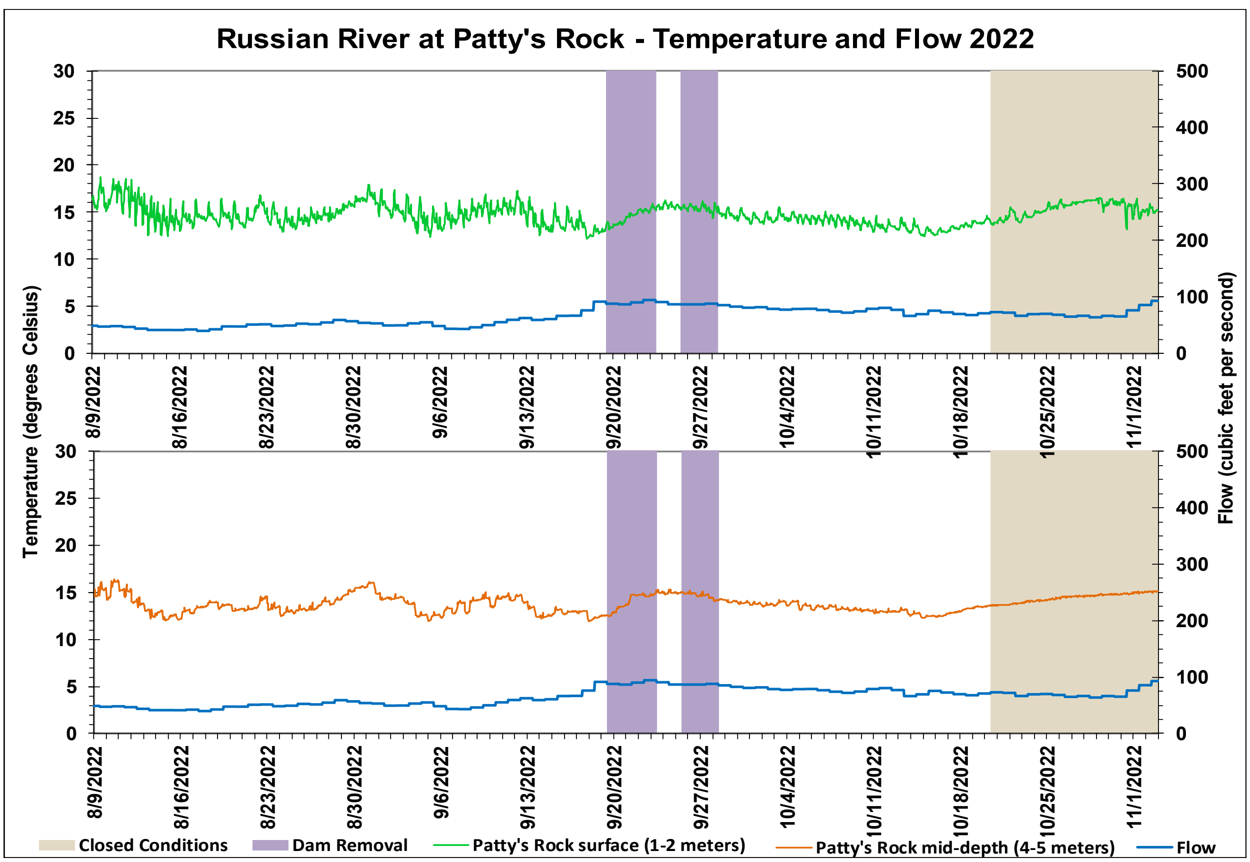


Figure 4.1.7. 2022 Russian River at Patty's Rock Temperature and Flow Graph

The Willow Creek station had a maximum temperature of 25.7°C, which occurred in mid-June in brackish water and open conditions (Figures 4.1.9 and 4.1.4). The mean temperature was 15.2 °C, and the minimum temperature was 3.9 °C, which occurred in December (Table 4.1.1). 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 closed Estuary conditions (Figure 4.1.8).

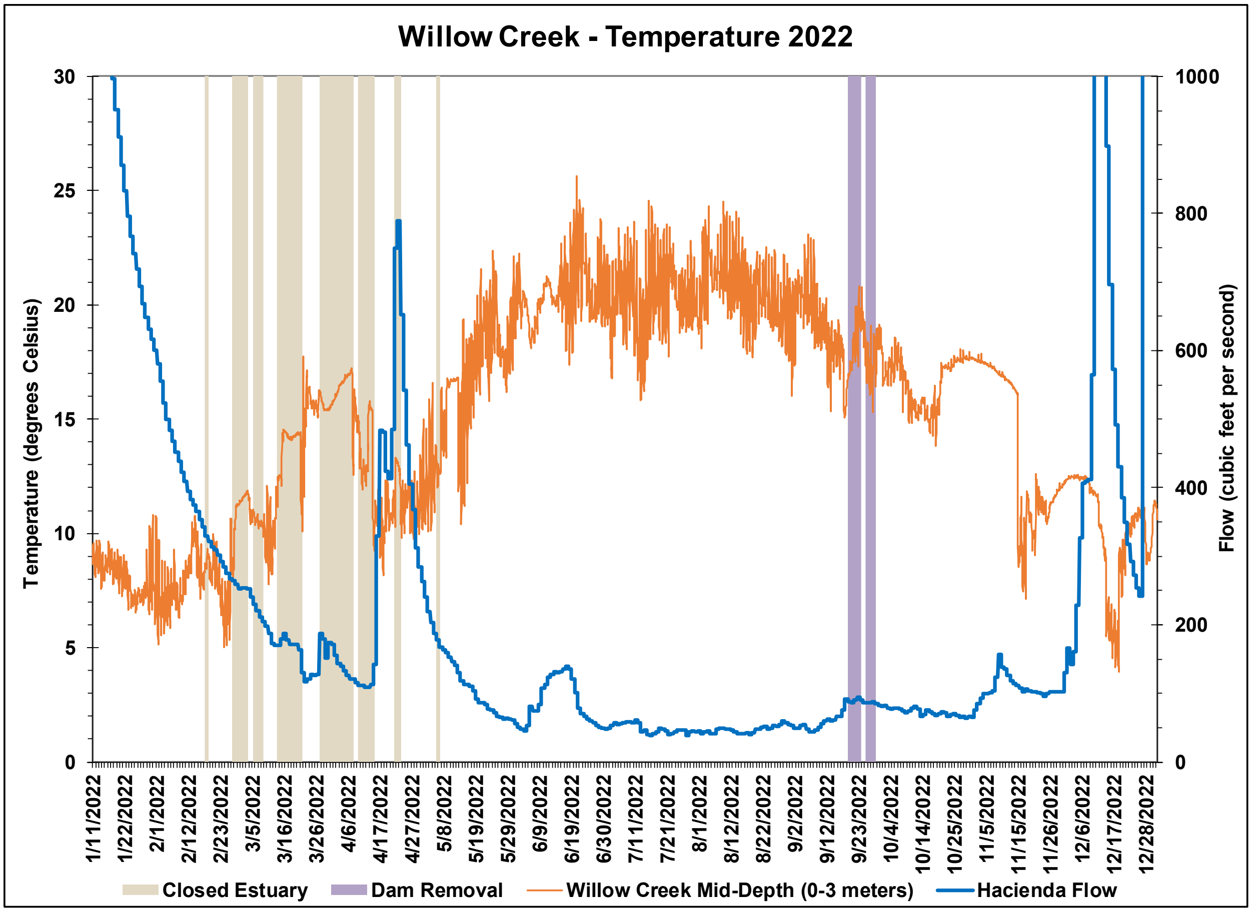


Figure 4.1.8. 2022 Willow Creek Temperature with Russian River Flow Graph

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 24.6 °C, a mean temperature of 22.1 °C, and a minimum temperature of 18.9 °C (Table 4.1.1). The Freezeout Creek bottom sonde had a maximum temperature of 24.1 °C, a mean temperature of 20.3 °C, and a minimum temperature of 13.5 °C (Table 4.1.1). Maximum temperatures were observed to occur in brackish water during open estuary conditions (Figures 4.1.9 and 4.1.5). Minimum temperatures occurred in freshwater during open and closed conditions in September at the mid-depth sonde and October at the bottom sonde (Figures 4.1.9 and 4.1.5).

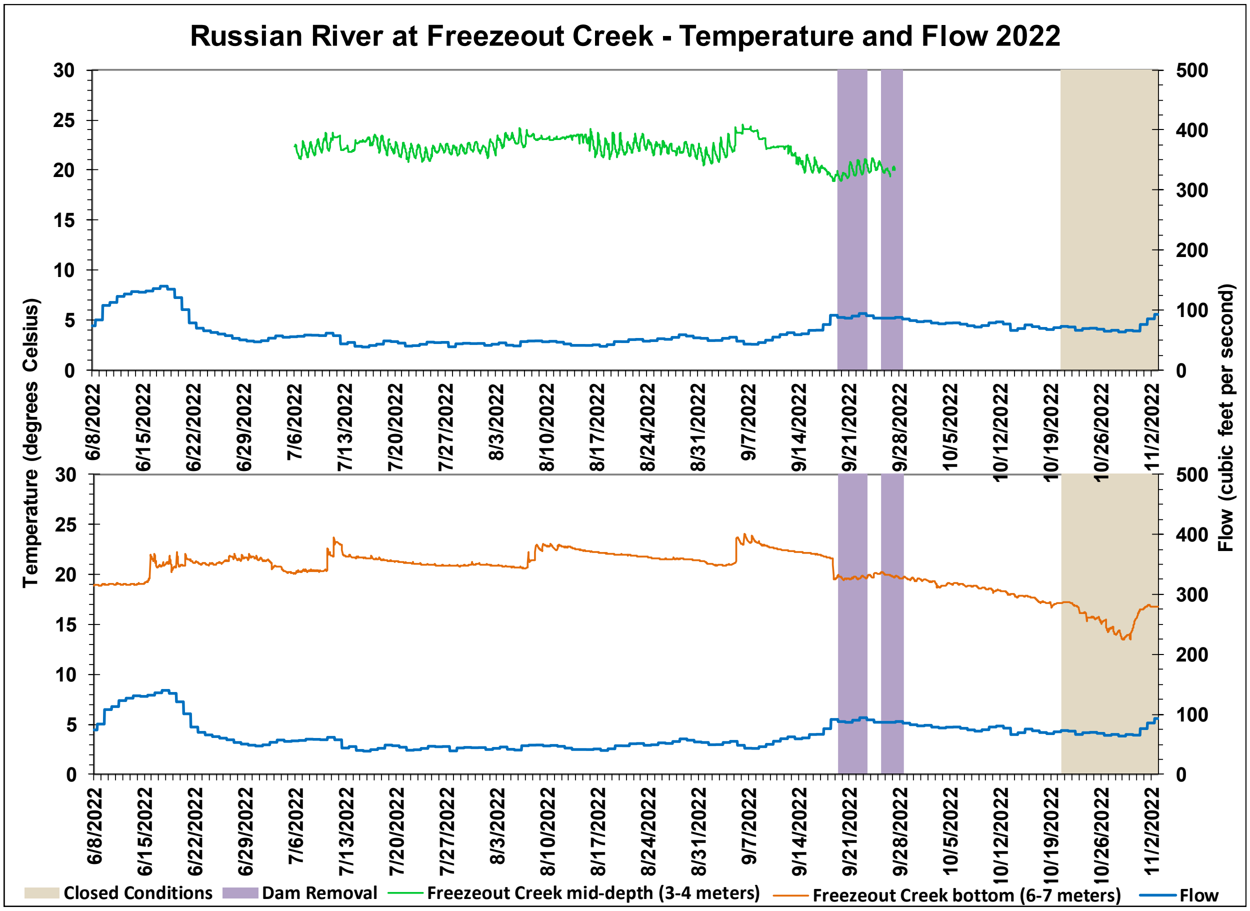


Figure 4.1.9. 2022 Russian River at Freezeout Creek Temperature and Flow Graph

The Brown's Pool mid-depth sonde had a maximum temperature of 24.1 °C, a mean temperature of 20.1 °C, and a minimum temperature of 12.6 °C (Table 4.1.1). The Brown's Pool bottom sonde had a maximum temperature of 19.2 °C, a mean temperature of 15.6 °C, and a minimum temperature of 14.9 °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 in the brackish water (Figure 4.1.10). 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 closed conditions in October (Figures 4.1.10 and 4.1.6).

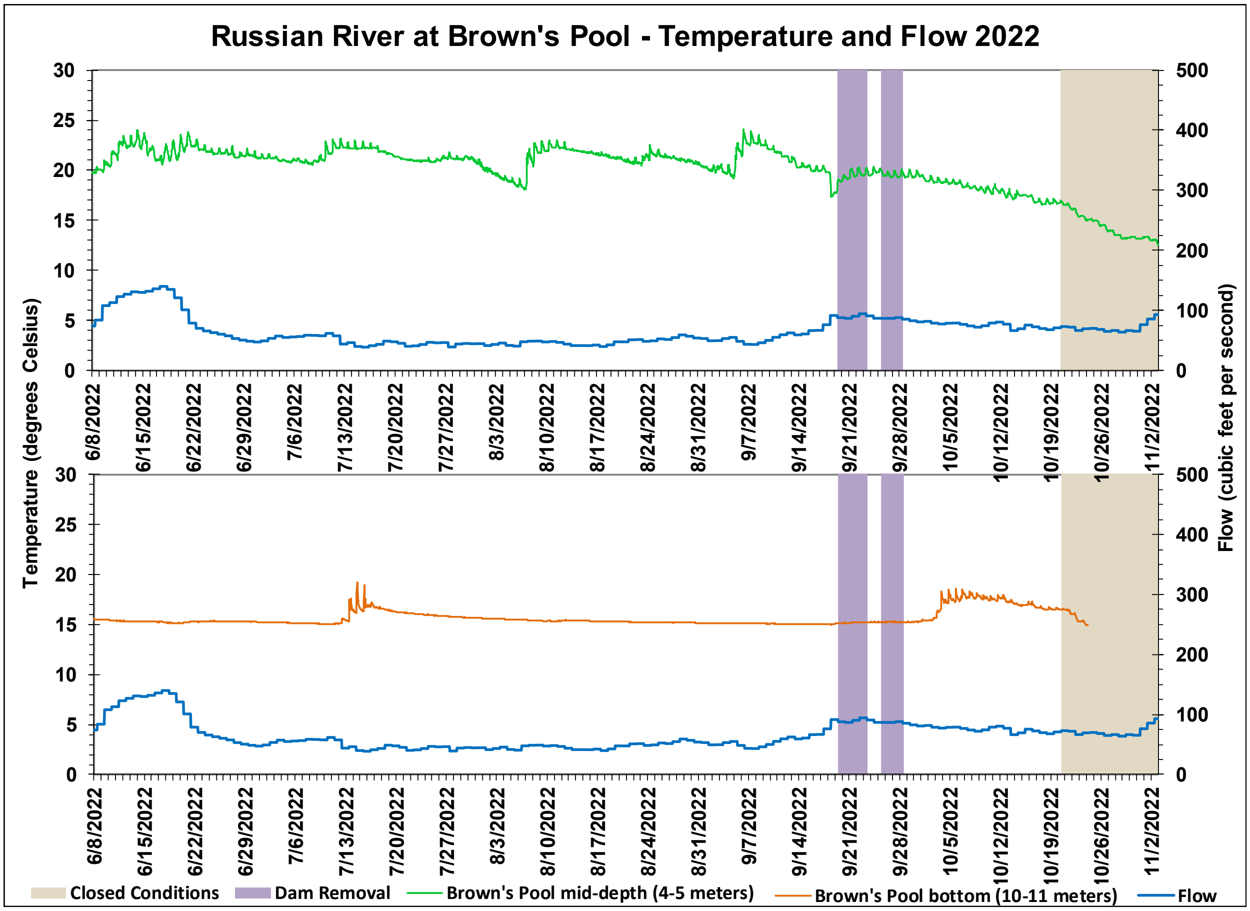


Figure 4.1.10. 2022 Russian River at Brown's Pool Temperature and Flow Graph

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,

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

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 DO

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 9.4 mg/L, the mid-depth sonde had a mean DO concentration of 7.4 mg/L (Table 4.1.1). The surface sonde was observed to experience supersaturation concentrations, during open and closed conditions, that contributed to the higher mean value. The mid-depth sonde was also observed to experience supersaturation conditions, as well as occasional hypoxic conditions during estuary closure that contributed to the lower mean value. These supersaturation events were observed during open and closed conditions, whereas hypoxic events were observed during closed conditions (Figure 4.1.11).

The Patty's Rock surface sonde had a minimum DO concentration of 6.0 mg/L (Table 4.1.1). Minimum concentrations were observed to occur in brackish to saline water during open and closed conditions (Figures 4.1.11 and 4.1.3).

DO concentrations were observed to become hypoxic to anoxic at the Patty's Rock mid-depth sonde during closed conditions (Figure 4.1.7). The minimum DO concentration at the mid-depth sonde was 0.6 mg/L, which occurred during the extended October to November closure event (Table 4.1.1 and Figure 4.1.11).

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 (Figure 4.1.11). 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 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 16.2 mg/L, which corresponded to approximately 188% saturation (Table 4.1.1). The maximum DO concentration at the mid-depth sonde was 13.3 mg/L, which corresponded to approximately159% saturation (Table 4.1.1).

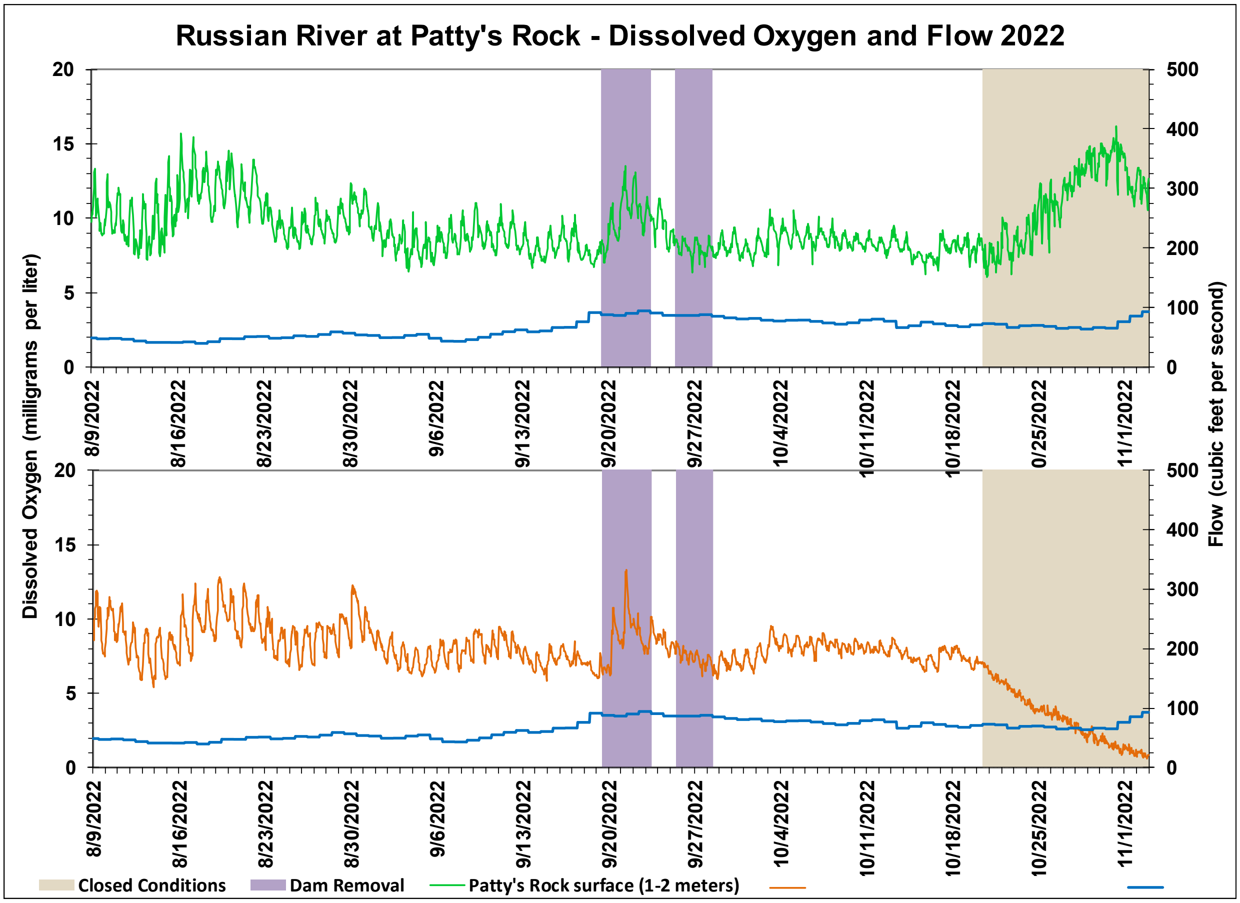


Figure 4.1.11. 2022 Russian River at Patty's Rock Dissolved Oxygen and Flow Graph

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 brackish to saline water and freshwater to a lesser degree during open barrier beach conditions (Figure 4.1.12). Whereas, dissolved oxygen concentrations were observed to steadily decline over a period of days during barrier beach closures in brackish to saline 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 4.1.12).

The Willow Creek sonde had a minimum DO concentration of 0.1 mg/L, a mean DO concentration of 7.8 mg/L, and a maximum DO concentration of 16.4 mg/L (201%) (Table 4.1.1).

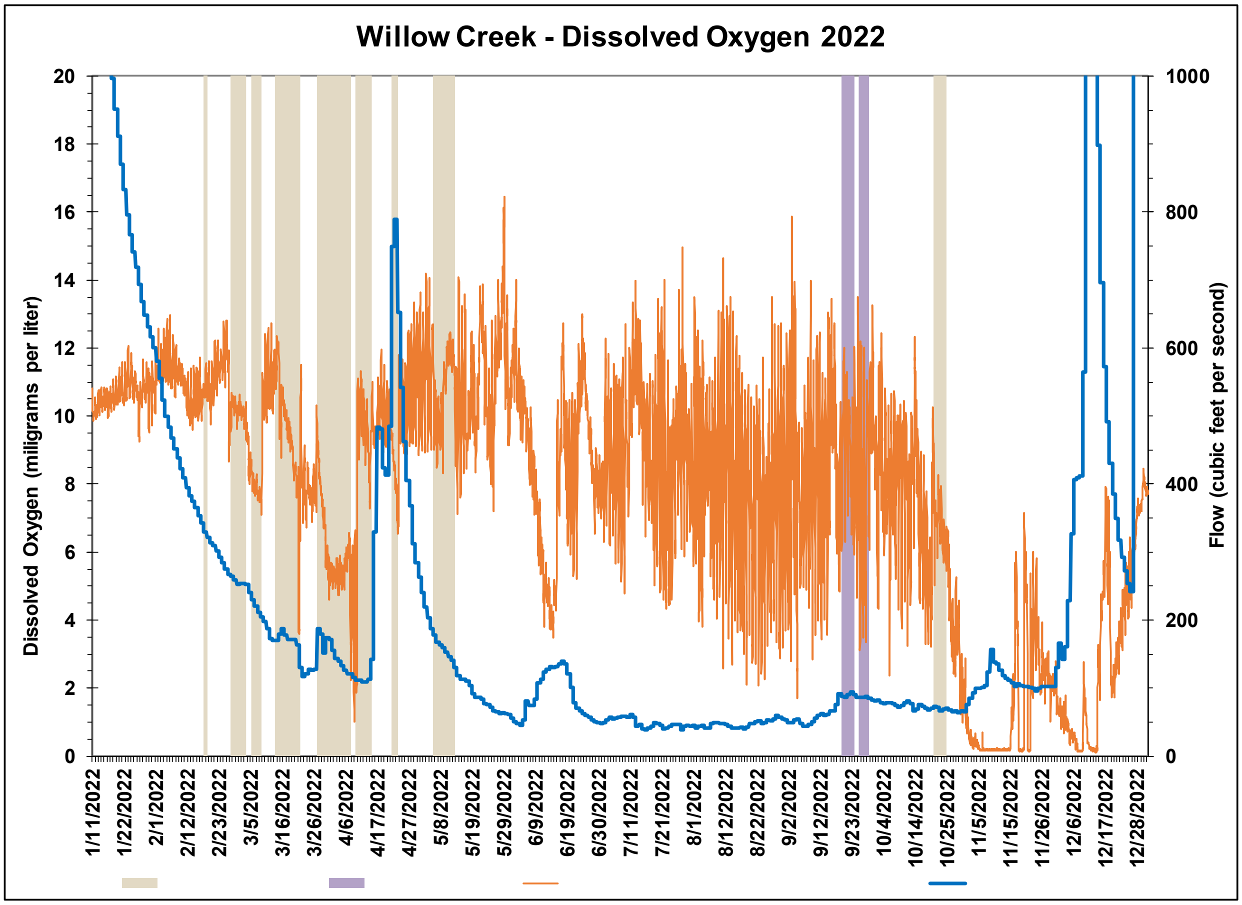


Figure 4.1.12. 2022 Willow Creek Dissolved Oxygen and Russian River Flow Graph

Upper Reach DO

Dissolved oxygen concentrations in the upper reach were influenced by the presence or absence of salinity, with lower minimum and mean DO concentrations observed in brackish water and higher minimum and mean concentrations observed in freshwater, especially during closed conditions.

Conditions at the bottom sonde at Freezeout Creek remained predominantly brackish through the monitoring season until summer dam removal at the end of September, when it transitioned to freshwater conditions. The mid-depth sonde remained predominantly freshwater habitat with occasional periods of brackish conditions during open conditions while the sonde was operating (Figure 4.1.5).

The Brown's Pool station remained predominantly freshwater habitat at the mid-depth sonde during the 2022 monitoring season, with slightly brackish conditions that remained below 2 ppt occurring predominantly at the bottom sonde (Figure 4.1.6).

Depressed oxygen concentrations declining to hypoxic and anoxic levels were observed to occur at both sondes at the Freezeout Creek station in brackish and freshwater habitat during open and closed Estuary conditions (Figure 4.1.13). Anoxic conditions were predominant during open and closed conditions at the bottom of the Brown's Pool station, although concentrations were observed to recover slightly at the end of the monitoring season leading into the extended closure in October. Oxygen concentrations were periodically hypoxic at the mid-depth sonde during open conditions before becoming anoxic during the extended closure in October (Figure 4.1.14).

The Freezeout Creek mid-depth sonde malfunctioned from June through early July and again in late September, but had a minimum concentration of 0.0 mg/L, a mean DO concentration 6.9 mg/L, and a maximum concentration of 13.7 mg/L (164%) during the time it was functioning (Table 4.1.1).

The Freezeout Creek bottom sonde had a minimum concentration of 0.1 mg/L, a mean DO concentration of 0.6 mg/L, and a maximum concentration of 11.2 mg/L (132%) (Table 4.1.1).

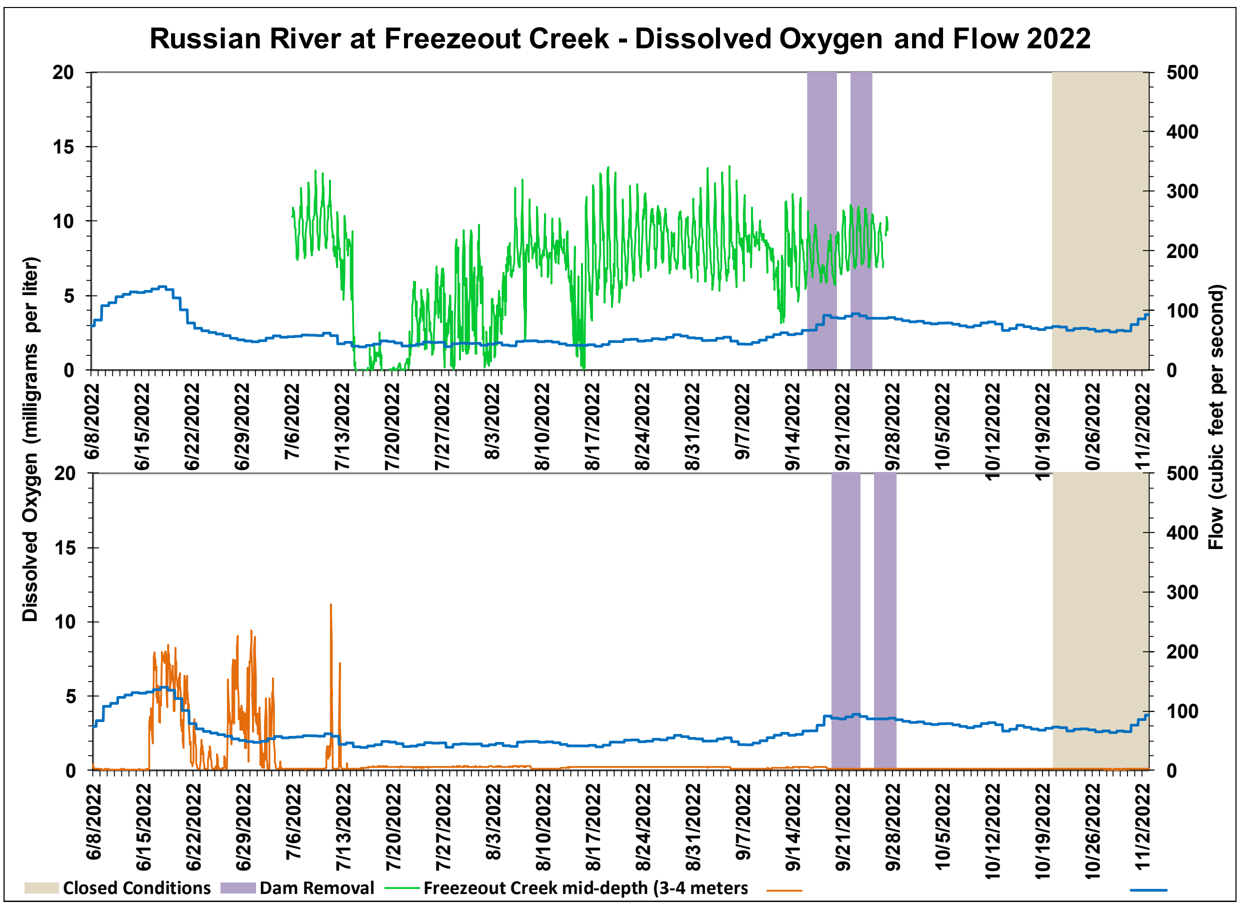


Figure 4.1.13. 2022 Russian River at Freezeout Creek Dissolved Oxygen and Flow Graph

The Brown's Pool mid-depth sonde had a minimum concentration of 0.0 mg/L, a mean DO concentration of 5.4 mg/L, and a maximum concentration of 9.3 mg/L (108%) (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 0.5 mg/L, and a maximum concentration of 7.5 mg/L (76%) (Table 4.1.1).

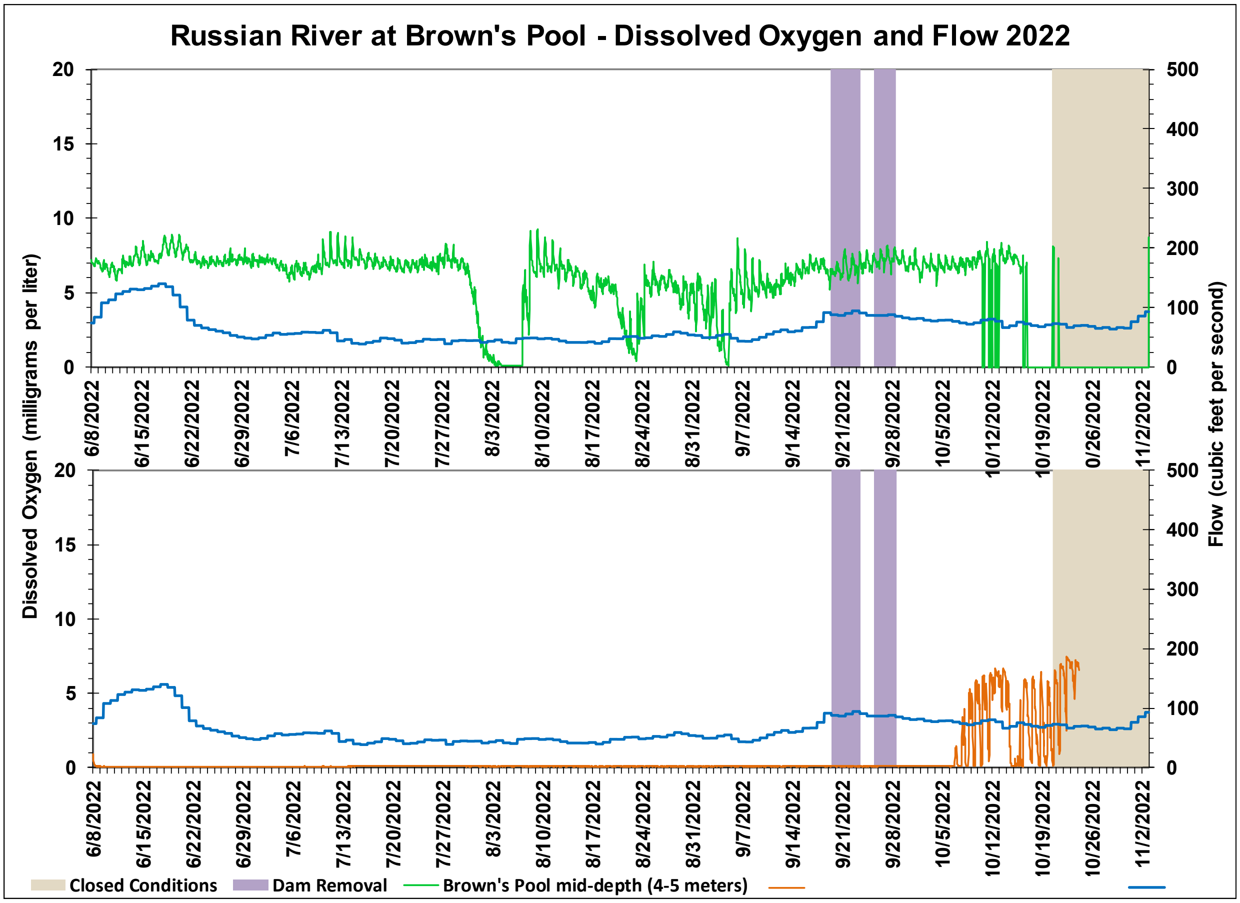


Figure 4.1.14. 2022 Russian River at Brown's Pool Dissolved Oxygen and Flow Graph

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 may be 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 7.4, a mean pH value of 8.0, and a maximum pH value of 8.5 pH (Table 4.1.1). The Patty's Rock mid-depth sonde had a minimum pH value of 7.2, a mean pH value of 7.9, and a maximum pH value of 8.3 pH. (Figure 4.1.15).

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 and anoxic conditions (Figures 4.1.15 and 4.1.11). Overall, pH values did not appear to be significantly affected by summer flows or closed conditions and remained fairly stable through the monitoring period.

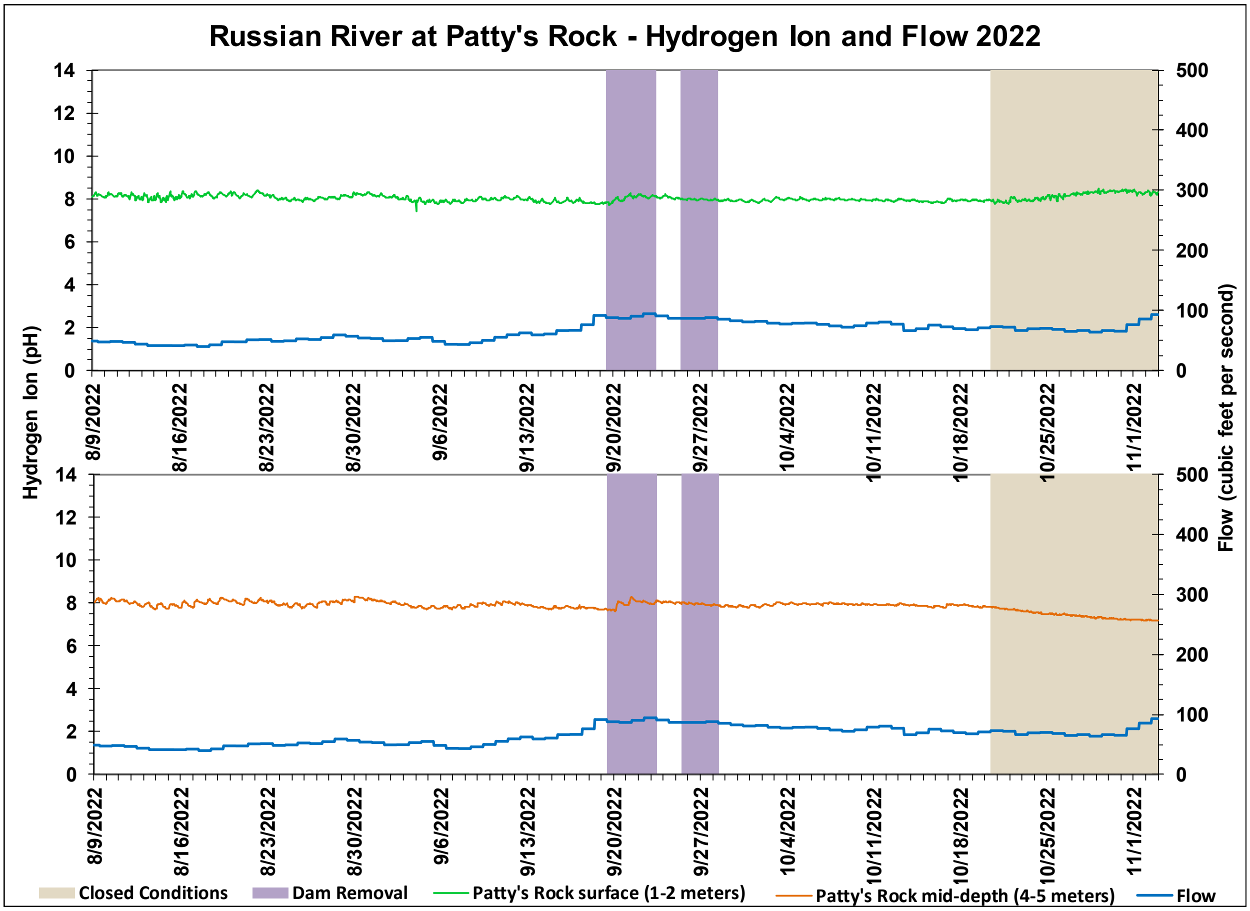


Figure 4.1.15. 2022 Russian River at Patty's Rock Hydrogen Ion and Flow Graph

The Willow Creek station had a minimum pH value of 6.3, a mean pH value of 7.6, and a maximum pH value of 8.7 (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 4.1.16 and 4.1.12).

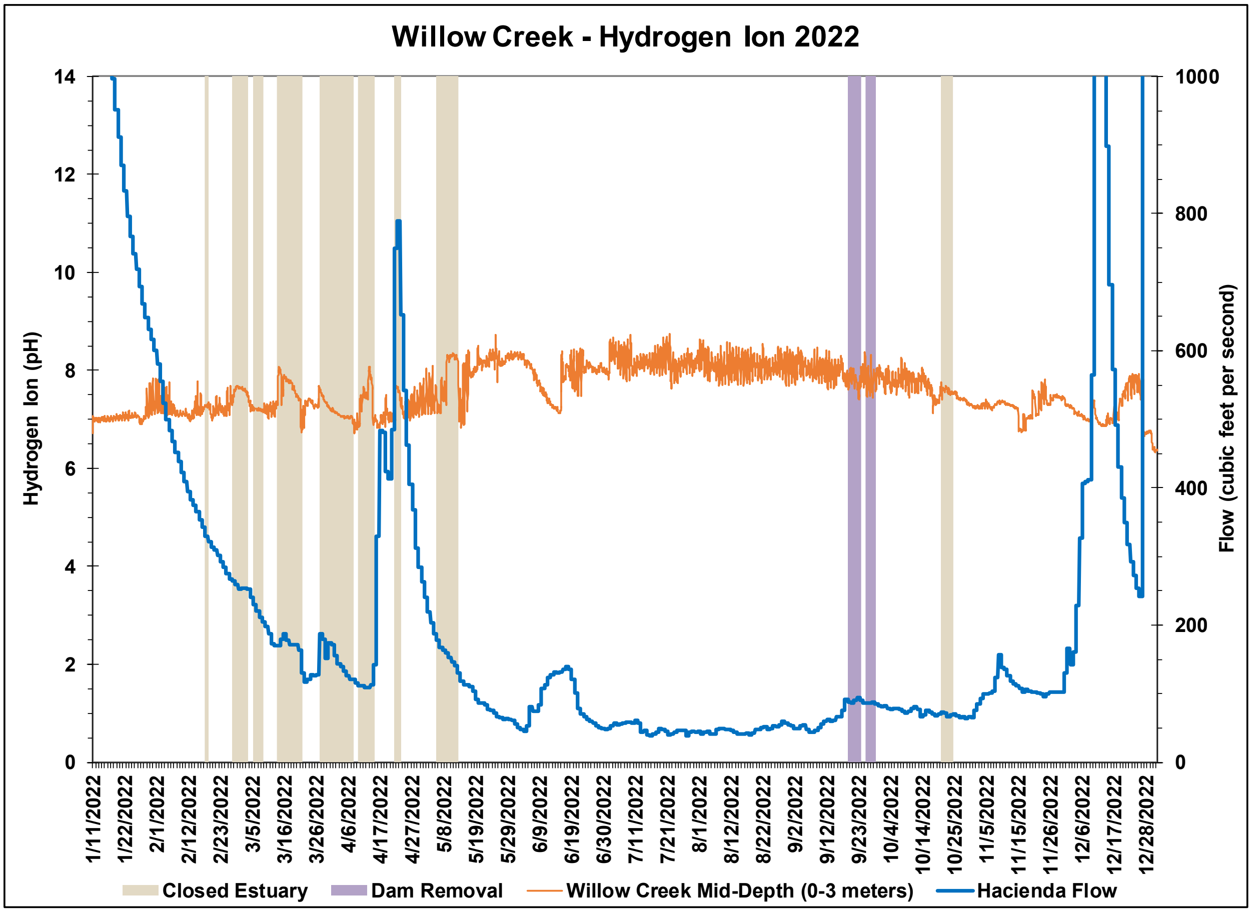


Figure 4.1.16. 2022 Willow Creek Hydrogen Ion and Russian River Flow Graph

Upper Reach pH

The Freezeout Creek mid-depth sonde recorded a minimum pH value of 7.6, a mean pH value of 8.5, and a maximum pH value of 9.2 (Table 4.1.1). The Freezeout Creek bottom sonde had a minimum pH value of 5.4, a mean pH value of 6.8, and a maximum pH value of 9.2 (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 4.1.17 and 4.1.13).

The Brown's Pool mid-depth sonde had a minimum pH value of 7.1, a mean pH value of 7.7, and a maximum pH value of 8.5 (Table 4.1.1). The Brown's Pool bottom sonde had a minimum pH value of 6.0, a mean pH value of 6.7, and a maximum pH value of 8.0 (Table 4.1.1). Minimum pH values occurred at the bottom sonde in brackish water during anoxic conditions when the Estuary was open (Figures 4.1.18 and 4.1.14).

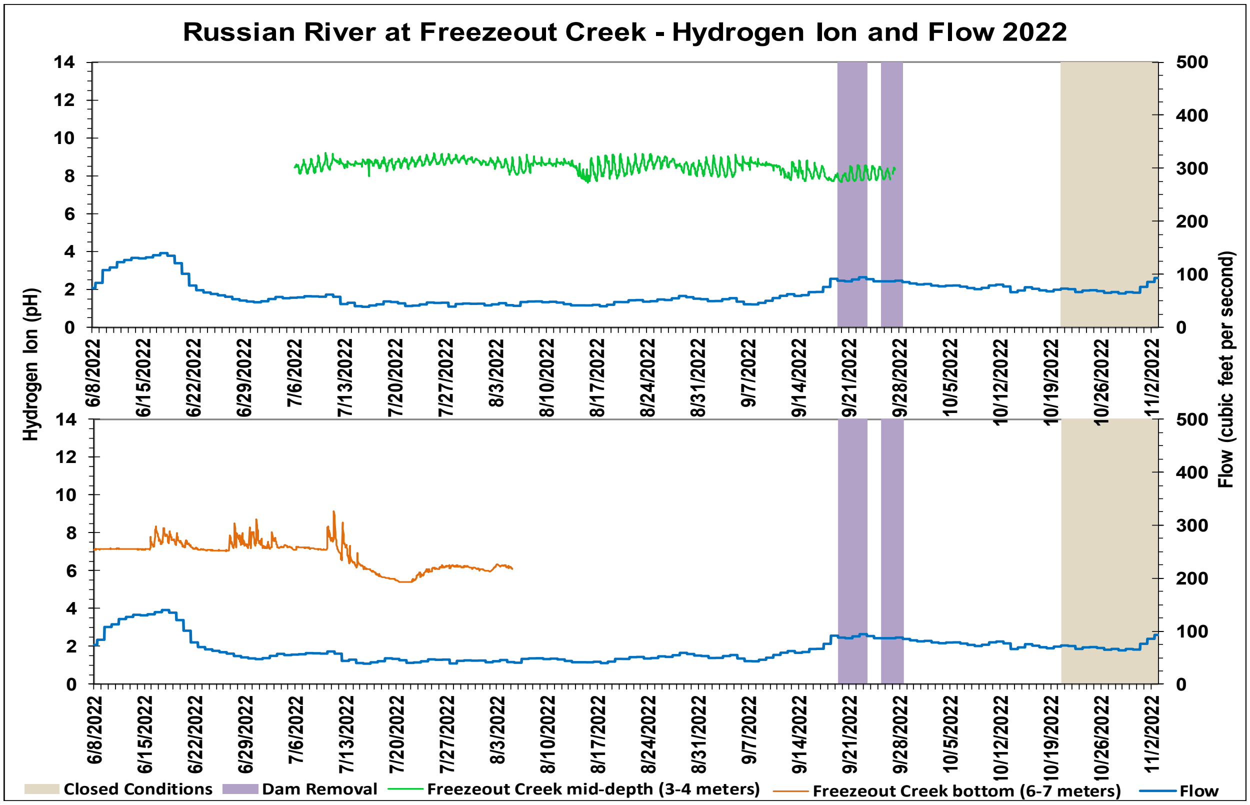


Figure 4.1.17. 2022 Russian River at Freezeout Creek Hydrogen Ion and Flow Graph

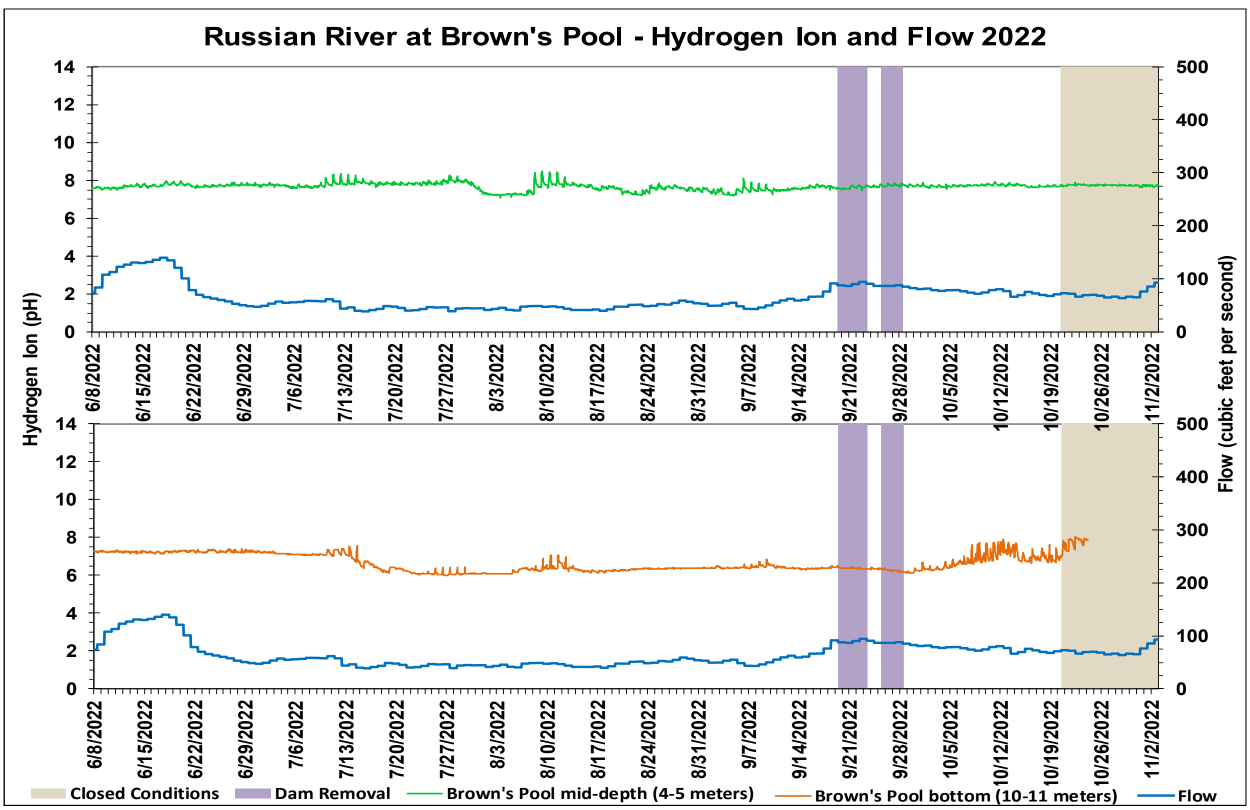


Figure 4.1.18. 2022 Russian River at Brown's Pool Hydrogen Ion and Flow Graph

Grab Sampling

Sonoma Water staff conducted weekly grab sampling from 19 April to 18 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 over a ten day period (Tables 4.1.2 through 4.1.7). Samples collected and analyzed for nutrients, turbidity, *chlorophyll a*, and indicator bacteria are discussed below. Other sample results including total and dissolved organic carbon and total dissolved solids are not discussed, but are included (Table 4.1.2 through 4.1.4).

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).

Highlighted values indicate those values exceeding EPA Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion III (EPA, 2000). Lab analysis constraints in 2022 resulted in a method detection limit (MDL) for *chlorophyll a*, which is the level of accuracy for a given lab analysis to provide a valid concentration of a given constituent, that was higher than the EPA criteria for exceedances for *chlorophyll a* in rivers and streams. Put simply, the EPA exceedance criteria for *chlorophyll a* in rivers and streams is approximately 0.0018 mg/L, whereas the lab analysis MDL for *chlorophyll a* was 0.0030 mg/L. Therefore, some lab results for *chlorophyll a* that are listed as non-detect (ND) could potentially have concentrations above the criteria and below the MDL, which in turn could result in an under representation of the actual number of exceedances observed. However, for reporting purposes, only those exceedances that are quantified will be included in the summation.

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.

Finally, it must be emphasized that the EPA criteria are not adopted standards and are therefore both subject to change (if it is determined that the guidelines or criteria are not accurate indicators) and are not currently enforceable.

Total Nitrogen

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 (Appendix A).

The EPA criteria for Total Nitrogen was exceeded three times (3 of 81 or 3.7%), including one exceedance at Patterson Point and two exceedances at Vacation Beach during the 2022 monitoring period with Hacienda flows ranging from approximately 47.7 cfs to 87.4 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.19). The exceedances were observed to occur during open estuary conditions and summer dam removal (Figure 4.1.19). There were several non-detects (ND) of total nitrogen that occurred periodically throughout the season during open and closed conditions, with flows ranging from 43.7 cfs to 219 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.19).

The maximum total nitrogen concentration observed at Patterson Point was 0.40 mg/L on 27 September during open conditions and summer dam removal, with a flow of approximately 87.4 cfs (Table 4.1.2 and Figure 4.1.19). The minimum concentration at Patterson Point was non-detect (ND), which occurred seven (7) times during open conditions with flows ranging from approximately 43.7 cfs to 219 cfs (Table 4.1.2).

The maximum total nitrogen concentration observed at Monte Rio was 0.34 mg/L on 19 April during open conditions with a flow of approximately 424 cfs (Table 4.1.3 and Figure 4.1.19). The minimum concentration at Monte Rio was ND, which occurred nine (9) times during open conditions and flows that ranged from approximately 43.7 cfs to 219 cfs (Table 4.1.3).

The maximum total nitrogen concentration observed at Vacation Beach was 0.50 mg/L which occurred on 19 July during open conditions and a flow of approximately 47.7 cfs (Table 4.1.4 and Figure 4.1.19). The minimum concentration at Vacation Beach was ND, which occurred nine (9) times during open and closed conditions and flows that ranged from approximately 43.7 cfs to 153 cfs (Table 4.1.4).

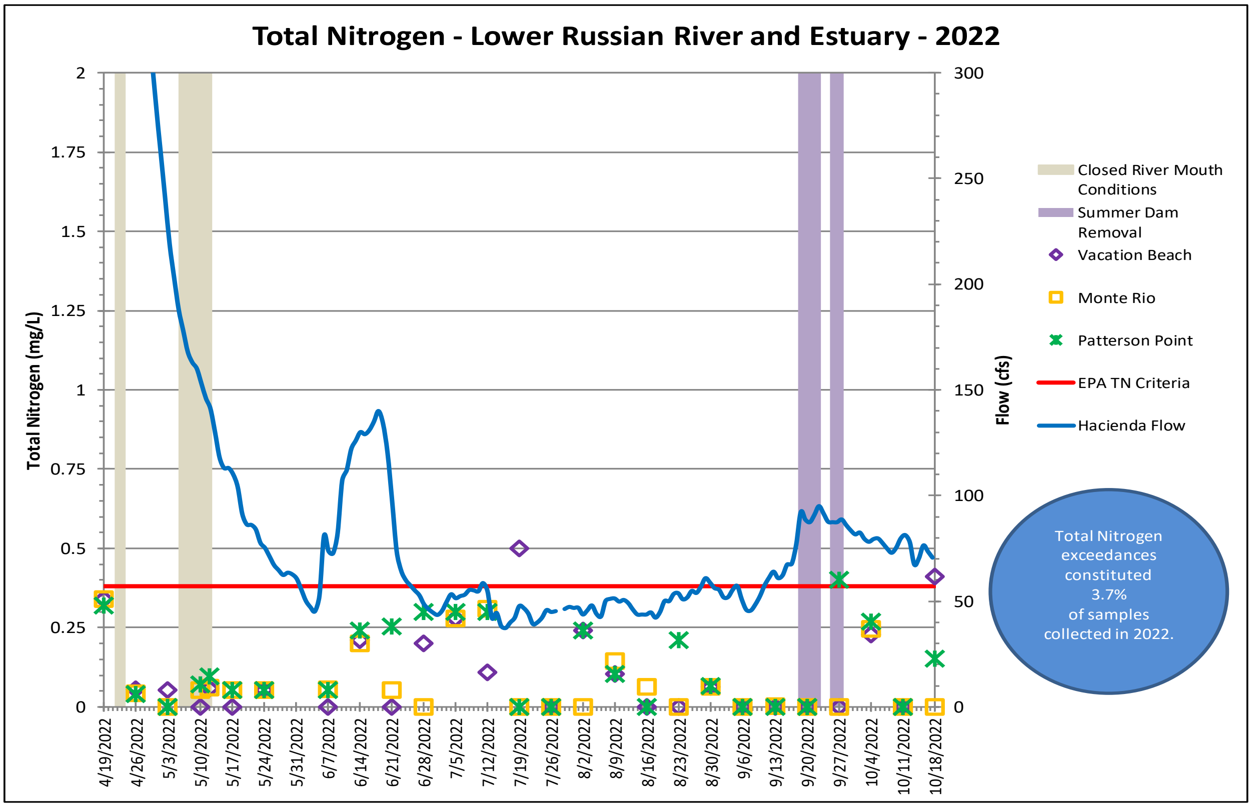


Figure 4.1.19. 2022 Russian River Grab Sampling Results for Total Nitrogen

Table 4.1.2. 2022 Russian River at Patterson Point Station Grab Sample Results

Patterson Point	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.10	0.10	0.00010	0.040	0.050	0.20	0.30	0.010	0.030	0.200	0.300	10	0.10	0.0030	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
4/19/2022	15.0	0.23	ND	ND	0.095	ND	0.23	0.32	**0.058**	0.14	3.07	3.21	170	**3.5**	**0.0059**	424	open	0.63
4/26/2022	17.0	ND	ND	ND	0.041	ND	ND	0.041	**0.064**	0.12	3.23	3.75	150	**4.4**	**0.0048**	463	open	3.75
5/3/2022	17.7	ND	ND	ND	ND	ND	ND	ND	**0.066**	0.15	2.20	2.85	180	1.6	ND	219	open	0.88
5/10/2022	17.0	ND	ND	ND	0.072	ND	ND	0.072	**0.068**	0.16	2.16	2.62	170	1.1	ND	153	closed	5.98
5/12/2022	17.7	ND	ND	ND	0.095	ND	ND	0.095	**0.064**	0.14	1.91	2.47	170	1.2	**0.0083**	141	closed	6.78
5/17/2022	20.1	ND	ND	ND	0.053	ND	ND	0.053	**0.061**	0.12	1.75	2.20	180	2.0	ND	110	open	0.42
5/24/2022	22.1	ND	ND	ND	0.054	ND	ND	0.054	**0.078**	0.18	1.94	2.30	180	1.2	**0.0064**	75.2	open	1.39
6/7/2022	22.3	ND	ND	ND	0.053	ND	ND	0.053	**0.070**	0.15	1.58	1.89	190	1.5	**0.0043**	73.7	open	1.85
6/14/2022	23.2	0.24	ND	ND	ND	ND	0.24	0.24	**0.080**	0.18	2.06	2.48	170	1.3	ND	130	open	2.99
6/21/2022	22.2	0.20	ND	ND	0.053	ND	0.20	0.253	**0.045**	0.081	1.94	2.12	150	0.93	ND	97.4	open	1.09
6/28/2022	23.3	0.27	ND	ND	ND	ND	0.27	0.30	**0.062**	0.11	1.73	2.07	170	**2.5**	**0.0048**	48.6	open	0.59
7/5/2022	22.8	0.30	ND	ND	ND	ND	0.30	0.30	**0.068**	0.14	1.70	2.09	160	1.4	ND	51.4	open	0.67
7/12/2022	23.9	0.30	ND	ND	ND	ND	0.30	0.30	**0.060**	0.12	1.99	2.79	150	2.0	ND	54.8	open	0.63
7/19/2022	23.7	ND	ND	ND	ND	ND	ND	ND	**0.059**	0.12	2.24	2.56	150	**4.2**	**0.0048**	47.7	open	0.76
7/26/2022	22.9	ND	ND	ND	ND	ND	ND	ND	**0.056**	0.099	1.99	2.52	160	1.6	ND	44.9	open	0.50
8/2/2022	23.1	ND	ND	ND	ND	ND	ND	ND	**0.056**	0.11	2.11	2.58	180	2.1	**0.0048**	43.7	open	0.50
8/9/2022	23.2	ND	0.12	0.0038	ND	ND	ND	0.1238	**0.060**	0.093	2.02	2.43	160	1.5	ND	51.3	open	0.55
8/16/2022	23.5	ND	ND	ND	ND	ND	ND	ND	**0.056**	0.079	1.91	2.24	140	1.2	**0.0051**	43.7	open	0.55
8/23/2022	23.3	0.21	ND	ND	ND	ND	0.21	0.21	**0.048**	0.077	1.90	2.24	140	1.8	**0.0040**	53.8	open	0.46
8/30/2022	22.3	ND	ND	ND	0.065	ND	ND	0.065	**0.041**	0.071	1.68	2.07	140	1.0	**0.0045**	58.8	open	0.46
9/6/2022	23.5	ND	ND	ND	ND	ND	ND	ND	**0.036**	0.053	1.75	2.09	150	1.1	ND	50.8	open	1.68
9/13/2022	21.8	ND	ND	0.0007	ND	ND	ND	0.0007	**0.037**	0.064	1.64	2.01	150	1.2	ND	64.0	open	0.55
9/20/2022	19.9	ND	ND	0.0001	ND	ND	ND	0.0001	**0.032**	0.038	1.71	2.17	140	0.85	ND	88.6	open	1.47
9/27/2022	19.9	0.40	ND	0.0002	ND	ND	0.40	**0.40**	**0.025**	0.034	1.63	2.06	170	1.5	ND	87.4	open	0.59
10/4/2022	19.1	ND	0.20	0.0033	0.066	ND	ND	0.2693	**0.029**	0.040	1.54	1.80	160	1.2	ND	78.1	open	1.60
10/11/2022	18.2	ND	ND	ND	ND	ND	ND	ND	**0.026**	0.030	1.52	1.85	120	0.70	ND	79.7	open	0.67
10/18/2022	17.1	ND	0.15	0.0021	ND	ND	ND	0.1521	**0.029**	0.045	1.43	1.86	160	1.0	ND	70.6	open	

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** 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 Phosphorus: 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

Total Phosphorus

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). All three lower river stations predominantly exceeded the EPA criteria for total phosphorous (81 of 81 or 100%) in 2022 with flows that ranged from 43.7 cfs to 463 cfs, continuing a trend of consistent exceedances observed in previous years (Tables 4.1.2 through 4.1.4 and Figure 4.1.20). Exceedances occurred during open and closed conditions, with concentrations generally declining through the monitoring season, including several concentrations below the EPA criteria from late August through October (Figure 4.1.20).

The maximum total phosphorus concentration observed at Patterson Point was 0.080 mg/L on 14 June during open conditions with a flow of approximately 130 cfs (Table 4.1.2 and Figure 4.1.20). The minimum concentration at Patterson Point was 0.025 mg/L, which occurred on 27 September during open conditions and summer dam removal, with a flow of approximately 87.4 cfs (Table 4.1.2). The lowest flow recorded during the sampling events was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with concentrations of 0.056 mg/L on both occasions (Table 4.1.2).

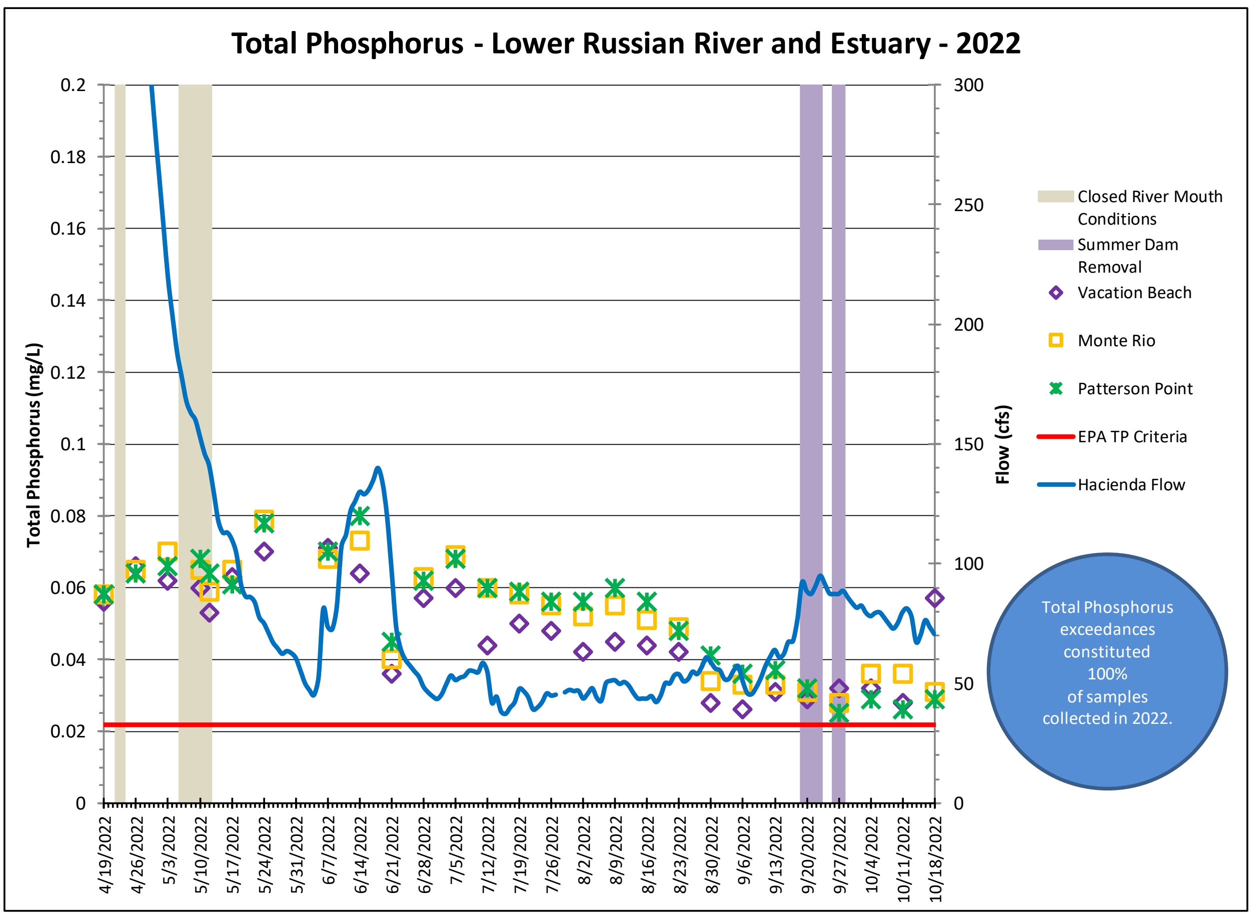


Figure 4.1.20. 2022 Russian River Grab Sampling Results for Total Phosphorus

Table 4.1.3. 2022 Russian River at Monte Rio Station Grab Sample Results

Monte Rio	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.10	0.10	0.00010	0.040	0.050	0.20	0.30	0.010	0.030	0.200	0.300	10	0.10	0.0030	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
4/19/2022	15.1	0.26	ND	ND	0.082	ND	0.26	0.34	**0.058**	0.13	2.88	3.67	260	**2.4**	**0.0032**	424	open	0.59
4/26/2022	16.7	ND	ND	ND	0.042	ND	ND	0.042	**0.065**	0.13	3.51	3.69	150	**6.0**	**0.0064**	463	open	3.75
5/3/2022	18.0	ND	ND	ND	ND	ND	ND	ND	**0.070**	0.15	2.31	2.83	180	1.9	**0.0035**	219	open	0.80
5/10/2022	17.3	ND	ND	ND	0.053	ND	ND	0.053	**0.065**	0.15	2.02	2.44	200	1.2	ND	153	closed	5.94
5/12/2022	17.3	ND	ND	ND	0.061	ND	ND	0.061	**0.059**	0.13	1.87	2.35	180	1.6	ND	141	closed	6.74
5/17/2022	20.4	ND	ND	ND	0.053	ND	ND	0.053	**0.065**	0.12	1.78	2.26	190	1.4	ND	110	open	0.42
5/24/2022	22.0	ND	ND	ND	0.054	ND	ND	0.054	**0.079**	0.17	1.93	2.33	200	1.6	**0.0040**	75.2	open	1.18
6/7/2022	22.4	ND	ND	ND	0.055	ND	ND	0.055	**0.068**	0.15	1.61	1.92	190	1.9	ND	73.7	open	1.81
6/14/2022	23.7	0.20	ND	ND	ND	ND	0.20	0.20	**0.073**	0.17	1.91	2.34	160	1.8	ND	130	open	2.95
6/21/2022	22.5	ND	ND	ND	0.054	ND	ND	0.054	**0.040**	0.077	1.93	2.24	180	0.96	ND	97.4	open	1.05
6/28/2022	23.2	ND	ND	ND	ND	ND	ND	ND	**0.063**	0.12	1.77	2.07	200	**2.9**	ND	48.6	open	0.59
7/5/2022	23.0	0.28	ND	ND	ND	ND	0.28	0.28	**0.069**	0.13	1.75	2.05	160	1.8	**0.0043**	51.4	open	0.63
7/12/2022	23.7	0.25	ND	ND	0.063	ND	0.25	0.31	**0.060**	0.11	1.92	2.62	150	1.9	ND	54.8	open	0.71
7/19/2022	23.9	ND	ND	ND	ND	ND	ND	ND	**0.058**	0.11	1.98	2.50	160	**3.2**	**0.0045**	47.7	open	0.59
7/26/2022	23.1	ND	ND	ND	ND	ND	ND	ND	**0.055**	0.099	2.03	2.41	150	2.1	ND	44.9	open	0.59
8/2/2022	23.2	ND	ND	ND	ND	ND	ND	ND	**0.052**	0.098	2.25	2.73	170	**2.4**	**0.0045**	43.7	open	0.50
8/9/2022	23.6	ND	0.14	0.0049	ND	ND	ND	0.1449	**0.055**	0.085	1.96	2.39	160	1.3	ND	51.3	open	0.63
8/16/2022	23.6	ND	ND	ND	0.063	ND	ND	0.063	**0.051**	0.071	1.87	2.29	140	1.2	ND	43.7	open	0.50
8/23/2022	23.5	ND	ND	ND	ND	ND	ND	ND	**0.049**	0.069	1.88	2.21	160	0.95	ND	53.8	open	0.55
8/30/2022	22.2	ND	ND	ND	0.063	ND	ND	0.063	**0.034**	0.059	1.65	2.07	130	1.1	ND	58.8	open	0.46
9/6/2022	23.7	ND	ND	ND	ND	ND	ND	ND	**0.033**	0.041	1.68	2.03	140	0.95	ND	50.8	open	1.81
9/13/2022	21.9	ND	ND	0.0013	ND	ND	ND	0.0013	**0.033**	0.056	1.78	2.16	150	0.95	**0.0043**	64.0	open	0.50
9/20/2022	19.8	ND	ND	0.0006	ND	ND	ND	0.0006	**0.031**	0.034	1.72	2.11	120	1.0	ND	88.6	open	1.68
9/27/2022	19.8	ND	ND	0.0008	ND	ND	ND	0.0008	**0.028**	0.030	1.57	1.89	170	2.3	ND	87.4	open	0.59
10/4/2022	18.9	ND	0.18	0.0030	0.063	ND	ND	0.246	**0.036**	0.036	1.67	1.79	160	1.6	ND	78.1	open	1.68
10/11/2022	17.9	ND	ND	ND	ND	ND	ND	ND	**0.036**	0.03	1.45	1.78	130	0.85	**0.0059**	79.7	open	0.80
10/18/2022	16.7	ND	ND	ND	ND	ND	ND	ND	**0.031**	0.049	1.50	1.71	66	2.0	ND	70.6	open	

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** 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 Phosphorus: 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

The maximum total phosphorus concentration observed at Monte Rio was 0.079 mg/L on 24 May during open conditions with a flow of approximately 75.2 cfs (Table 4.1.3 and Figure 4.1.20). The minimum concentration at Monte Rio was 0.028 mg/L, which occurred on 27 September during open conditions, with a flow of approximately 87.4 cfs (Table 4.1.3). The lowest flow recorded during the sampling events was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with concentrations of 0.052 mg/L and 0.051 mg/L, respectively (Table 4.1.3).

The maximum total phosphorus concentration observed at Vacation Beach was 0.071 mg/L on 7 June during open conditions and a flow of approximately 73.7 cfs (Table 4.1.4 and Figure 4.1.20). The minimum concentration at Vacation Beach was 0.026 mg/L, which occurred on 6 September during open conditions and a flow of approximately 50.8 cfs (Table 4.1.4). The lowest flow recorded during the sampling events was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with concentrations of 0.42 mg/L and 0.044 mg/L, respectively (Table 4.1.4).

Turbidity

The EPA recommended criteria of 2.34 nephelometric turbidity units (NTU) for turbidity was exceeded four (4) times at Patterson Point, five (5) times at Monte Rio, and five (5) times at Vacation Beach (14 of 81 or 17.3%) during the 2022 monitoring season (Tables 4.1.2 through 4.1.4). Exceedances were observed to occur periodically through season with open and closed conditions and flows ranging from 43.7 cfs to 463 cfs (Figure 4.1.21). One of the exceedances at Vacation Beach occurred during summer dam removal. Turbidity values were occasionally higher at Vacation Beach than at the other stations, and may be a result of increased turbulence from the Vacation Beach summer dam located just upstream of the monitoring location.

The maximum turbidity value observed at Patterson Point was 4.4 NTU on 26 April during open conditions and a flow of approximately 463 cfs at the Hacienda USGS gage (Table 4.1.2 and Figure 4.1.21). The minimum value at Patterson Point was 0.70 NTU, which occurred on 11 October during open conditions and a flow of approximately 79.7 cfs (Table 4.1.2). The lowest flow recorded during sampling was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with values of 2.1 NTU and 1.2 NTU, respectively (Table 4.1.2).

The maximum turbidity value observed at Monte Rio was 6.0 NTU on 26 April during open conditions and a flow of approximately 463 cfs (Table 4.1.3 and Figure 4.1.21). The minimum value at Monte Rio was 0.85 NTU, which occurred on 11 October during open conditions and a flow of approximately 79.7 cfs (Table 4.1.3). The lowest flow recorded during sampling was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with values of 2.4 NTU and 1.2 NTU, respectively (Table 4.1.3).

The maximum turbidity value observed at Vacation Beach was 5.5 NTU on 26 April during open conditions and a flow of approximately 463 cfs (Table 4.1.4 and Figure 4.1.21). The minimum value at Vacation Beach was 0.70 NTU, which occurred on 11 October during open conditions and a flow of approximately 79.7 cfs (Table 4.1.4). The lowest flow recorded during sampling was approximately 43.7 cfs, which occurred twice on 2 August and 16 August during open conditions, with values of 2.2 NTU and 1.8 NTU, respectively (Table 4.1.4).

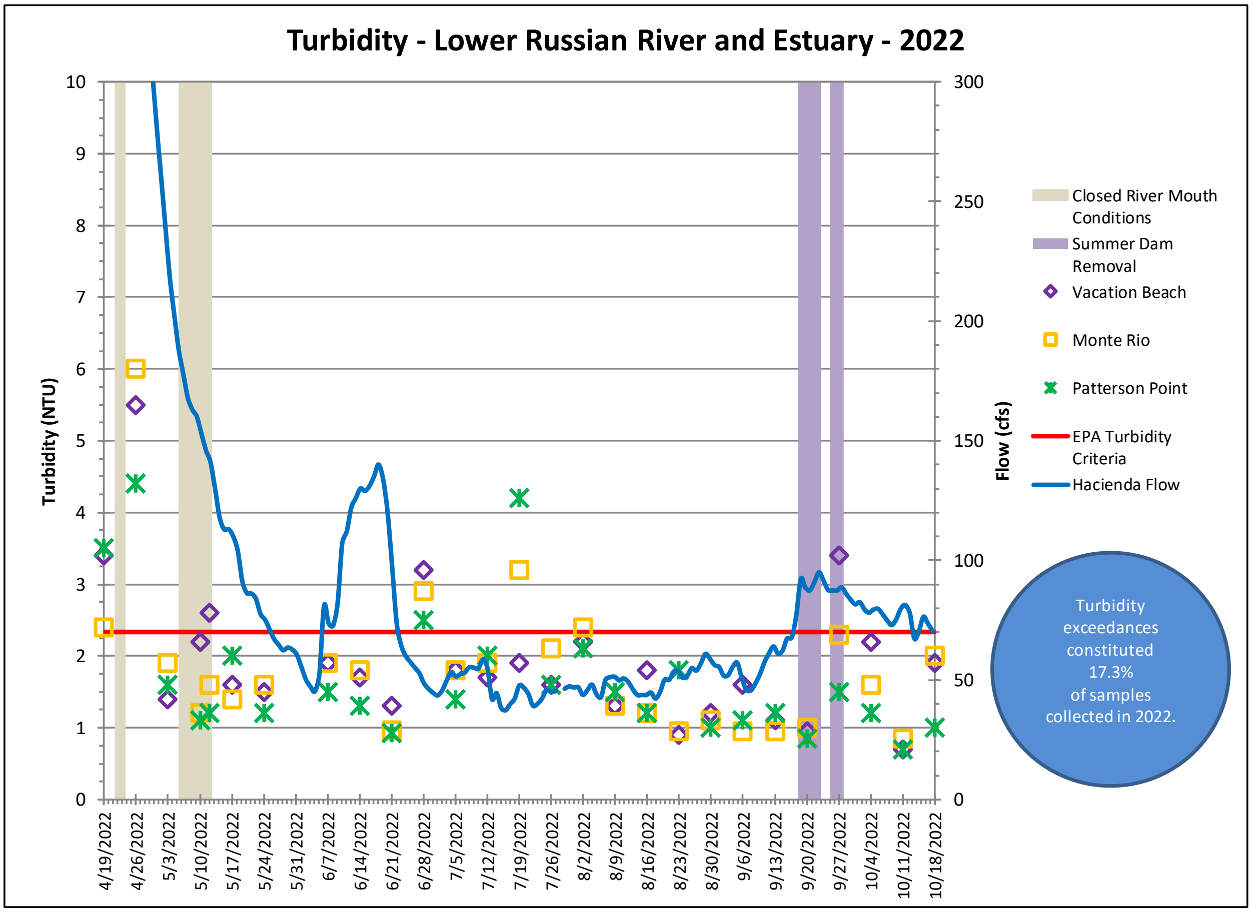


Figure 4.1.21. 2022 Russian River Grab Sampling Results for Turbidity

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).

As mentioned above, lab analysis constraints in 2022 resulted in the MDL for *chlorophyll a* being higher than the EPA criteria for exceedances for *chlorophyll a* in rivers and streams.

Therefore, some lab results for *chlorophyll a* that are listed as non-detect (ND) could potentially have concentrations above the criteria and below the MDL. However, for reporting purposes, only those exceedances that are quantified will be included in the summation.

In addition, 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 results exceeded the EPA criteria eleven (11) times at Patterson Point, nine (9) times at Monte Rio, and sixteen (16) times at Vacation Beach (36 of 81 or 44.4%) under open and closed conditions, with flows that ranged from 43.7 cfs to 463 cfs (Tables 4.1.2 through 4.1.4 and Figure 4.1.22).

Chlorophyll a values varied through the season with several ND values occurring at all three stations during open and closed barrier beach conditions (Figure 4.1.22).

The maximum *Chlorophyll a* concentration observed at Patterson Point was 0.0083 mg/L on 12 May during closed conditions with a flow of approximately 141 cfs (Table 4.1.2 and Figure 4.1.22). The minimum value at Patterson Point was ND, which occurred sixteen (16) times through the season, during open and closed conditions and summer dam removal, with flows that ranged from 44.9 cfs to 219 cfs (Table 4.1.2).

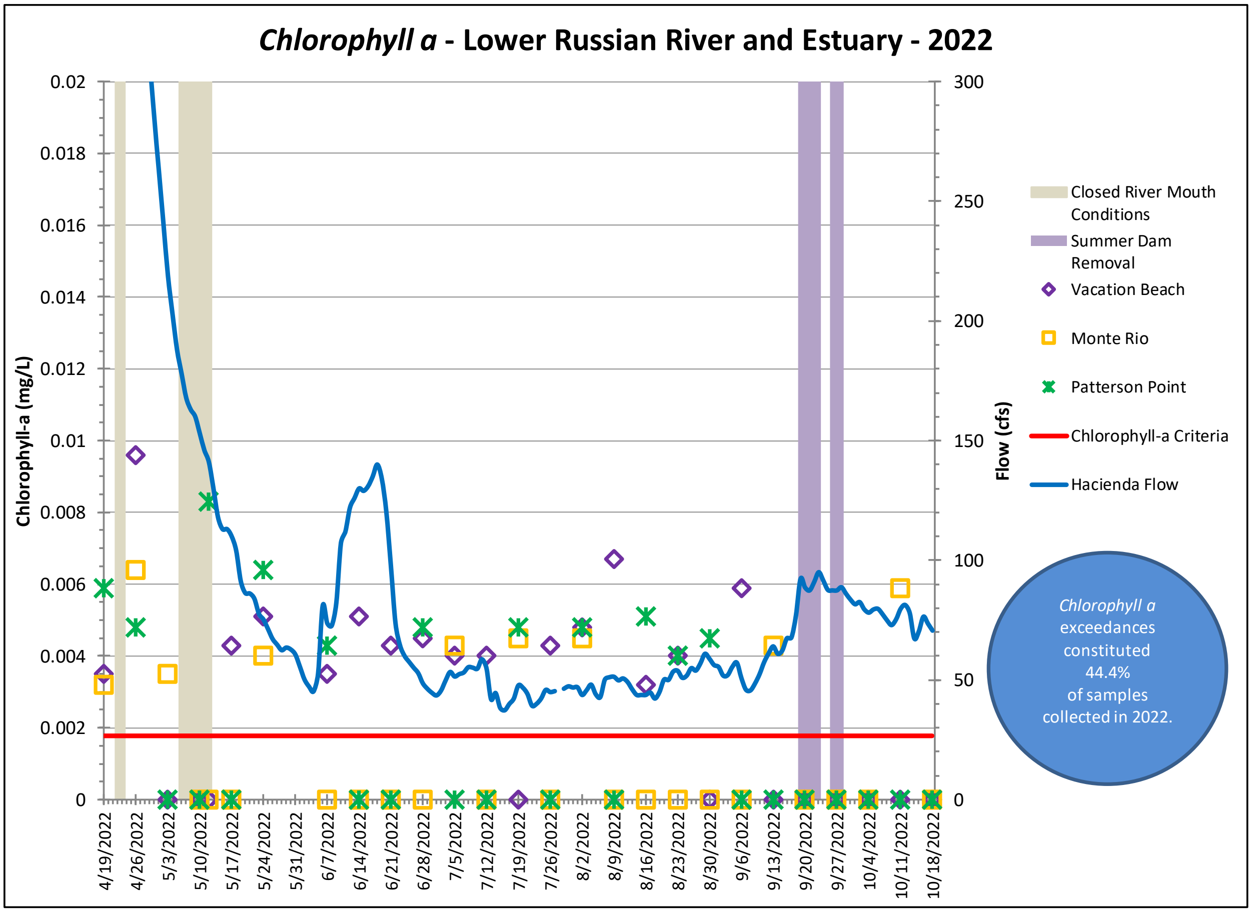


Figure 4.1.22. 2022 Russian River Grab Sampling Results for *Chlorophyll a*

Table 4.1.4. 2022 Russian River at Vacation Beach Station Grab Sample Results

Vacation Beach	Temperature	Total Organic Nitrogen	Ammonia as N	Ammonia as N Unionized	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen	Total Nitrogen**	Phosphorus, Total	Total Orthophosphate	Dissolved Organic Carbon	Total Organic Carbon	Total Dissolved Solids	Turbidity	Chlorophyll-a	USGS 11467000 RR near Guerneville (Hacienda)***	Estuary Condition	Jenner Gauge
MDL*		0.10	0.10	0.00010	0.040	0.050	0.20	0.30	0.010	0.030	0.200	0.300	10	0.10	0.0030	Flow Rate****		
Date	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	(cfs)		(ft)
4/19/2022	15.3	0.24	ND	ND	0.10	ND	0.24	0.34	**0.056**	0.12	3.03	3.47	160	**3.4**	**0.0035**	424	open	0.55
4/26/2022	16.7	ND	ND	ND	0.056	ND	ND	0.056	**0.066**	0.13	3.06	3.62	160	**5.5**	**0.0096**	463	open	3.79
5/3/2022	17.6	ND	ND	ND	0.054	ND	ND	0.054	**0.062**	0.13	2.26	2.72	170	1.4	ND	219	open	0.71
5/10/2022	17.1	ND	ND	ND	ND	ND	ND	ND	**0.060**	0.12	1.88	2.29	170	2.2	ND	153	closed	5.94
5/12/2022	16.2	ND	ND	ND	0.058	ND	ND	0.058	**0.053**	0.11	1.77	2.28	180	**2.6**	ND	141	closed	6.74
5/17/2022	20.5	ND	ND	ND	ND	ND	ND	ND	**0.063**	0.17	1.80	2.34	170	1.6	**0.0043**	110	open	0.38
5/24/2022	22.7	ND	ND	ND	0.053	ND	ND	0.053	**0.070**	0.14	1.84	2.13	190	1.5	**0.0051**	75.2	open	1.05
6/7/2022	22.9	ND	ND	ND	ND	ND	ND	ND	**0.071**	0.14	1.64	1.94	180	1.9	**0.0035**	73.7	open	1.77
6/14/2022	22.6	0.21	ND	ND	ND	ND	0.21	0.21	**0.064**	0.13	1.88	2.31	160	1.7	**0.0051**	130	open	2.86
6/21/2022	22.3	ND	ND	ND	ND	ND	ND	ND	**0.036**	0.061	2.17	2.14	160	1.3	**0.0043**	97.4	open	1.05
6/28/2022	23.8	ND	ND	ND	ND	ND	0.20	0.20	**0.057**	0.093	1.83	2.15	180	**3.2**	**0.0045**	48.6	open	0.59
7/5/2022	23.1	0.28	ND	ND	ND	ND	0.28	0.28	**0.060**	0.11	1.72	2.22	160	1.8	**0.0040**	51.4	open	0.59
7/12/2022	24.5	ND	0.11	ND	ND	ND	ND	0.11	**0.044**	0.077	1.98	2.77	140	1.7	**0.0040**	54.8	open	0.97
7/19/2022	24.4	0.47	ND	ND	ND	ND	0.47	**0.50**	**0.050**	0.089	2.07	2.56	150	1.9	ND	47.7	open	0.55
7/26/2022	23.3	ND	ND	ND	ND	ND	ND	ND	**0.048**	0.076	2.01	2.44	150	1.6	**0.0043**	44.9	open	0.63
8/2/2022	23.5	0.24	ND	ND	ND	ND	0.24	0.24	**0.042**	0.078	2.06	2.66	150	2.2	**0.0048**	43.7	open	0.42
8/9/2022	23.2	ND	0.10	0.0031	ND	ND	ND	0.1031	**0.045**	0.057	1.97	2.33	150	1.3	**0.0067**	51.3	open	0.84
8/16/2022	24.0	ND	ND	ND	ND	ND	ND	ND	**0.044**	0.043	2.04	2.19	140	1.8	**0.0032**	43.7	open	0.46
8/23/2022	23.7	ND	ND	ND	ND	ND	ND	ND	**0.042**	0.049	1.86	2.18	150	0.90	**0.0040**	53.8	open	0.67
8/30/2022	22.6	ND	ND	ND	0.063	ND	ND	0.063	**0.028**	0.042	1.67	2.07	130	1.2	ND	58.8	open	0.50
9/6/2022	24.1	ND	ND	ND	ND	ND	ND	ND	**0.026**	ND	1.62	1.96	140	1.6	**0.0059**	50.8	open	1.85
9/13/2022	22.3	ND	ND	0.0007	ND	ND	ND	0.0007	**0.031**	0.039	1.67	2.07	130	1.1	ND	64.0	open	0.50
9/20/2022	19.6	ND	ND	0.0007	ND	ND	ND	0.0007	**0.029**	0.034	1.62	2.04	94	0.95	ND	88.6	open	1.73
9/27/2022	19.6	ND	ND	0.0001	ND	ND	ND	0.0001	**0.032**	0.030	1.56	1.88	170	**3.4**	ND	87.4	open	0.67
10/4/2022	19.0	ND	0.16	0.0038	0.064	ND	ND	0.2278	**0.032**	0.04	1.47	1.75	170	2.2	ND	78.1	open	1.73
10/11/2022	18.3	ND	ND	ND	ND	ND	ND	ND	**0.028**	ND	1.49	1.79	140	0.70	ND	79.7	open	1.01
10/18/2022	17.0	0.41	ND	ND	ND	ND	0.41	**0.41**	**0.057**	0.032	1.44	1.71	160	1.9	ND	70.6	open	

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** 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 Phosphorus: 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

The maximum *Chlorophyll a* concentration observed at Monte Rio was 0.0064 mg/L on 26 April during open conditions and a flow of approximately 463 cfs (Table 4.1.3 and Figure 4.1.22). The minimum value at Monte Rio was ND, which occurred eighteen (18) times through the season, during open and closed conditions and summer dam removal, with flows that ranged from 43.7 cfs to 153 cfs (Table 4.1.3).

The maximum *Chlorophyll a* concentration observed at Vacation Beach was 0.0096 mg/L on 26 April during open conditions and a flow of approximately 463 cfs (Table 4.1.4 and Figure 4.1.22). The minimum value at Vacation Beach was ND, which occurred eleven (11) times through the season during open and closed conditions and summer dam removal, with flows that ranged from 47.7 cfs to 219 cfs (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 75th 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 4.1.5 through 4.1.7 and Figures 4.1.23 and 4.1.25. Samples collected for Enterococcus were undiluted only and results are included in Tables 4.1.5 through 4.1.7 and Figure 4.1.25. 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 4.1.25 and 4.1.26 utilize undiluted sample results unless the reporting limit has been exceeded, at which point the diluted results are utilized.

Beginning in 2014, 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 discuss potential adaptive management actions including mechanical breaching of the barrier beach to address potential threats to public health.

E. coli

There was one (1) exceedance (1 of 75 or 1.3%) of the EPA criteria for E. coli during the 2022 monitoring season at the lower river stations (Tables 4.1.5 through 4.1.7 and Figure 4.1.23), which was observed at Vacation Beach on 26 July (Tables 4.1.5 through 4.1.7 and Figure 4.1.23).

The maximum E. coli concentration observed at Patterson Point was 93.3 MPN/100mL, which occurred on 3 May during open conditions and a flow of approximately 219 cfs (Table 4.1.5 and Figure 4.1.23).

The maximum E. coli concentration observed at Monte Rio was 73.3 MPN/100mL, which occurred on 11 October during open conditions and a flow of approximately 79.7 cfs (Table 4.1.6 and Figure 4.1.23).

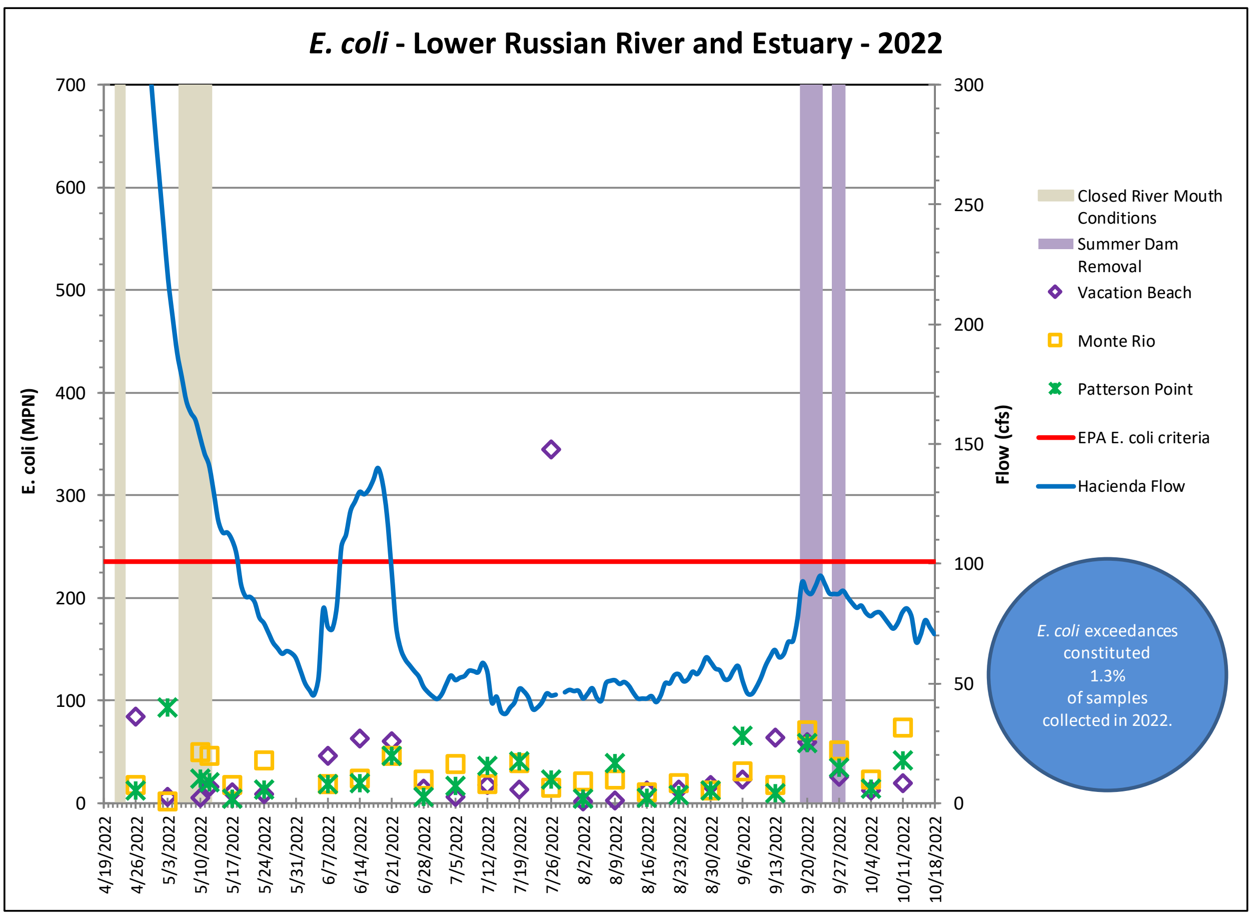


Figure 4.1.23. 2022 Russian River Grab Sampling Results for E. coli

Table 4.1.5. 2022 Russian River at Patterson Point Station Indicator Bacteria Grab Sample Results

Patterson Point	Temperature	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)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
4/26/2022	17.0	>2419.6	816	12.2	10	21.1	463	open	3.75
5/3/2022	17.7	344.8	435	93.3	121	4.1	219	open	0.88
5/10/2022	17.0	816.4	776	24	41	19.9	153	closed	5.98
5/12/2022	17.7	686.7	323	20.1	31	7.5	141	closed	6.78
5/17/2022	20.1	1986.3	2412	4.1	<10	8.6	110	open	0.42
5/24/2022	22.1	1413.6	1439	13.5	<10	6.3	75.2	open	1.39
6/7/2022	22.3	1732.9	1259	18.7	20	9.8	73.7	open	1.85
6/14/2022	23.2	2419.6	1616	19.9	31	30.9	130	open	2.99
6/21/2022	22.2	1732.9	1439	46.4	20	52.1	97.4	open	1.09
6/28/2022	23.3	1203.3	1169	6.3	<10	6.3	48.6	open	0.59
7/5/2022	22.8	1299.7	1500	17.1	20	2.0	51.4	open	0.67
7/12/2022	23.9	2419.6	1860	35.9	31	39.9	54.8	open	0.63
7/19/2022	23.7	1553.1	1314	41	<10	**63**	47.7	open	0.76
7/26/2022	22.9	816.4	959	23.1	20	16.0	44.9	open	0.5
8/2/2022	23.1	1046.2	1017	4.1	10	2.0	43.7	open	0.5
8/9/2022	23.2	1299.7	2140	39.3	31	27.5	51.3	open	0.55
8/16/2022	23.5	1046.2	789	5.2	<10	5.2	43.7	open	0.55
8/23/2022	23.3	1553.1	1236	7.5	41	8.6	53.8	open	0.46
8/30/2022	22.3	1299.7	1720	12.1	<10	3.1	58.8	open	0.46
9/6/2022	23.5	1986.3	2014	65.7	135	**65.1**	50.8	open	1.68
9/13/2022	21.8	1299.7	1515	9.7	10	2.0	64.0	open	0.55
9/20/2022	19.9	2419.6	3282	58.3	63	**151.5**	88.6	open	1.47
9/27/2022	19.9	1732.9	1850	34.5	52	60.9	87.4	open	0.59
10/4/2022	19.1	1413.6	1296	14.4	10	14.5	78.1	open	1.6
10/11/2022	18.2	1732.9	880	41.4	30	23.8	79.7	open	0.67

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.

Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml *Enterococcus*(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

The maximum E. coli concentration observed at Vacation Beach was 344.8 MPN/100mL, which occurred on 26 July during open conditions and a flow of approximately 44.9 cfs (Table 4.1.7 and Figure 4.1.23).

Total Coliform

There was one exceedance (1 of 75 or 1.3%) of the CDPH guideline for Total Coliform during the 2022 monitoring season (Tables 4.1.5 through 4.1.7 and Figure 4.1.24). Aside from the one exceedance at Vacation Beach, Total Coliform concentrations remained low at all three stations during the monitoring season (Figure 4.1.24).

The maximum Total Coliform concentration observed at Patterson Point was >2419.6 MPN/100mL, which occurred on 26 April during open estuary conditions and a flow of approximately 463 cfs (Table 4.1.5 and Figure 4.1.24).

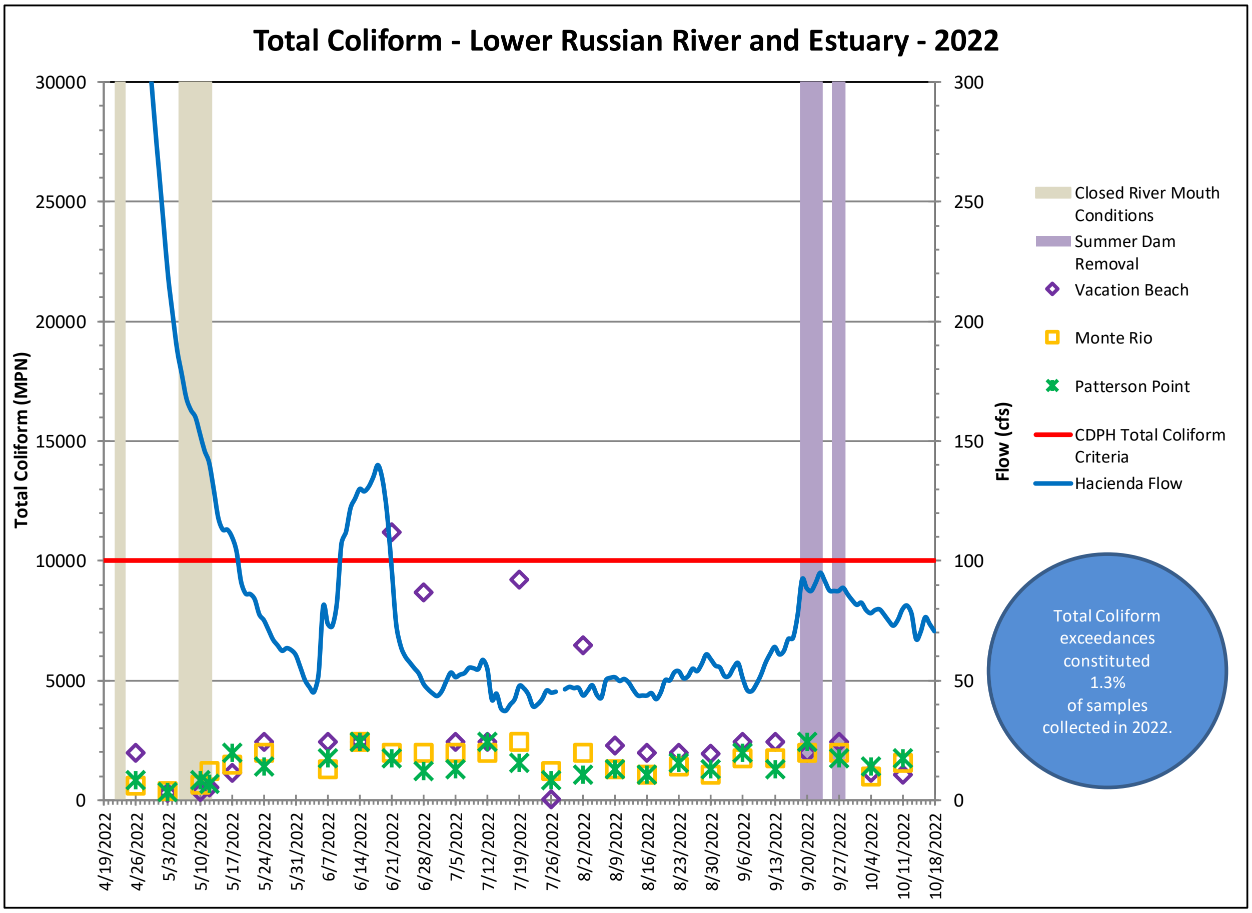


Figure 4.1.24. 2022 Russian River Grab Sampling Results for Total Coliform

The maximum Total Coliform concentration observed at Monte Rio was >2419.6 MPN/100mL, which occurred three times on 26 April, 17 May, and 12 July during open conditions and flows that ranged from 54.8 cfs to 463 cfs (Table 4.1.6 and Figure 4.1.24).

There was one exceedance of the Total Coliform guideline at the Vacation Beach station with a maximum concentration of 11,199 MPN/100mL, which occurred on 21 June during open conditions and a flow of approximately 97.4 cfs (Table 4.1.7 and Figure 4.1.24).

Table 4.1.6. 2022 Russian River at Monte Rio Station Indicator Bacteria Grab Sample Results

Monte Rio	Temperature	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)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
4/26/2022	16.7	>2419.6	624	17.5	20	18.3	463	open	3.75
5/3/2022	18.0	365.4	201	2.0	<10	4.1	219	open	0.8
5/10/2022	17.3	648.8	823	49.5	41	42.8	153	closed	5.94
5/12/2022	17.3	1203.3	932	46.5	31	**65.1**	141	closed	6.74
5/17/2022	20.4	>2419.6	1467	17.3	<10	5.2	110	open	0.42
5/24/2022	22.0	1986.3	2909	42.0	20	27.5	75.2	open	1.18
6/7/2022	22.4	1299.7	1396	18.9	20	29.2	73.7	open	1.81
6/14/2022	23.7	2419.6	1850	23.8	20	10.8	130	open	2.95
6/21/2022	22.5	1986.3	2064	46.2	10	22.6	97.4	open	1.05
6/28/2022	23.2	1986.3	1918	22.8	10	9.8	48.6	open	0.59
7/5/2022	23.0	1986.3	2282	38.4	75	21.3	51.4	open	0.63
7/12/2022	23.7	>2419.6	1989	18.7	41	49.5	54.8	open	0.71
7/19/2022	23.9	2419.6	2046	39.3	41	56.3	47.7	open	0.59
7/26/2022	23.1	1203.3	1670	14.6	20	44.1	44.9	open	0.59
8/2/2022	23.2	1986.3	1354	21.6	20	18.5	43.7	open	0.50
8/9/2022	23.6	1299.7	2978	23.3	20	13.2	51.3	open	0.63
8/16/2022	23.6	1046.2	958	10.8	<10	10.9	43.7	open	0.50
8/23/2022	23.5	1413.6	1500	19.9	31	8.4	53.8	open	0.55
8/30/2022	22.2	1046.2	1720	12.2	<10	9.7	58.8	open	0.46
9/6/2022	23.7	1732.9	2143	30.9	41	7.5	50.8	open	1.81
9/13/2022	21.9	1732.9	**12997**	17.5	10	7.5	64	open	0.5
9/20/2022	19.8	1986.3	1467	70.6	85	21.3	88.6	open	1.68
9/27/2022	19.8	1986.3	2359	51.2	41	53.7	87.4	open	0.59
10/4/2022	18.9	980.4	1162	23.1	31	12.1	78.1	open	1.68
10/11/2022	17.9	1553.1	1014	73.3	10	27.5	79.7	open	0.80

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.

Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml *Enterococcus*(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

Enterococcus

Enterococcus results exceeded the EPA criteria three times at Patterson Point, once at Monte Rio, and twice at Vacation Beach (6 of 75 or 8%) during open and closed conditions and summer dam removal, with flows that ranged from 47.7 cfs to 141 cfs (Tables 4.1.5 through 4.1.7 and Figure 4.1.25).

The Patterson Point station had a maximum Enterococcus concentration of 151.5 MPN/100mL on 20 September during open conditions and summer dam removal, with a flow of approximately 88.6 cfs (Table 4.1.5 and Figure 4.1.25).

The Monte Rio station had a maximum Enterococcus concentration of 65.1 MPN/100mL that occurred on 12 May during closed conditions and a flow of approximately 141 cfs (Table 4.1.6 and Figure 4.1.25).

The Vacation Beach station had a maximum concentration of 146.7 MPN/100mL that occurred on 21 June during open conditions and a flow of approximately 97.4 cfs (Table 4.1.7 and Figure 4.1.25).

External factors including contact recreation, barrier beach closure, and the late-September removal of summer dams in lower river likely had an effect on elevated Enterococcus concentrations observed during the 2022 monitoring season (Figure 4.1.25).

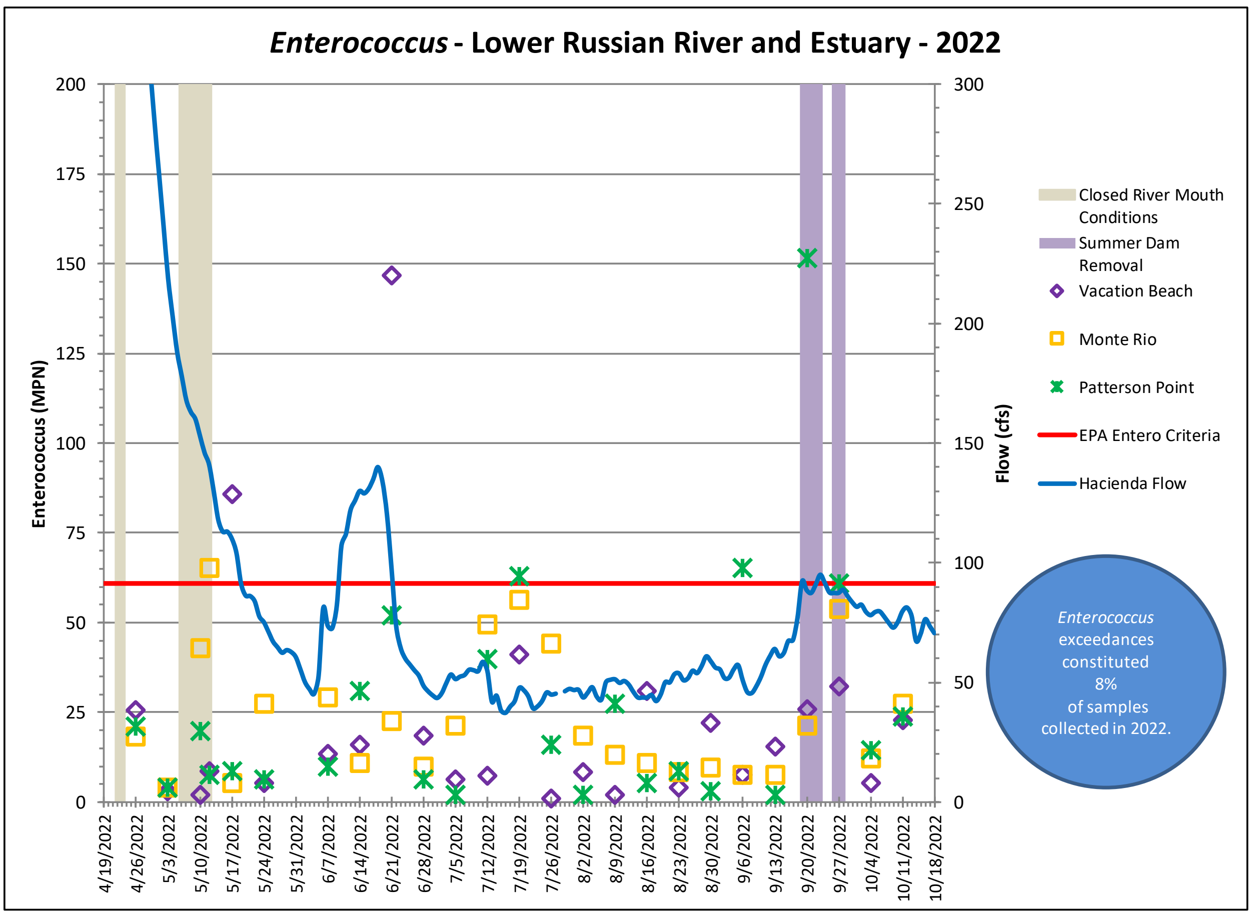


Figure 4.1.25. 2022 Russian River Grab Sampling Results for Enterococcus

Table 4.1.7. 2022 Russian River at Vacation Beach Station Indicator Bacteria Grab Sample Results

Vacation Beach	Temperature	Total Coliforms (Collilert)	Total Coliforms Diluted 1:10 (Collilert)	E. coli (Collilert)	E. coli Diluted 1:10 (Collilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)**	Estuary Condition	Jenner Gauge
MDL*		<1	<10	<1	<10	<1	Flow Rate***		
Date	°C	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)		(ft)
4/26/2022	16.7	1986.3	933	83.9	109	25.6	463	open	3.79
5/3/2022	17.6	307.6	389	6.3	20	3.1	219	open	0.71
5/10/2022	17.1	344.8	384	5.2	<10	2.0	153	closed	5.94
5/12/2022	16.2	517.2	350	15.5	<10	8.6	141	closed	6.74
5/17/2022	20.5	1119.9	1664	11.0	40	**85.7**	110	open	0.38
5/24/2022	22.7	2419.6	3076	8.6	20	5.2	75.2	open	1.05
6/7/2022	22.9	2419.6	2382	45.7	10	13.4	73.7	open	1.77
6/14/2022	22.6	2419.6	3076	63.0	63	16	130	open	2.86
6/21/2022	22.3	>2419.6	**11199**	60.2	20	**146.7**	97.4	open	1.05
6/28/2022	23.8	>2419.6	8664	14.5	20	18.5	48.6	open	0.59
7/5/2022	23.1	2419.6	2359	6.3	10	6.3	51.4	open	0.59
7/12/2022	24.5	2419.6	5475	17.3	<10	7.4	54.8	open	0.97
7/19/2022	24.4	>2419.6	9208	13.5	<10	41.0	47.7	open	0.55
7/26/2022	23.3	>2419.6	31	**344.8**	<11	1	44.9	open	0.63
8/2/2022	23.5	>2419.6	6488	2.0	10	8.4	43.7	open	0.42
8/9/2022	23.2	>2419.6	2282	3.0	<10	2.0	51.3	open	0.84
8/16/2022	24.0	1986.3	1597	12.2	10	31.0	43.7	open	0.46
8/23/2022	23.7	1986.3	1439	13.5	<10	4.1	53.8	open	0.67
8/30/2022	22.6	>2419.6	1956	17.3	10	22.1	58.8	open	0.5
9/6/2022	24.1	2419.6	3654	23.1	31	7.5	50.8	open	1.85
9/13/2022	22.3	2419.6	3076	63.7	31	15.5	64	open	0.50
9/20/2022	19.6	1986.3	2098	59.1	52	25.9	88.6	open	1.73
9/27/2022	19.6	2419.6	1918	25.6	10	32.3	87.4	open	0.67
10/4/2022	19.0	1119.9	1658	12.2	10	5.2	78.1	open	1.73
10/11/2022	18.3	1046.2	**14281**	19.9	20	22.8	79.7	open	1.01

* Method Detection Limit - limits can vary for individual samples depending on matrix interference and dilution factors, all results are preliminary and subject to final revision.
** United States Geological Survey (USGS) Continuous-Record Gaging Station
*** Flow rates are preliminary and subject to final revision by USGS.

Recommended California Department of Public Health (CDPH) Draft Guidance - Single Sample Maximum (SSM):
Total Coliform (SSM): 10,000 per 100ml
Environmental Protection Agency (EPA) Recreational Water Quality Criteria - Beach Action Value (BAV):
E. coli (BAV): 235 per 100 ml *Enterococcus*(BAV): 61 per 100 ml
(Beach notification is recommended when indicator organisms exceed the SSM for Total Coliform or the BAV for *E. coli*) - Indicated by red text

Conclusions and Recommendations

Continuous Water Quality Monitoring Conclusions

Water quality conditions observed during the 2022 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 2022 as the mouth of the Estuary did not close during the management period.

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.

Salinity migration patterns in the upper reach of the Estuary were fairly similar to prior monitoring years of 2017 through 2019, with the Brown’s Pool (RK 11.3) station observed to remain primarily freshwater during the 2022 management period with a maximum concentration of 1.7 ppt at the bottom and 0.26 ppt at the mid-depth. Whereas in 2016, the bottom of Brown’s Pool became predominantly brackish during open and closed conditions throughout the 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.

Salinity migration patterns in the MBA of the Estuary were not monitored in 2022 at Patterson Point due to a lack of boat access to the site. However, monitoring conducted in 2020 in the MBA at the Patterson Point station continued to show freshwater conditions with a maximum salinity value of approximately 0.3 ppt (Table 4.1.2). 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 2022 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 2022 is being presented (Figure 4.1.26). 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.

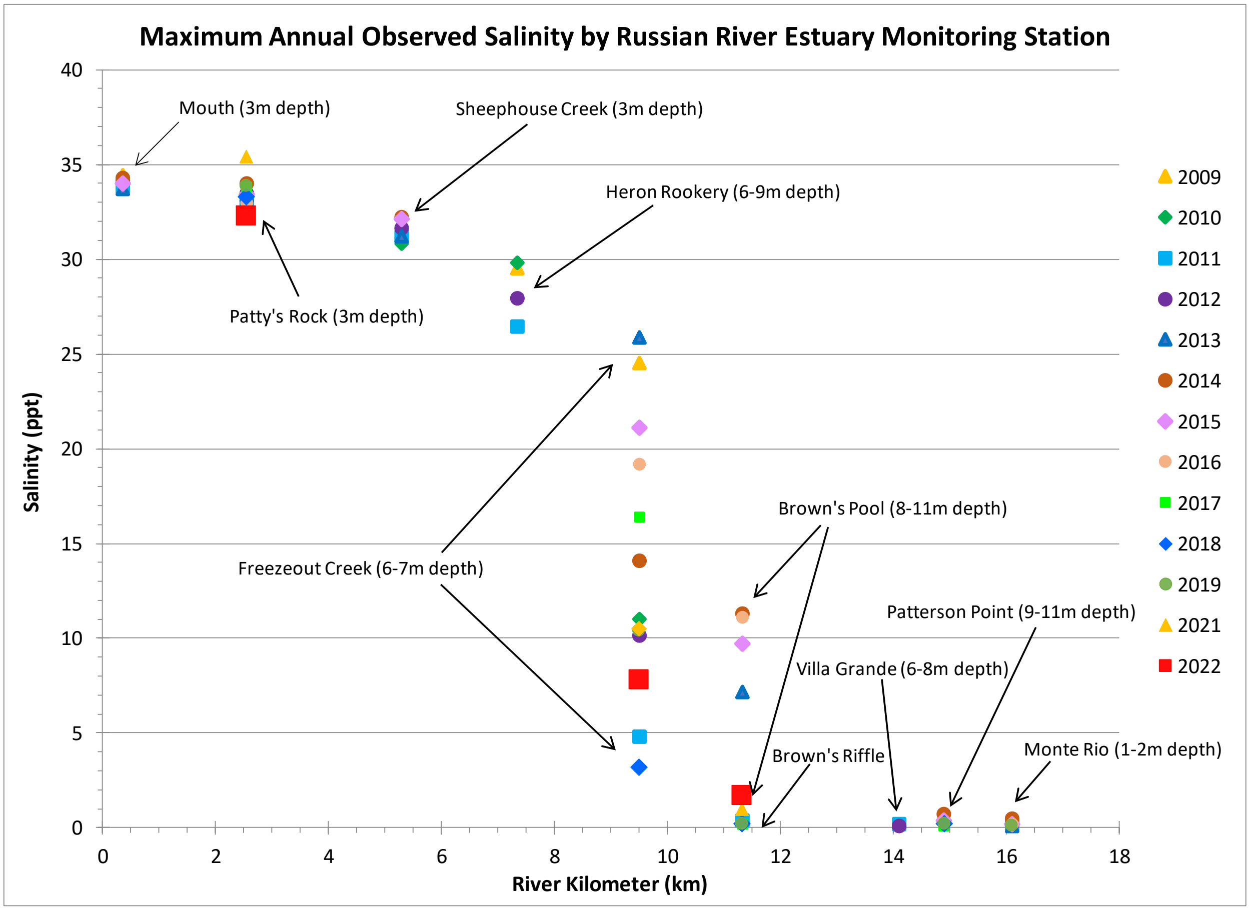


Figure 4.1.26. The maximum salinities at monitoring stations throughout the Russian River Estuary and Maximum Backwater Area between the years of 2009 and 2022.

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.

Note that there are no elevated salinity levels recorded in the Maximum Backwater Area for any monitoring seasons when monitoring was conducted. 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 2022 grab sampling effort in the Russian River Estuary continued to collect a robust set of data similar in effort to the 2012 through 2021 monitoring seasons. Additional focused sampling was conducted during summer dam removal in late September and barrier beach closure in October. Table 4.1.8 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 BO in 2009.

Table 4.1.8. 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
2020	24	72
2021	29	87
2022	25-27	75-81

The mainstem Russian River, as measured at the USGS Hacienda gage, experienced lower flows in 2022 compared to past years including 2019 (Figure 4.1.27). For example, a late season storm in 2019 significantly elevated flows from approximately 600 cfs to over 3000 cfs at Hacienda in mid-May. Flows remained above 500 cfs into early June, resulting in mainstem flows decreasing to base summertime flows later in the dry season compared to previous years, including 2022 (Figure 4.1.27).

By comparison a dry spring in 2022 resulted in Hacienda flows dropping below 100 cfs by mid-May, resulting in flows decreasing far earlier in the season compared to previous years (Figure 4.1.27). Finally, while summertime base flows at Hacienda remained above 150 cfs in 2019, summertime base flows in 2022 were generally below 75 cfs and frequently below 50 cfs (Figure 4.1.27).

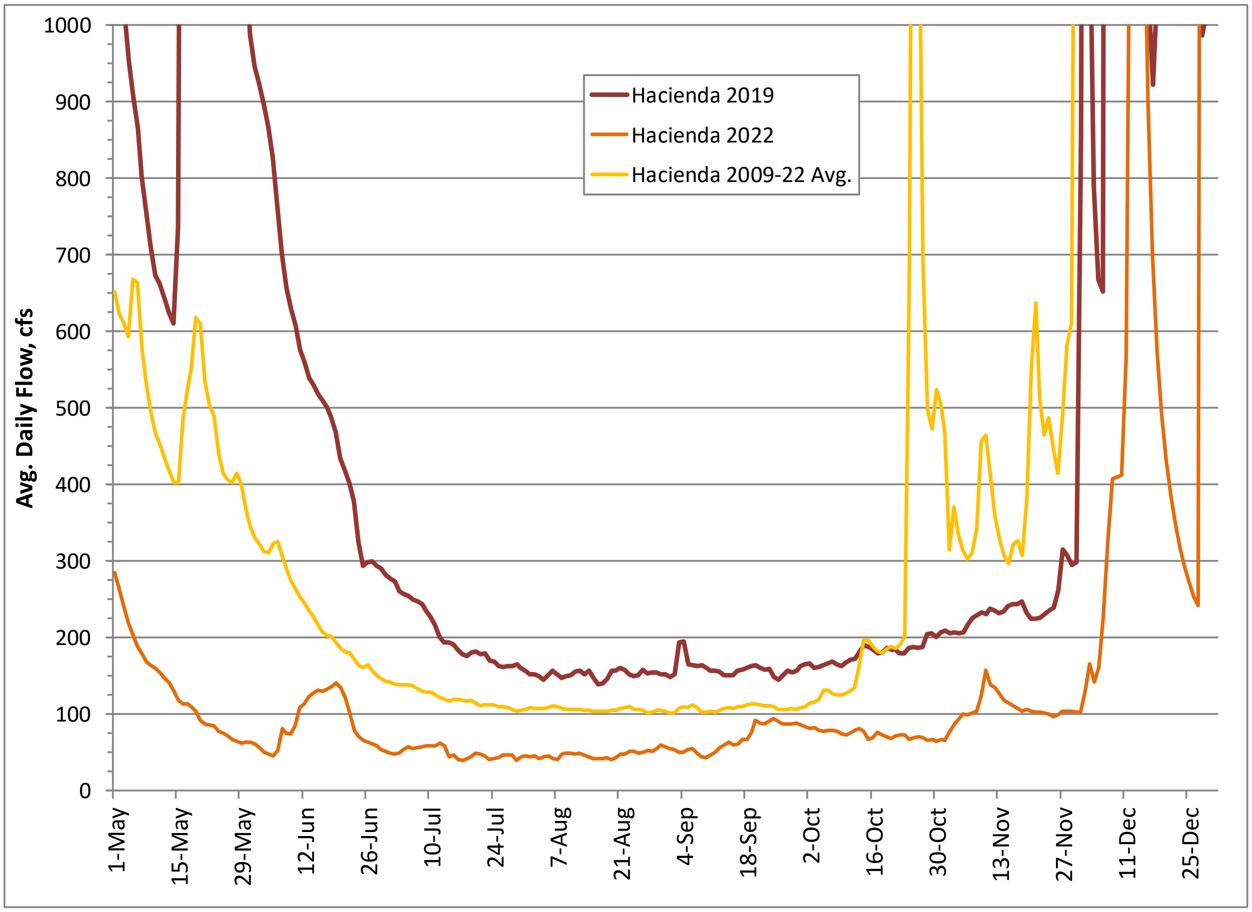


Figure 4.1.27. Comparison of 2019, 2022 and 2009-2022 average daily flows in the Lower Russian River as measured at USGS Hacienda gage in cubic feet per second. Flow rates are preliminary and subject to final revision by USGS.

The 2022 grab sampling effort observed Total Phosphorus exceedances in 100% of all samples collected (Table 4.1.9). This is not uncommon in the lower Russian River, and was on the higher end of percent exceedances of samples analyzed for Total Phosphorus during previous monitoring seasons. Table 4.1.9 shows the percentage of samples that were in exceedance each season since 2009.

Year to year variability in the percentage of exceedances, and concentrations and values, for the constituents discussed above can be attributed in large part to: the frequency, timing, and severity of storm events; fluctuating stream flow rates; atmospheric conditions; contact recreation; 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 4.1.9. 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. Finally, samples were not analyzed for Turbidity in 2009.

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	Percentage of Turbidity Samples in Exceedance
2009	100	N/A	N/A	N/A
2010	84.6	15.4	18.0	23.1
2011	92.3	30.8	23.7	25.0
2012	61.5	6.9	11.5	2.8
2013	99.0	15.3	44.9	13.3
2014	100	14.4	23.1	22.0
2015	86.5	1.9	26.0	3.9
2016	83.9	8.1	39.1	19.5
2017	97.3	9.3	54.7	38.7
2018	93.3	5.3	36.6	9.3
2019	85.3	9.5	48.0	53.3
2020	98.6	0	19.4	8.3
2021	70.1	5.8	23.0	8.1
2022	100	3.7	44.4	17.3

The percentage of E. coli exceedances from 2009 until 2022 can be seen in Table 4.1.10. The percentage of exceedances for Total coliform and E. coli have been observed to remain relatively low over the years of sampling.

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 2022 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 4.1.10. 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 2022. Note that for 2009, the analyzing method was multiple tube fermentation, and for 2011-2022 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
2020	0	1.4
2021	0	2.3
2022	1.3	1.3

Overall, data collected through the grab sampling effort in 2022 appear consistent with data collected between 2009 and 2021.

Additionally, based on the assemblage of data collected by Sonoma Water, it does not appear that lower flows observed in 2022 negatively affected water quality or the availability of aquatic habitat, or provided a significant contribution to biostimulatory conditions when compared to data collected during years with normal water year flow rates, such as 2019.

Time series trend analyses of the data collected could prove useful in the future. 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.

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 2022 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 2008 Biological Opinion stated that "densities of steelhead appear to be low in the Russian River Estuary, a condition that is likely due to reduced water quality (e.g., elevated salinity and other water quality dynamics) as well as diminished production of invertebrates that are typically the forage base of juvenile salmonids. The Russian River Biological Opinion requires the 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 Estuary (NMFS, 2008). Specifically, the 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; and to provide a qualitative description of salmonid diet in the Estuary.

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, the 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, the 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 Dr. Charles “Si” Simenstad and his colleagues at 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. Dr. Simenstad is a researcher with expertise in estuarine/early marine ecology of juvenile Pacific salmon, feeding ecology of fishes, estuarine food webs, tidal wetland landscape ecology, restoring estuarine wetlands, and the ecological effects of anthropogenic alterations to coastal ecosystems. 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 Estuary through 2019. The following information was provided in the annual report for monitoring year 2020 and is repeated here for informational purposes.

Sonoma Water implemented ten years of extensive aquatic invertebrate research for the Estuary Management Project. Monitoring reports were completed annually, including a summary and synthesis report of the decadal dataset and findings (Accola et al., 2021). This report provides a long-term analysis and summary of several independent studies related to salmonid diet, prey availability, juvenile steelhead distribution and behavior, and comparison of invertebrate composition and steelhead performance in other Pacific coast estuaries. In addition, these Estuary studies evaluated the response of invertebrates and steelhead to changing river mouth conditions. The scope of many of these studies are beyond the requirements stated in the Biological Opinion. Scientific journal articles and graduate theses/dissertation produced from Estuary invertebrate research are listed below.

- Fuller, J. A. 2011. Extended residency and movement behavior of juvenile steelhead (*Oncorhynchus mykiss*) in the Russian River Estuary, California. Master's thesis. Humboldt State University.
- Seghesio, E. E. 2011. The influence of an intermittently closed, Northern California estuary on the feeding ecology of juvenile steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*). Master's thesis. University of Washington, School of Aquatic and Fishery Sciences.
- Matsubu, W. C., C. A. Simenstad, and G. E. Horton. 2017. Juvenile steelhead locate cold water refugia in an intermittently closed estuary. Transactions of the American Fisheries Society 146:680–695.
- Matsubu, W. C. 2019. Tradeoffs of juvenile steelhead (*Oncorhynchus mykiss*) rearing in an intermittently closed estuary, northern California USA. PhD dissertation. University of Washington, School of Aquatic and Fishery Sciences.

Summary of Methods

Field sampling and laboratory process methods implemented by Sonoma Water and UW-WET are described in previous reports. Following is a summary of the field and laboratory efforts conducted over the entire monitoring effort.

Invertebrate surveys were conducted from 2010 to 2019 in the Estuary. Surveys were completed monthly and at 7 and 14 days after a river mouth closure to monitor conditions during the transition from tidal Estuary to lagoon. Sampling for fish diet and prey availability was 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). Each survey event consisted of sampling 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 included 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). Collections at each station consisted of 12 benthic, 14 epibenthic, and 3 zooplankton for a total of 29 samples/station and combined total of

116 samples/survey event. During mouth closures an additional three benthic and three epibenthic samples were collected along the inundated shoreline. These samples were placed in jars, preserved, and sent to UW-WET for taxonomic identification, enumeration, and analysis. Over the course of study, 48 survey events were completed (32 open mouth, 16 closed mouth) for a total collection of 5,585 invertebrate samples.

In addition, gastric-lavaged stomach samples were collected from 338 juvenile steelhead and 662 Chinook salmon smolts, and processed by UW-WET. Overall, there were 6,585 diet and prey availability samples collected, processed, and analyzed since 2010. UW-WET processed a subset of samples in the latter years of the study and targeted samples collected in association with river mouth closure events.

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 the 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.

Summary of Results

Accola et al. (2021) compiled and reviewed all of the Estuary invertebrate studies into a summary and synthesis report of the decadal dataset and findings. Below is a summary of the important research findings that comply with the Biological Opinion invertebrate monitoring requirements.

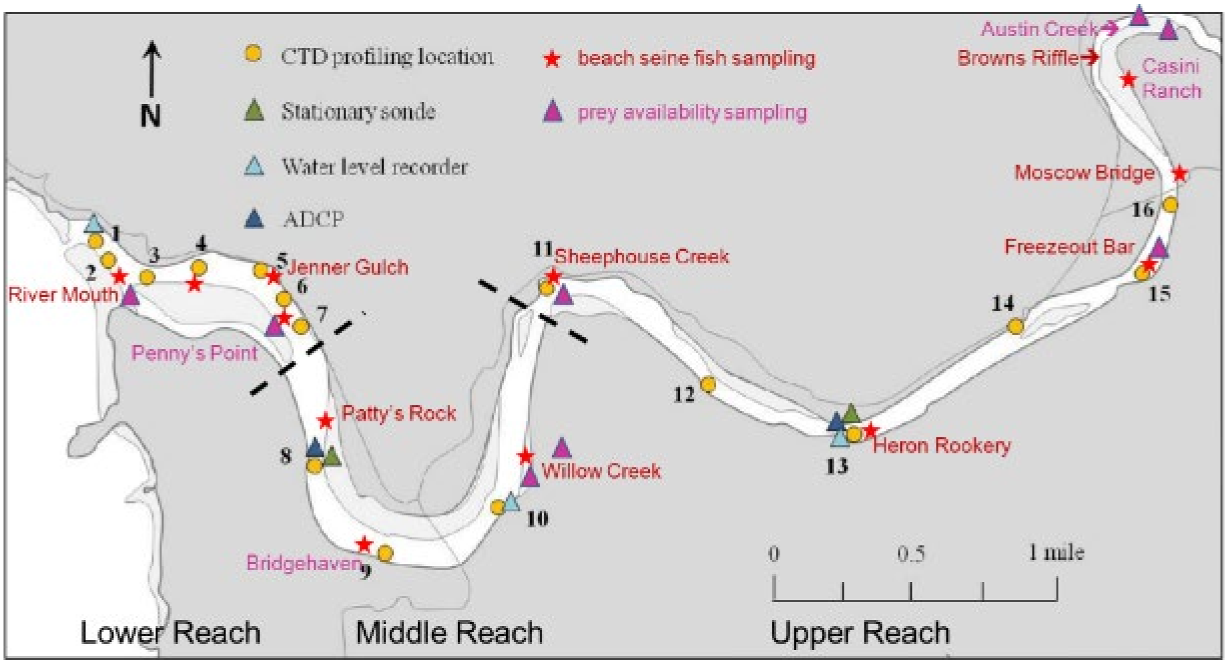


Figure 4.3.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (benthic infauna, epibenthos, zooplankton) in three reaches of the Russian River Estuary.

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.

Spatial Distribution, Composition, and Relative Abundance of Invertebrates

Invertebrate composition showed differences between and among the three reaches of the Estuary that appeared to follow longitudinal water conditions transitioning from seawater in the lower reach to freshwater in the upper reach. However, the invertebrates that are important prey for juvenile steelhead were relatively consistent during a decade of study, see below for more details. Epibenthic sampling indicated a somewhat distinct invertebrate prey community composition between the River Mouth and the Penny Point sampling sites in the lower reach, but often distinct prey assemblages between the upper reach at Freezeout Bar 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.

Salmonid Diet and Invertebrate Response to River Mouth Condition

Prey composition and densities in the Estuary were relatively comparable over the ten years of study, 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. The supplemental epibenthic sled sampling along the inundated shoreline during continued Estuary closures suggested no recognizable gradient or differentiation in the composition and relative density distribution of preferred prey. This would suggest that within the three Estuary reaches (lower, middle, upper) there was uniform or a relatively minor gradient of prey density distribution from their deeper channel to their shallower, marginal habitats due to Estuary closure.

In comparing juvenile steelhead diets between open and closed Estuary mouth conditions, there was no detection of any significant changes in diet composition. Juvenile steelhead consistently fed on common prey taxa over an inter-annual timespan. Spatial variation among Estuary reaches accounted for prey differences more than temporal variation or even variation due to open or closed mouth condition. Prey distributions are consistently organized along a salinity gradient (primarily distinguishing the upper reach of the Estuary dominated by freshwater river flows); however, prey composition was consistent within the three Estuary reaches (lower, middle, and upper) regardless of mouth condition.

A bioenergetics model investigating the relationship of diet composition and water temperature determined that growth rates of juvenile steelhead in the Estuary rival the highest in literature both in natural environments and under laboratory conditions. Therefore, growth of juvenile steelhead in the Estuary is likely not a limiting factor in the recovery of threatened steelhead in the Russian River watershed.

Diet composition of both juvenile steelhead and Chinook salmon in the Estuary indicated that these fish feed on relatively few taxa of aquatic invertebrates, consisting of epibenthic crustaceans and aquatic insects, that are common in the Estuary. In addition, there was a persistent uniformity in juvenile steelhead foraging on epibenthic prey. Accola et al. (2021) concluded that “our results and related accounts from other intermittent estuaries in the region indicates that juvenile salmonid feeding ecology in the Estuary is of relatively modest diversity and remarkably consistent. Thus, their feeding should be predictable as long as the spectrum of available prey is not dramatically altered…and…these prey taxa are reported to be common components in juvenile steelhead (and Chinook salmon, in a few cases) diets in other intermittent systems estuaries along the California coast.”

Conclusions

The invertebrate studies in the Estuary were able to quantify and determine several characteristics of the invertebrate community and their importance as prey for rearing juvenile steelhead, which are listed below.

- The annual composition and abundance of invertebrates in the Estuary were similar across the ten years of study, implying a relatively consistent prey base for juvenile steelhead.
- Invertebrate distributions were consistently organized along a salinity gradient from seawater at the river mouth to freshwater at the upstream end of the Estuary.
- Invertebrate composition was consistent within the three reaches of the Estuary regardless of mouth condition.
- During river mouth closures that inundated the shoreline, the density and distribution of invertebrates in the newly created marginal habitat was similar to the adjacent deeper channel.

- Juvenile steelhead consistently fed on relatively few taxa of common aquatic invertebrates consisting of epibenthic crustaceans and aquatic insects.
- The diet of juvenile steelhead did not appear to change under open or closed mouth conditions.
- The development of juvenile steelhead was exceptionally high in the Estuary, indicating that growth rate is likely not a limiting factor in the recovery of steelhead in the Russian River watershed.
- The high growth rates of juvenile steelhead suggest that prey abundance is not a limiting factor for rearing steelhead survival.

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 2022, 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 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.

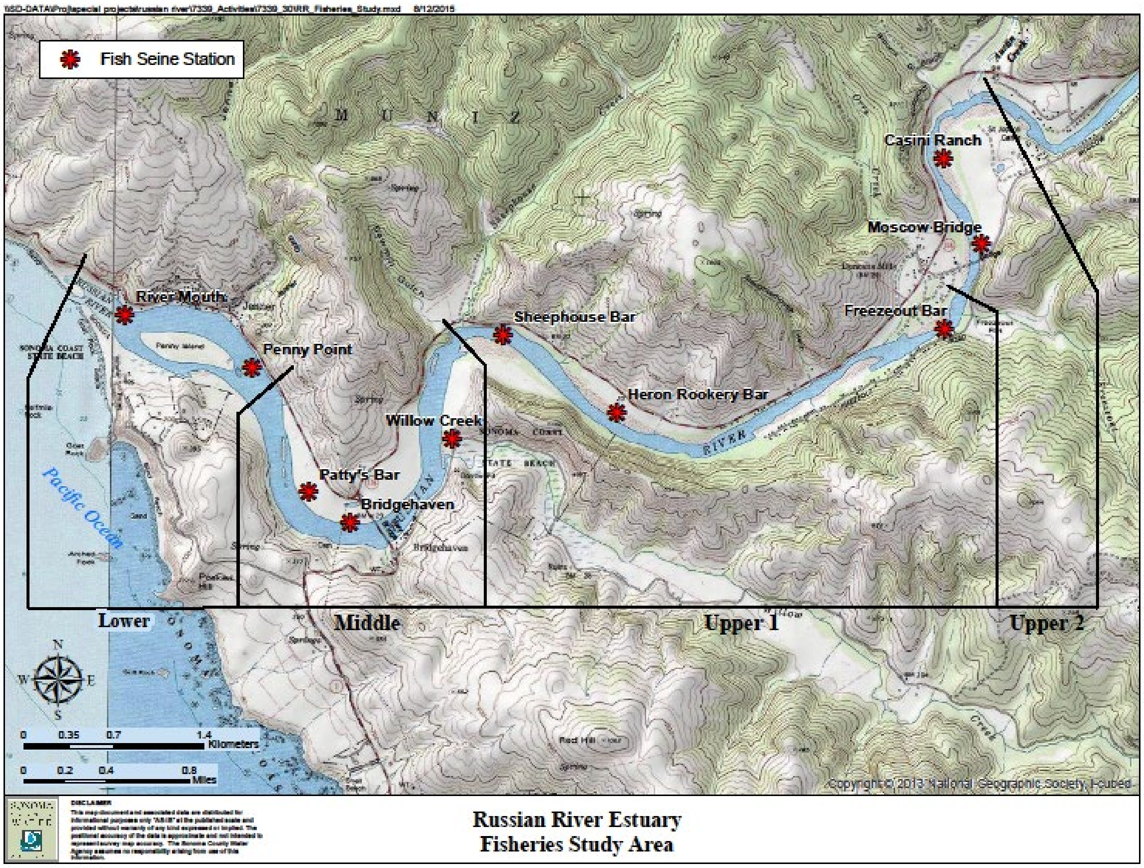


Figure 4.4.1. Russian River Estuary fisheries seining study reaches and sample sites, 2022.

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 prolonged closure occurred or a lagoon outlet channel was successfully installed forming a freshwater lagoon seine events occur monthly from May to June. In 2022, 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.

Due to difficulties accessing the upper reach during the ongoing drought conditions in 2022, seining effort was shifted from the upper estuary sites to the lower and middle estuary sites for the June and September, 2022 sampling events. Jenner Gulch in the lower Estuary was added as a sample site for the September sampling event to help redistribute some of the effort from the upper estuary sample sites (Table 4.4.1).

Table 4.4.1 The number of seine sets for the May, June, and September seine events shown by reach. Due to difficulties accessing the upper reach seining effort was shifted from the upper estuary sites to the lower and middle estuary sites for the September.

Seine event	Lower	Middle	Upper1	Upper2	**Total**
May	10	15	16	10	**51**
June	17	20	12	0	**49**
September	17	22	12	0	**51**
Total	**44**	**57**	**40**	**10**	**151**

Results

Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary for 2022 are summarized in Table 4.4.2. During the 15 years of study over 50 fish species were caught in the Estuary. In 2022, seine captures consisted of 26,669 fish comprised of 34 species. In addition to fin fish 120 European green crabs were captured in 2022. European green crabs are a non-native species and only 1 individual had been captured seining prior to 2021. In 2021 734 European green crabs were observed in the estuary.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity. 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 4.4.2). 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 2022, a total of 2 steelhead were captured (Table 4.4.2) in 151 seine sets. These steelhead were wild origin fish. The resulting CPUE was 0.01 fish/set (Figure 4.4.3). In comparison, during 2021, a total of 35 steelhead were captured in 183 seine sets for a CPUE of 0.19 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 4.4.4). In 2022 juvenile steelhead were only captured during the May survey. Since seining surveys began in 2004, steelhead appear to have a patchy distribution and vary in abundance in the Estuary (Figure 4.4.5). Over all 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 2022, which limited the temporal and spatial evaluation of steelhead in the Estuary (Figure 4.4.6). The typical pattern observed in previous study years consisted of relatively large numbers of juveniles in the Upper Estuary in May and June, the largest number of juveniles shifted to in the Middle Estuary in mid-summer, and then to the Lower Estuary in September. The pattern observed in 2022 consisted of few steelhead in the upper reach of the estuary in May and no steelhead captured in other locations or months.

Table 4.4.2. Total fish caught seining in the Russian River Estuary, 2022. Due to access issues resulting from drought conditions Freezeout, Moscow, and Casini were not sampled in September and the seining effort typically allotted to these upper sites was shifted to downstream sites in September.

Species	River Mouth (7)	Jenner Gulch (3)	Penny Point (3)	Patty's Bar (3)	Bridgehaven (7)	Willow Creek (5)	Sheephouse Bar (5)	Heron Rookery Bar (6)	Freezeout Bar (4)	Moscow Bridge (5)	Cassini Ranch (5)	Total
American shad							2					2
Chinook salmon	69		35	12	36	1						153
coho salmon	16				5		1		1			23
steelhead								1			1	2
Dungeness crab	1											1
bluegill									2	1		3
cabezon	9											9
cyprinid sp							1		1			2
English sole	4		1									5
European green crab	17	20	15	62	6							120
green sunfish									3			3
greenling sp	2											2
hardhead								1				1
hitch							1			3		4
kelp greenling	2											2
Pacific herring					6							6
Pacific sardine					1							1
penpoint gunnel	1											1
prickly sculpin	15	10	30	46	178	53	24	6				362
Russian River tule perch					3		1	4	4	8		20
Sacramento pikeminnow						1	6	60	2	12		81
Sacramento sucker							18	80	3	71	171	343
sculpin sp	1	3	5	69	21			15	31	25	9	179

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Species	River Mouth (7)	Jenner Gulch (3)	Penny Point (3)	Patty's Bar (3)	Bridgehaven (7)	Willow Creek (5)	Sheephouse Bar (5)	Heron Rookery Bar (6)	Freezeout Bar (4)	Moscow Bridge (5)	Cassini Ranch (5)	Total
sebastes sp	43	3	17		11							74
sharpnose sculpin	1											1
bay pipefish	2		2	19	4	13	1					41
shiner surfperch				18	571	707	121	95				1,512
smelt sp					1							1
starry flounder	1		4	6	3	10	2	6				32
staghorn sculpin	164	9	94	85	74	109						535
surfperch sp				1								1
topsmelt	333	131	155	66	373	73	13					1,144
surf smelt	1437	1	1	8	6							1,453
northern anchovy	55		2		610							667
threespine stickleback	43	17	617	5,674	4,545	3,463	483	1,760	2,926	241	234	20,003
Total												26,789

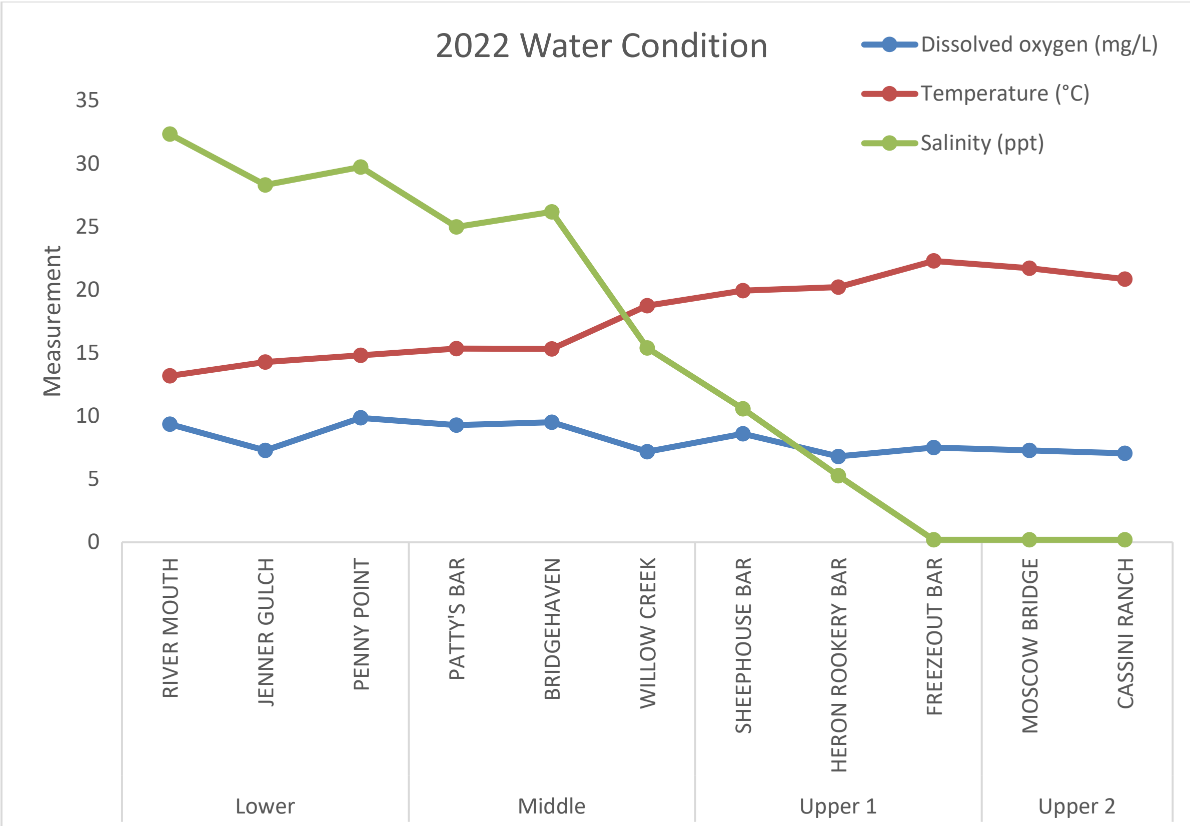


Figure 4.4.2. Generalized water conditions at fish seining stations in the Russian River Estuary, 2022. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May, June, and September during primarily open mouth conditions. Water measurements are salinity in parts per thousand (ppt), dissolved oxygen in milligrams per liter (mg/L), and temperature in Celsius (°C).

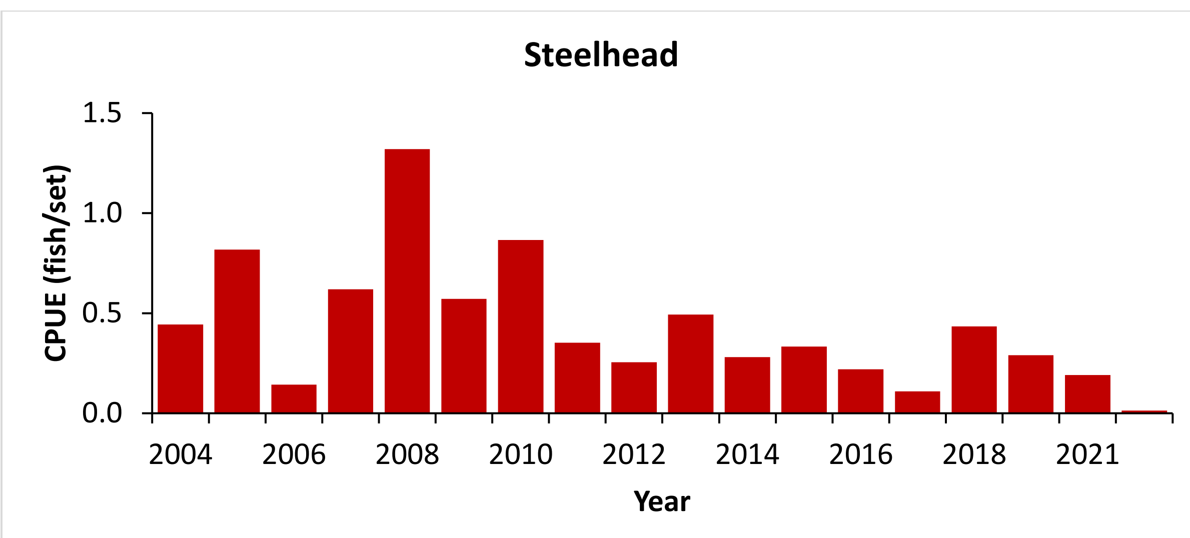


Figure 4.4.3. Annual abundance (represented as catch per unit effort) of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2022. Samples are from 96 to 300

seine sets conducted yearly from May to October, except in 2022, when sampling ended in September.

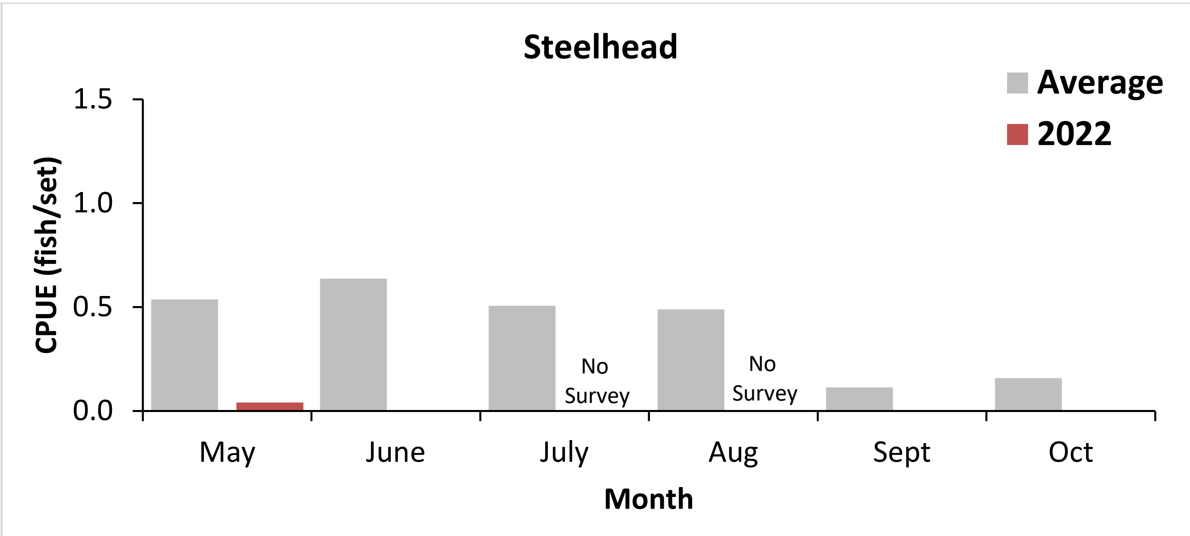


Figure 4.4.4. Seasonal abundance (represented as catch per unit effort) of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2022. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. No October 2022 survey was conducted.

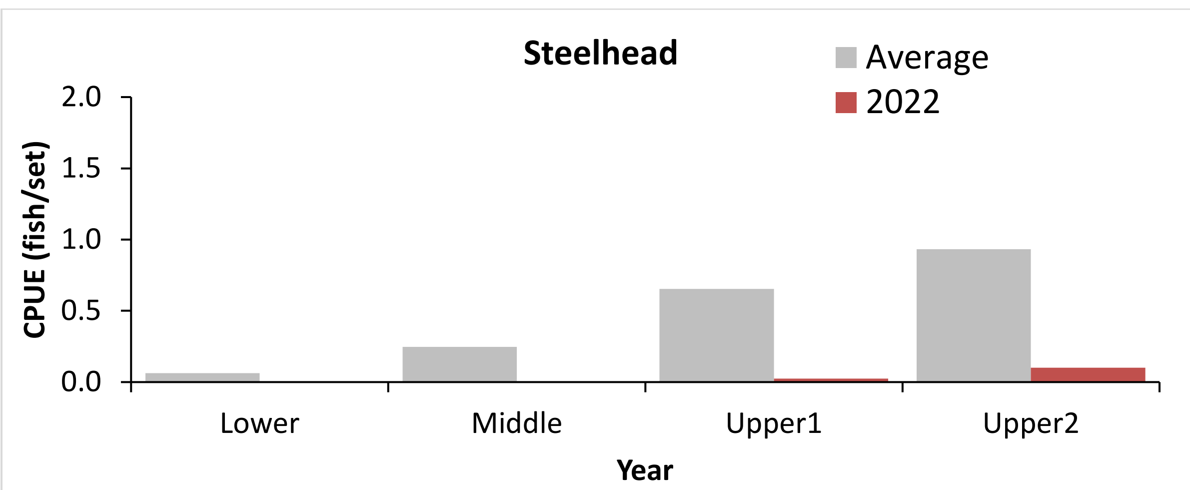


Figure 4.4.5. Distribution of juvenile steelhead in the Russian River Estuary, 2004-2022. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2022 were averaged.

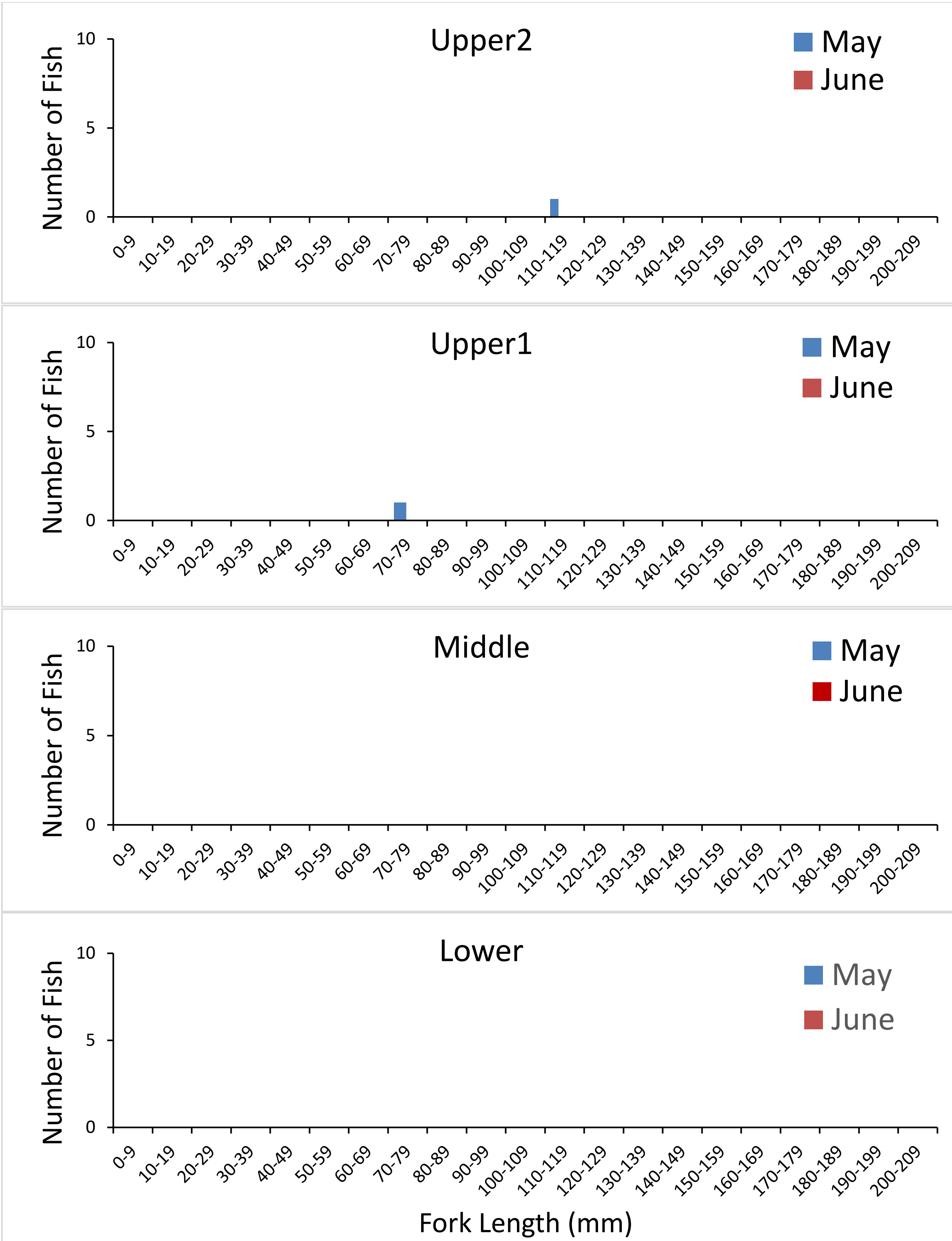


Figure 4.4.6. Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2022. Fish captures are grouped by Estuary reach and month.

Juvenile steelhead captured in 2022 were age 0+ parr or age 1+ smolts and ranged in size from 75 mm to 119 mm fork length (Figure 4.4.7).

In 2022, 2 juvenile steelhead captured during Estuary seining surveys were implanted with PIT tags. In addition, 818 juvenile steelhead where PIT-tagged during downstream migrant trapping studies in the Russian River and tributaries upstream of the Estuary in 2022. There were no PIT-tagged steelhead recaptured in the Estuary during 2022 seining.

Chinook Salmon

A total of 153 Chinook salmon smolts were captured by beach seine in the Estuary during 2022 (Table 4.4.2). The abundance of smolts in the Estuary has varied since studies began in 2004 (Figure 4.4.8). 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 2022 the CPUE for Chinook was 0.99. Chinook salmon smolts are usually most abundant during May and June (Figure 4.4.9) and rarely encountered after July. Monthly smolt captures in 2022 were highest during May at 1.73 fish/set. In 2022, Chinook salmon smolts were captured in the lower and middle reaches of the estuary (Figure 4.4.10).

Coho Salmon

There have been relatively few Coho Salmon smolts captured in the Estuary during our beach seining surveys (Figure 4.4.11). 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 the 2022 sampling season, the total capture of Coho was 23 smolts at a CPUE of 0.15 fish/set. Seven smolts were not marked and presumed wild. The remaining smolts were hatchery raised. Nearly all Coho Salmon smolts are captured by June and in 2022, 9 coho smolts were captured in May and 14 were captured in June (Figure 4.4.12). The spatial distribution of Coho smolts has varied annually (Figure 4.4.13). In 2022 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 PIT tags. Four PIT tagged Coho were recaptured at in the Estuary. One fish was recaptured at Bridgehaven on May 26, and the remaining three were recaptured at the River Mouth on June 27, 2022. The history of these Coho are shown in Table 4.4.3. Three of these fish were captured and PIT tagged at the Willow Creek Smolt trap (one on May 27, 2022, and 2 on June 24, 2022). Initial tagging information on the remaining fish was not available at the time this report was written.

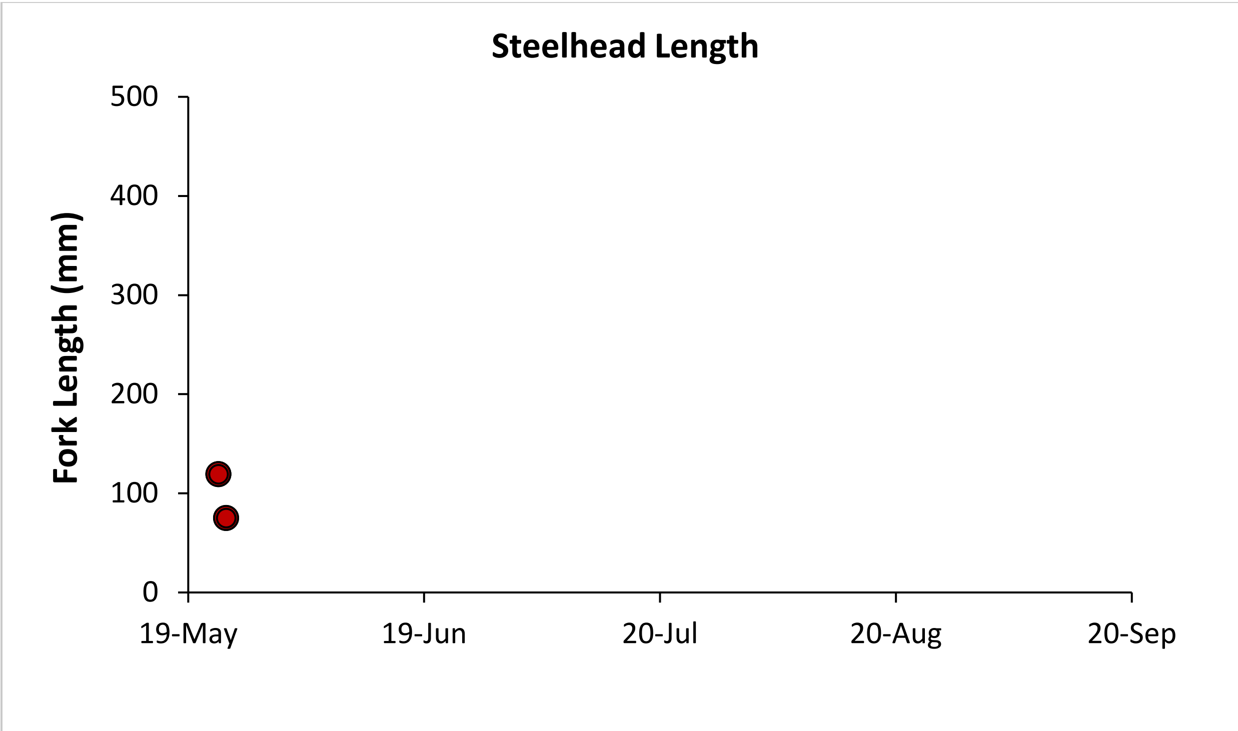


Figure 4.4.7. Juvenile steelhead sizes captured by beach seine in the Russian River Estuary, 2022.

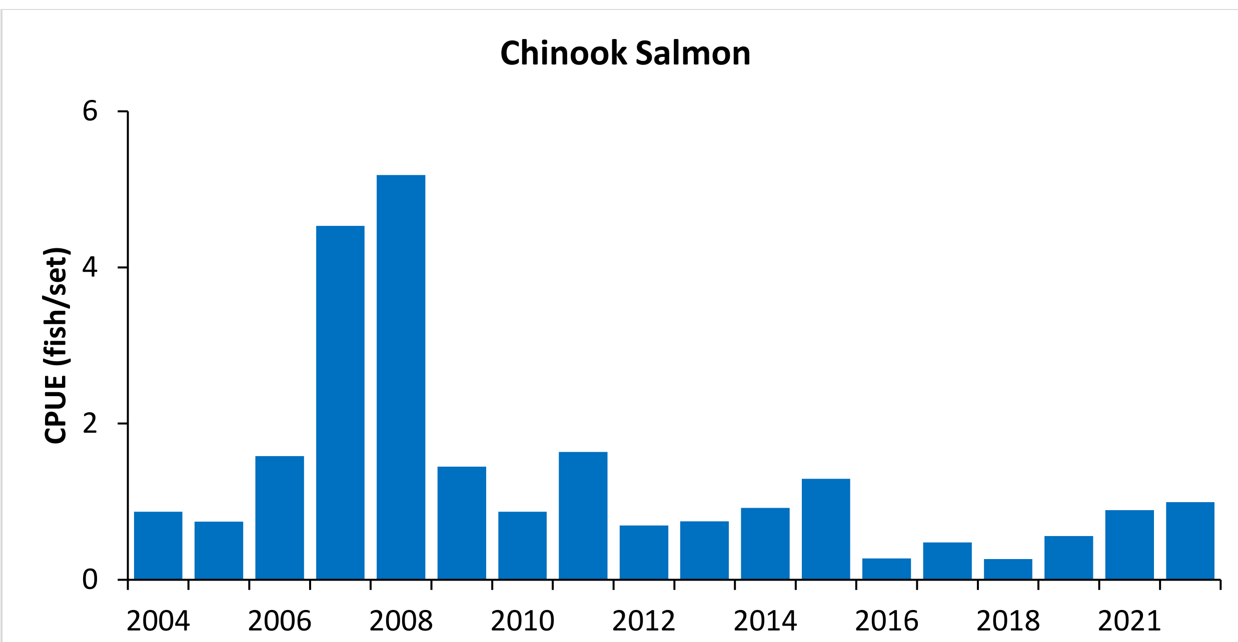


Figure 4.4.8. Annual abundance (represented as catch per unit effort) of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2022. Samples are from 96 to 300 seine sets yearly from May to October. No October 2022 survey was conducted.

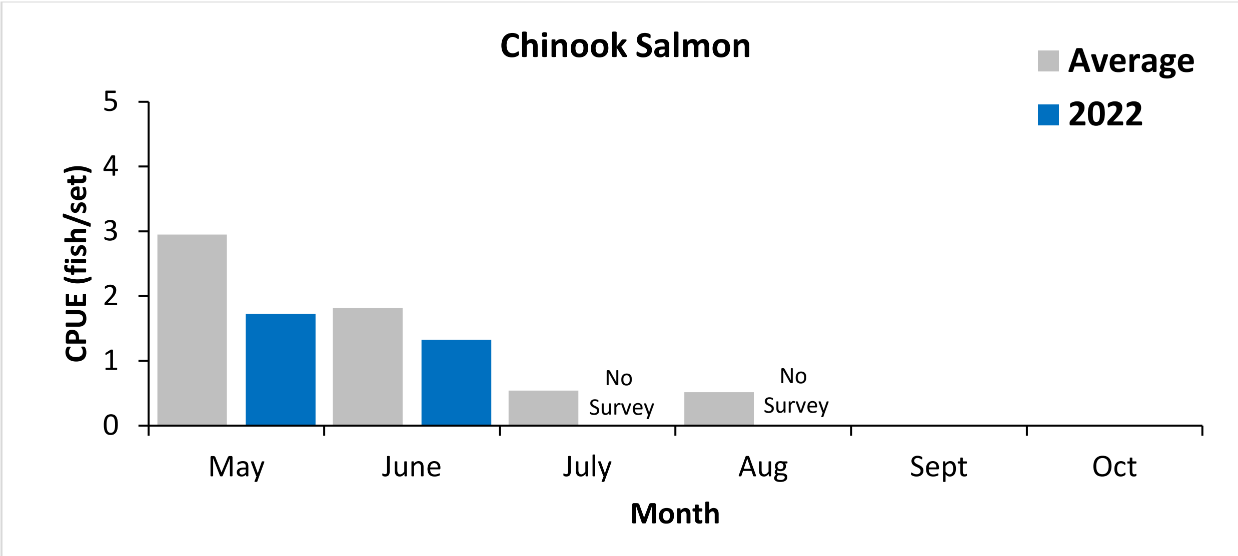


Figure 4.4.9. Seasonal abundance (represented as catch per unit effort) of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2022. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2022 were averaged. No October 2022 survey was conducted.

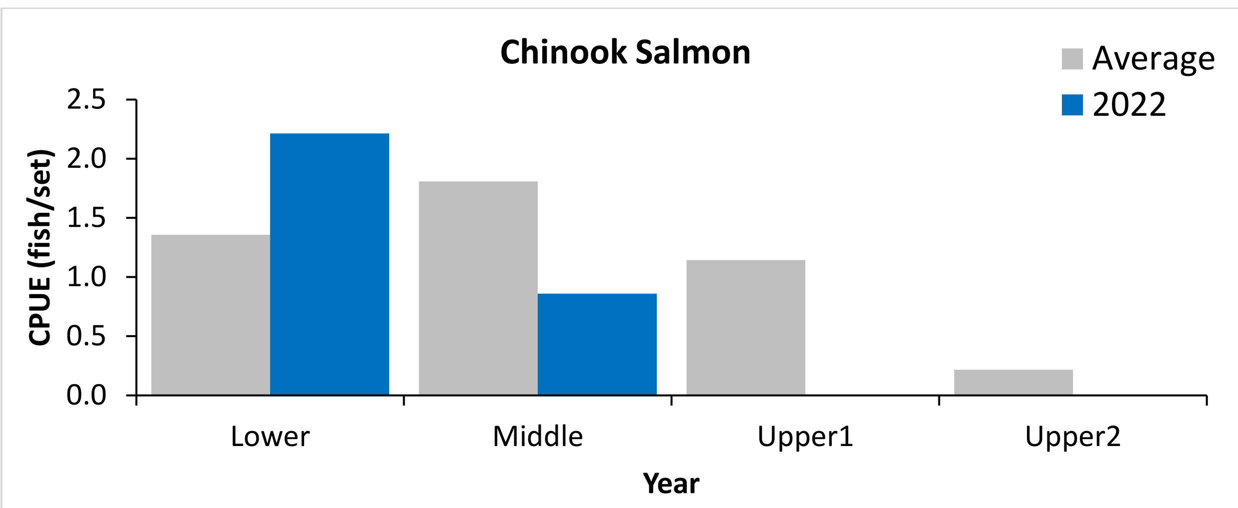


Figure 4.4.10. Spatial distribution of Chinook salmon smolts in the Russian River Estuary, 2004-2022. Fish were sampled by beach seine consisting of 96 to 300 sets annually. Data from 2004 to 2022 were averaged. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

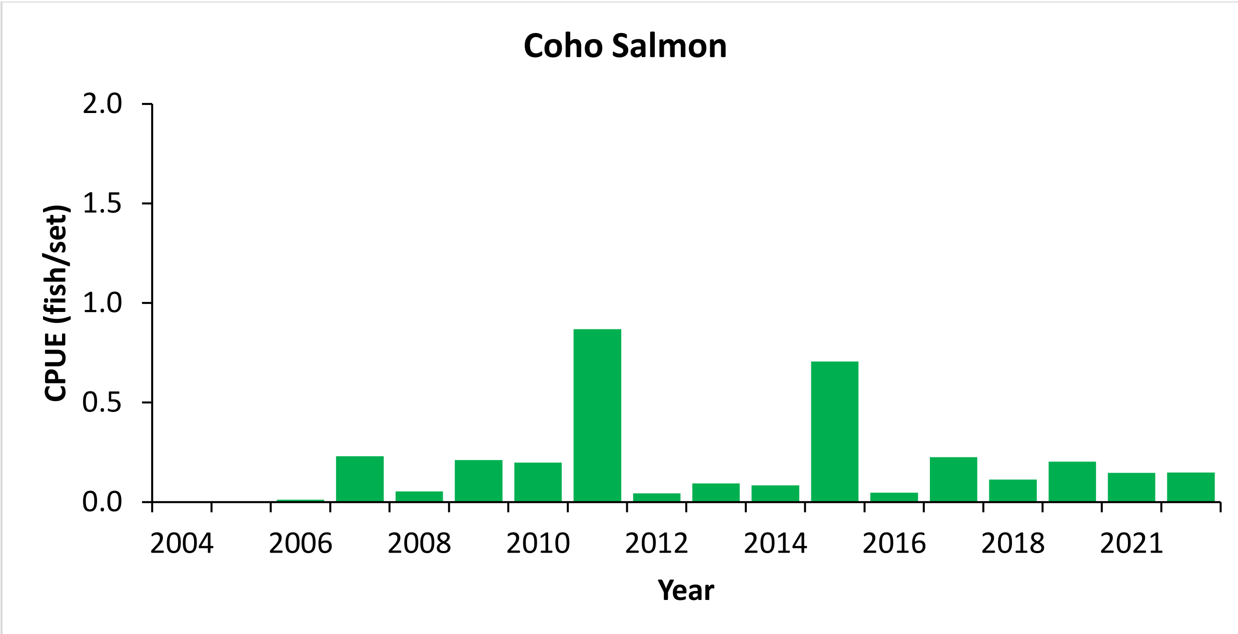


Figure 4.4.11. Annual abundance (represented as catch per unit effort) of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2022. Samples are from 96 to 300 seine sets yearly from May to October. No October 2022 survey was conducted.

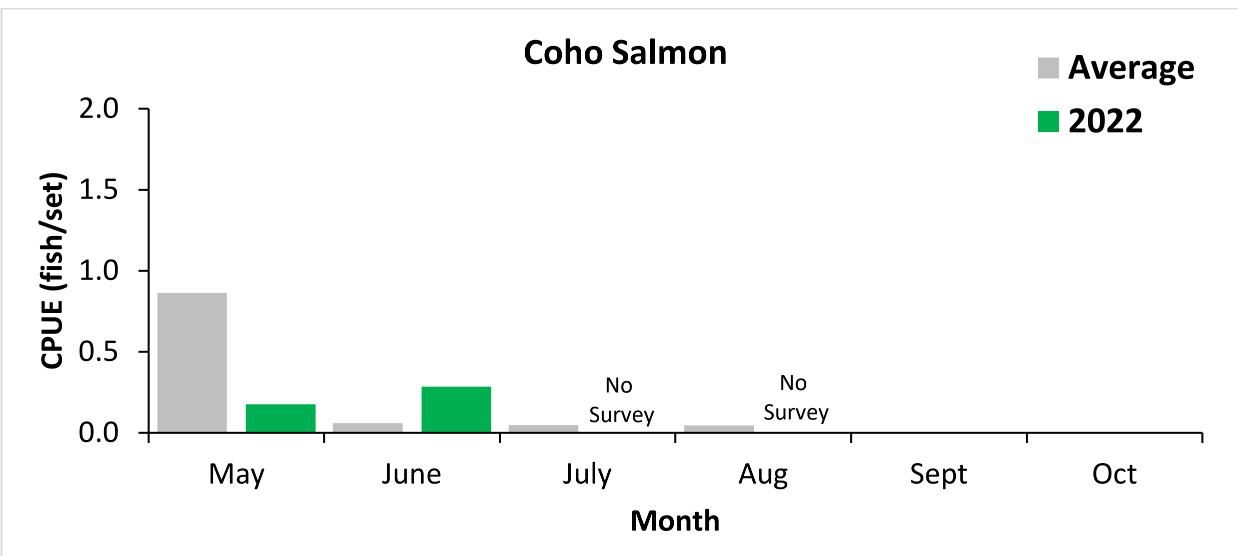


Figure 4.4.12. Seasonal abundance (represented as catch per unit effort) of Coho Salmon smolts captured by beach seine in the Russian River Estuary, 2004-2022. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2022 were averaged. No October 2022 survey was conducted.

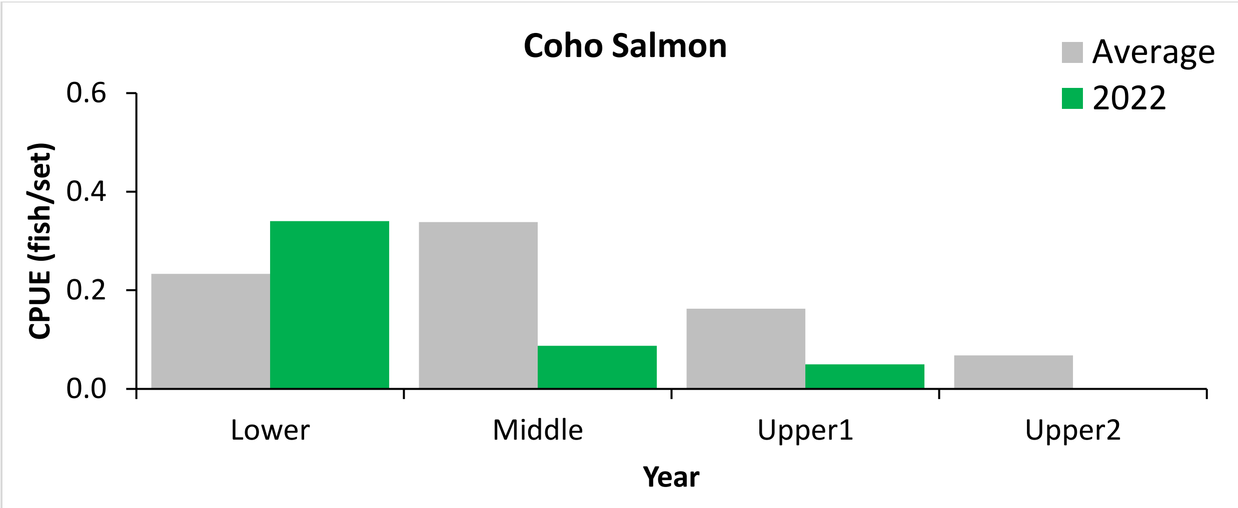


Figure 4.4.13. Spatial distribution of Coho Salmon smolts in the Russian River Estuary, 2004-2022. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2022 were averaged.

Table 4.4.3. PIT tagged Coho Salmon detection sites and seasons captured in the Russian River Estuary in 2022. PIT tagged Coho were either stocked in creeks or captured at downstream migrant traps. The fish without release site information is likely a fish released from the Hatchery as part of 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.003D6893AF	WIL SMOLT TRAP	5/24/2022	90	Bridgehaven	5/26/2022	90
3DD.003D689550	WIL SMOLT TRAP	6/5/2022	108	River Mouth	6/27/2022	108
3DD.003D689529	WIL SMOLT TRAP	6/5/2022	125	River Mouth	6/27/2022	125
3D9.1C2CEC2374	-	-	-	-	6/27/2022	110

Conclusions and Recommendations

Fish Sampling - Beach Seining

The results of Estuary fish surveys from 2004 to 2022 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 2022 fish studies contribute to the 18-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. However, the abundance of steelhead in 2022 was unusually low with only two individuals being captured during the seining season. 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 2022. It is worth noting that steelhead abundance was low in 2022 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. For more information on Sonoma Water’s downstream migrant trapping efforts see Chapter 4.5.

The capture of 734 European green crabs in 2021 and 120 in 2022 is alarming. Prior to 2021 only one individual had been captured seining and that capture occurred in 2014. European green crabs have been present in the estuary for some time and were captured in small numbers by Sonoma Water during invertebrate sampling. However, based on seining results from 2021 and 2022 their abundance and distribution appears to have increased. Lower than normal winter rainfall may have resulted in increased salinity in the lower estuary that may be partly responsible for the increased number of European green crabs as there may have been more suitable habitat during the winter of 2021 and 2022.

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 are presented in other sections of the Russian River Biological Opinion Status and Data Report Year 2022-2023.

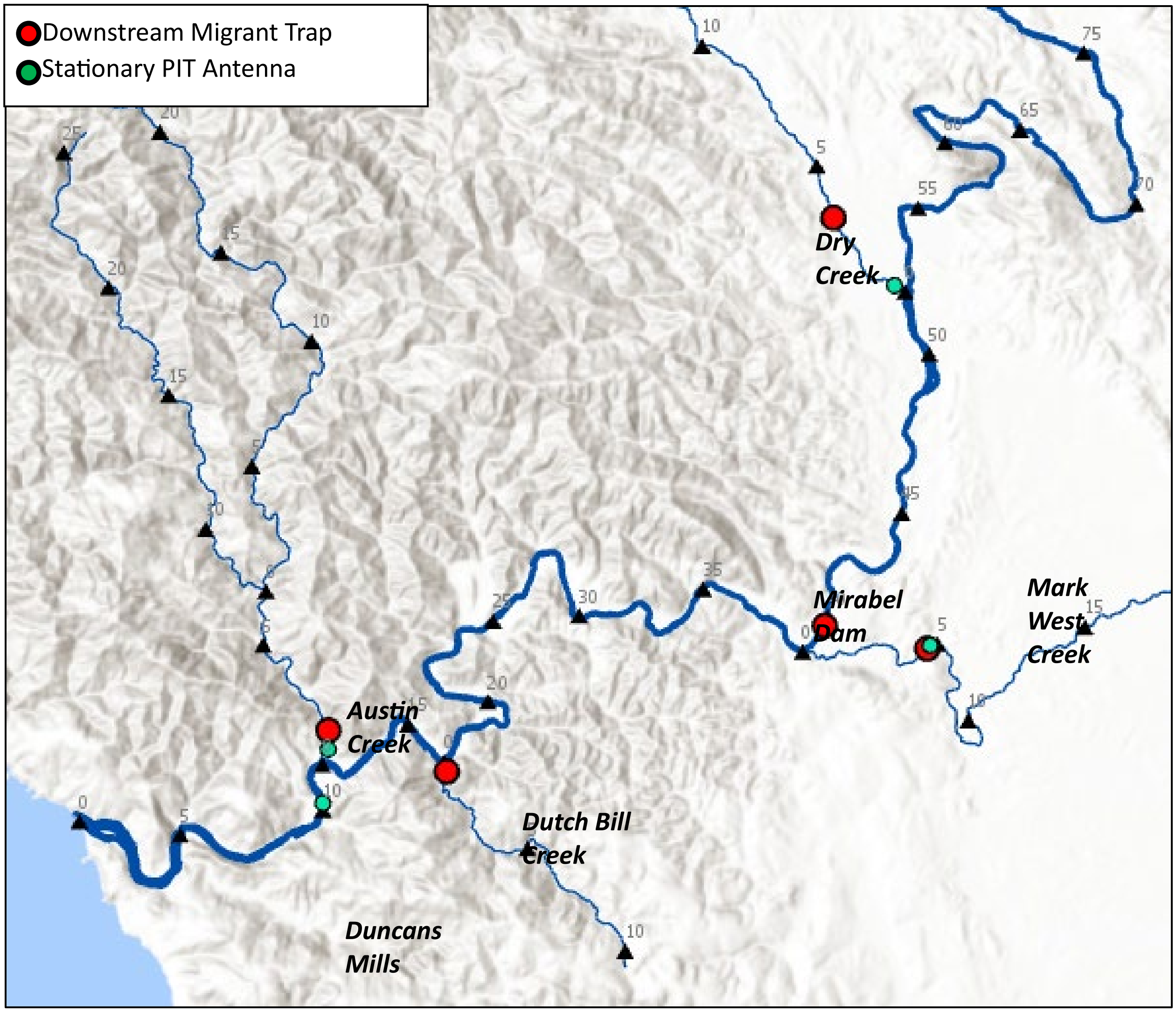


Figure 4.5.1. Map of downstream migrant detection sites in the lower Russian River, 2022. Numbered symbols along stream courses represent distance (km) from the mouth of each stream.

Methods

In 2022 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 2021, 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 (riverKm 10.46) to detect PIT-tagged fish entering the estuary (Figure 4.5.2). Generally, 10 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 5 antennas placed side by starting at the west river bank and extending out into the channel.

Figure 4.5.2. Flat plate antenna arrays at Duncans Mills (river km 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 2022: 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

Mark West Creek: Pipe trap (fished 3/4-6/20).

Dutch Bill Creek: Pipe trap (fished 3/17-5/31).

Austin Creek: Funnel trap (fished 3/17-5/31), pipe trap (fished 6/1-6/20).

Figure 4.5.3. Photographs of downstream migrant traps operated by the Sonoma Water (Mark West, Dutch Bill and Austin Creeks). See the Russian River Biological Opinion Status and Data Report year 2022-2023 for details regarding operation of the Dry Creek trap.

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 the Sonoma Water's inflatable dam site at Mirabel (approximately 38.7 km upstream of the river mouth in Jenner), although only one trap may be operated in years with relatively low stream flow (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. In 2022 rotary screw traps were fished at Mirabel from April 7 to July 7 and at Dry Creek from March 30 to July 28.

Mark West Creek

A pipe trap was installed on Mark West Creek approximately 4.8 km upstream of the mouth on March 24. The pipe trap was removed and all trapping operations were suspended on June 20 when fish captures declined 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 March 17, and fished until the completion of trapping operations on May 31, when stream flow in lower Dutch Bill Creek became disconnected (Table 4.5.1).

Austin Creek

A funnel net was installed in Austin Creek on March 17. Due to low water velocity this trap was changed to a pipe trap on June 1. Trapping continued until June 20 when surface flow in lower Austin Creek was no longer contiguous and daily catches of steelhead dropped to zero (Table 4.5.1).

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 (Figure 5.4). 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. 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 due to a low number of detections at Duncans Mills the paired antenna array in Austin Creek was used to calculate efficiency in 2022.

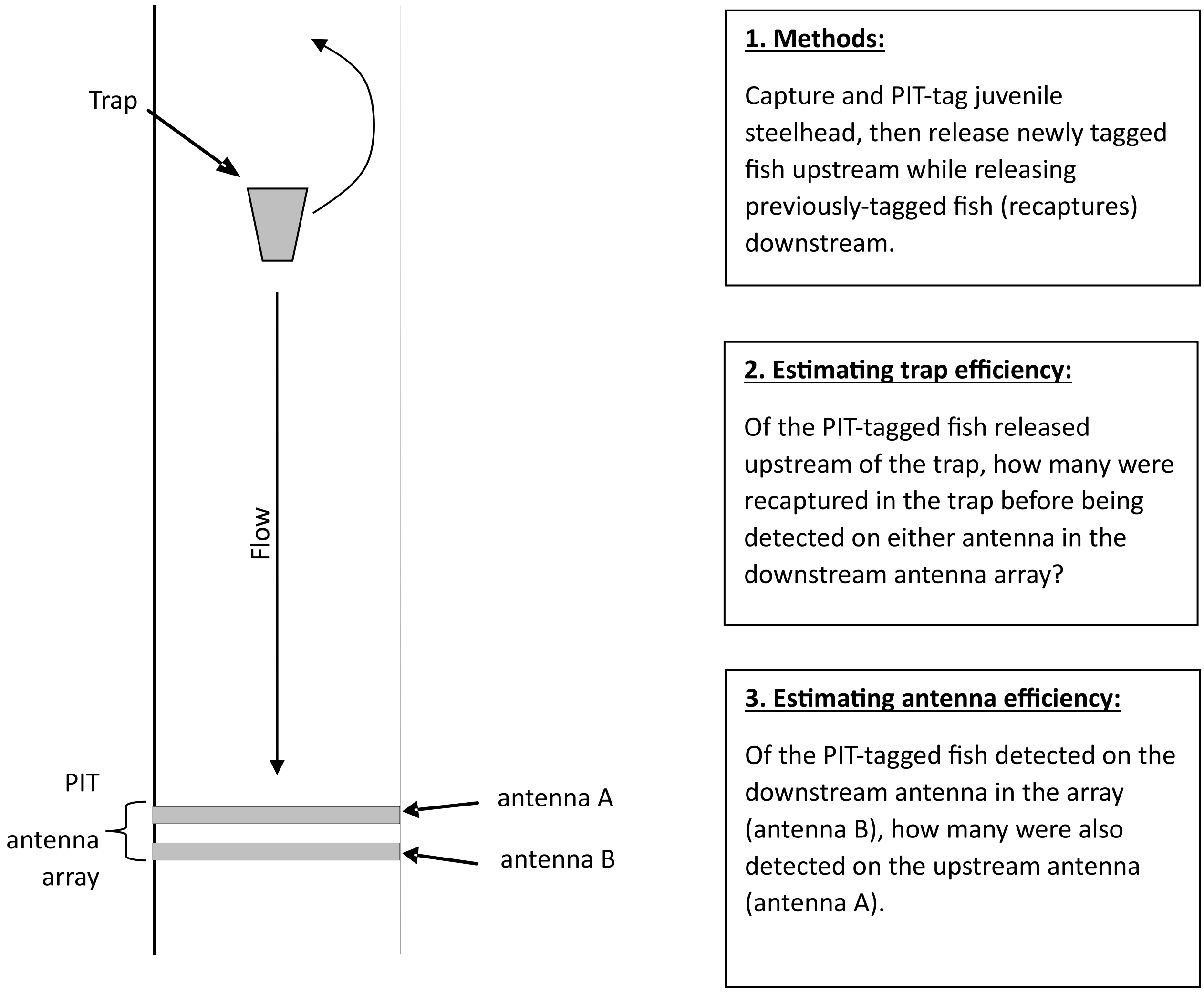


Figure 4.5.4. Diagram illustrating the relative location of the downstream migrant trap and PIT antenna array operated on Austin Creek and outline of how antenna efficiency was estimated.

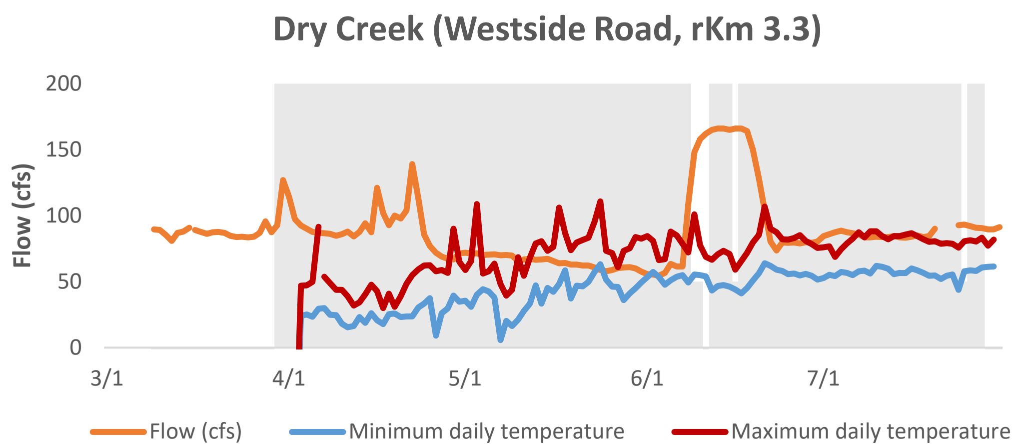
Table 4.5.1. Installation and removal dates, and total number of days fished for lower Russian River monitoring sites operated by Sonoma Water in 2022.

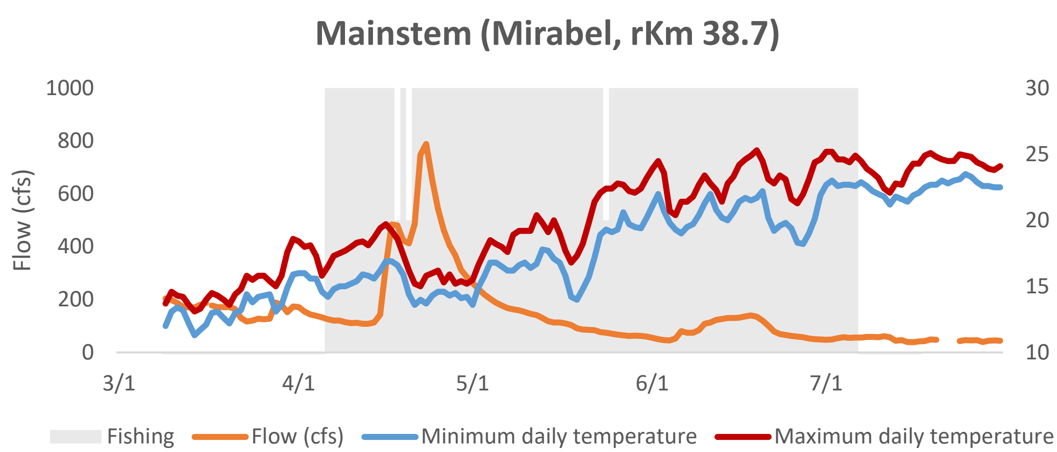
Monitoring site (gear type)	Installation date	Removal date	Number of days fished
Dry Creek (DSMT)	3/30	7/28	118
Mirabel (DSMT)	3/30	7/7	91
Mark West Creek (DSMT)	3/24	6/20	73
Dutch Bill Creek (DSMT)	3/17	5/31	69
Austin Creek (DSMT)	3/17	5/20	84
Duncans Mills (PIT antenna array)[1]	Continuous	Continuous	Continuous

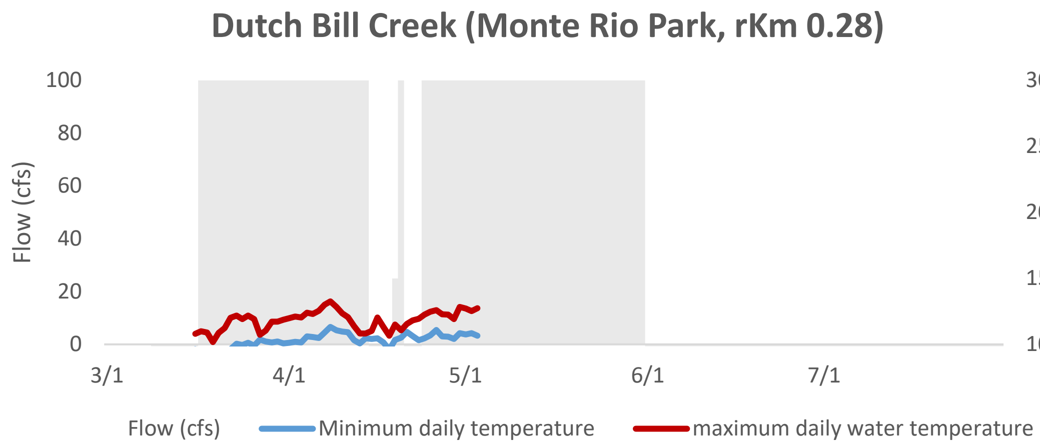
[1]See text for details on changes to PIT antenna array throughout the season.

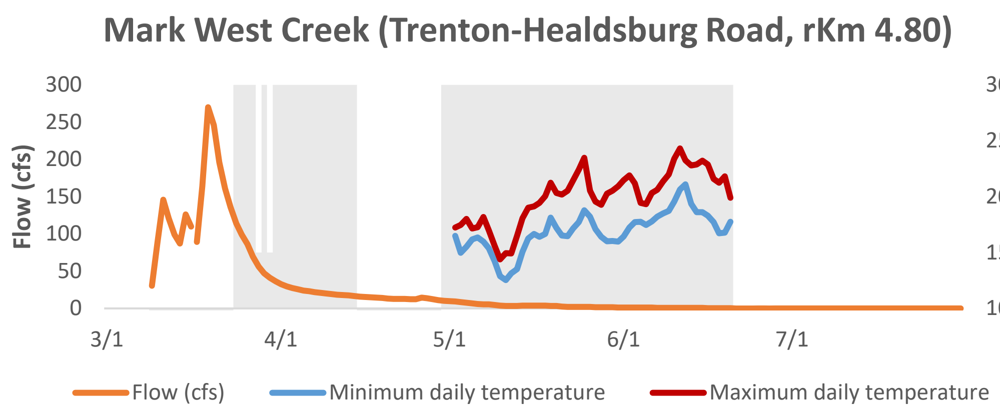
Results

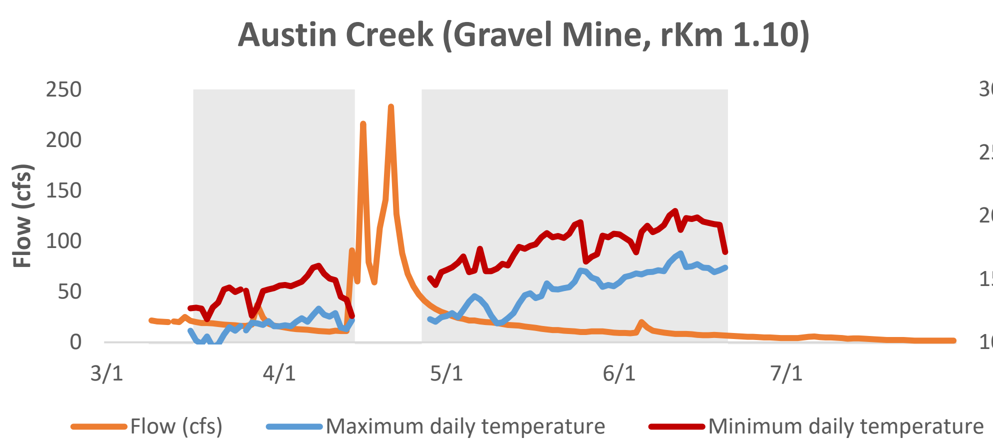
Stream flow largely dictates when downstream migrant traps can be installed (Figure 4.5.5). The sampling period most likely encompassed a high portion of the juvenile steelhead movement period but a substantial portion of the steelhead smolt migration period was likely missed due to the early run timing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






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


Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
Flow (cfs)
300
250
200
150
100
50
0
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


Austin Creek (Gravel Mine, rKm 1.10)
Flow (cfs)
250
200
150
100
50
0
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

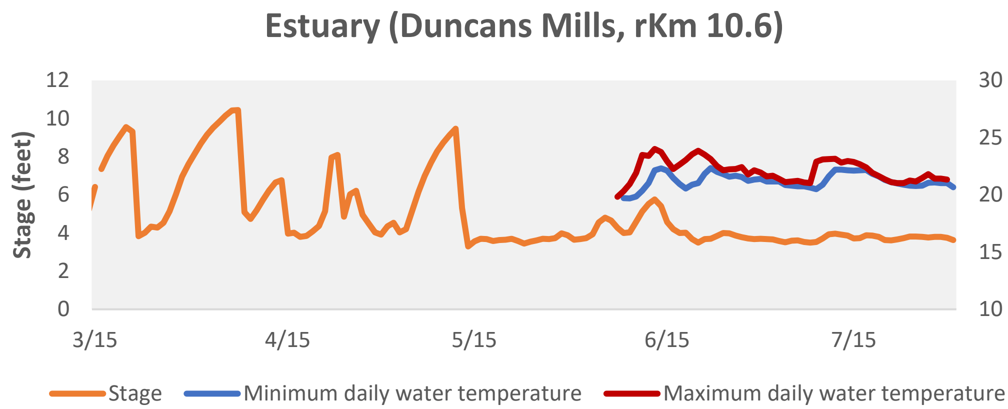


Figure 4.5.5. Environmental conditions at downstream migrant detection sites from March through July. Gray shading indicates the proportion of each day that each facility was operated. Discharge data are from the USGS gage at Healdsburg (mainstem Russian, 11464000), the USGS gage at Trenton-Healdsburg Road (Mark West Creek, 11466800), a gage operated by CMAR on Dutch Bill Creek (data unavailable in 2022) 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). Estuary water temperature was collected by Sonoma Water in the Russian River at Freezeout creek. Mainstem water temperature data are from the USGS Hacienda gage (11467000). Water temperature for Dry Creek was collected at the USGS Dry Creek gage at Lambert Bridge (11465240). At all other sites temperature data are from the data loggers operated by Sonoma Water at each monitoring site.

Steelhead

Steelhead were most frequently encountered at the Dry Creek trap. In total 2,864 YOY and parr, and 316 smolts were captured at the Dry Creek trap. In Austin Creek 1,588 YOY and parr and 15 smolt were captured. At Dutch Bill Creek 30 YOY and parr and 6 smolts were captured. At Mark West Creek 192 YOY and parr, and 9 smolts were captured. At the Mainstem Russian River trap 308 YOY and parr and 299 smolts were captured (Figure 4.5.6).

In 2022 Sonoma Water relied on the Duncans Mills PIT tag antennas for estimating the number of steelhead YOY and parr that entered the estuary. Of the 818 juvenile steelhead that were PIT-tagged in the downstream migrant traps, 49 (6%) were detected on the PIT antenna array at Duncans Mills (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 Duncans Mills.

Table 4.5.2. Number of steelhead juveniles PIT-tagged at downstream migrant traps, 2009-2022 (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	2020	2021	2022
Dry Creek	N.T.	N.T.	N.T.	N.T.	2,703	1,348	N.T.	N.T.	N.T.	N.T.	N.T.	N.T	N.T.	N.T.
Mainstem	5	96	99	315	100	101	-	-	1	63	40	46	100	191
Mark West Creek	-	-	-	43	135	18	19	546	49	62	125	14	22	124
Dutch Bill Creek	-	46	22	6	12	21	7	46	377	12	74	176	3	2
Austin Creek	-	996	500	1,636	1,749	590	107	1,205	359	780	172	383	159	501
Total	**5**	**1,138**	**621**	**2,000**	**4,699**	**2,078**	**133**	**1,797**	**791**	**917**	**411**	**618**	**284**	**284**

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, 2022.

Site	Number Captured	Number PIT- Tagged	Number (proportion) Detected at Duncans Mills
Mainstem	312	191	0 (0)
Mark West Creek	182	124	0 (0)
Dutch Bill Creek	30	2	0 (0)
Austin Creek	1588	501	49 (0.10)
Total	2112	818	49 (0.06)

Over the course of the season, 1,603 steelhead were captured at Austin Creek of which 849 were YOY (509 of the 849 YOY were ≥60 mm, Figure 4.5.11). Although Sonoma Water applied PIT tags to 501 total individuals (YOY+parr), based on their size, 482 of these PIT-tagged fish were estimated to be YOY. While the Austin Creek trap was installed on March 17, 2022, the PIT antenna was not installed until May 18, 2022. In total, 83 PIT-tagged steelhead YOY were released upstream of the trap and 6 were released downstream of the trap during the period of time that the Austin Creek PIT antenna was running (Table 4.5.4). Because 42 of the 83 PIT-tagged YOY were detected on the PIT antenna arrays downstream of the trap, at least 50.6% (42 / 83) 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 501 steelhead (YOY + parr) PIT tagged in Austin Creek 3 were detected on the downstream antenna in the array (Duncans Mills), 3 were also detected on the upstream antenna array (Austin Creek) resulting in an estimated antenna efficiency of 100% (3/3). In order to estimate the number of YOY out of the original 483 that actually moved downstream of

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	2020	2021	2022
Number PIT-tagged YOY released upstream of trap	765	324	1,356	0	214	101	1,132	244	713	128	273	132	83
Number PIT-tagged YOY released downstream of trap	195	2	162	1,746	269	6	73	2	6	7	98	16	6
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	189	54	42
Number PIT-tagged YOY released upstream & detected on antenna array	389	131	486	0	57	13	151	80	291	49	127	40	35
Number released upstream & recaptured in trap & detected on antenna	47	8	196	0	2	0	60	0	61	3	5	1	1
Estimated trap efficiency	**12.1%**	**6.1%**	**40.3%**	**N/A**	**N/A**	**N/A**	**39.7%**	**N/A**	**21.0%**	**5.7%**	**N/A**	**N/A**	**N/A**
Number YOY+parr detected on both antennas in array	241	93	85	399	129	34	76	52	60	64	31	47	3
Number YOY+parr detected on downstream antenna	288	178	129	463	162	35	205	55	75	71	37	49	3
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%**	**83.7%**	**95.9%**	**100%[1]**
Number YOY captured and pit-tagged	960	324	1,518	1,746	483	42	993	319	719	168	371	148	483
Total number of YOY captured (≥60 mm only)	2,617	453	2,341	4,216	541	42	2,427	319	2,056	368	344	444	509
Estimated number of PIT-tagged YOY emigrants (≥60 mm only)	**632**	**251**	**759**	**1,549**	**325**	**32**	**520**	**55**	**93**	**138**	**225**	**61**	**42**
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%**	**50%**	**41.3%**	**50%**
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**	**N/A**	**N/A**	**NA**
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**	**N/A**	**N/A**	**NA**

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

the Austin Creek antenna array, this proportion was used to expand the number of YOY detected on the Austin antenna (42) detections to 42 (42/100%).

In total 35 YOY that were detected on either of the downstream PIT antenna arrays were also released upstream of the trap, however only 1 were recaptured in the trap. Because so few steelhead were recaptured in the trap a population estimate was not calculated.

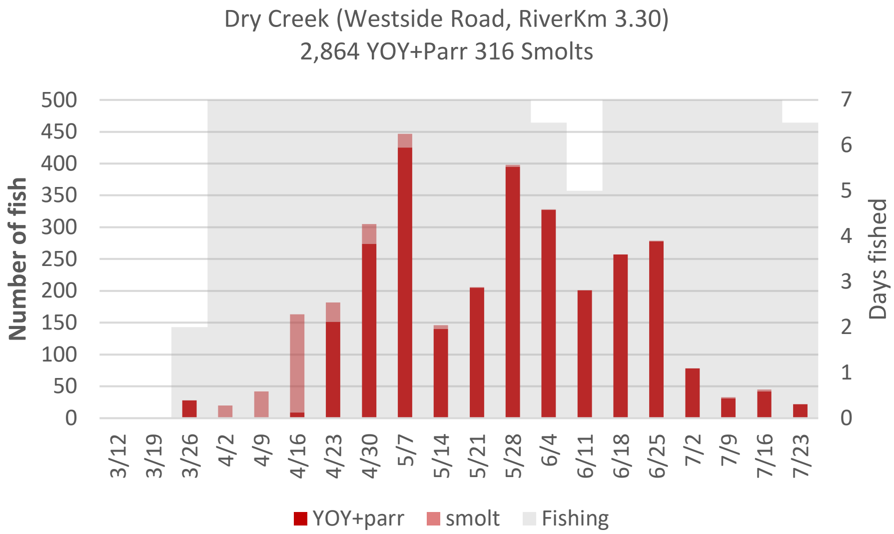
When compared to Austin, Dry, and Dutch Bill creeks fewer numbers of juvenile steelhead were captured at the mainstem Russian River and Mark West (Figure 4.5.6) meaning that fewer numbers of juvenile steelhead were PIT-tagged at these locations (Table 4.5.3). Fork lengths of fish caught at these traps show at least three 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 (Figures 4.5.8 through 4.5.12).

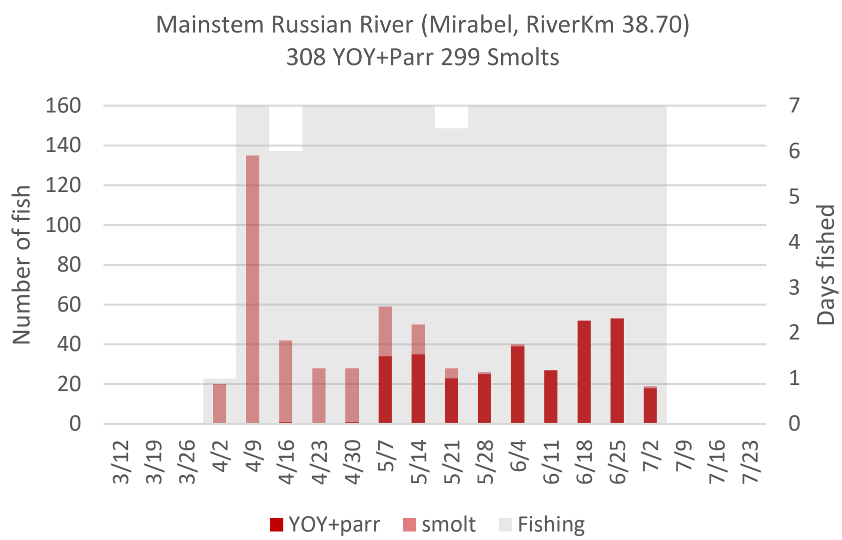
Coho Salmon

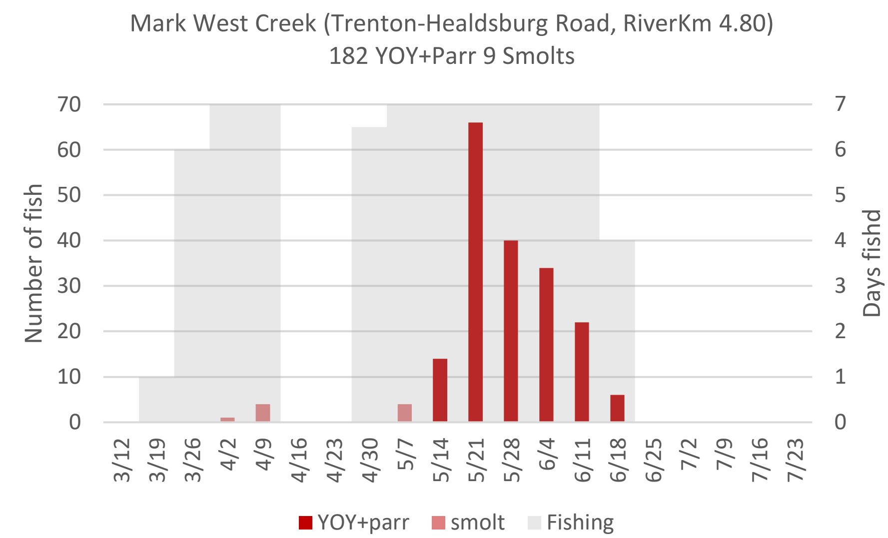
At Dry Creek 429 hatchery smolts, 477 wild smolts, 20 smolts of unknown origin, 11 YOY of unknown origin, and 2 wild YOY were detected at the trap (Figures 4.5.8 and 4.5.14). On the mainstem Russian River 902 hatchery smolts, 492 wild smolts, 27 smolts of unknown origin, 1 hatchery YOY, 7 wild YOY, and 1 YOY of unknown origin were detected at the trap (Figures 5.9 and 5.14). At Mark West Creek, 159 hatchery smolts, 10 wild smolts, and 1 smolt of unknown origin, 10 wild YOY, and 2 YOY of unknown origin were captured (Figures 4.5.10 and 4.5.14). A total of 121 hatchery smolts, 4 smolt of unknown origin, 34 wild smolts, 1 wild YOY, and 1 YOY of unknown origin were captured at the Dutch Bill Creek trap (Figure 4.5.11 and Figure 4.5.14). At Austin Creek, 24 hatchery smolts, 21 wild smolts, 1 hatchery YOY, 92 YOY of unknown origin, and 70 wild YOY were captured (Figures 4.5.12 and 4.5.14). 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). For a more detailed analysis of downstream migrant trapping catches of Coho from other Russian River streams see UCCE Coho Salmon Monitoring Program results for 2022.

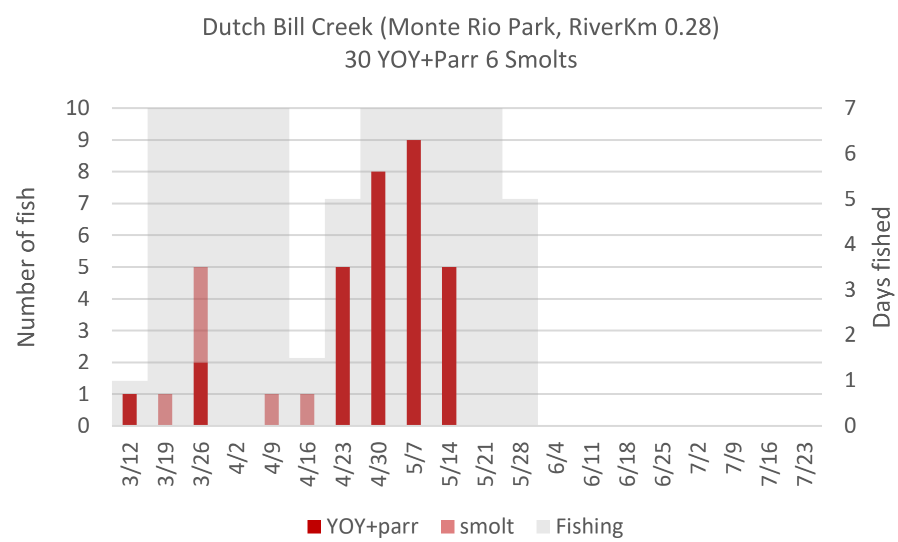
Chinook Salmon

In 2022 relatively few Chinook smolts were captured in Austin Creek, Dutch Bill Creek, and Mark West Creek (0, 0, and 2 respectively). In the mainstem Russian River 19,325 Chinook smolts were captured (Figures 4.5.15 and 4.5.16). Fork lengths of Chinook increased over the course of the trapping season (Figure 4.5.17). A total of 2,336 Chinook salmon smolts were marked with fin clips and released upstream of the mainstem Russian River trap. Of the 225 (9.6 percent) were recaptured. Based on weekly recapture rates of fin clipped Chinook salmon it is estimated that 285,393 (95% CI: ± 80,098) Chinook smolts passed the Mirabel trap during the period that fin clips were applied (4/7-6/27). For more details on characteristics of Chinook smolts captured at Dry Creek see the Russian River Biological Opinion Status and Data Report year 2022-2023.


Dry Creek (Westside Road, RiverKm 3.30)
2,864 YOY+Parr 316 Smolts
Number of fish
Days fished
500
450
400
350
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0
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
YOY+parr
smolt
Fishing


Mainstem Russian River (Mirabel, RiverKm 38.70)
308 YOY+Parr 299 Smolts
Number of fish
Days fished
160
140
120
100
80
60
40
20
0
7
6
5
4
3
2
1
0
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
YOY+parr
smolt
Fishing


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
182 YOY+Parr 9 Smolts
Number of fish
Days fishd
70
60
50
40
30
20
10
0
7
6
5
4
3
2
1
0
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
YOY+parr
smolt
Fishing


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28)
30 YOY+Parr 6 Smolts
Number of fish
Days fished
10
9
8
7
6
5
4
3
2
1
0
7
6
5
4
3
2
1
0
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
YOY+parr
smolt
Fishing

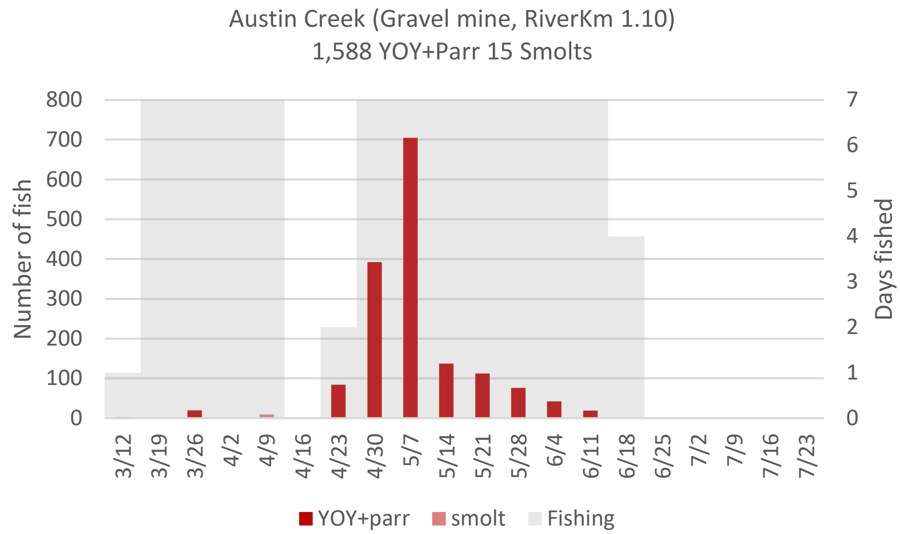
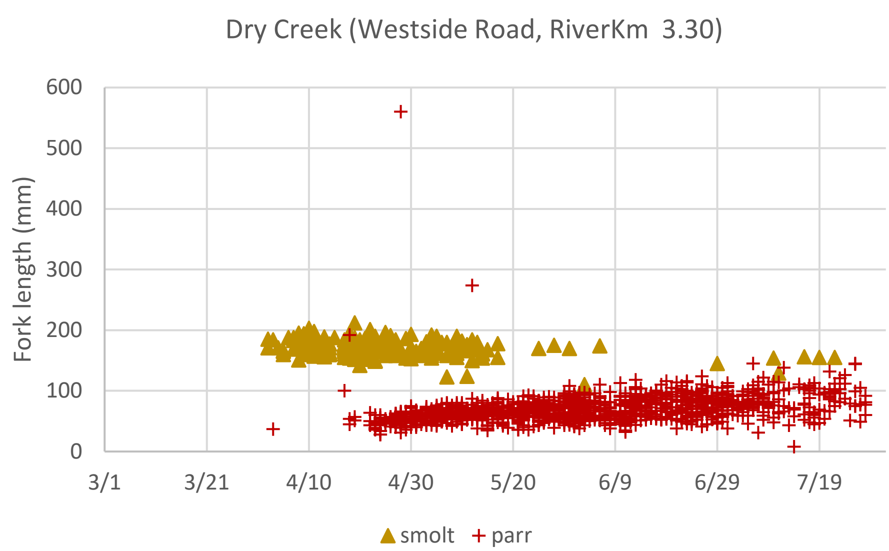
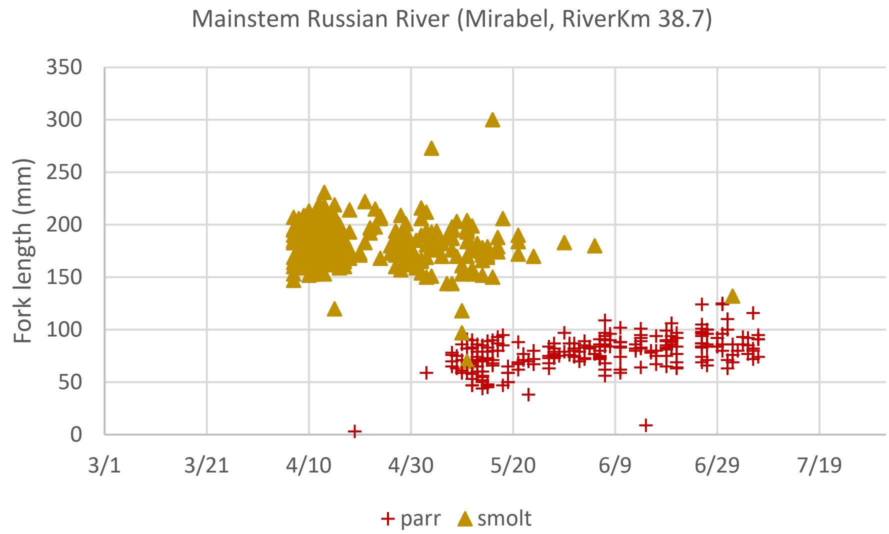
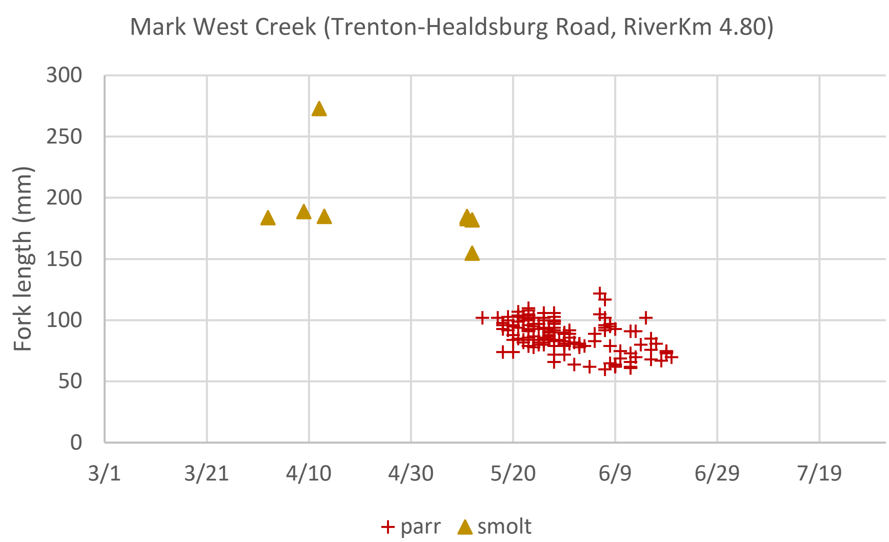


Figure 4.5.6. Weekly capture of steelhead by life stage at lower Russian River downstream migrant trapping sites, 2022. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.




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


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork length (mm)
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

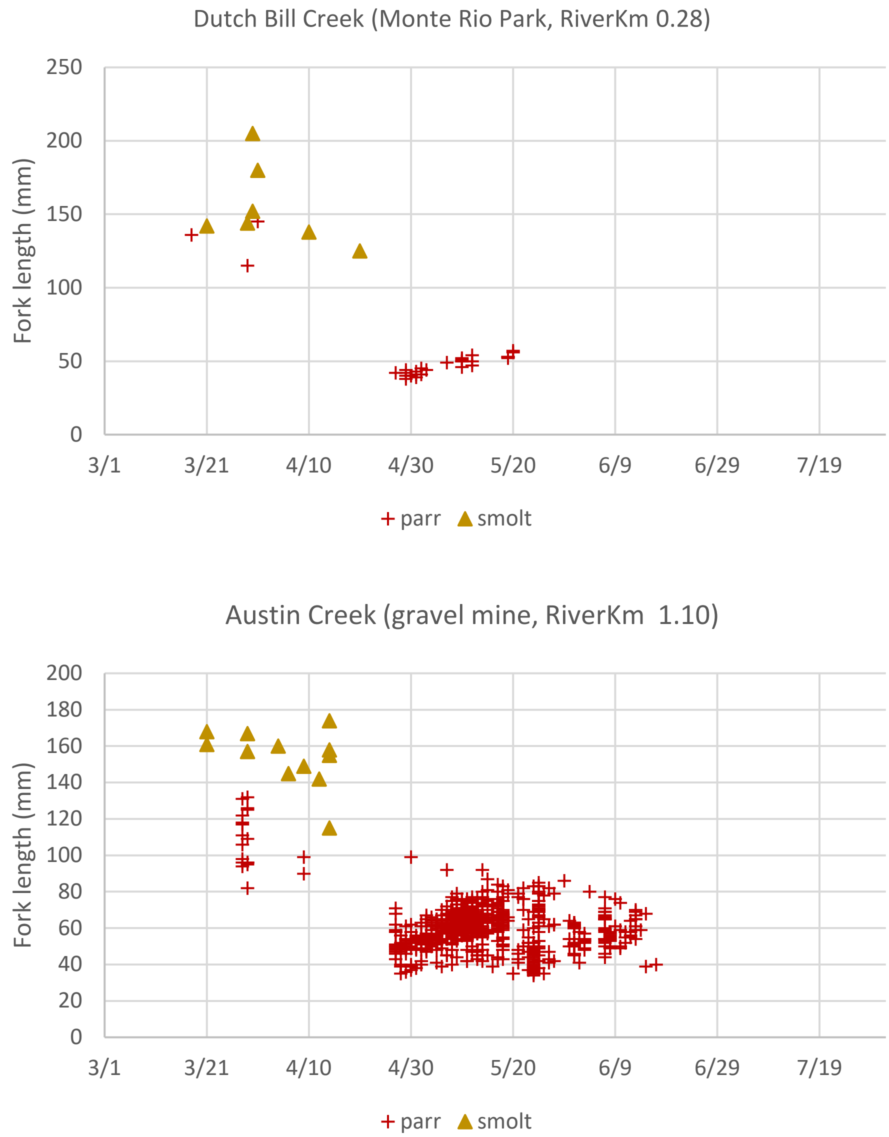


Figure 4.5.7. Weekly fork lengths of steelhead captured at lower Russian River downstream migrant trap sites, 2022.

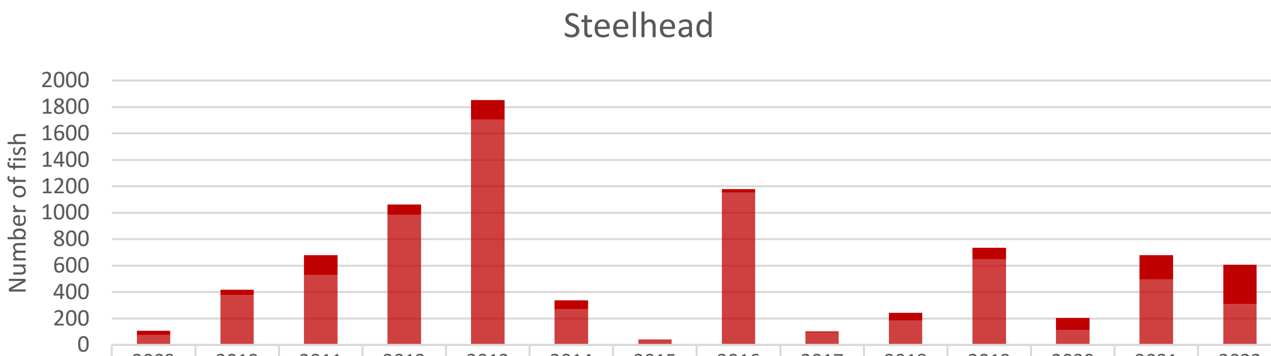
Steelhead

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Smolt	219	33	72	56	281	564	339	106	50	126	60	49	90	316
Parr	5258	2049	2879	4706	3619	2563	4696	4221	3966	3767	5626	3370	1899	2864

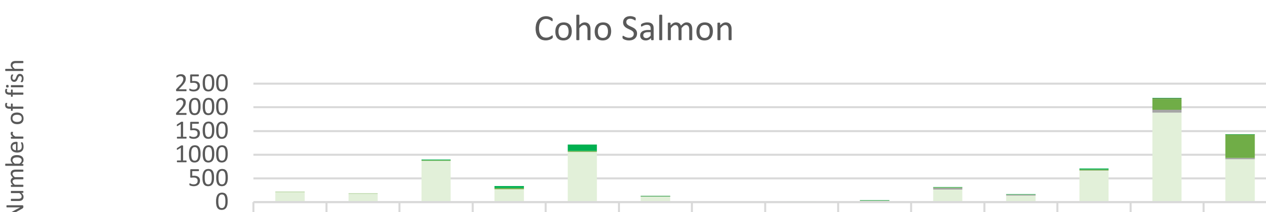
Coho salmon

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
YOY/parr-wild	0	2	18	35	1	4	0	22	3	5	8	4	6	2
YOY/parr-hatchery											151	1	1	
YOY/parr-unknown	0	0	0	0	0	9	4	16	1	1	626	1	8	11
smolt-unknown	0	0	0	0	0	11	0	1	2	2	0	0	6	20
smolt-hatchery	7	19	113	127	760	858	264	227	301	19	102	146	583	429
smolt wild	3	1	83	117	19	54	49	13	35	83	8	32	180	477

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), 2009-2022.

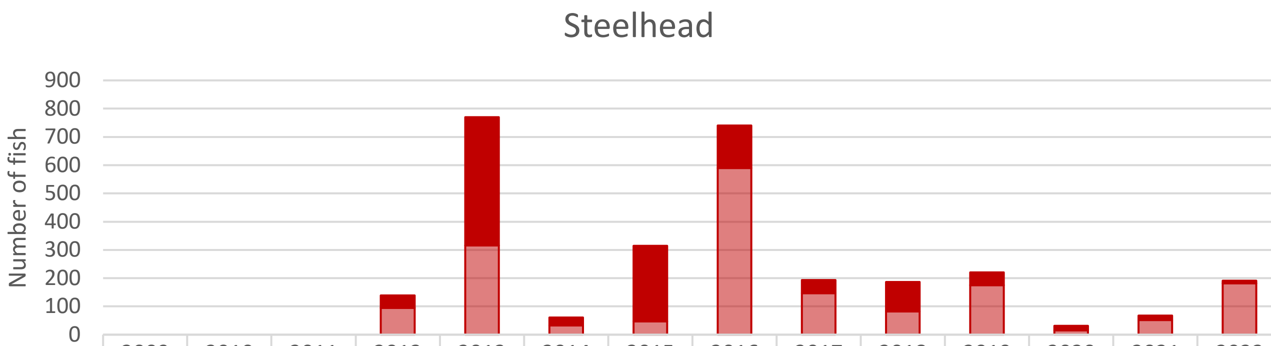


	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
smolt	33	42	151	78	148	67		28	7	57	86	94	183	299
parr	75	375	528	984	1705	270	42	1151	95	185	648	111	495	308

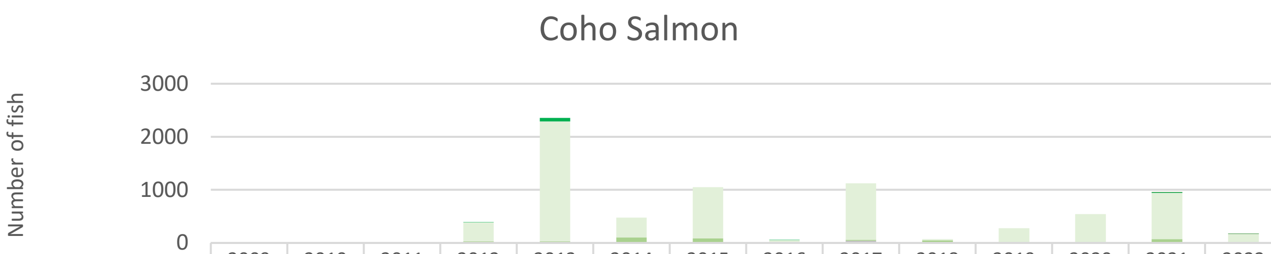


	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
YOY/parr-wild	0	0	10	45	137	1	0	11	1	1	2	24	8	7
YOY/parr-unknown	0	0	0	0	0	1	0	0	0	0	0	0	12	1
smolt-wild	5	1	15	26	20	6		2	4	14	8	16	228	492
smolt-unknown	0	0	0	0	0	1	0	0	1	33	21	4	61	27
smolt-hatchery	208	180	872	270	1059	117			28	265	136	668	1891	902

Figure 4.5.9. Number of steelhead and coho salmon captured by life stage and origin at the mainstem Russian River at Chalk Hill and Mirabel-Wohler downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2022.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Smolt				44	454	29	268	150	46	104	45	15	16	9
Parr				95	316	32	47	590	147	82	175	16	52	182



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
YOY/parr-unknown													1	2
YOY/parr-wild	0	0	0	7	66	0	0	5	0	0	0	0	15	2
smolt-hatchery				357	2258	375	967	37	1065	23	273	530	865	159
smolt-wild				28	32	84	80	16	17	50	3	14	67	10
smolt-unknown	0	0	0	0	0	18	4	0	44	1	0	0	8	1

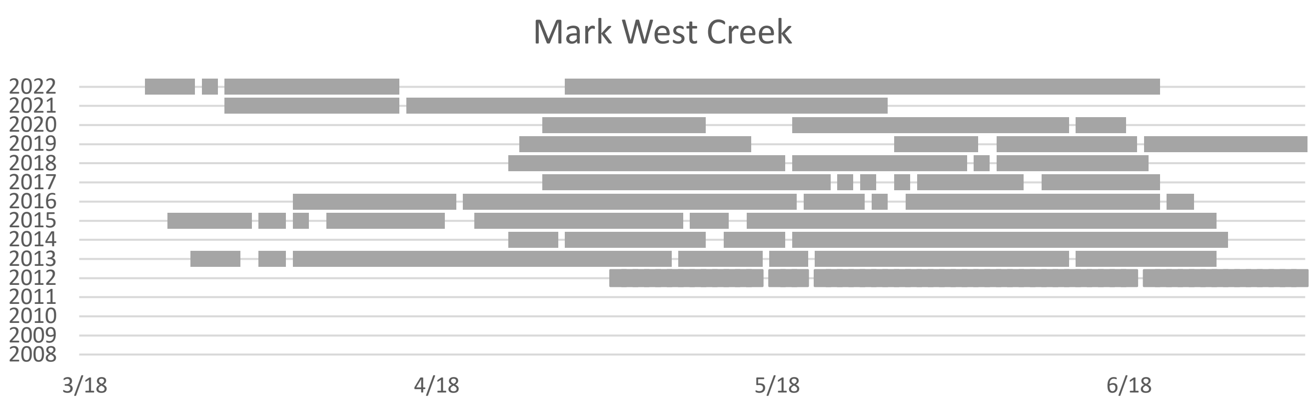
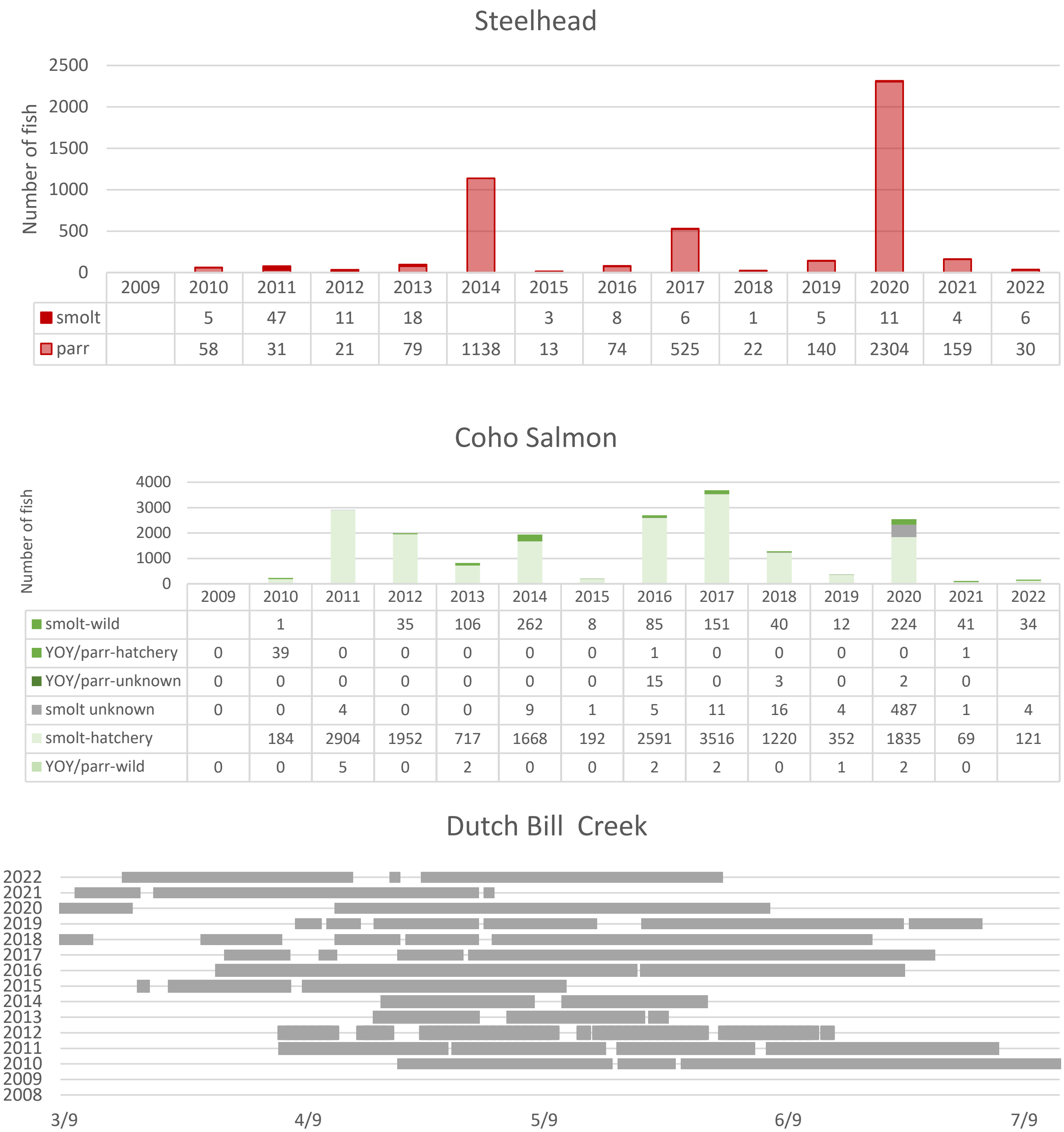


Figure 4.5.10. Number of steelhead and coho salmon captured by life stage and origin at the Mark West Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2022.



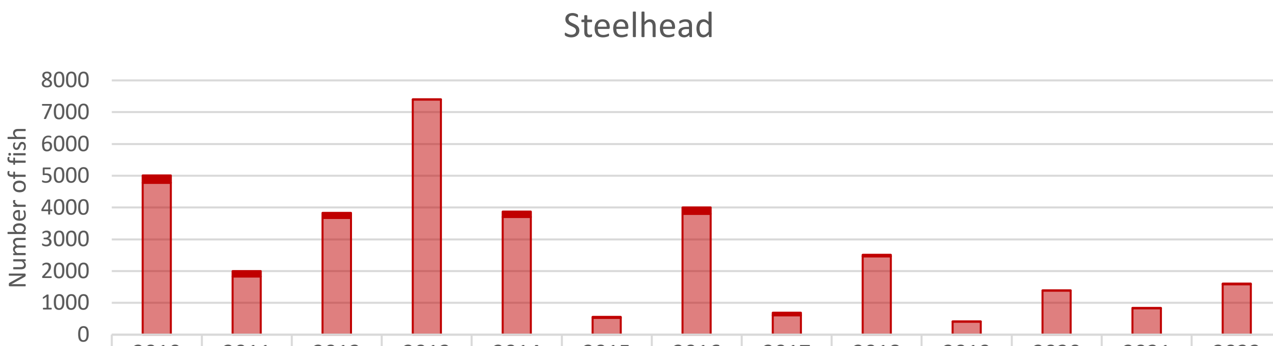
Steelhead

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
smolt		5	47	11	18		3	8	6	1	5	11	4	6
parr		58	31	21	79	1138	13	74	525	22	140	2304	159	30

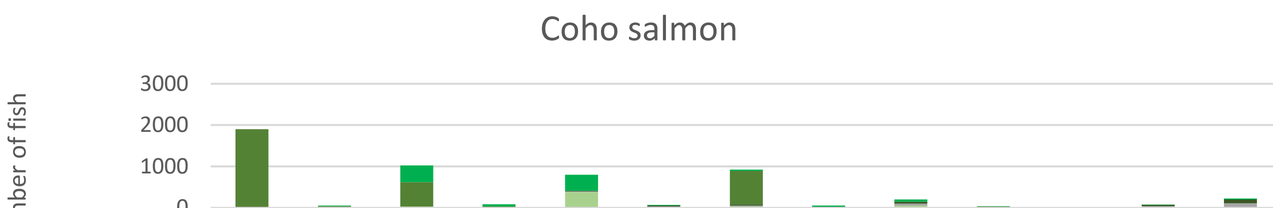
Coho Salmon

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
smolt-wild		1		35	106	262	8	85	151	40	12	224	41	34
YOY/parr-hatchery	0	39	0	0	0	0	0	1	0	0	0	0	1	
YOY/parr-unknown	0	0	0	0	0	0	0	15	0	3	0	2	0	
smolt unknown	0	0	4	0	0	9	1	5	11	16	4	487	1	4
smolt-hatchery		184	2904	1952	717	1668	192	2591	3516	1220	352	1835	69	121
YOY/parr-wild	0	0	5	0	2	0	0	2	2	0	1	2	0	

Figure 4.5.11. 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), 2009-2022.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
smolt	232	175	164	14	173	30	201	79	50	6	1	4	15
parr	4774	1829	3672	7397	3702	527	3798	611	2466	411	1387	830	1588



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
YOY/parr wild	0	14	409	50	387	9	32	27	55	2	10	11	21
YOY/parr-Hatchery	1906	45	584	24	0	0	809	0	0	30	0	1	1
YOY/parr-unknown	0	0	0	0	16	26	26	1	49	2	1	30	92
smolt-unknown	0	0	0	0	16	26	26	1	49	2	1	30	92
smolt-hatchery			37	12	386	9	32	26	55	2	10	11	21
smolt-wild													

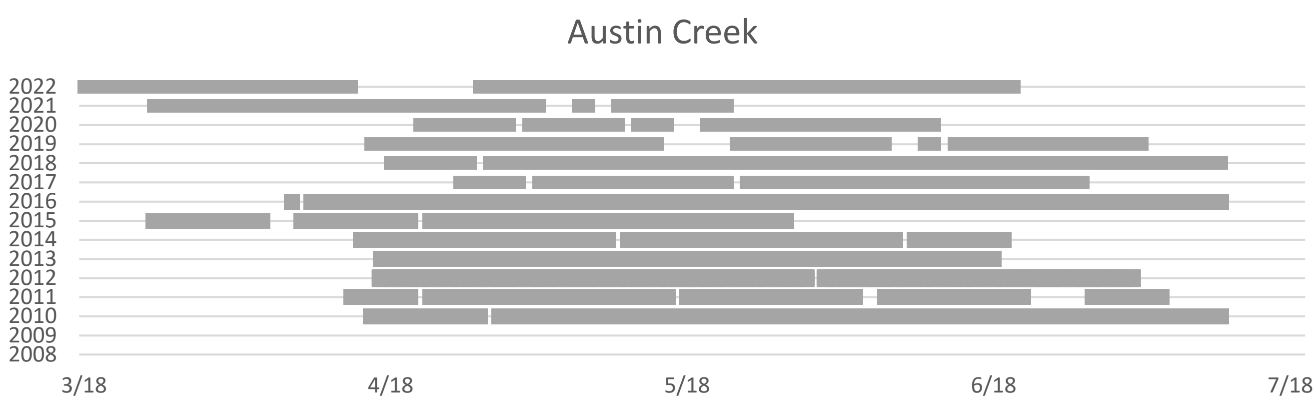
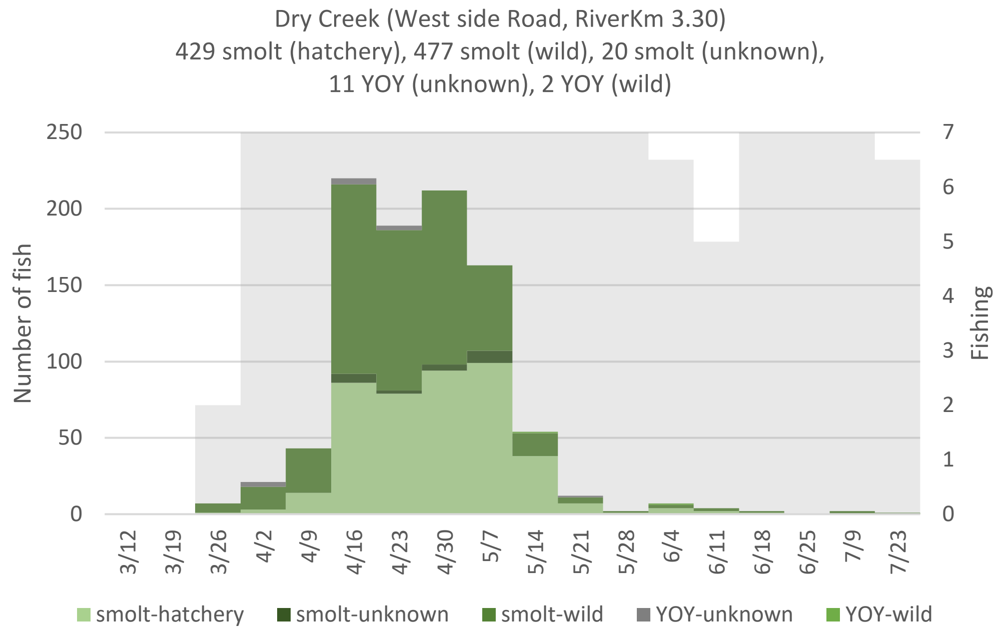
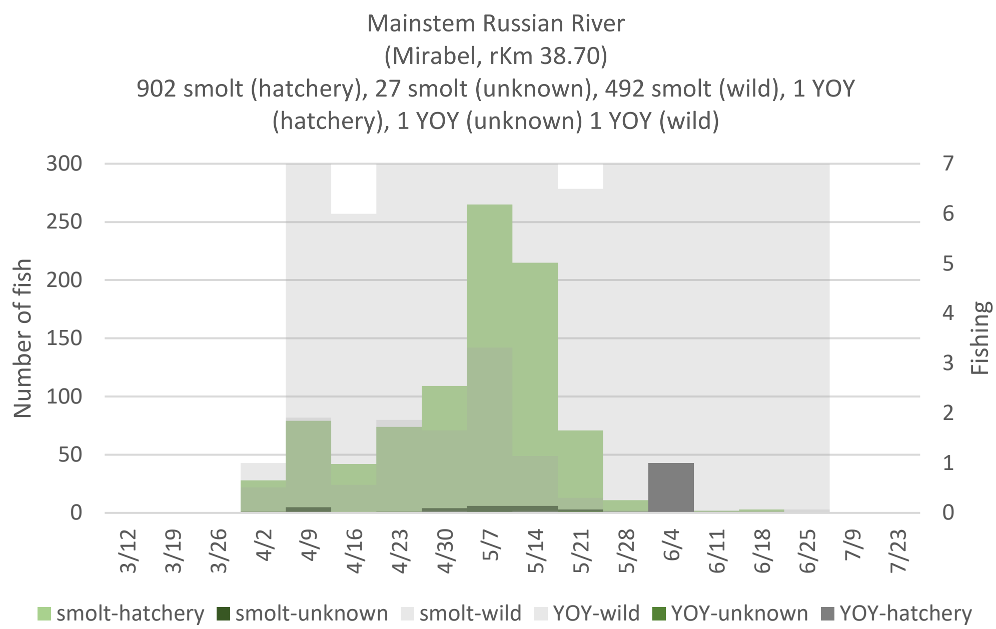
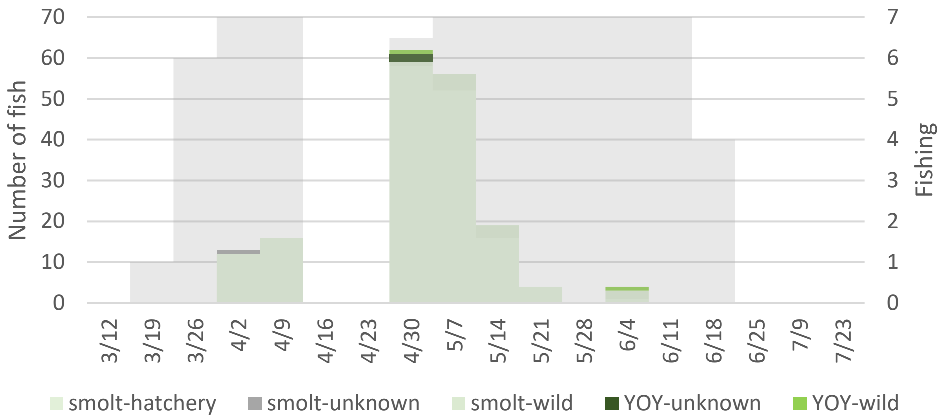


Figure 4.5.12. Number of steelhead and coho salmon captured by life stage and origin at the Austin Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2022.

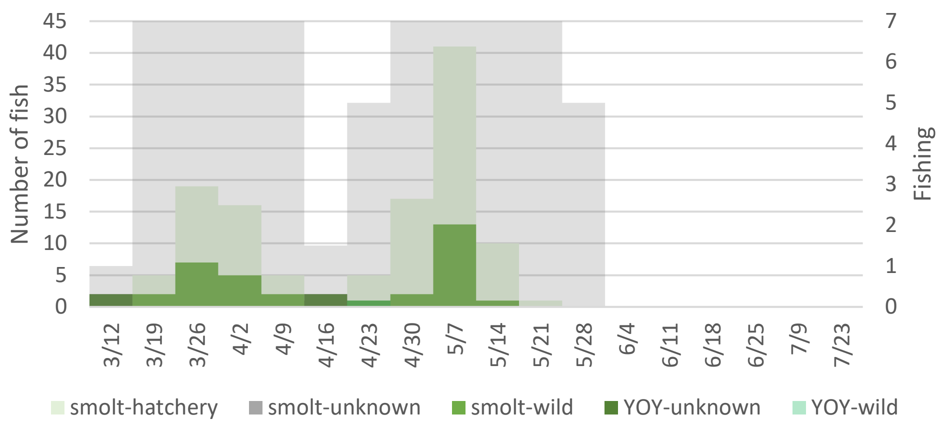

Dry Creek (West side Road, RiverKm 3.30)
429 smolt (hatchery), 477 smolt (wild), 20 smolt (unknown), 11 YOY (unknown), 2 YOY (wild)
Number of fish
Fishing
0
50
100
150
200
250
0
1
2
3
4
5
6
7
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/9
7/23
smolt-hatchery
smolt-unknown
smolt-wild
YOY-unknown
YOY-wild


Mainstem Russian River
(Mirabel, rKm 38.70)
902 smolt (hatchery), 27 smolt (unknown), 492 smolt (wild), 1 YOY (hatchery), 1 YOY (unknown) 1 YOY (wild)
Number of fish
Fishing
0
50
100
150
200
250
300
0
1
2
3
4
5
6
7
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
7/9
7/23
smolt-hatchery
smolt-unknown
smolt-wild
YOY-wild
YOY-unknown
YOY-hatchery

Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
159 smolt (hatchery), 10 smolt (wild) , 1 smolt (unknown), 2 YOY wild, 2 YOY (unknown)



Dutch Bill Creek (Monte Rio Park, riverKm 0.28)
121 smolt (hatchery), 4 smolt (unknown), 34 smolt (wild), 2 YOY (unknown), 1 YOY (wild)



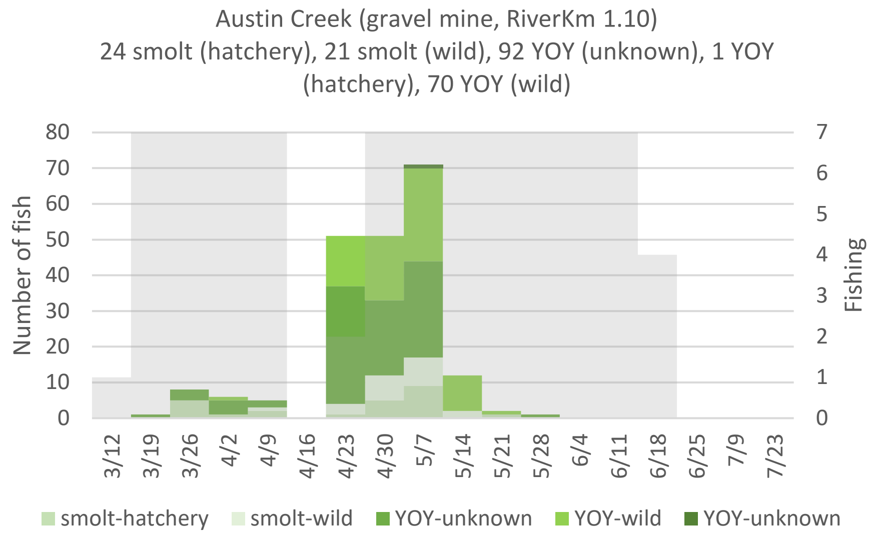
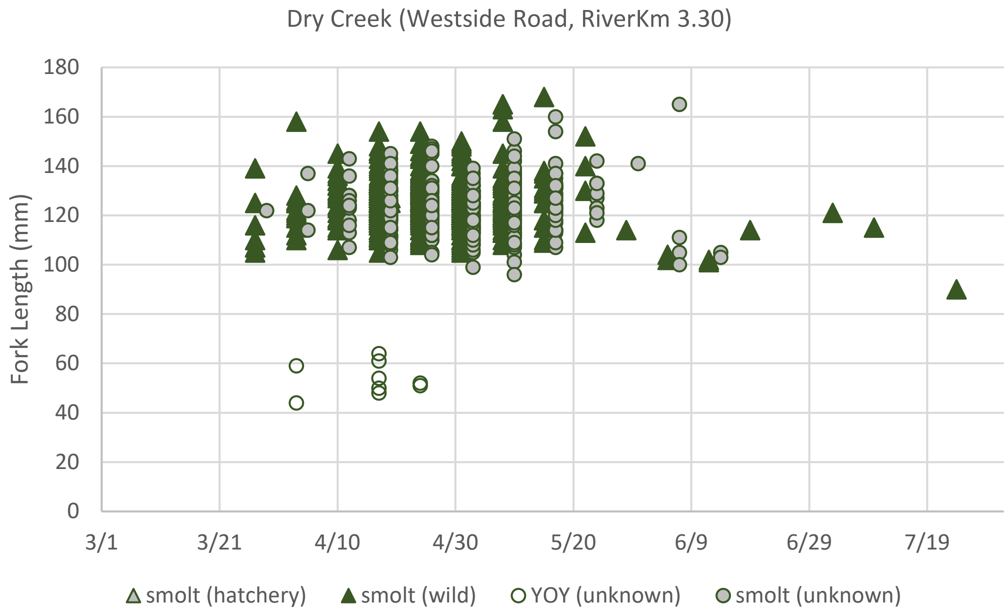
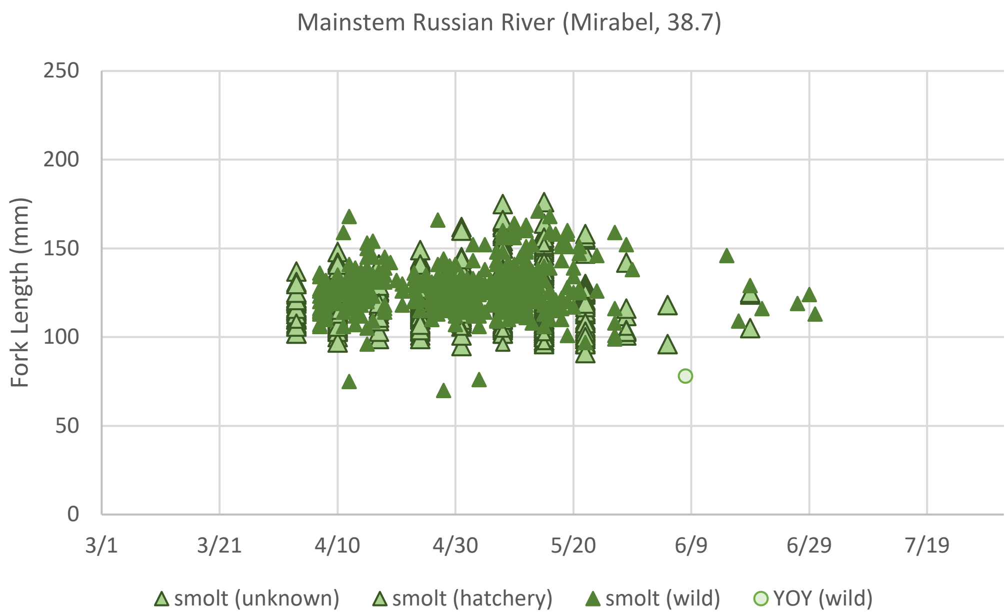
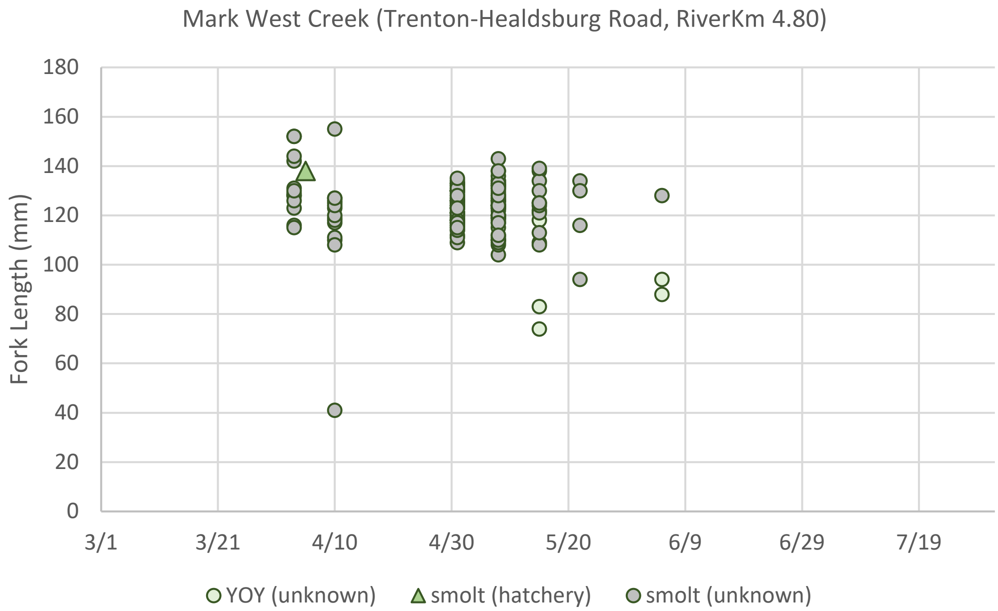
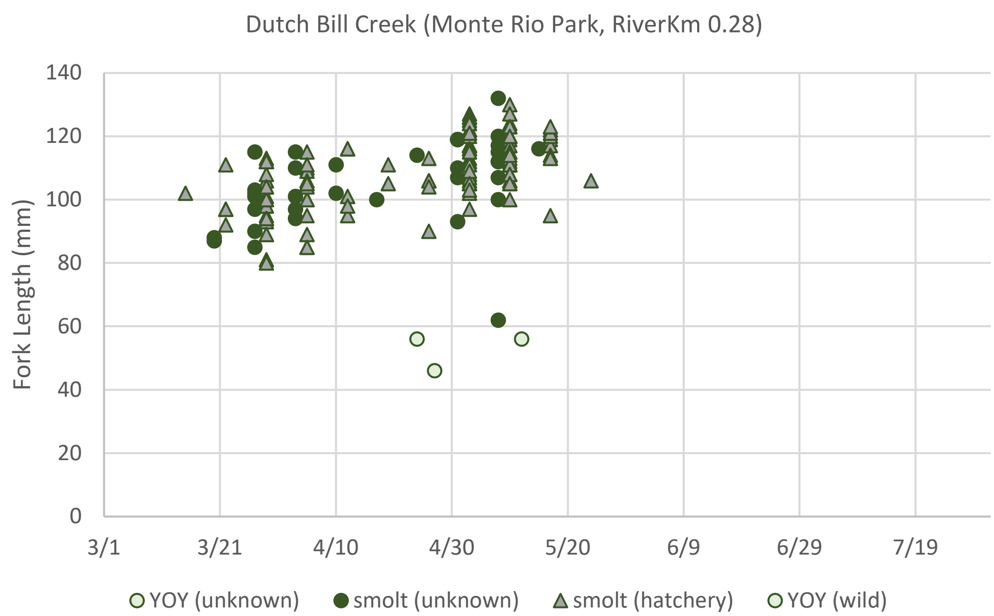


Figure 4.5.13. Weekly capture of coho salmon by life stage at lower Russian River downstream migrant trapping sites, 2022. Gray shading indicates the number of days per week that the trap was fishing. Note the different vertical scale among plots for each site.


Dry Creek (Westside Road, RiverKm 3.30)
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
smolt (hatchery)
smolt (wild)
YOY (unknown)
smolt (unknown)


Mainstem Russian River (Mirabel, 38.7)
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
smolt (unknown)
smolt (hatchery)
smolt (wild)
YOY (wild)


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
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
YOY (unknown)
smolt (hatchery)
smolt (unknown)


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

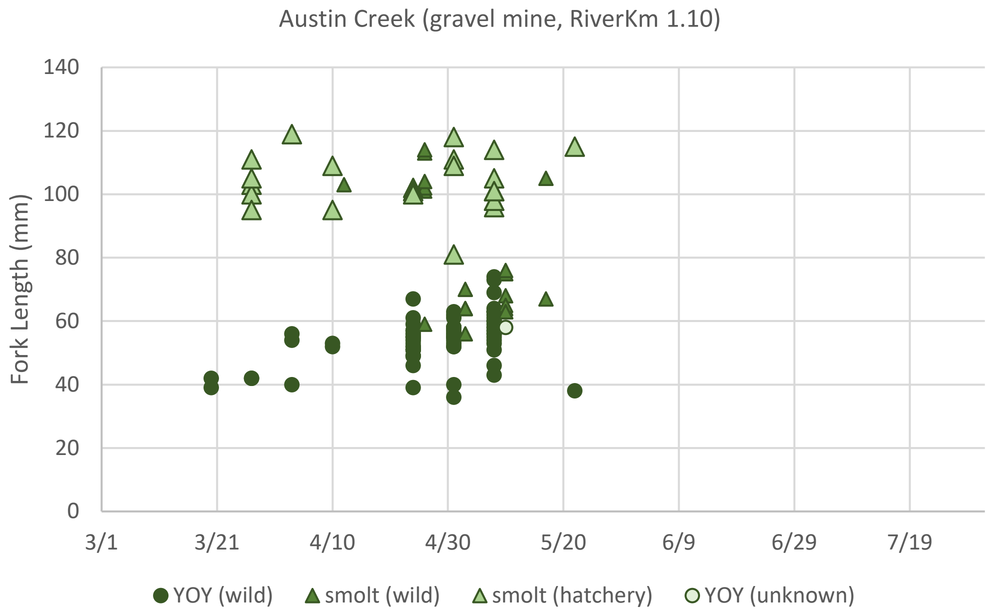


Figure 4.5.14. Weekly fork lengths of coho salmon captured at lower Russian River downstream migrant trap sites, 2022.

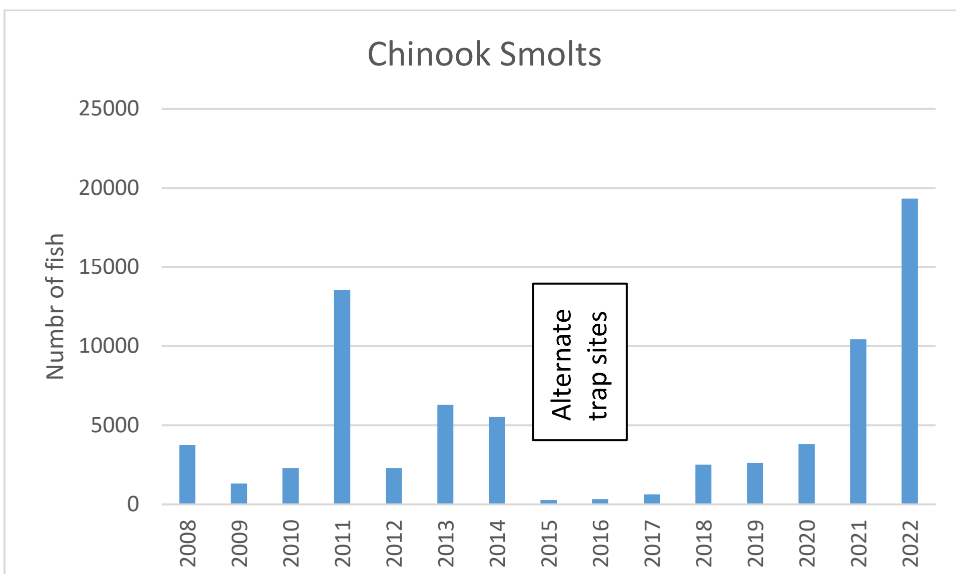


Figure 4.5.15. Number Chinook salmon smolts captured in the mainstem Russian River downstream migrant trap. In 2015 and 2016 the Mirabel dam was under construction and the mainstem Russian River trap was operated further upstream at Chalk Hill (river Km 69.82).

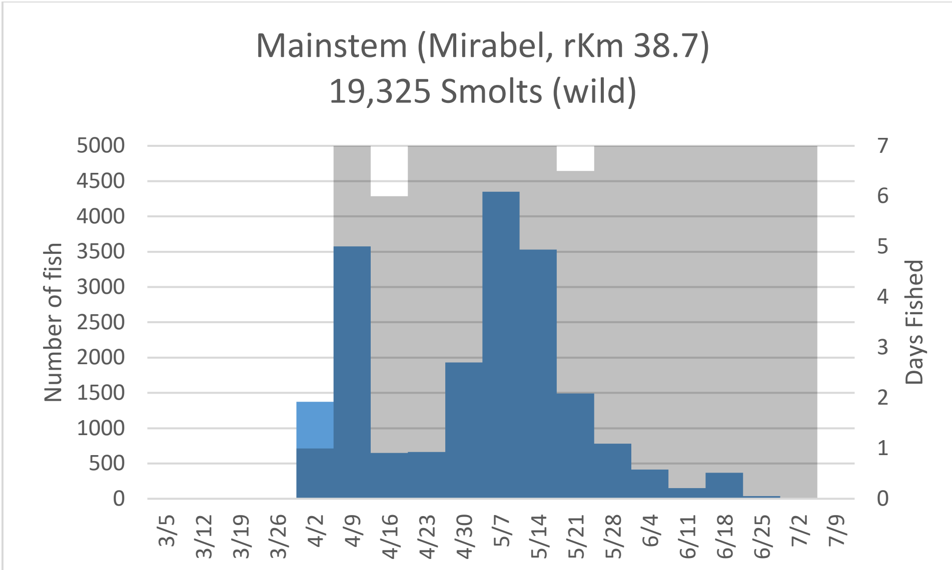


Figure 4.5.16. Weekly capture of Chinook salmon smolts at the Mirabel fish ladder on the mainstem Russian River, 2022. Gray shading indicates portion of each week trap was fishing.

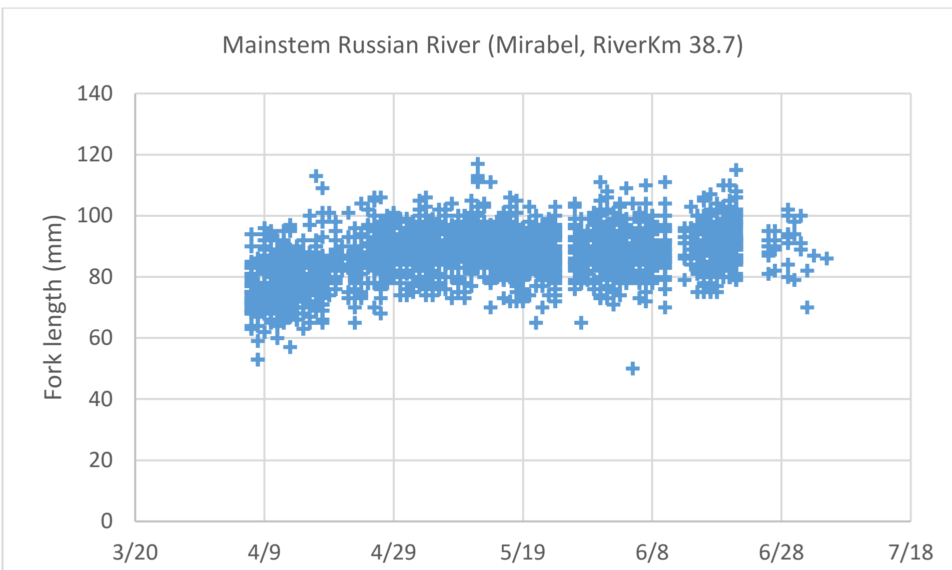


Figure 4.5.17 Weekly fork lengths of Chinook salmon captured at the Wohler Mirabel trap site on the mainstream Russian River downstream migrant trap sites, 2022.

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 2022, 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 lower river 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 2022, PIT tag detection at Austin Creek were relied upon to estimate the number of 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. 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. Attempts continue to measure antenna efficiency at Duncans Mills 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, Sonoma Water 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, Sonoma Water 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. In 2020, Sonoma Water started construction of the Phase 3, Part 3 (Reach 5A) habitat work. Also in 2020, Sonoma Water conducted maintenance work at several of the existing habitat sites in Reaches 4A, 7, and 8 to maintain or restore habitat function. In 2021, Sonoma Water completed the remaining portion of the Phase 3, Part 3 (Reach 5A) habitat work. In 2022, the Corps of Engineers started construction of the Dry Creek Ecosystem Restoration Project – Phase 1. The Corps of Engineer's Phase 1 work is a re-naming of what would be Sonoma Water's Phase 4

(Mile 4) habitat work. Sonoma Water is partnered with the Corps of Engineers on the design and implementation of the Corps of Engineers' Phase 1, 2, and 3 (Sonoma Water's Phase 4, 5, and 6 efforts) projects. The Corps of Engineer's Phase 1 work covers habitat construction in the Reach 13 and Reach 10 areas, with the Reach 13 work constructed in 2022 and the Reach 10 work scheduled for 2023. The Corps of Engineer's Phase 2 work will cover habitat projects in Reach 4 and Reach 2, with that effort anticipated to start in 2023. The Phase 3 work will cover habitat projects in Reaches 2 and 1 with that work anticipated to start in 2024. Figure 5.2 provides an overview of the habitat sites that are completed as of 2022 and tentative future sites still in design.

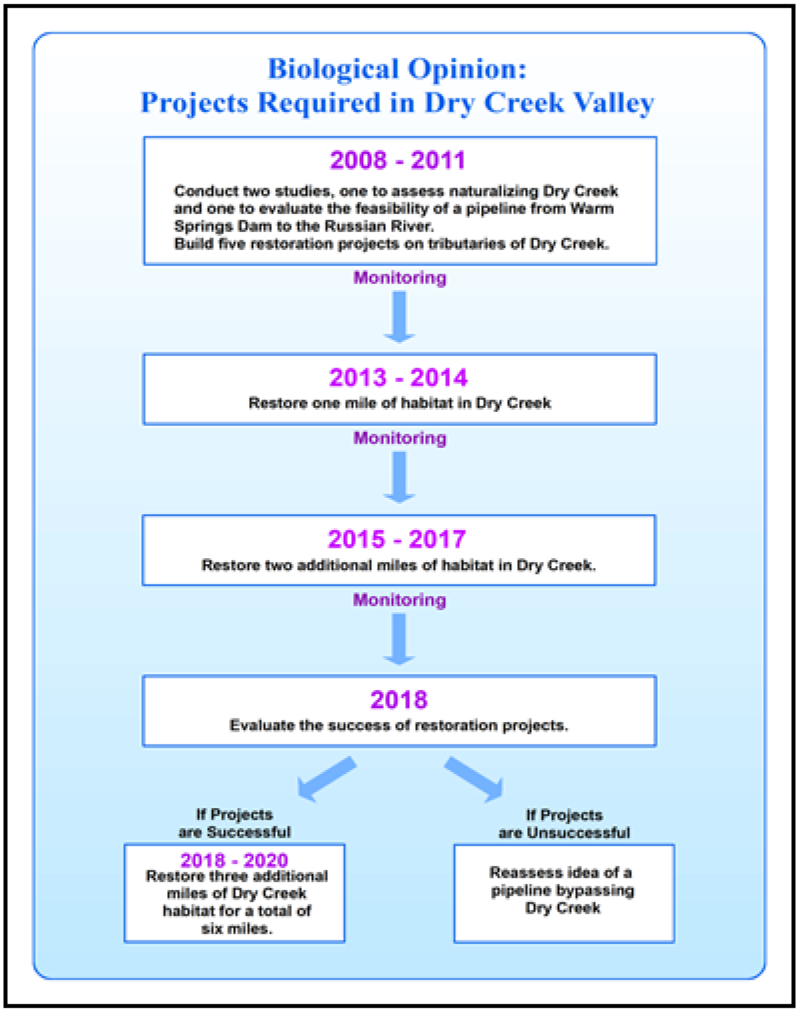

Figure 5.1. Timeline for implementation of Biological Opinion projects on Dry Creek.

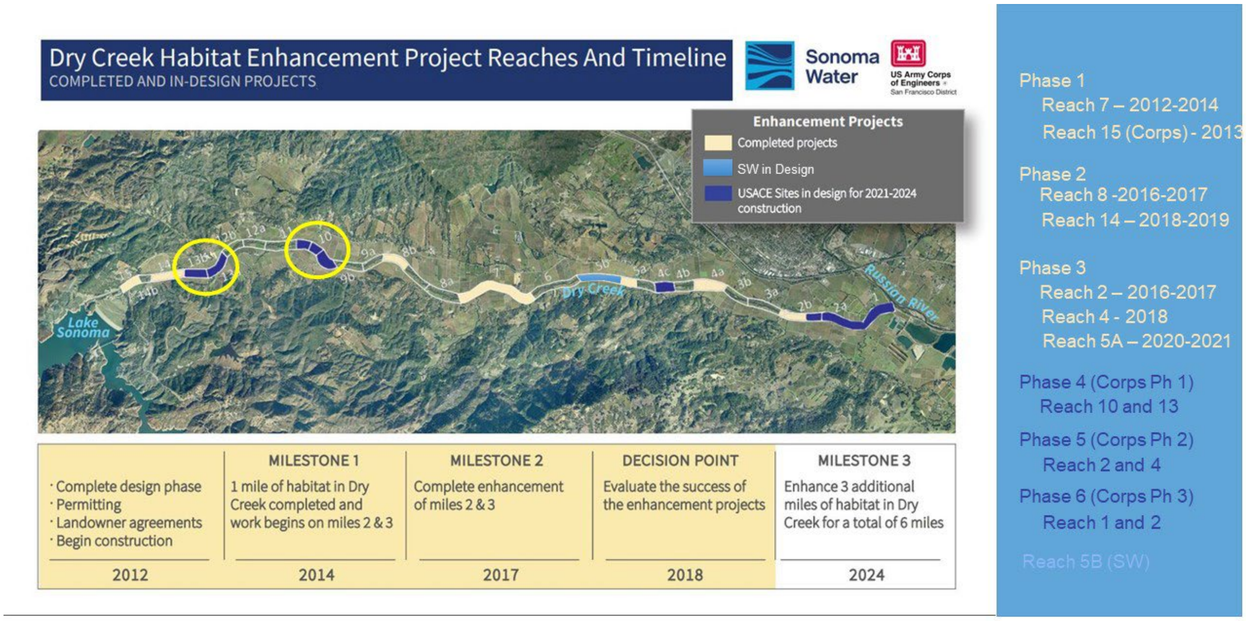

Figure 5.2. Dry Creek habitat projects constructed in 2022 and tentatively planned for future construction. The two areas circled, Reach 13 and Reach 10, make up the two project areas included in the Dry Creek Ecosystem Restoration Project - Phase 1 construction contract. The Reach 13 work area construction was in 2022 and the Reach 10 work area will be in 2023.

2022 Habitat Enhancement Overview

In 2022 construction was started on the Dry Creek Ecosystem Restoration Project - Phase 1. In the 2022 season, Sonoma Water staff monitored and rated seven enhancement reaches stretching from Reach 4a to Reach 15. Pre-enhancement monitoring was conducted for the Reach 13 areas (Foley/Gallo, and Foley sites) of the Dry Creek Ecosystem Restoration Project, Phase 1 work and six enhancement reaches post-effective flow (Army Corps, Army Corps Reach 14, Truett-Hurst, Farrow/Wallace, Boaz/Gros-Balthazard, and Ferrai-Carano). All six post-effective flow sites surveyed in 2022 resulted in good ratings (Table 5.1)

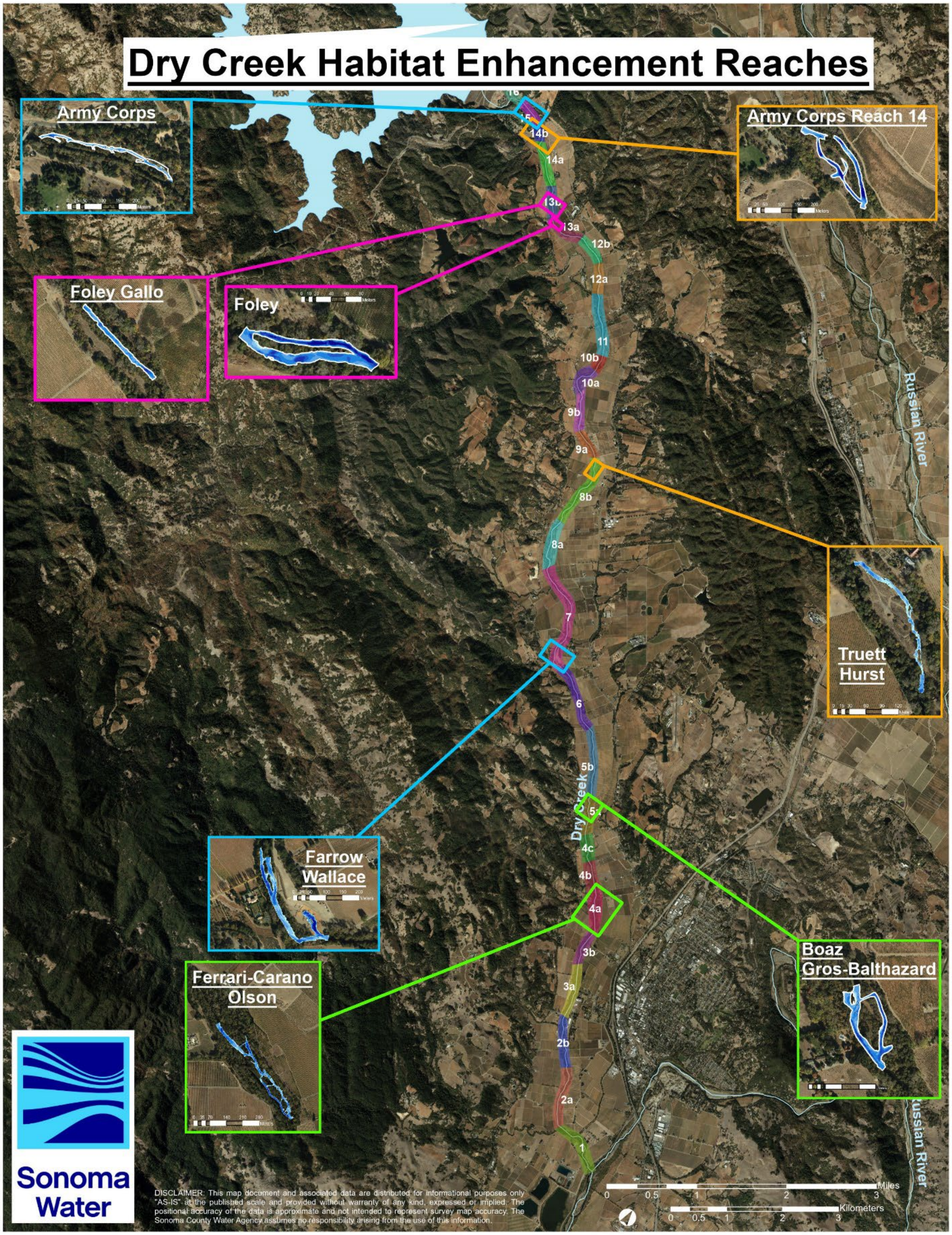

Figure 5.3. Location of Dry Creek habitat enhancement reaches monitored for effectiveness in 2022.

Table 5.1. Enhancement ratings for Dry Creek enhancement reaches surveyed in 2022.

Enhancement Reach	Post-effective Flow Rating
Army Corps	Good
Army Corps Reach 14	Good
Truett-Hurst	Good
Farrow/Wallace	Good
Boaz/Gros-Balthazard (includes Stromberg)	Good
Ferrari-Carano/Olson	Good

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 Timer#31combining 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 5.4).

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 5.4).

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.

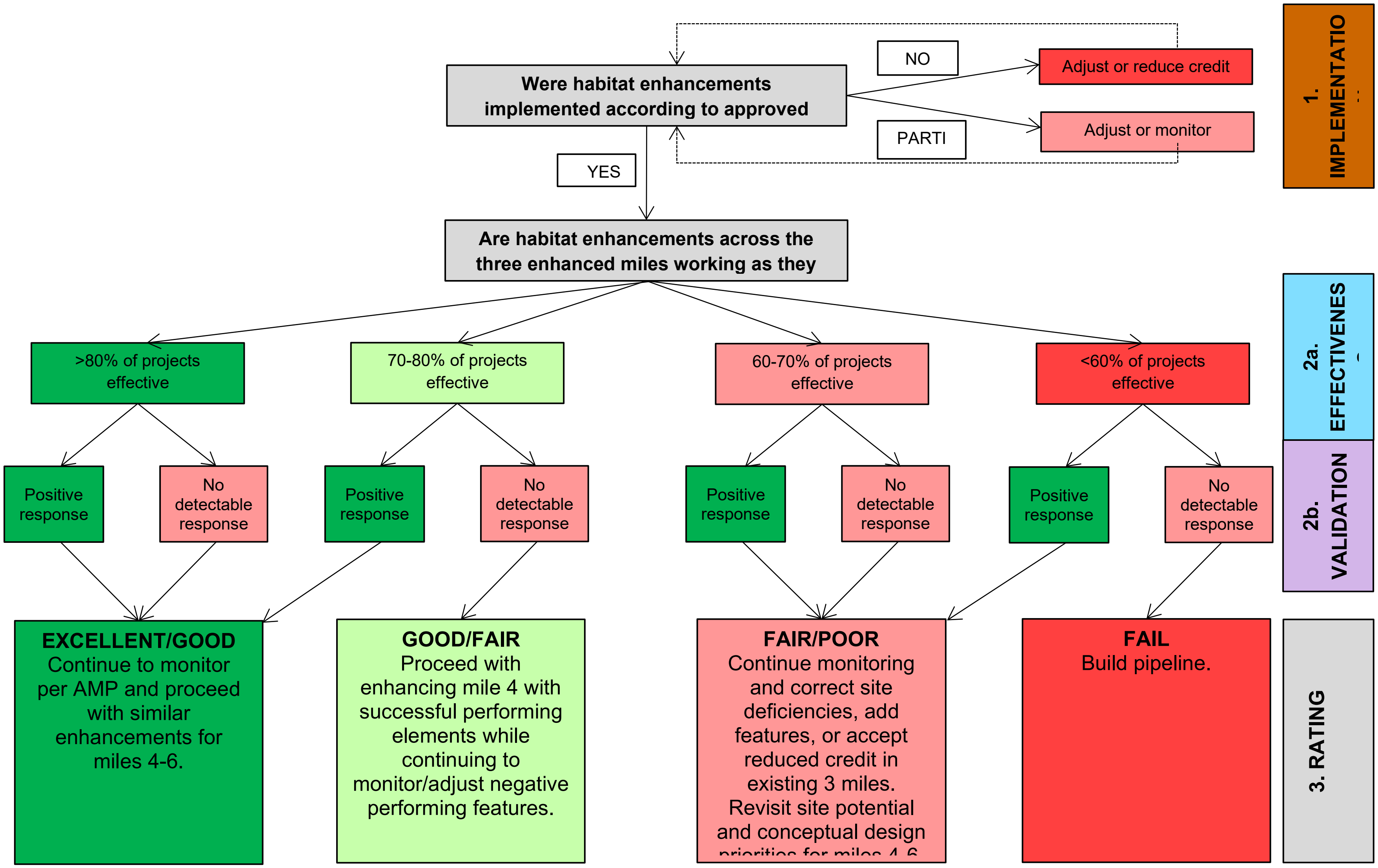

Figure 5.4. Process for determining course of action after the first three miles of Dry Creek have been enhanced. Ratings will be based on an objective evaluation in a step-wise phased monitoring approach which includes physical and biological quantitative measurements which lead to qualitative ratings (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 5.5).

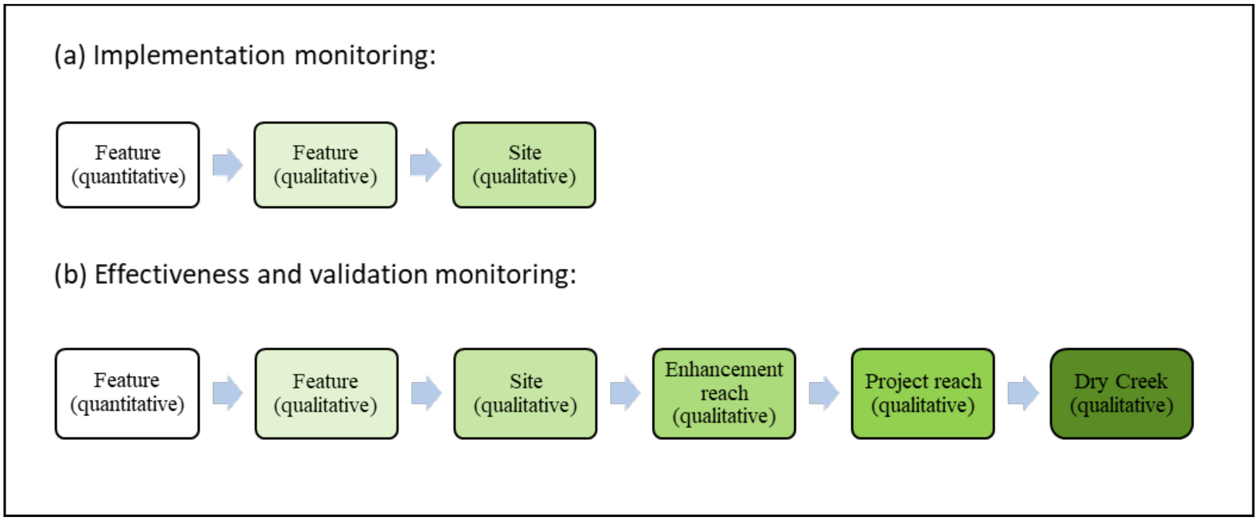

Figure 5.5. Illustration of the rollup concept for (a) implementation and (b) effectiveness and validation monitoring (from Porter et al. 2014).

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 5.4Figure 5.4).

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

5.1 Dry Creek Habitat Enhancement Implementation

Ecosystem Restoration Project – Phase 1

The 2022 construction season saw the start of construction for the Dry Creek Ecosystem Restoration Project – Phase 1 (Reaches 13 and 10) habitat work, with the Reach 13 work in 2022 and the Reach 10 work scheduled for 2023. The construction management for Phase 1 work is being was overseen by the U.S. Army Corps of Engineers. This project was cost-shared through the Corps of Engineers' Ecosystem Restoration Project, which is being used to fund work towards Miles 4, 5, and 6 (Corps of Engineers Phases 1, 2, and 3) of the habitat work in Dry Creek. Sonoma Water managed the design contract with InterFluve and the U.S. Army Corps of Engineers is managing the construction process. Construction of this work began in 2022 in Reach 13 and continued in 2023 in Reach 10. The Reach 10 work is expected to be completed during the 2024 construction season. See Figure 5.2 above for the general project location and Figure 5.6 below for the project work area layout at the site.

The Phase 1 project area is along approximately 2,100 feet of Dry Creek in the Reach 13 area of Dry Creek, approximately 2 miles downstream of Warm Springs Dam and approximately 4,200 feet of Dry Creek in the Reach 10 area, immediately downstream of Yoakim Bridge. The Reach 13 sites consist of two side-channels. The Reach 10 area is a complex of side-channels, alcoves, and bank repair sites. The Reach 13 sites were constructed in 2022 and the Reach 10 area is scheduled for construction in 2023. Please refer to Photo 5.1, Photo 5.2, and Photo 5.3.

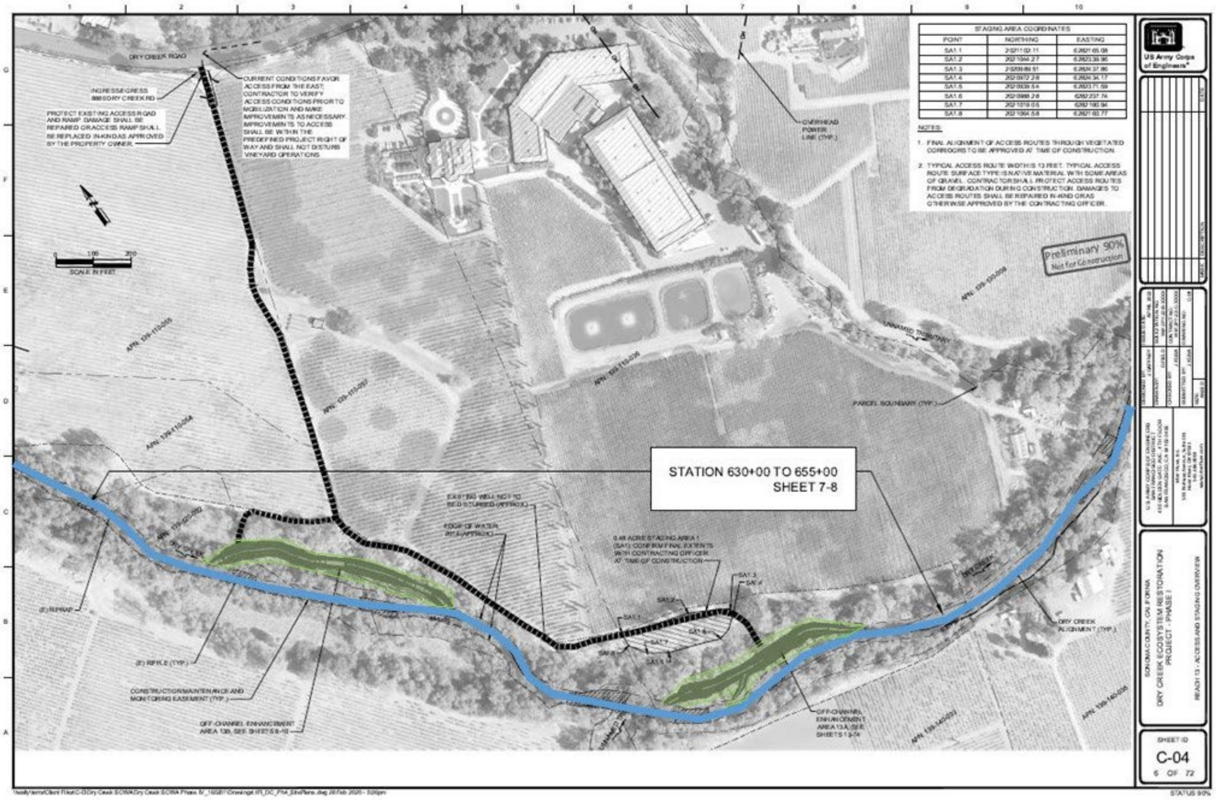

Figure 5.6. This figure shows the work area for the Dry Creek Ecosystem Restoration Project – Phase 1, Reach 13 work area. The constructed side-channels are shown in green and the existing mainstem of Dry Creek is shown in blue. The majority of the work for the habitat work in Reach 13 was completed by the Corps of Engineers in 2022. A small portion of one the side-channels will be completed by Sonoma Water in 2023.

Photo 5.1. Dry Creek Ecosystem Restoration Project - Phase 1. Installation of an apex log feature at the inlet to a constructed side-channel in Reach 13. October 4, 2022.

Photo 5.2. Dry Creek Ecosystem Restoration Project - Phase 1. Construction of habitat side-channel partially complete in Reach 13. August 29, 2022.

Photo 5.3. Dry Creek Ecosystem Restoration Project - Phase 1. Congressman Huffman and staff touring the construction progress in Reach 13. October 12, 2022.

2022 Dry Creek Habitat Maintenance Work

No notable maintenance work at any of the previously constructed habitat sites occurred during the 2022 construction season.

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
Primary	Depth (ft)	fry	0.5-2.0 ft	n/a	n/a
Primary	Velocity (ft/sec)	Summer/winter parr	0-0.5 ft/s	0-0.5 ft/s	0-0.5ft/s
Primary	Depth (ft)	Summer/winter parr	2-4 ft	2-4 ft	2-4 ft
Primary	Shelter value	Juvenile	$\geq$80	$\geq$80	$\geq$80
Primary	Pool: Riffle ratio	Juvenile	n/a	1:2 to 2:1	n/a
Secondary	Temperature (°C)	Juvenile	n/a	8-16° C	n/a
Secondary	Dissolved oxygen (mg/l)	Juvenile	n/a	6-10 mg/l	n/a
Secondary	Canopy (%)	Juvenile	80 %	80 %	80 %
Secondary	Quiet water (< 0.5 ft/s) (%)	Juvenile	n/a	n/a	$\geq$ 25%
Secondary	Off-channel access (off-ramps) (ft/sec)	Juvenile	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)	.05 – 0.06 ft/s (Ucrit); 3.3 ft/s (burst speed)
Secondary	Connectivity	Juvenile	Undefined	Undefined	Undefined
Secondary	Substrate particle size (in.)	Adult	n/a	n/a	0.25-2.5 in.
Secondary	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 cubic feet per second (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 November during summer baseflow conditions. Daily average discharge ranged from 75 to 185 cubic feet per second (cfs) over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240]), and most monitoring did not occur at discharges above 125 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.

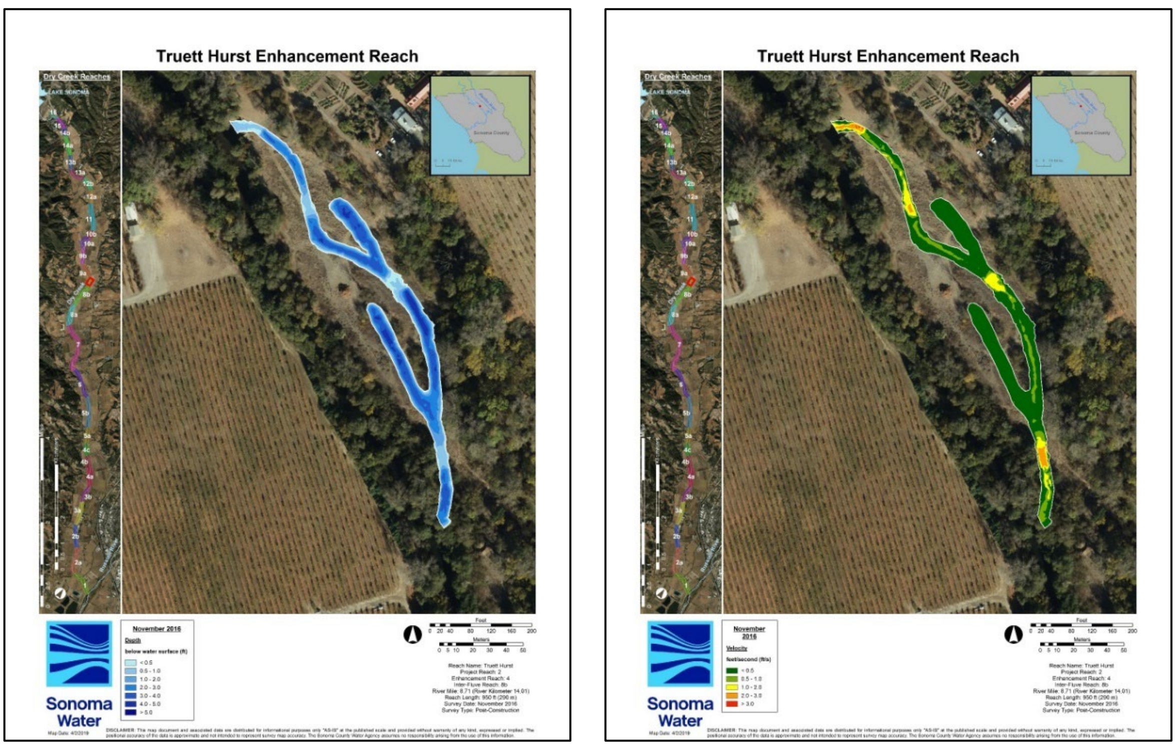

Figure 5.2.2. Digital elevation models (DEMs) created from spatially referenced depth and velocity points.

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).

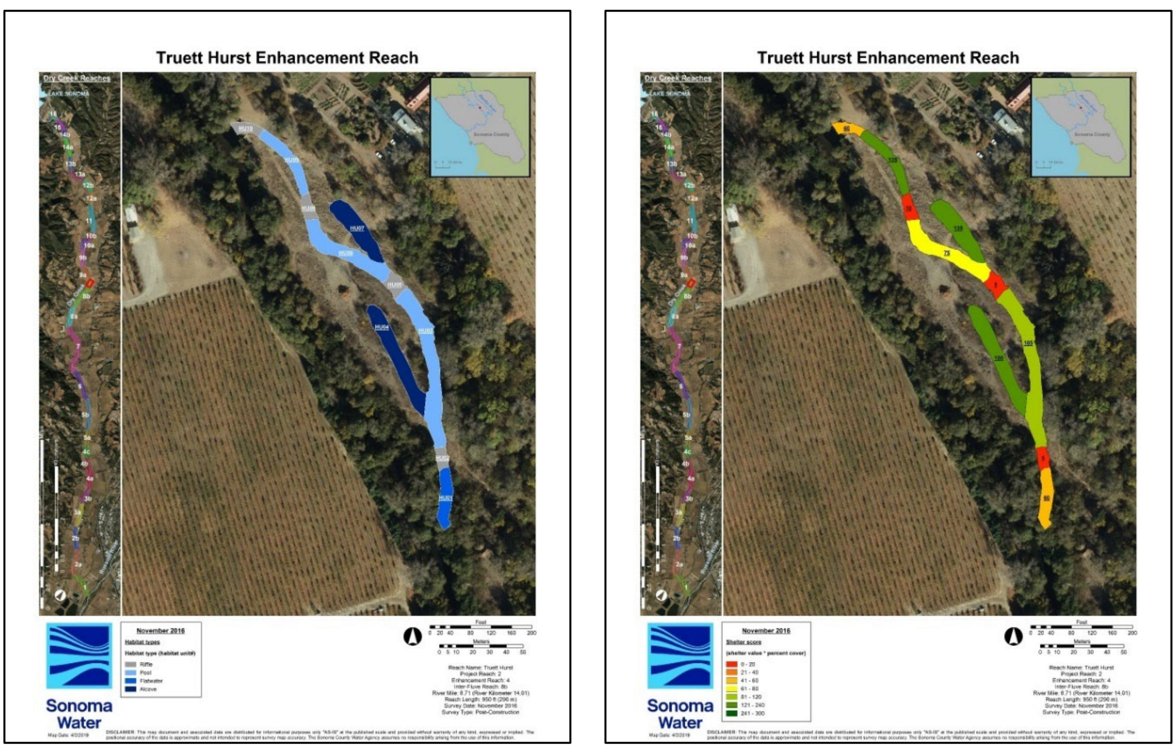

Figure 5.2.3. Example of inventoried habitat types and estimated shelter values within a Dry Creek habitat enhancement reach.

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 side channel, main channel, and areas along the bank for a total of six individual checklists (See Porter et al [2014], pp. 40-45). We modified side channel and main 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 side and main 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. Side 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
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 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 UNI**T: 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	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
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

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 side and main 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 (>700 as of December 2022) 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 side and main 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 5.2). 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 (>900 as of November 2022) 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[a]		**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	Calculate the shelter rating for the **habitat unit**: 0-300[d]	5
28.	Percent of **habitat unit** within targeted velocity: (%)[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 quantitative rating	**(sum of above)**	**35**
Habitat qualitative rating[a]		**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). We calculated an average feature rating and an average habitat unit rating for each site. The sum of the site average feature rating and site average habitat unit ratings equaled the overall site quantitative rating (up to 50 points), which we 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 from habitat unit to site, the average of all sites within an enhancement reach determined 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** quantitative rating[a]	15	15	15
Site average **feature** qualitative rating[a]	Excellent	Excellent	Excellent
Site average **habitat unit** quantitative rating[b]	35	35	35
Site average **habitat unit** qualitative rating[b]	Excellent	Excellent	Excellent
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 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 of enhancement sites. 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.

In 2017, we 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 time periods to differentiate from post-enhancement monitoring that occurs after a site is newly constructed. We will include a post-repair monitoring time period as necessary in future monitoring reports.

In 2021, we added spring flow monitoring in response to higher than normal release flows from Warm Springs Dam. We typically collect data from April to November during summer baseflow conditions. Daily average discharge ranges from 95 to 135 cubic feet per second (cfs) over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240; Lambert Bridge gage]), and most monitoring does not occur at discharges above 135 cfs to ensure accuracy and consistency when measuring depth and velocity, determining habitat types, and evaluating cover. In June 2021, Sonoma Water released 165 cfs from Warm Springs Dam to meet water supply needs, with discharges of 162-184 cfs recorded at the Lambert Bridge gage. We monitored side channel sites of three enhancement reaches during 165 cfs releases to evaluate conditions during higher than normal summer discharges.

Results

During the summer and fall 2022, Sonoma Water effectiveness monitored seven enhancement reaches totaling nearly 415,000 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 383 features for their condition, and evaluated 154 aquatic habitat units for their hydraulic (depth and velocity) and shelter characteristics. The monitored enhancement reaches stretch from Reach 4a (as defined by Inter-Fluve 2012, River Mile [RM] 3.06) to Reach 15 (RM 13.29) (Figure 5.2.4). We monitored and rated the pre-enhancement condition of two reaches (Foley Gallo and Foley; see Pre-enhancement results below), post-enhancement condition of one reach constructed in 2022 (Foley; see Post-enhancement results below; Foley Gallo construction not completed until 2023), and six enhancement reaches post-effective flow (Army Corps, Army Corps Reach 14, Truett Hurst, Farrow Wallace, Boaz Gros-Balthazard, Ferrari-Carano; see Post-effective flow results below). Sonoma Water constructed the Boaz Gros-Balthazard enhancement reach in 2020 and this is the first post-effective flow monitoring survey for the reach. The results below summarize effectiveness monitoring results for pre-enhancement, post-enhancement, and post-effective flow by enhancement reach. 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 2022, 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-release-flow (ft^2)
Army Corps	--	--	--	--
Army Corps Reach 14	--	--	67,031	--
Foley Gallo	--	--	22,352	--
Foley	--	--	78,935	--
Truett Hurst	--	--	59,506	--
Farrow Wallace	--	--	98,290	--
Boaz Gros-Balthazard	23,388	--	--	--
Ferrari-Carano Olson	25,184	39,845	--	--
TOTAL (ft^2)	**48,571**	**39,845**	**326,114**	--
GRAND TOTAL (ft^2)	**414,531**			

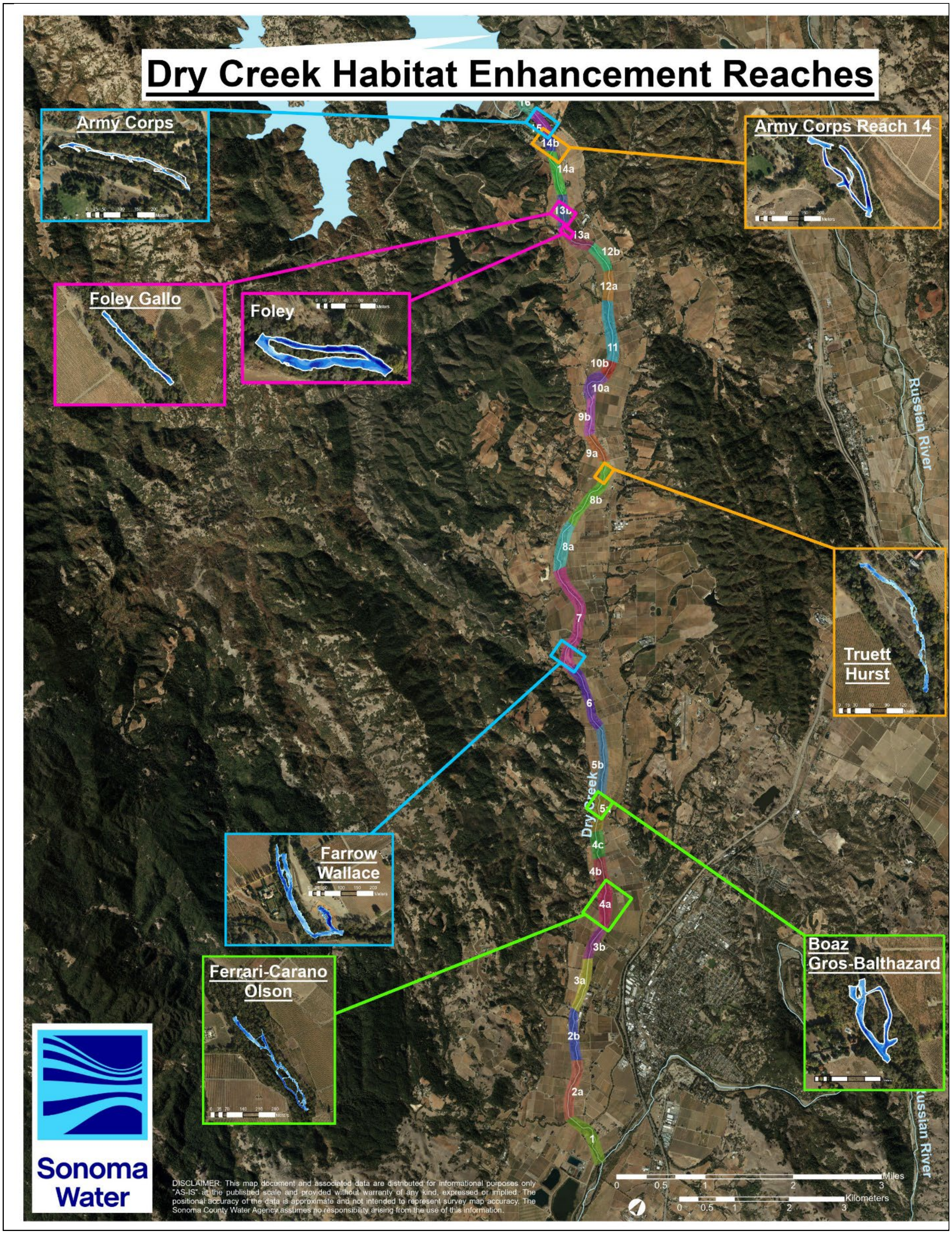

Figure 5.2.4. Location of Dry Creek habitat enhancement reaches monitored in 2022.

Pre-enhancement

Summary

Sonoma Water monitored the pre-enhancement conditions of the Foley Gallo, and Foley enhancement reaches in 2022 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 48,571 ft^2 within main channel areas, with 24% of the total area meeting optimal depth and velocity criteria (Table 5.2.22). Crews observed 14 habitat units across all enhancement reaches with a total pool to riffle ratio of 8:4 (2.00) and a total average shelter score of 80 (Table 5.2.23). The average shelter score for all pool habitats exceeded the optimum shelter score of 80. Pre-enhancement, all monitored enhancement reaches rated fair (Table 5.2.24; see below for individual enhancement reach summaries and Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.9. Post-effective flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches surveyed in 2022.

Dry Creek, Post-effective Flow 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	48,571	22,884	20,148	43,032	15,995	7,318	4,253	11,571
Total area	**48,571**	**22,884**	**20,148**	**43,032**	**15,995**	**7,318**	**4,253**	**11,571**
Main channel % of wetted area	100%	47%	41%	89%	33%	15%	9%	24%
Total % of wetted area	**100%**	**47%**	**41%**	**89%**	**33%**	**15%**	**9%**	**24%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.10. Pre-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches surveyed in 2022 (-- indicates habitat type not observed).

Habitat Type	# of Habitat Units	Shelter Score
Riffle	4	53
Pool	8	96
Flatwater	2	68
Alcove	--	--
Pool: riffle	**8:4 (2.00)**	**Avg: 80**

Reach ratings

Table 5.2.11. Pre-enhancement ratings for Dry Creek enhancement reaches surveyed in 2022.

Enhancement Reach	Pre-enhancement Rating
Foley	Fair
Foley Gallo	Fair

Foley Gallo Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Foley Gallo enhancement reach in June 2022. The reach covered 23,388 ft^2 within the main channel of Dry Creek, with 23% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.12, Figure 5.2.5). Six habitat units made up the enhancement reach, with a pool to riffle ratio of 2: 2 (1.00) and an average shelter score of 89 (Table 5.2.13, Figure 5.2.6, Figure 5.2.7). Four habitat units met or exceeded the optimal shelter value of 80. The reach comprised one mainstem enhancement site with fair habitat unit ratings and fair overall site and reach ratings (Table 5.2.14, Figure 5.2.8, Figure 5.2.9, Figure 5.2.10; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.12. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Foley Gallo enhancement reach, June 2022.

Foley Gallo Pre-enhancement, June 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft, < 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	23,388	11,311	9,224	20,535	7,660	3,775	1,571	5,346
Total area	**23,388**	**11,311**	**9,224**	**20,535**	**7,660**	**3,775**	**1,571**	**5,346**
Main channel % of wetted area	100%	48%	39%	88%	33%	16%	7%	23%
Total % of wetted area	**100%**	**48%**	**39%**	**88%**	**33%**	**16%**	**7%**	**23%**

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 Foley Gallo enhancement reach, June 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.13. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Foley Gallo enhancement reach, June 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	35	105
HU02	Riffle	3	50	150
HU03	Flatwater	3	35	105
HU04	Pool	3	35	105
HU05	Riffle	2	20	40
HU06	Flatwater	2	15	30
Pool: riffle	**2: 2 (1.00)**			**Avg = 89**

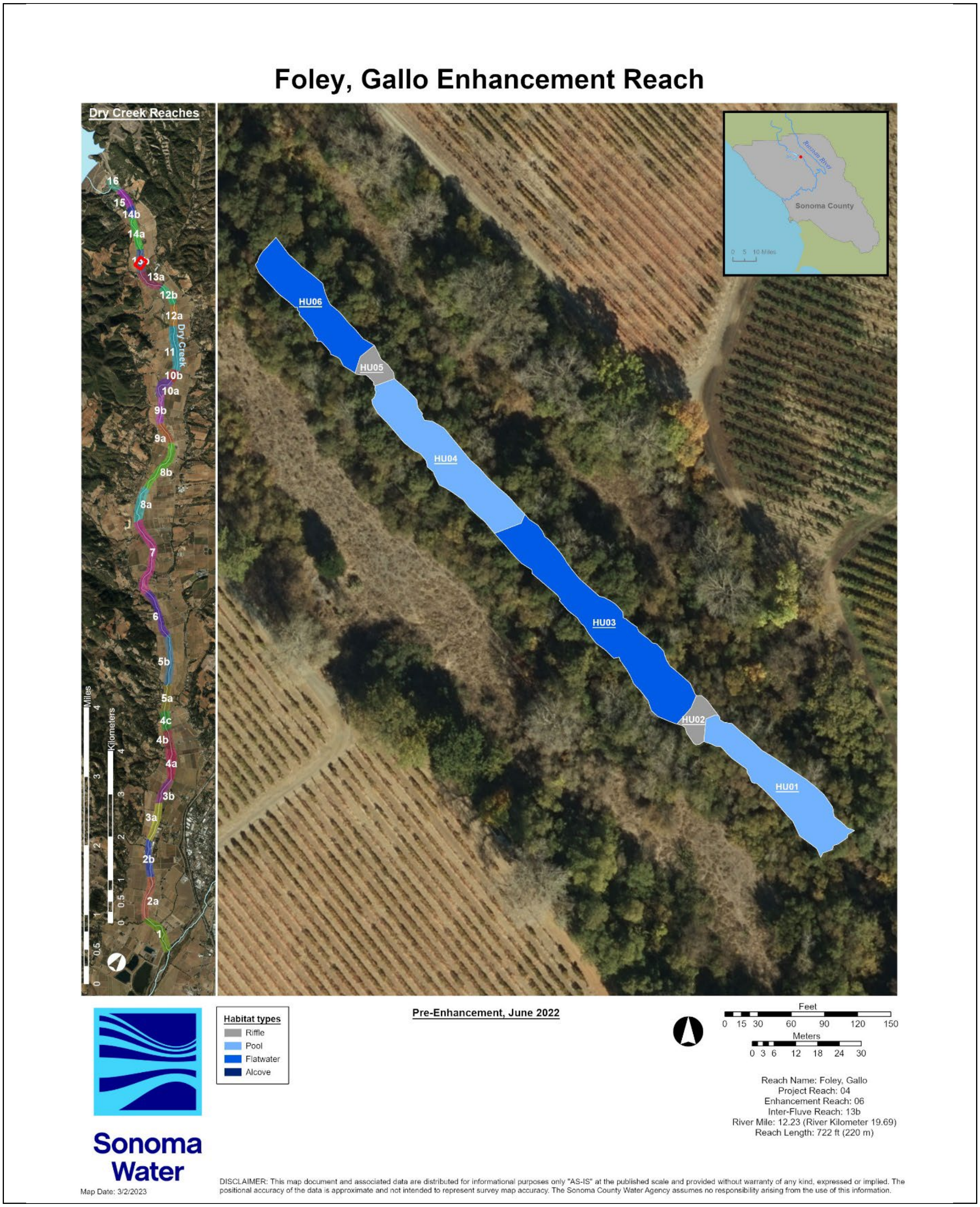

Figure 5.2.6. Habitat unit number and type within the Foley Gallo enhancement reach, June 2022.

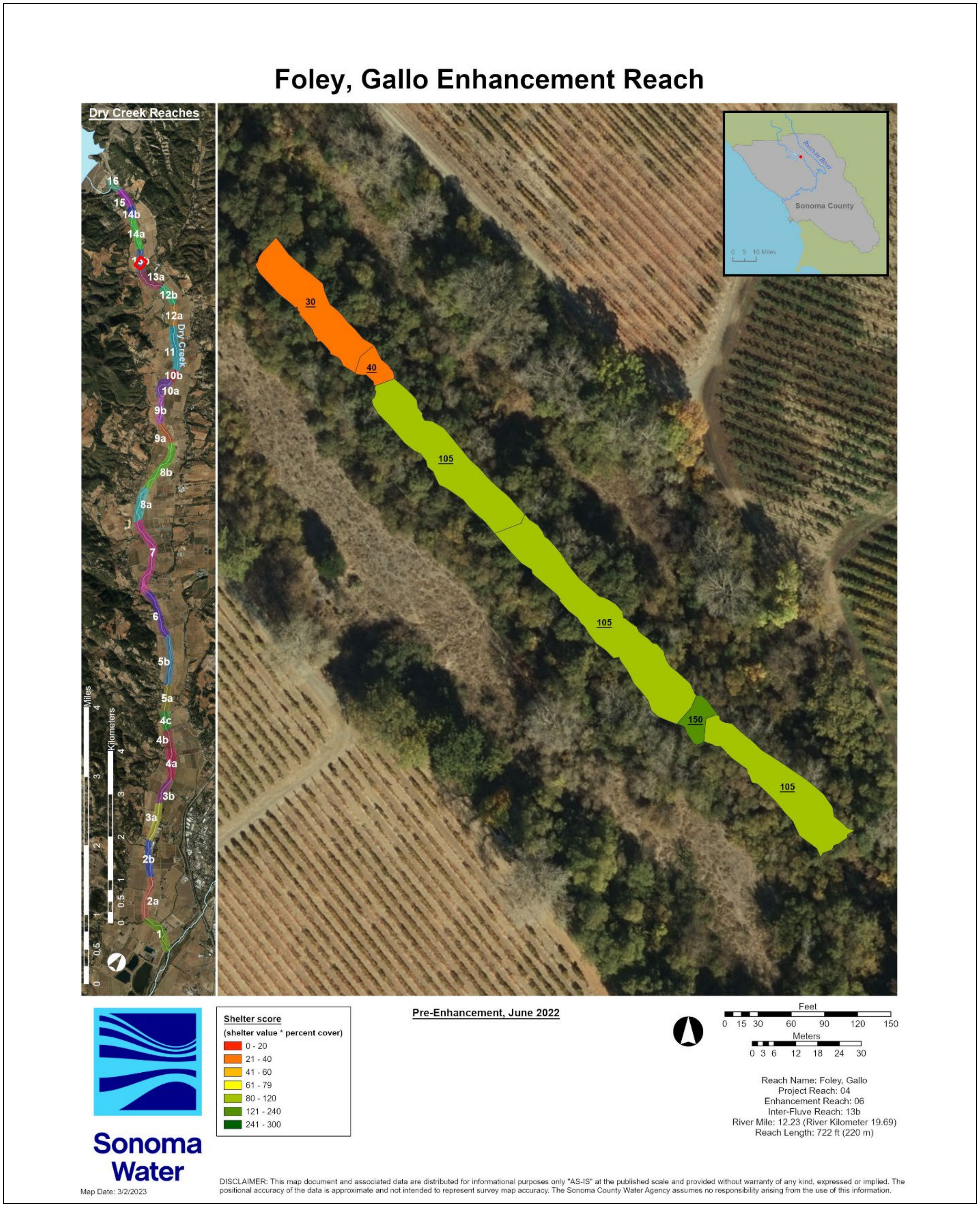

Figure 5.2.7. Habitat unit shelter values within the Foley Gallo enhancement reach, June 2022.

Habitat unit, site, and reach ratings

Table 5.2.14. Pre-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Foley Gallo enhancement reach, May 2020.

Site number	1			
Site type	Main channel			
Site average feature quantitative rating[a]	0			
Site average feature qualitative rating[a]	Not rated			
Site average habitat unit quantitative rating[b]	20			
Site average qualitative rating[b]	Fair			
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	20			
Site qualitative rating[c]	Fair			
Enhancement reach quantitative rating (average of site rating)[c]	20			
Enhancement reach qualitative rating[c]:	Fair			

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

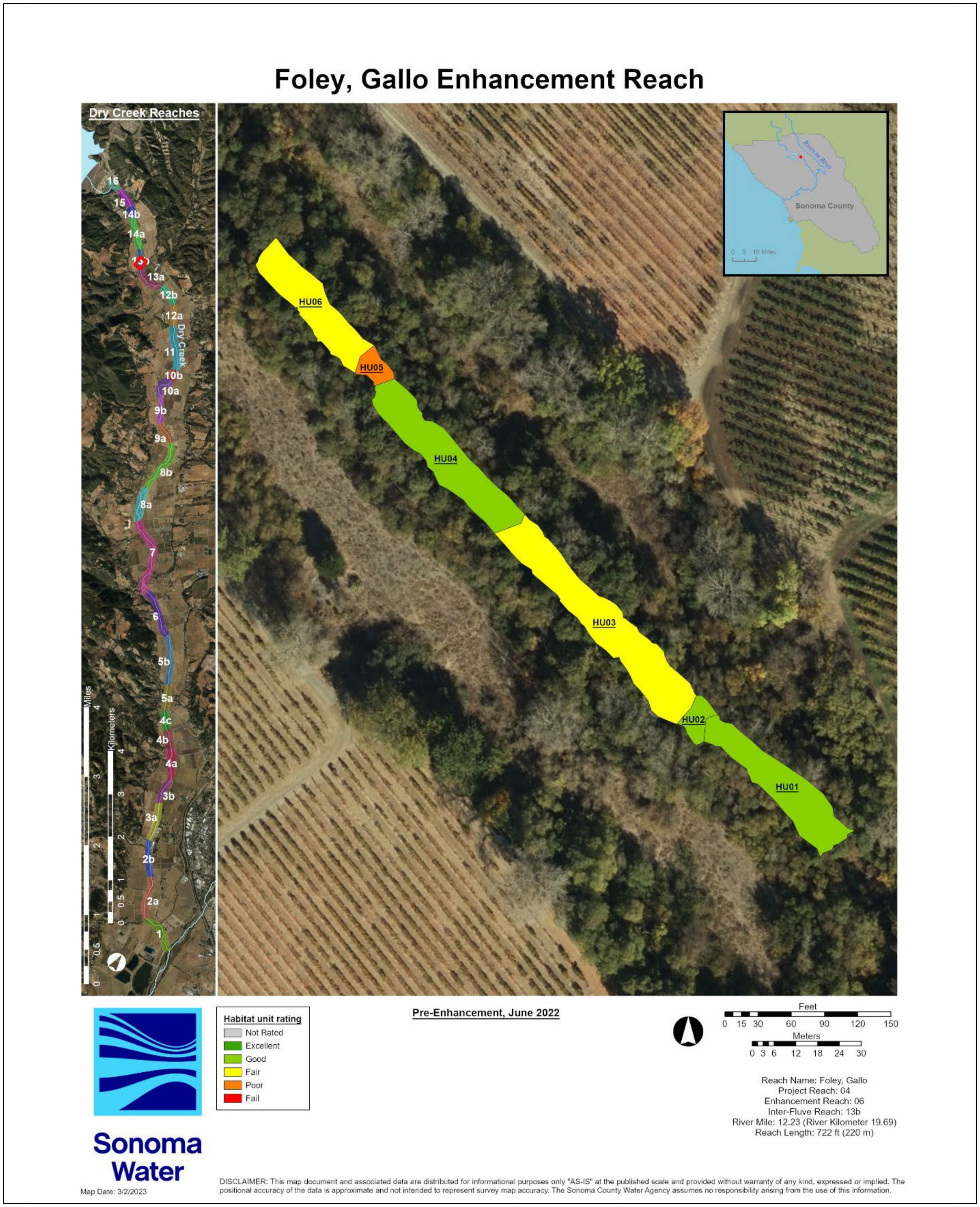

Figure 5.2.8. Habitat unit ratings for the Foley Gallo enhancement reach, June 2022.

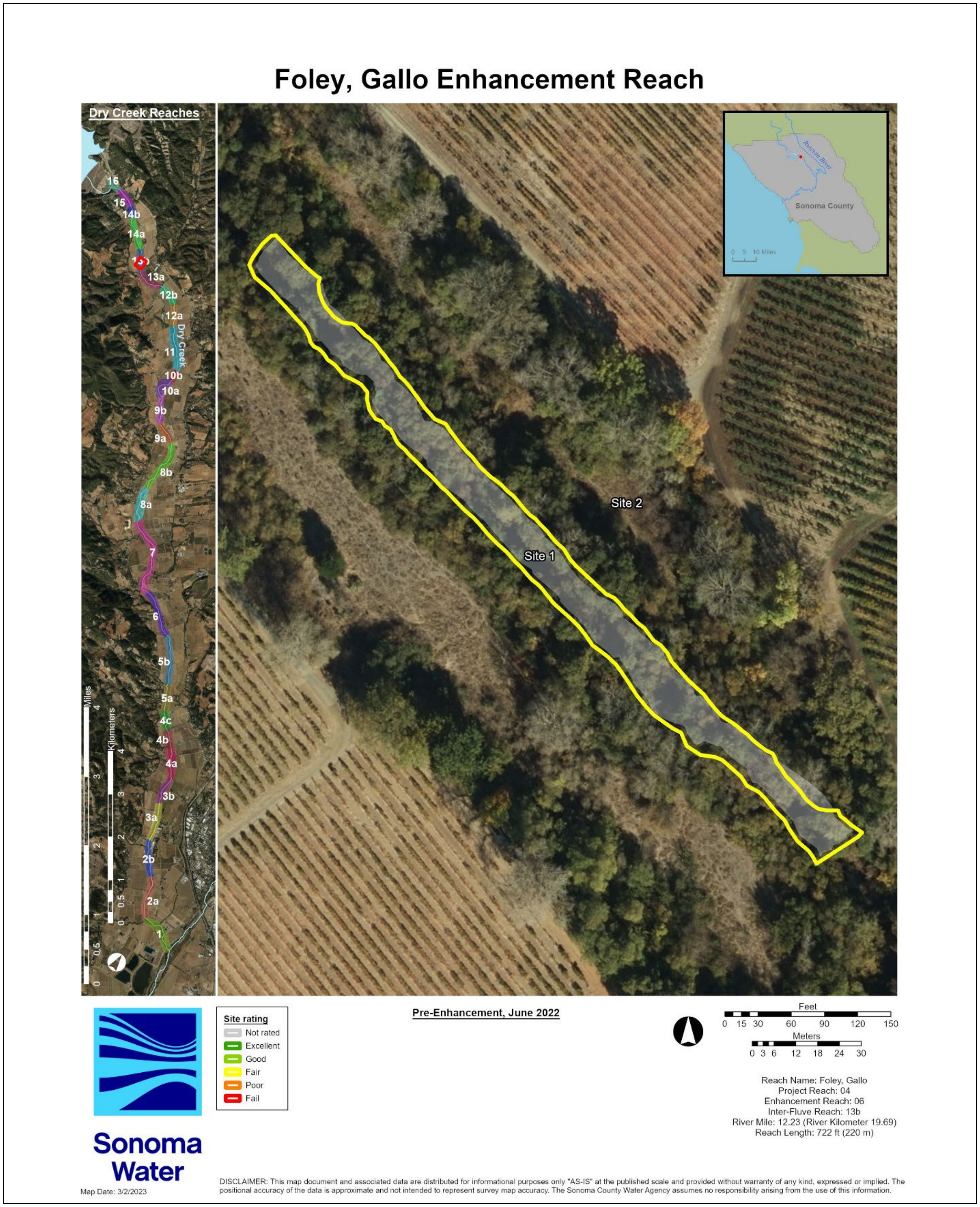

Figure 5.2.9. Pre-enhancement site rating for the Foley Gallo enhancement reach, June 2022.

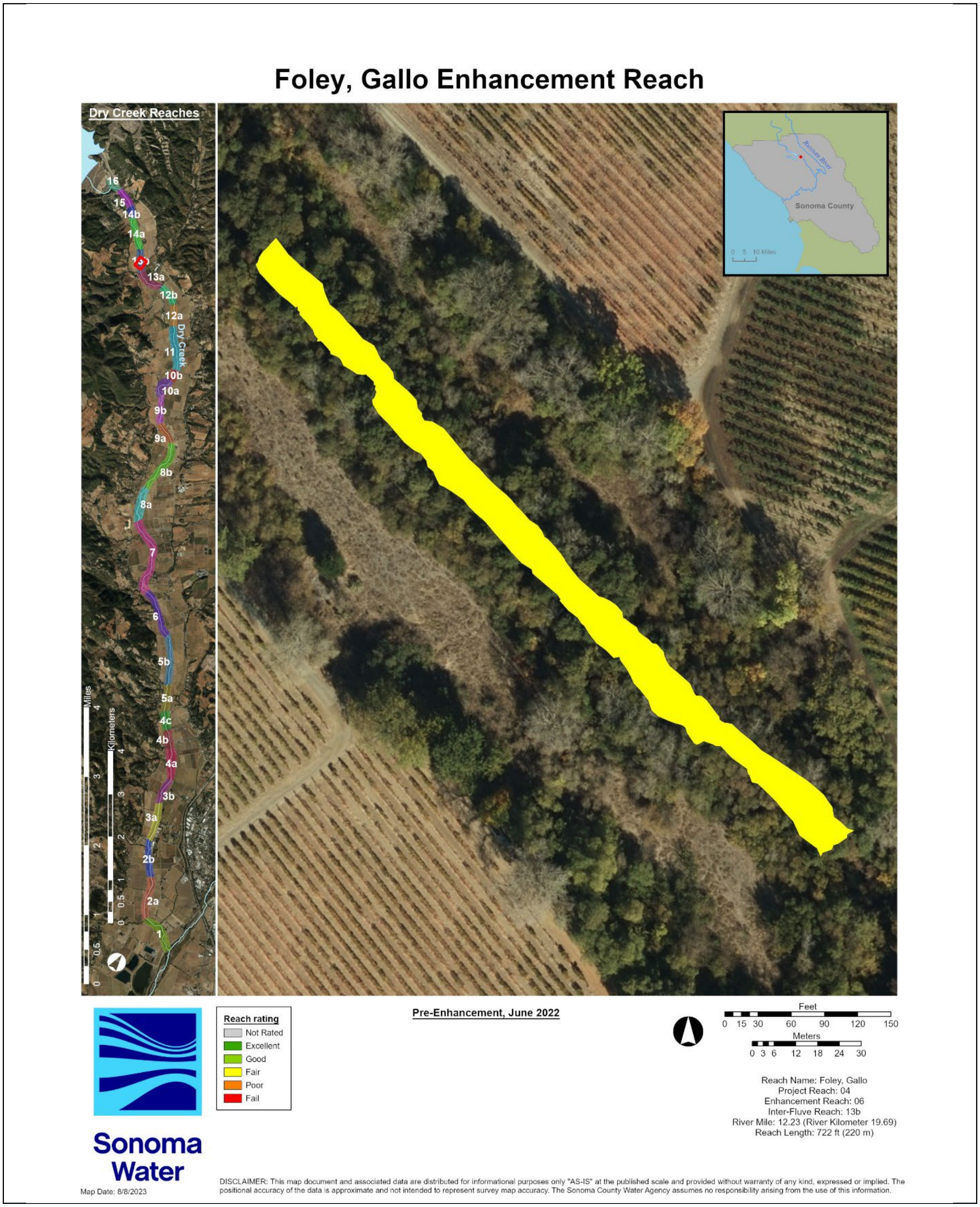

Figure 5.2.10. Pre-enhancement reach rating for the Foley Gallo enhancement reach, June 2022

Foley Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Foley enhancement reach in July 2022. The reach covered 25,184 ft^2 within the main channel of Dry Creek, with 25% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.15, Figure 5.2.11). Eight habitat units made up the enhancement reach, with a pool to riffle ratio of 6: 2 (3.00) and an average shelter score of 73 (Table 5.2.16, Figure 5.2.12, Figure 5.2.13). Four habitat units met or exceeded the optimal shelter value of 80. The reach comprised one mainstem enhancement site with fair habitat unit ratings and fair overall site and reach ratings (Table 5.2.17, Figure 5.2.14, Figure 5.2.15, Figure 5.2.16; see Appendix 5.2 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 Foley enhancement reach, July 2022.

Foley Pre-enhancement, July 2022	**Wetted area (ft^2)**	**0.5 – 2.0 ft (ft^2)**	**2.0 – 4.0 ft (ft^2)**	**Total (ft^2)**	**< 0.5 ft/s (ft^2)**	**0.5 – 2.0 ft, < 0.5 ft/s (ft^2)**	**2.0 – 4.0 ft, < 0.5 ft/s (ft^2)**	**Total (ft^2)**
Main channel area	25,184	11,572	10,924	22,496	8,335	3,543	2,682	6,224
Total area	**25,184**	**11,572**	**10,924**	**22,496**	**8,335**	**3,543**	**2,682**	**6,224**
Main channel % of wetted area	100%	46%	43%	89%	33%	14%	11%	25%
Total % of wetted area	100%	46%	43%	89%	33%	14%	11%	25%

Figure 5.2.11. 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 Foley enhancement reach, July 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.16. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Foley enhancement reach, July 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	35	105
HU02	Pool	3	45	135
HU03	Pool	3	40	120
HU04	Pool	3	15	45
HU05	Riffle	3	25	75
HU06	Pool	1	5	5
HU07	Riffle	3	30	90
HU08	Pool	3	40	120
Pool: riffle	**6: 2 (3.00)**			**Avg = 73**

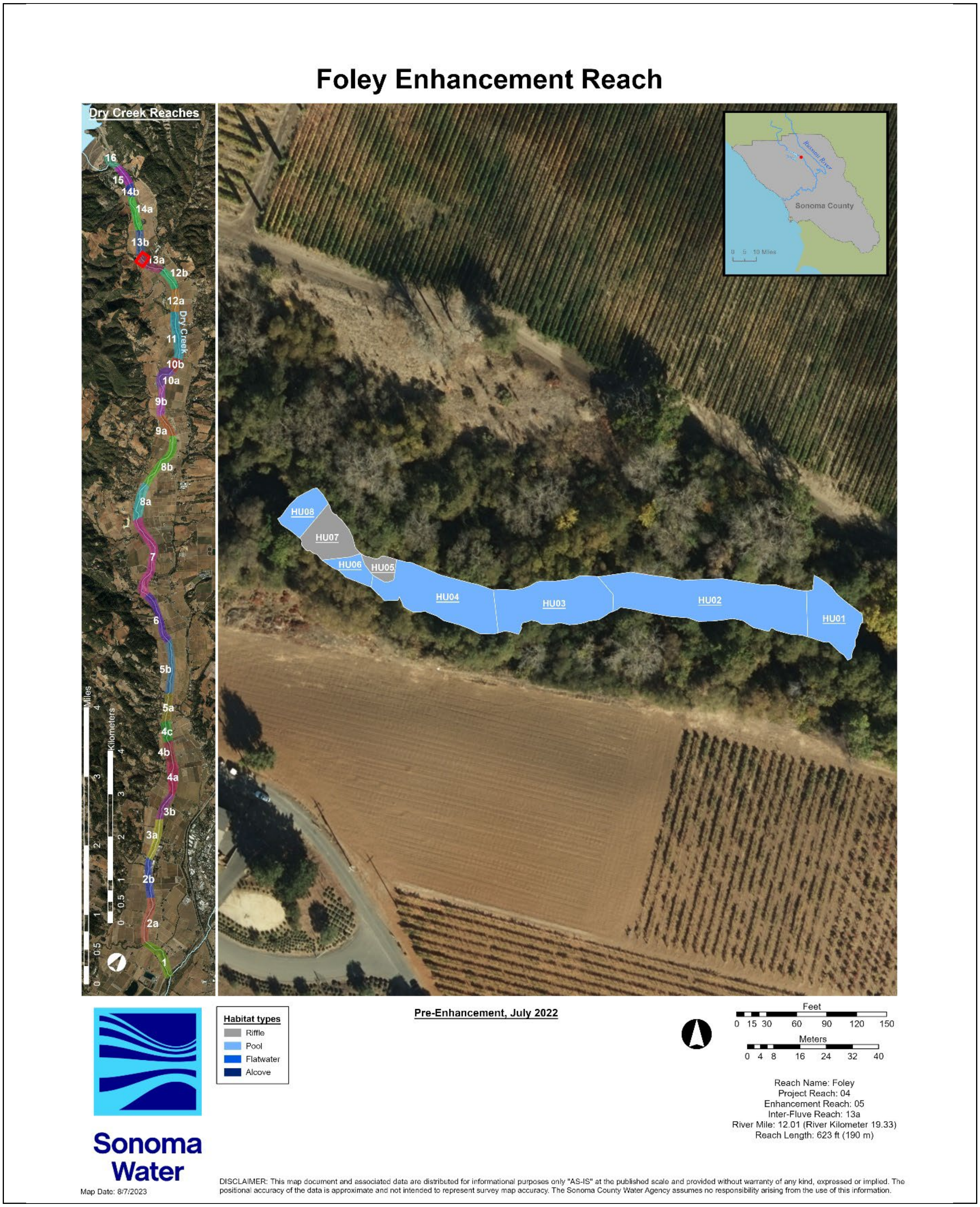

Figure 5.2.12. Habitat unit number and type within the Foley enhancement reach, July 2022.

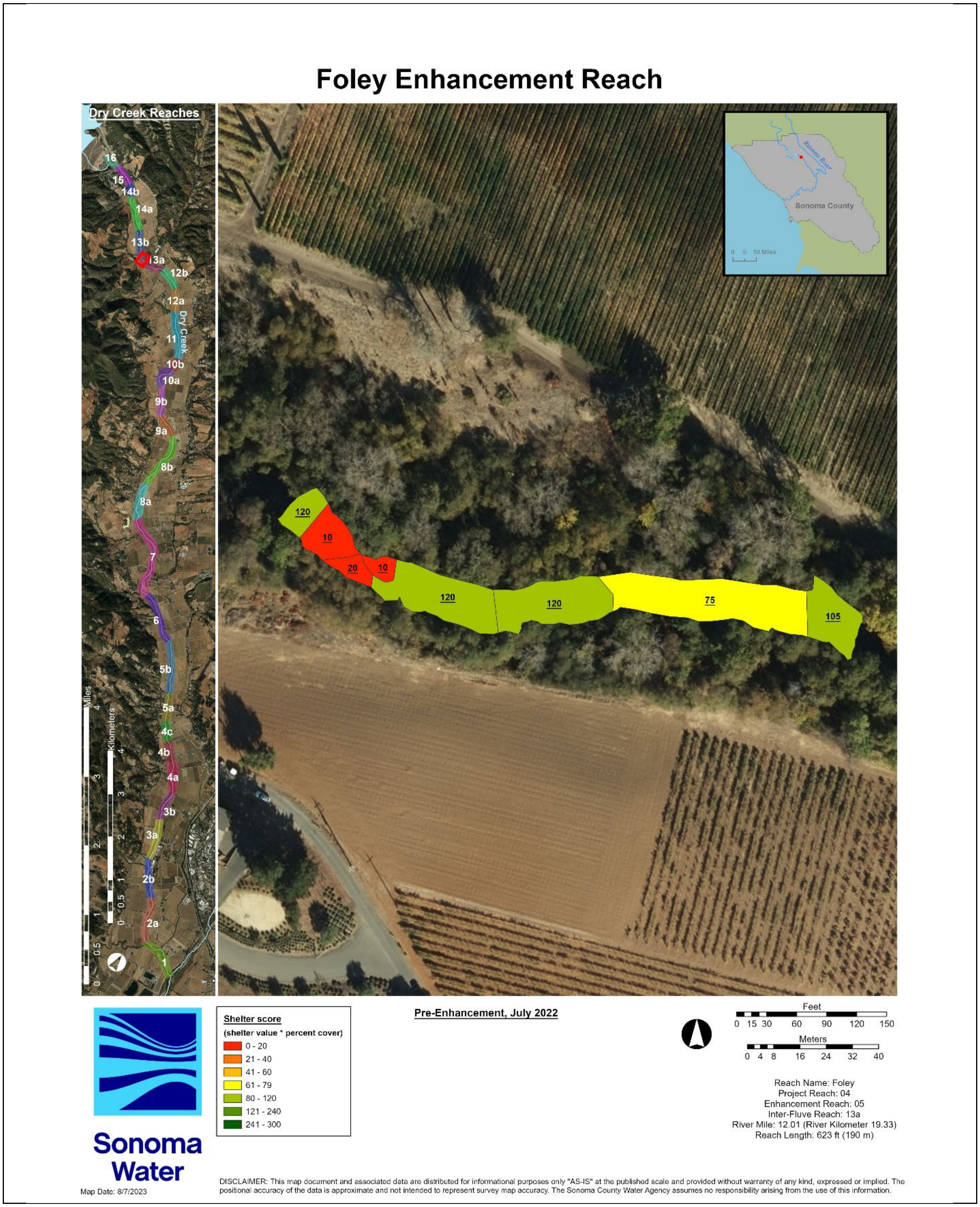

Figure 5.2.13. Habitat unit shelter values within the Foley enhancement reach, July 2022.

Habitat unit, site, and reach ratings

Table 5.2.17. Pre-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Foley enhancement reach, July 2022.

Site number	1			
Site type	**Main channel**			
Site average feature quantitative rating[a]	0			
Site average feature qualitative rating[a]	Not rated			
Site average habitat unit quantitative rating[b]	19			
Site average qualitative rating[b]	Fair			
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	19			
Site qualitative rating[c]	Fair			
Enhancement reach quantitative rating (average of site rating)[c]	19			
Enhancement reach qualitative rating[c]:	Fair			

[a]not included in rating
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)

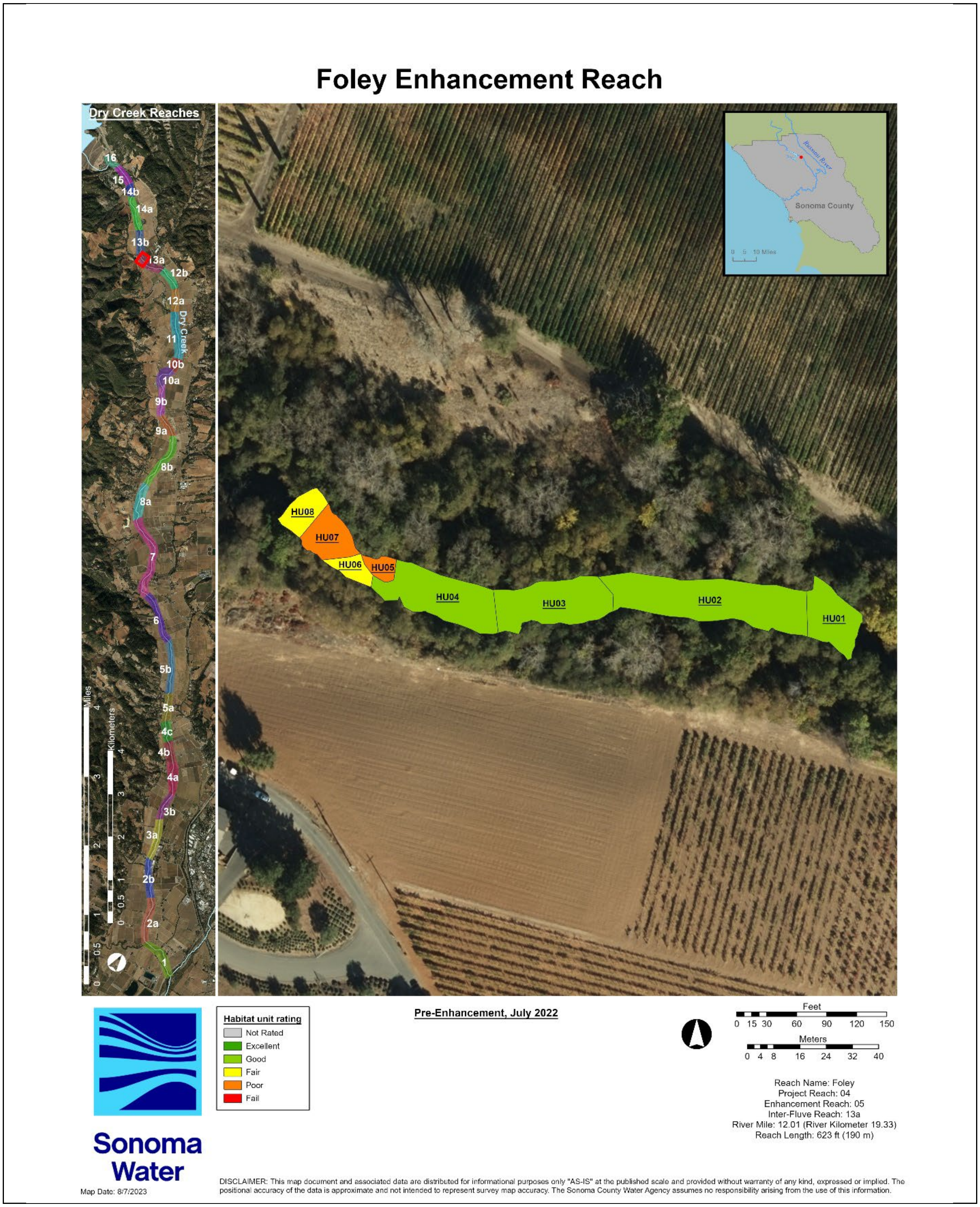

Figure 5.2.14. Habitat unit ratings for the Foley enhancement reach, July 2022.

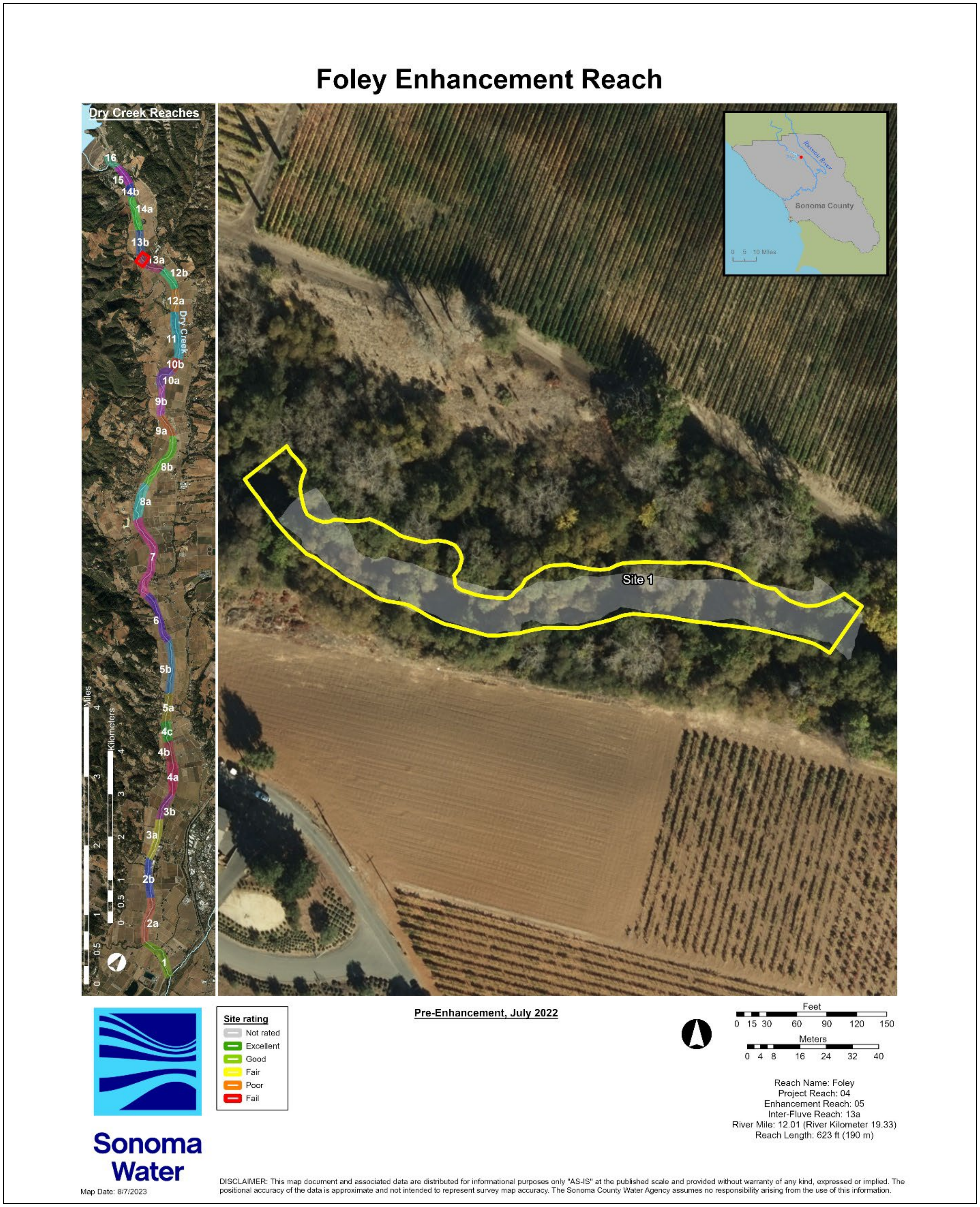

Figure 5.2.15. Pre-enhancement site rating for the Foley enhancement reach, July 2022

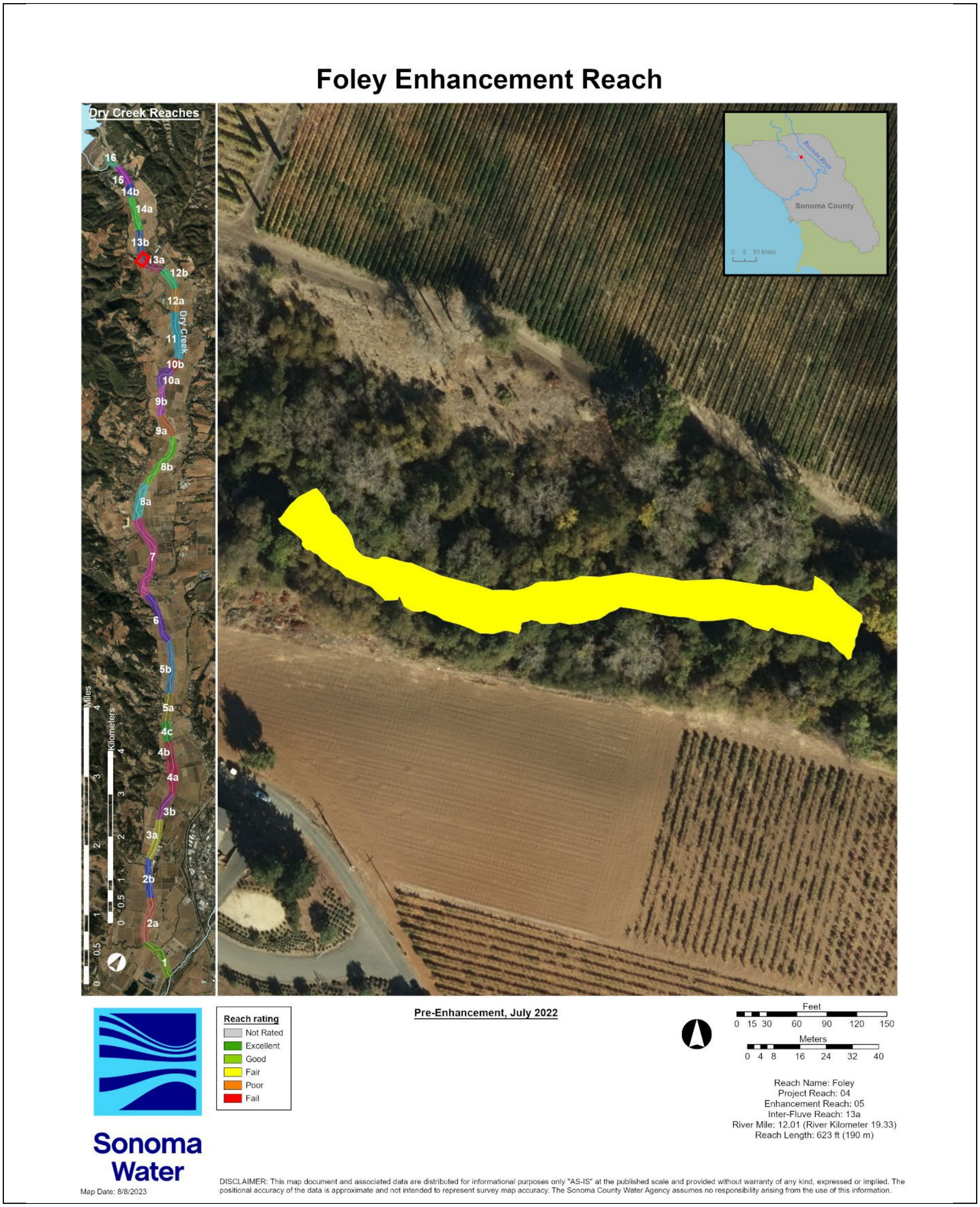

Figure 5.2.16. Pre-enhancement reach rating for the Foley enhancement reach, July 2022.

Post-enhancement

Foley Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Foley enhancement reach in November 2022. Previous effectiveness monitoring surveys occurred in July 2022 (pre-enhancement) (Table 5.2.18).

Table 5.2.18. Foley enhancement reach effectiveness monitoring surveys and ratings. (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2022	Fair	Good	--	--	--

The enhanced reach covered 39845 ft^2 within the main channel and side channel areas of Dry Creek, with 33% meeting optimal depth and velocity criteria (Table 5.2.19**,** Figure 5.2.17). The monitoring characterized 27,121 ft^2 of main channel area, 12,725 ft^2 of side channel area, of which 29% and 41% met optimal depth and velocity criteria, respectively. Nine habitat units made up the enhancement reach, with a pool to riffle ratio of 2:0 and an average shelter score of 82 (Table 5.2.20, Figure 5.2.18, Figure 5.2.19). Five habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised two enhancement sites (main channel and side channel; Table 5.2.21, Figure 5.2.20) that received excellent site average feature ratings, and fair to good site average habitat unit ratings (Figure 5.2.21; Figure 5.2.22). Enhancement sites received good ratings (Figure 5.2.23). Overall, the Foley enhancement reach received a good effectiveness monitoring rating (Table 5.2.21, Figure 5.2.24; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.19. Post-enhancement flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Foley enhancement reach, November 2022.

Foley Post-enhancement, November 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft, < 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	27,121	9,944	12,903	22,846	10,884	4,040	3,760	7,800
Side channel area	12,725	2,810	4,025	6,835	8,672	2,380	2,840	5,220
Total area	**39,845**	**12,754**	**16,928**	**29,681**	**19,557**	**6,420**	**6,600**	**13,020**
Main channel % of wetted area	68%	37%	48%	84%	40%	15%	14%	29%
Side channel % of wetted area	32%	22%	32%	54%	68%	19%	22%	41%
Total % of wetted area	**100%**	**32%**	**42%**	**74%**	**49%**	**16%**	**17%**	**33%**

Figure 5.2.17. 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 Foley enhancement reach, November 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.20. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Foley enhancement reach, November 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	15	45
HU02	Flatwater	2	15	30
HU03	Pool	2	20	40
HU04	Flatwater	3	45	135
HU05	Riffle	2	5	10
HU06	Pool	3	35	105
HU07	Pool	3	50	150
HU08	Flatwater	3	45	135
HU09	Riffle	3	30	90
Pool: riffle	**4: 2 (2.00)**			**Avg = 82**

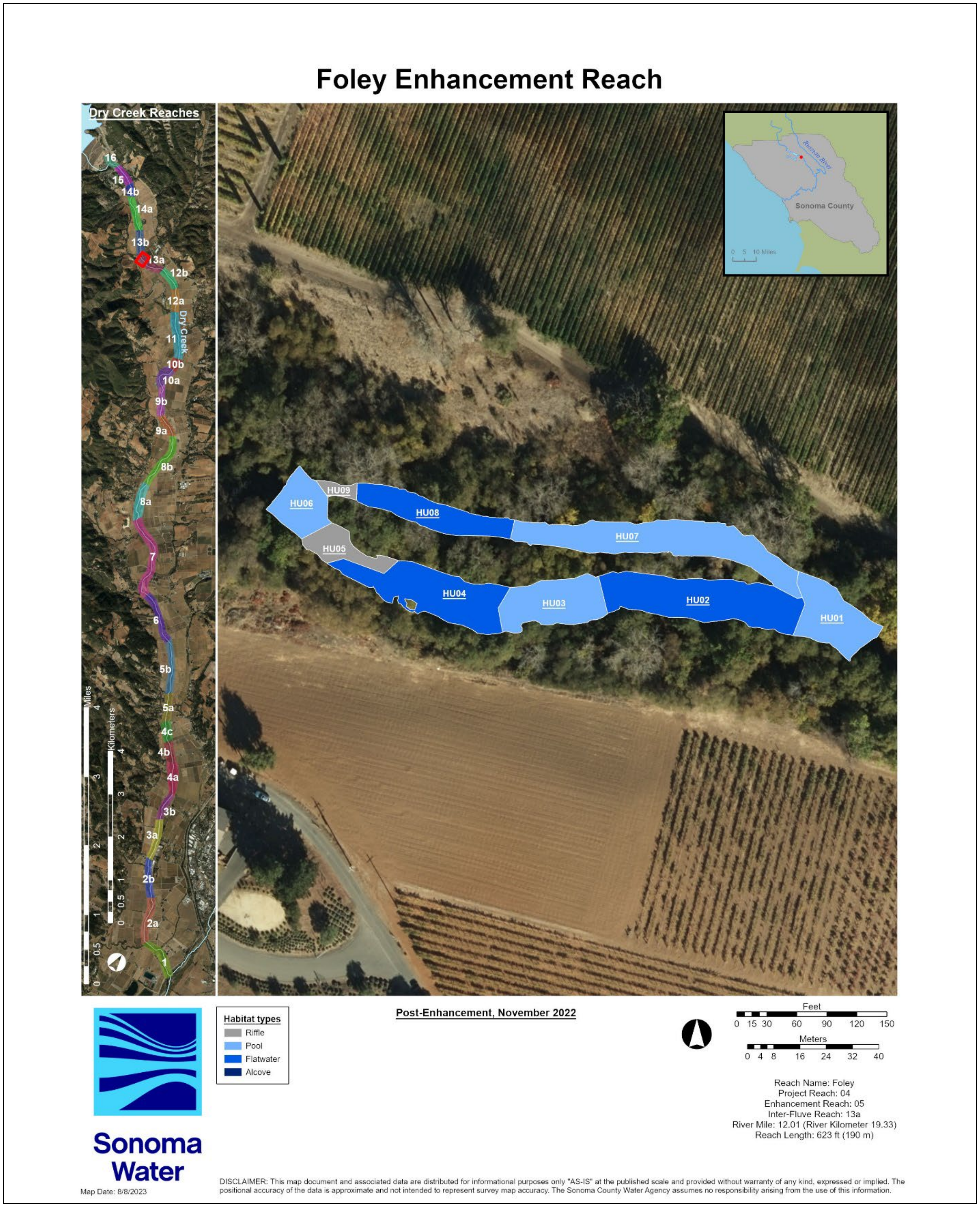

Figure 5.2.18. Habitat unit number and type within the Foley enhancement reach, November 2022.

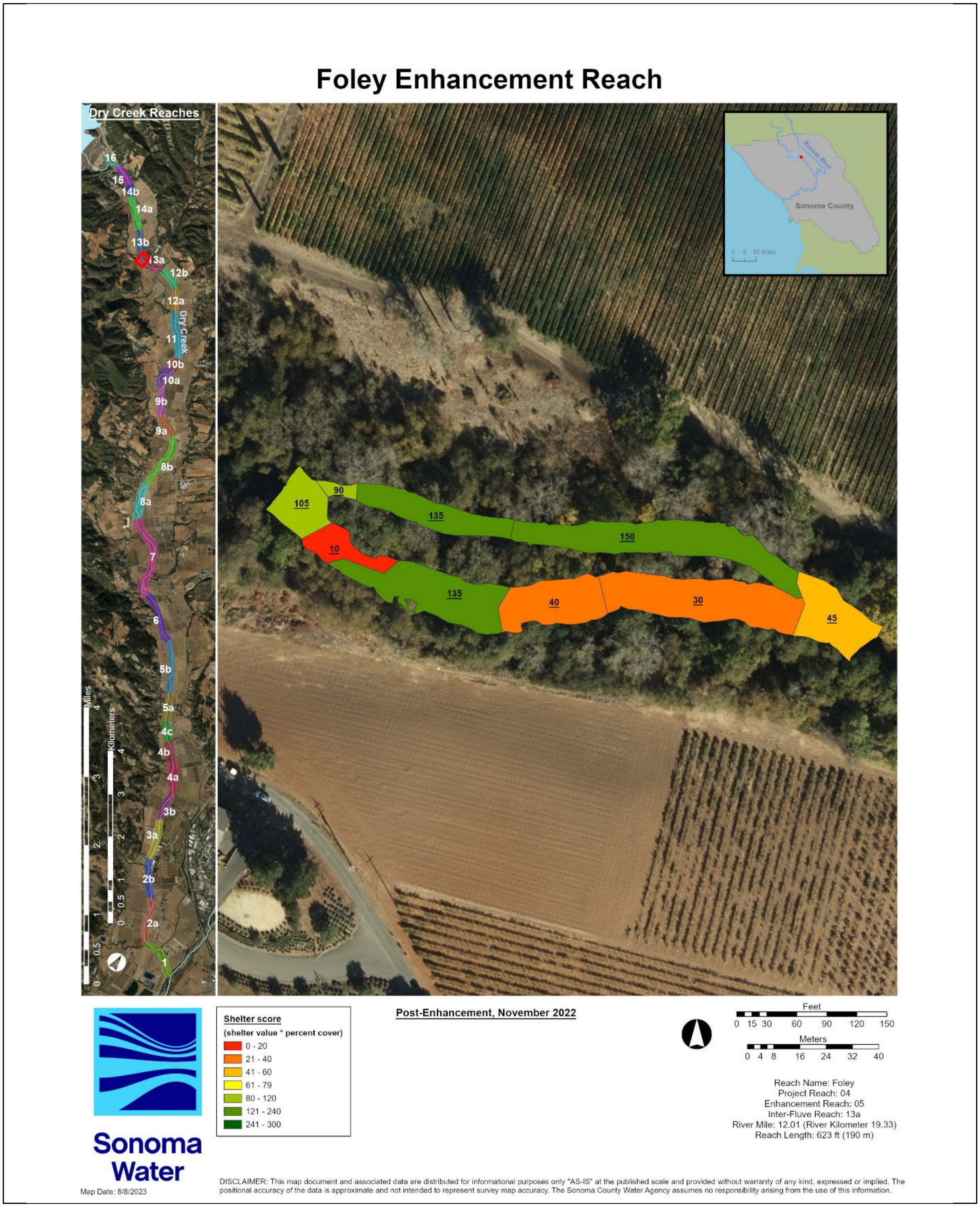

Figure 5.2.19. Habitat unit shelter values within the Foley enhancement reach, November 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.21. Post-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Foley enhancement reach, November 2022.

Site number	1	2		
Site type	Main channel	Side Channel		
Site average feature quantitative rating[a]	14	14		
Site average feature qualitative rating[a]	Excellent	Excellent		
Site average habitat unit quantitative rating[b]	19	22		
Site average qualitative rating[b]	Fair	Good		
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	33	35		
Site qualitative rating[c]	Good	Good		
Enhancement reach quantitative rating (average of site rating)[c]	34			
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)

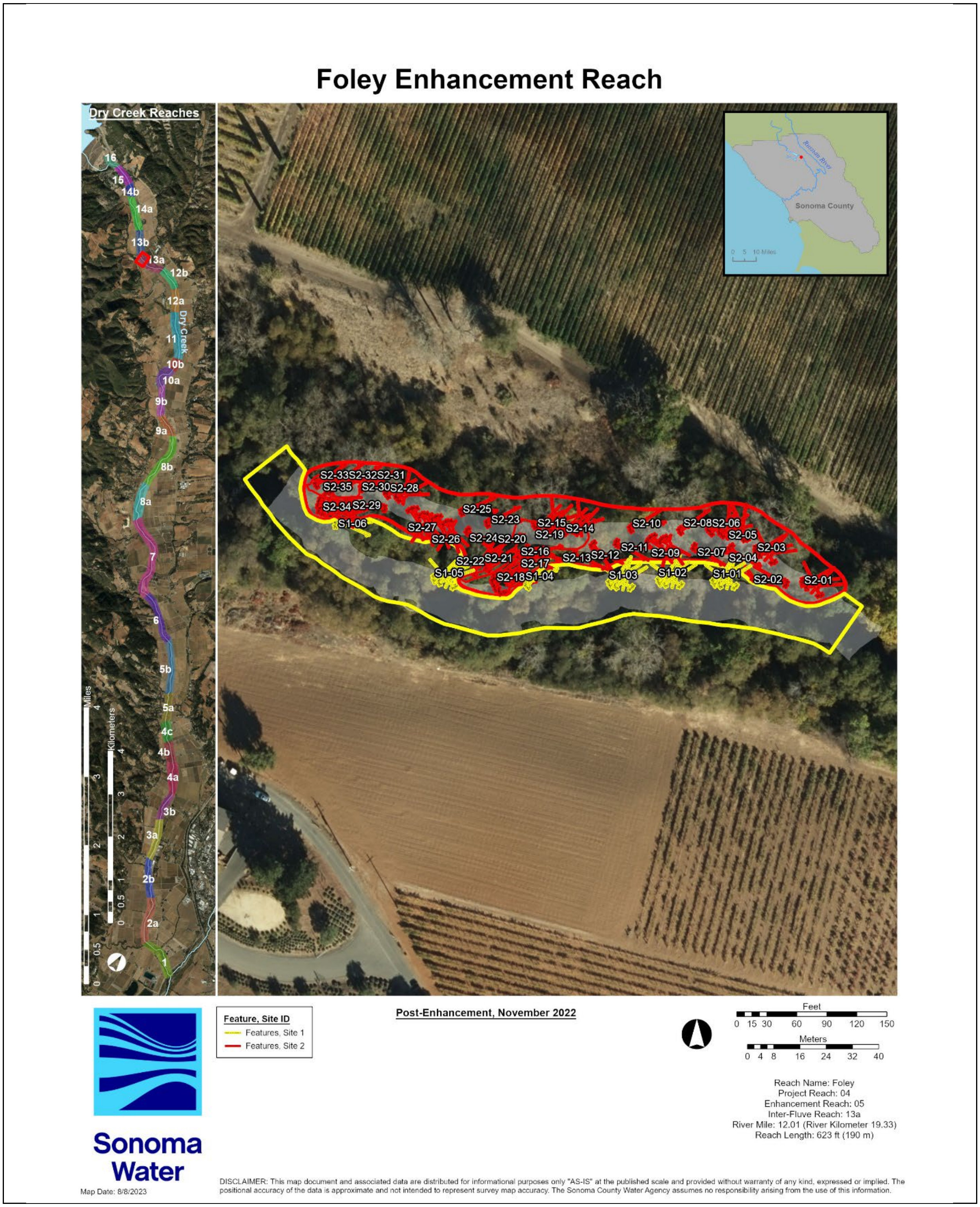

Figure 5.2.20. Enhancement sites and features within the Foley enhancement reach, November 2022.

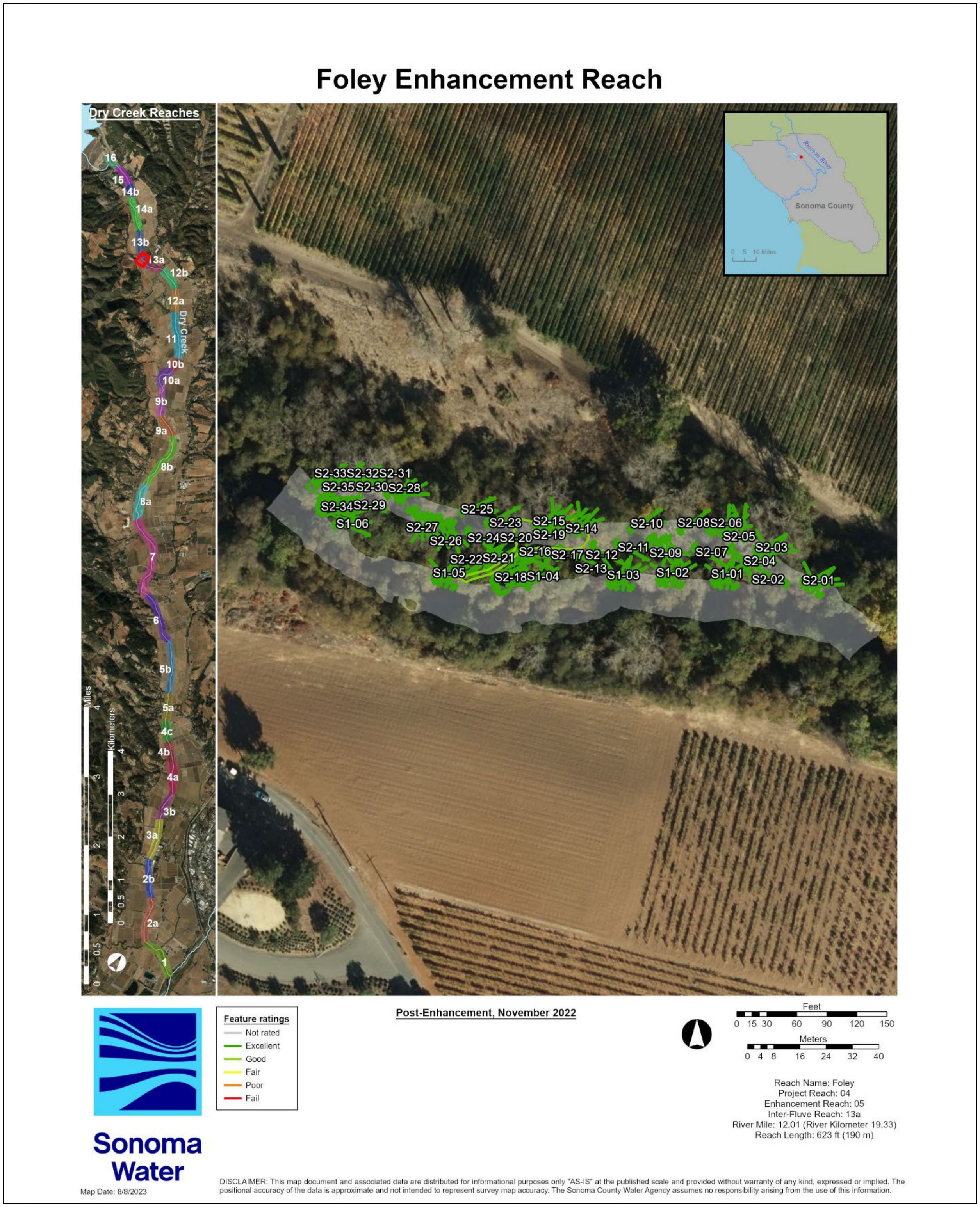

Figure 5.2.21. Feature ratings for the Foley enhancement reach, November 2022.

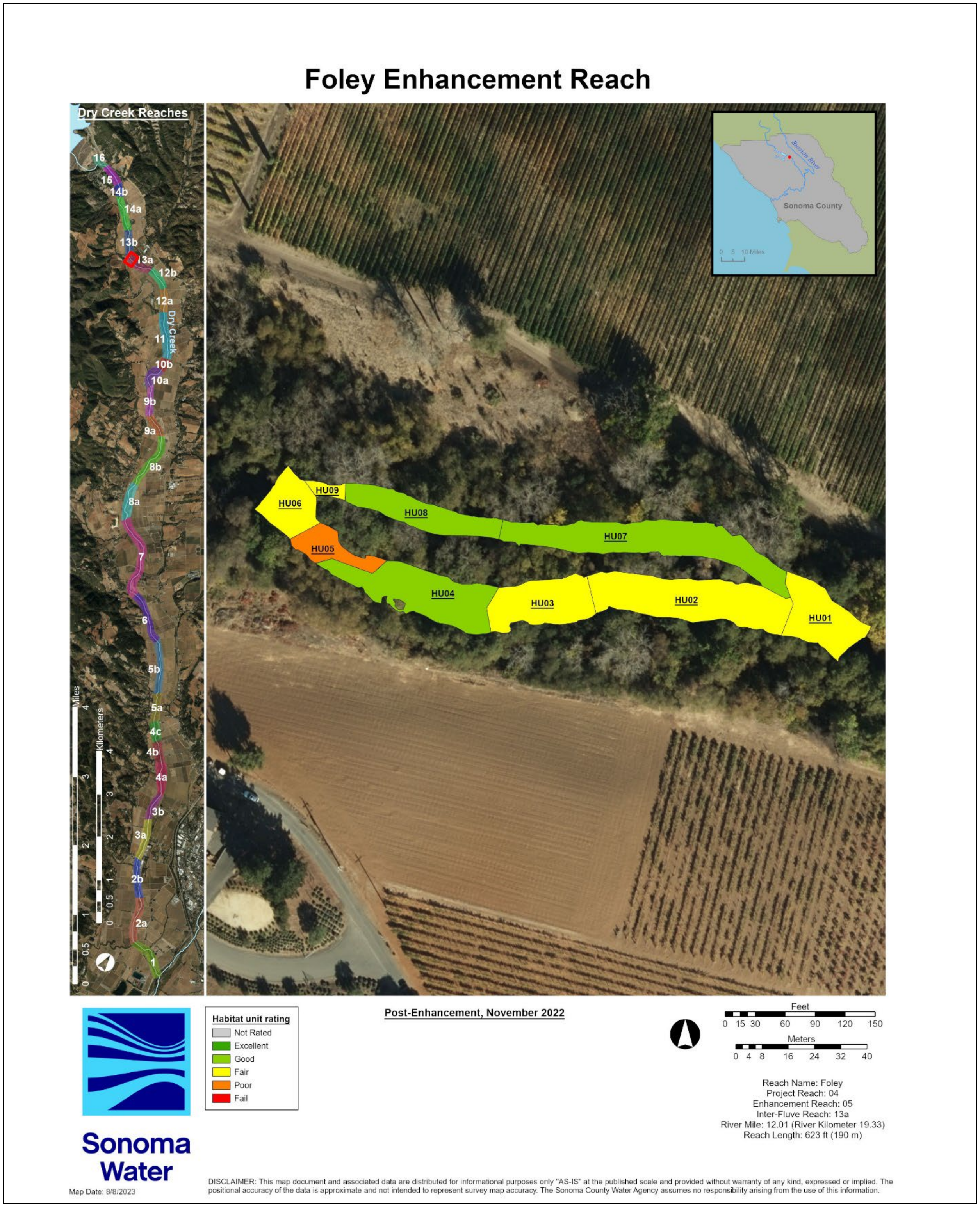

Figure 5.2.22. Habitat unit ratings for the Foley enhancement reach, November 2022.

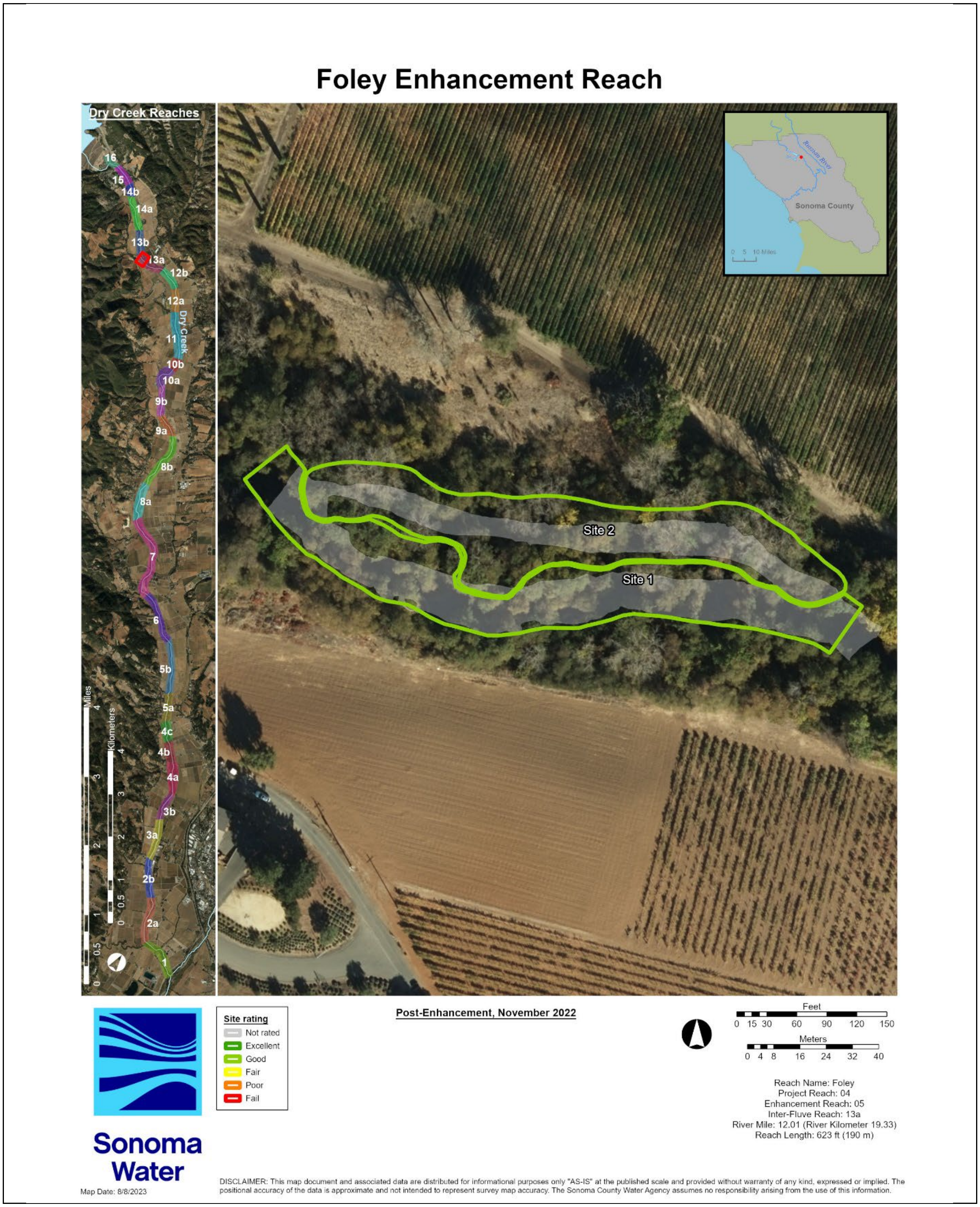

Figure 5.2.23. Post-enhancement site ratings for the Foley enhancement reach, November 2022.

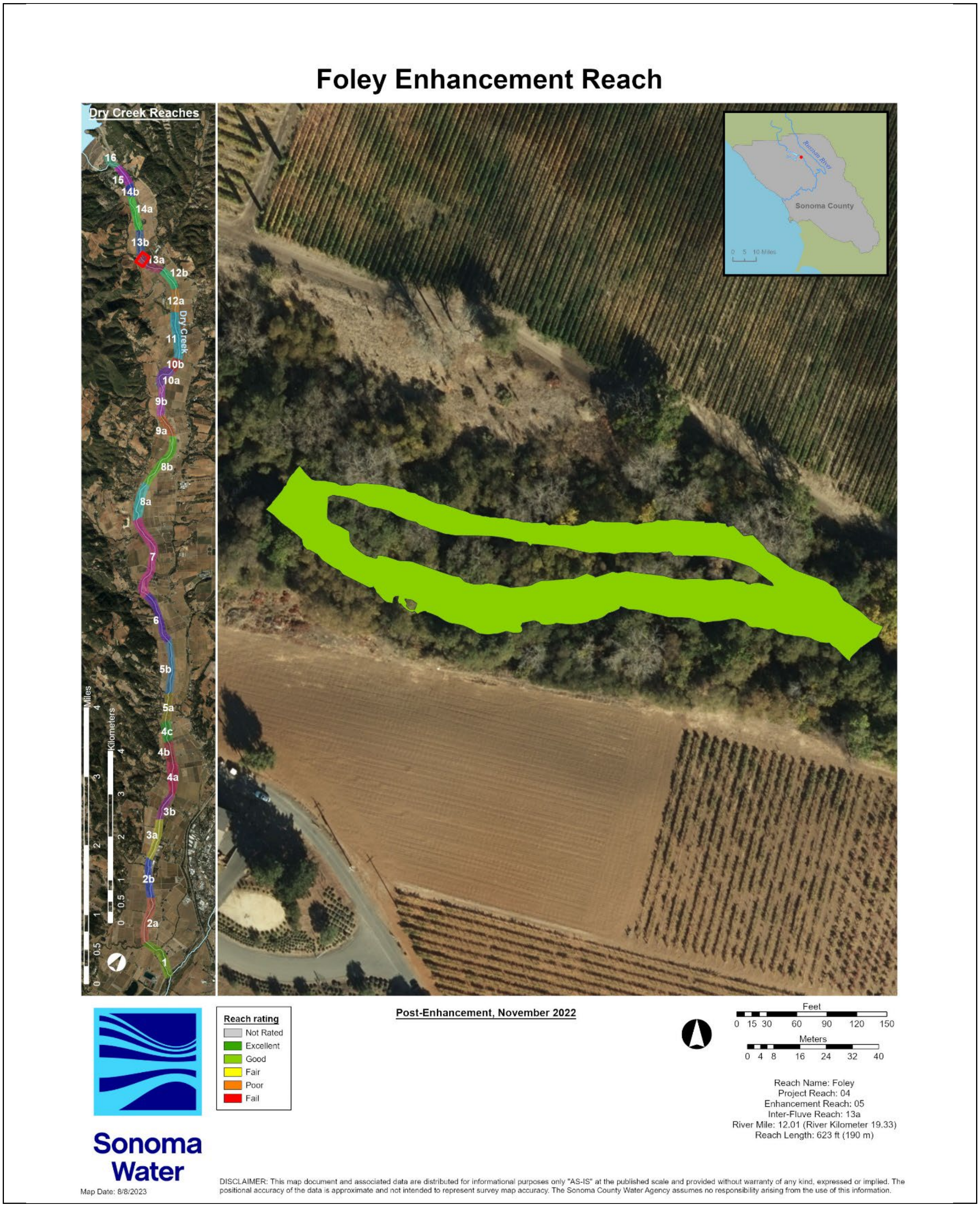

Figure 5.2.24. Post-enhancement reach rating for the Foley enhancement reach, November 2022.

Post-effective Flow

Summary

Sonoma Water monitored the post-effective flow conditions of the Army Corps, Army Corps Reach 14, Truett Hurst, Farrow Wallace, Boaz Gros-Balthazard, and Ferrari-Carano Olson enhancement reaches in 2022 (Table 5.2.8, Figure 5.2.4). Overall, the enhancement reaches encompassed 326,114 ft^2 within main and side channel areas, with 38% of the total area meeting optimal depth and velocity criteria (Table 5.2.22). Monitoring examined 115,024 ft^2 of side channel area, of which 54% met optimal depth and criteria, compared with 211,090 ft^2 and 29% in the main channel. Crews observed 131 habitat units across all enhancement reaches with a total pool to riffle ratio of 48:32 (1.50) and a total average shelter score of 120 (Table 5.2.23). Average shelter score for all habitat types exceeded the optimum shelter score of 80. Post-effective flow, all monitored enhancement reaches rated good (Table 5.2.24; see below for individual enhancement reach summaries and Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.22. Post-effective flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches surveyed in 2022.

Dry Creek, Post-effective Flow 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	211,090	106,822	66,226	173,048	86,180	35,536	24,845	60,380
Side channel area	115,024	52,371	33,576	85,947	87,309	37,172	27,031	64,202
Total area	**326,114**	**159,193**	**99,802**	**258,995**	**173,490**	**72,707**	**51,875**	**124,583**
Main channel % of wetted area	65%	51%	31%	82%	41%	17%	12%	29%
Side channel % of wetted area	35%	45%	29%	74%	75%	32%	23%	54%
Total % of wetted area	**100%**	**49%**	**31%**	**79%**	**53%**	**22%**	**16%**	**38%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.23. Post-effective flow habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches surveyed in 2022.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	32	86
Pool	48	139
Flatwater	39	104
Alcove	12	190
Pool: riffle	**48:32 (1.50)**	**Avg: 120**

Reach ratings

Table 5.2.24. Post-effective flow ratings for Dry Creek enhancement reaches surveyed in 2022.

Enhancement Reach	Post-effective Flow Rating
Army Corps	Good
Army Corps Reach 14	Good
Truett Hurst	Good
Farrow Wallace	Good
Boaz Gros-Balthazard	Good
Ferrari-Carano, Olson	Good

Army Corps Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Army Corps enhancement reach in December 2022. Previous effectiveness monitoring surveys occurred in November 2015 (post-effective flow), September 2016 (post-effective flow), and October 2019 (post-effective flow) (Table 5.2.25).

Table 5.2.25. Army Corps enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2015	Fair	--	Excellent	--	--
2016	--	--	Excellent	--	--
2017	--	--	--	--	--
2018	--	--	--	--	--
2019	--	--	Good	--	--
2020	--	--	--	--	--
2021	--	--	--	--	--
2022	--	--	Good	--	--

In 2022, Sonoma Water was unable collect depth and velocity data within the Army Corps enhancement reach (Table 5.2.26, Figure 5.2.25), but still evaluated features and collected habitat data (type and shelter value). Twenty habitat units composed the enhancement reach, with a pool to riffle ratio of 7:1 (7.0) and average shelter score of 118 (Table 5.2.27, Figure 5.2.26, Figure 5.2.27). Eleven 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 5.2.28, Figure 5.2.28), with excellent site average feature ratings, and fair to excellent average habitat unit ratings (Table 5.2.28, Figure 5.2.29, Figure 5.2.30). Enhancement sites received good ratings (Figure 5.2.31). Overall, the Army Corps enhancement reach received a good effectiveness monitoring rating (Table 5.2.28, Figure 5.2.32; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.26. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Army Corps enhancement reach, December 2022. Sonoma Water was unable to collect depth and velocity data (-- indicates data not collected).

Army Corps, Post-effective flow, December 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft, < 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	--	--	--	--	--	--	--	--
Side channel area	--	--	--	--	--	--	--	--
Total area	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Main channel % of wetted area	--	--	--	--	--	--	--	--
Side channel % of wetted area	--	--	--	--	--	--	--	--
Total % of wetted area	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**

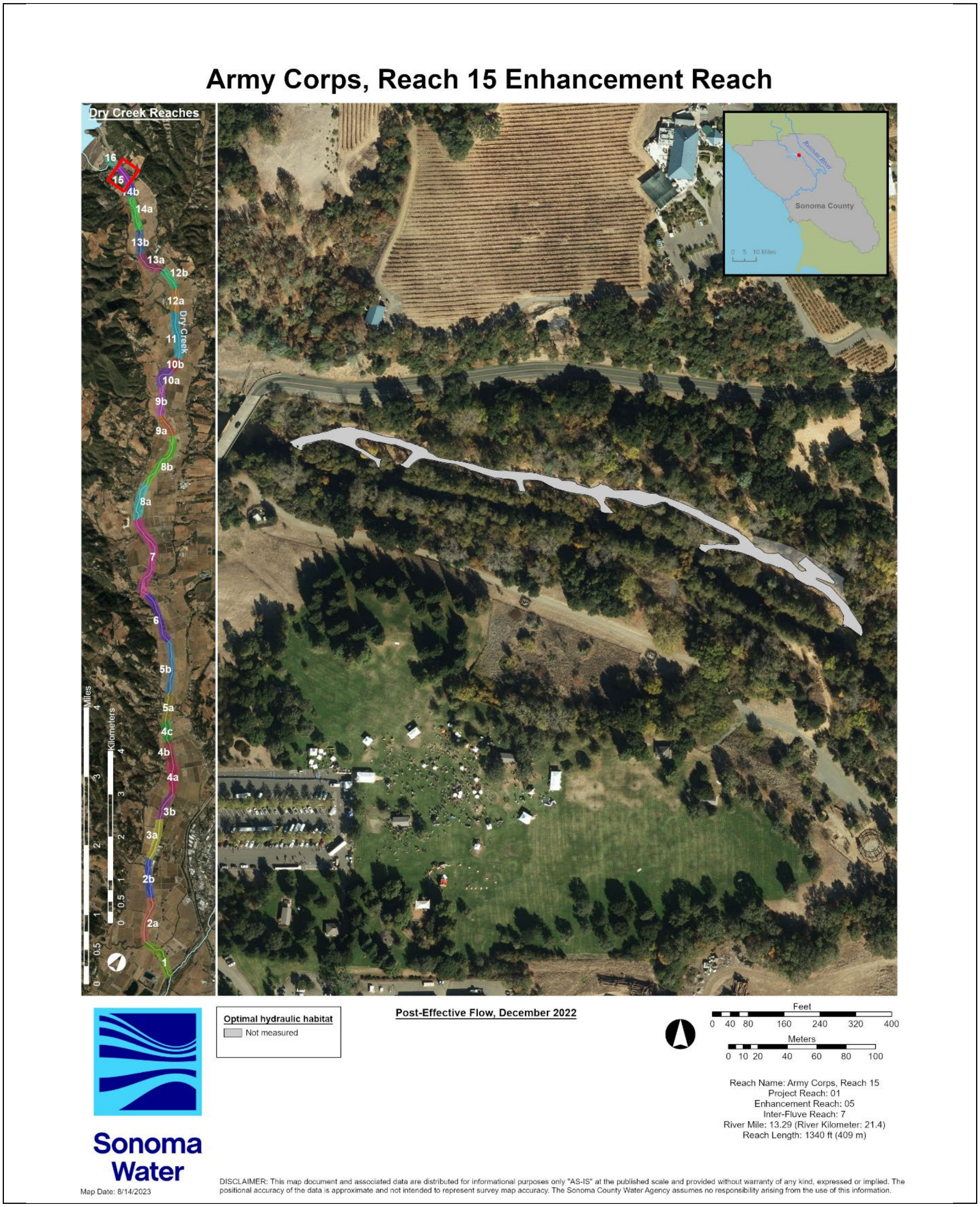

Figure 5.2.25. Sonoma Water was unable to collect depth and velocity data within the Army Corps enhancement reach, December 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.27. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Army Corps enhancement reach, December 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	45	135
HU02	Pool	3	85	255
HU03	Alcove	3	80	240
HU04	Flatwater	3	20	60
HU05	Pool	3	60	180
HU06	Flatwater	2	70	140
HU07	Flatwater	3	15	45
HU08	Pool	3	45	135
HU09	Flatwater	3	35	105
HU10	Pool	3	20	60
HU11	Flatwater	2	15	30
HU12	Pool	3	45	135
HU13	Flatwater	2	35	70
HU14	Flatwater	3	15	45
HU15	Riffle	2	15	30
HU16	Pool	3	65	195
HU17	Flatwater	3	70	210
HU18	Flatwater	2	60	120
HU19	Pool	3	40	120
HU20	Flatwater	2	20	40
Pool: riffle	**7:1 (7.0)**			**Avg = 118**

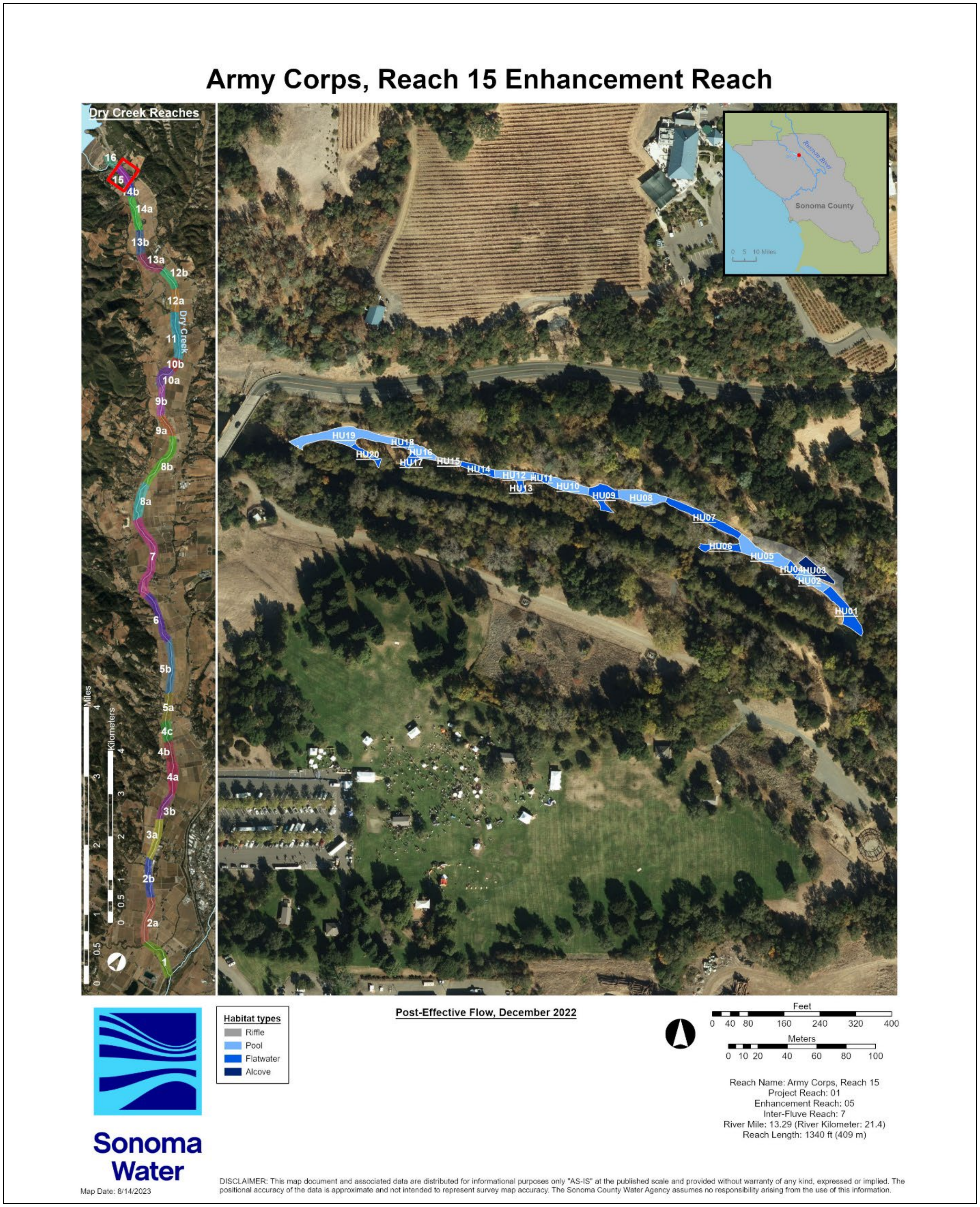

Figure 5.2.26. Habitat unit number and type within the Army Corps enhancement reach, December 2022.

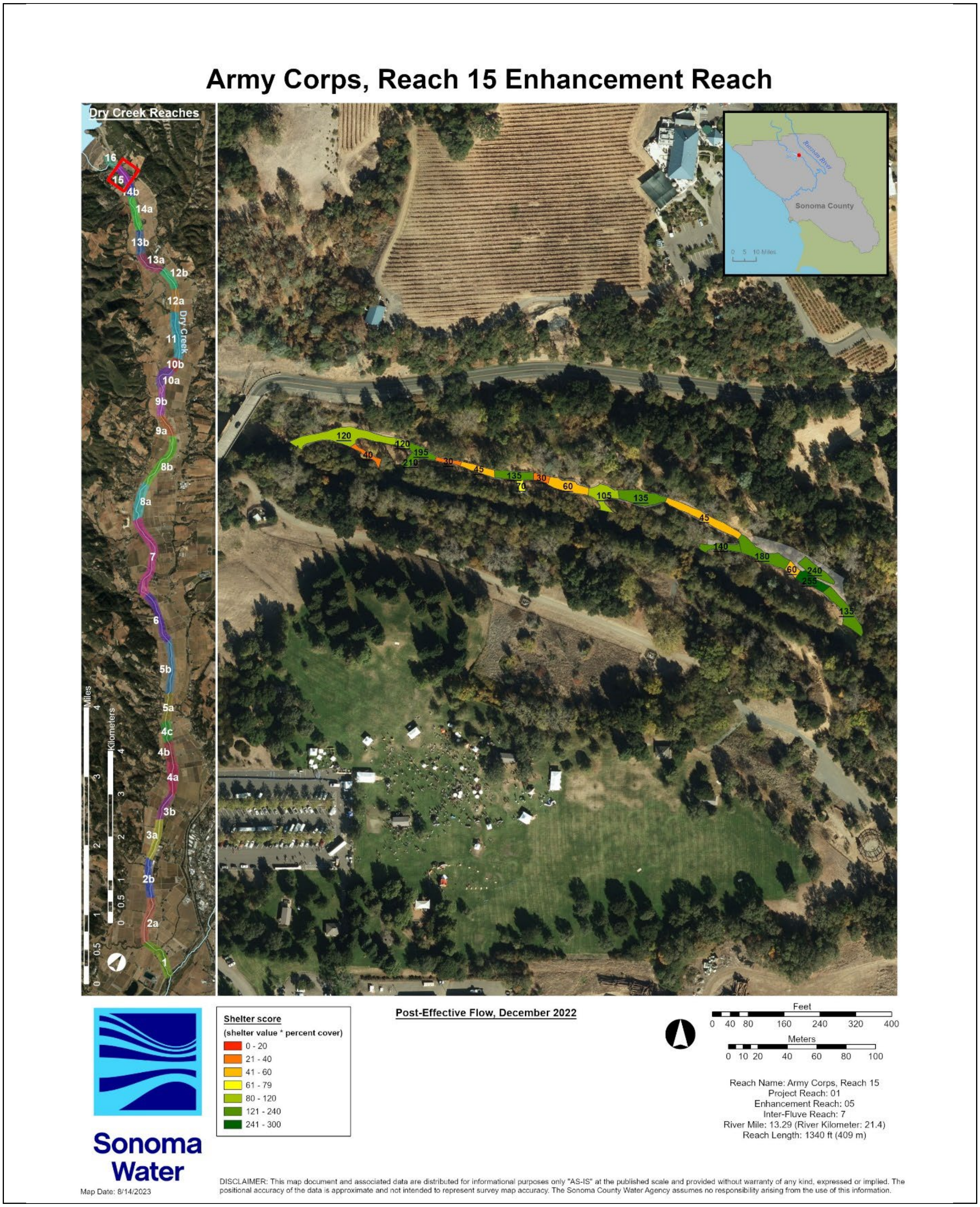

Figure 5.2.27. Habitat unit shelter scores within the Army Corps enhancement reach, December 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.28. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Army Corps enhancement reach, December 2022.

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 quantitative rating[a]	13	13	13	12	13	12
Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Site average habitat unit quantitative rating[a]	10	13	8	8	11	11
Site average qualitative rating[a]	Good	Excellent	Fair	Fair	Good	Good
Site quantitative rating (sum of site average feature and habitat unit rating)[b]	22	26	21	20	24	24
Site qualitative rating[b]	Good	Excellent	Good	Good	Good	Good
Enhancement reach quantitative rating (average of site rating)[b]	23					
Enhancement reach qualitative rating[b]	Good					

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 30; Excellent (>=24), Good (>=18), Fair (>=12), Poor (>=6), Fail (<6)

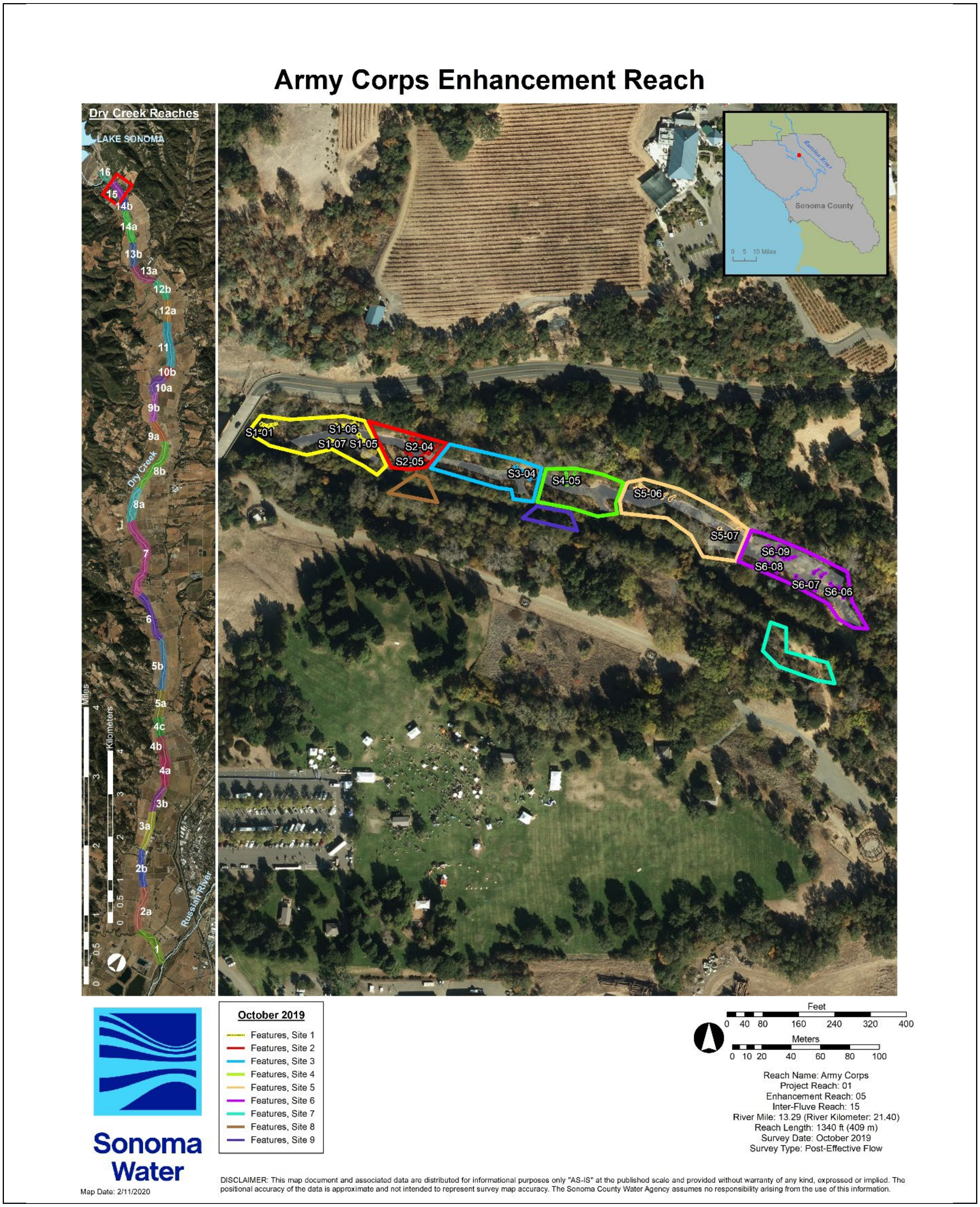

Figure 5.2.28. Enhancement sites and features within the Army Corps enhancement reach, December 2022.

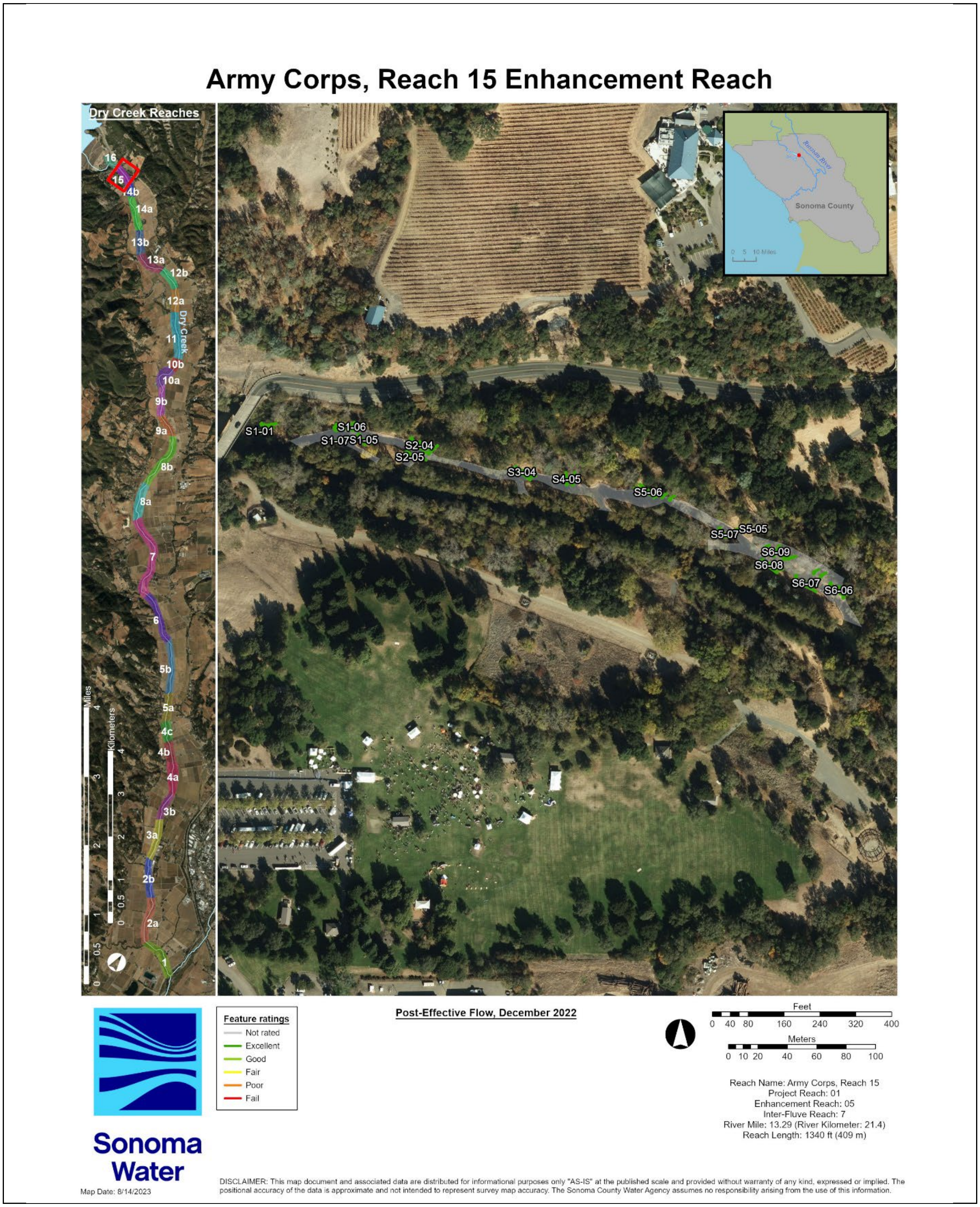

Figure 5.2.29. Feature ratings for the Army Corps enhancement reach, December 2022.

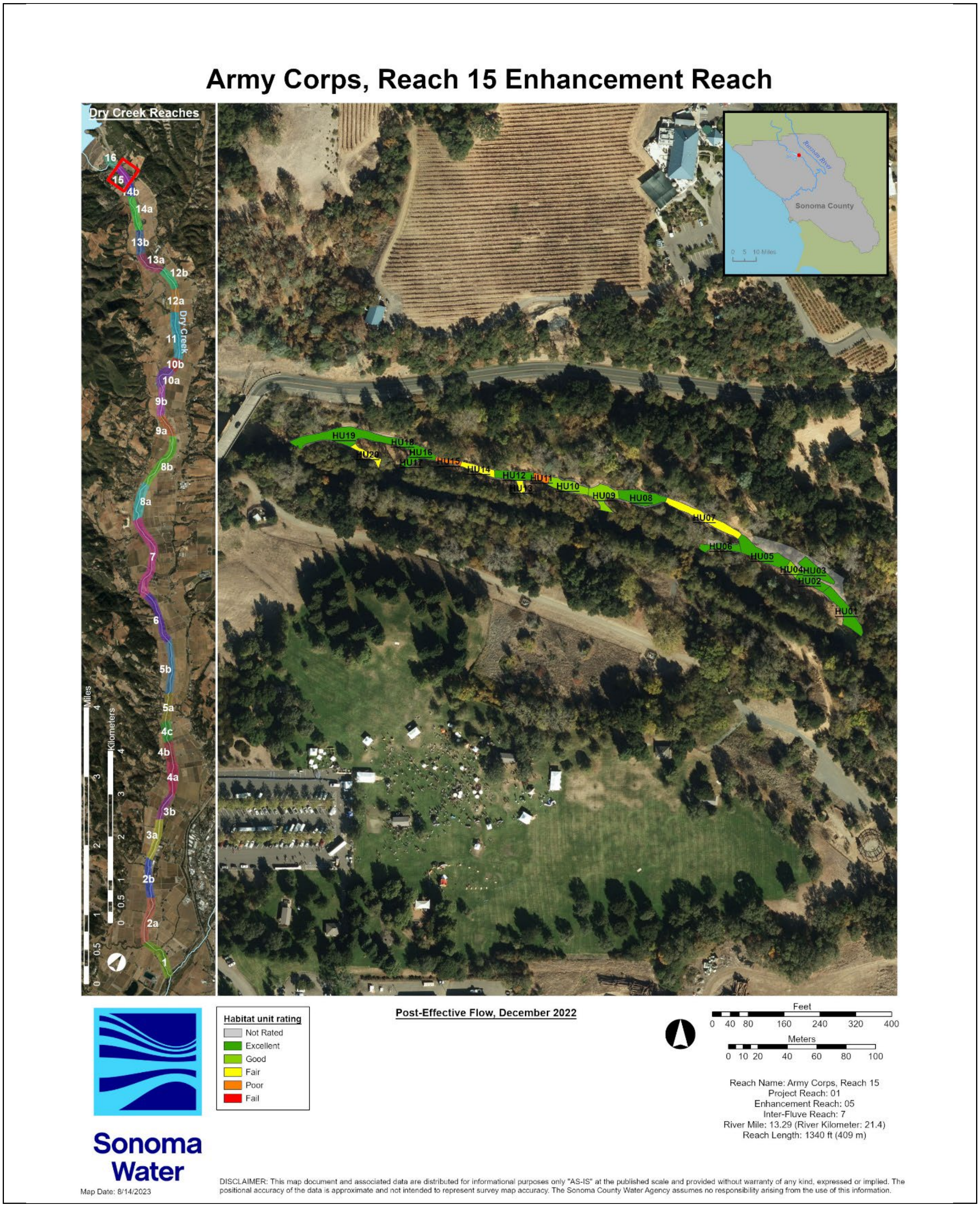

Figure 5.2.30. Habitat unit ratings for the Army Corps enhancement reach, December 2022.

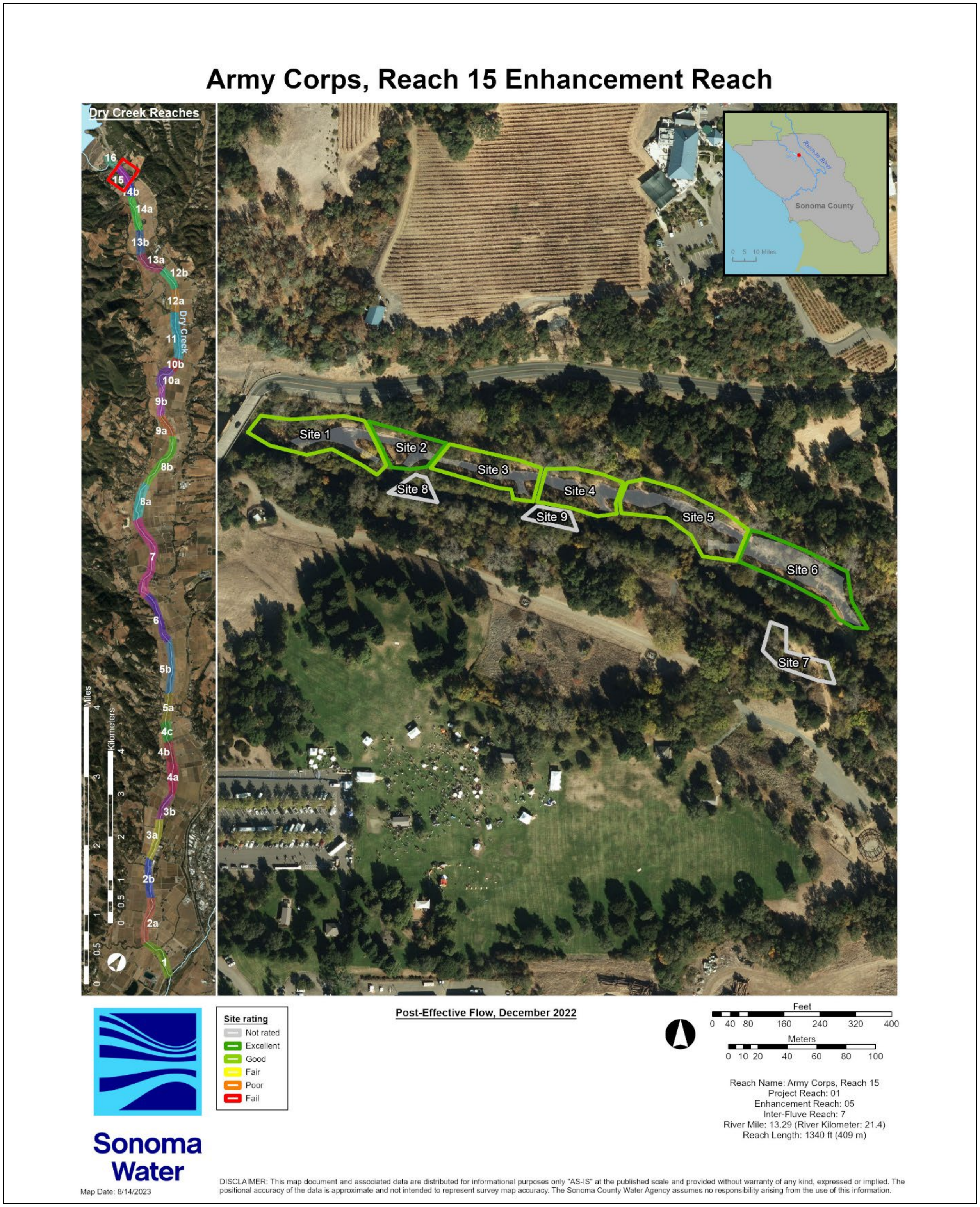

Figure 5.2.31. Post-enhancement site ratings for the Army Corps enhancement reach, December 2022.

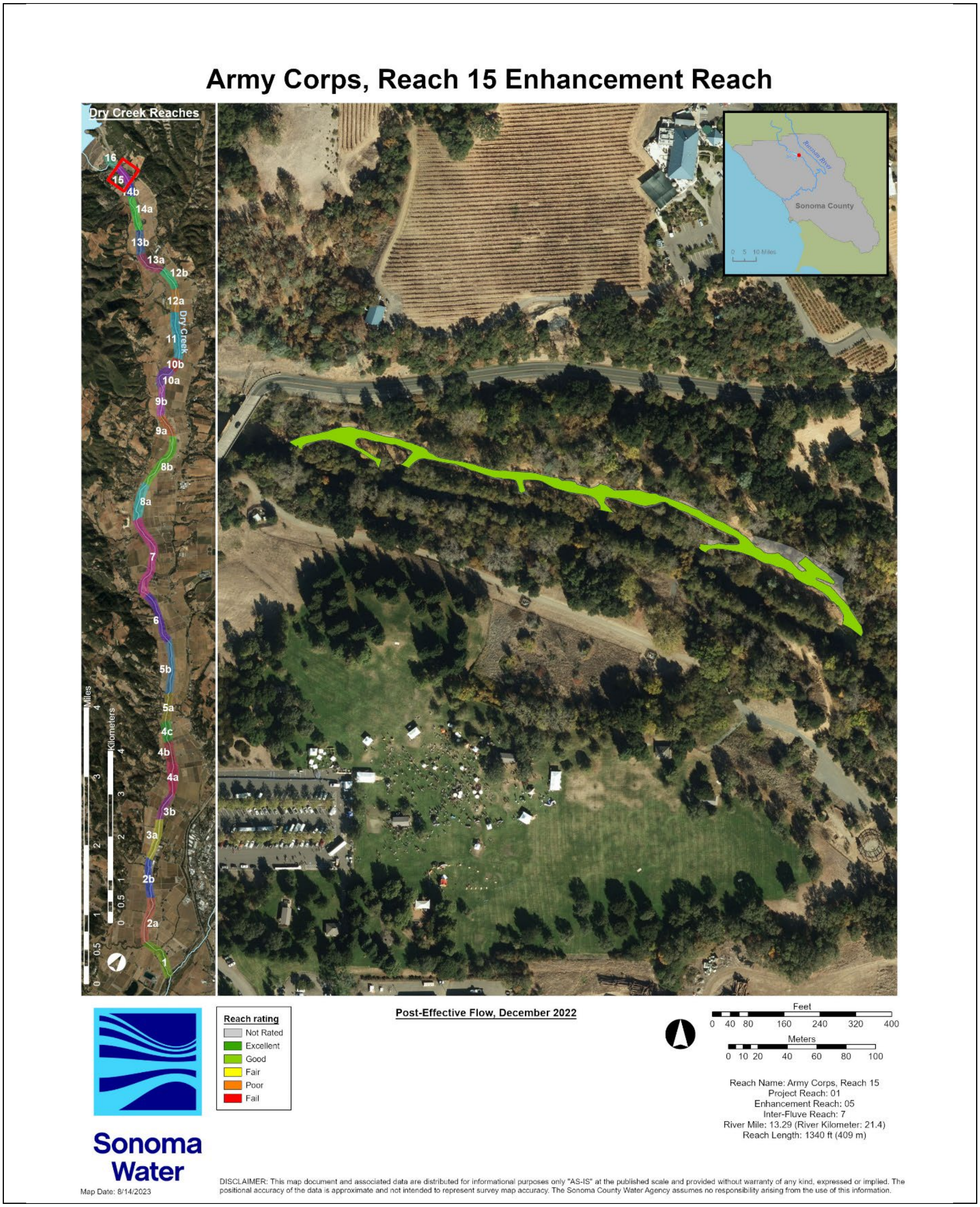

Figure 5.2.32. Post-enhancement reach rating for the Army Corps enhancement reach, December 2022.

Army Corps Reach 14 Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Army Corps Reach 14 enhancement reach in April 2022. Previous effectiveness monitoring surveys occurred in May 2018 (pre-enhancement), October 2018 (post-enhancement flow), and September 2019 (post-effective flow) (Table 5.2.29).

Table 5.2.29. Army Corps Reach 14 enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2018	Fair	Good	--	--	--
2019	--	--	Good	--	--
2020	--	--	--	--	--
2021	--	--	--	--	--
2022	--	--	Good	--	--

The 2022 monitored area encompassed 67,031 ft^2 within main- and off-channel areas of Dry Creek with 41% of the total area meeting optimal depth and velocity criteria (Table 5.2.30, Figure 5.2.33). The monitoring characterized 3,059 ft^2 of side channel alcove area and 24,715 ft^2 of side channel area, of which 81% and 44% met optimal depth and velocity criteria, compared with 39,257 ft^2 and 36% for the main channel area. Nineteen habitat units composed the enhancement reach, with a pool to riffle ratio of 9:7 (1.29) and average shelter score of 93 (Table 5.2.31, Figure 5.2.34, Figure 5.2.35). Eleven 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 5.2.32; Figure 5.2.36), with excellent site average feature ratings, and fair to excellent average habitat unit ratings (Table 5.2.32, Figure 5.2.37, Figure 5.2.38). Enhancement sites received good ratings (Figure 5.2.39). Overall, the Army Corps enhancement reach received a good effectiveness monitoring rating (Table 5.2.32, Figure 5.2.40; see Appendix 5.2 for all 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 Army Corps Reach 14 enhancement reach, April 2022.

Army Corps Reach 14, Post-effective flow, April 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft,< 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	39,257	18,101	10,383	28,484	22,166	7,933	6,293	14,226
Side channel area	24,715	8,730	9,858	18,588	16,121	5,020	5,960	10,980
Side channel alcove area	3,059	1,721	757	2,478	3,059	1,721	757	2,478
Total area	**67,031**	**28,552**	**20,998**	**49,550**	**41,346**	**14,674**	**13,010**	**27,684**
Main channel % of wetted area	59%	46%	26%	73%	56%	20%	16%	36%
Side channel % of wetted area	37%	35%	40%	75%	65%	20%	24%	44%
Side channel alcove area % of wetted area	4%	56%	25%	81%	100%	56%	25%	81%
Total % of wetted area	**100%**	**43%**	**31%**	**74%**	**62%**	**22%**	**19%**	**41%**

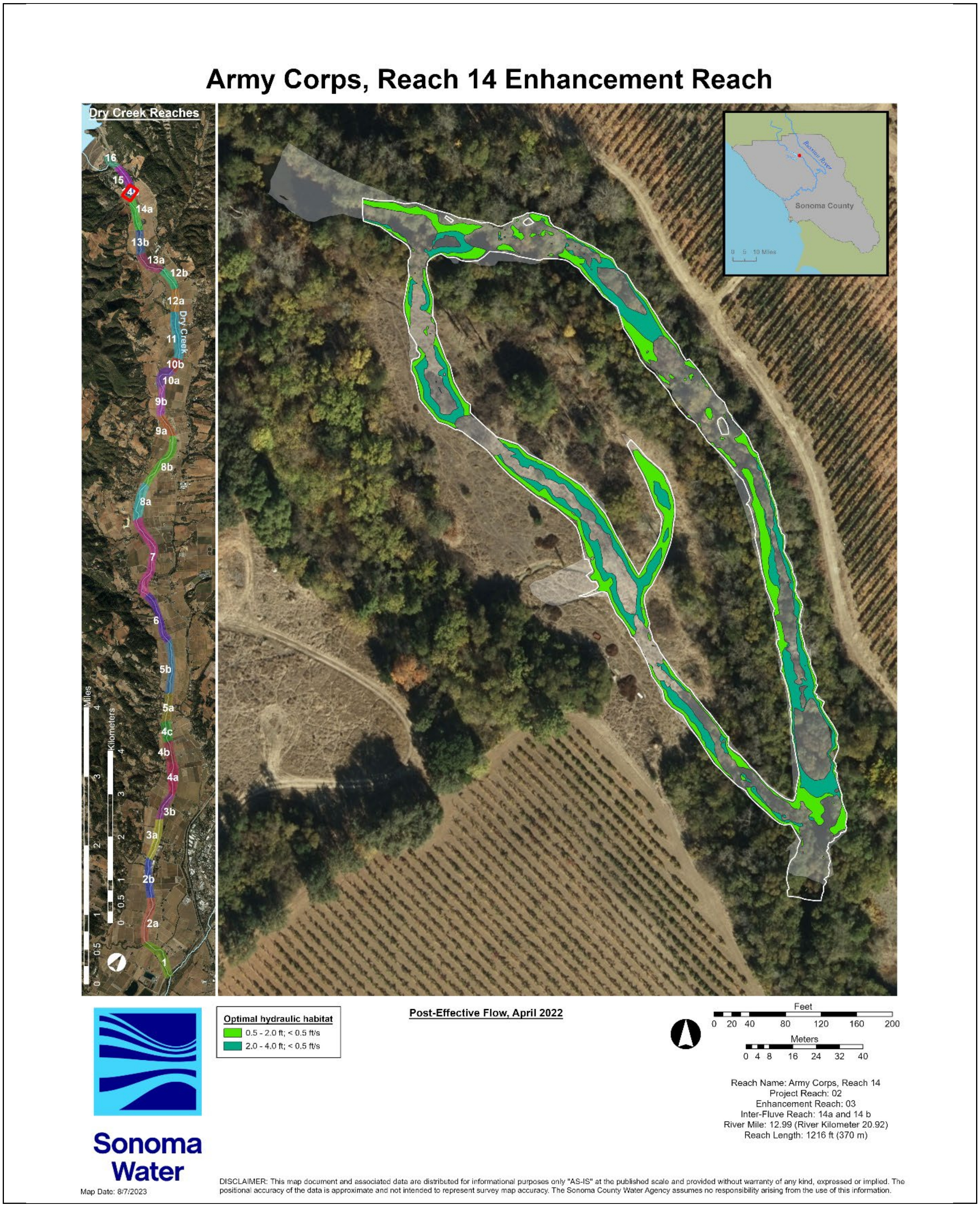

Figure 5.2.33. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Army Corps Reach 14 enhancement reach, April 2022.

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 Army Corps Reach 14 enhancement reach, April 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	15	30
HU02	Pool	3	40	120
HU03	Flatwater	2	10	20
HU04	Riffle	2	25	50
HU05	Flatwater	2	15	30
HU06	Pool	3	45	135
HU07	Riffle	3	30	90
HU08	Pool	2	25	50
HU09	Pool	3	40	120
HU10	Pool	3	50	150
HU11	Pool	3	50	150
HU12	Riffle	2	35	70
HU13	Pool	3	45	120
HU14	Riffle	1	15	15
HU15	Pool	3	70	210
HU16	Riffle	3	20	60
HU17	Pool	3	30	90
HU18	Riffle	3	40	120
HU19	Alcove	3	45	135
Pool: riffle	**9:7 (1.29)**			**Avg = 93**

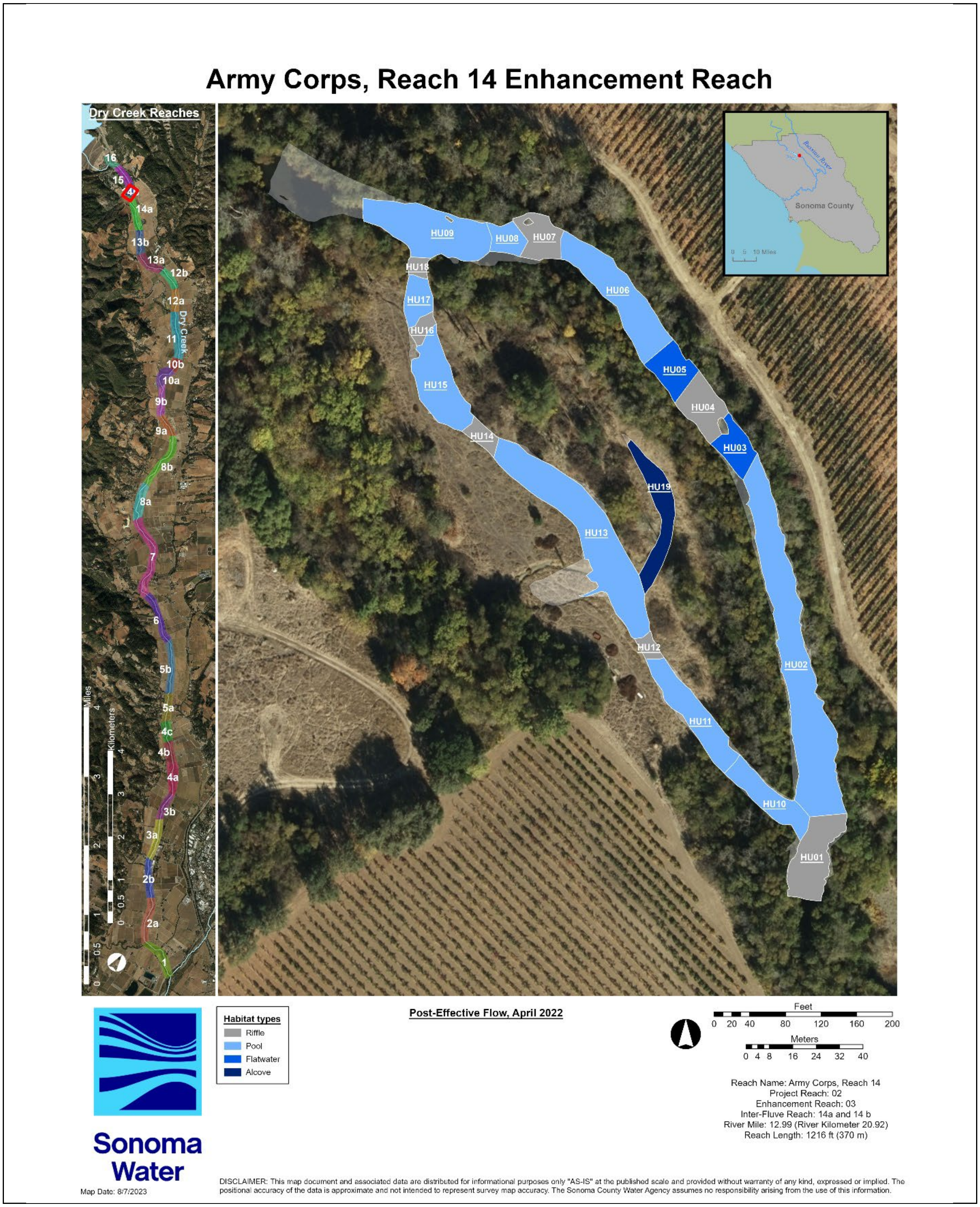

Figure 5.2.34. Habitat unit number and type within the Army Corps Reach 14 enhancement reach, April 2022.

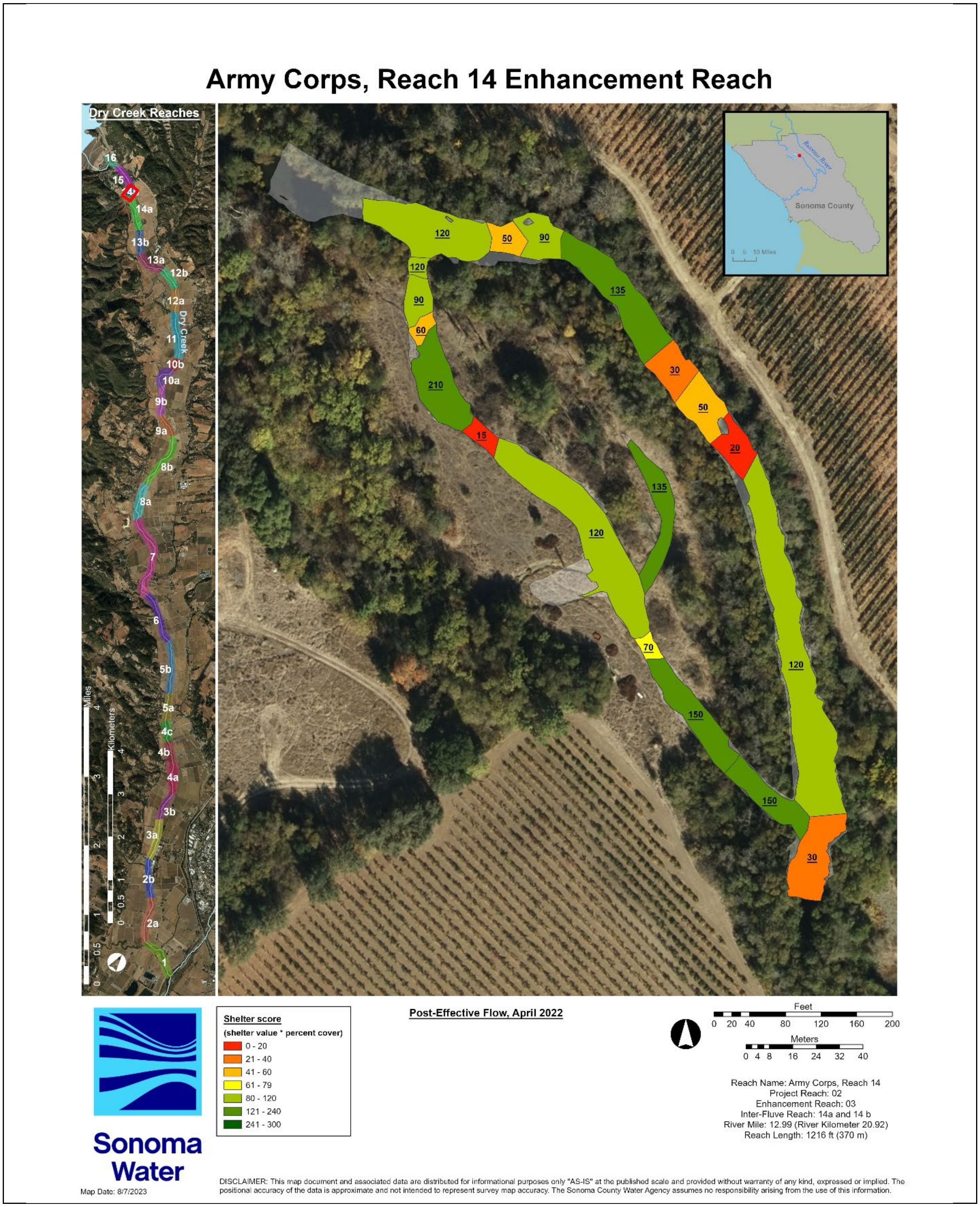

Figure 5.2.35. Habitat unit shelter scores within the Army Corps Reach 14 enhancement reach, April 2022.

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 Army Corps reach 14 enhancement reach, April 2022.

Site number	1	2	3	4
Site type	Main channel	Side channel	Alcove	Alcove
Site average feature quantitative rating	0	14	14	8
Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	Fair
Site average habitat unit quantitative rating	18	22	28	14
Site average qualitative rating[b]	Fair	Good	Excellent	Poor
Site quantitative rating (sum of site average feature and habitat unit rating)	18	36	42	22
Site qualitative rating	Fair[b]	Good[c]	Excellent[c]	Fair[c]
Enhancement reach quantitative rating (average of site rating)	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)
[d]out of 46; Excellent (>=37), Good (>=28), Fair (>=19), Poor (>=9), Fail (<9)

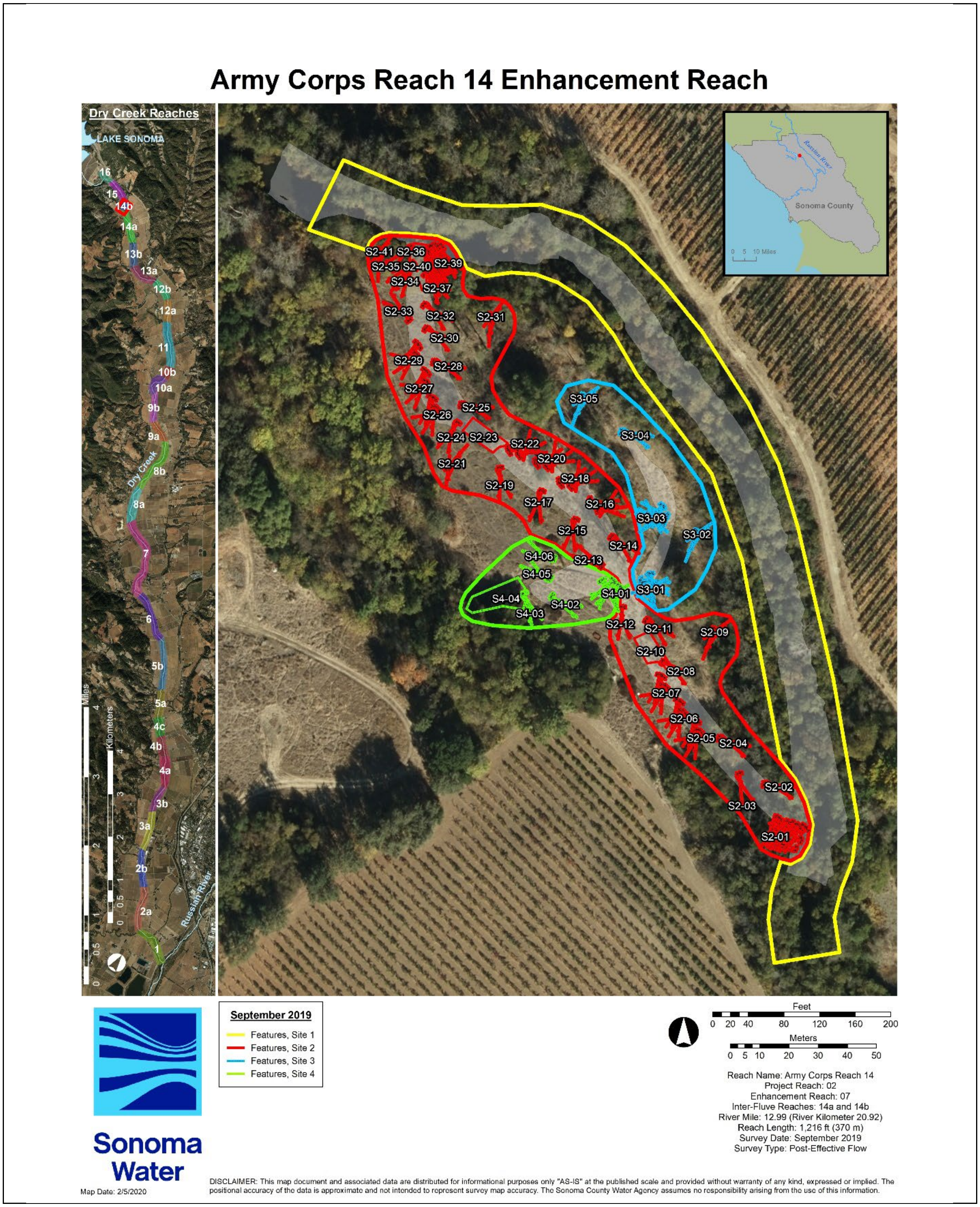

Figure 5.2.36. Enhancement sites and features within the Army Corps Reach 14 enhancement reach, April 2022.

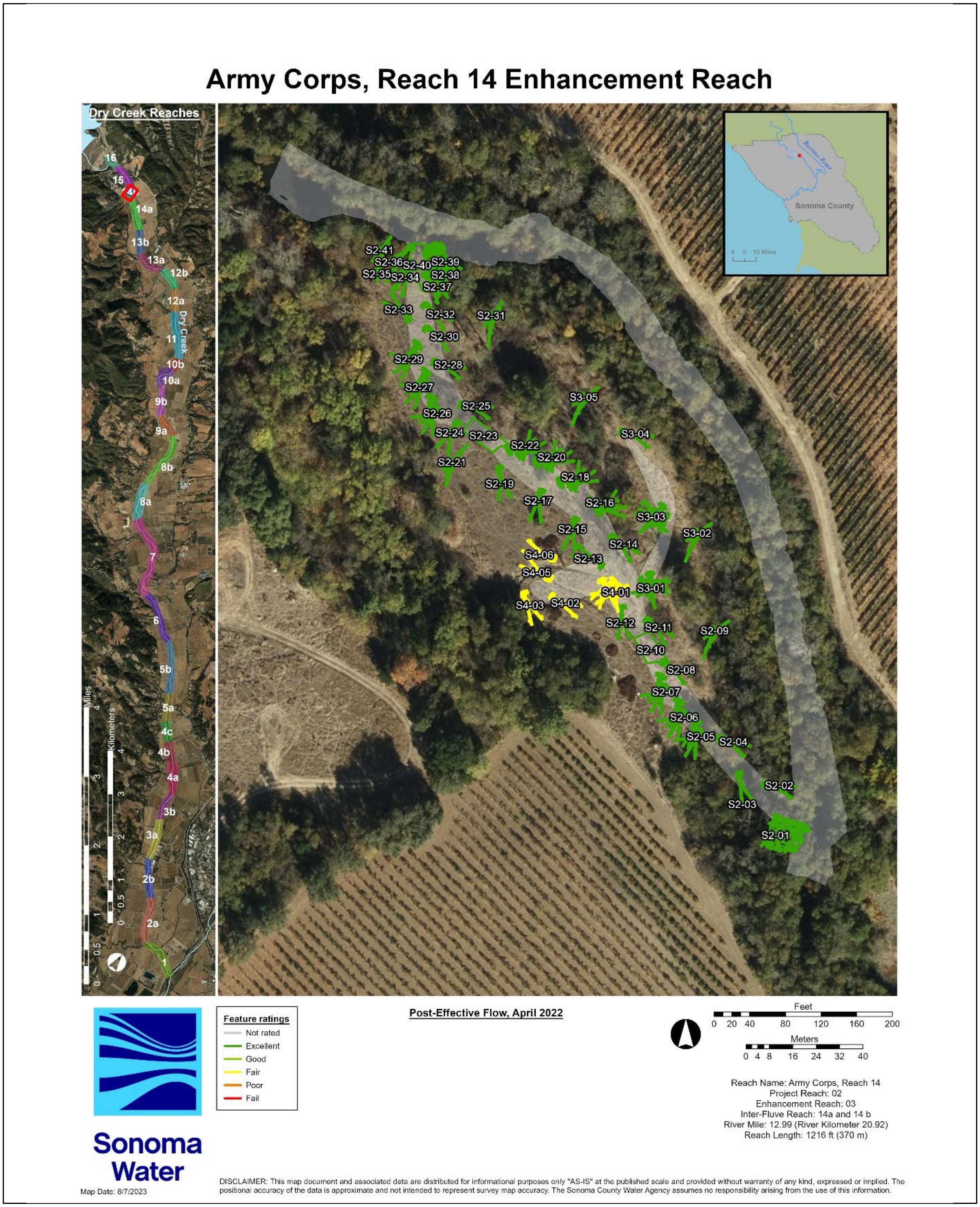

Figure 5.2.37. Feature ratings for the Army Corps Reach 14 enhancement reach, April 2022.

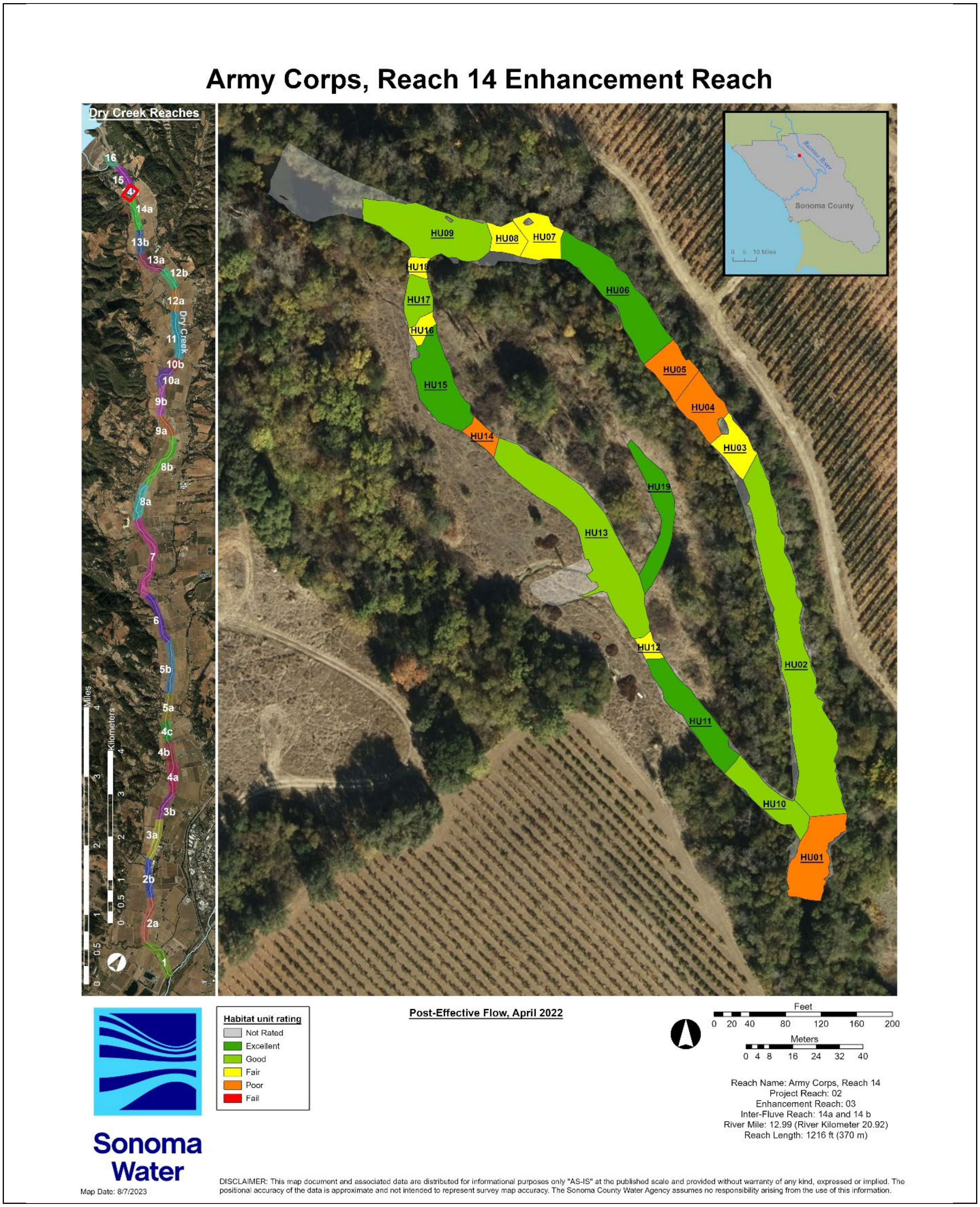

Figure 5.2.38. Habitat unit ratings for the Army Corps Reach 14 enhancement reach, April 2022.

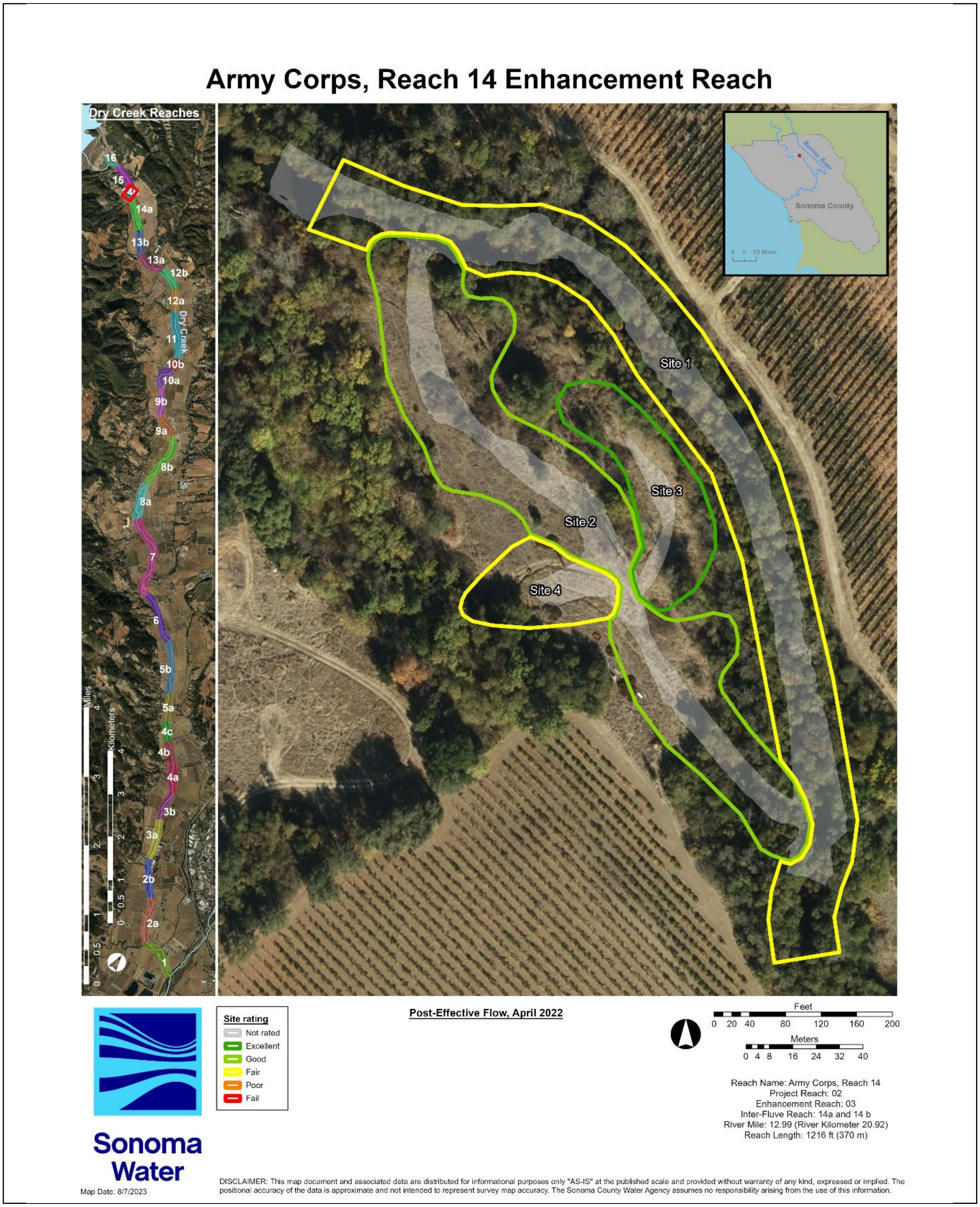

Figure 5.2.39. Post-enhancement site ratings for the Army Corps Reach 14 enhancement reach, April 2022.

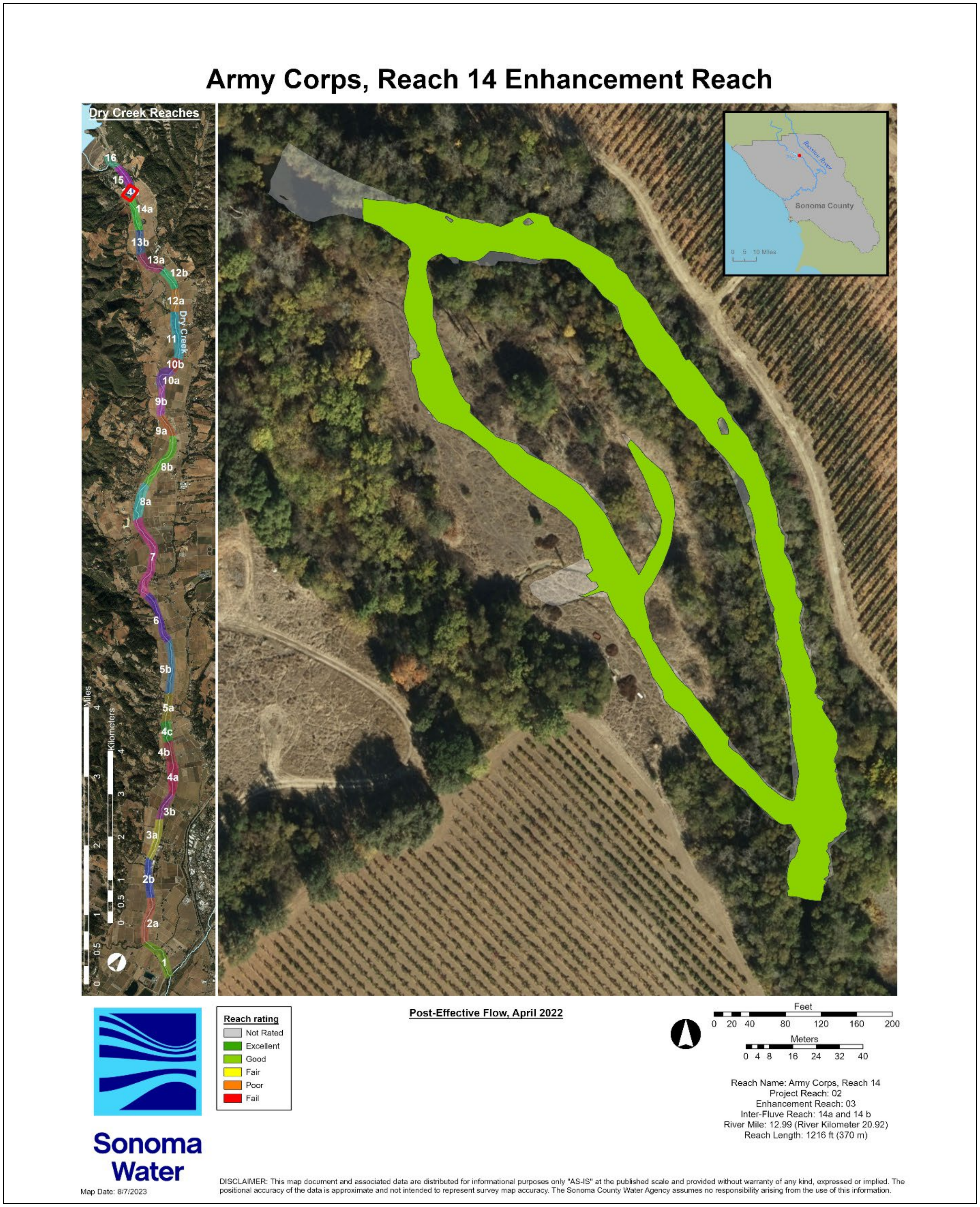

Figure 5.2.40. Post-enhancement reach rating for the Army Corps Reach 14 enhancement reach, April 2022.

Truett Hurst Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Truett Hurst enhancement reach in June 2022. 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. Sonoma Water monitored the post-effective flow habitat condition in August 2018, August 2019, and August 2020, April 2021, and spring flow in May 2021 (Table 5.2.33).

Table 5.2.33. Truett Hurst enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2016	Fair	Good			--
2017			Poor	Good	--
2018	--	--	Good	--	--
2019	--	--	Fair	--	--
2020	--	--	Good	--	--
2021	--	--	Good	--	Good
2022			Good		

The 2022 monitored area encompassed 22,352 ft^2 within side channel areas with 55% of the total area meeting optimal depth and velocity criteria (Table 5.2.34, Figure 5.2.41). The monitored area included 21,511 ft^2 of side channel and 840 ft^2 of side channel alcove area, of which 56% and 43%, respectively met optimal depth and velocity criteria, but did not include main channel area as crews were unable to survey the main channel. Twenty three habitat units composed the enhancement reach post-effective flow 2022, with a pool to riffle ratio of 7:8 (0.88) and an average shelter score of 144 (Table 5.2.35, Figure 5.2.42, Figure 5.2.43). Eighteen 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 5.2.36, Figure 5.2.44) that received fair to excellent site average feature ratings (we did not rate enhancement site 1 [main channel] as crews were unable to survey), and poor to good site average habitat unit ratings (Table 5.2.36, Figure 5.2.45, Figure 5.2.46). Enhancement site ratings ranged from fair to good, with the main channel site (site 1) receiving no rating, the two alcove sites receiving excellent and poor ratings, and the side channel and bank sites receiving excellent ratings (Table 5.2.36, Figure 5.2.47). Overall, the Truett Hurst enhancement reach received a good effectiveness monitoring rating (Table 5.2.36, Figure 5.2.48; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.34. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, June 2022.

Truett Hurst, Post-effective flow, June 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft, < 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	0	0	0	0	0	0	0	0
Side channel area	21,511	11,496	2,290	13,786	17,460	9,728	2,281	12,009
Side channel alcove area	840	493	0	493	630	361	0	361
Total area	**22,352**	**11,989**	**2,290**	**14,279**	**18,090**	**10,089**	**2,281**	**12,370**
Main channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Side channel % of wetted area	96%	53%	11%	64%	81%	45%	11%	56%
Side channel alcove area % of wetted area	4%	59%	0%	59%	75%	43%	0%	43%
Total % of wetted area	**100%**	**54%**	**10%**	**64%**	**81%**	**45%**	**10%**	**55%**

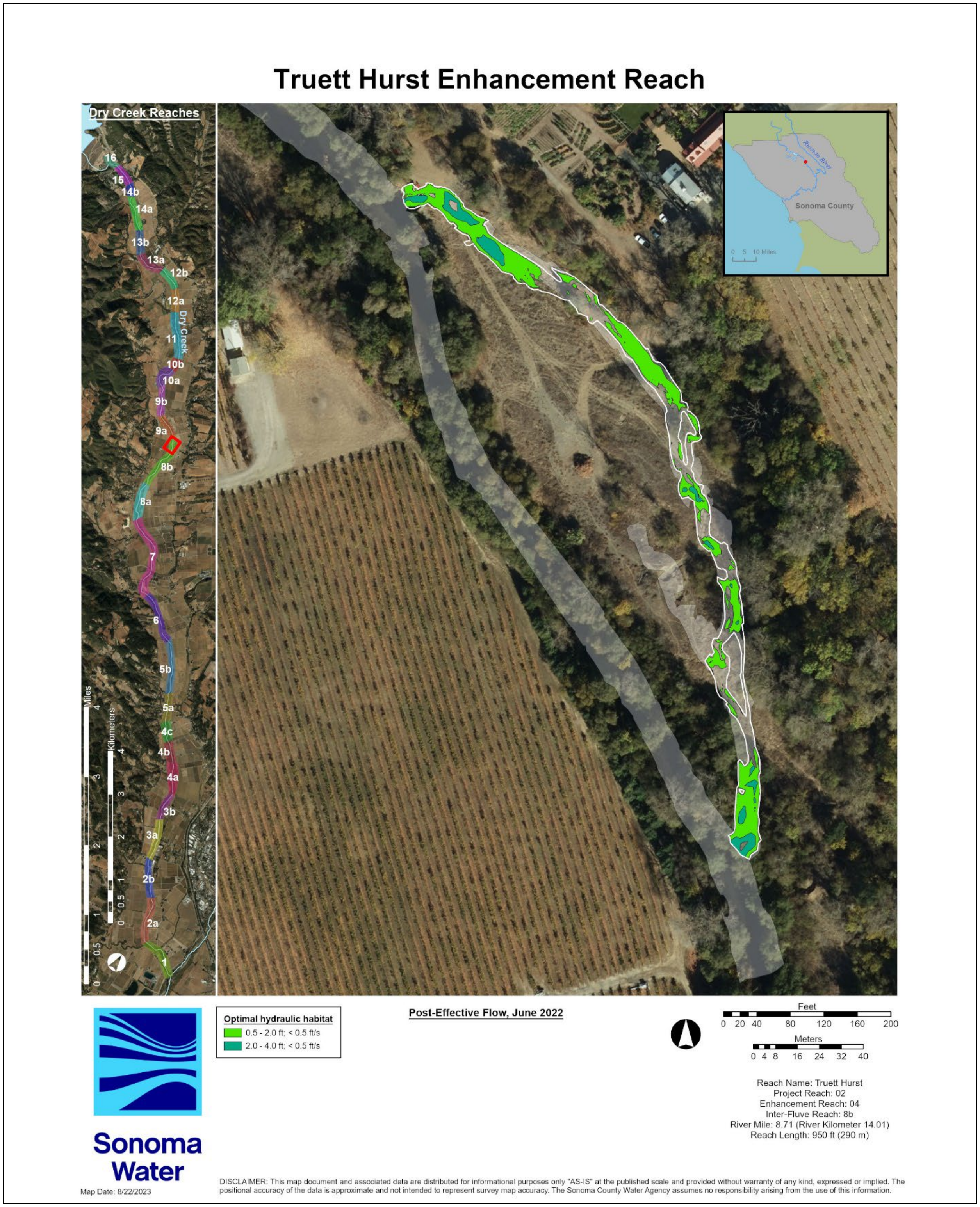

Figure 5.2.41. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, June 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.35. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, June 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	60	180
HU02	Riffle	3	15	45
HU03	Flatwater	3	30	90
HU04	Riffle	3	45	135
HU05	Pool	3	45	135
HU06	Riffle	1	5	5
HU07	Riffle	2	65	130
HU08	Flatwater	2	65	130
HU09	Flatwater	3	40	120
HU10	Riffle	3	50	150
HU11	Pool	3	35	105
HU12	Riffle	1	20	20
HU13	Pool	3	60	180
HU14	Flatwater	2	10	20
HU15	Flatwater	2	50	100
HU16	Riffle	2	70	140
HU17	Flatwater	3	90	270
HU18	Flatwater	3	70	210
HU19	Riffle	3	95	285
HU20	Alcove	3	80	240
HU21	Pool	3	70	210
HU22	Pool	3	75	225
HU23	Pool	3	65	195
Pool: riffle	**7:8 (0.88)**			**Avg = 144**

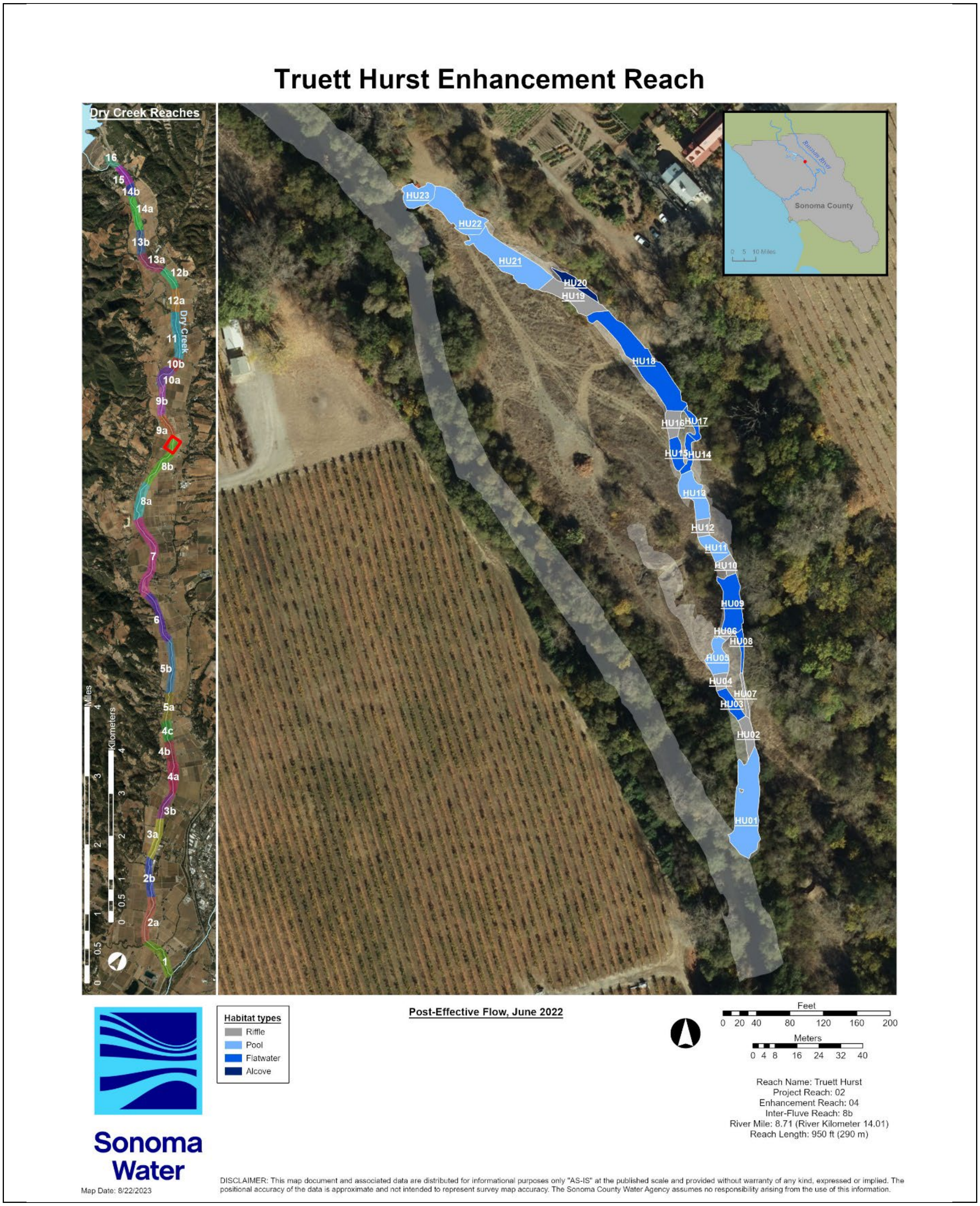

Figure 5.2.42. Habitat unit number and type within the Truett Hurst enhancement reach, June 2022.

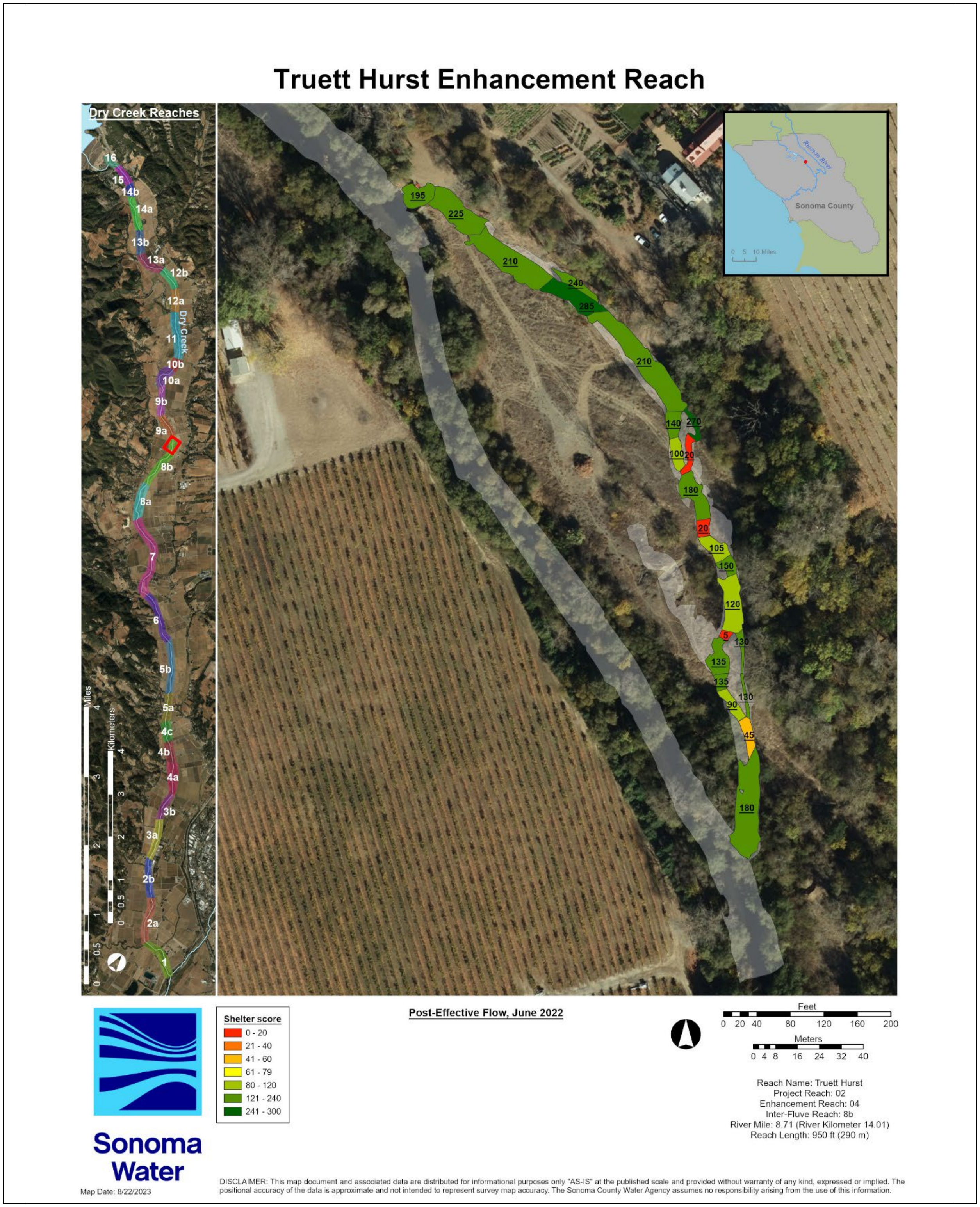

Figure 5.2.43. Habitat unit shelter scores within the Truett Hurst enhancement reach, June 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.36. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Truett Hurst enhancement reach, June 2022.

Site number	1	2	3	4	5
Site type	Main channel	Side channel	Alcove	Alcove	Bank
Site average feature quantitative rating[a]	0	12	6	10	12
Site average feature qualitative rating[a]	Not rated	Excellent	Fair	Good	Excellent
Site average habitat unit quantitative rating[b]	0	21	12	23	24
Site average habitat unit qualitative rating[b]	Not rated	Fair	Poor	Good	Good
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	0	33	18	33	36
Site qualitative rating[c]	Not rated	Good	Poor	Excellent	Excellent
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)

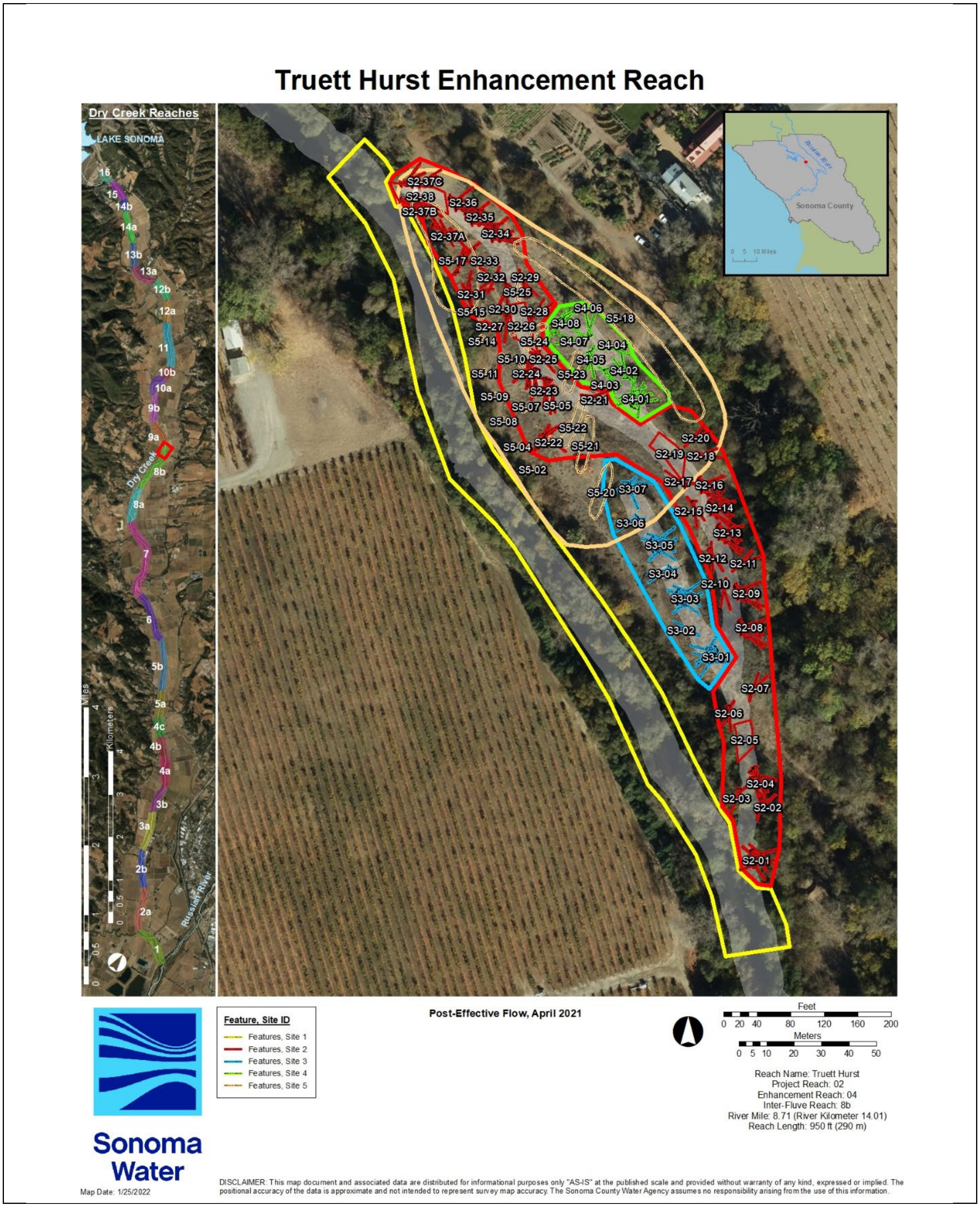

Figure 5.2.44. Enhancement sites and features within the Truett Hurst enhancement reach, June 2022.

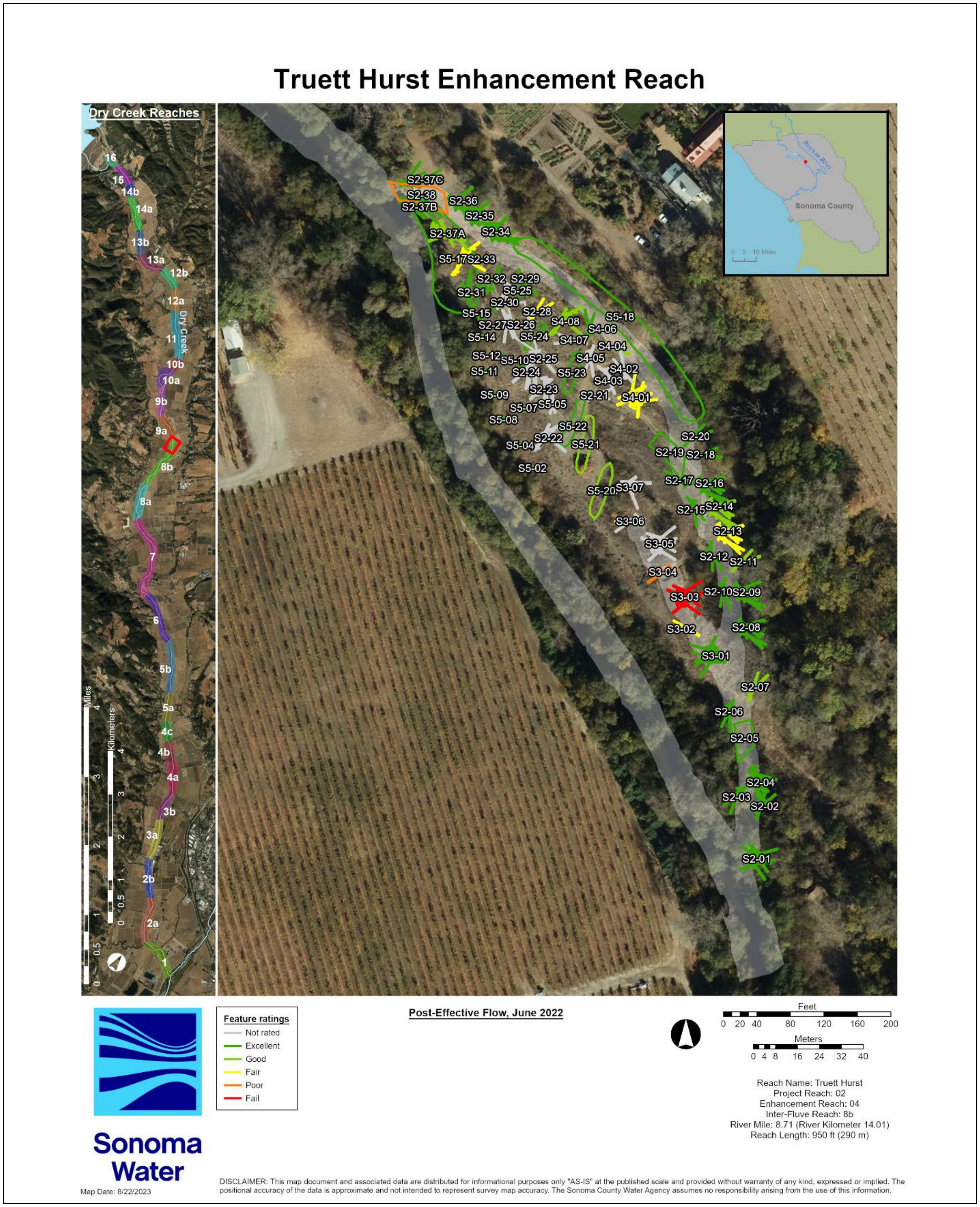

Figure 5.2.45. Feature ratings for the Truett Hurst enhancement reach, June 2022.

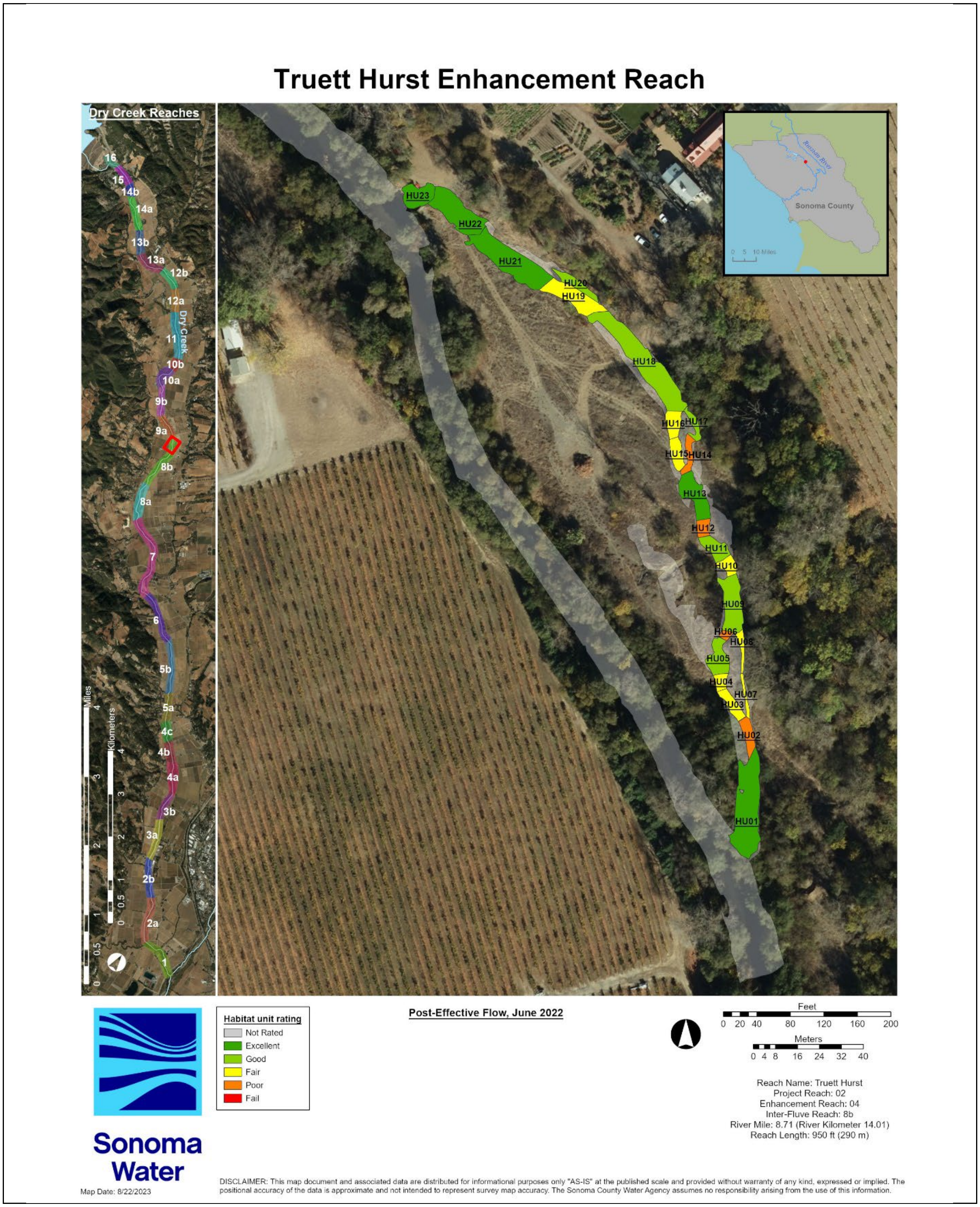

Figure 5.2.46. Habitat unit ratings for the Truett Hurst enhancement reach, June 2022.

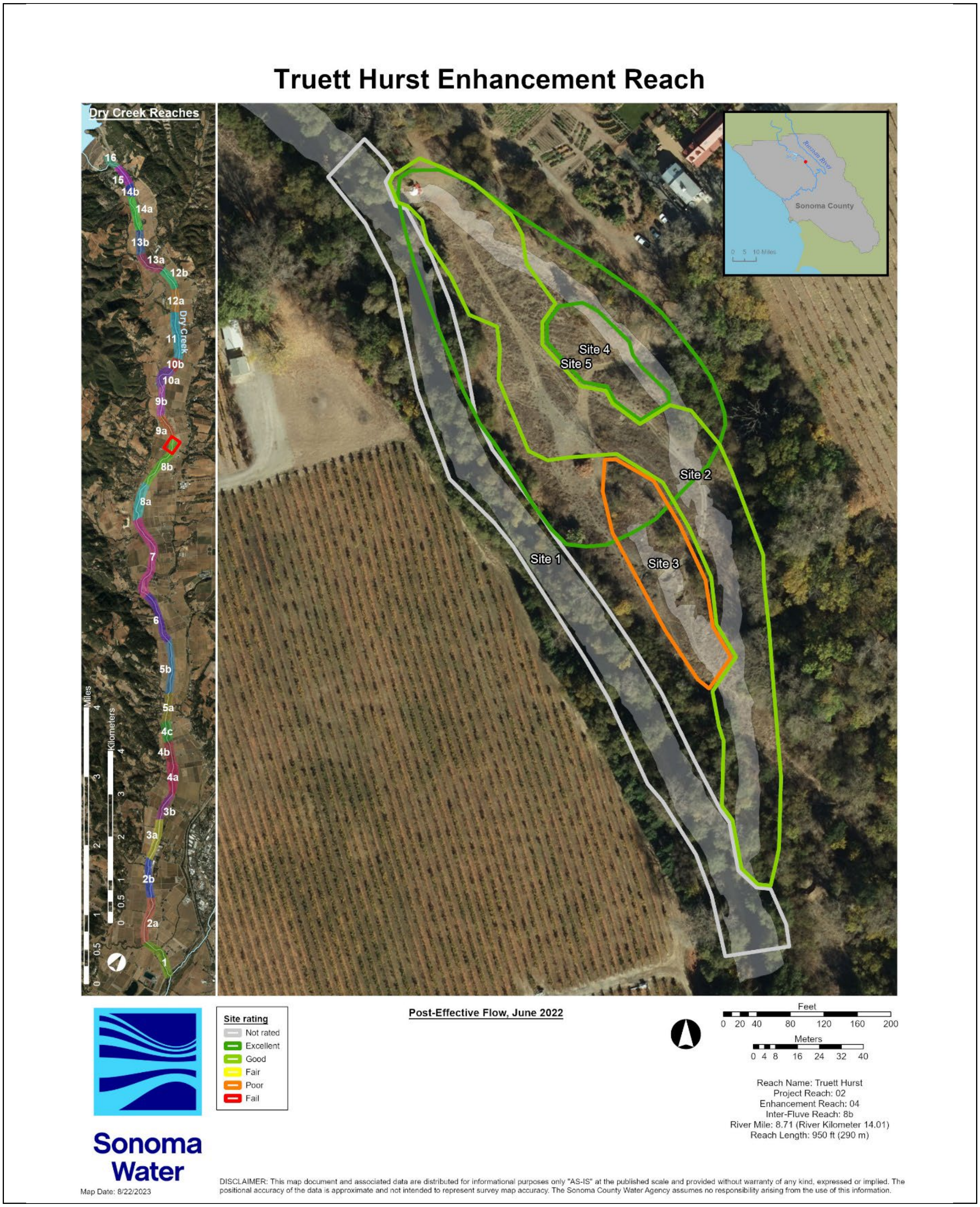

Figure 5.2.47. Post-effective flow site ratings for the Truett Hurst enhancement reach, June 2022.

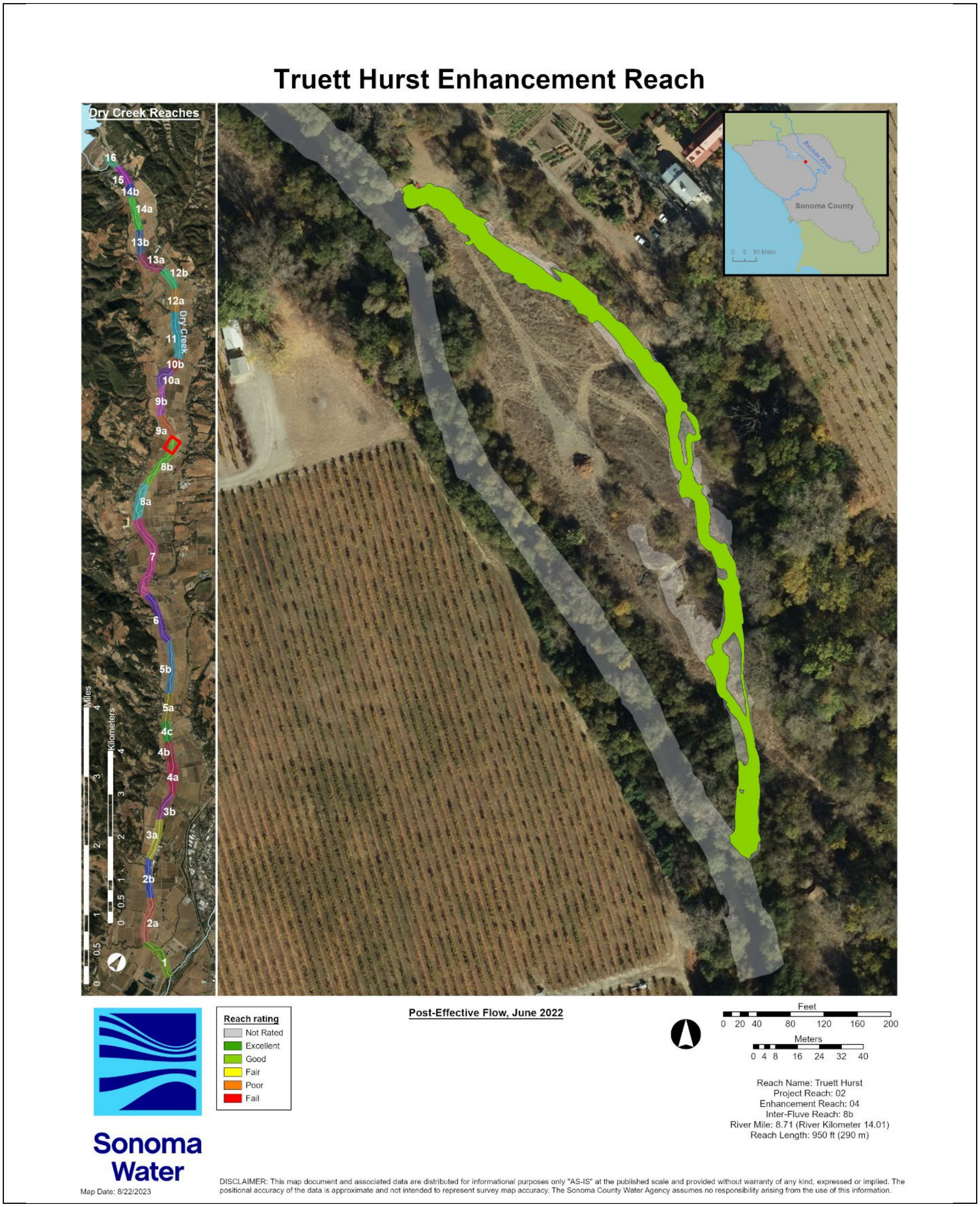

Figure 5.2.48. Post-effective flow reach rating for the Truett Hurst enhancement reach, June 2022.

Farrow Wallace Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Farrow Wallace enhancement reach in October 2022. Previous effectiveness monitoring surveys occurred (all post-effective flow) in August 2015, August 2017, November 2019, July 2020, and June 2021 (Table 5.2.37).

Table 5.2.37. Farrow Wallace enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2015	--	--	Good	--	--
2016	--	--	--	--	--
2017	--	--	Fair	--	--
2018	--	--	--	--	--
2019	--	--	Good	--	--
2020	--	--	Good	--	--
2021	--	--	Good	--	--
2022			Good		

The 2022 monitored area encompassed 78,935 ft^2 within main and side channel areas of Dry Creek with 35% of the total area meeting optimal depth and velocity criteria (Table 5.2.38, Figure 5.2.49). The monitoring characterized 13,536 ft^2 of main channel alcove area and 13,600 ft^2 of side channel area, of which 55% and 72% met optimal depth and velocity criteria, compared with 51,799 ft^2 and 21% for the main channel area. Seventeen habitat units composed the enhancement reach, with a pool to riffle ratio of 5:6 (0.83) and average shelter score of 102 (Table 5.2.39, Figure 5.2.50, Figure 5.2.51). 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 5.2.40, Figure 5.2.52), with good to excellent site average feature ratings (we did not rate enhancement site 2 as it contained no features), and fair to good average habitat unit ratings (we did not rate site 4 as it contained no aquatic habitat; Table 5.2.40, Figure 5.2.53, Figure 5.2.54). Enhancement sites received fair to excellent ratings (Table 5.2.40, Figure 5.2.55). Overall, the Farrow Wallace enhancement reach received a good effectiveness monitoring rating (Table 5.2.40, Figure 5.2.56; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.38. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Farrow Wallace enhancement reach, October 2022.

Farrow Wallace, Post-effective flow, October 2022	Wetted area (ft^2)	0.5 – 2.0 ft (ft^2)	2.0 – 4.0 ft (ft^2)	Total (ft^2)	< 0.5 ft/s (ft^2)	0.5 – 2.0 ft, < 0.5 ft/s (ft^2)	2.0 – 4.0 ft, < 0.5 ft/s (ft^2)	Total (ft^2)
Main channel area	51,799	25,557	16,287	41,844	16,266	5,635	5,065	10,701
Main channel alcove area	13,536	5,042	6,031	11,073	9,602	3,714	3,743	7,457
Side channel area	13,600	5,794	5,102	10,895	12,450	5,196	4,568	9,764
Total area	**78,935**	**36,393**	**27,419**	**63,812**	**38,319**	**14,545**	**13,376**	**27,921**
Main channel % of wetted area	66%	49%	31%	81%	31%	11%	10%	21%
Main channel alcove % of wetted area	17%	37%	45%	82%	71%	27%	28%	55%
Side channel % of wetted area	17%	43%	38%	80%	92%	38%	34%	72%
Total % of wetted area	**100%**	**46%**	**35%**	**81%**	**49%**	**18%**	**17%**	**35%**

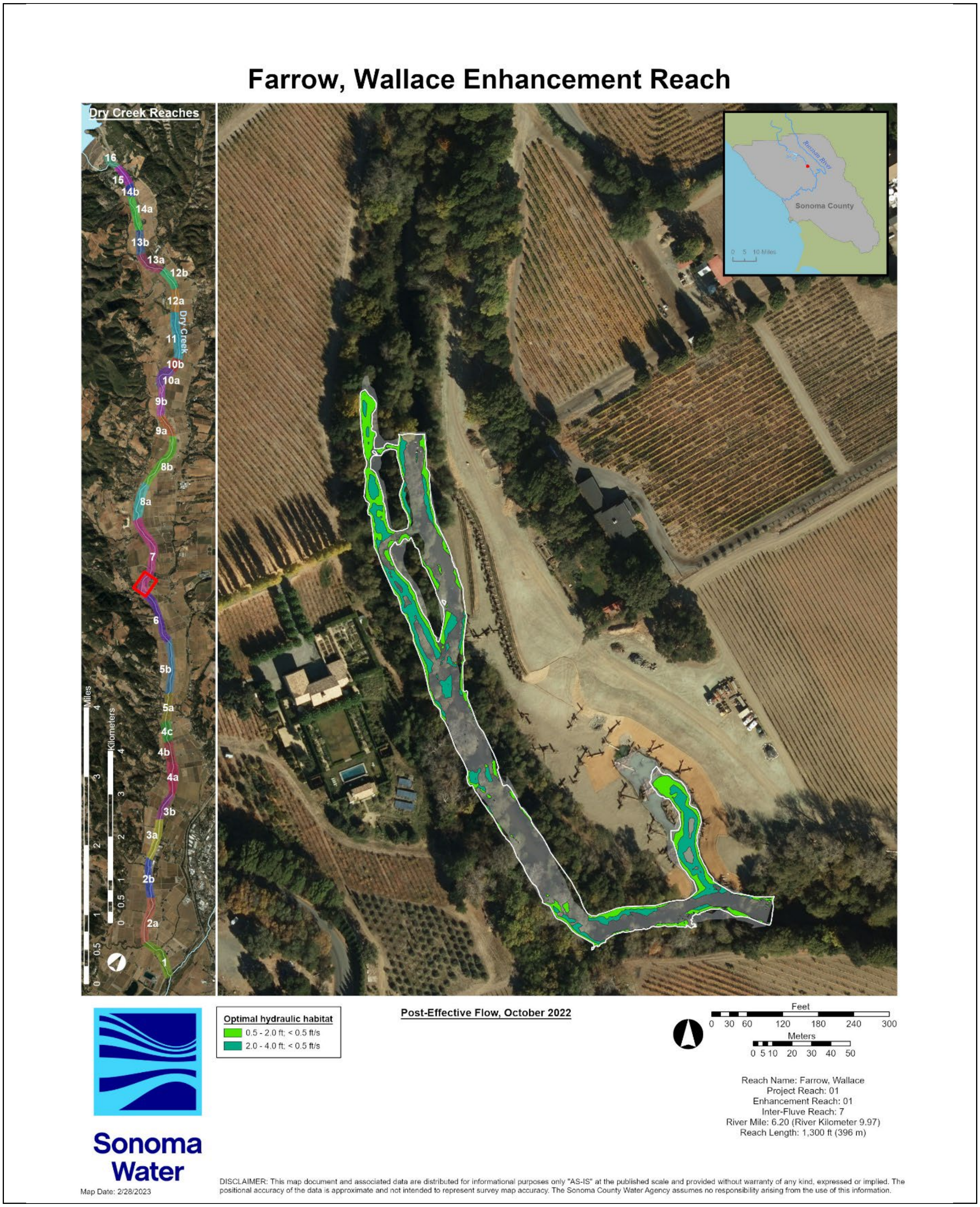

Figure 5.2.49. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Farrow Wallace enhancement reach, October 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.39. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Farrow Wallace enhancement reach, October 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	2	30	60
HU02	Pool	3	50	150
HU03	Alcove	3	90	270
HU04	Riffle	3	40	120
HU05	Pool	3	45	135
HU06	Flatwater	2	30	60
HU07	Riffle	1	5	5
HU08	Flatwater	2	10	20
HU09	Pool	2	15	30
HU10	Riffle	2	45	90
HU11	Pool	3	50	150
HU12	Flatwater	3	60	180
HU13	Alcove	2	90	180
HU14	Riffle	2	15	30
HU15	Pool	2	10	20
HU16	Riffle	3	70	210
HU17	Riffle	2	10	20
Pool: riffle	**5:6 (0.83)**			**Avg = 102**

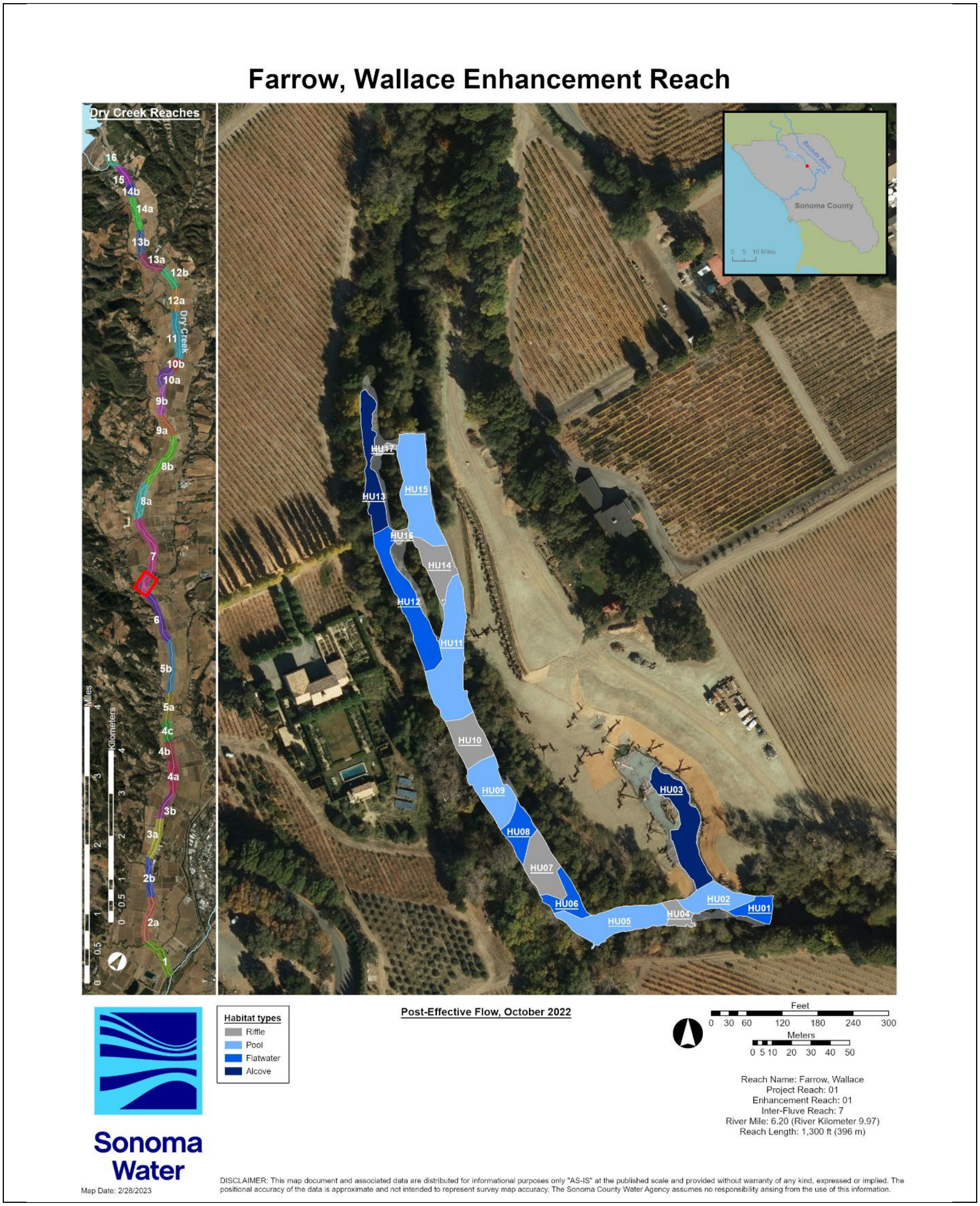

Figure 5.2.50. Habitat unit number and type within the Farrow Wallace enhancement reach, October 2022.

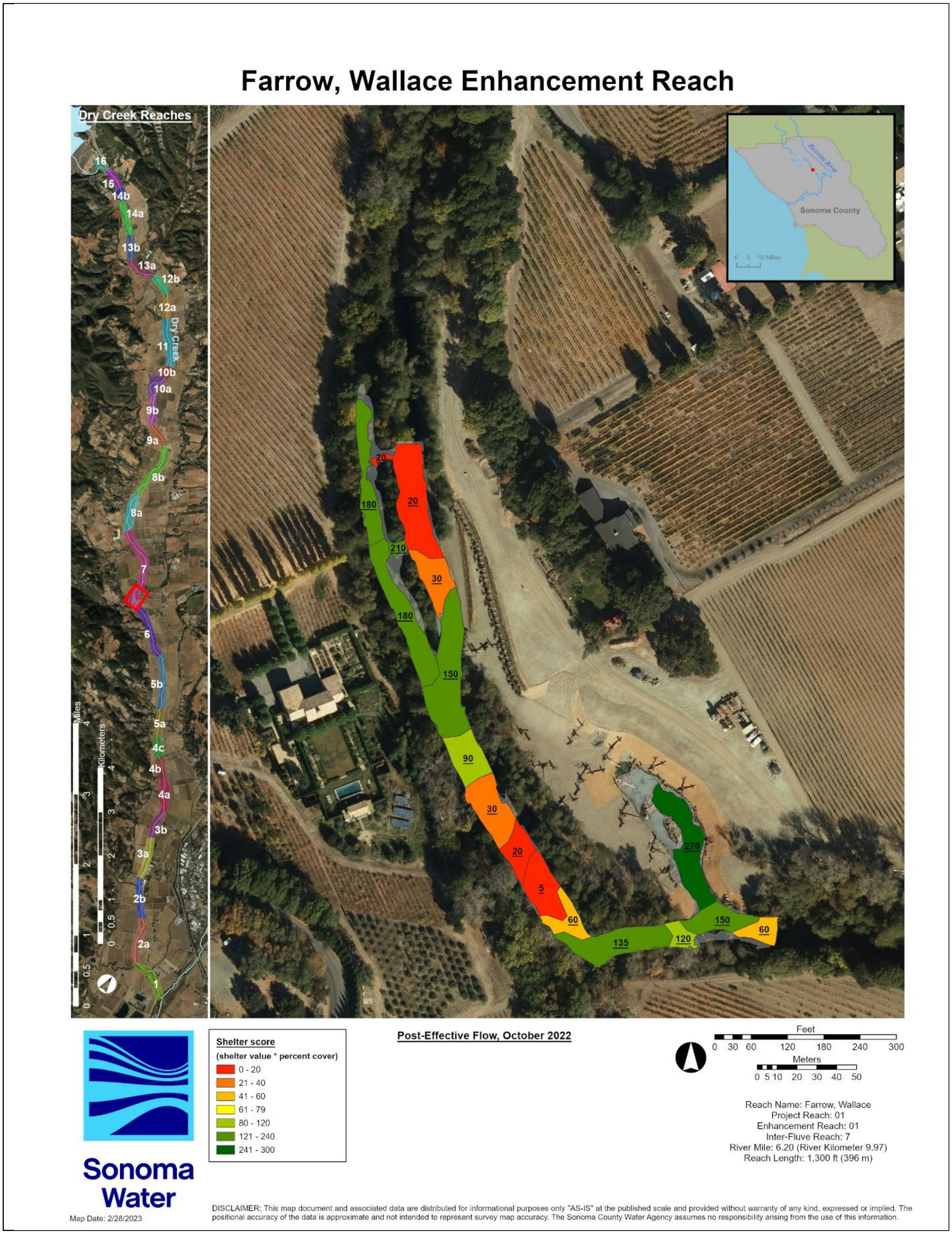

Figure 5.2.51. Habitat unit shelter scores within the Farrow Wallace enhancement reach, October 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.40. Post-effective flow average feature, average habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Farrow Wallace enhancement reach, October 2022.

Site number	1	2	3	4	5	6	7
Site type	Alcove	Main channel	Main channel	Bank	Main channel	Side channel	Main channel
Site average feature quantitative rating[a]	12	0	13	13	13	12	13
Site average feature qualitative rating[a]	Excellent	Not rated	Excellent	Excellent	Excellent	Good	Excellent
Site average habitat unit quantitative rating[b]	25	16	17	0	19	26	14
Site average habitat unit qualitative rating[b]	Good	Fair	Fair	Not rated	Fair	Good	Fair
Site quantitative rating (sum of site average feature and habitat unit rating)	37	16[b]	30	13[a]	32	37	27
Site qualitative rating	Good	Fair[b]	Good	Excellent[a]	Good	Good	Fair
Enhancement reach quantitative rating (average of site rating)[d]	27						
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)

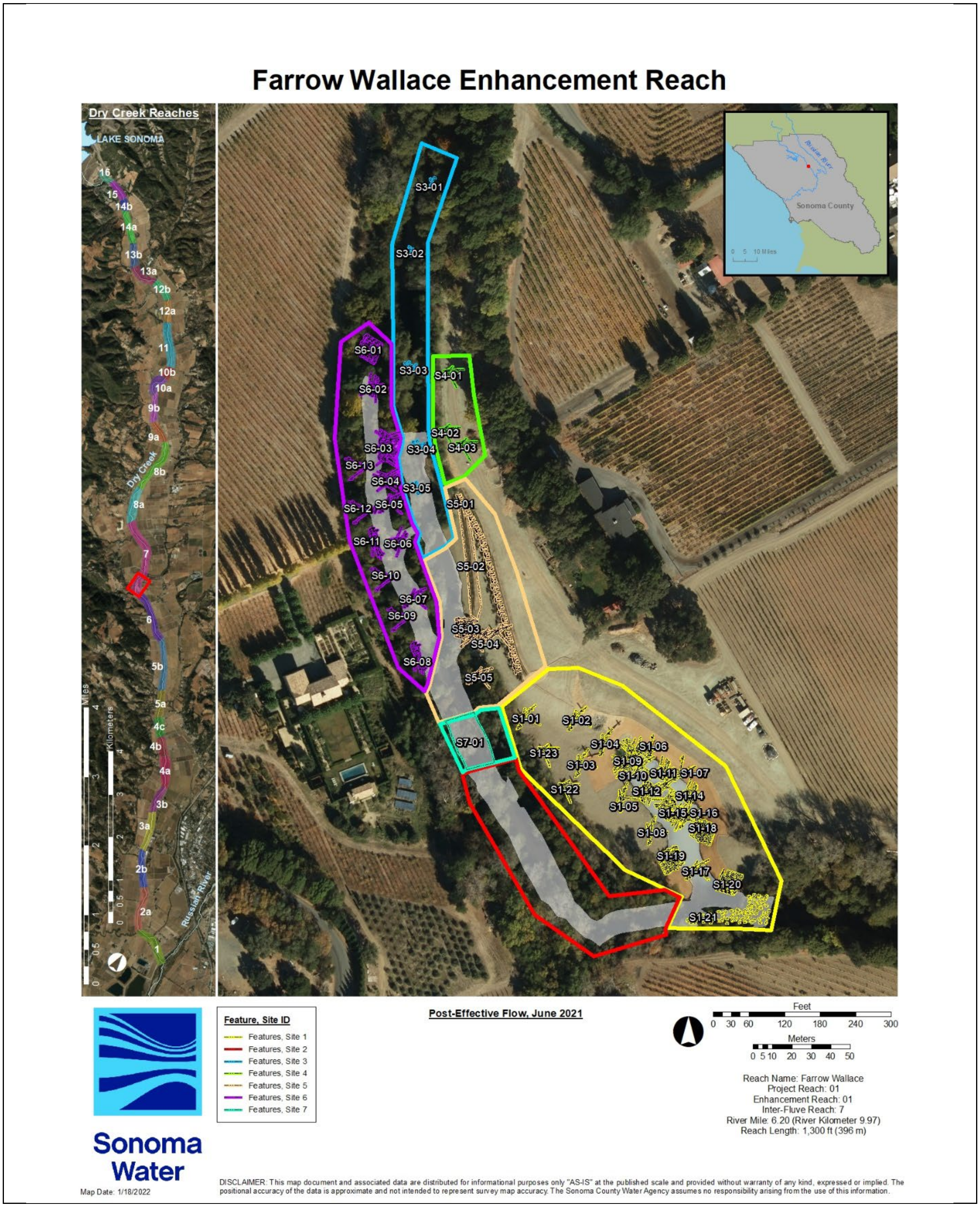

Figure 5.2.52. Enhancement sites and features within the Farrow Wallace enhancement reach, October 2022.

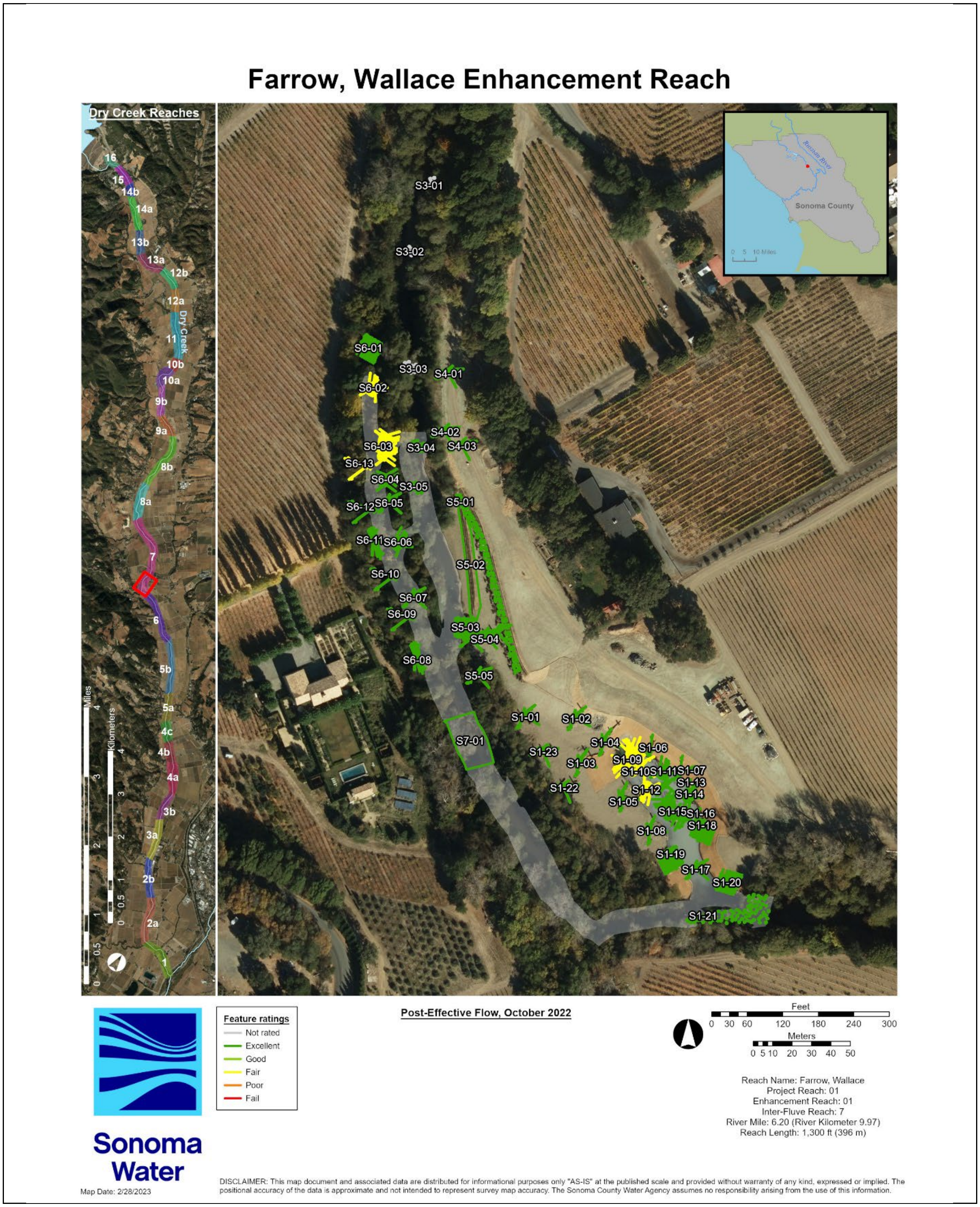

Figure 5.2.53. Feature ratings for the Farrow Wallace enhancement reach, October 2022.

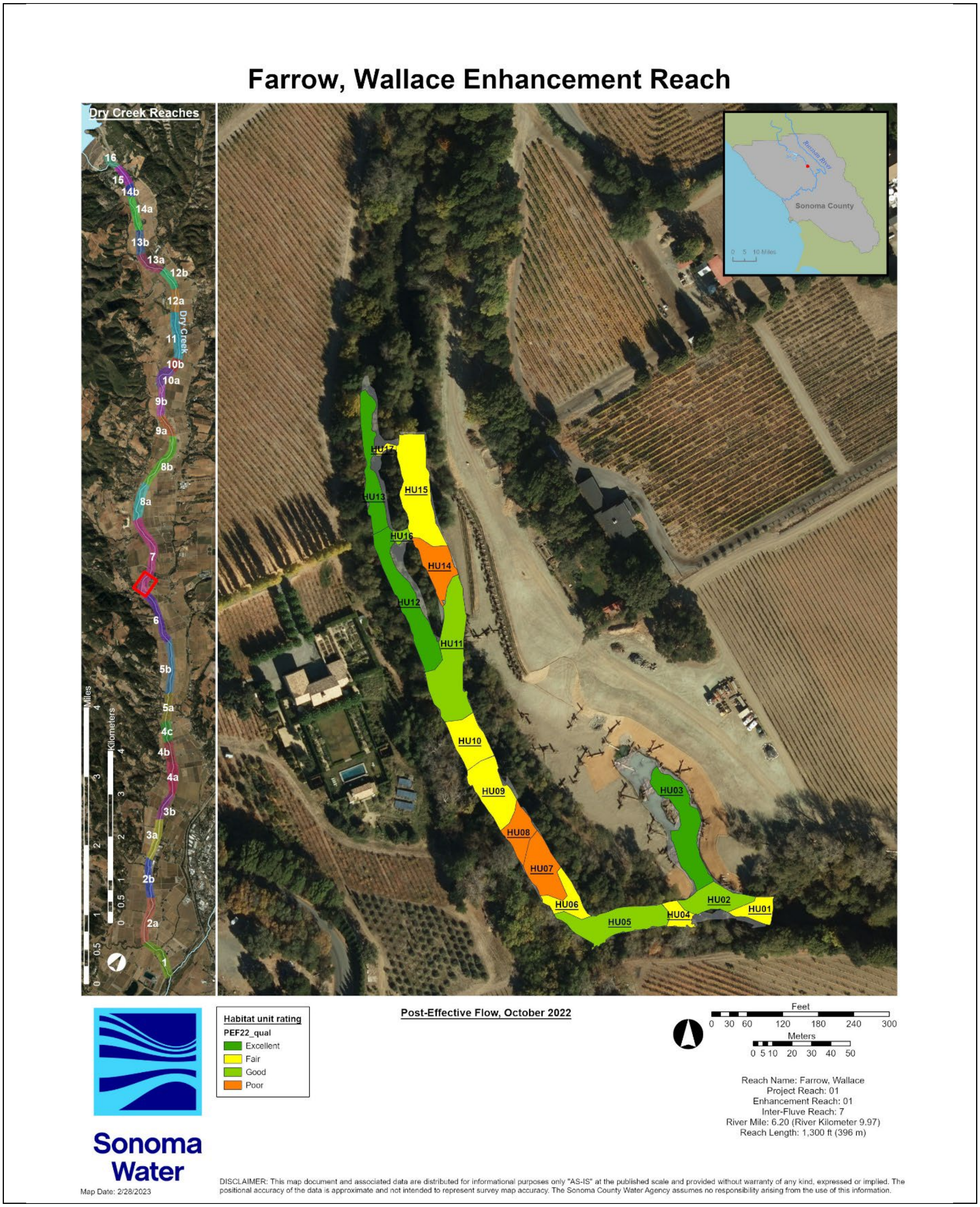

Figure 5.2.54. Habitat unit ratings for the Farrow Wallace enhancement reach, October 2022.

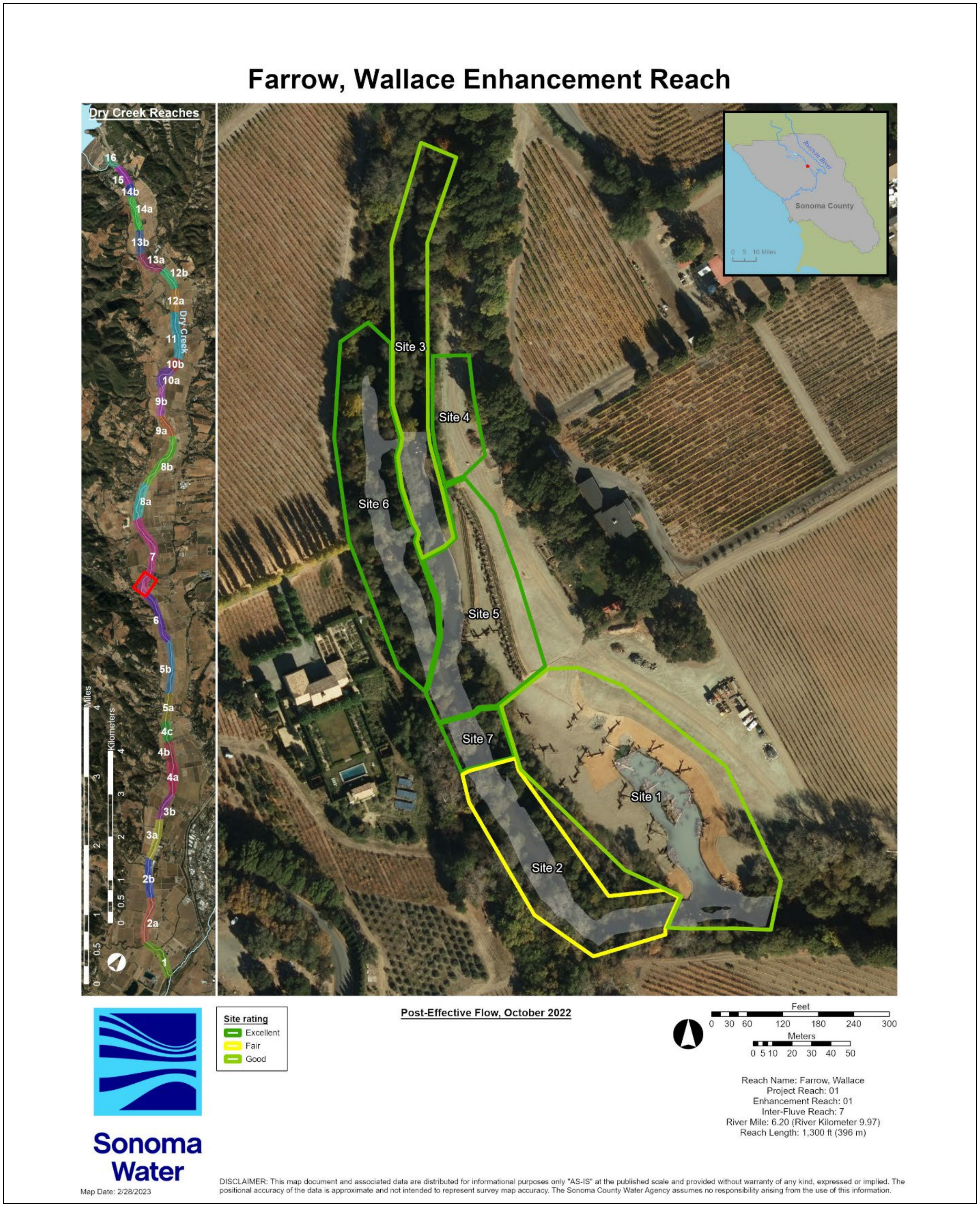

Figure 5.2.55. Post-effective flow site ratings for the Farrow Wallace enhancement reach, October 2022.

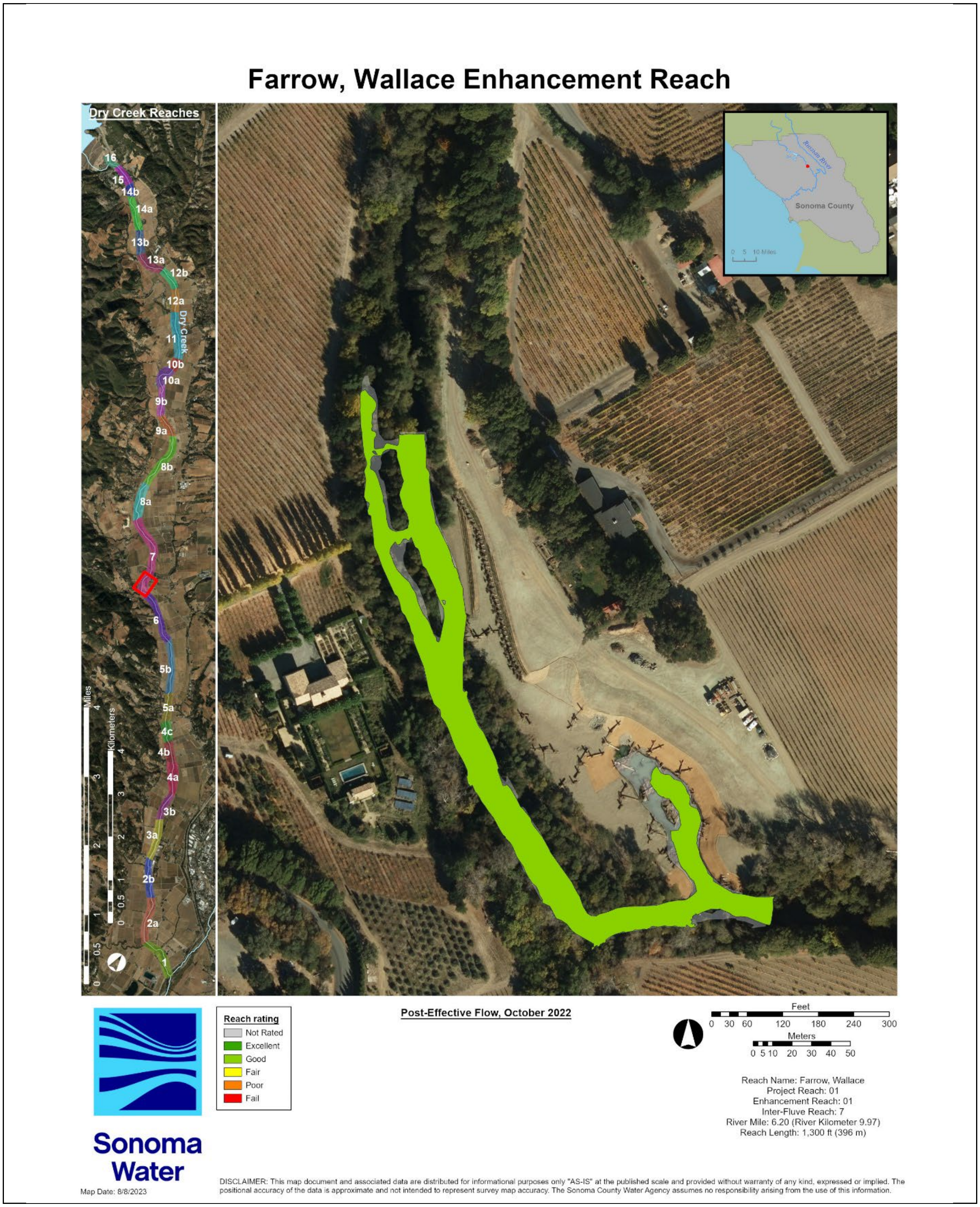

Figure 5.2.56. Post-effective flow reach rating for the Farrow Wallace enhancement reach, October 2022.

Boaz Gros-Balthazard Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Boaz Gros-Balthazard enhancement reach in March 2022. Previous effectiveness monitoring surveys occurred in May 2020 (pre-enhancement) and October 2021 (post-enhancement) (Table 5.2.41).

Table 5.2.41. Boaz Gros-Balthazard enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2020	Fair	--		--	--
2021	--	Good	--	--	--
2022	--	--	Good	--	--

The 2022 monitored area enhanced reach covered 59,506 ft^2 within the main channel and side channel areas of Dry Creek, with 51% meeting optimal depth and velocity criteria (**Table 5.2.**42**,** Figure 5.2.57). The monitoring characterized 35,170 ft^2 of main channel area, 21,631 ft^2 of side channel area, and 2,706 ft^2 of side channel alcove area, of which 36%, 72%, and 89% met optimal depth and velocity criteria, respectively. Eleven habitat units made up the enhancement reach, with a pool to riffle ratio of 3:3 (1.00) and an average shelter score of 125 (Table 5.2.43, Figure 5.2.58, Figure 5.2.59). Nine habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised six enhancement sites (main channel, main channel floodplain, two side channels, side channel alcove, side channel bank floodplain; Table 5.2.44, Figure 5.2.60) that received excellent site average feature ratings, and fair to excellent site average habitat unit ratings (Figure 5.2.61; Figure 5.2.62). Enhancement sites received good to excellent ratings (Figure 5.2.63). Overall, Boaz-Gros Balthazard enhancement reach received a good effectiveness monitoring rating (Table 5.2.44, Figure 5.2.64; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.42. Post-enhancement flow areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Boaz Gros-Balthazard enhancement reach, March 2022.

Boaz, Gros-Balthazard, Post-effective flow, March 2022	**Wetted area (ft^2)**	**0.5 – 2.0 ft (ft^2)**	**2.0 – 4.0 ft (ft^2)**	**Total (ft^2)**	**< 0.5 ft/s (ft^2)**	**0.5 – 2.0 ft, < 0.5 ft/s (ft^2)**	**2.0 – 4.0 ft,< 0.5 ft/s (ft^2)**	**Total (ft^2)**
Main channel area	35,170	20,499	10,285	30,783	15,661	9,148	3,560	12,708
Side channel area	21,631	9,193	9,691	18,884	17,969	6,690	8,798	15,489
Side channel alcove area	2,706	874	1,544	2,418	2,706	874	1,544	2,418
Total area	**59,506**	**30,566**	**21,520**	**52,086**	**36,336**	**16,712**	**13,903**	**30,615**
Main channel % of wetted area	59%	58%	29%	88%	45%	26%	10%	36%
Side channel % of wetted area	36%	43%	45%	87%	83%	31%	41%	72%
Side channel alcove area % of wetted area	5%	32%	57%	89%	100%	32%	57%	89%
Total % of wetted area	**100%**	**51%**	**36%**	**88%**	**61%**	**28%**	**23%**	**51%**

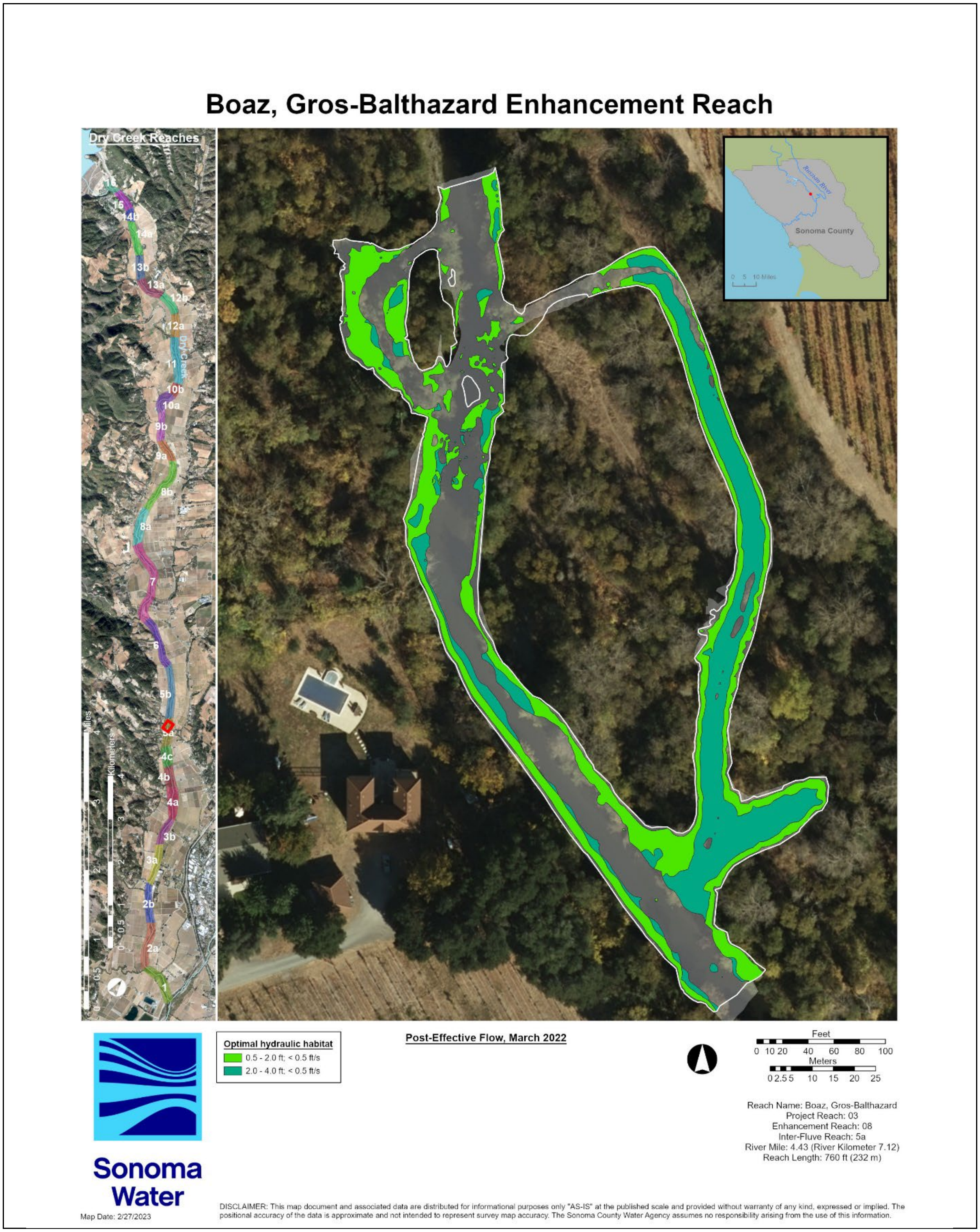

Figure 5.2.57. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Boaz Gros-Balthazard enhancement reach, March 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.43. Habitat, types, shelter score, percent cover, and shelter value for main channel habitat units within the Boaz Gros-Balthazard enhancement reach, March 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	60	180
HU02	Flatwater	3	45	135
HU03	Riffle	3	50	150
HU04	Pool	3	30	90
HU05	Flatwater	3	40	120
HU06	Flatwater	3	45	135
HU07	Alcove	3	50	150
HU08	Riffle	2	20	40
HU09	Pool	3	45	135
HU10	Riffle	1	5	5
HU11	Alcove	3	80	240
Pool: riffle	**3:3 (1.00)**			**Avg = 125**

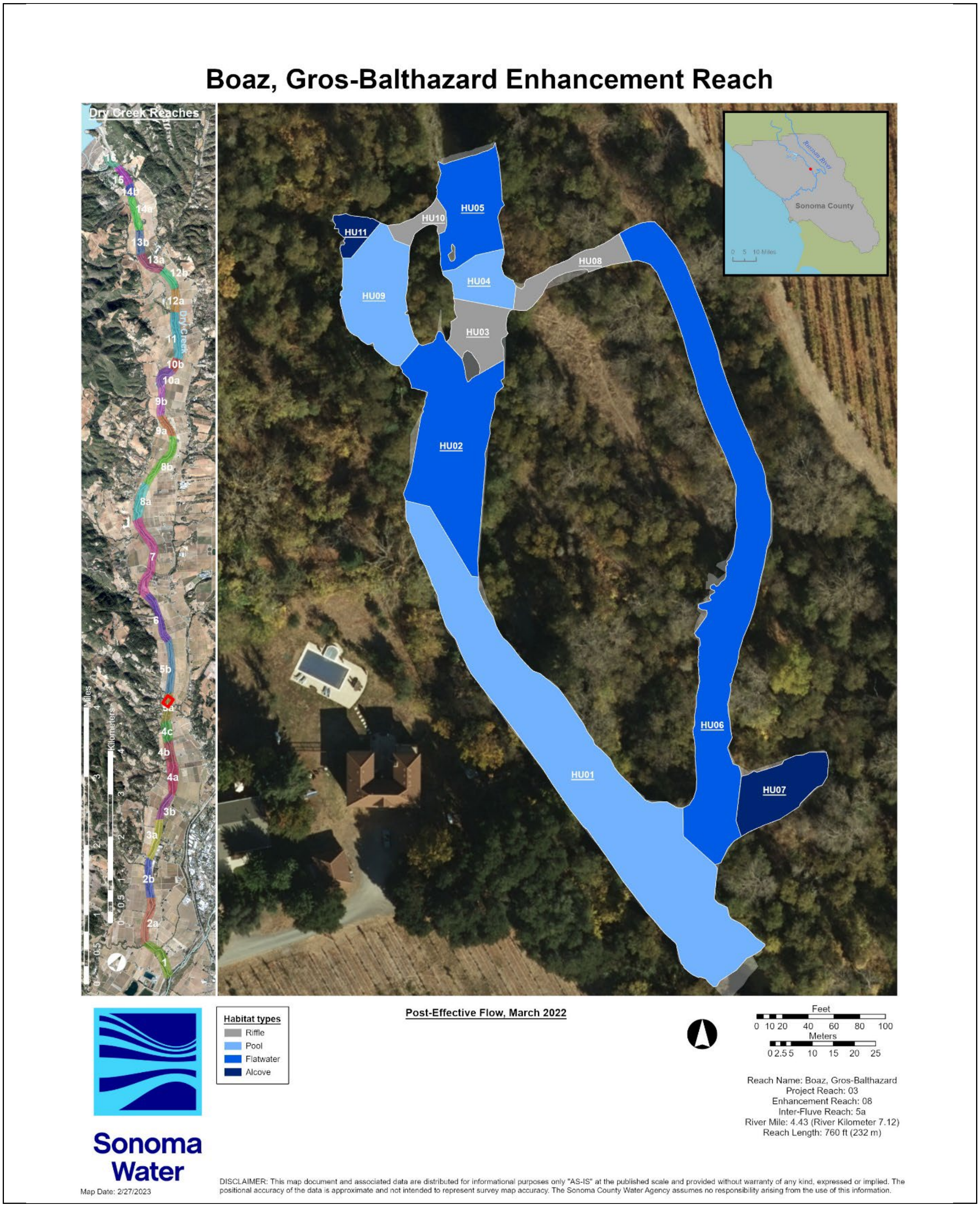

Figure 5.2.58. Habitat unit number and type within the Boaz Gros-Balthazard enhancement reach, March 2022.

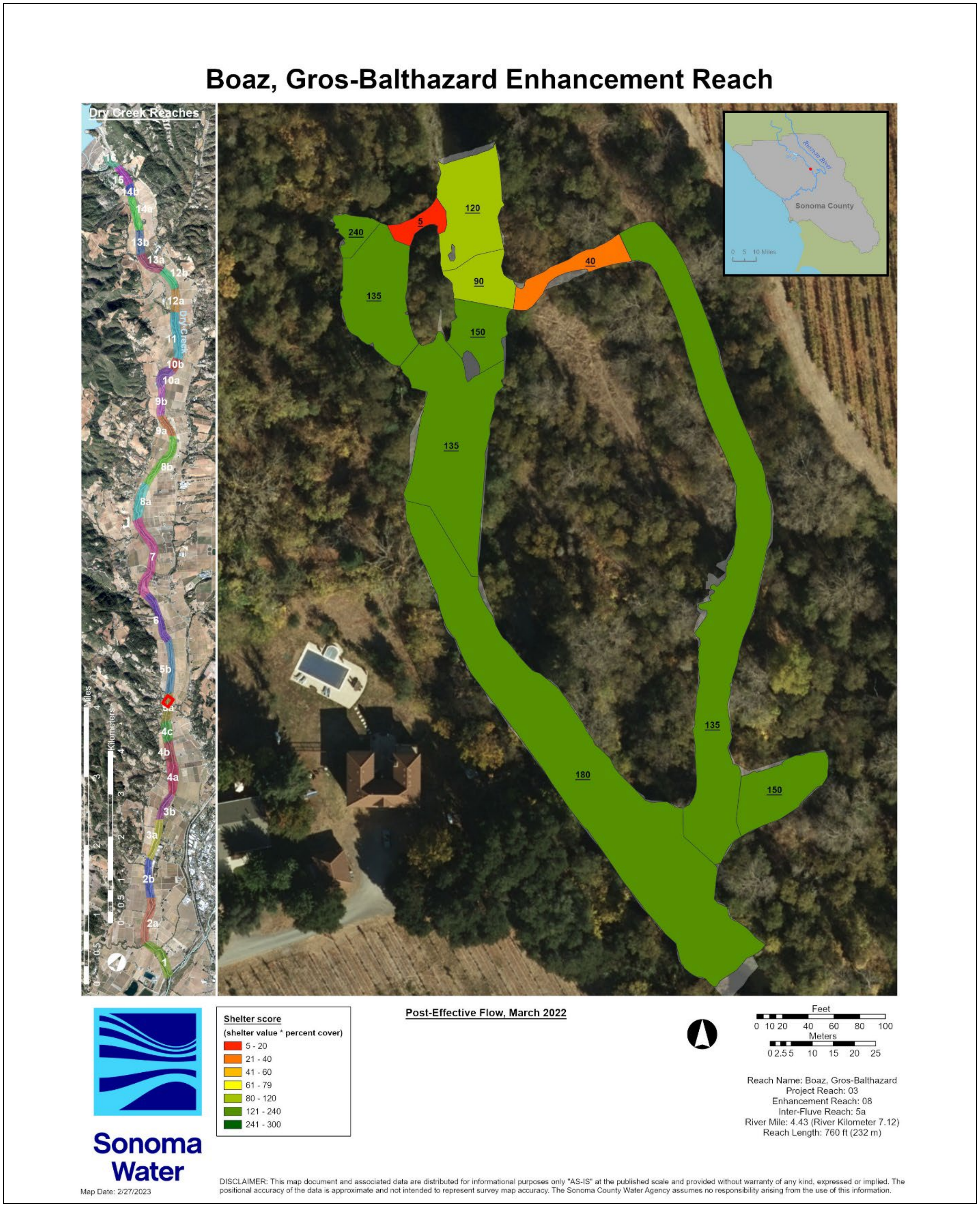

Figure 5.2.59. Habitat unit shelter values within the Boaz Gros-Balthazard enhancement reach, March 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.44. Post-enhancement average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the for the Boaz Gros-Balthazard enhancement reach, March 2022.

Site number	1	2	3	4	5	6
Site type	Main channel	Main channel floodplain	Side Channel	Side channel alcove	Side channel bank floodplain	Side channel
Site average feature quantitative rating[a]	14	14	13	12	12	13
Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Site average habitat unit quantitative rating[b]	18	29	18	31	28	21
Site average qualitative rating[b]	Fair	Excellent	Fair	Excellent	Excellent	Good
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	32	43	31	44	40	34
Site qualitative rating[c]	Good	Excellent	Good	Excellent	Excellent	Good
Enhancement reach quantitative rating (average of site rating)[c]	37					
Enhancement reach qualitative rating[c]:	Good					

[a]out of 35; Excellent (>=28), Good (>=21), Fair (>=14), Poor (>=7), Fail (<7)
[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)

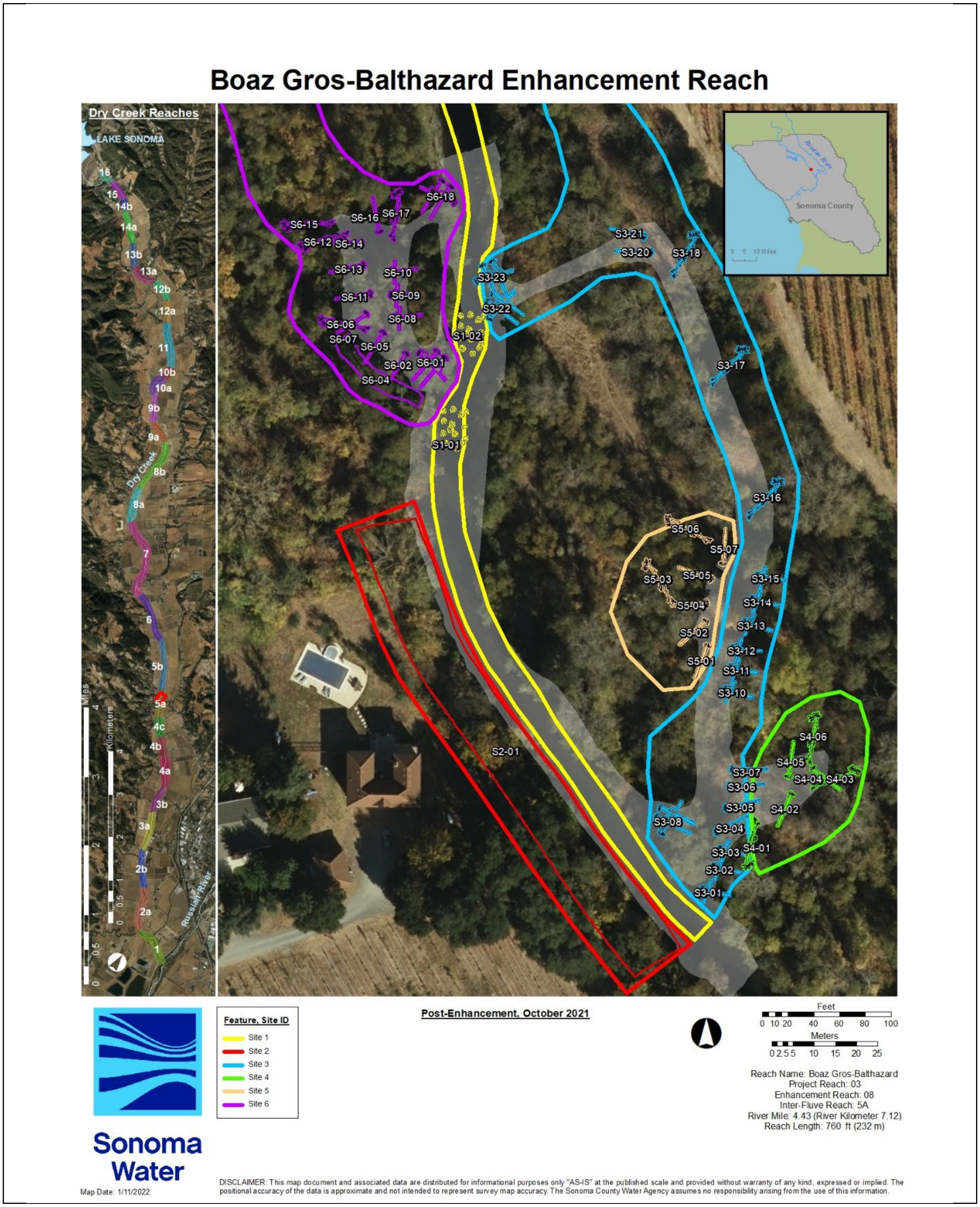

Figure 5.2.60. Enhancement sites and features within the Boaz Gros-Balthazard enhancement reach, March 2022.

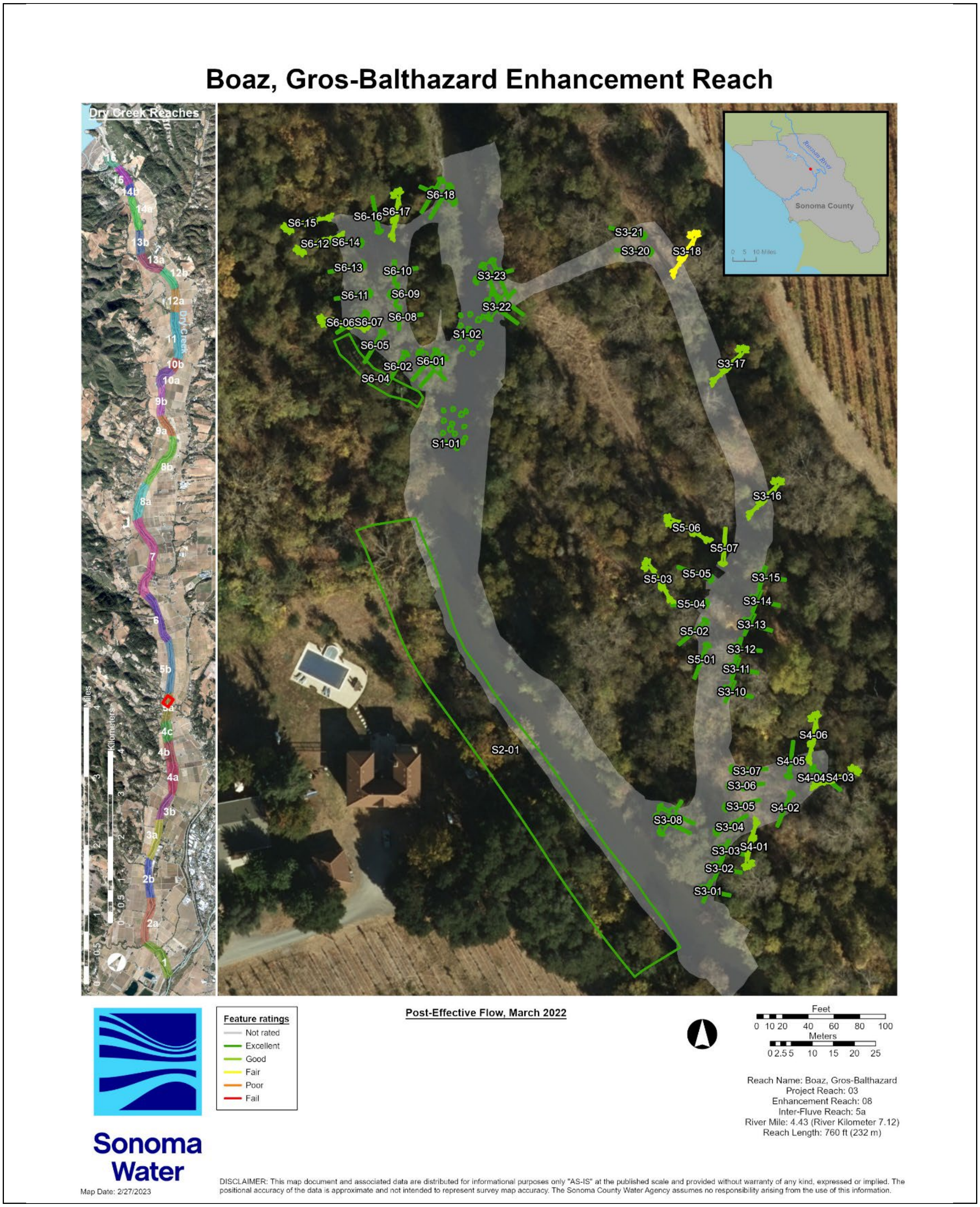

Figure 5.2.61. Feature ratings for the Boaz Gros-Balthazard enhancement reach, March 2022.

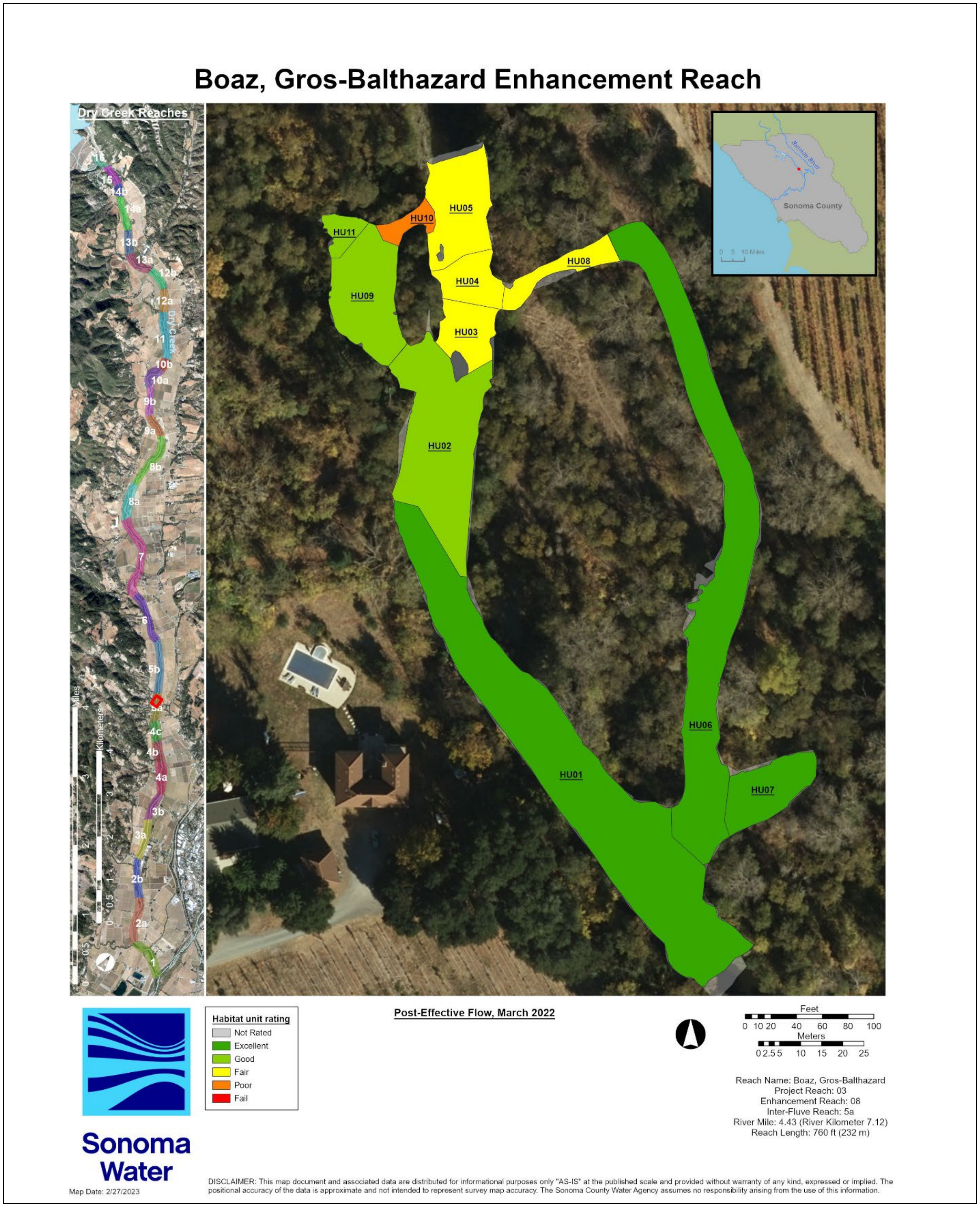

Figure 5.2.62. Habitat unit ratings for the Boaz Gros-Balthazard enhancement reach, March 2022.

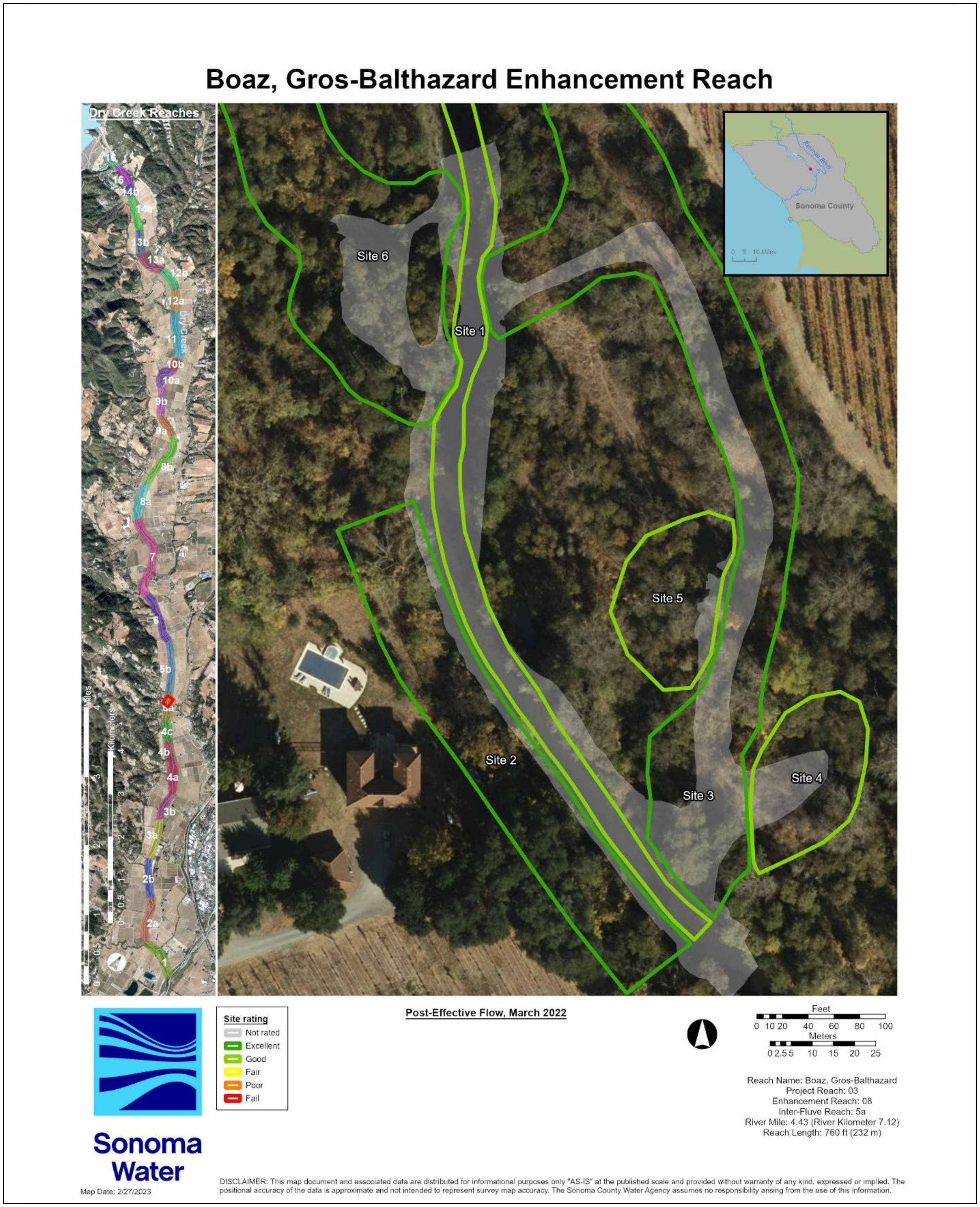

Figure 5.2.63. Post-enhancement site ratings for the Boaz Gros-Balthazard enhancement reach, March 2022.

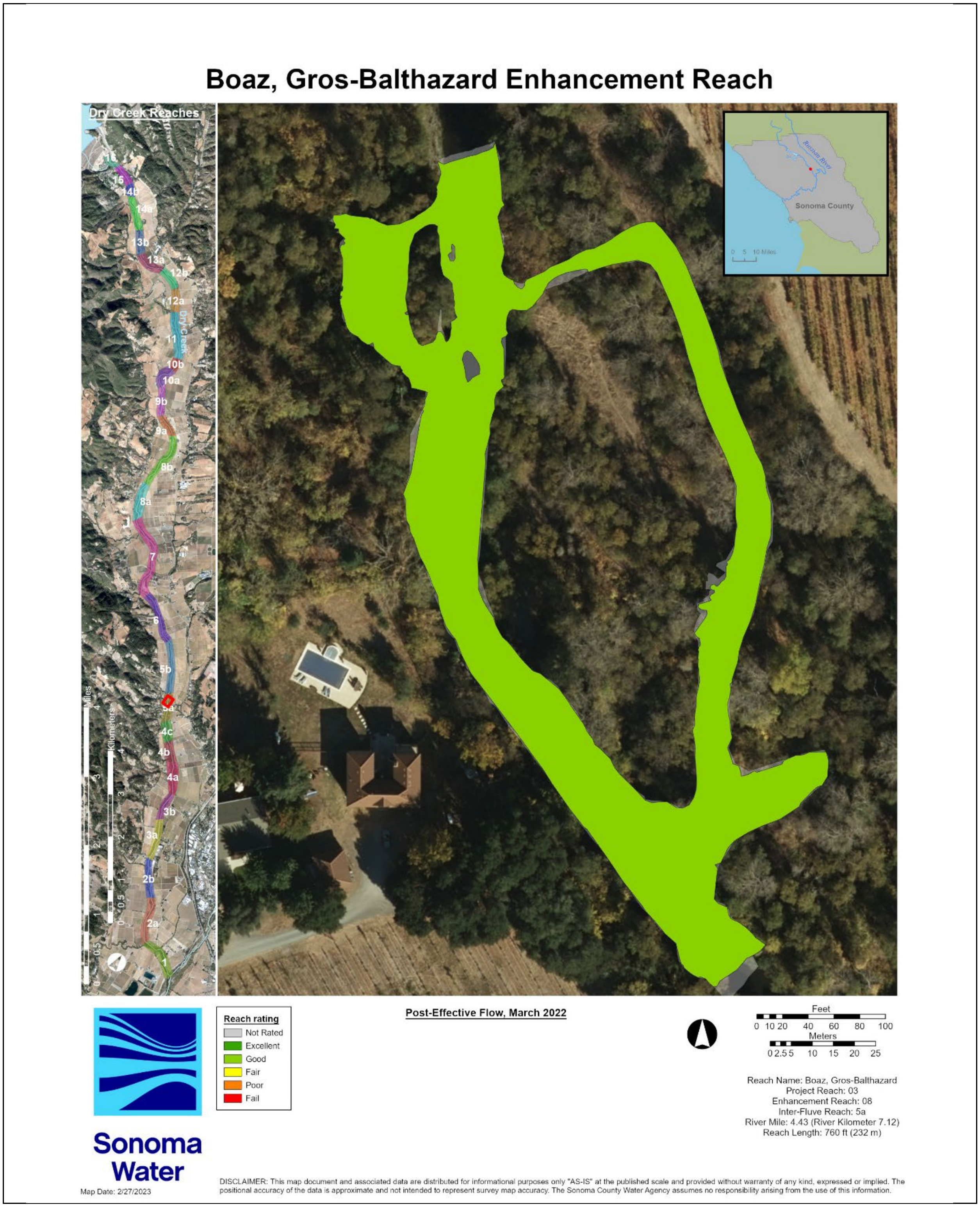

Figure 5.2.64. Post-enhancement reach rating for the Boaz Gros-Balthazard enhancement reach, March 2022.

Ferrari-Carano Olson Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Ferrari-Carano Olson enhancement reach in August 2022. Previous effectiveness monitoring surveys occurred in May 2018 (pre-enhancement), October 2018 (post-enhancement), June 2019 (post-effective flow), June 2020 (post-effective flow), and October 2020 (post-repair) (Table 5.2.45).

Table 5.2.45. Ferrari-Carano, Olson enhancement reach effectiveness monitoring surveys and ratings (-- indicates monitoring not conducted).

Year	Pre-enhancement	Post-enhancement	Post-effective flow	Post-repair	Spring flow
2018	Fair	Good	--	--	--
2019	--	--	Fair	--	--
2020	--	--	Fair	Good	--
2021	--	--	--	--	--
2022	--	--	Good		--

The post-effective flow 2022 enhancement reach encompassed 98,290 ft^2 within main and off channel areas with 26% of the total area meeting optimum depth and velocity criteria (Table 5.2.46, Figure 5.2.65). Monitoring recorded 71,329 ft^2 of main channel area and 26,961 ft^2 of side channel area, of which 21% and 40% met optimal depth and velocity criteria. Thirty eight habitat units made up the enhancement reach, with a pool to riffle ratio of 16:6 (2.67) and an average shelter score of 123 (Table 5.2.47, Figure 5.2.66, Figure 5.2.67). Twenty six habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel and two side channel sites) that received good to excellent site average feature ratings, and fair to good site average habitat unit ratings (Table 5.2.48, Figure 5.2.68, Figure 5.2.69,Figure 5.2.70). Enhancement site ratings ranged from fair to good (Table 5.2.48, Figure 5.2.71). Overall, the Ferrari-Carano, Olson enhancement reach received a good enhancement reach rating in August 2022 (Table 5.2.48, Figure 5.2.72; see Appendix 5.2 for all measured values, scores, and ratings).

Depth and velocity

Table 5.2.46. Areas and percentages of wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, August 2022.

Ferrari-Carrano, Olson, Post-effective flow, August 2022	**Wetted area (ft²)**	**0.5 – 2.0 ft (ft²)**	**2.0 – 4.0 ft (ft²)**	**Total (ft²)**	**< 0.5 ft/s (ft²)**	**0.5 – 2.0 ft, < 0.5 ft/s (ft²)**	**2.0 – 4.0 ft, < 0.5 ft/s (ft²)**	**Total (ft²)**
Main channel area	71,329	37,624	23,241	60,864	22,485	9,105	6,183	15,288
Side channel area	26,961	14,070	4,334	18,404	16,915	7,582	3,123	10,705
Total area	**98,290**	**51,693**	**27,575**	**79,268**	**39,399**	**16,687**	**9,306**	**25,993**
Main channel % of wetted area	73%	53%	33%	85%	32%	13%	9%	21%
Side channel % of wetted area	27%	52%	16%	68%	63%	28%	12%	40%
Total % of wetted area	**100%**	**53%**	**28%**	**81%**	**40%**	**17%**	**9%**	**26%**

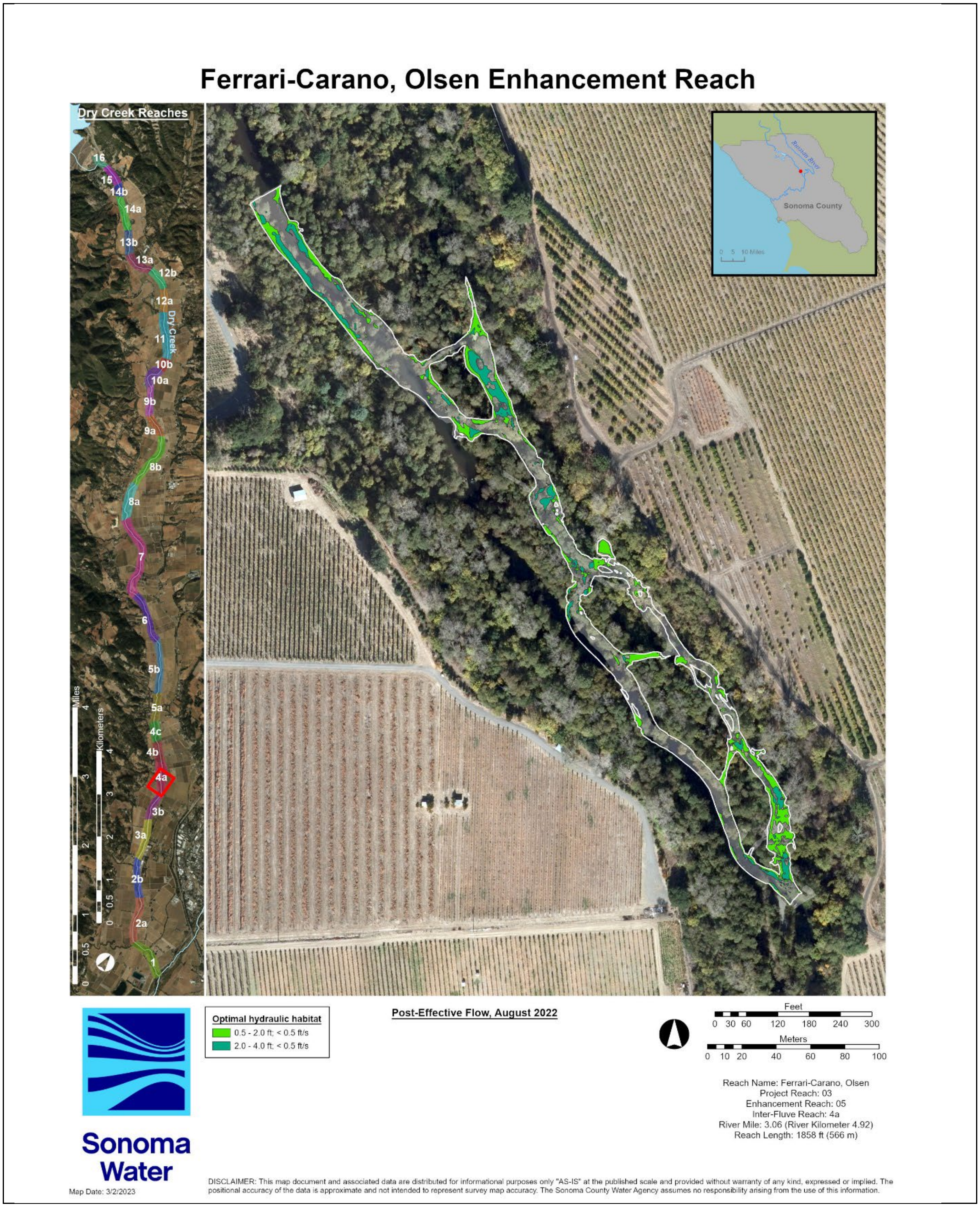

Figure 5.2.65. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Ferrari-Carano, Olson enhancement reach, August 2022.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.47. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Ferrari-Carano, Olson enhancement reach, August 2022.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	95	285
HU02	Flatwater	3	80	240
HU03	Pool	3	75	225
HU04	Flatwater	2	45	90
HU05	Pool	3	75	225
HU06	Alcove	3	75	225
HU07	Flatwater	3	70	210
HU08	Riffle	3	25	75
HU09	Pool	3	30	90
HU10	Alcove	3	50	150
HU11	Flatwater	2	30	60
HU12	Pool	3	35	105
HU13	Riffle	1	10	10
HU14	Pool	3	40	120
HU15	Flatwater	2	30	60
HU16	Riffle	3	40	120
HU17	Riffle	3	30	90
HU18	Alcove	0	99	0
HU19	Pool	3	35	105
HU20	Flatwater	3	25	75
HU21	Riffle	3	20	60
HU22	Pool	3	30	90
HU23	Alcove	3	70	210
HU24	Pool	3	40	120
HU25	Pool	3	45	135
HU26	Flatwater	3	15	45
HU27	Pool	3	50	150
HU28	Pool	3	30	90
HU29	Flatwater	3	60	180
HU30	Pool	3	55	165
HU31	Riffle	3	20	60
HU32	Pool	3	80	240
HU33	Flatwater	2	30	60
HU34	Alcove	3	80	240
HU35	Pool	2	20	40
HU36	Flatwater	2	15	30
HU37	Pool	3	40	120
HU38	Flatwater	3	30	90
Pool: riffle	**16:6 (2.67)**			**Avg = 123**

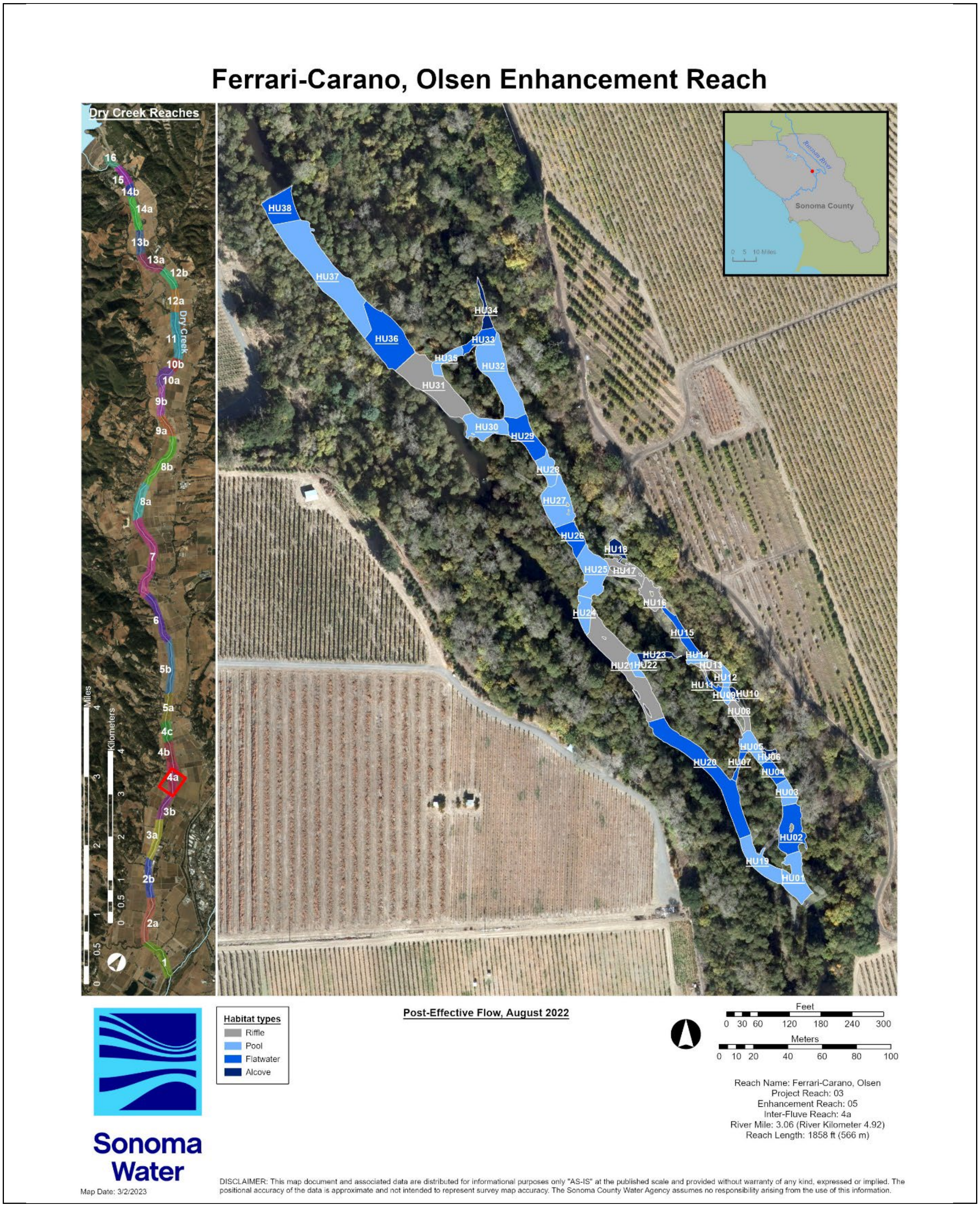

Figure 5.2.66. Habitat unit number and type within the Ferrari-Carano, Olson enhancement reach, August 2022.

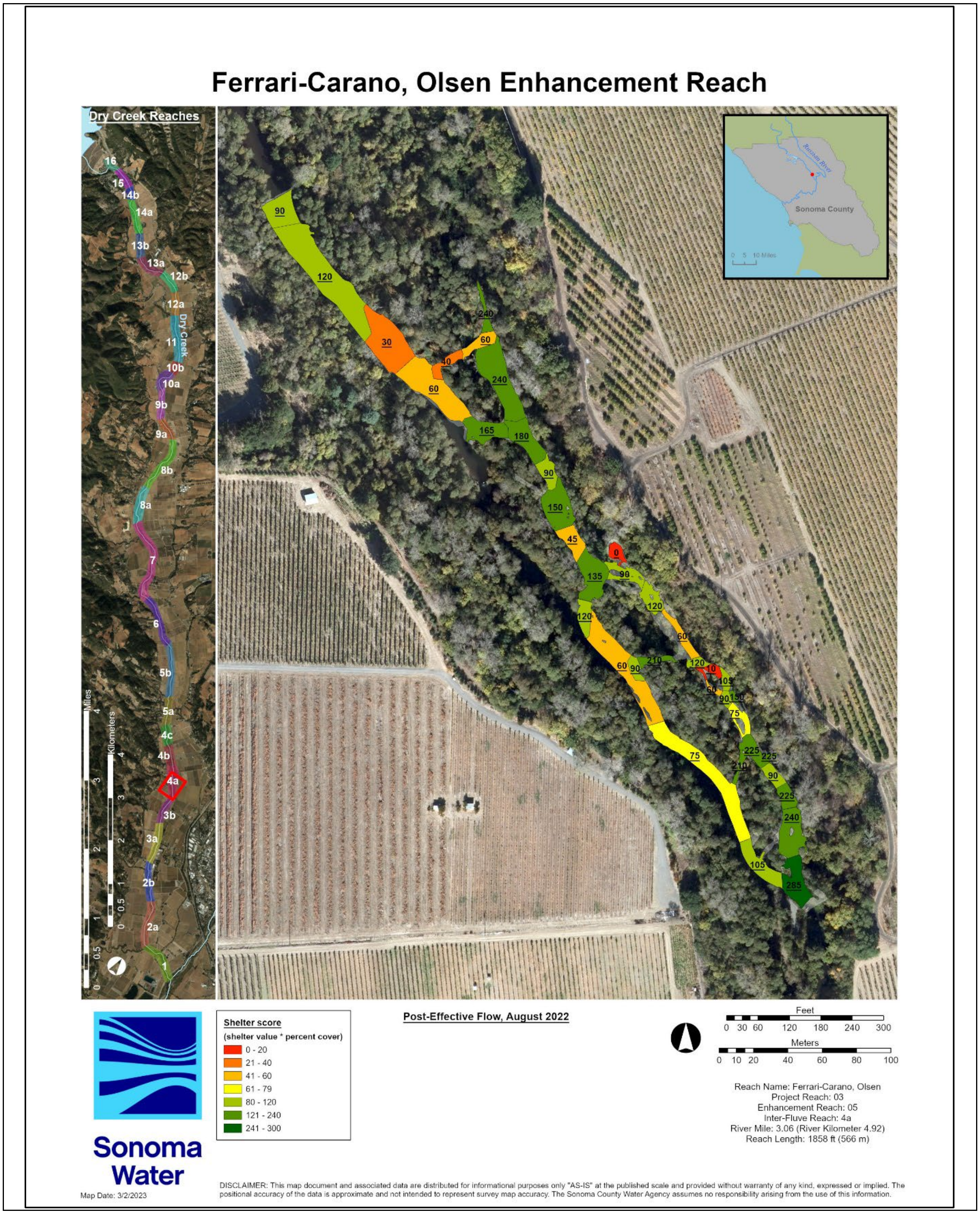

Figure 5.2.67. Habitat unit shelter scores within the Ferrari-Carano, Olson enhancement reach, August 2022.

Feature, habitat unit, site, and reach ratings

Table 5.2.48. Post-effective flow average feature, habitat unit, site, and reach ratings (rounded to the nearest whole number) for the Ferrari-Carano, Olson enhancement reach, August 2022.

Site number	1	2	3	
Site type	Main channel	Side channel	Side channel	
Site average feature quantitative rating[a]	11	12	13	
Site average feature qualitative rating[a]	Good	Good	Excellent	
Site average habitat unit quantitative rating[b]	21	22	14	
Site average qualitative rating[b]	Fair	Good	Fair	
Site quantitative rating (sum of site average feature and habitat unit rating)[c]	32	34	27	
Site qualitative rating[c]	Good	Good	Fair	
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)

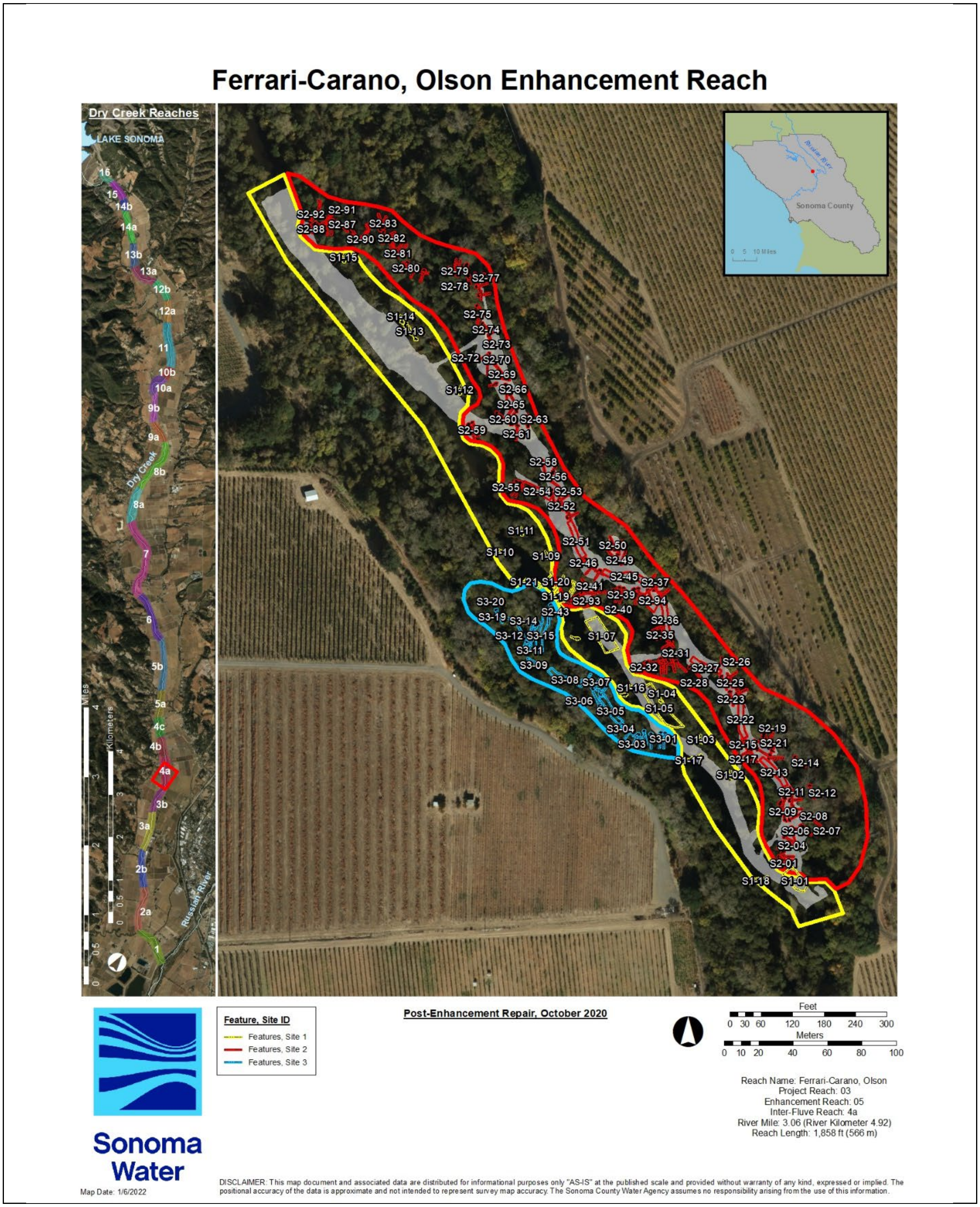

Figure 5.2.68. Enhancement sites and features within the Ferrari-Carano, Olson enhancement reach, August 2022.

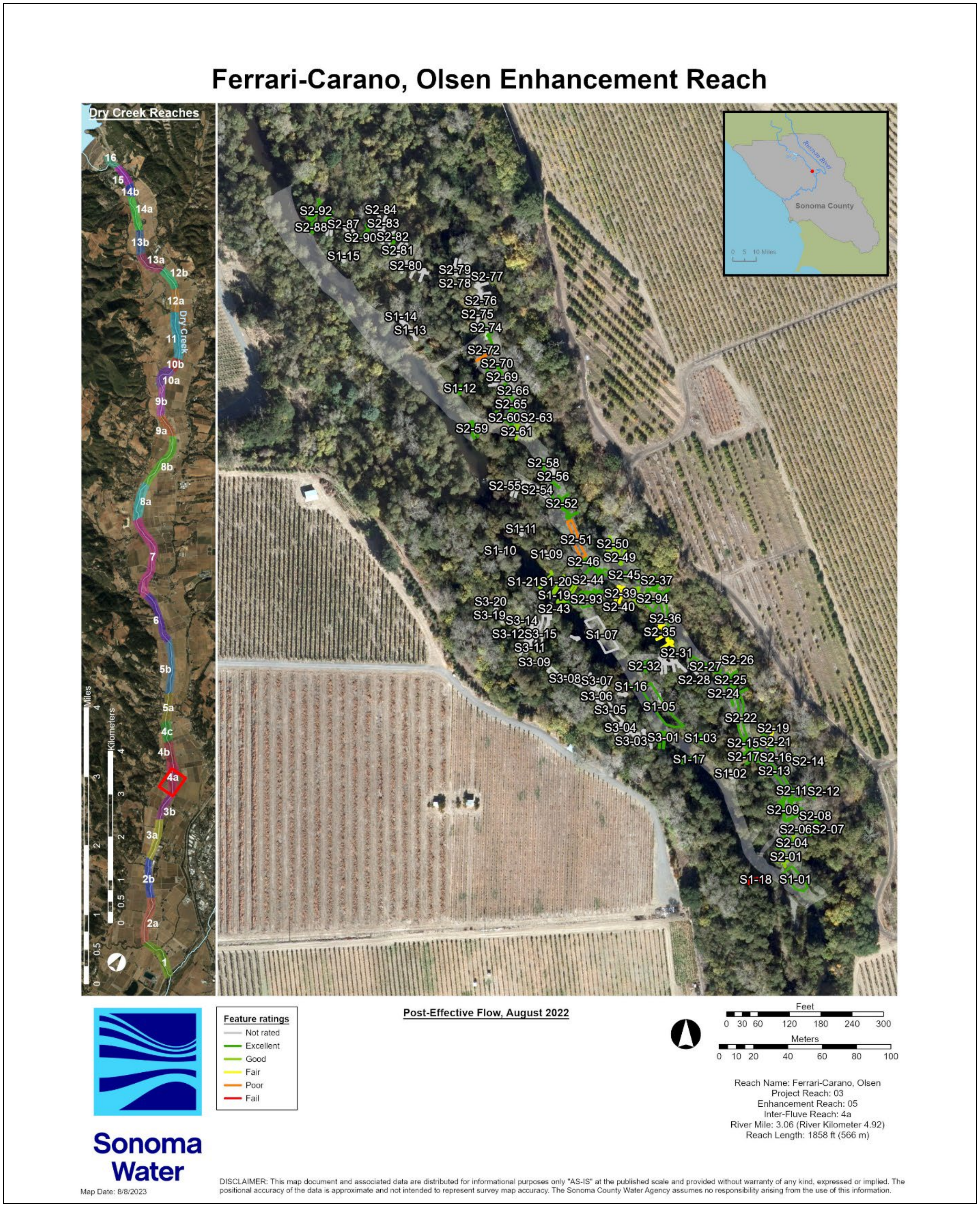

Figure 5.2.69. Feature ratings for the Ferrari-Carano, Olson enhancement reach, August 2022.

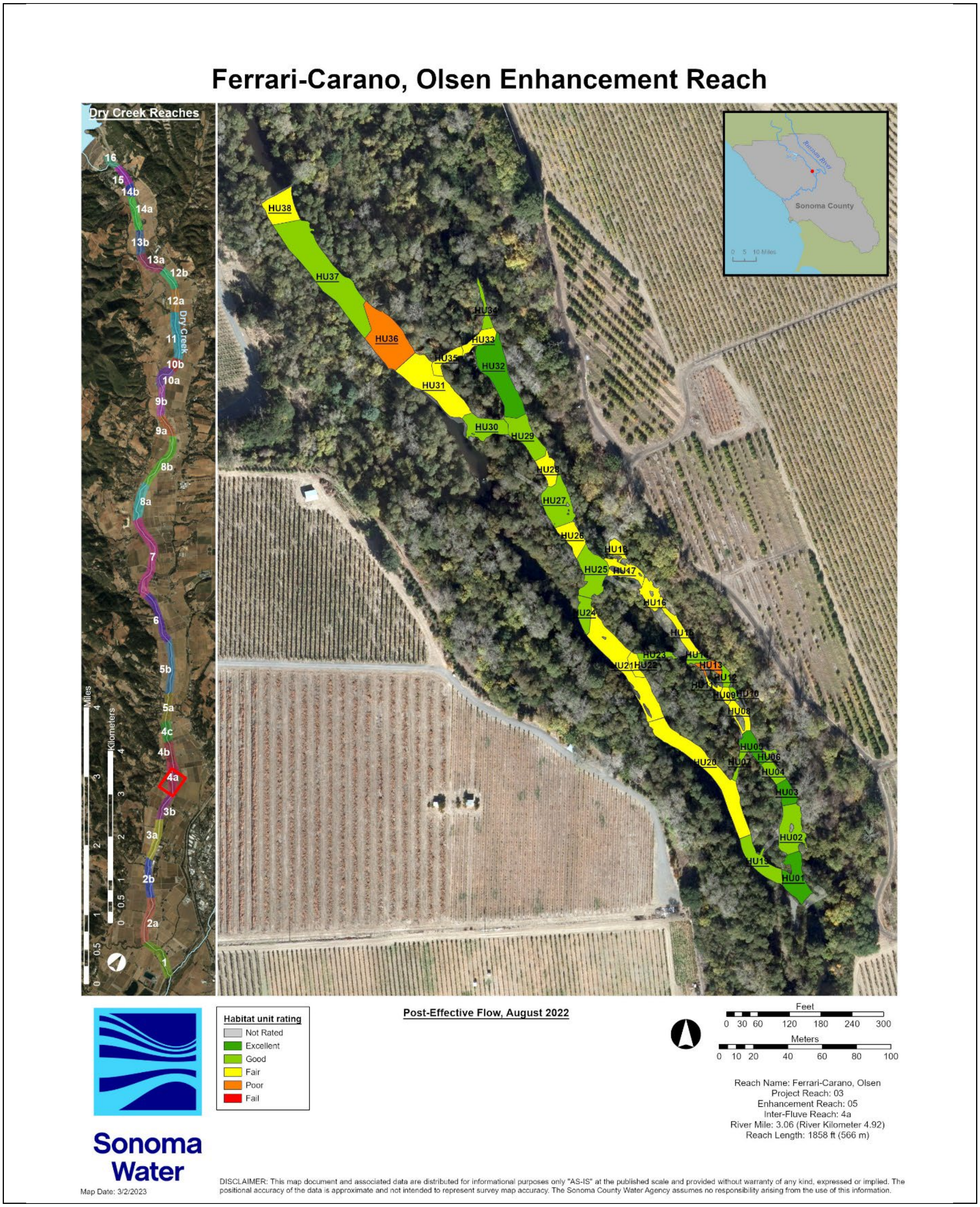

Figure 5.2.70. Post-effective flow habitat unit rating for the Ferrari-Carano, Olson enhancement reach, August 2022.

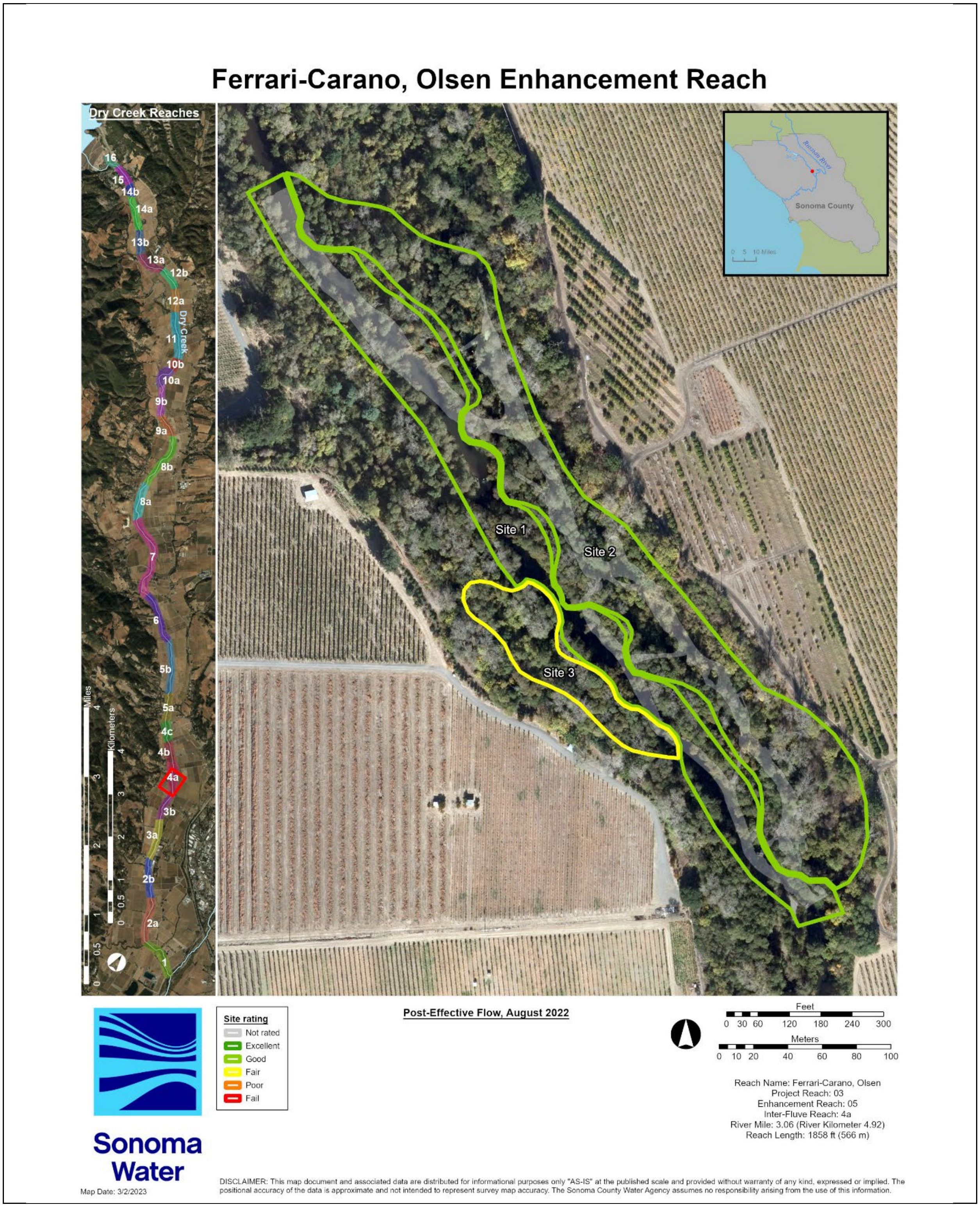

Figure 5.2.71. Post-effective flow site ratings for the Ferrari-Carano, Olson enhancement reach, August 2022.

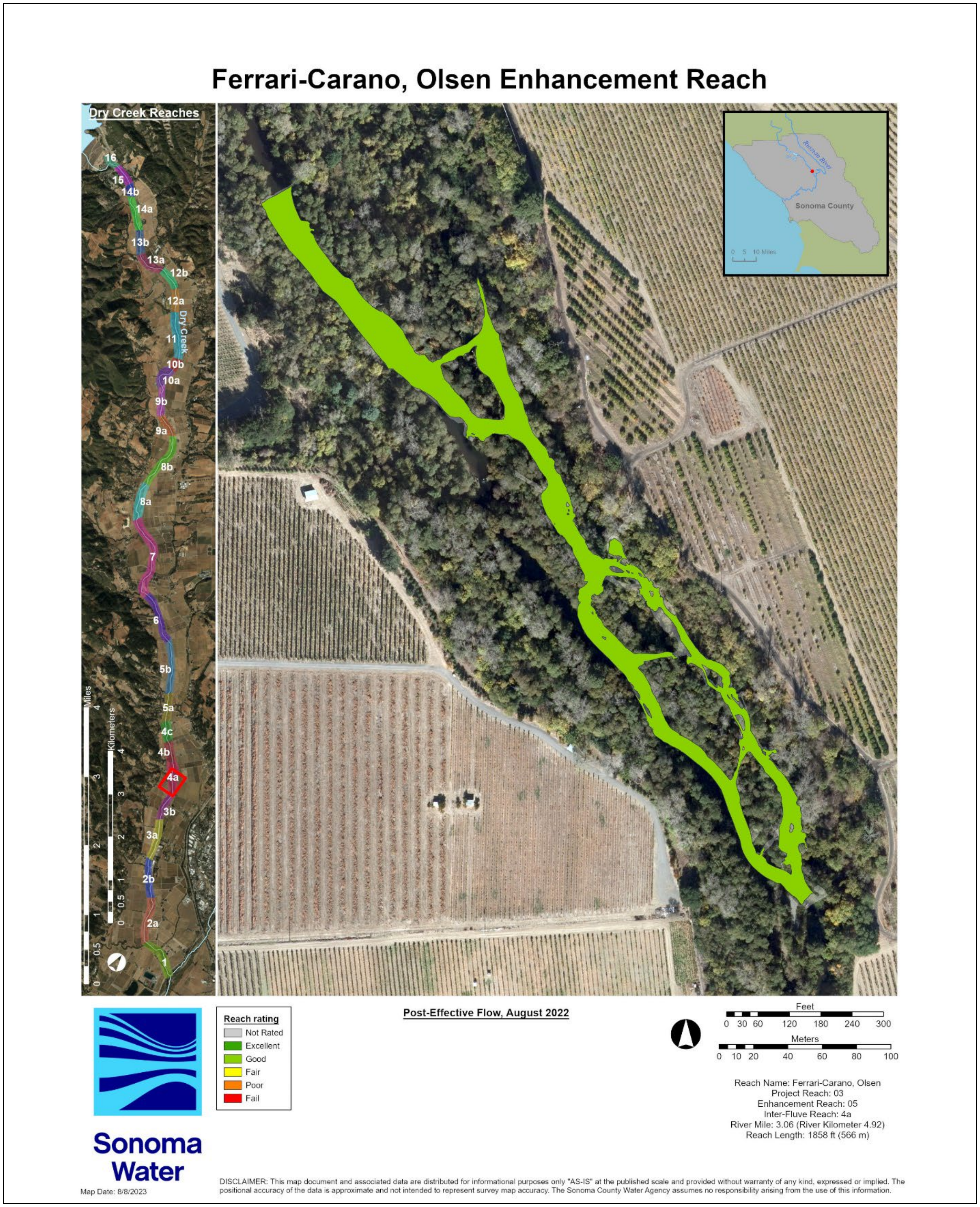

Figure 5.2.72. Post-effective flow reach rating for the Ferrari-Carano, Olson enhancement reach, August 2022.

Summary

Enhancement Reach Ratings

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 be the most recent post-effective flow ratings. The latest post-effective flow ratings, as of 2022, show two excellent ratings, eight good ratings, three fair ratings, and one poor rating (Table 5.2.49). With 87% (13/15) of ratings either good or excellent, the AMP suggests to continue to monitor according to the adaptive management plan (Table 5.2.2). Sonoma Water will continue to monitor habitat units, features, sites, and enhancement reaches according to the AMP. Any future actions will be guided by monitoring data.

Table 5.2.49. 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; -- indicates monitoring not conducted).

Enhancement Reach	2015	2016	2017	2018	2019	2020	2021	2022	Latest post-effective flow rating
Army Corps	--	Excellent	--	--	Good	--	--	Good	Good
Army Corps Reach 14	--	--	--	--	Good	--	--	Good	Good
Weinstock	--	--	--	--	Good	Good	--	--	Good
Gallo	--	--	--	--	--	Good	Good	--	Good
Truett Hurst	--	--	Poor	Good	Fair	Good	Good	Good	Good
Meyer	--	--	Fair	Fair	--	--	Good	--	Good
Carlson Lonestar	--	--	--	Good	--	--	Good	--	Good
Quivira	--	Excellent	--	--	--	--	--	--	Excellent
Van Alyea	--	--	Good	--	--	Excellent	--	--	Excellent
Rued	Good	--	--	--	--	--	--	--	Good
Farrow Wallace	--	--	Fair	--	Good	Good	Good	Good	Good
Ferrari-Carano, Olson	--	--	--	--	Fair	Fair	--	Good	Good
Boaz Gros-Balthazard	--	--	--	--	--	--	--	Good	Good
City of Healdsburg Yard	--	--	--	Good	Poor	--	--	--	Poor
Geyser Peak	--	--	Poor	Fair	Fair	Fair	Fair	--	Fair

Depth and Velocity

Effectiveness data from all monitoring time periods in 2022 showed substantial differences in the amount of optimal depth and velocity habitat between main and side channel areas, and between habitat types (Table 5.2.50). Overall, 54% of side channel area supported optimal depth and velocity, compared with 28% in main channel areas. Alcoves supported the greatest area of optimal depth and velocity, regardless of channel location (76-77%) followed by pools (side channel [54%], main channel [33%]) and flatwater (side channel [63%], main channel [21%]). In the main channel, the percentage of optimal depth and velocity in flatwaters and riffles was substantially lower than alcoves or pools. 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 (>0.5 f/s) and shallower depths (<0.5 ft) at low flows than the optimal depth and velocity conditions recommended by the BO or the AMP (≤0.5 ft/s velocity, 0.5-2.0 ft depth). Riffles still perform important ecological roles, such as nutrient retention and food production.

Table 5.2.50. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.

Habitat Type	Side channel % optimal depth and velocity	Main channel % optimal depth and velocity
Riffle	10%	8%
Pool	54%	33%
Flatwater	63%	21%
Alcove	77%	76%
Average	**54%**	**28%**

Shelter Scores

Effectiveness monitoring data from all monitoring time periods in 2022 showed differences in average shelter score between main and side channel areas, and differences in average shelter score between habitat types (Table 5.2.51). Overall, side channel areas supported an average shelter score of 132, compared with 91 in main channel areas. Alcoves supported the highest average shelter score in both areas, followed by pools. As with the percentage of optimal depth and velocity, average shelter score in flatwaters and riffles was lower than alcoves and pools across both channel locations, but side channel area flatwaters showed substantially higher shelter scores (119) than in the main channel (73). The results reinforce depth and velocity observations (above) that side channels and alcoves are effective at providing habitat conditions recommended (shelter scores ≥80) in the BO and in the AMP.

Table 5.2.51. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.

Habitat Type	Side channel mean shelter score	n	Main channel mean shelter score	n
Riffle	93	23	60	15
Pool	160	27	105	33
Flatwater	119	28	73	16
Alcove	180	10	240	2
Average	**132**		**91**	

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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 2022. These data are part of an ongoing pre- and post-construction monitoring efforts 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 observations of Coho in the backwaters and side channels during surveys and observations on PIT antennas. In 2022 no hatchery reared juvenile Coho were released into Dry Creek, therefore we relied on observations of Coho in the backwaters during electrofishing and snorkel surveys during the summer season.

To address use of newly created habitat by juvenile steelhead and Coho Salmon at the site and feature scale, sampling consisted of repeated electrofishing samples in the summer. We 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 conducted backpack electrofishing in stream sections (reach-scale) that were not enhanced. Additional sampling events were conducted to evaluate the growth of juvenile salmonids during the summer, in both un-enhanced main channel sections and enhanced side channels habitats. Habitat utilization in newly constructed side channels was further evaluated with visual surveys. 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)

Habitat utilization

Summer, 2022

Snorkel surveys have been used in previous years to validate use of habitat enhancements by juvenile salmonids. In 2022 snorkel surveys were attempted in eight habitat enhancement side channels: Geyser Peak (rkm 2.68), Boaz (rkm 7.12), Wallace (rkm 9.97), Meyer (rkm 13.82), Truett-Hurst (rkm 14.01), Weinstock (rkm 20.48), Army Corps Reach 14 (rkm 21.02), and Army Corps Reach 15 (rkm 21.40). Surveys were conducted with two snorkelers working in tandem. Species and approximate size class was noted for each individual observed. Though length of sections snorkeled in habitat enhancement sites was not recorded, we attempted to survey as much of the length and width of each habitat enhancement site as possible.

Fall/Winter 2022-2023

The only constructed side channel where we operated a PIT antenna in fall/winter 2022-2023 was in the Boaz side channel in reach 5 (rkm 7. 2 Figure 5.3.1). We also operated PIT antennas in the main channel at the mouth of Dry Creek (rkm 0.36) and in reach 4 (rkm 5.0).

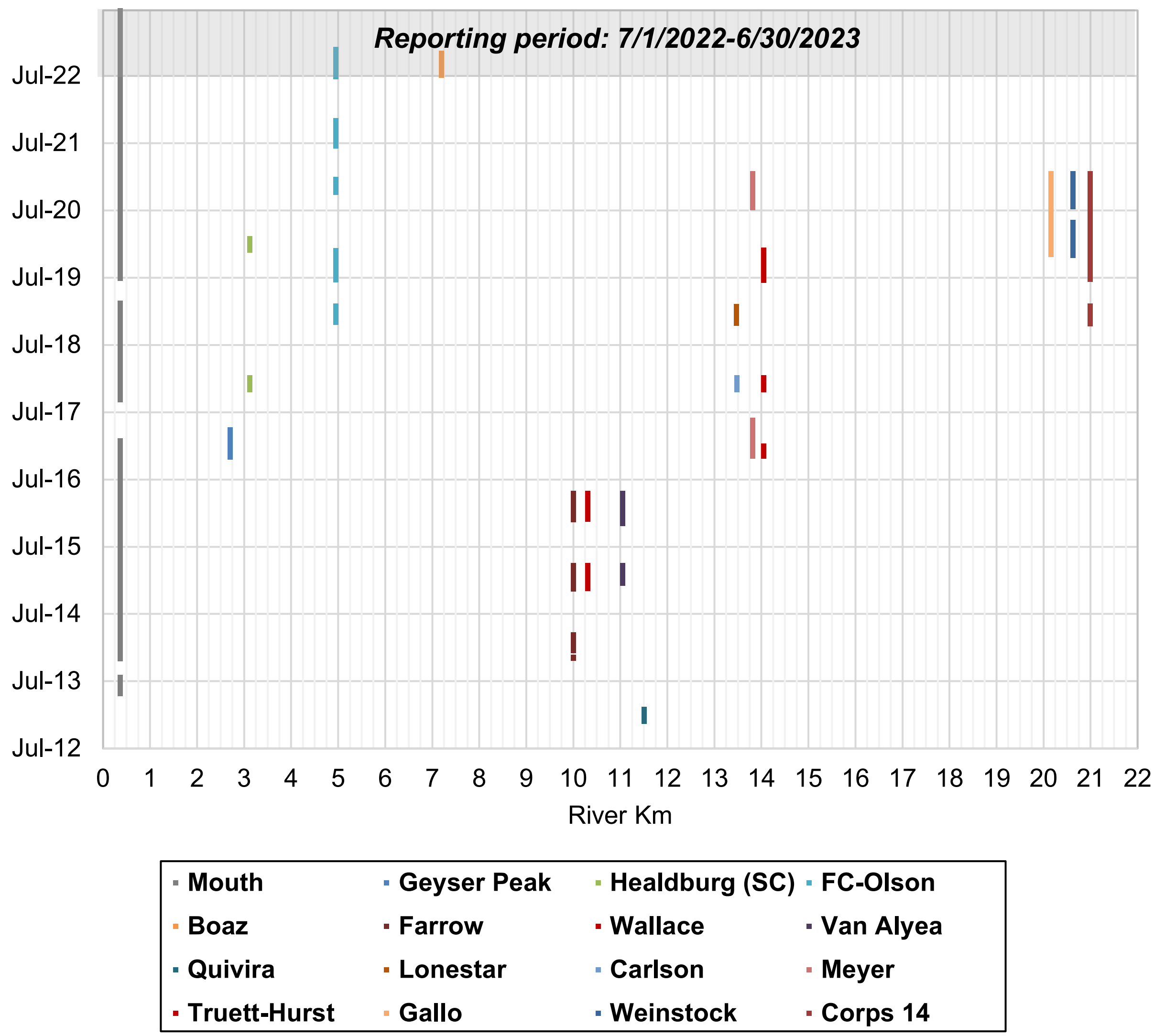


Figure 5.3.1. Period of operation of PIT antennas, July 2012-June 2023 in constructed habitats. Note that the downstream-most antenna near the mouth of Dry Creek (rkm 0.36) is not in constructed habitat and, in some years, the antennas at rkm ~0.5 were in constructed habitats while in other years they were not.

Late summer population density

Site-scale sampling

We estimated population density in the Ferrari Carano-Olson (rkm 4.92), Boaz (rkm 7.12), Truett Hurst (rkm 14.01), and Army Corps Reach 15 (rkm 21.40) constructed side channels in the summer of 2022 (Figure 5.3.1). A depletion method was used for the Ferrari Carano-Olson and Truett Hurst side channels, relying on block nets to temporarily close two sections of the side channels for sampling. Multiple electrofishing passes were conducted through each section on the same day. To estimate local population abundance, all fish captured on each pass were counted and temporarily "removed" from the stream by holding them in live cars or aerated buckets of stream water while subsequent passes were conducted. Much of the Boaz side channel was too deep for electrofishing or seining therefore we sampled only the shallow riffle-run section at the upstream end of the site. Backpack electrofishers were used in combination with a single block net positioned at the downstream end of the riffle section to sample the site. Sampling was conducted on day 1 (the marking event) followed by a second sampling event two days later (the recapture event). Individuals captured on day 1 were marked with a PIT tag, released at their capture location, and subject to recapture on day 2. 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 sample 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. We sampled each of the three geomorphically-based reaches identified by Inter-Fluve (2011) (Figure 5.3.2). 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 were unbiased (White et al. 1982). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the site.

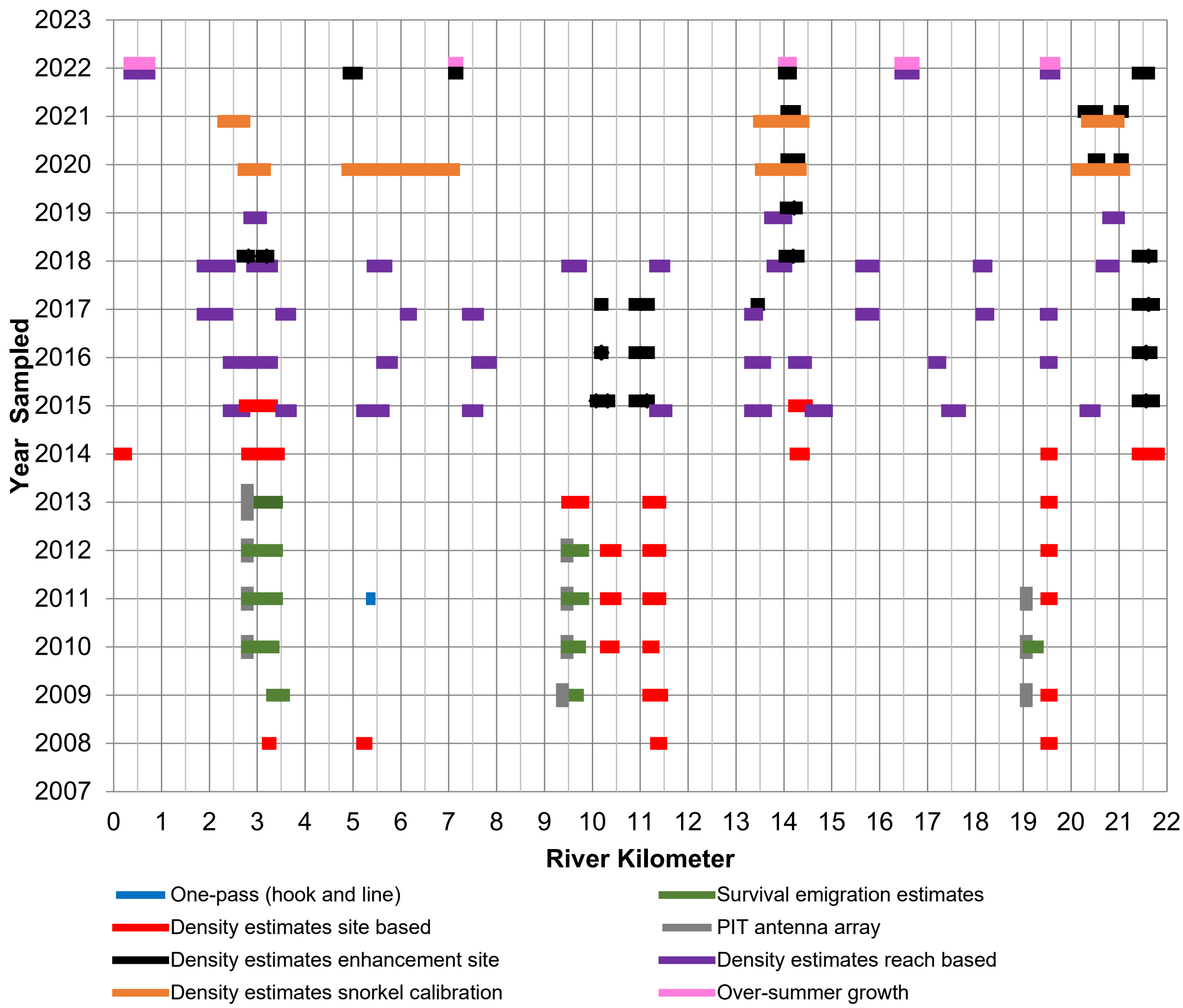


Figure 5.3.2. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in Dry Creek, 2008-2022. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass 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.

Growth

Repeated sampling conducted during the summer was used to calculate growth rates for juvenile steelhead in both main channel and constructed side channel sites. Each main channel site was first sampled in July (7/18/22 – 7/20/22) using backpack electrofishers. Salmonids ≥ 60 mm were anesthetized, PIT-tagged, measured for fork length (±1 mm), and weight (±0.1 g). During subsequent sampling of the same sites later in the summer (8/28/22 – 9/22/22) salmonids were measured and PIT-tagged fish that were recaptured were used to calculate over-summer growth as the change in fork length per day. Two constructed side channel sites (Boaz, rkm 7.12, and Truett Hurst, rkm 14.01) were sampled in a similar manner, providing a means to compare observed over-summer growth rates to those in the main channel.

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 (±1 mm) each day, and a subsample of salmonid species was weighed (±0.1 g) 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.

Coho Salmon

Because of the small numbers of Coho Salmon smolts captured in the Dry Creek trap, a population estimate is not possible based on mark-recapture methods available for Chinook Salmon smolts. Therefore, we report trap catch as the minimum count in the Dry Creek trap each year.

Chinook Salmon

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. An upper caudal fin clip was used to mark fish. Marked fish 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 is based on the period of time that fish were marked and recaptured (March 30-July 2, 2022).

Steelhead

Much of the steelhead smolt migration period occurs prior to the time the migrant trap can safely be installed and operated in mainstem Dry Creek; therefore, the catch of steelhead smolts in the trap does not adequately account for the abundance of steelhead smolt emigrating from Dry Creek. To account for this discrepancy, we employed a pre-smolt abundance model that relied on backpack electrofishing in the late summer/early fall and year-round, stationary PIT antenna monitoring to estimate smolts and/or juvenile steelhead leaving Dry Creek. To estimate the number of steelhead emigrants leaving Dry Creek in the 2022 smolt season we relied on the detection of marked individuals on the antenna array located at the mouth of Dry Creek (rkm 0.36). In the absence of trapping and handling steelhead to determine which individuals are smolts, steelhead were classified as smolts if they were detected leaving Dry Creek during the period from November 1, 2021, through June 30, 2022. Based on empirical observations of juvenile steelhead growth, it is reasonable to assume that all or most of these individuals could have reached a size large enough to smolt by the following late winter/early spring.

During electrofishing surveys in the summer of 2021 in the mainstem of Dry Creek, and the Truett-Hurst, Weinstock, and Army Corps Reach 14 side channels, 705 juvenile steelhead were PIT-tagged. The proportion of these individuals that were detected leaving Dry Creek as smolts in 2022 was calculated as a “survival” index, corrected for antenna efficiency. The survival index (si) was then applied to the estimate of juvenile steelhead density ($fish * m^{-1}$) multiplied by the total reach length ($length_r$) to calculate an estimate for the number of smolts from Dry Creek in 2022 ($\hat{Y}$).

$$\hat{Y} = \sum_{i=1}^{r} si(length_r * (fish * m^{-1}))$$

Results and Discussion

Habitat utilization

Summer, 2022

In 2022 snorkel surveys were conducted in the Boaz (rkm 7.12), Weinstock (rkm 20.48), and Army Corps Reach 14 (rkm 21.02) side channels. The Geyser Peak, Wallace, Meyer, Truett-Hurst, and Army Corps Reach 15 side channels were visited, but not surveyed due to poor sampling conditions such as low visibility, large amounts of aquatic vegetation, or shallow water depths due to aggradation. Visibility ranged from 1 to 2 meters depending on the site sampled and from 0-1 meter in the sites visited, but not sampled. In total, 578 steelhead (207 of the 578 steelhead were over 100 mm FL), 63 Coho, and no Chinook were observed in these side channels (Table 5.3.2).

Fall/Winter 2022

We detected nine PIT-tagged steelhead in the Boaz side channel that were PIT-tagged during electrofishing surveys. Four fish were tagged approximately 2 kilometers downstream in the Ferrari Carano-Olson side channel and five fish were PIT-tagged in the main channel approximately 9 kilometers upstream. We also detected steelhead that were PIT-tagged in the Boaz side channel indicating at least short-term residence time in the constructed habitat.

Table 5.3.2. The site and date of snorkel surveys conducted in Dry Creek in 2022, shown with the number of Chinook, Coho, and steelhead in 50-100 mm fork length (FL) and greater than 100 mm FL size bins.

Site	Date	Steelhead				Coho
		0-50 mm	50-100 mm	100-200 mm	200 mm	50-100 mm
Boaz	6/22/2022	22	103		7	
	7/14/2022		34	82	7	
	8/8/2022		16	51	1	
	9/21/2022		10	35	2	
Weinstock	6/22/2022	7	30		4	
Army Corps Reach 14	6/22/2022	14	135		18	63
Grand Total		**43**	**328**	**168**	**39**	**63**

Late summer population density

Site-scale sampling

The average estimated density of juvenile steelhead from side channel sites was 0.19 fish*m^{-2} and was greatest in the Ferrari Carano-Olson side channel (Figure 5.3.3) (Table 5.3.3). In 2022, we were able to calculate a density for Coho in the Army Corps Reach 15 side channel (Table 5.3.3). However, while these individuals were determined to be of natural origin, CDFW relocated a total 2,276 juvenile Coho from drying Russian River tributaries into the Army Corps Reach 14 side channel (rkm 21.02) on six occasions from June 23 to August 16, 2022. We sampled the Army Corps Reach 15 side channel (rkm 21.40) on September 27 and 29, 2022.

Reach-scale sampling

The average density of juvenile steelhead in mainstem sections was 0.33 fish*m^{-2} (range 0.02 fish*m^{-2} to 0.82 fish*m^{-2}) (Figure 5.3.3). When averaged for all sites within a year, densities in 2022 were greater than the running average from 2008-2021 (0.25 fish*m^{-2}). While lower than the previous year, the average population density for enhanced sites was slightly lower than for un-enhanced sites (Figure 5.3.3).

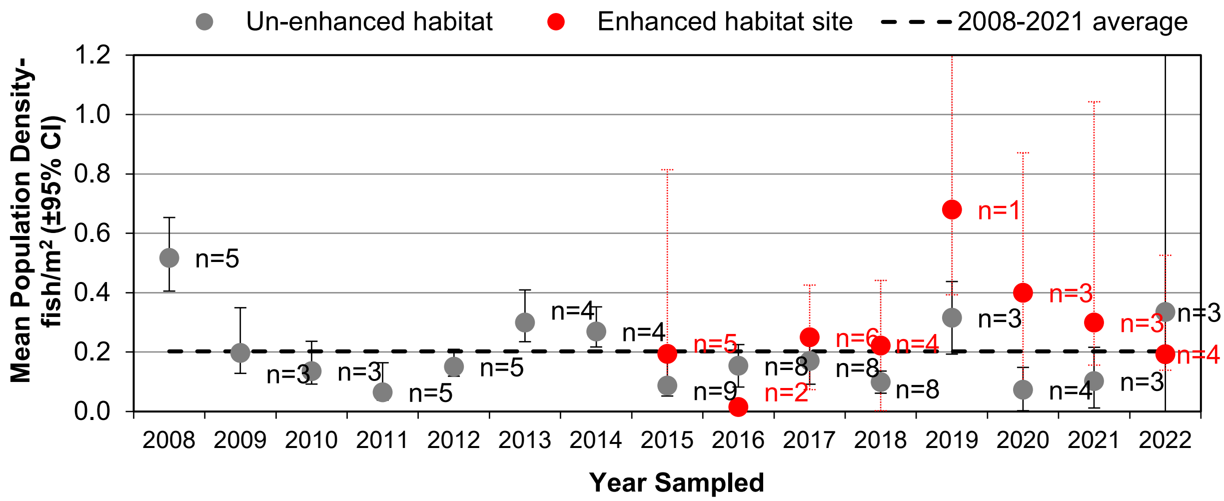


Figure 5.3.3. Mean juvenile steelhead density among all sites sampled within a year in mainstem Dry Creek, 2008-2022. "n" refers to the number of sites sampled per year.

Table 5.3.3. Density of steelhead and Coho juveniles and number of Coho observed in constructed enhancement side channels sampled in the summer 2022. Coho density and counts include hatchery and non-hatchery origin individuals.

Enhancement site	River km	Steelhead density (fish * m^{-2})	Coho density (fish * m^{-2})	Number Coho observed non-hatchery (unknown)
Ferrari Carano-Olson	4.92	0.33	NA	0
Boaz	7.12	0.19	NA	0
Truett-Hurst	14.06	0.20	NA	0
Army Corps Reach 15	21.40	0.06	0.10	70(1)

Growth

Repeated sampling conducted during the summer provided the opportunity to calculate growth rates for recaptured steelhead in both main channel and constructed side channel sites. Growth rates ranged from 0.27 to 0.86 mm*day^{-1} and were greatest in the lower sections of Dry Creek (Figure 5.3.4). Days between fork length measurements varied and ranged from 28 to 68 days during July, August, and September.

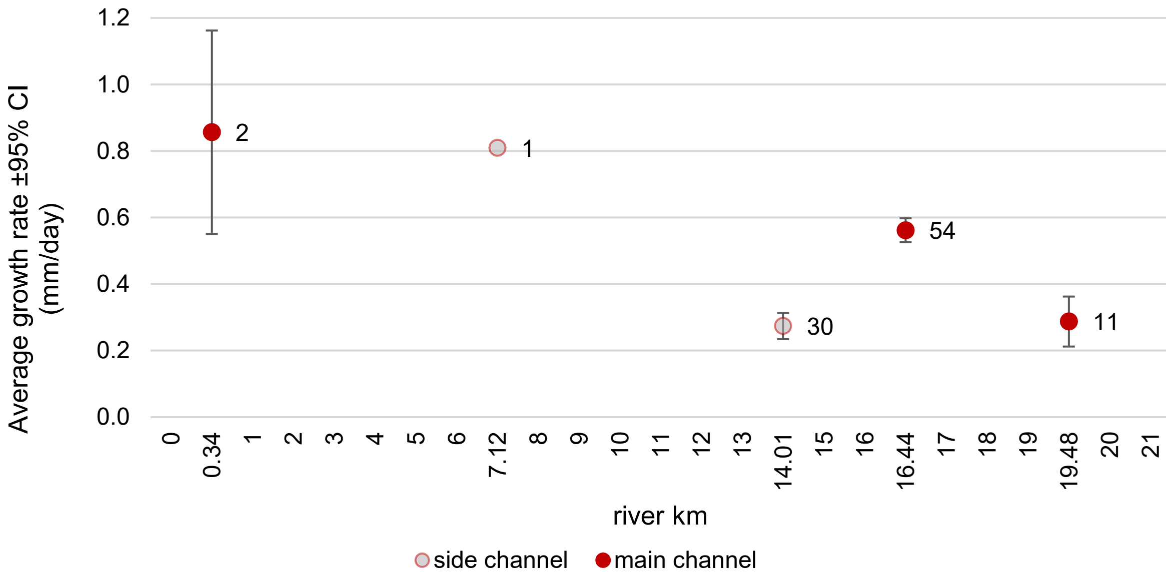


Figure 5.3.4. Calculated average over-summer growth rates of juvenile steelhead from Dry Creek, 2022. Individual growth rates were calculated as the change in fork length (mm) per day of PIT-tagged fish between initial tagging and recapture. Sample size is indicated by the number adjacent to the data points.

Smolt abundance

We installed the rotary screw trap on March 29 (Figure 5.3.5). 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 28.

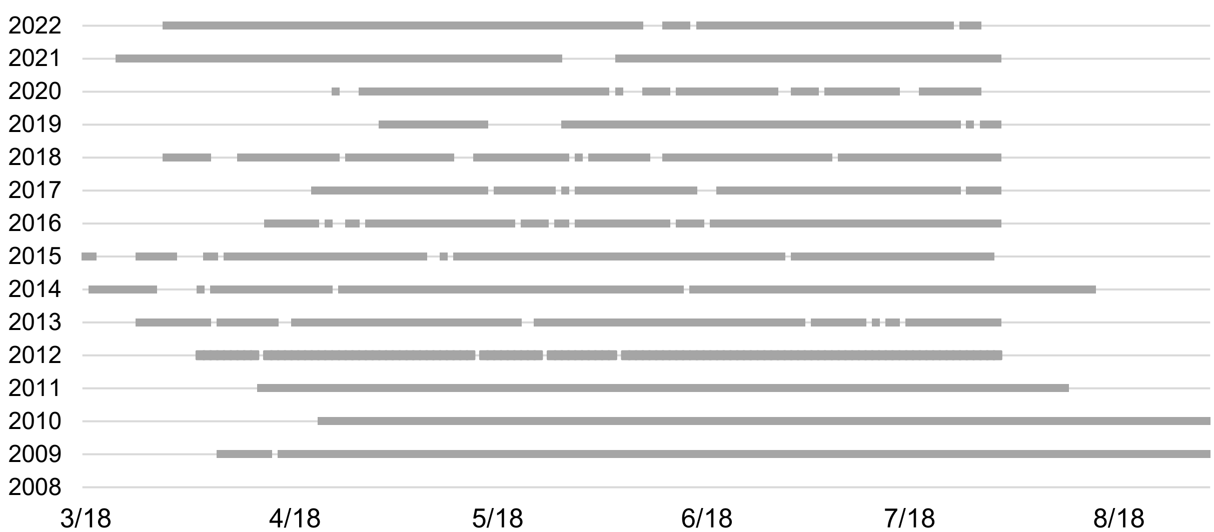


Figure 5.3.5. Beginning and end dates and data gaps (spaces in lines) for operation of the Dry Creek downstream migrant trap, 2009-2022.

The total catch of Chinook Salmon smolts in 2022 was 23,848 individuals. The peak capture of Chinook Salmon smolts (1,081) occurred during the week of 4/17 (Figure 5.3.6). Based on the estimated average weekly capture efficiency (range: 10% to 27%), the resulting population size of Chinook smolts passing the Dry Creek trap between March 30 and July 2 was 156,921 (±95% CI: 18,470, Figure 5.3.7).

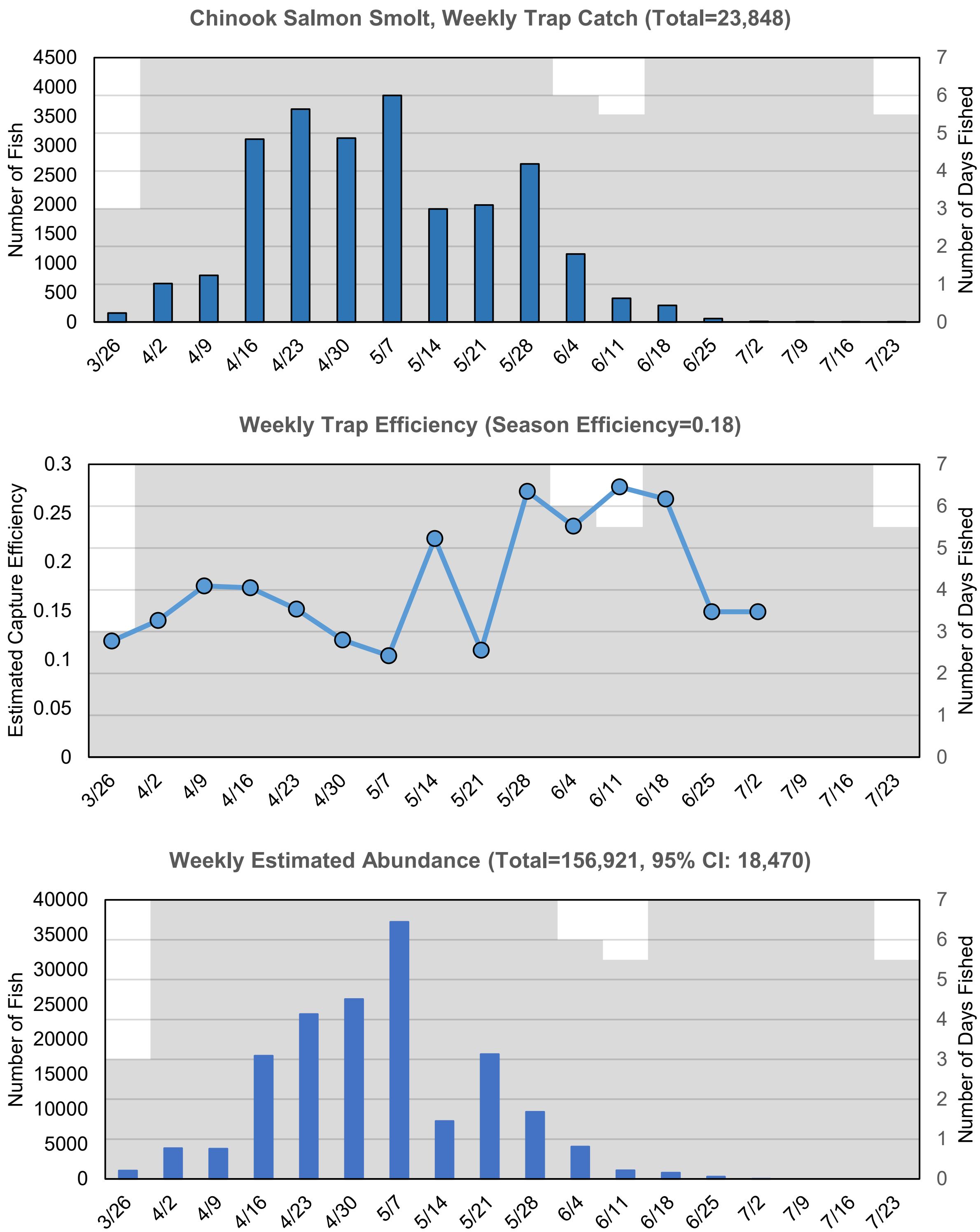
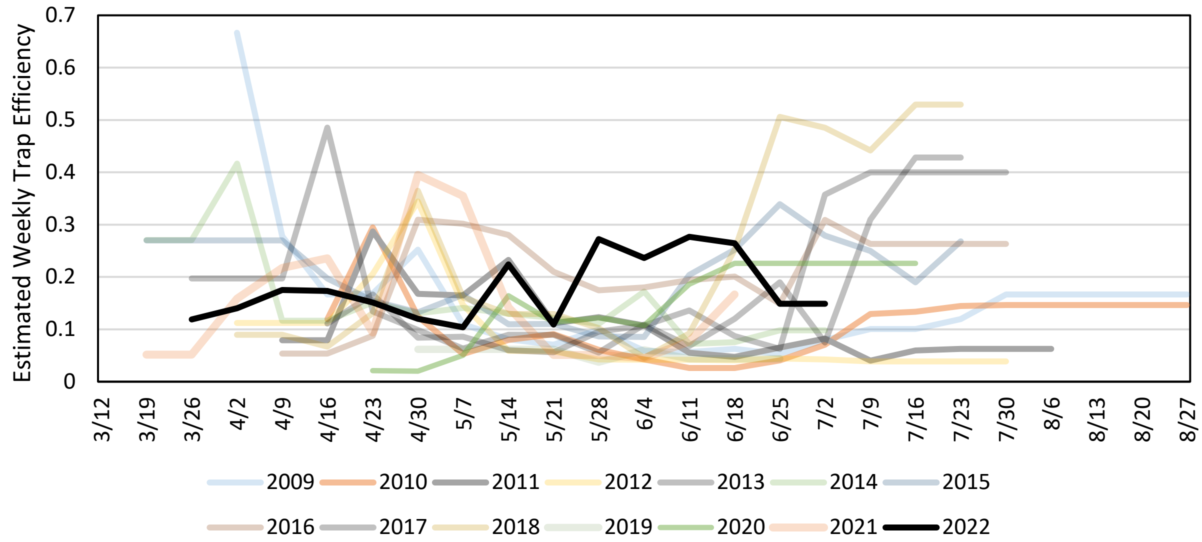


Figure 5.3.6. Weekly trap catch (upper panel), estimated average weekly capture efficiency (middle panel) and population estimate of Chinook Salmon smolts in the Dry Creek rotary screw trap (lower panel), 2022. Estimates are from DARR (Bjorkstedt 2005). The number of days each week the trap was fished is represented by the shaded area.



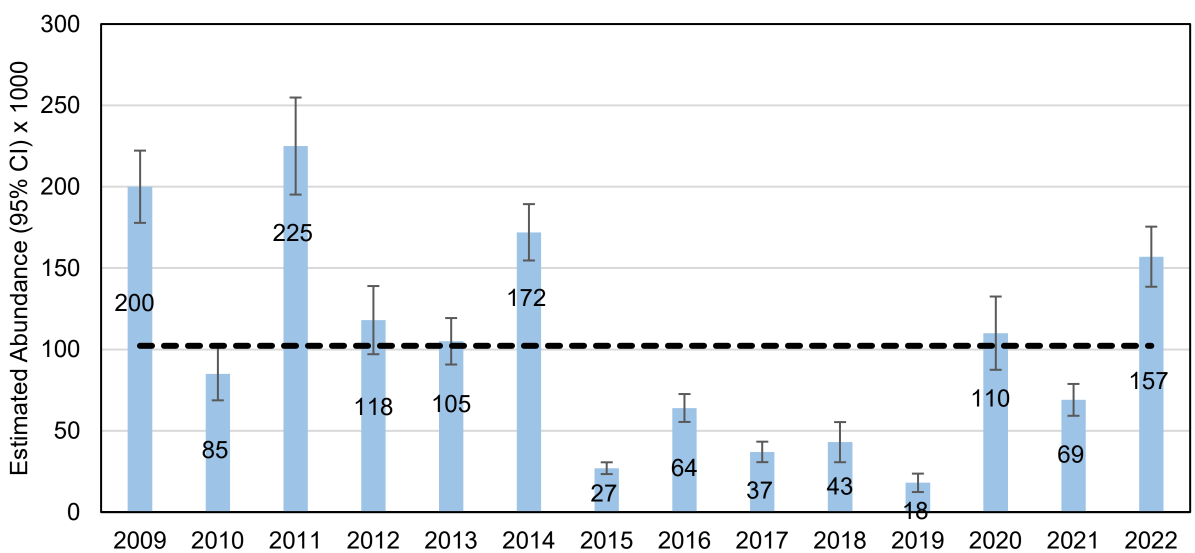
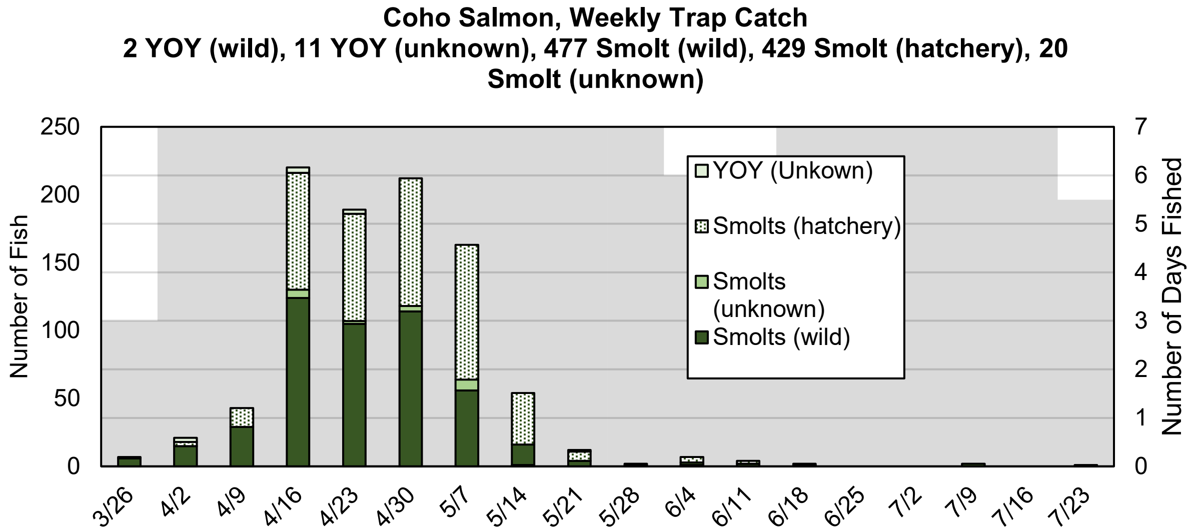


Figure 5.3.7. Estimated average weekly capture efficiency (upper panel) and population estimate of Chinook Salmon smolts (x1000) produced from the Dry Creek watershed upstream of Westside Road smolt trap site (rkm=3.3) (lower panel), 2009-2022. Dashed line is the twelve-year average abundance for all years combined.

Coho salmon were the least abundant of the three salmonid species captured with 477 natural-origin and 429 hatchery-origin smolts. Steelhead parr capture was highest in May and June (Figure 5.3.8).



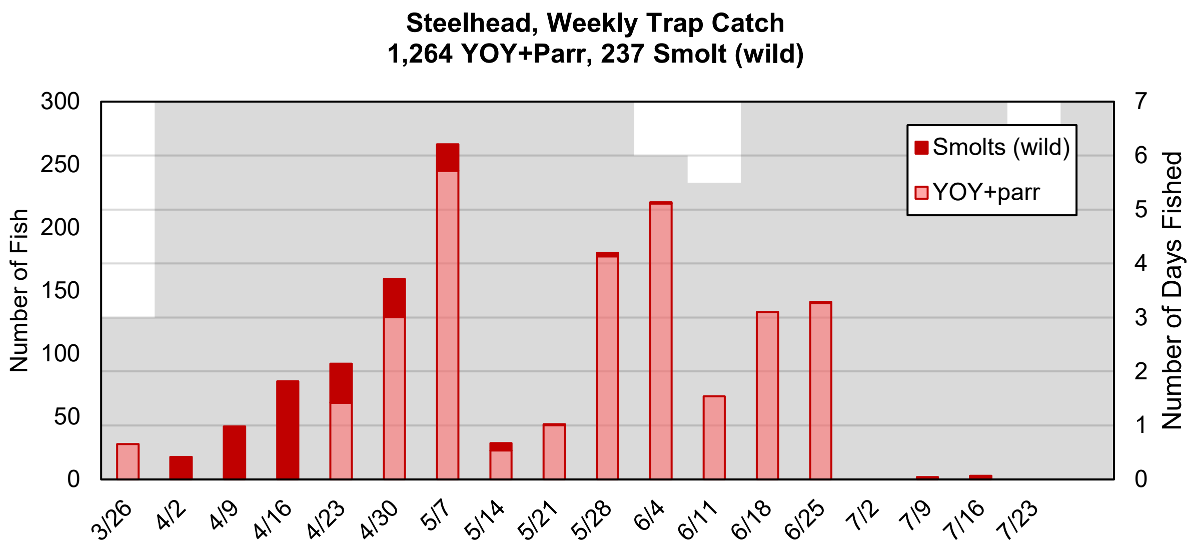


Figure 5.3.8. Weekly trap catch of juvenile Coho Salmon and steelhead in the Dry Creek rotary screw trap, 2022.

Coho smolt trap catch for the season was relatively high (Figure 5.3.9). Steelhead smolt and YOY/parr captures (237 and 1,264) for 2022 were similar to previous years.

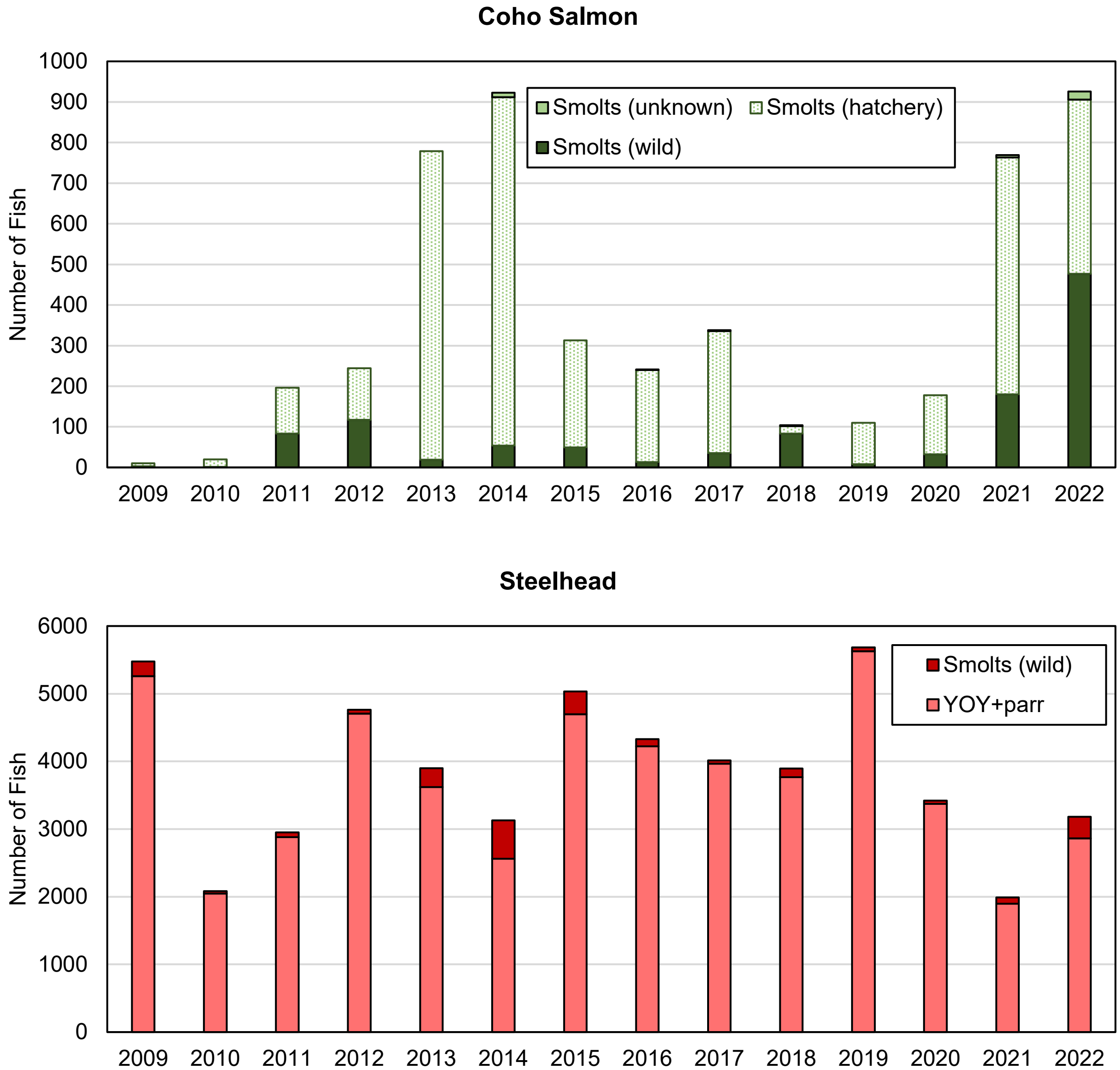


Figure 5.3.9. Trends in trap catch for Coho smolts and steelhead smolts and parr, 2009-2022.

Weekly sizes of all salmonids captured at the Dry Creek trap increased over the course of the trapping season in 2022 (Figure 5.3.10).

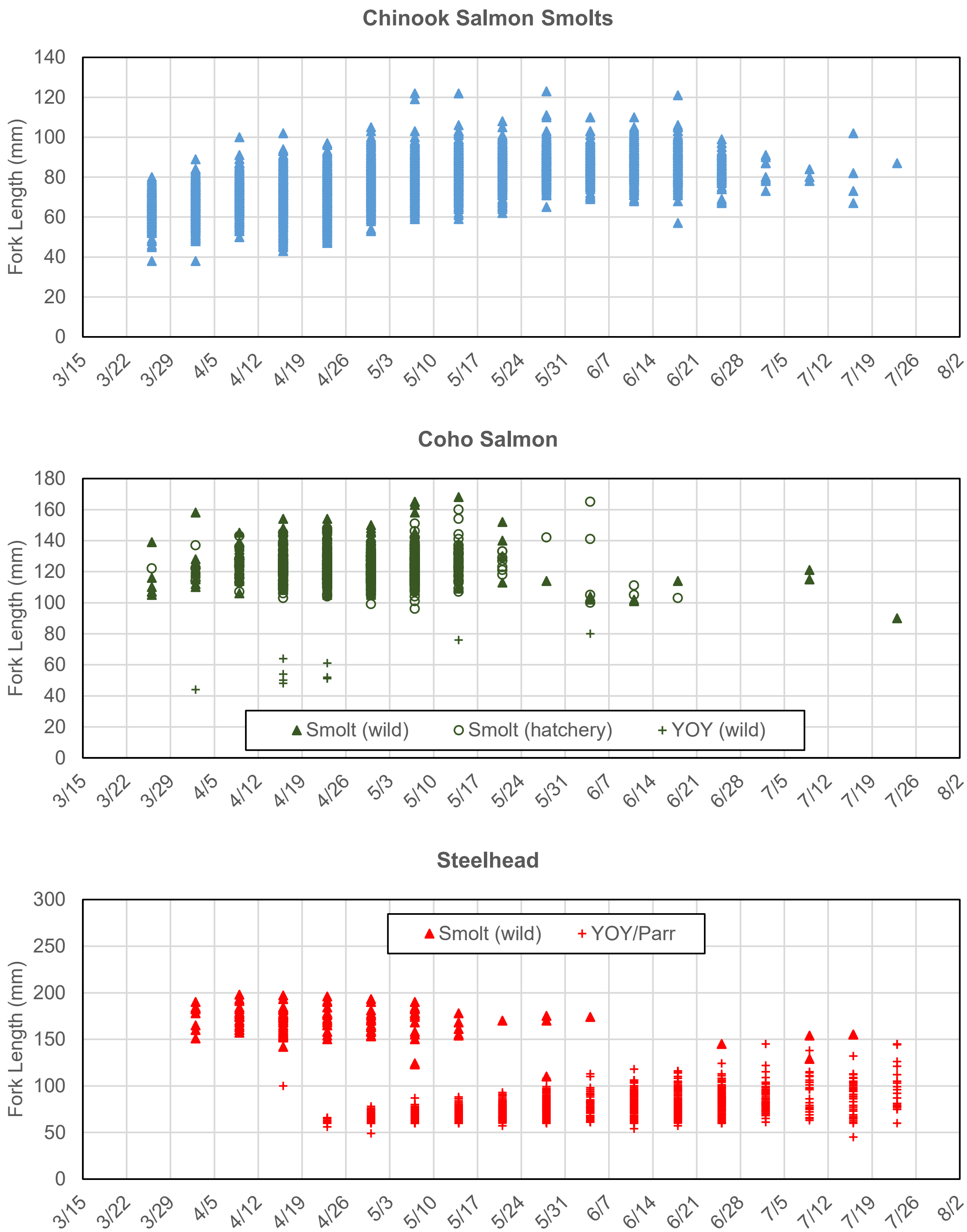


Figure 5.3.10. Fork lengths of juvenile salmonids captured in the Dry Creek rotary screw trap by week, 2022.

Steelhead smolt survival index

Antenna detections of PIT-tagged steelhead during the smolt migration period was used to calculate a survival index for juveniles that left Dry Creek during the subsequent smolt season. Due to the low number of emigrants detected (20) from the total number of steelhead tagged (705), a single survival index was calculated for 2021-2022, and this was applied to the respective expanded population estimates to generate the smolt estimate (Table 5.3.4). The survival index was lower in 2021-2022 compared to the previous two years (0.09 and 0.06).

Table 5.3.4. Estimated number of steelhead smolts in Dry Creek in mainstem and side channel reaches for 2022 based on number of juvenile steelhead estimated in summer 2021 and calculated survival index to the 2022 smolt migration season.

Location	River km	Density (fish * m^{-1})	Expansion estimate (juvenile)	Survival index	Smolt estimate
Lower reach	00.00 – 06.87	1.10	7,561	0.04	322
Middle reach	06.87 – 18.90	2.56	30,821	0.04	1,312
Upper reach	18.90 – 21.81	1.06	3,138	0.04	134
Total mainstem					***1,768***
Truett-Hurst SC	14.01 – 14.30	2.12	615	0.04	26
Weinstock SC	20.48 – 20.53	1.97	493	0.04	21
Army Corps Reach 14 SC	21.02 – 21.07	0.73	270	0.04	11

Conclusions and Recommendations

Many of our conclusions regarding smolt abundance for steelhead depend on the successful operation of PIT antennas at the mouth of Dry Creek throughout the steelhead smolt migration period. The reason we operate multiple antennas within a PIT antenna array oriented longitudinally along the stream course is so that we can calculate antenna detection efficiency. In the case of downstream-migrating individuals such as smolts, the proportion of tagged individuals that are detected on the downstream antenna within the array that were previously detected on one or more upstream antennas in the array is used to represent antenna detection efficiency. High winter discharge and related debris flow (e.g., large wood) can result in physical damage to PIT antennas leading to gaps in data. However even when antennas are not physically damaged and remain operational, stream flow that exceeds channel capacity can impact antenna detection efficiency as the stream flow jumps its banks affording individuals the opportunity to swim around antenna sites. Although the PIT antenna array at the mouth of Dry Creek spans the width of the main channel during the majority of flows occurring in a given year, during periods of high flow (typically in the winter) there are opportunities for fish to pass the PIT antenna site without passing near the PIT antennas themselves. If individuals are migrating during this period (which is more likely for steelhead smolts), antenna detection efficiency will be upward biased to an unknown degree. This could, in turn, lead to downward biased expanded counts and mark-recapture estimates for steelhead smolts.

Conceptually, we may be able to overcome this issue by basing estimates on site detection efficiency rather than antenna detection efficiency. Site efficiency is similar to antenna efficiency in that the proportion of tagged individuals that are detected downstream of the antenna array of interest that were previously detected on the array is used to represent site detection efficiency. However, very often the same set of environmental conditions that compromise detection efficiency at the mouth of Dry Creek will impact the ability of downstream antennas to detect PIT-tagged fish. During the 2021-2022 steelhead smolt migration period, this likely played a larger role not only in in our expanded count of steelhead smolts, but also in our ability to install downstream migrant traps during a time that encompassed the majority of the Coho and Chinook smolt migration periods (Figure 5.3.11).

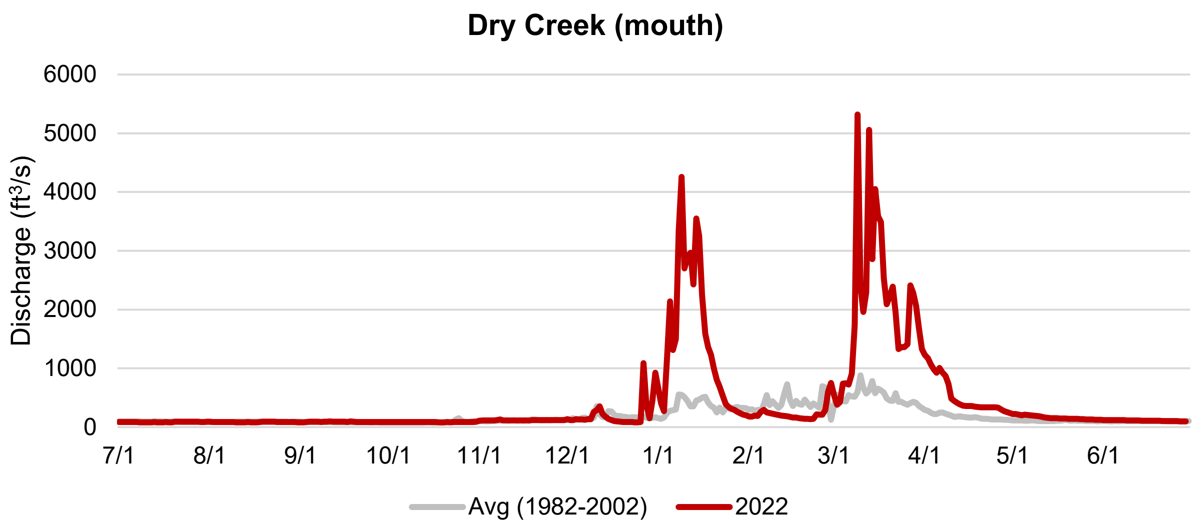


Figure 5.3.11. Stream discharge at the USGS gage station at the mouth of Dry Creek.

Validation monitoring continues to confirm that juvenile salmonids utilize newly constructed habitat soon after construction. In 2022 we were able to sample the recently constructed side channel (Boaz rkm 7.12) as well as side channels that were constructed in the past four to nine years (Table 5.3.5). Density estimates for juvenile steelhead vary from year to year but have generally trended slightly upwards. Complex habitat including root wads, instream vegetation, and bolder fields, as well as channel depth make it challenging to effectively conducted backpack electrofishing and seining surveys in newly constructed enhancement sites. For un-enhanced habitat, the greater depth, width, and overall length of the main channel also make it difficult to effectively sample much of the stream. These challenges lead to density estimates that have wide margins of error (Figure 5.3.3). Growth of juvenile steelhead during the summer was greater compared to 2010, prior to the construction of enhancement sites (Figure 5.3.12).

Table 5.3.5. Outcomes from validation monitoring conducted in 2022 in Dry Creek habitat enhancements.

Metric	Life stage	Species	River km	Enhancement site	Method	Season	Outcome
Habitat use	Juvenile	Coho Salmon	21.02	Army Corps Reach 14	snorkel	summer	present
		steelhead	7.12	Boaz	antenna	summer	present
					snorkel	summer	present
			20.48	Weinstock	snorkel	summer	present
density (fish * m^{-2})	juvenile	Coho Salmon	21.40	Army Corps Reach 15	electrofish	summer	0.10^{-2}
		steelhead	4.92	Ferrari Carano-Olson	electrofish	summer	0.33^{-2}
			7.12	Boaz	electrofish	summer	0.19^{-2}
			14.06	Truett-Hurst	electrofish	summer	0.20^{-2}
			21.40	Army Corps Reach 15	electrofish	summer	0.06^{-2}

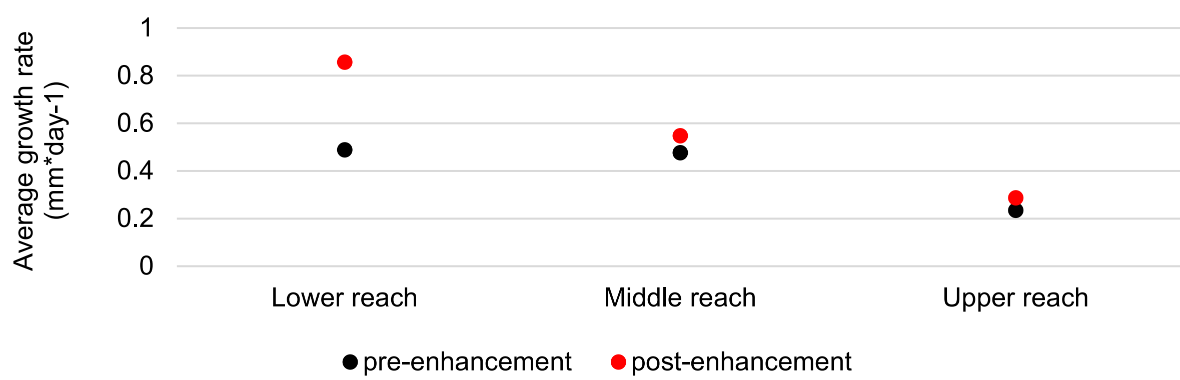


Figure 5.3.12. Comparison of average growth rates by geomorphic reach for steelhead juveniles (≥ 60 mm fork length) in Dry Creek during the summer. Pre-enhancement growth rates were measured in mainstem Dry Creek in 2010 and post-enhancement growth rates were measured in mainstem and constructed side channels in 2022. Sample sizes varied.

Overall, the survival indices estimated for steelhead juveniles in Dry Creek follow trends we observe in tributary streams sampled for the Coastal Monitoring Program (Figure 5.3.13). Environmental conditions in the smaller tributary streams limit our ability to conduct surveys in some years, including the 2021-2022 steelhead smolt migration season.

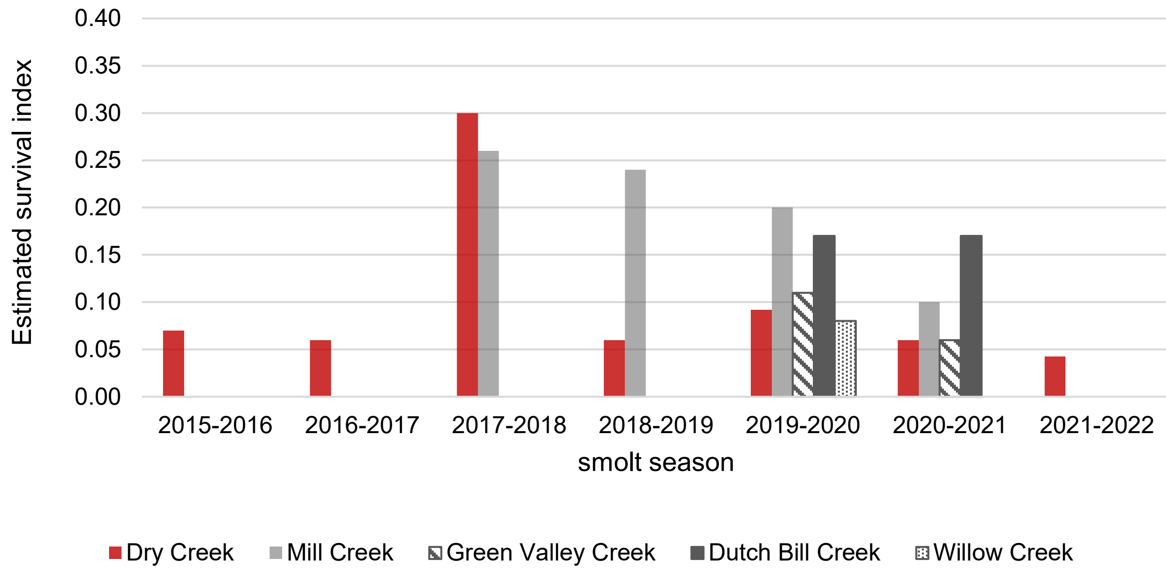


Figure 5.3.13. Comparison of estimated survival index for steelhead juveniles during the smolt migration period (November 1 – June 30) for steelhead originating in Dry Creek and the CMP life cycle monitoring streams (LCM). Estimates were not calculated in LCM streams in seasons 2015-2016, 2016-2017, and 2021-2022 due to drought conditions. The LCM streams Green Valley, Dutch Bill and Willow Creeks were added to the sampling effort beginning in 2019.

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CHAPTER 6 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 7 Adult Salmonid Returns

7.1 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 categorized as "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 2022, the Mirabel fish ladder cameras were in operation from September 1 to December 9 (Figure 7.1.1). With a few exceptions these cameras were operated 24 hours/day after installation until they were removed (Figure 7.1.2).

Chinook Salmon

For the 2022 video monitoring season, 1,180 adult Chinook Salmon were observed passing the Mirabel fish counting station (including "unknown salmonids" prorated as Chinook) (Table 7.1.1). A total of 34 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 63 unknown salmonids 29 were partitioned to Chinook Salmon.

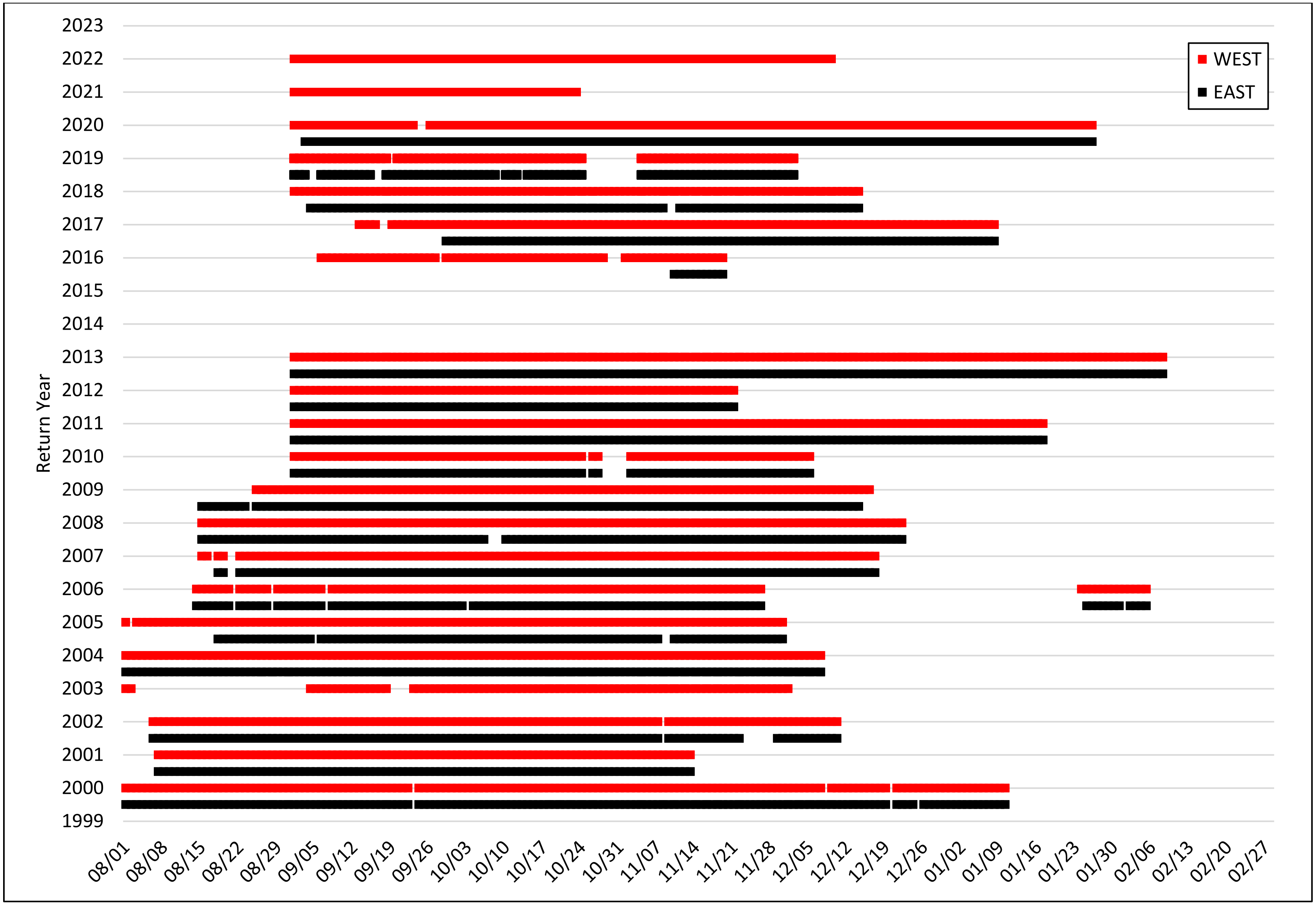

Figure 7.1.1. Period of operation by adult salmonid return year for the video counting station at the Mirabel dam.

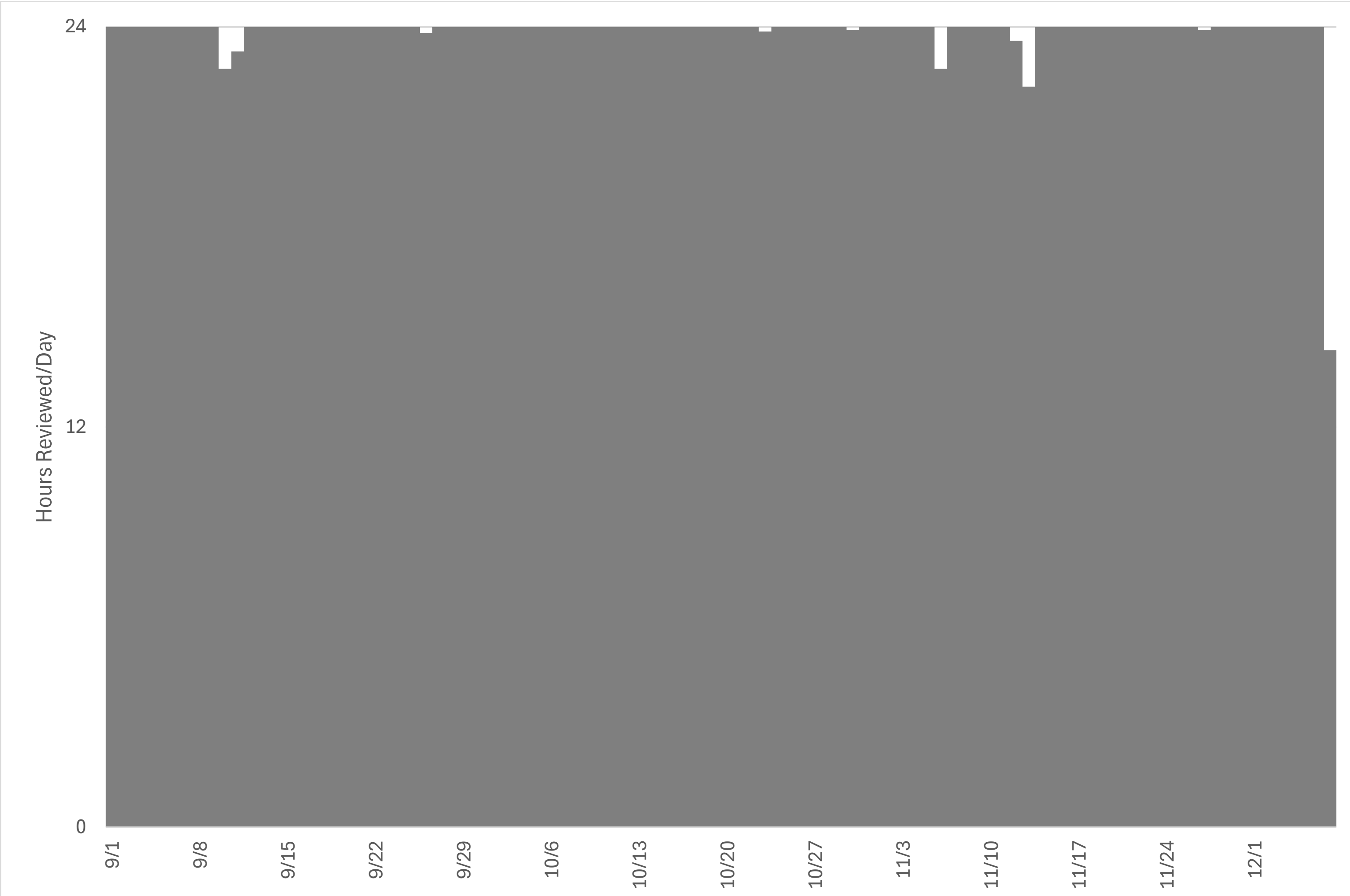

Figure 7.1.2. Number of hours/per day that the west and east fish ladder cameras were in operation at the Mirabel dam in 2022.

Table 7.1.1. Weekly count of adult Chinook salmon at the Mirabel dam fish ladders, 2000-2022. 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	2020	2021	2022
15-Aug	0	0	1	--	0	0	0	0	0	0	--	--	--	--			--	--	--	--	--		--
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	0		0
5-Sep	9	1	18	7	1	4	0	0	0	0	0	0	1	1			0	--	0	0	1		0
12-Sep	36	7	19	20	3	14	3	0	2	0	0	0	2	2			0	0	1	0	0		0
19-Sep	25	12	65	23	8	14	4	1	17	0	3	1	0	1			0	3	4	4	0		2
26-Sep	50	17	1223	181	16	31	8	4	84	0	1	158	70	17			8	2	37	43	12		25
3-Oct	31	240	113	146	42	27	317	10	126	78	669	534	51	44			32	91	77	29	3		10
10-Oct	115	51	628	515	52	112	87	39	82	562	896	390	551	4			291	50	47	26	0		8
17-Oct	81	10	272	232	651	556	532	26	13	177	153	1070	1886	8			392	125	158	52	1		21
24-Oct	465	300	153	532	2287	309	114	106	22	285	280	273	996	27			131	81	50	2	80		37
31-Oct	64	661	505	2969	185	613	1531	250	511	135	94	223	1654	315	Not Operated	Not Operated	56	612	68	22	40	Not Reported	168
7-Nov	23	81	2337	1289	1189	699	298	429	174	335	169	90	619	731			50	366	60	170	135		473
14-Nov	182	--	20	47	221	127	459	154	15	38	43	120	851	1063			103	508	145	110	216		58
21-Nov	201	--	37	95	57	63	53	96	24	129	113	266	50	179			--	71	461	333	64		38
28-Nov	110	--	14	45	60	33	--	425	19	24	76	6	--	99			--	82	66	131	9		190
5-Dec	19	--	53	--	16	--	--	476	18	9	5	1	--	172			--	24	38	--	14		150
12-Dec	15	--	--	--	--	--	--	4	8	28	--	2	--	125			--	24	6	--	36		--
19-Dec	17	--	--	--	--	--	--	--	13	--	--	10	--	73			--	16	--	--	2		--
26-Dec	1	--	--	--	--	--	--	--	--	--	--	16	--	32			--	27	--	--	4		--
2-Jan	0	--	--	--	--	--	--	--	--	--	--	2	--	53			--	11	--	--	5		--
9-Jan	0	--	--	--	--	--	--	--	--	--	--	10	--	58			--	--	--	--	3		--
16-Jan	--	--	--	--	--	--	--	--	--	--	--	1	--	28			--	--	--	--	2		--
23-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	73			--	--	--	--	0		--
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**	**626**	**--**	**1,180**

*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.
***No counts reported for 2021 due to high stream flows in October that ended video operations early.

Coho Salmon

During the monitoring period for the 2022 return year, we observed 67 adult Coho Salmon. These images were reviewed by fisheries biologists 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. Typically, we suggest the basinwide redd survey estimate of 74 (95% CI: 24-124) as the most comprehensive and accurate indicator of all adult Coho (hatchery- and natural-origin) returning to the Russian River basin in 2022-23. However, in 2022-23 there were fewer opportunities to conduct spawning surveys due to high stream flows and the redd survey estimate likely underrepresents the number of redds. 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 historical data from hatchery returns, steelhead migrate and spawn in the Russian River primarily between December and March each year; however, we removed the Mirabel cameras in early December 2022, which missed a significant portion of the steelhead run that occurs after December. In total, 3 steelhead were observed migrating through the Mirabel Fish ladder between September 1 and December 9, 2022.

Conclusions and Recommendations

In 2022 we were able to successfully operate the video camera in the Mirabel dam fish ladder for the duration of the Chinook migration with few issues. In 2016 Sonoma Water determined 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 2020 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 2020 Sonoma Water decommissioned the east fish ladder and improved the power system for the west ladder by implementing a low voltage power system. In 2022 the low voltage power system performed well and little video was lost. However, there were frequently 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.

7.2 Chinook Salmon Spawning Ground Surveys

Although not an explicit requirement of the Biological Opinion, the 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 (the application for which is required by the Biological Opinion) issued by the State Water Resources Control Board (see CHAPTER 3 Pursue Changes to Decision 1610 Flows of this report). Sonoma Water began conducting Chinook salmon spawning surveys in fall 2002 to address concerns that minimum instream flow requirements and subsequent reduction of 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 (Manning and Martini-Lamb 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 7.2.1). 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, which typically occurs in November-December. A crew of two biologists in kayaks visually searched 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 are cancelled or postponed if increased turbidity from heavy rainfall and subsequent high flows that obscure the detection of redds. 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.

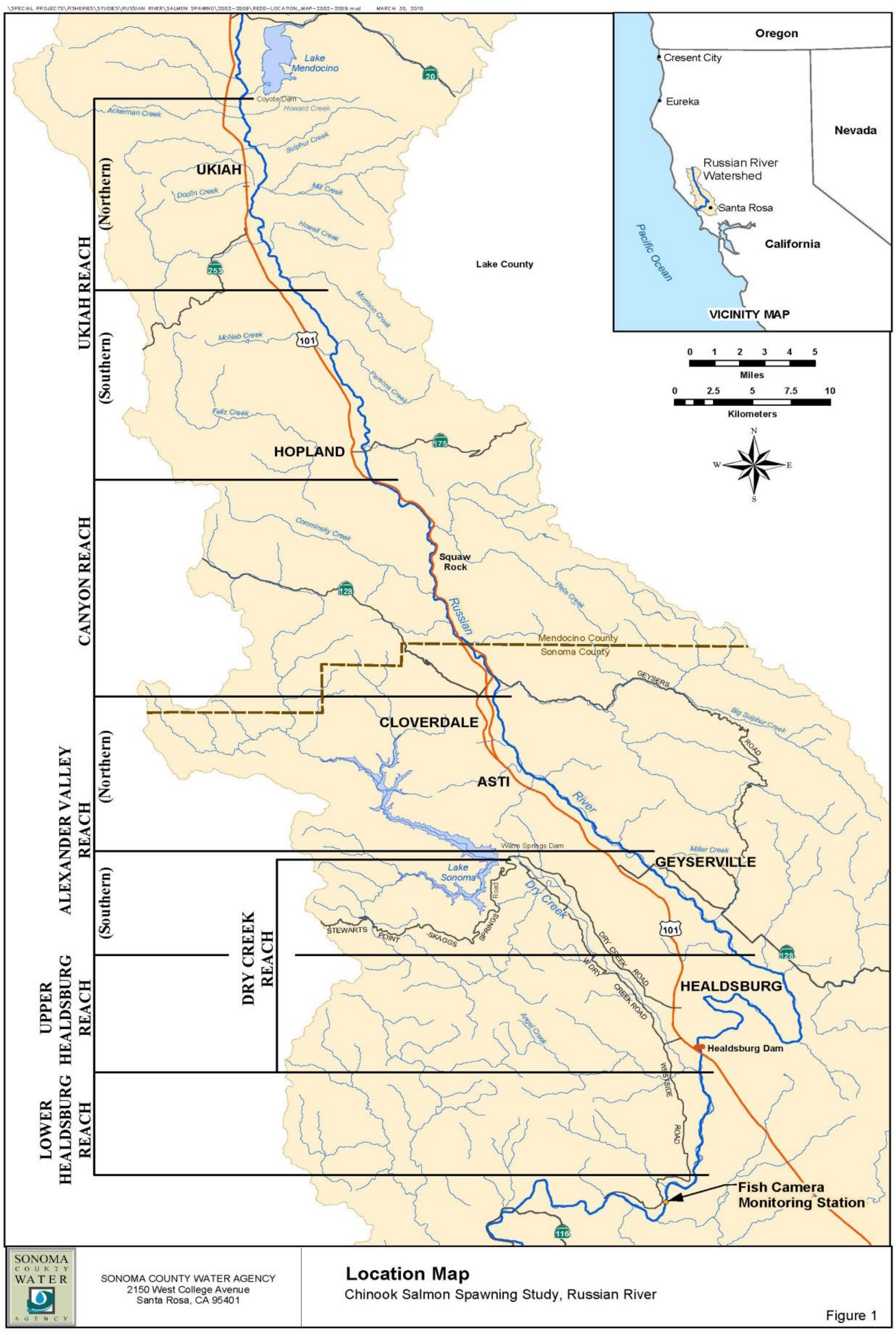

Figure 7.2.1. Chinook salmon spawning survey reaches along the Russian River.

Results

Chinook spawning surveys were conducted in Alexander Valley along the Russian River on December 19, 2022. Chinook salmon spawning surveys were curtailed in Ukiah and Canyon reaches due to high turbidity from Lake Mendocino water releases. Dry Creek surveys were conducted on December 8, 2022.

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek (Table 7.2.1). During 2022, there were 15 redds observed in the Alexander Valley reach of the Russian River. This redd count was the lowest on record. In Dry Creek there were 154 Chinook salmon redds detected, which is below the 20-year average in Dry Creek at 190/year. The highest count of redds in Dry Creek was 362 redds in 2012.

Overall, there has been a substantial decrease in the number of Chinook redds observed in the Russian River watershed since around 2014 (Table 7.2.1). This trend is based primarily on surveys that were conducted most consistently in Alexander Valley, Upper Healdsburg, and Dry Creek reaches. The average number of redds in Alexander Valley reach from 2002 to 2014 was 130 redds and 34 redds from 2015 to 2022, which is a four-fold decrease. Similarly, the averages of redds in Dry Creek reach before and after 2014 was 246 redds and 90 redds, respectively, indicating a near three-fold decline.

Conclusions and Recommendations

Although Chinook salmon surveys were restricted to two reaches in 2022 the distribution of redds appear to be similar to other study years. The abundance of Chinook salmon redds have shown a sharp decline since 2014. 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 to the low abundance of redds.

Table 7.2.1. Chinook Salmon redd abundances by reach, upper Russian River, and Dry Creek, 2002-2022. Redd counts are from a single pass survey conducted during the peak of fall spawning activity. *Survey either not conducted or incomplete.

Reach	River km	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
Ukiah	33.1	511	464	284	*	248	118	20	38	*	*	90[2]	81	*	*	*	*	*	*	*	*	*
Canyon	20.8	277	190	169	*	68	88	36	38	*	*	*	43	*	*	16[2]	*	*	*	*	11	*
Alexander Valley	26.2	163	213	90	*	62	131	65	129	*	97	185	163	*	61[2]	41[2]	39	25	*	*	26	15
Upper Healdsburg	25.6	79	40	8	*	23	67	48	38	*	66	53	57	*	*	1[2]	14	*	*	29	2	*
Lower Healdsburg	8.2	6	0	7	*	1	2	9	30	*	7	4	18	*	*	*	6	*	*	18	0	*
Russian River Total	**113.9**	**1036**	**907**	**558**	*	**402**	**406**	**178**	**273**	*	**170**	**332**	**362**	*	*	*	*	*	*	*	*	*
Dry Creek	21.7	*	256	342	*	201	228	65[1]	223	269	229	362	325	*	78	90	112	86	15	91	*	154

[1]Redd numbers are an estimate.
[2]Redd numbers are presumably an underestimate due to poor survey conditions.

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