Russian River Biological Opinion Status and Data Report

Year 2017 - 2018

Sonoma Water

June 2020

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Accessibility Statement

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Table of Contents

List of Appendices

CHAPTER 1 Introduction

On September 24, 2008, the National Marine Fisheries Service (NMFS) issued a 15-year Biological Opinion for water supply, flood control operations, and channel maintenance conducted by the U.S. Army Corps of Engineers (USACE), Sonoma County Water Agency (Sonoma Water), 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 Sonoma Water. Each organization has its own reporting requirements to NMFS. Because Coho Salmon are also listed as endangered by the California Endangered Species Act (CESA), Sonoma Water is party to a Consistency Determination issued by the California Department of Fish and Wildlife (CDFW) in November 2009. The Consistency Determination mandates that Sonoma Water implement a subset of Biological Opinion projects that pertain to Coho Salmon and Sonoma Water is required to report progress on these efforts to CDFW.

Project implementation timelines in the Biological Opinion, and Consistency Determination, specify Sonoma Water reporting requirements to NMFS and CDFW and encourage frequent communication among the agencies. Sonoma Water 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, Sonoma Water has elected to coalesce reporting requirements into one annual volume for presentation to the agencies. The following document represents the ninth report for year 2017-2018. Previous annual reports can be accessed at http://www.sonomawater.gov.

Sonoma Water 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 Sonoma Water 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 will prioritize options for implementation" of habitat enhancement.

The remaining RPAs do not mention public outreach.

Water Agency Public Outreach Activities – 2017

Meetings

Public Policy Facilitating Committee (PPFC) meeting - The PPFC met in March 2017 at the Sonoma County Board of Supervisors Chambers. Notices for the meetings were sent out to approximately 800 individuals and agencies and a press release was issued. Approximately 80 people attended the meeting.

In 2017, the meeting included a presentation by Jessica Martini Lamb (Sonoma Water) on the Russian River Estuary flood risk feasibility study, followed by a presentation by Natalie Cosentino-Manning on the NOAA Habitat Blueprint, Studying for Sea Level Rise. Pam Jeane (Sonoma Water) reported on the Russian River Fish Ladder and Viewing Gallery. Keenan Foster (Sonoma Water) and Katharine Carter and Rich Fadness (North Coast Regional Water Quality Control Board) discussed the Water Quality Cooperative Monitoring Program, focusing on Cyanobacteria.

[1] DFG (Department of Fish and Game) is now known as the California Department of Fish and Wildlife.

David Manning (Sonoma Water) gave a brief presentation on the Dry Creek Habitat Enhancement Project.

Community Meetings, Events & Tours – The ninth Russian River Estuary Lagoon Management Community Meeting was held on May 15, 2017 at the Monte Rio Community Center. The meeting included discussions of 2016 Lagoon Management efforts and the 2017 plan (Martini Lamb); results from 2016 water quality monitoring and 2017 plans (Jeff Church, Sonoma Water); and 2016 pinniped monitoring results (Andrea Pecharich, Sonoma Water). About 60 people attended the meeting.

A community meeting on Dry Creek habitat enhancement was held in February 2017 at the Lake Sonoma Visitors Center. The meeting was co-hosted by the Dry Creek Valley Association, the Winegrape Growers of Dry Creek, the USACE and the Water Agency. Informational mailers were sent to more than 700 people and about 50 people attended. Manning provided an overview of the project, including 2016 construction and 2017 plans, and monitoring efforts.

Tours held for public officials and others (coordinated with NMFS, DFG, Corps and Water Agency staff) included Sonoma Water Director Lynda Hopkins, Sonoma Water's water contractors, and the general public. In addition, the Mirabel Fish Passage Improvement Project was incorporated into the Water Education field tours, introducing more than 1,000 students to the project and its purpose.

Other Outreach

Free Media – In 2017, press releases were issued on community meetings regarding the estuary and Dry Creek, the Public Policy Facilitating Committee meeting, the Fish Habitat Flow and Water Rights project, the cost sharing agreement between the USCAE and Sonoma Water for the Dry Creek project. The Water Advisory Committee (comprised of elected officials from cities and water districts that receive water from Sonoma Water) received Monthly Updates of Biological Opinion activities.

Electronic Media – The Water Agency continually updated its Biological Opinion webpage, including links on new documents and meetings. Email alerts regarding activities in the estuary were issued about half a dozen times in 2017.

Materials – In 2017, educational signs were developed and installed in the Mirabel Fish Passage Improvement Project focused on the purpose of the project, the Russian River watershed and the salmon life cycle.

Nearly 800 copies of the Dry Creek Habitat Enhancement Bulletin were mailed to residents throughout the Dry Creek Valley and distributed at meetings and during tours. The six-page newsletter covered topics including: Plans for construction of habitat features in the summer of 2017; USACE funding; monitoring of habitat features; profiles of participating landowners; and an article on adaptive management following the winter high flows.

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. Sonoma Water 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, Sonoma Water manages the water supply storage space in these reservoirs to provide a water supply and maintain summertime Russian River and Dry Creek streamflows.

Sonoma Water holds water-right permits[1] issued by the State Water Resources Control Board (SWRCB) that authorize Sonoma Water to divert[2] Russian River and Dry Creek flows and to re-divert[3] water stored and released from Lake Mendocino and Lake Sonoma. Sonoma Water 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). Sonoma Water 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

[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 Sonoma Water "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 Sonoma Water 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. Sonoma Water 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.

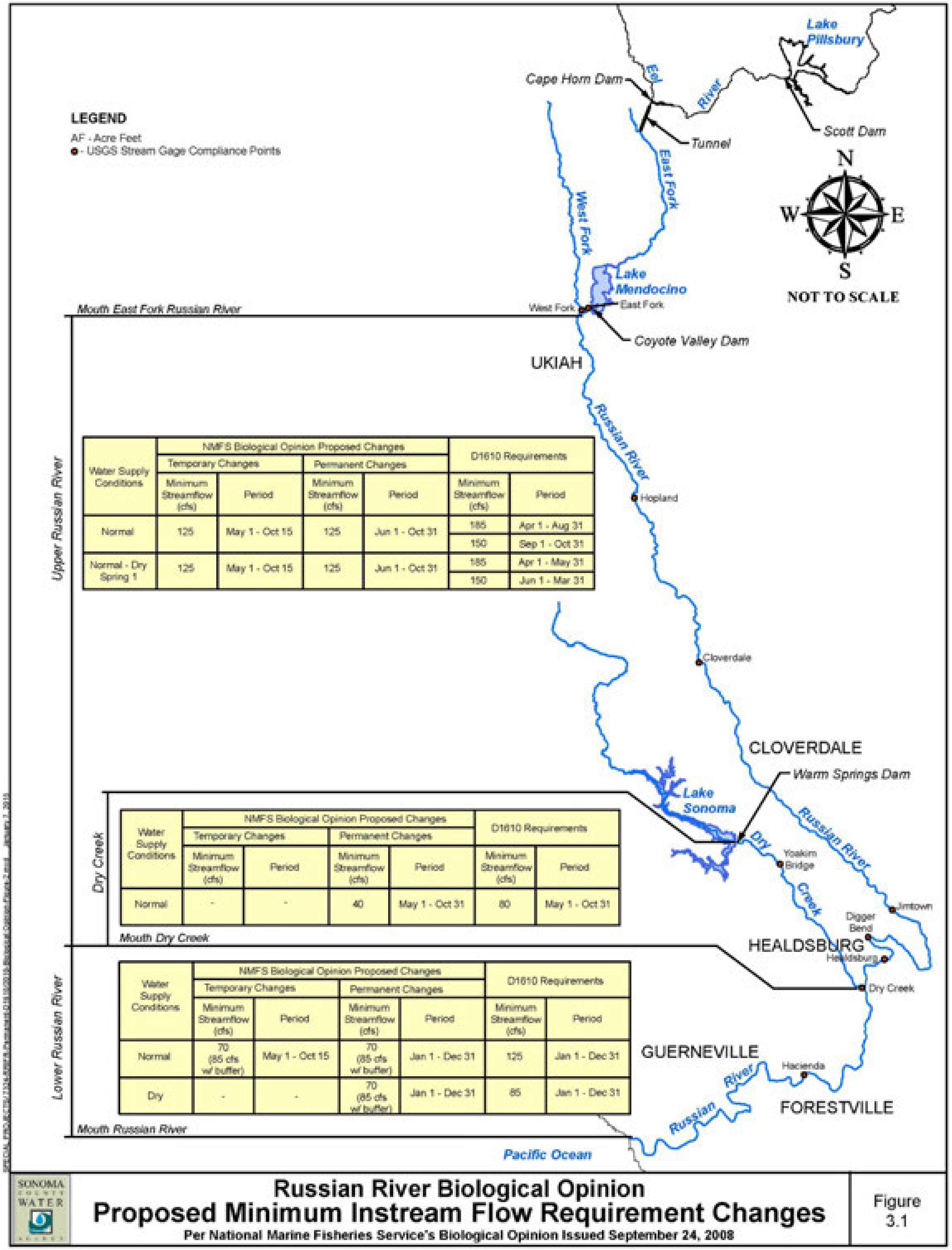
Summary Status

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, Sonoma Water issued a Notice of Preparation (NOP) of an Environmental Impact Report (EIR) for the Fish Habitat Flows and Water Rights Project (Fish Flow Project).

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

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 Sonoma Water 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

Sonoma Water submitted a Temporary Urgency Change Petition to the SWRCB on April 17, 2017, to comply with the requirements of the Russian River Biological Opinion (Appendix 3.1). The SWRCB issued an Order approving the Water Agency's TUCP on May 19, 2017 (Appendix 3.2).

The SWRCB's Order made the following changes to the Water Agency's permits until October 15, 2017: minimum instream flow in the upper Russian River (from its confluence with the East Fork of the Russian River to its confluence with Dry Creek) remained at or above 125 cfs; and minimum instream flow in the lower Russian River (from its confluence with Dry Creek to the Pacific Ocean) remained at or above 70 cfs.

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

Reports to fulfill the terms of the Order were prepared and submitted to the SWRCB and are provided in Appendix 3.3. Water quality monitoring results were posted to Sonoma Water website and are provided in Appendix 3.3. Water quality monitoring in the Russian River Estuary is further discussed in Chapter 4.

References

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

CHAPTER 4 Estuary Management

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 County Water Agency 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 Sonoma Water. The Water Agency'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 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 PWA) to prepare the Russian River Estuary Outlet Channel Adaptive Management Plan (Appendix 4.1). 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. The annual meeting with regulatory agency staff to discuss the prior year's beach management activities and preparation of the updated 2017 annual Outlet Channel Adaptive Management Plan Estuary management for 2017 was discussed at a meeting on April 20, 2017, that included representatives from NMFS and CDFW, as well as Sonoma Water, University of California, Davis's Bodega Marine Laboratory (Bodega Marine Lab), the USACE, the North Coast Regional Water Quality Control Board (NCRWQCB), and ESA PWA. Only minor updates to the prior year's plan were made in the 2017 plan, which includes a summary of physical processes from 2011 to 2016 as appendices to the plan. Prior to 2016, outlet channel implementation had occurred only in 2010 (summarized in Appendix F of the 2017 Outlet Channel Adaptive Management Plan; Appendix 4.1). An outlet channel was attempted twice in 2017, on July 17 and September 28. In the first instance, water flowing through the outlet channel scoured the channel and, within a day, caused self-breaching of the barrier beach. In the second, the outlet channel appeared to have been intermittent over a five-day period, and ended in a full breach, which may have been caused by beachgoers, as described in the following sections.

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 2017 and provided to NMFS and CDFW. The April 2017 topographic survey was cancelled due to the presence of neonate (less than 1 week old) harbor seals at the mouth of the Russian River. The beach topographic maps are provided in Appendix 4.2. 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.

2017 Beach and River Mouth Conditions

Several inlet closure events occurred early in the management period: July 4 – 17, August 5 – 27, September 12 – October 3, and October 7 – 19 (ending in an artificial breach outside the lagoon management season, Figures 4.1 – 4.3). A lagoon outlet channel was attempted twice in 2017 during the lagoon management period on July 17 and September 28.

A barrier beach was formed eight times during 2017, during four of these closure events Sonoma Water conducted water level management activities at the barrier beach (Table 4.1). The Russian River mouth was closed to the ocean for a total of 85 days (or 23%) in 2017, mostly during the fall months. As described in Appendix M of the 2018 Outlet Channel Adaptive Management Plan, during the 2017 management period, May 15 to October 15, Sonoma Water staff regularly monitored current and forecasted Estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state (Appendix 4.3; ESA PWA 2018).

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

Time series of Estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 4.1 for the entire 2017 management period. The lagoon water level time series (Figure 4.1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall. During the management period, Russian River flows were higher in 2017 than the previous drought years, 2013-2015. As shown in Figure 4.1d, flows at Guerneville never dropped below 100 cfs during the management period, which was common in most years after 2010.

As in prior years, wave heights declined through July and August (Figure 4.1b). However, there were several prolonged periods of swell wave conditions, which are the likely cause of the closure events that occurred in July and August.

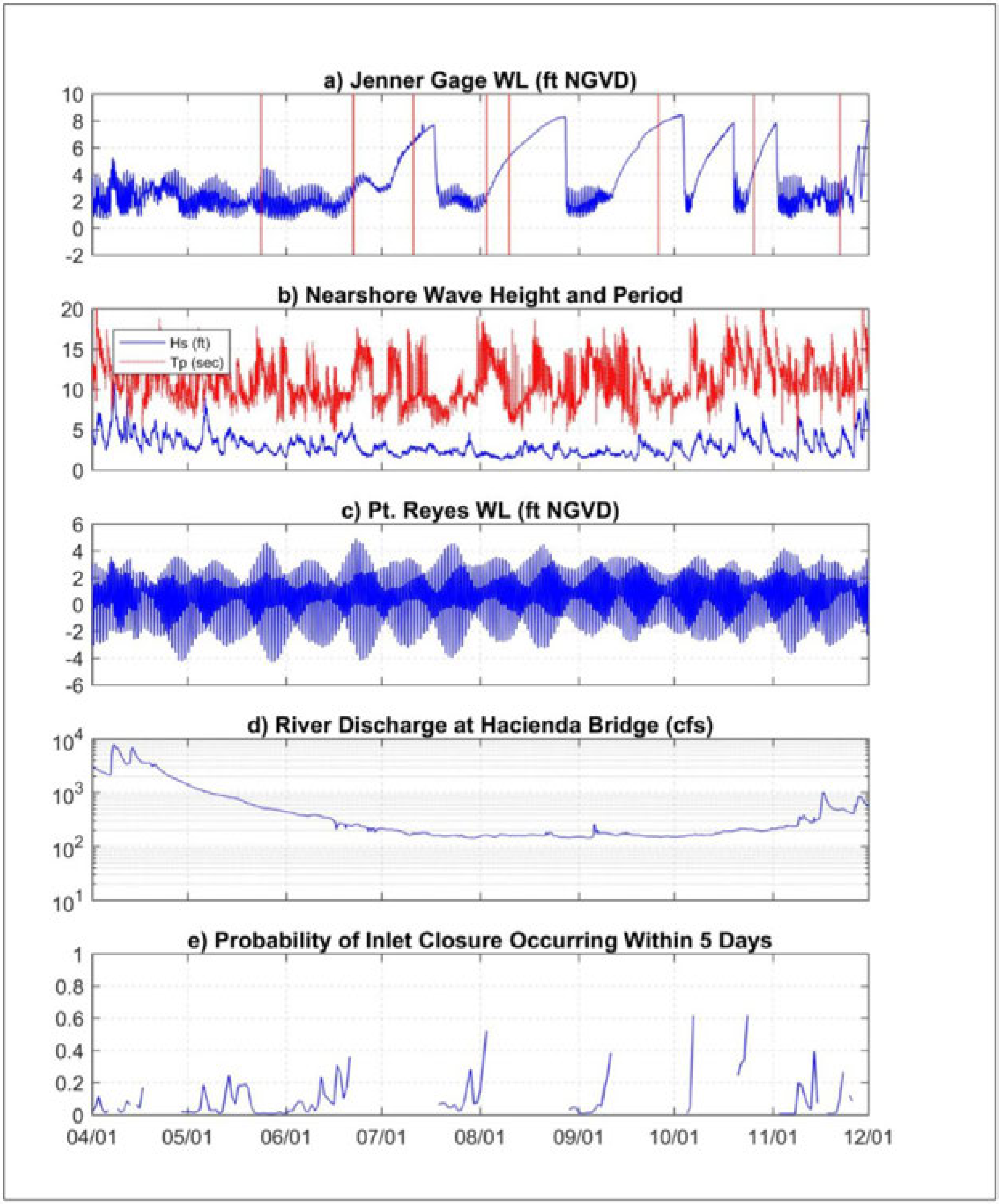


Figure 4.1. Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2017.

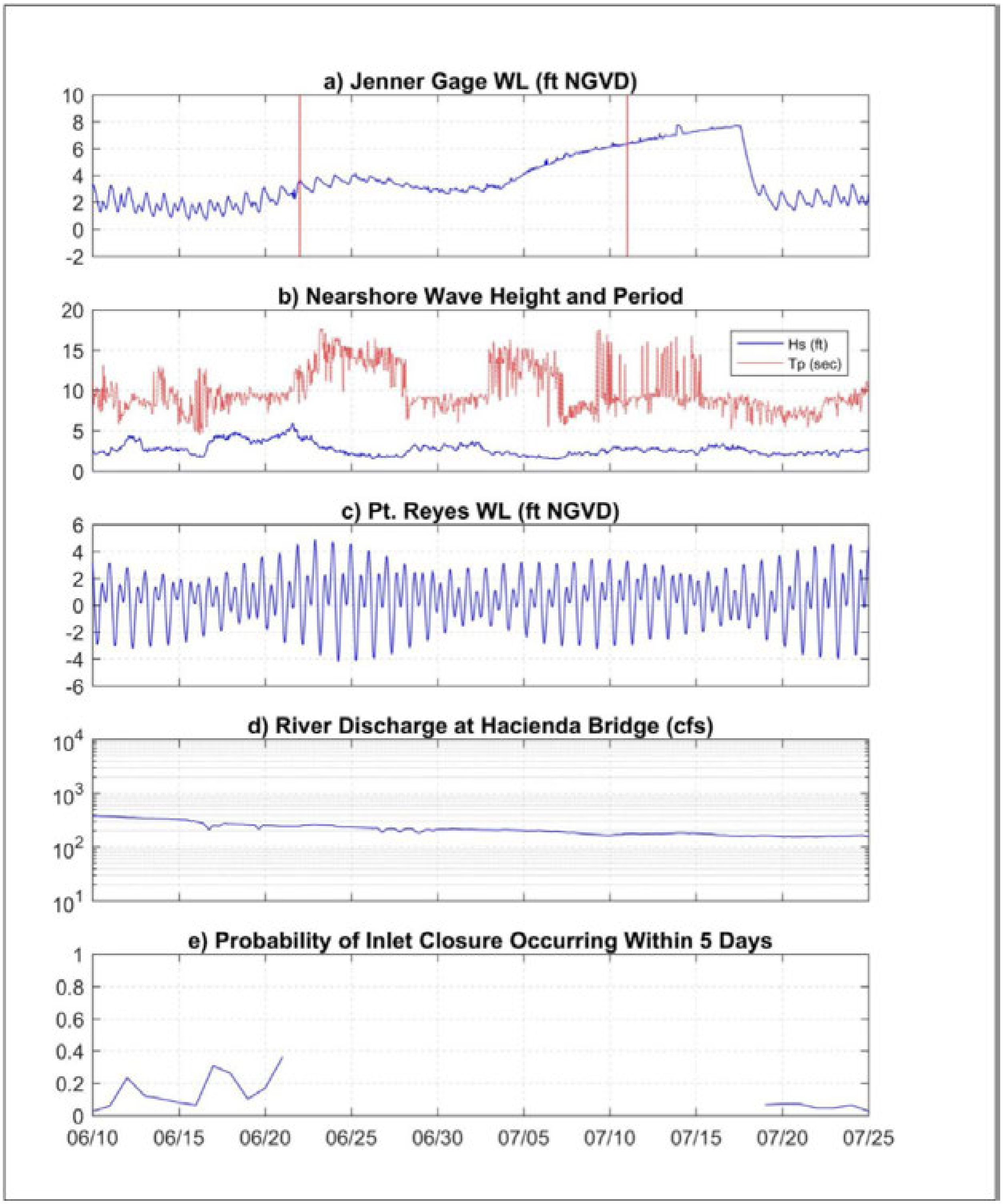


Figure 4.2. Estuary, Ocean, and River Conditions Compared with Closure Probability: June – July 2017.

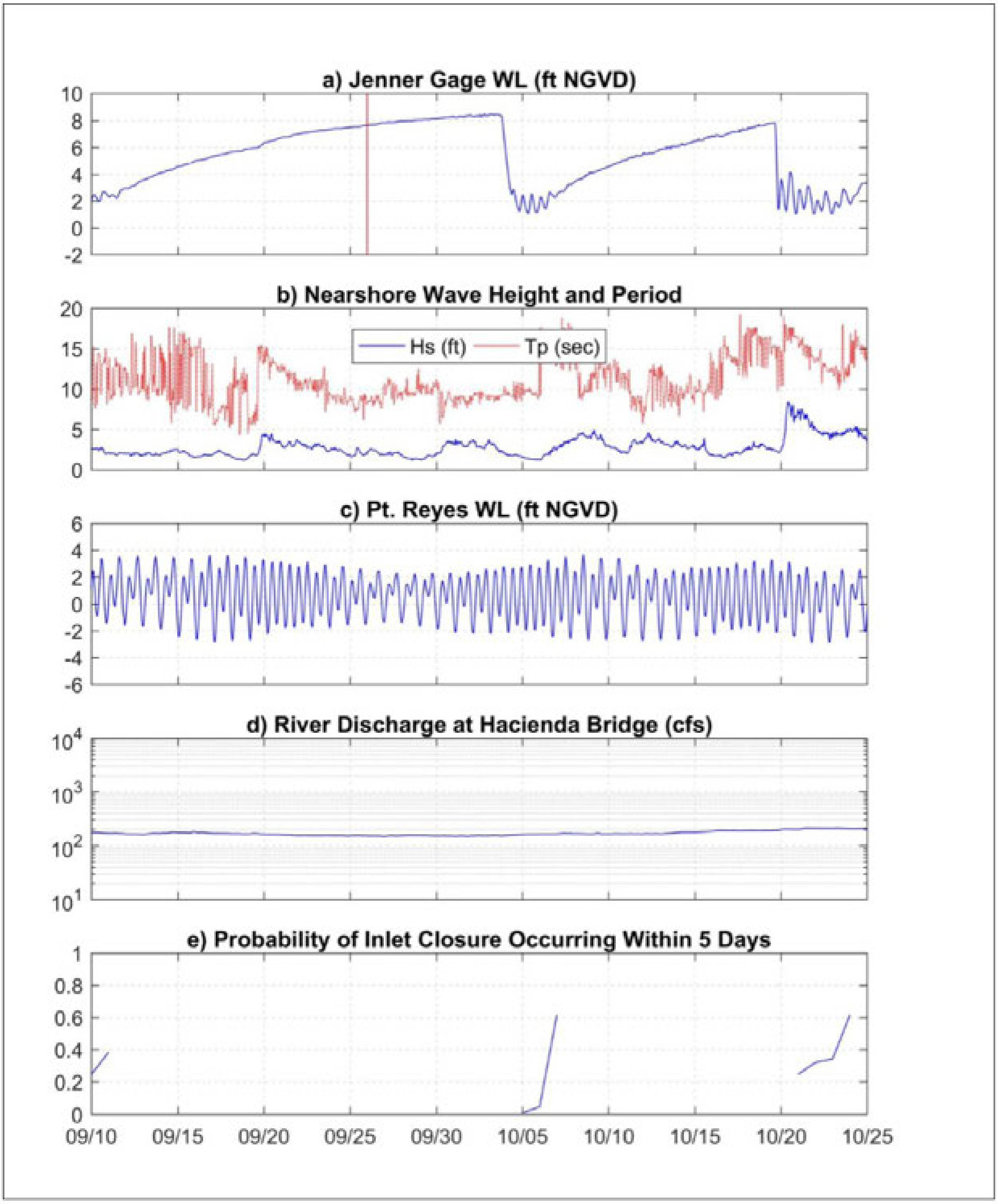


Figure 4.3. Estuary, Ocean, and River Conditions Compared with Closure Probability: September – October 2017.

Table 4.1. Summary of beach management activities at Goat Rock State Beach for the Russian River Estuary Management Project, 2017.

Closure Date	Beach Management Date	No. Days Closed	Activity Time[1]	Water Elevation (ft)[2]	Beach Management Activity[3]	Excavated Volume (CY)[4]
4-Jul	17-Jul	13	11:20am-12:50pm	7.75	Lagoon Outlet Channel	668
5-Aug	27-Aug	22	None	8.34	None	0
12-Sep	28-Sep	22	9:40-10:55am	7.96	Lagoon Outlet Channel	278
7-Oct	19-Oct	12	12:44-1:51pm	7.88	Pilot Channel	402
25-Oct	2-Nov	8	None	7.88	None	0
26-Nov	28-Nov	2	None	6.19	None	0
29-Nov	2-Dec	3	2:04pm-3:18pm	10.07	Pilot Channel	390
13-Dec	18-Dec	5	None	7.42	None	0

[1] Estimated period that excavator/bulldozer equipment was on the beach.
[2] Water surface elevation recorded at the Jenner gage located at the Jenner Visitor's Center.
[3] Beach management activity consists of a pilot channel to initiate an artificial breach of the barrier beach or outlet channel to form a lagoon.
[4] Estimated volume of sand excavated with heavy equipment during artificial breach or lagoon management activity.

The river mouth migrated north of Haystack Rock in 2017 due to winter high flows (Figure 4.4). This set up conditions for a naturally-elongated channel in June, influencing the beach growth pattern throughout the management season (ESA 2018). The first closure of the season occurred after the mouth was naturally perched above tides from June 27 to July 4 (Figures 4.1 and 4.2). High winter flows in 2017 may have encouraged this condition because this northward location typically causes the inlet to elongate as flows draw down into summer conditions, leaving a long, more frictional channel. Thus, despite relatively high discharge to the Estuary in June (200-400 cfs), the river mouth was constraining tides in the lagoon to a range of less than 2 feet for much of the month, possibly as a result of higher friction through the channel. A swell wave event with periods above 15 seconds occurred on June 22 and 23, causing the channel bed to shoal, and the water level in the lagoon to rise to above 3 feet NGVD. By June 27, water surface elevations in the Estuary were at 4 ft NGVD and slowly falling with minimal tidal fluctuations. Water levels declined to about 3 ft NGVD by July 4, which suggests that flows were strong enough to erode bed sediments and that the natural outlet channel may not likely have persisted for long. On July 4, another swell wave event occurred, creating a barrier beach and closing the mouth.

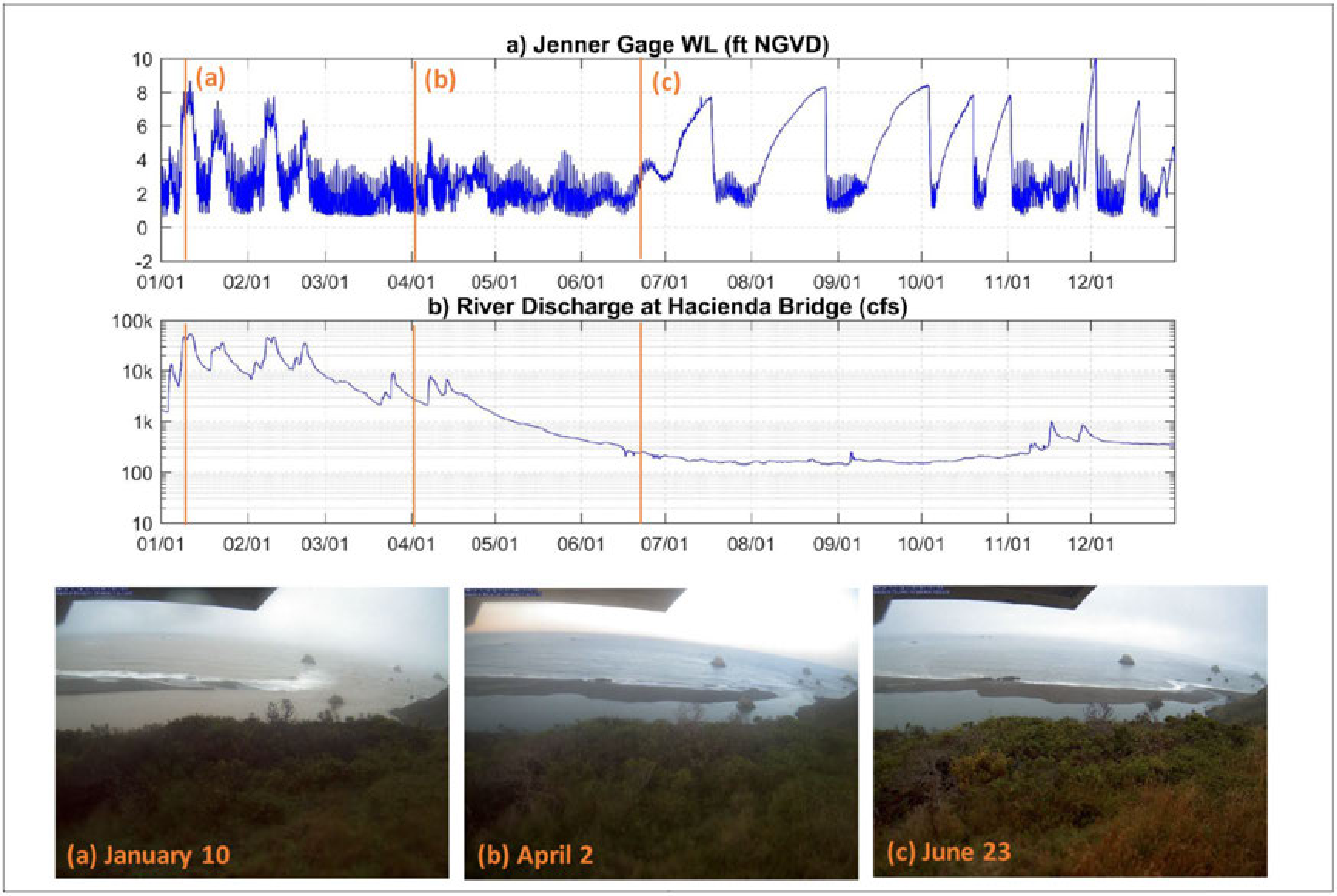


Figure 4.4. Russian River during a) fluvial flooding on January 10, 2017; b) during moderate discharge conditions on April 2, 2017; and c) during natural perched conditions on June 23, 2017.

Sonoma Water monitored conditions throughout the early July closure event. Flows continued to decline to about 180 cfs by mid-July, and water levels at the Jenner gage increased to above 7 ft NGVD. Since the inlet was located at the north end of the beach, rather than at the jetty like in the drought years of 2013-2015, the beach was able to grow quickly enough to allow the higher water levels to occur. The years in which the inlet remained near the jetty coincided with a multi-year drought, and may have been due, in part, to the relatively small size of wet season discharge which historically had caused the inlet to shift north (Behrens et al. 2009).

Sonoma Water implemented an outlet channel on July 17 at 12:50 pm (Figure 4.5). Peak water surface elevation at the Jenner Visitor Center prior to the event was 7.75 ft. The outlet channel was excavated approximately 1,000 feet northwest of the jetty in roughly the same location that the prior natural perched mouth had occurred (Figure 4.6). The channel had a width of 30 feet, length of 90 feet, and an invert elevation of approximately 7.2 ft NGVD. Excavation of the outlet channel was planned during rising tides in anticipation of the tides conveying sand into the channel and thereby reducing the potential for self-breaching. Less than a day after the outlet channel excavation, the channel scoured open (Figure 4.5) and water surface elevations in the Estuary declined.The river mouth remained open through the remainder of July (Figure 4.1), but a swell-wave event with periods above 15 seconds occurred for several days during the first week of August, closing the river mouth on August 5. During this time, river inflows were still relatively high for summer, between 150 and 180 cfs. Water surface elevations in the Estuary/lagoon increased more slowly than the prior event, but surpassed 7 ft by August 17. Despite otherwise favorable conditions for outlet channel implementation, the beach berm was too narrow for safe access of equipment to the site. Water levels continued to rise to approximately 8.3 ft at the Jenner Visitor’s Center gage before the mouth self-breached on August 27.

Swell wave conditions were present throughout September, and the river mouth closed again on September 12 (Figure 4.3). Unlike the August event, long-period waves were consistently present, allowing the barrier beach to widen and creating safer conditions for equipment to reach the site. River inflows remained steady at 150-180 cfs. Sonoma Water implemented an outlet channel on September 28 at 10:55 am. The outlet channel was again located about 1,000 feet north of the jetty, where an outlet channel had naturally occurred in June. Compared to the July implementation, this channel was longer and wider, with a length of 150 feet and a width of 50 feet. The invert elevation was also higher, at 8.3 ft NGVD, which was approximately 0.3 feet above the lagoon water surface elevation at the time the channel was constructed. The plan was to allow lagoon water levels to increase to the outlet channel’s elevation, at which time the outlet channel would allow lagoon water to flow out into the ocean to reduce the chance of flooding and prolong the freshwater/brackish water conditions for salmon rearing habitat, up until just below the flood stage of 9 ft NGVD. Just as water levels reached the elevation of the outlet channel, the mouth breached on October 3. A photograph taken from the Highway 1 overlook indicates a narrow (<10 ft wide) and lower elevation channel located within the full outlet channel, which suggests that the narrower channel may have been excavated by beachgoers (Figure 4.7). Unfortunately, this possible interference obfuscates the potential performance of excavating an outlet channel above existing lagoon water levels.

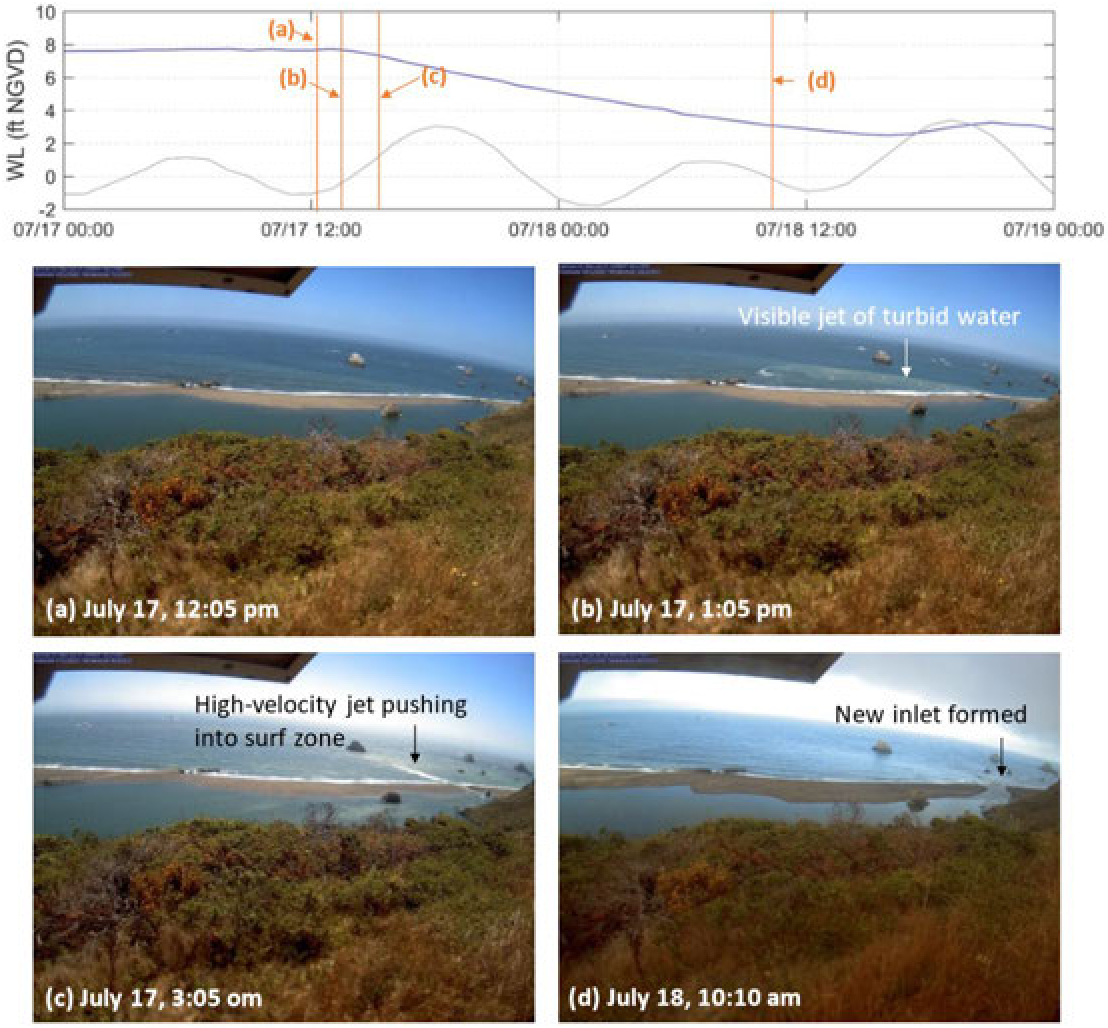


Figure 4.5. Sequence of photographs depicting the July 17, 2017, outlet channel implementation.

Figure 4.6. Locations of beach management activities in 2017 at the Russian River mouth, Goat Rock State Beach. Lines crossing the barrier beach are pilot channels for artificial breaching (red) and outlet channels to form a lagoon (blue). Self-breach events are not shown.

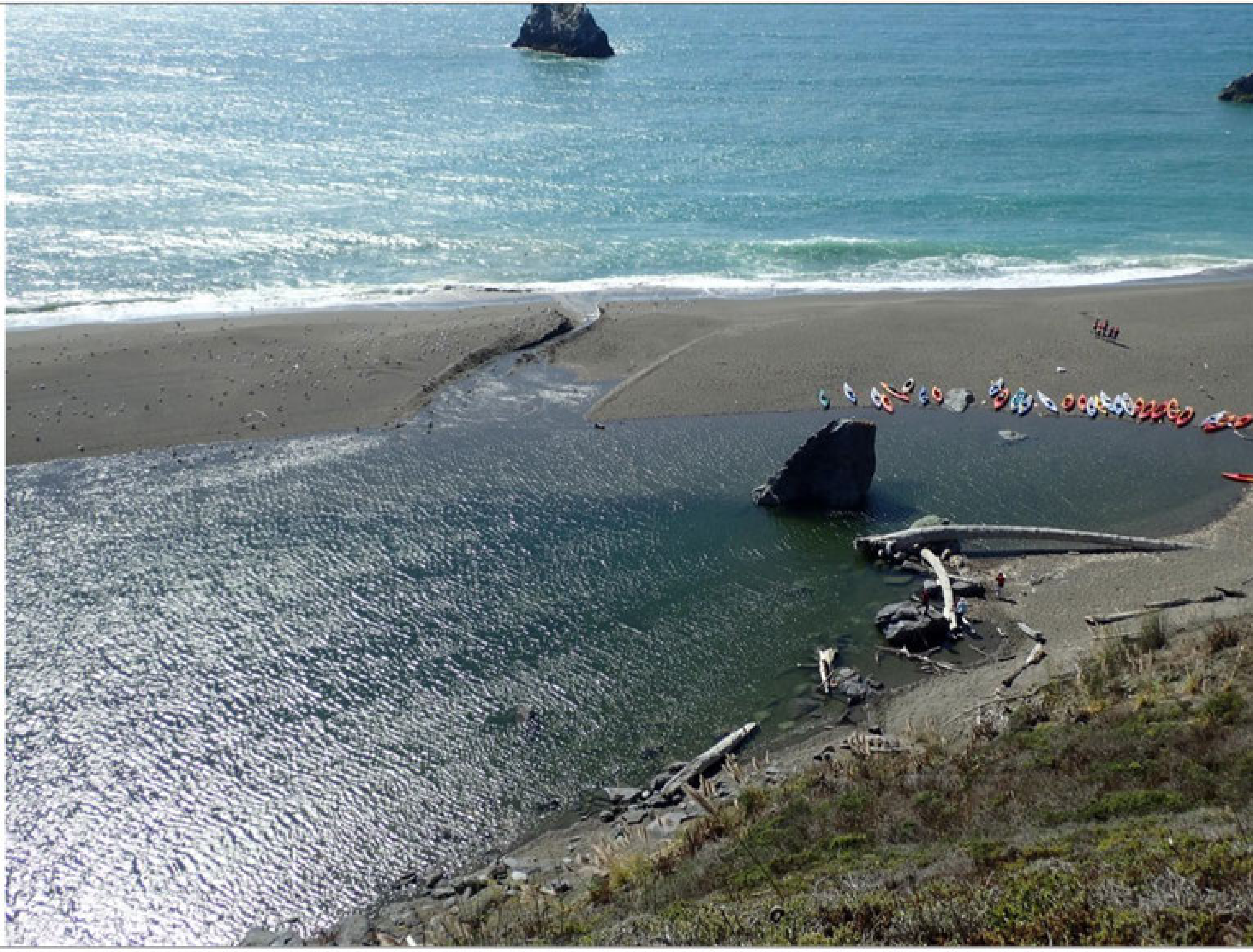


Figure 4.7. Photograph from October 3, 2017, showing conditions immediately after unplanned breach within the excavated outlet channel.

The mouth closed again on October 7, but an outlet channel could not be implemented prior to the end of the management season on October 15. Sonoma Water artificially breached just north of Haystack Rock on October 19, with estuary water levels reaching a peak of 8.38 ft.

In addition to having two outlet channel implementations and a period of naturally perched conditions, 2017 was also notable for having significant winter flows, which led to the mouth migrating to the north end of the beach. This led to a pronounced change in beach morphology, lowering the overall beach crest height north of the jetty groin and regrowth along most of the site throughout the management season. This is notable because in 2016, without mouth migration to the north, the beach north of Haystack Rock had grown as high as 18-19 ft NGVD by October.

Appendix M of the 2018 Russian River Estuary Outlet Channel Adaptive Management Plan (ESA 2018) offers lessons learned based on 2017 observations of the Estuary, associated physical processes, and the Water Agency's planning for outlet channel management. These are summarized here and may be found in Appendix 4.3 of this report for fuller context:

- Flows of 55,000 cfs appear to be sufficient to cause the inlet to migrate north of Haystack Rock, which set up large-scale resetting of the beach berm. This was the first time that peak river flows surpassed 43,000 cfs since 2006.
- Natural outlet channel conditions (though rare and short-lived) are more likely to occur when the channel is naturally elongated, which was the case in June 2017 when the inlet was at the far north end of the beach. This natural channel was several hundred feet long, and likely longer than could be implemented within the allowable limit of excavation on the beach for managed outlet channel implementations..
- The natural outlet channel conditions observed from June 27 to July 3 happened at relatively-low water levels (3-4 ft NGVD), and had a steady decline, suggesting that the channel would likely have eventually eroded to re-form an inlet if the mouth had not been closed on July 4 due to wave action.
- With the inlet located north of Haystack Rock, the beach between the inlet and the jetty groin gained elevation more rapidly in spring than in years when the inlet remained south near the jetty. This added height enabled the outlet channel implementation in early July.
- Rare closure events that occur in late summer, such as the early August 2017 event, may not have enough seasonal wave power to build a wide enough beach to access the site, even if discharge and other conditions are ideal.

Artificial Breaching

Outside of the management season, there were four mouth closures in 2017. Sonoma Water artificially breached the barrier beach at the Russian River mouth outside the lagoon management period twice in 2017 (Table 4.1; Figure 4.6). Time series photographs of the December 2 event are shown in Figure 4.8. The breachings were necessary to minimize flood risk to low-lying structures, which occurs at or above an elevation of approximately 9 feet NGVD at the Jenner gage located at State Parks' Jenner visitor center. The December 2 breaching event was a result of closure of the river mouth on November 29. Water surface elevations

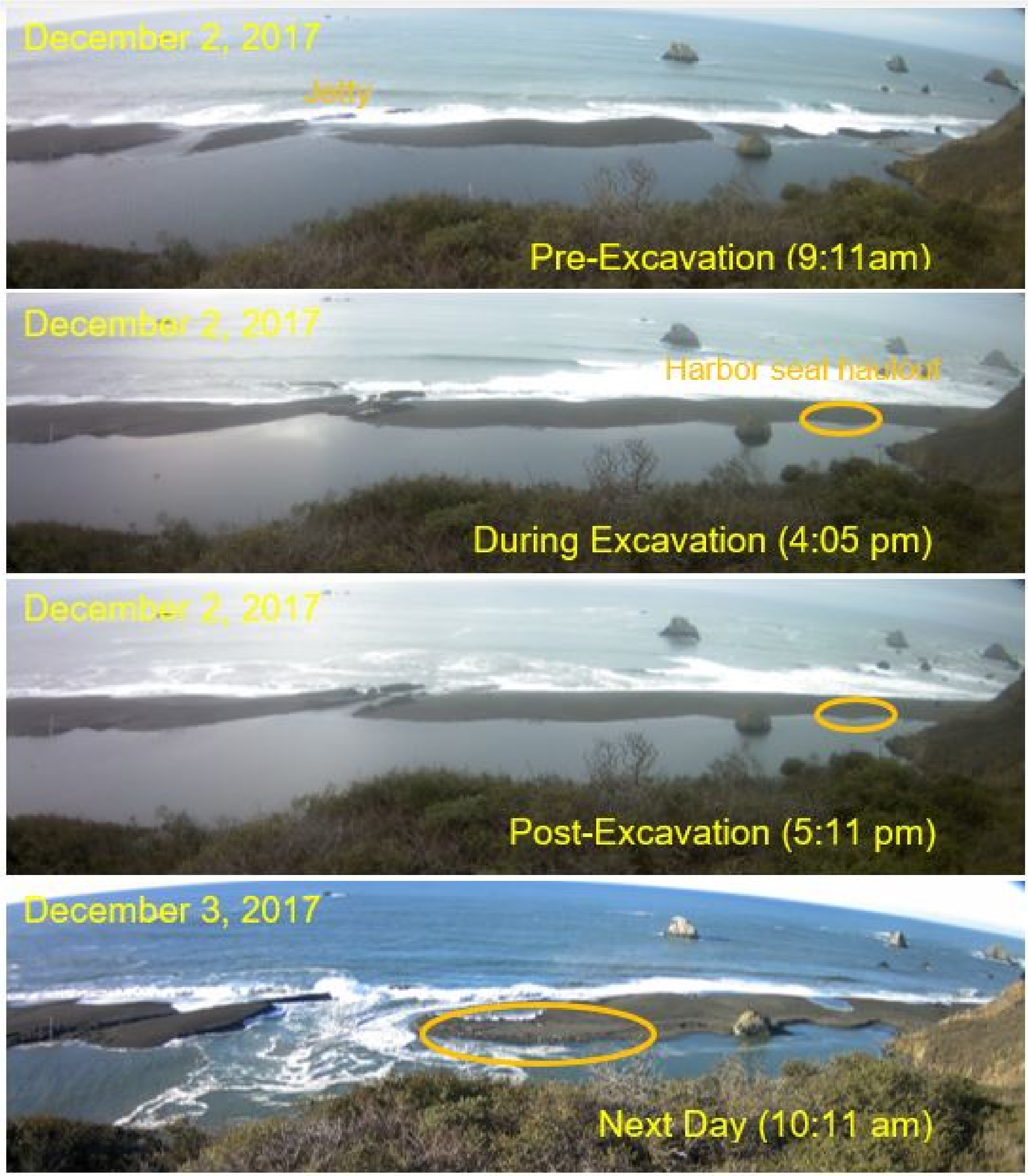


Figure 4.8. Artificial breaching at the mouth of the Russian River Estuary, December 2, 2017. Large waves and high tide delayed excavation until late afternoon (top panel). Photographs show pre-management through next day conditions.

within the lagoon increased quickly, exceeding the 9 foot flood stage within a couple of days. Water surface elevation in the lagoon reached 10.07 ft at the time of artificial breaching. No artificial breaching activities occurred during the lagoon management period (May 15 – October 15).

A pre-construction field meeting to discuss pinniped haulouts, permit conditions, and safety issues was held at the Highway 1 overlook in the morning with Sonoma Water staff prior to staff entering the beach for each breaching event. Project activities were monitored by the project manager, breaching crew lead staff, and biological monitor at the Highway 1 overlook and were in radio contact with the breaching crew on the beach.

Sonoma Water breaching crew was comprised of the equipment operator, two staff on foot monitoring safety conditions, and an additional staff member near the jetty and work area boundary to talk with any beach visitors. The excavator was escorted from the Goat Rock State Beach parking lot across the unvegetated sandbar to the river mouth. The excavator and field crew departed the beach once the barrier beach was breached.

Jetty Study

The Russian River Biological Opinion, RPA 2, includes a step if adaptive management of the outlet channel as described, “is not able to reliably achieve the targeted annual and seasonal Estuary management water surface elevations by the end of 2010, Sonoma Water will draft a study plan for analyzing the effects and role of the Russian River jetty at Jenner on beach permeability, seasonal sand storage and transport, seasonal flood risk, and seasonal water surface elevations in the Estuary. That study will also evaluate alternatives for achieving targeted estuarine management water surface elevations via jetty removal, partial removal of the jetty, jetty notching, and potential use of the jetty as a tool in maintaining the estuary water surface elevations described above.”

ESA PWA, at the request of Sonoma Water, developed a plan to study the effects of the Goat Rock State Beach jetty on the Estuary in 2011 (ESA PWA 2011). In addition, it described the recommended approach for developing and assessing the feasibility of alternatives to the existing jetty that may help achieve target estuarine water surface elevations. As such, this study plan fulfills a portion of the Water Agency’s obligations under the Biological Opinion. The Biological Opinion directs Sonoma Water to change its management of the Estuary’s water surface elevations with the intent of improving juvenile salmonid habitat while minimizing flood risk. Geophysical field studies were completed in 2014. The draft report was reviewed by resources agencies in 2016. The final report was prepared in 2017.

The Jetty Study described the extent and composition of the jetty structure; its effects on beach (groundwater) permeability, sand storage and sand transport (ocean wave conditions, beach morphology, and inlet morphology); and evaluated its role in flood risk to property adjacent to the estuary. The Jetty Study provided initial evaluation of the future beach morphology with sea level rise. It also described the feasibility of alternatives for modifying or removing the jetty to enhance management of the estuary.

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. 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.

Sonoma Water was awarded federal funding from the National Oceanic and Atmospheric Administration (NOAA) under its Habitat Blueprint framework. The Habitat Blueprint is NOAA's strategy to integrate habitat conservation throughout NOAA, focus efforts in priority areas, and leverage internal and external collaborations to achieve measurable benefits within key habitats. The Russian River watershed was selected as the nation's first Habitat Focus Area under the Habitat Blueprint strategy. One of the federally-funded projects was an effort to expand the United States Geological Survey (USGS) 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. In 2016, the USGS completed the Sonoma Coast and Russian River Estuary model scenarios that included an open Russian River mouth. These model scenarios were incorporated into the Our Coast, Our Future (OCOF) web platform by Point Blue Conservation Science (http://beta.ourcoastourfuture.org/index.php?page=russian-river-project-team). The model scenarios for a closed Russian River mouth were completed in 2017. The Russian River scenarios illustrate the differences in extent of flooding and depths of sea level risk and storms combined with river discharge under conditions of an open or closed Russian River mouth. The results were computed with the same 100-year coastal storm event as in previous CoSMoS simulations in this area, but with a higher fluvial discharge rate that approaches the flood stage in Guerneville (9.75 m or 32 feet). This grant-funded effort included staff of the County of Sonoma working on the Local Coastal Plan update. The County's Permit Resources and Management Department is updating its Local Coastal Plan, including consideration of sea level rise impacts to the lower Russian River. Sonoma Water hopes to use the CoSMoS and OCOF information to inform future flood risk feasibility studies of sea level rise and climate change effects on estuary flood risk and habitat management.

Pinniped Monitoring

In addition to the Flood Management, Water Quality, and Habitat Conditions monitoring summarized in this report, Sonoma Water also monitors pinnipeds at the mouth of the Russian River.

An Incidental Harassment Authorization Letter of Authorization (LOA) was issued by the NMFS pursuant to Section 101(a)(5)(A) of the Marine Mammal Protection Act (16 U.S.C 1371(a)(5)(A)) to take small numbers of marine mammals, by Level B harassment, incidental to the Water Agency's Estuary Management Project (issued April 21, 2017, NMFS LOA). A summary of the results of 2017 pinniped monitoring as reported in the *Russian River Estuary Management Project, Marine Mammal Protection Act Incidental Harassment Authorization, Report of Activities and Monitoring Results – January 1 to December 31, 2017* (SCWA 2018; Appendix 4.4) are provided below.

Harbor seals (*Phoca vitulina richardsi*) regularly haul out at the mouth of the Russian River (Jenner haul-out). California sea lions (*Zalophus californianus*) and northern elephant seals (*Mirounga angustirostris*) are occasionally observed at the haul-out. There are also several known resting areas in the river at logs and rock piles.

Pinniped monitoring was performed in accordance with the requirements of the NMFS LOA issued April 21, 2017, and the Russian River Estuary Management Activities Pinniped Monitoring Plan (Sonoma County Water Agency and Stewards of the Coast and Redwoods 2016). Baseline monitoring was performed to gather additional information about the population of harbor seals utilizing the Jenner haul-out including population trends, patterns in seasonal abundance and the influence of barrier beach condition on harbor seal abundance. Pinniped monitoring was also conducted in relation to Sonoma Water water level management events (lagoon outlet channel implementation and artificial breaching). Estuary management monitoring occurred during the Water Agency's monthly topographic surveys of the barrier beach and biological and physical monitoring of the Estuary.

The purpose of the Russian River Estuary Management Project Pinniped Monitoring Plan (Sonoma County Water Agency and Stewards of the Coast and Redwoods 2016) is to detect the response of pinnipeds to estuary management activities at the Russian River estuary. Specifically, the following questions are of interest: 1) Under what conditions do pinnipeds haul out at the Russian River estuary mouth at Jenner?; 2) How do seals at the Jenner haul-out respond to activities associated with the construction and maintenance of the lagoon outlet channel and artificial breaching activities?; 3) Does the number of seals at the Jenner haul-out significantly differ from historic averages with formation of a summer (May 15th to October 15th) lagoon in the Russian River estuary?; and 4) Are seals at the Jenner haul-out displaced to nearby river and coastal haul-outs when the mouth remains closed in the summer?

The Estuary management and monitoring activities in 2017 resulted in incidental harassment (Level B harassment) of 1,290 harbor seals, well under the total allowed by NMFS LOA. The

Russian River estuary management activities in 2016, 2014, 2013, 2012, 2011 and 2010 resulted in incidental harassment (Level B harassment) of 1,915, 2,383, 2,121, 1,351, 208, 42 and 290 harbor seals, respectively.

Harbor seals are found at the mouth of the Russian River (Jenner haul-out) throughout the year. They are observed on the beach throughout the tidal cycle and at any time of day. Our baseline pinniped monitoring concluded that tidal state and time of day influenced harbor seal abundance at the Jenner haul-out, with seals less abundant in the early morning and at high tide (SCWA 2012). Harbor seals were most abundant on the Jenner haul-out in July during their annual molt (SCWA 2012), with these same trends being observed in subsequent years (SCWA 2013, 2014, 2016). Seasonal variation in the abundance of harbor seals at their haul-out locations is commonly observed throughout their range (Allen et al. 1989, Stewart and Yochem 1994, Gemmer 2002). The variation in their abundance can mostly be explained by changes in their biological and physiological requirements throughout the year.

During 2017 the seasonal abundance patterns of harbor seals at the Jenner haul-out did not follow the trend observed in most previous years. The peak in haul-out abundance, as measured by the single greatest count of seals on land and the highest daily average count, was observed in February. During July, when seal abundance is usually at its maximum, there were fewer seals on land compared to the same month in all previous years. Additionally, there were two monitoring days in July where no harbor seals were observed on the beach. This has not been observed since monitoring began in 2009. Even if one only compared the number of seals observed when seals were present the single daily maximum count during July for previous years ranges from 295 to 548; in 2017 the most recorded at one time was 199. The river mouth was closed (or perched) for a total of 16 days in July 2017. When one compares previous July surveys when the river mouth was closed to surveys in 2017, the average daily maximum count is 201 seals (2010-2016, n=5) to 78 seals (2017, n=6). The abundance of seals during the pupping season (March – June) and the number of pups observed during a season has remained relatively stable since these monitoring efforts began, so the population size of harbor seals using the Jenner haul-out as a rookery does not appear to have declined. Seal abundance was higher in January and February compared to previous years and compared to the 2009-2016 average. The abundance of seals on the haul-out has been declining in the July – September period over the past 2 years. Graphical depiction of this data is available in Appendix 4.4, Figures 2, 4, and 6.

Harbor seals will use the beach when there is an open channel or when a barrier beach has formed, however, the number of seals at Jenner was influenced by river mouth condition. Daily average seal abundance was lower during closed conditions compared to open conditions. The closure of the barrier beach for a portion of July may have contributed to the low number of seals observed at that time for 2017, but this result was not consistent with results in previous years under similar conditions.

The response of harbor seals at the Jenner haul-out to water level management activities in 2017 was similar to the responses observed in previous years of monitoring (Merritt Smith Consulting 1997, 1998, 1999, 2000; Sonoma County Water Agency and Merritt Smith

Consulting 2001; SCWA 2011, 2012, 2013, 2014, 2015, and 2016). Harbor seals alerted to the sound of equipment on the beach and left the haul-out as the crew and equipment approached closer on the beach. When breaching activities were conducted south of the haul-out, or when seals were hauled out on the ocean side of the beach, seals often remained on the beach during all or some of the breaching activity. This indicates that seals are less disturbed by activities when equipment and crew do not pass directly past their haul-out.

Two attempts were made to implement a lagoon outlet channel in 2017. The first attempt ended when the lagoon outlet channel failed to an open river mouth and estuary water levels dropped within 24 hours of implementation. During this period the river mouth was closed for 13 days in July. While the length of the July closure was similar to previous years, fewer harbor seals were observed during lagoon conditions in July 2017 when compared to previous years when the river mouth was closed in the same month. The second attempt resulted in lagoon conditions lasting a total of 21 days (during September, October), until the barrier beach was breached 5 days after an outlet channel was excavated. During these lagoon conditions, when estuary water levels were high and there was no outlet to the ocean, harbor seals were observed using the haul-out. The number of seals observed under lagoon conditions in the fall was similar to observations in previous years.

Conclusions and Recommendations

A barrier beach formed eight times during 2017; during four of these closure events Sonoma Water conducted water level management activities at the barrier beach. Four inlet closures occurred within the lagoon management period; one in July, one in August, one in September, and one in October. Outlet channels were excavated by Sonoma Water during the closures in July and September. The approach to excavation of the outlet channel in July was to work during rising tides in anticipation of the tides conveying sand into the channel and reducing the potential for self-breaching. The bed of the outlet channel was excavated to meet the lagoon water surface elevation. Less than a day after the outlet channel excavation, the channel scoured open and water surface elevations in the Estuary declined.

For the September 28 outlet channel the approach was to excavate the channel with a bed elevation (invert) above the lagoon water surface elevation. The outlet channel was again located about 1,000 feet north of the jetty, where an outlet channel had naturally occurred in June. Compared to the July implementation, this channel invert elevation was higher, at 8.3 ft NGVD, which was approximately 0.3 feet above the lagoon water surface elevation at the time the channel was excavated. The plan was to allow lagoon water levels to increase to the outlet channel's elevation, at which time the outlet channel would allow lagoon water to flow out into the ocean to minimize the chance of flooding and prolong the freshwater/brackish water conditions for salmon rearing habitat, up until the flood stage of 9 ft NGVD. Just as water levels reached the elevation of the outlet channel, there was a breach on October 3. A photograph taken from the Highway 1 overlook indicates a narrow (<10 ft wide) and lower elevation channel had been dug within the fully excavate outlet channel, which suggests that the narrower channel may have been excavated by beachgoers (Figure 4.7). Unfortunately, this possible interference obfuscates the potential performance of excavating an outlet channel above existing lagoon water levels. Unfortunately, this is not the first time that private individuals have breached the barrier beach, which impacts the management of enhanced rearing habitat for juvenile steelhead when it occurs during the lagoon management season. Regardless of the time of year, breaching by private individuals poses a safety risk to those individuals in case of high wave events and risk of beach scour during such activities.

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.

Methods

Continuous Multi-Parameter Monitoring

Water quality was monitored using YSI Series 6600 multi-parameter datasondes. Hourly salinity (parts per thousand), water temperature (degrees Celsius), dissolved oxygen (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.

Six (6) stations were established for continuous water quality monitoring, including three stations in the mainstem Estuary, two tributary stations, and one station in the MBA near Villa Grande (Figure 4.1.1). One mainstem Estuary station was located in the middle reach at Patty’s Rock upstream of Penny Island (Patty’s Rock Station). One tributary station was located in the mouth of Willow Creek, which flows into the middle reach of the Estuary (Willow Creek Station). Two mainstem Estuary stations were located in the upper reach; downstream of Freezeout Creek in Duncans Mills (Freezeout Creek Station) and downstream of Austin Creek in Brown’s Pool (Brown’s Pool Station). The other tributary station was located downstream of the first steel bridge in lower Austin Creek, which flows into the mainstem Russian River above Brown’s Pool Station. Finally, one mainstem station was located in the MBA: in a pool across from Patterson Point in Villa Grande (Patterson Point Station). A seventh and eighth station were established in

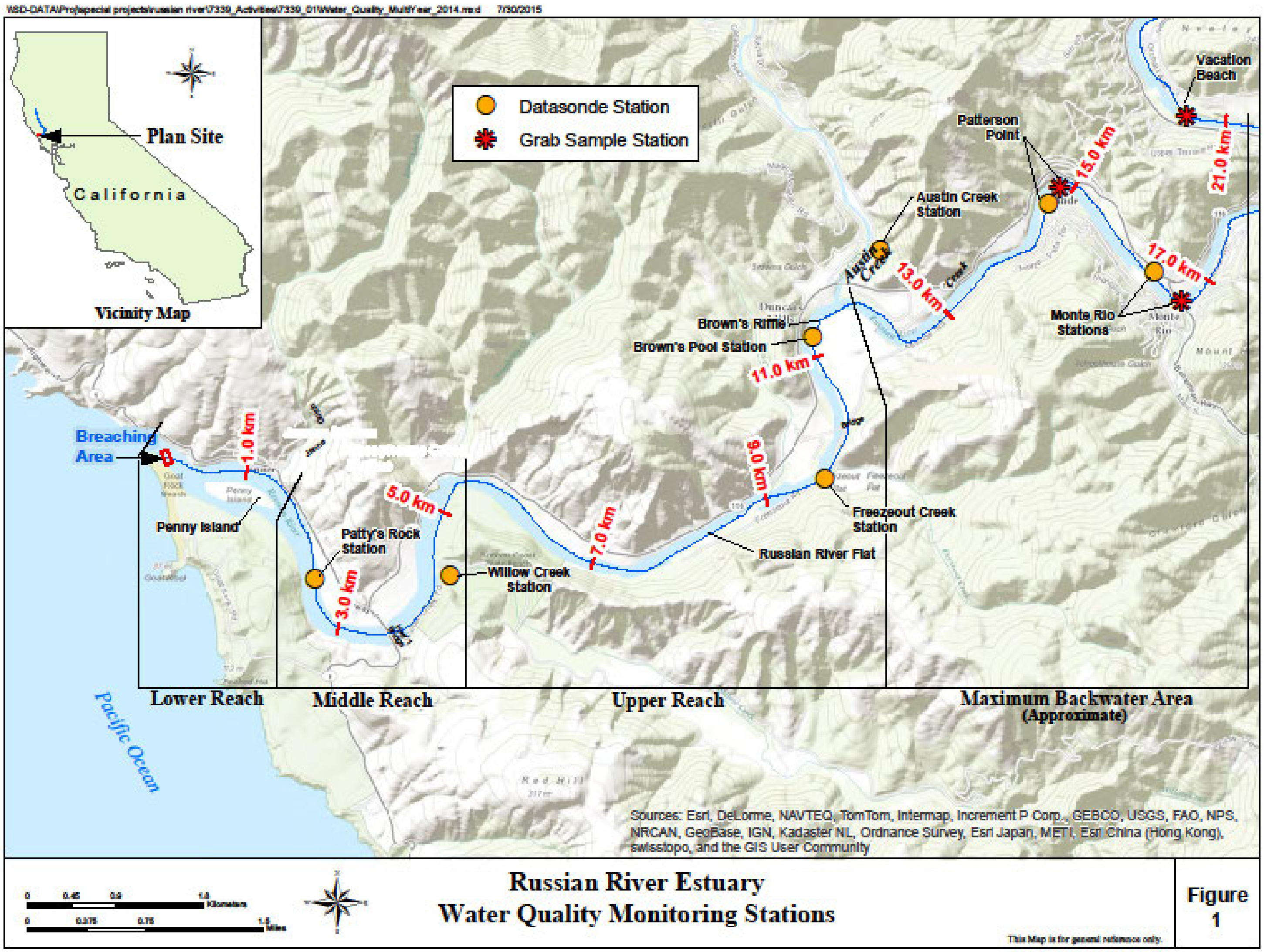


Figure 4.1.1. 2017 Russian River Estuary Water Quality Monitoring Stations

the middle reach at Sheephouse Creek and the MBA at Monte Rio, however due to equipment malfunctions no data was collected at these stations in 2017.

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

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

The Patty's Rock, Freezeout Creek, Brown's Pool, and Patterson Point stations had a vertical array of two datasondes to collect water quality profiles. The Patty's Rock station, located in the middle reach of the Estuary, is predominantly saline and had sondes placed near the surface at approximately 1 meter depth (~1m), and at the mid-depth (~4-5m) portion of the water column. Stations in the upper reach of the Estuary, where the halocline is deeper and the water is predominantly fresh to brackish, had sondes placed at the bottom (~5-11m) and mid-depth (~3-6m) portions of the water column. The Patterson Point monitoring station, located in the MBA, also had datasondes placed at the bottom (~9-11m) and mid-depth (~6-7m) portions of the water column (Figure 4.1.2). Sondes were located in this manner to track vertical and longitudinal changes in water quality characteristics during periods of tidal circulation, barrier beach closure, lagoon formation, lagoon outlet channel implementation, and sandbar breach.

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

The Patty's Rock station was deployed from August to November. The Freezeout Creek station was deployed from July to November. The Brown's Pool and Patterson Point stations were deployed from May to November. The Austin Creek and Willow Creek sondes were deployed from April to November.

Grab Sample Collection

In 2017, 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 MBA, including one station established in 2010 just downstream of the Monte Rio Bridge (Monte Rio Station). The 2017 grab sampling effort represented the fourth year of collecting samples at Patterson Point in Villa Grande (Patterson Point Station); and just downstream of the Vacation Beach summer dam (Vacation Beach station). Refer to Figure 4.1.1 for grab sampling locations.

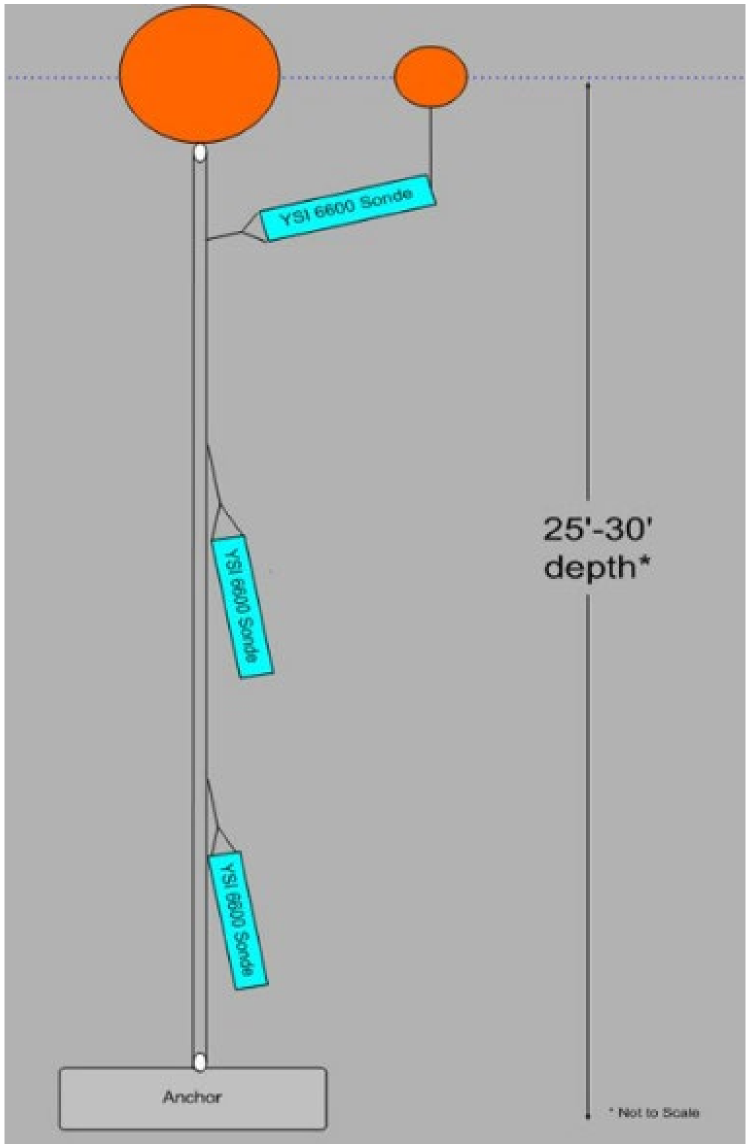


Figure 4.1.2. Typical Russian River Estuary monitoring station datasonde array.

Sonoma Water staff collected grab samples weekly from May 16 to October 17. Additional focused sampling (collecting three samples over a ten day period) was conducted following or during specific river management and operational events including: barrier beach closure, lagoon outlet channel implementation, sandbar breach, or removal of summer recreational dams.

Nutrient sampling was conducted for total organic nitrogen, ammonia, unionized ammonia, nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen, and total phosphorus, 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 collected for the presence of indicator bacteria including total coliforms, 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 in Appendix 4.5; however, an analysis and discussion of these constituents is not included in this report. Temperature, dissolved oxygen, pH, salinity, specific conductance, and turbidity values were recorded using a YSI 6600 datasonde during grab sampling events and are also included in Appendix 4.5.

Results

Water quality conditions in 2017 were similar to trends observed in sampling from 2004 to 2016. 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 (DO), 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 4.1.34. These data gaps may affect minimum, mean, and maximum values of the various constituents monitored in 2017, including temperature, dissolved oxygen, pH, and salinity at the Freezeout Creek mid-depth sonde for the entire season, Brown’s Pool bottom sonde during the first half of the season, and the Patterson Point bottom sonde during the second half of the season. Sondes were not placed at Sheephouse Creek, Monte Rio, or the mid-depth at Brown’s Pool in 2017 due to a shortage of properly functioning datasondes.

Although gaps exist in the 2017 data that affect sample statistics, Sonoma Water staff has collected long time-series data on an hourly frequency for several years at most of these stations, and it is unlikely that the missing data appreciably affected the broader understanding of water quality conditions within the estuary. The following sections provide a brief discussion of the results observed for each parameter monitored.

Table 4.1.1. Russian River Estuary 2017 Water Quality Monitoring Results. Minimum, mean, and maximum values for temperature (degrees Celsius), depth (meters), dissolved oxygen (percent) saturation, dissolved oxygen concentration (milligrams per Liter), hydrogen ion (pH units), and salinity (parts per thousand).

Monitoring Station	Temperature	Depth	Dissolved Oxygen	Dissolved Oxygen	Hydrogen Ion	Salinity
Sonde	(°C)	(m)	(mg/L)	(%) saturation	(pH)	(ppt)
Patty's Rock						
Surface						
August 9, 2017 - November 21, 2017						
Min	12.0	0.7	6.5	73.5	7.3	0.3
Mean	17.3	0.8	9.0	98.6	8.0	7.6
Max	**22.9**	**1.0**	**15.7**	**198.6**	**8.8**	**30.5**
Mid-Depth						
August 9, 2017 - November 21, 2017						
Min	11.7	2.9	0.3	4.1	7.1	0.4
Mean	17.0	3.3	8.2	96.9	8.0	22.6
Max	**23.2**	**3.5**	**14.4**	**165.9**	**8.8**	**33.8**
Willow Creek						
Mid-Depth						
April 15, 2017 - November 21, 2017						
Min	7.7	0.0	0.1	0.7	6.2	0.1
Mean	16.5	0.9	7.6	79.1	7.3	2.1
Max	**24.5**	**2.3**	**15.8**	**174.3**	**8.8**	**25.2**
Freezeout Creek						
Bottom						
July 27, 2017 - November 21, 2017						
Min	11.8	5.4	0.2	1.8	6.8	0.1
Mean	19.7	6.5	7.1	79.4	7.6	3.4
Max	**24.5**	**7.0**	**10.5**	**116.8**	**8.3**	**16.4**
Brown's Pool						
Bottom						
May 23, 2017 - November 21, 2017						
Min	12.0	8.7	0.0	0.0	7.0	0.1
Mean	19.2	10.0	6.8	70.2	7.6	0.1
Max	**25.8**	**10.7**	**10.7**	**103.6**	**8.2**	**0.2**
Austin Creek						
Surface						
April 25, 2017 - November 14, 2017						
Min	12.6	0.0	1.1	11.2	6.7	0.1
Mean	16.8	0.5	5.5	57.0	7.2	0.1
Max	**20.6**	**1.4**	**9.9**	**99.8**	**7.8**	**0.2**
Patterson Point						
Mid-Depth						
May 18, 2017 - November 21, 2017						
Min	11.9	6.5	2.0	23.4	7.2	0.1
Mean	20.2	6.6	8.1	89.4	7.6	0.1
Max	**26.3**	**7.0**	**11.0**	**119.7**	**8.1**	**0.1**
Bottom						
May 18, 2017 - August 24, 2017						
Min	14.3	10.4	0.0	0.3	5.3	0.1
Mean	17.9	11.1	4.3	45.8	7.1	0.1
Max	**22.6**	**11.4**	**12.1**	**123.3**	**8.1**	**0.2**

Salinity

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

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

The Austin Creek, Patterson Point and Monte Rio stations are located in the MBA in freshwater habitat that can become inundated during high tides, barrier beach closures, perched conditions, and lagoon formation. Elevated salinity levels were not observed at any of the stations in the MBA during either open river mouth or closed barrier beach conditions in 2017.

Lower and Middle Reach Salinity

The Patty's Rock station is located at River Kilometer 2.5 (RK 2.5), which is approximately 2.5 km upstream from the river mouth. The surface sonde at the Patty's Rock station was suspended at a depth of approximately 1 meter, and experienced frequent hourly fluctuations in salinity during open conditions. These fluctuations are influenced by freshwater inflows, tidal movement and expansion and contraction of the salt wedge. The freshwater layer was observed to deepen and become more persistent at the surface sonde during closed barrier beach conditions (Figure 4.1.3). Concentrations ranged from 0.3 to 30.5 ppt at the Patty's Rock surface sonde with a mean salinity value of 7.6 ppt (Table 4.1.1).

The mid-depth sonde at the Patty's Rock station was suspended at a depth of approximately 3 to 4 meters, and also experienced frequent fluctuations in salinity during open and closed conditions, though to a lesser degree than the surface sonde. Concentrations ranged from 0.4 to 33.8 ppt at the Patty's Rock mid-depth sonde with a mean salinity value of 22.6 ppt (Table 4.1.1). Minimum concentrations were observed to occur at the Patty's Rock mid-depth sonde during closed river mouth conditions (Figure 4.1.3).

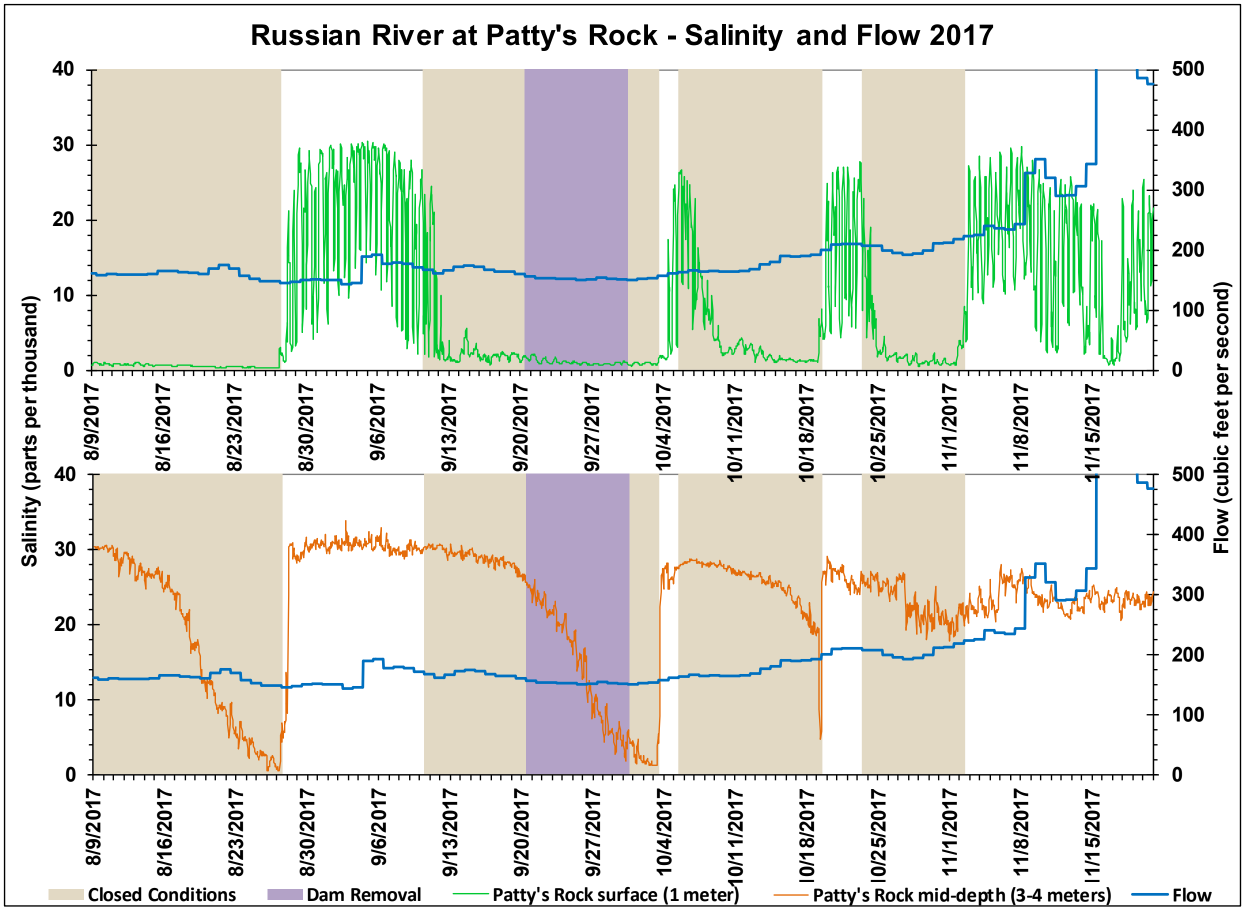


Figure 4.1.3. 2017 Russian River at Patty's Rock Salinity and Flow Graph

The Estuary experienced four closures during the 2017 management period, including one closure that lasted 23 days between August 5 and August 27 and another closure that lasted 22 days from September 12 to October 3 (Figure 4.1.3). Declines in salinity during barrier beach closure and lagoon formation were due to a combination of freshwater inflows increasing the depth of the freshwater layer over the salt layer, a reduction in tidal inflow, the compression and leveling out of the salt layer, and seepage of saline water through the barrier beach. Salinity generally returned to pre-closure levels after the barrier beach reopened, although the time required to return to pre-closure conditions varied between closure events. This variability was 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. The Willow Creek station was located in predominantly freshwater habitat through July until increased tidal action allowed saline water to migrate to this station during open conditions..

Salinity was observed to generally decline during the two closures in August and September, but remained brackish through the rest of the monitoring season, including during late season closures (Figure 4.1.4). However, salinity concentrations were also observed to fluctuate significantly at times during open and closed barrier beach conditions. The mean salinity

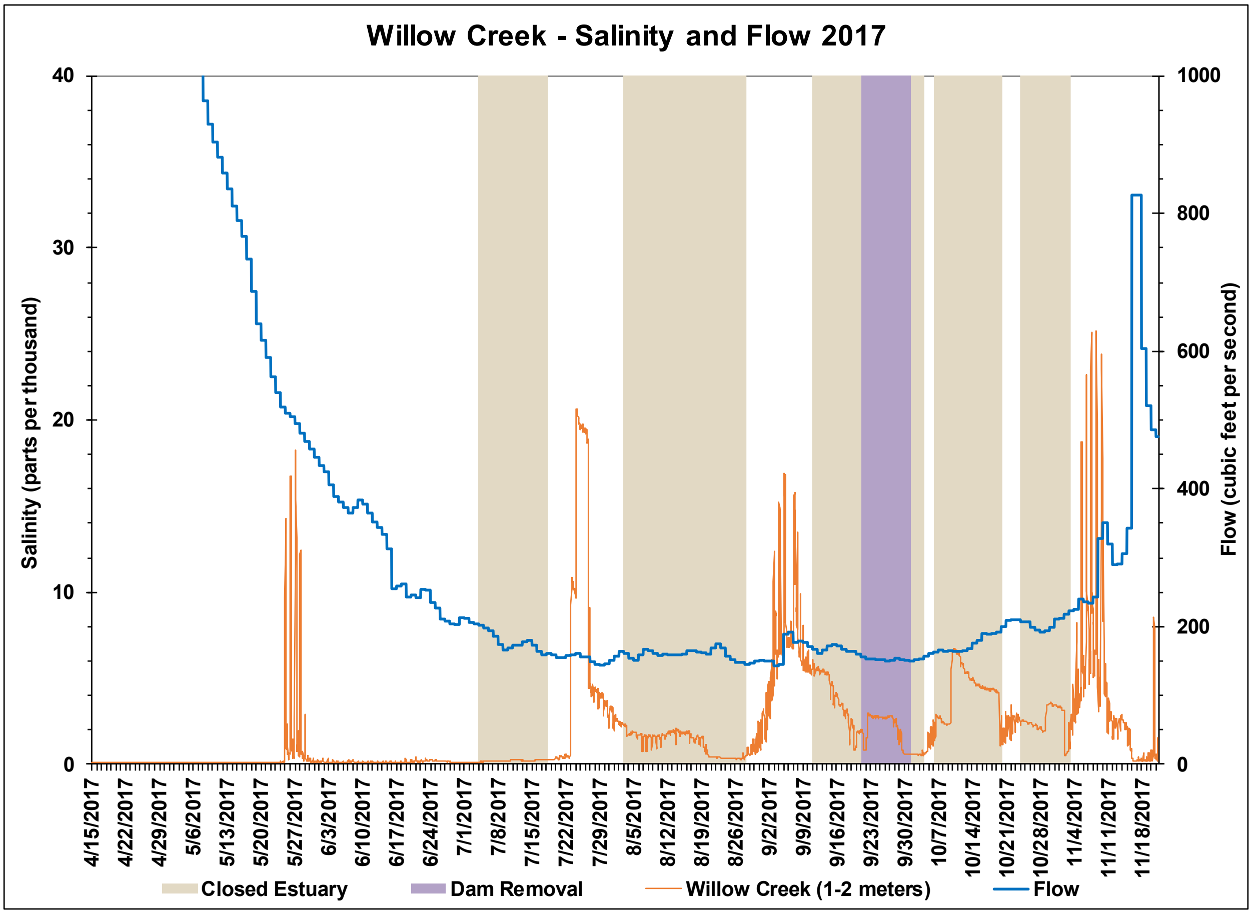


Figure 4.1.4. 2017 Willow Creek Salinity and Russian River Flow Graph

concentration observed at the Willow Creek station was 2.1 ppt, with a minimum concentration of 0.1 ppt, and a maximum concentration of 25.2 ppt (Table 4.1.1).

Upper Reach Salinity

Two stations were monitored in the upper reach in 2017; Freezeout Creek and Brown's Pool. The Freezeout Creek station included a bottom sonde and a mid-depth sonde, whereas the Brown's Pool station included a bottom sonde only. Sondes were located in this manner to track changes in the presence and concentration of salinity in the water column as well as the presence of thermal refugia for salmonids.

The Freezeout Creek station is located at River Kilometer 9.5 (RK 9.5) in a pool approximately 300 meters downstream of the confluence of Freezeout Creek and the mainstem of the river. This station was located in a predominantly freshwater habitat that was subject to elevated salinity levels as the salt wedge migrated up the Estuary during both open and closed conditions (Figure 4.1.5). The bottom sonde at Freezeout Creek had a mean salinity concentration of 3.4 ppt, and salinity levels that ranged from 0.1 to 16.4 ppt (Table 4.1.1). The mid-depth sonde malfunctioned and no data was available at that depth for this station in 2017.

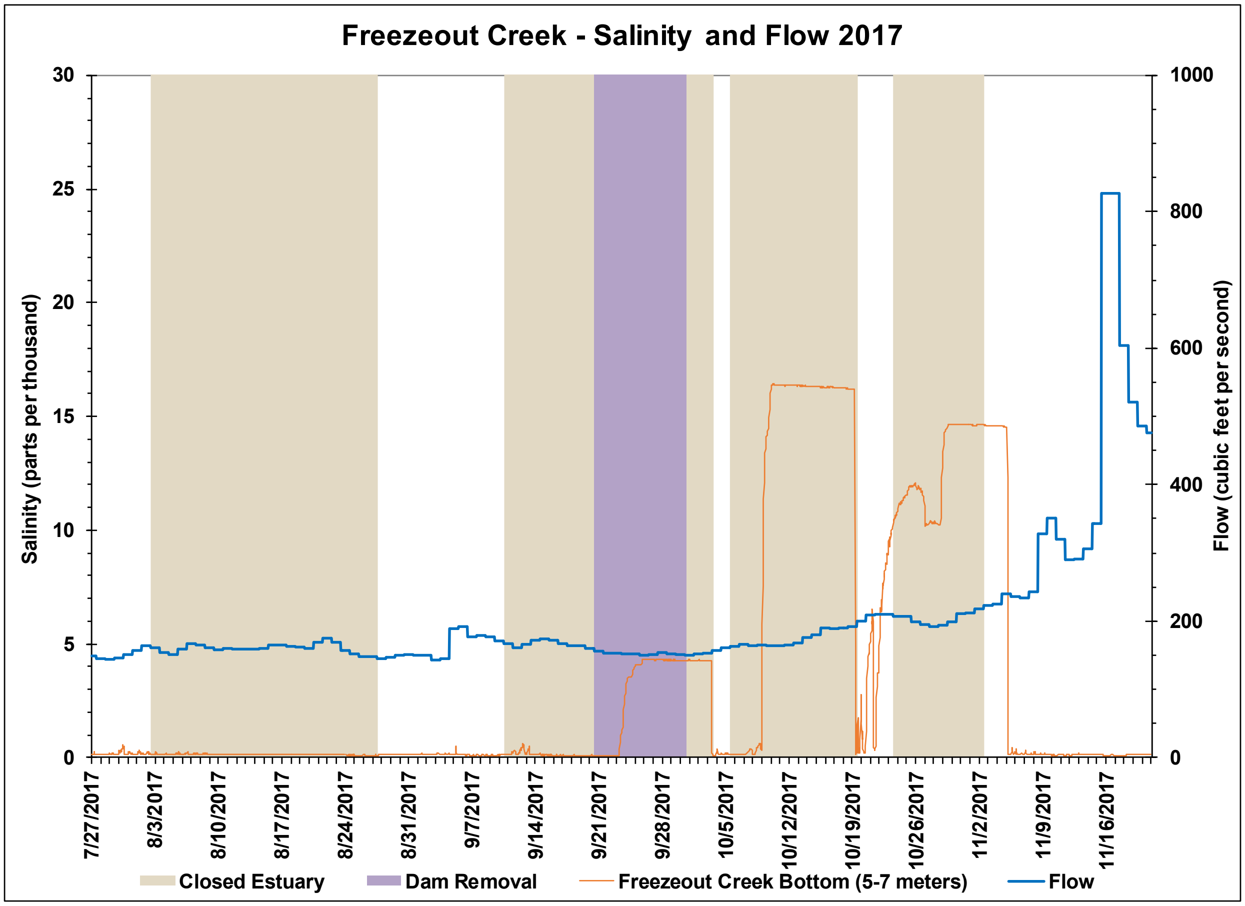


Figure 4.1.5. 2017 Russian River at Freezeout Creek Salinity and Flow Graph

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

This station did not experience any elevated salinity levels and remained freshwater habitat during the entire monitoring season of 2017 (Figure 4.1.6). The bottom sonde at Brown's Pool had a mean salinity concentration of 0.1 ppt, and salinity levels that ranged from 0.1 to 0.2 ppt (Table 4.1.1). This station did not have a mid-depth sonde deployed in 2017.

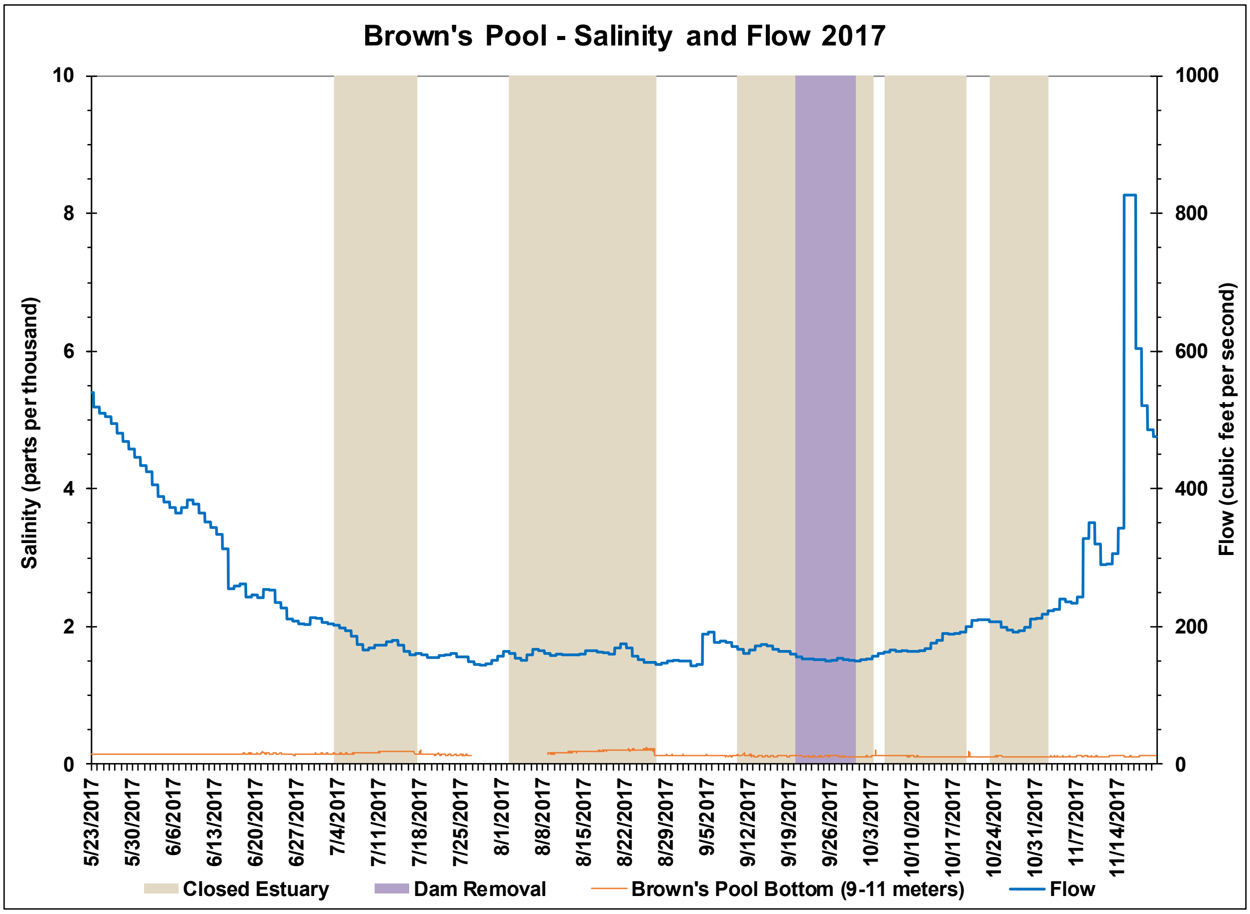


Figure 4.1.6. 2017 Russian River at Brown's Pool Salinity and Flow Graph

Maximum Backwater Area Salinity

Two stations were located in the MBA, including one tributary station in lower Austin Creek and one mainstem Russian River station located in Patterson Point (RK 14.9) (Figure 4.1.1). Neither of these stations were observed to have salinity levels above normal background conditions expected in freshwater habitats, during both open and closed barrier beach conditions (Figures 4.1.7 and 4.1.8).

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

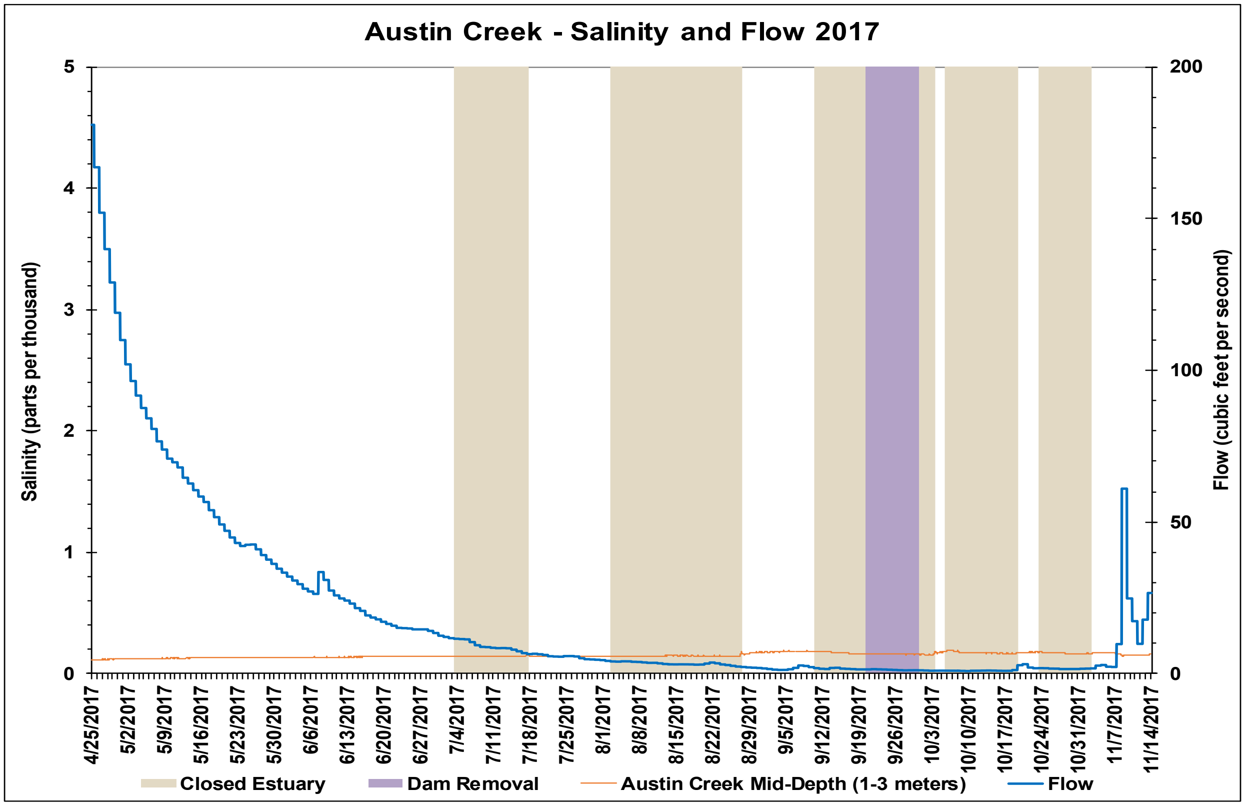


Figure 4.1.7. 2017 Austin Creek Salinity and Flow Graph

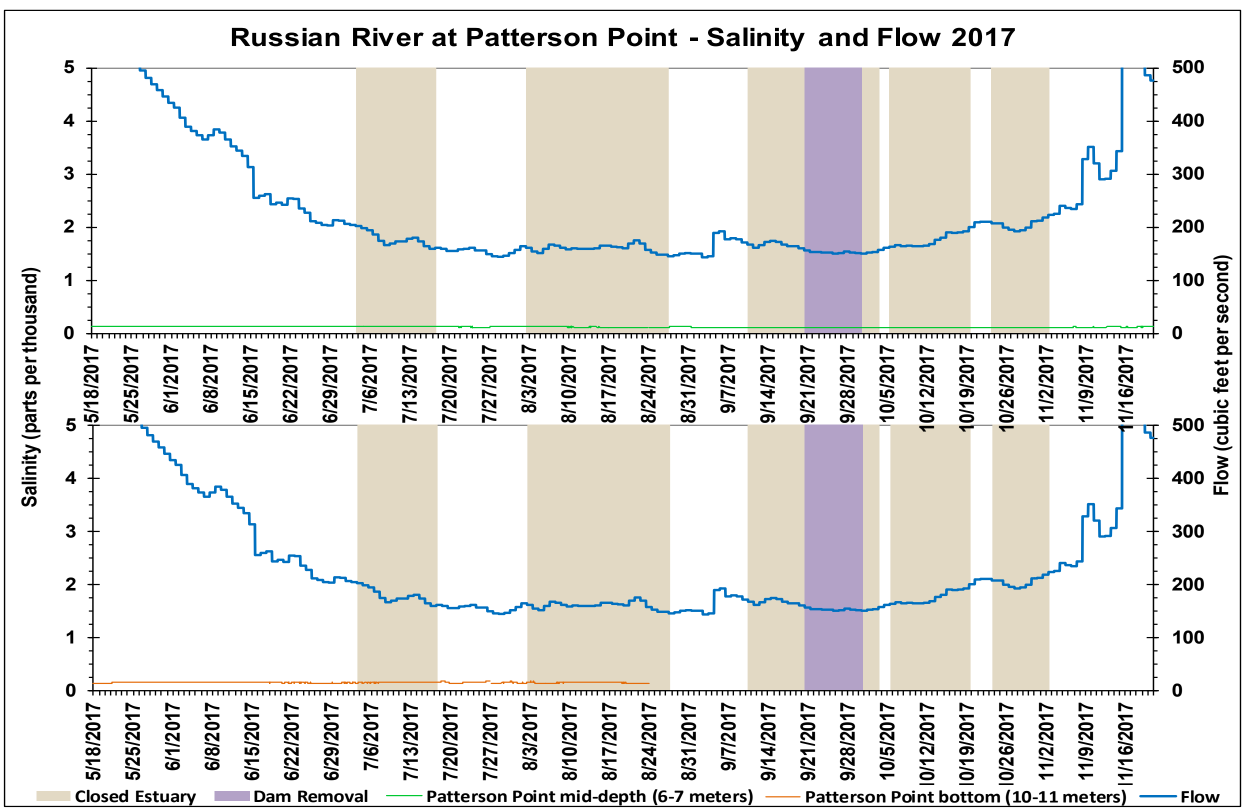


Figure 4.1.8. 2017 Russian River at Patterson Point Salinity and Flow Graph

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 4.1.9 through 4.1.13). The differences in temperatures between the underlying saline layer and the overlying freshwater layer can be attributed in part to the source of saline and fresh water. During open estuary conditions, the Pacific Ocean, where temperatures are typically around 10 degrees Celsius (°C), is the source of saltwater in the Estuary. Whereas, the mainstem Russian River, with water temperatures reaching as high as 27 °C in the interior valleys, is the primary source of freshwater in the Estuary.

During closed Estuary conditions, increasing temperatures associated with fresh/saltwater stratification were observed to occur (Figure 4.1.9). 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. When the estuary is closed, or the river mouth is perched and the supply of cool tidal inflow is reduced, solar radiation heats the underlying saline layer. Additionally, the overlying freshwater surface layer restricts the release of this heat, which can result in higher water temperatures in the underlying saline layer than in the overlying freshwater layer (Figure 4.1.9). 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 system. 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 22.9 °C (Table 4.1.1). Whereas, the mid-depth sonde was located primarily in saltwater and had a maximum temperature of 23.2 °C. Maximum temperatures were observed to occur in brackish to saline water during closed barrier beach conditions (Figures 4.1.3 and 4.1.9). The Patty's Rock surface sonde had a mean temperature of 17.3 °C and a minimum temperature of 12.0 °C. The mid-depth sonde had a mean temperature of 17.0 °C and a minimum temperature of 11.7 °C.

The Willow Creek station had a maximum temperature of 24.5 °C, which occurred on 28 July in brackish water and open conditions (Figures 4.1.10 and 4.1.4). The mean temperature was 16.5 °C, and the minimum temperature was 7.7 °C. Elevated salinity was observed in late May with mainstem flows still above 400 cfs (Figure 4.1.4). However, the station returned to freshwater conditions within a week and remained that way until after the first closure of the monitoring season occurred in July. After the barrier beach reopened, saline water migrated to the station, and it remained brackish during open and closed conditions through the rest of the monitoring season (Figure 4.1.4). 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 4.1.10). This was most apparent during several late season river mouth closure events when warm brackish water was observed to signficantly decrease in

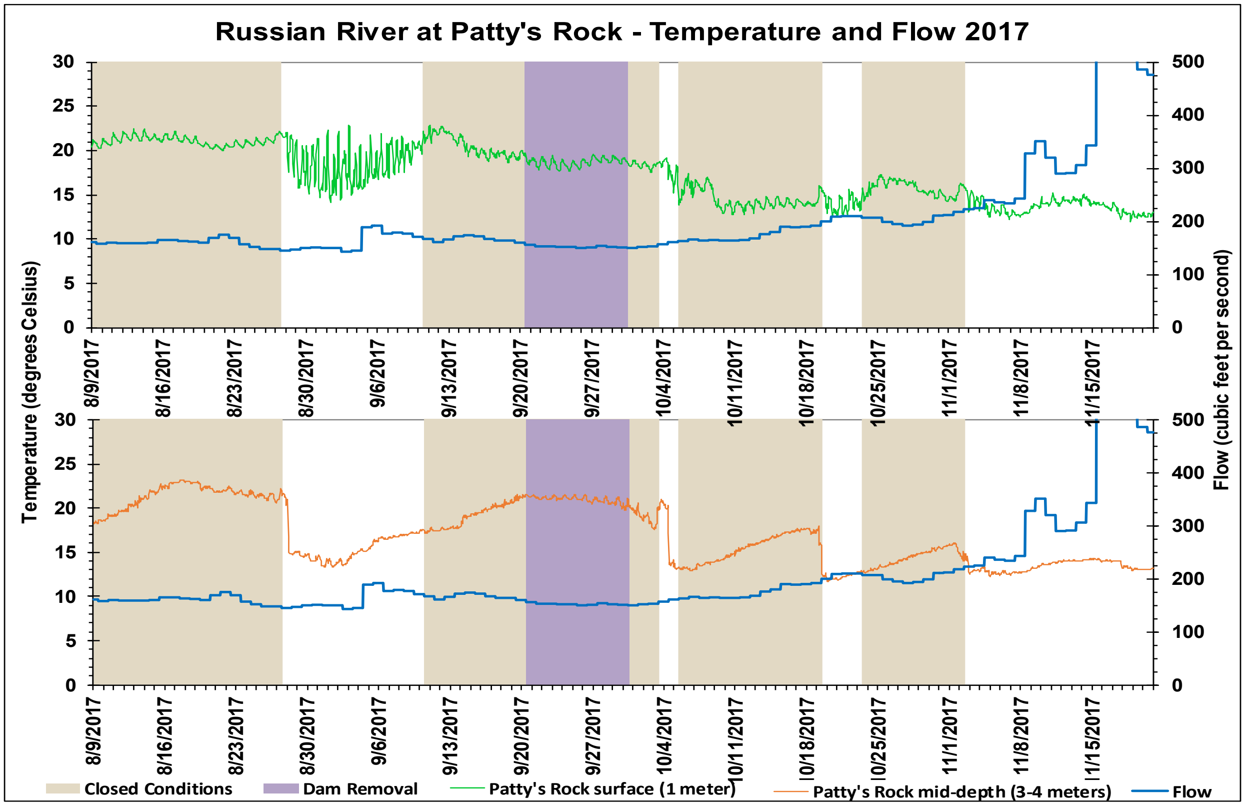


Figure 4.1.9. 2017 Russian River at Patty's Rock Temperature and Flow Graph

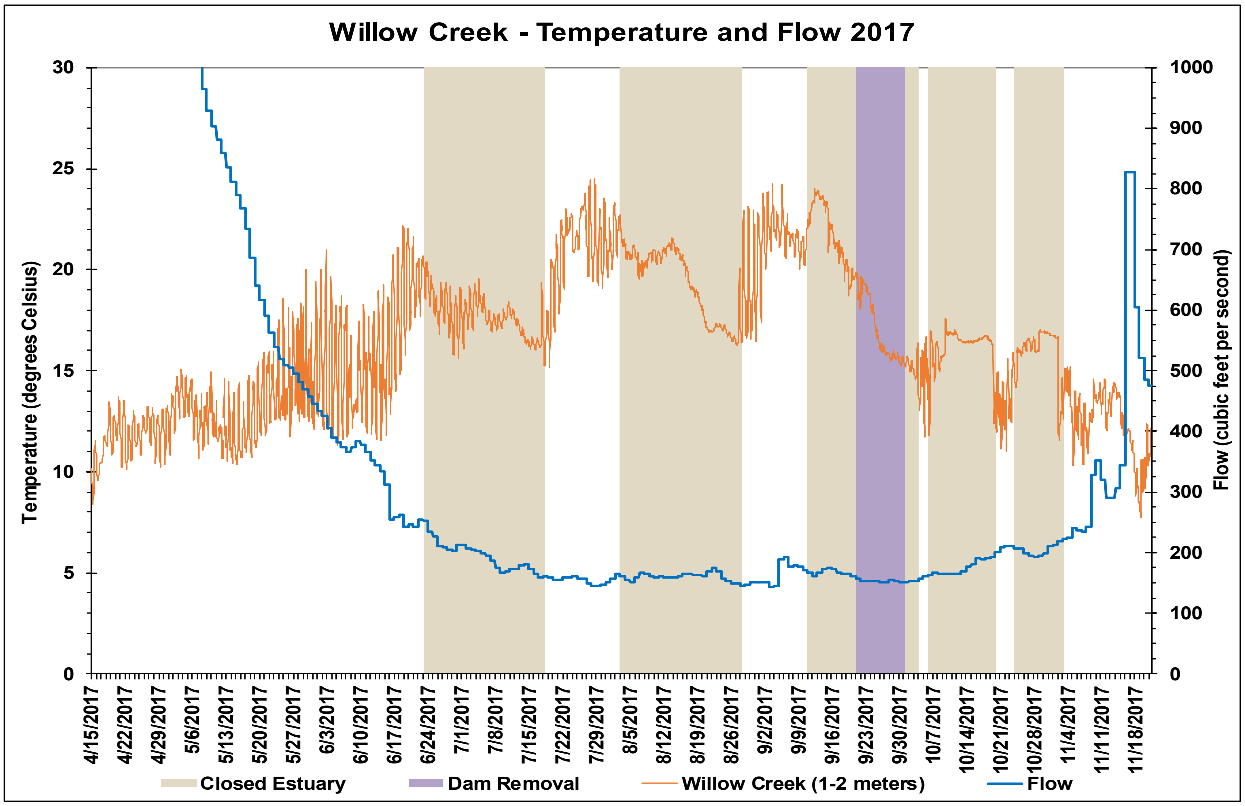


Figure 4.1.10. 2017 Willow Creek Temperature with Russian River Flow Graph

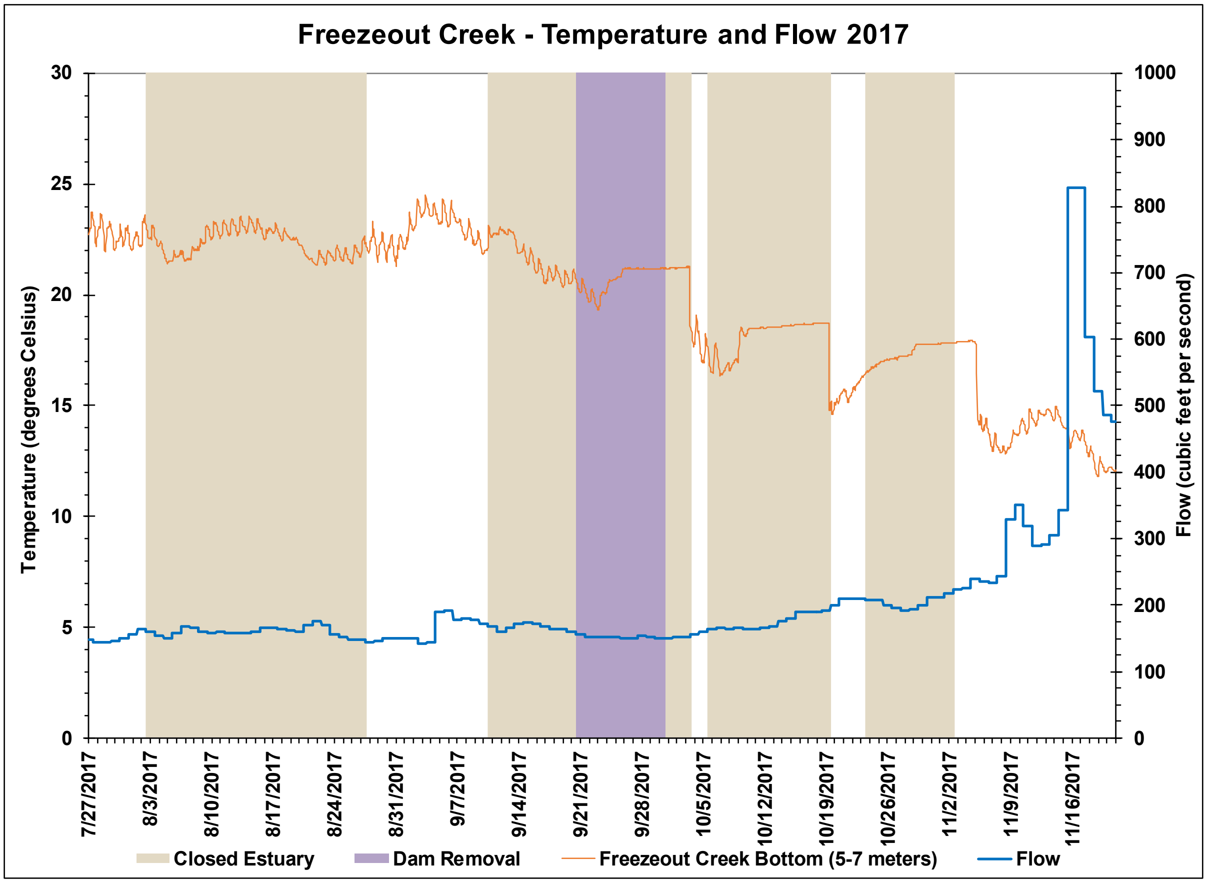


Figure 4.1.11. 2017 Russian River at Freezeout Creek Temperature and Flow Graph

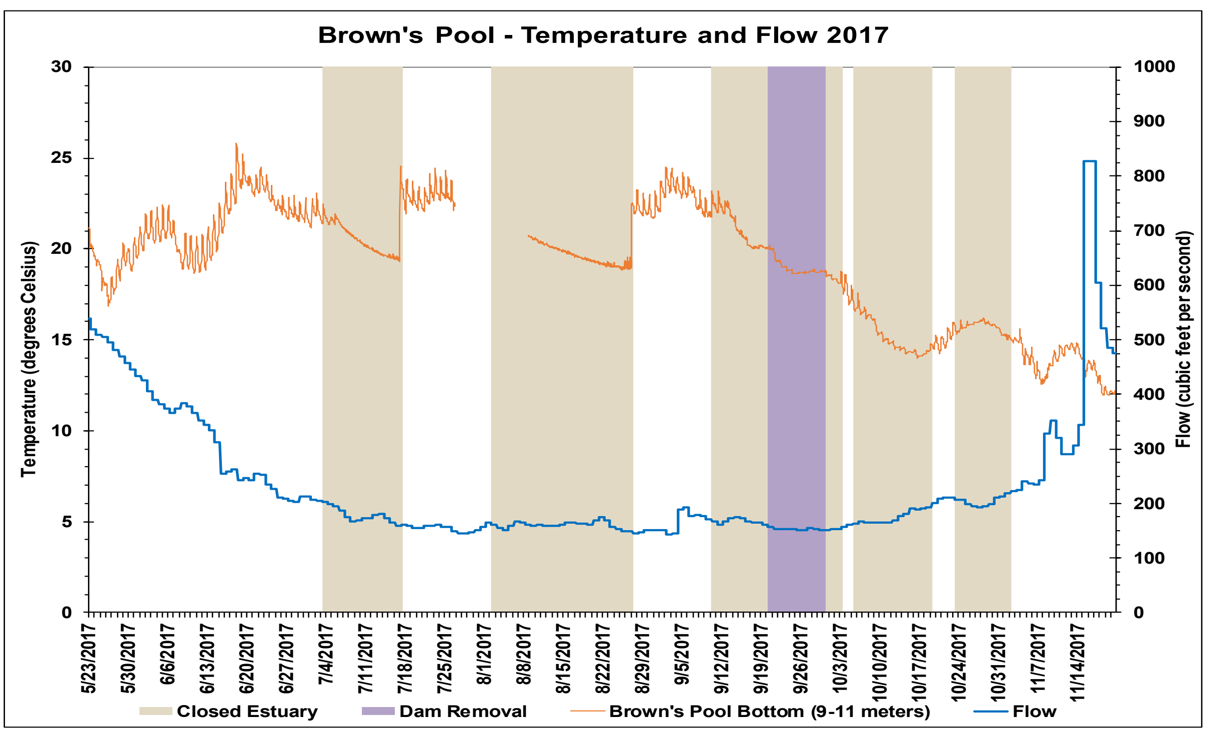


Figure 4.1.12. 2017 Russian River at Brown's Pool Temperature and Flow Graph

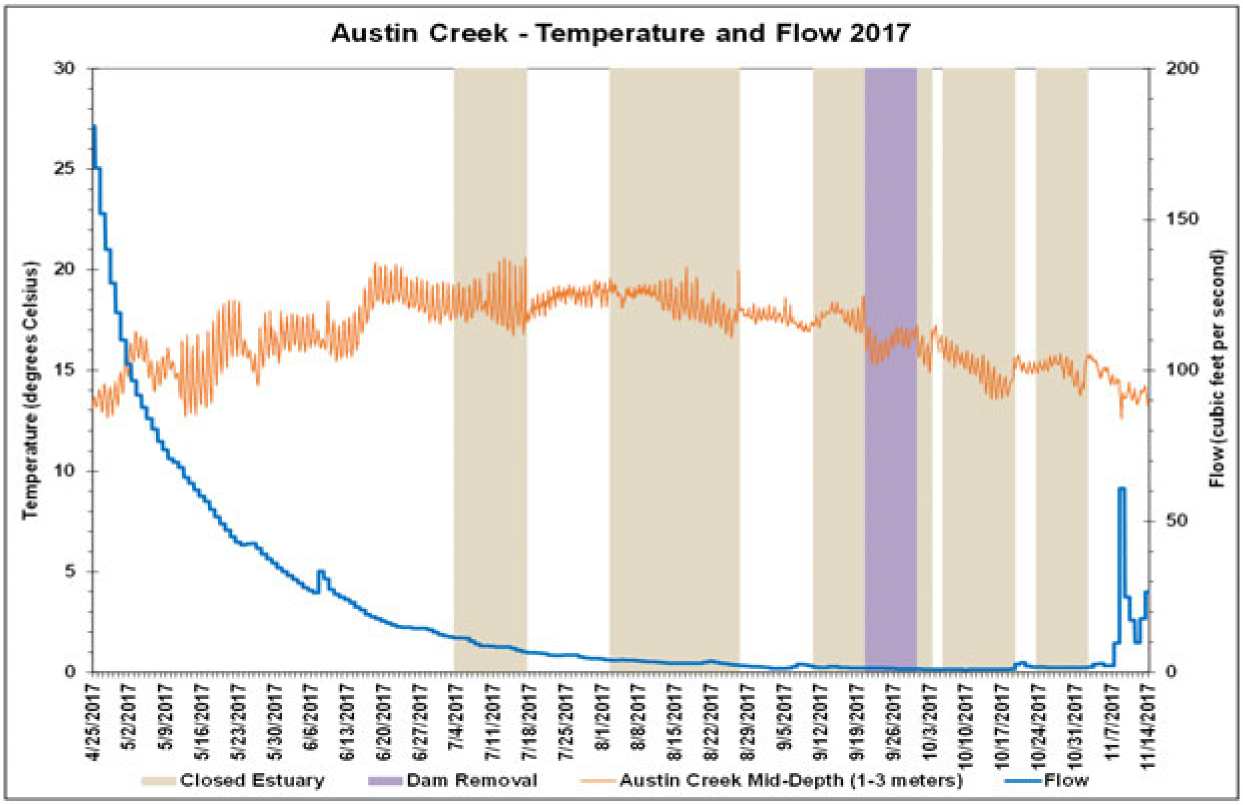


Figure 4.1.13. 2017 Austin Creek Temperature and Flow Graph

temperature after freshwater or a fresh source of tidally migrating salt water migrated to the station during and between barrier beach closures (Figure 4.1.10).

Upper Reach Temperature

Overall estuarine temperatures in both the saline layer and freshwater layer were typically hottest 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 bottom sonde at the Freezeout Creek station had a maximum temperature of 24.5 °C, a mean temperature of 19.7 °C, and a minimum temperature of 11.8 °C (Table 4.1.1). Minimum temperatures at the bottom sonde occurred in freshwater during open conditions in November (Figure 4.1.11). The maximum temperatures were observed to occur at the bottom and mid-depth sondes in freshwater conditions during open estuary conditions in early September (Figures 4.1.11 and 4.1.5).

The bottom sonde at the Brown's Pool station had a maximum temperature of 25.8 °C, a mean temperature of 19.2 °C, and a minimum temperature of 12.0 °C (Table 4.1.1). Minimum temperatures at the Brown's Pool station were observed in freshwater habitat during open conditions in November (Figures 4.1.12 and 4.1.6). Temperatures were observed to generally decrease in freshwater habitat during barrier beach closures with the exception of the river mouth closure that occurred in late October (Figures 4.1.12 and 4.1.6).

Maximum Backwater Area Temperature

Austin Creek had a maximum temperature of 20.6 °C, a mean temperature of 16.8 °C, and a minimum temperature of 12.6 °C (Table 4.1.1). A gradual increase in temperature through the summer months of the estuary management period coincided with increases in air temperatures (Figure 4.1.13). Closed estuary conditions did not appear to have a significant effect on the temperatures at the Austin Creek station,with slight increases and decreases in water temperature typically coinciding with increases and decreases in air temperatures (Figure 4.1.13).

The Patterson Point bottom sonde had a maximum temperature of 22.6 °C, a mean temperature of 17.9 °C, and a minimum temperature of 14.3 °C (Table 4.1.1). The Patterson Point mid-depth sonde had a maximum temperature of 26.3 °C, a mean temperature of 20.2 °C, and a minimum temperature of 11.9 °C. Under open and closed conditions, daily temperatures were often lower at Patterson Point than at Brown's Pool, which suggests that thermal stratification may be occurring at depth (Figure 4.1.14). It is also possible that a groundwater source could be contributing colder water at depth, or it could a combination of both effects occurring in tandem. Temperatures continued to decline with atmospheric temperatures through the end of the season and did not appear to be affected by the extended closures (Figure 4.1.14).

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

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

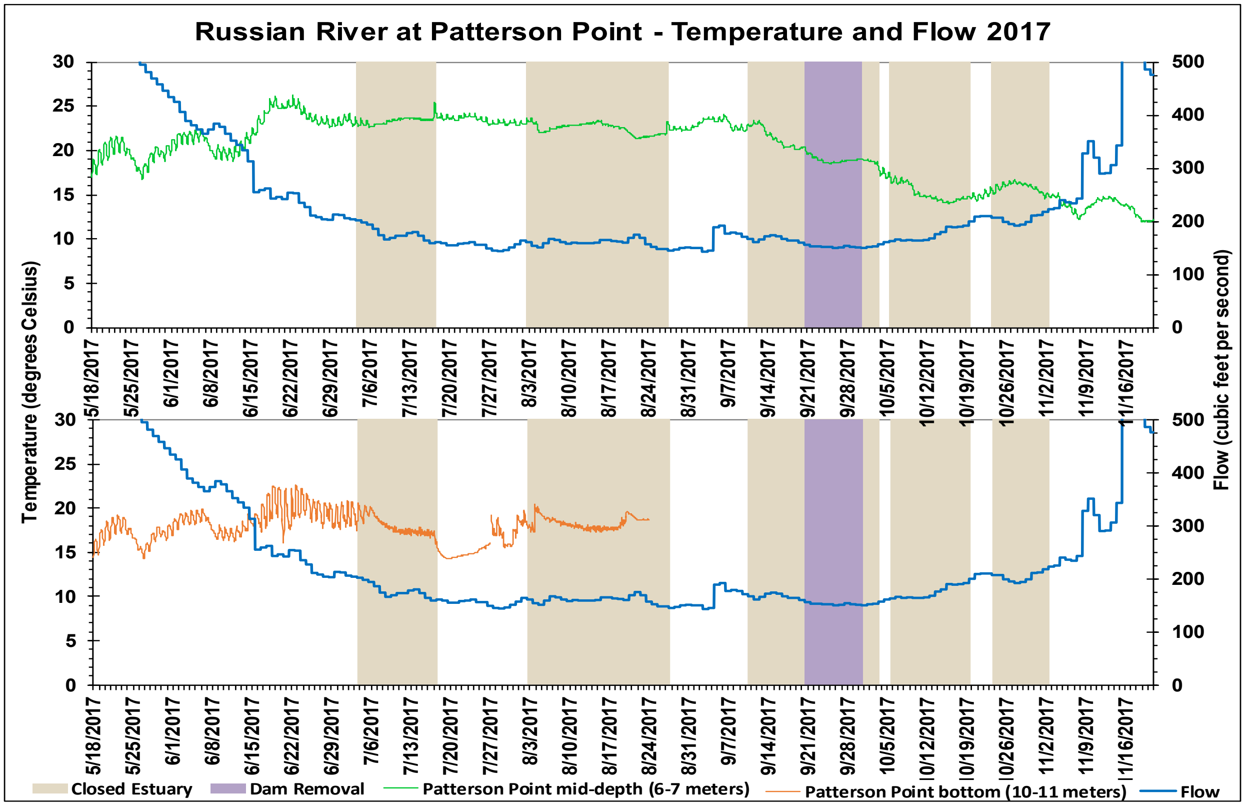


Figure 4.1.14. 2017 Russian River at Patterson Point Temperature and Flow Graph

Lower and Middle Reach Dissolved Oxygen

Mean dissolved oxygen concentrations at Patty's Rock were generally higher at the surface sonde compared to the mid-depth sonde. Whereas the Patty's Rock surface sonde had a mean DO concentration of 9.0 mg/L, the mid-depth sonde had a mean DO concentration of 8.2 mg/L (Table 4.1.1). Although the mid-depth and surface sondes were both observed to experience supersaturation conditions, the mid-depth sonde also experienced more frequent hypoxic and anoxic conditions that served to decrease the mean seasonal value. These supersaturation and hypoxic events were observed during open and closed conditions (Figure 4.1.15).

The effect of closed conditions at the surface sonde was variable as DO concentrations were observed to remain relatively unaffected, slightly decline, or increase in some instances (Figure 4.1.15). The Patty's Rock surface sonde had a minimum DO concentration of 6.5 mg/L (Table 4.1.1). Minimum concentrations were observed to occur in brackish water following the transition from closed to open barrier beach conditions (Figures 4.1.15 and 4.1.3).

DO concentrations were observed to become hypoxic and anoxic at the Patty's Rock mid-depth sonde during and immediately following river closures (Figure 4.1.15). The minimum DO concentration at the mid-depth sonde was 0.3 mg/L (Table 4.1.1).

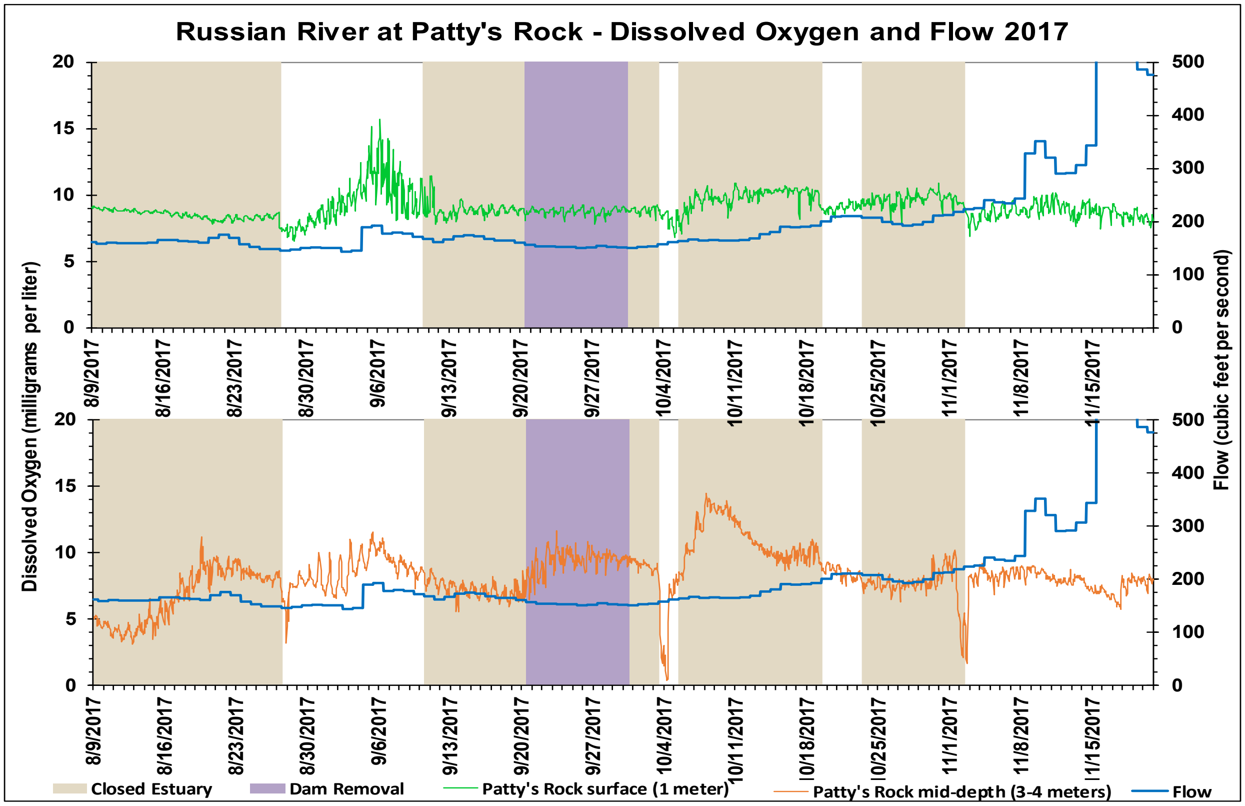


Figure 4.1.15. 2017 Russian River at Patty's Rock Dissolved Oxygen and Flow Graph

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 and mid-depth sondes during open and closed estuary conditions (Figure 4.1.15). 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 15.7 mg/L, which corresponded to 199% saturation (Table 4.1.1). The maximum DO concentration at the mid-depth sonde was 14.4 mg/L, which corresponded to 166% saturation (Table 4.1.1).

Dissolved oxygen concentrations in Willow Creek were observed to fluctuate in response to a variety of events including tidal water movement, saline intrusion, and open or closed Estuary conditions. Large diurnal swings in dissolved oxygen concentrations were observed to occur with frequent supersaturation events in both brackish and freshwater during open barrier beach conditions in the first half of the monitoring season (Figure 4.1.16). Whereas, dissolved oxygen concentrations were observed to steadily decline over a period of days during barrier beach closures in both brackish and freshwater conditions. However, dissolved oxygen concentrations

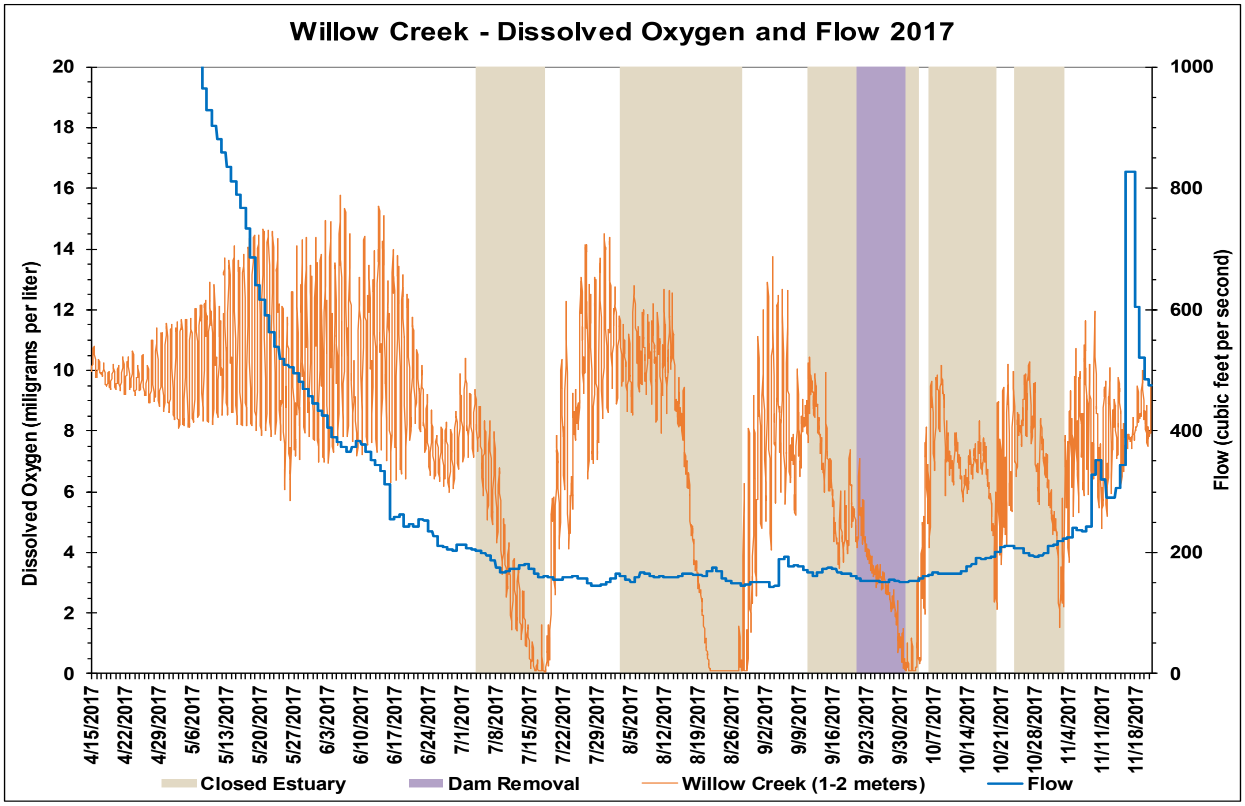


Figure 4.1.16. 2017 Willow Creek Dissolved Oxygen and Russian River Flow Graph

were observed to recover between and after closures as oxygenated saline water or freshwater migrated back into the station (Figure 4.1.16).

The Willow Creek sonde had a minimum DO concentration of 0.1 mg/L, a mean DO concentration of 7.6 mg/L, and a maximum DO concentration of 15.8 mg/L (174%) (Table 4.1.1).

Upper Reach Dissolved Oxygen

Dissolved oxygen concentrations in the upper reach were influenced by the presence or absence of salinity, with lower minimum and mean DO concentrations observed in brackish water and higher minimum and mean concentrations observed in freshwater, especially during closed conditions. In 2017, the Freezeout Creek station was a predominantly freshwater habitat that was subject to elevated salinity levels as the salt wedge migrated up the Estuary during both open and closed conditions in the latter half of the monitoring season (Figure 4.1.5). The Brown's Pool station remained a freshwater habitat during the entire monitoring season (Figure 4.1.6). Hypoxic and anoxic conditions at the Freezeout Creek station were observed to occur in brackish and freshwater habitat during open and closed Estuary conditions (Figure 4.1.17). Hypoxic and anoxic conditions were more closely associated with closed Estuary conditions at the Brown's Pool station (Figure 4.1.18).

The Freezeout Creek bottom sonde had a minimum concentration of 0.2 mg/L, a mean DO concentration of 7.1 mg/L, and a maximum concentration of 10.5 mg/L (117%) (Table 4.1.1).

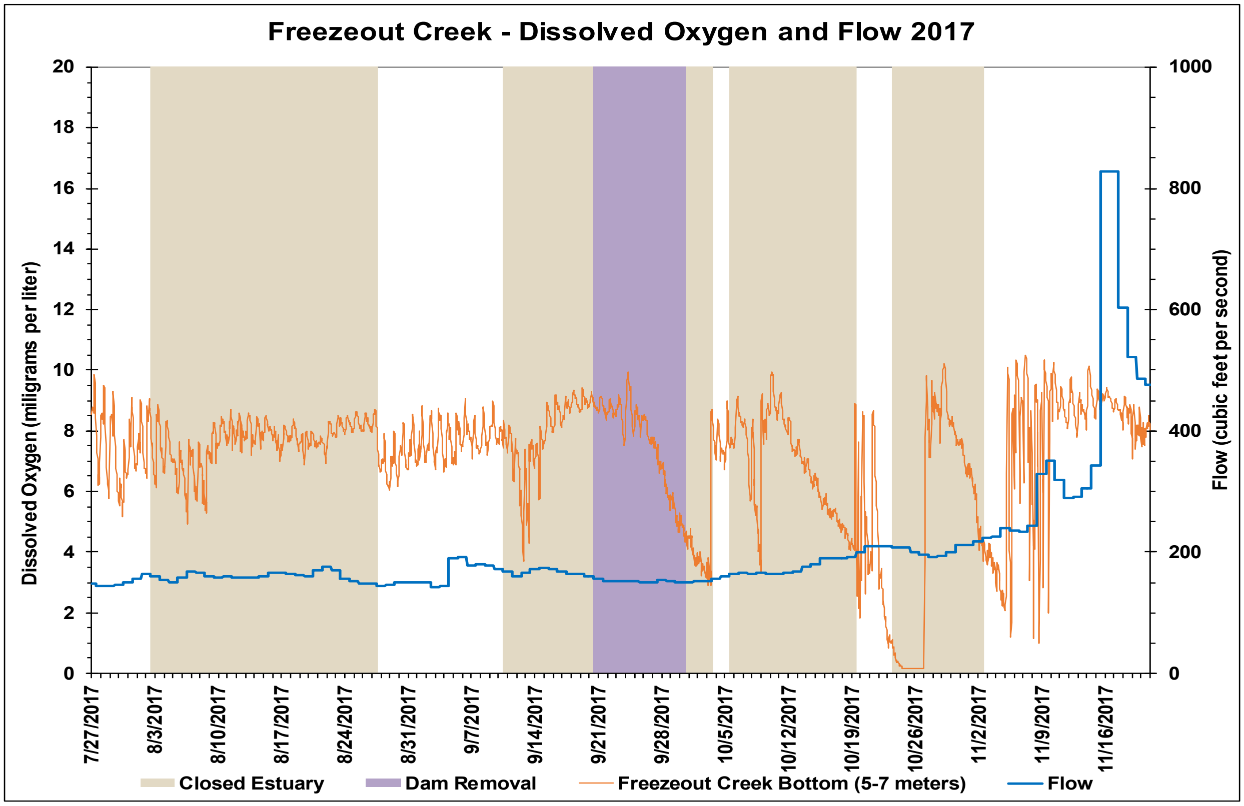


Figure 4.1.17. 2017 Russian River at Freezeout Creek Dissolved Oxygen and Flow Graph

The Freezeout Creek bottom sonde was in predominantly freshwater habitat during open and closed conditions, however there were several episodes of saline water migrating to the site in during the latter half of the monitoring season (Figure 4.1.5). DO concentrations were observed to become depressed in saline water, although there was a brief period of recovery in the presence of saline water during the closure in early November. DO concetrations were generally observed to recover in freshwater and appeared to fully recover after the Estuary reopened and flows began to increase in November (Figure 4.1.17).

The Brown's Pool bottom sonde had a malfunctioning DO probe during the first half of the season whereby no data was recorded (Figure 4.1.18). Data collected during the latter half of the season at the Brown's Pool bottom sonde were observed to have a minimum DO concentration of 0.0 mg/L, a mean concentration of 6.8 mg/L, and a maximum concentration of 10.7 mg/L (104%) (Table 4.1.1).

The bottom of Brown's Pool remained freshwater during the entire monitoring season in open and closed conditions (Figure 4.1.6). DO concentrations were observed to remain relatively stable in freshwater conditions, however depressed concentrations as low as 0.0 mg/L were observed during estuary closure in August (Figure 4.1.18). These concentrations remained anoxic until the river mouth reopened. Depressed concentrations were also observed to briefly occur during and immediately following closures in October.

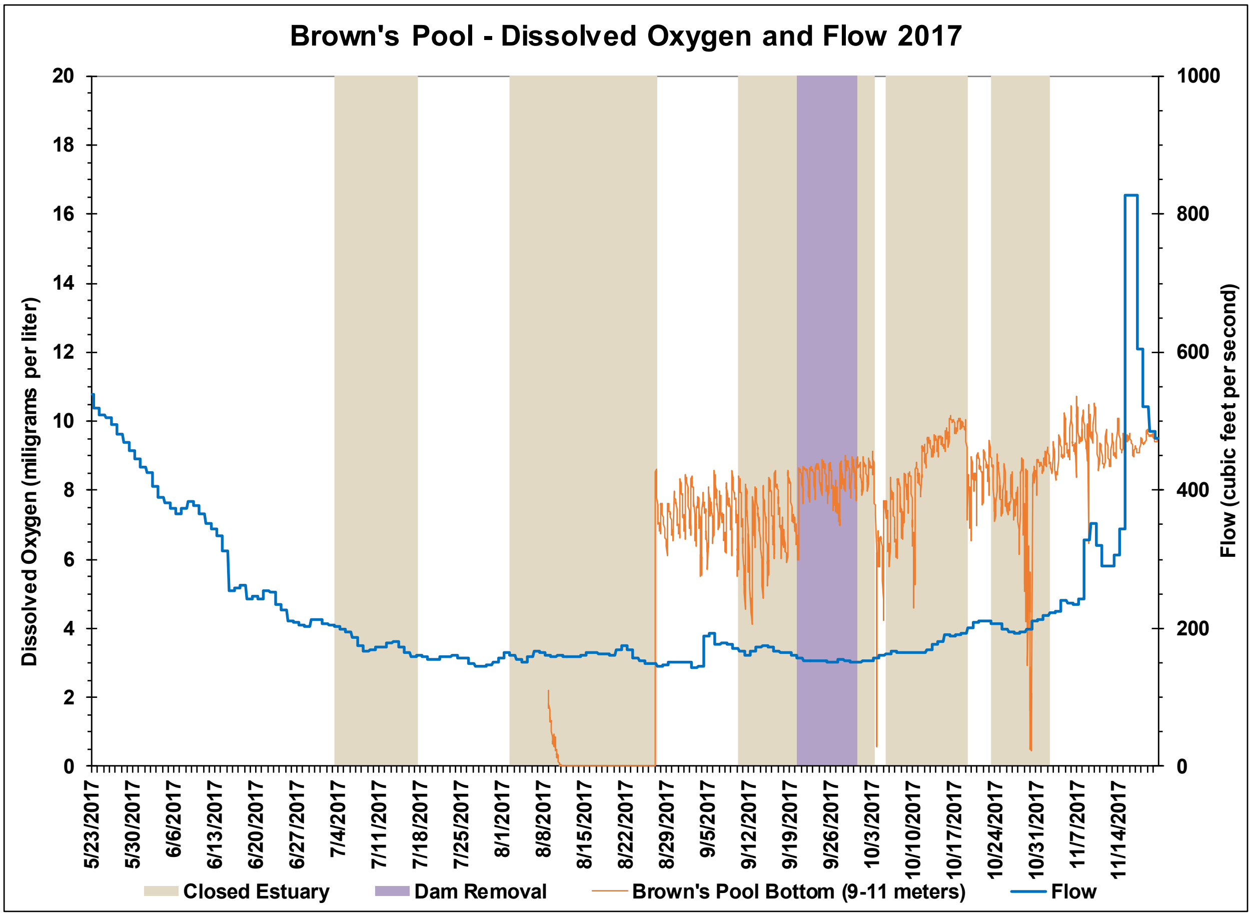


Figure 4.1.18. 2017 Russian River at Brown's Pool Dissolved Oxygen and Flow Graph

Maximum Backwater Area Dissolved Oxygen

The Austin Creek station had a minimum DO concentration of 1.1 mg/L, a mean concentration of 5.5 mg/L, and a maximum concentration of 9.9 mg/L (100%) (Table 4.1.1).

Flows were higher in 2017 compared to the drought years and did not drop below 2 cfs at the upstream USGS gauging station until the end of August (Figure 4.1.19). The USGS gauging station was observed to have measurable flow all season, however flows were below 1 cfs in late September and early October, resulting in isolated pools. Minimum concentrations at Austin Creek were observed during the transition from closed to open estuary conditions in July and August (Figure 4.1.19). DO concentrations were observed to recover after the barrier beach reopened in July, but remained depressed after the barrier beach reopened in August. DO concentrations were not observed to fully recover to springtime levels until flows increased during a storm event in early November. DO response to estuary closures was variable and was observed to both increase and decrease.

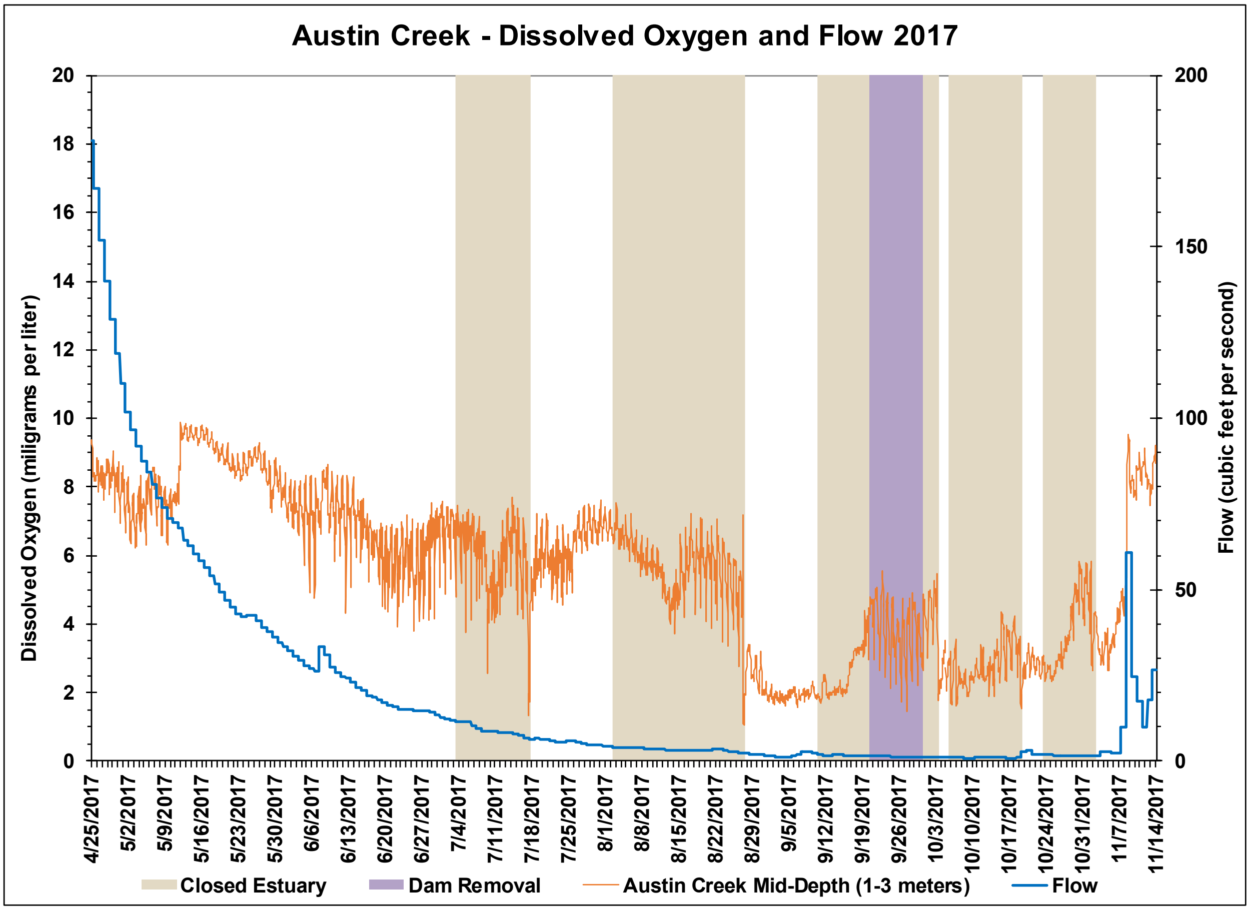


Figure 4.1.19. 2017 Austin Creek Dissolved Oxygen and Flow Graph

The Patterson Point bottom sonde malfunctioned during the latter half of the monitoring season and no data was recorded. During the first half of the season, the Patterson Point bottom sonde had a minimum DO concentration of 0.0 mg/L, a mean concentration of 4.3 mg/L, and a maximum concentration of 12.1 (123%). The bottom sonde remained predominantly hypoxic to anoxic through the first half of the monitoring season under both open and closed conditions (Figure 4.1.20). Frequent fluctuations in DO concentrations were observed during higher spring to early summer flows, but the bottom sonde became anoxic during the July closure and remained predominantly anoxic during open and closed conditions through August (Figure 4.1.20).

The Patterson Point mid-depth sonde had minimum, mean, and maximum DO concentrations of 2.0, 8.1, and 11.0 (120%) mg/L, respectively (Table 4.1.1). DO concentrations were observed to remain relatively stable in freshwater conditions, with depressed concentrations as low as 2.0 mg/L being observed to briefly occur at the end of an Estuary closure event in July (Figure 4.1.20).

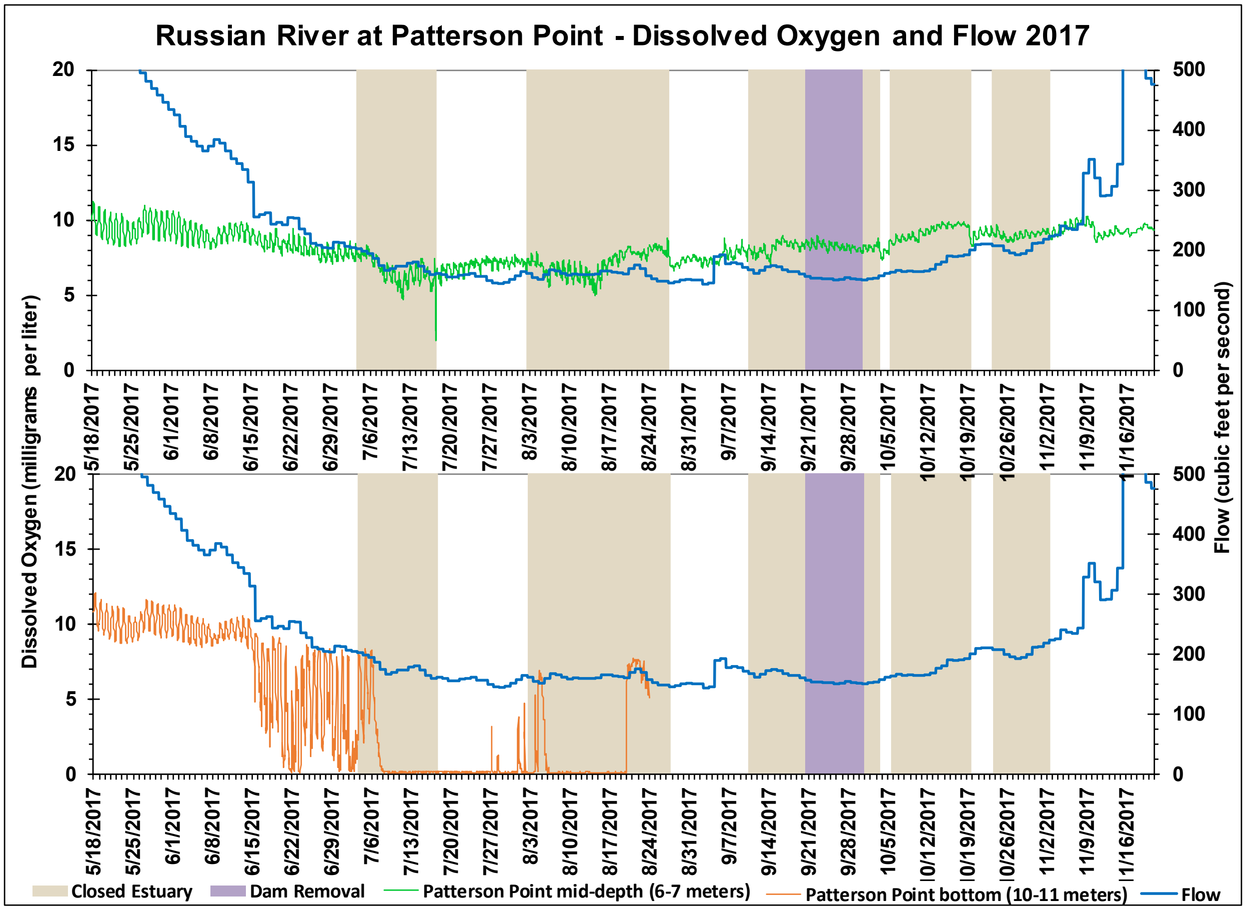


Figure 4.1.20. 2017 Russian River at Patterson Point Dissolved Oxygen and Flow Graph

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 is a noticeable reduction in the abundance of many species, including snails, amphibians, crustacean zooplankton, and fish such as salmon and some trout species (Horne 1994).

Lower and Middle Reach pH

The Patty's Rock surface sonde had a minimum pH value of 7.3, a mean pH value of 8.0, and a maximum pH value of 8.8 pH (Table 4.1.1). The Patty's Rock mid-depth sonde had a minimum pH value of 7.1, a mean pH value of 8.0, and a maximum pH value of 8.8 pH.

Patty's Rock pH values were observed to vary with increases and decreases of DO concentrations, with higher values generally observed during supersaturation conditions and lower values during hypoxic conditions (Figure 4.1.21). This was especially apparent when pH

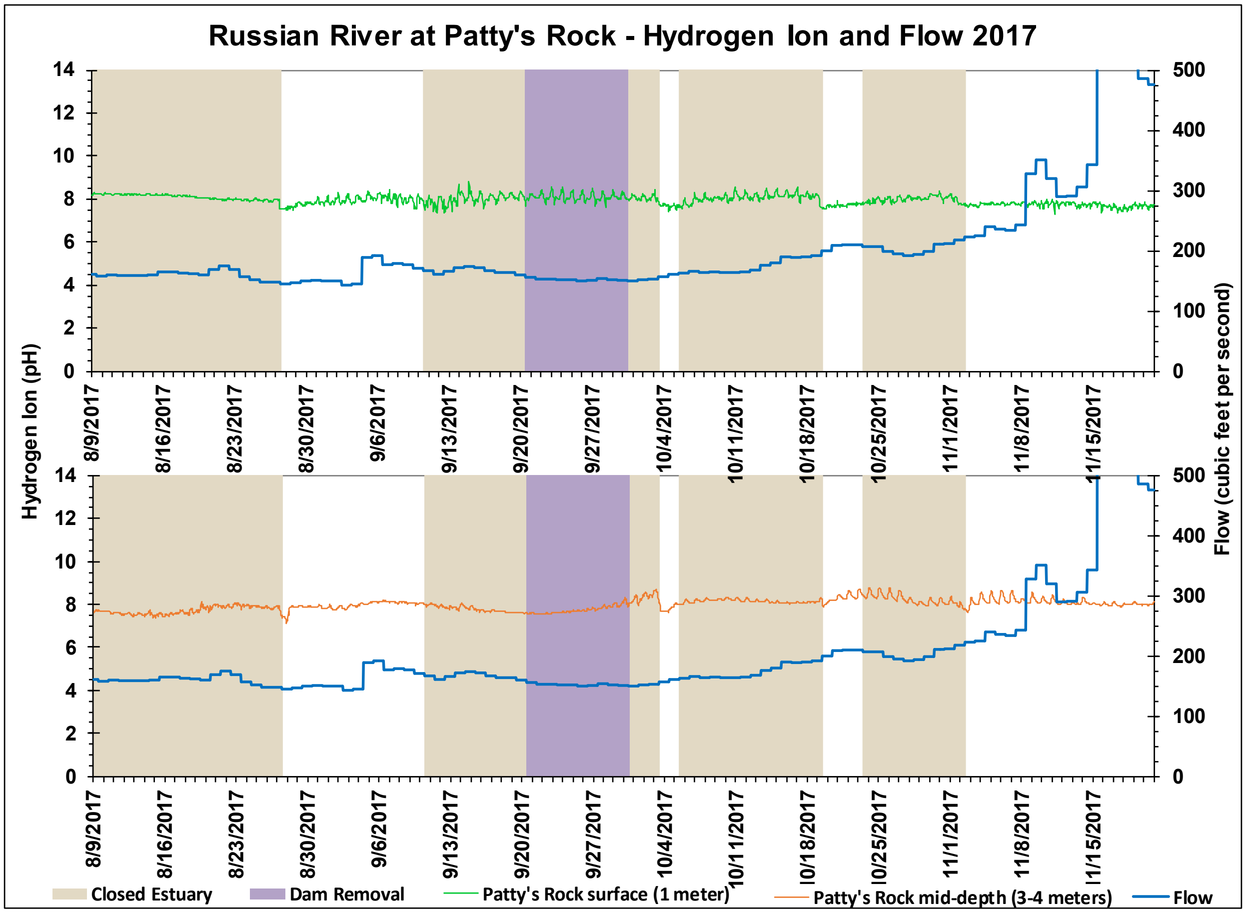


Figure 4.1.21. 2017 Russian River at Patty's Rock Hydrogen Ion and Flow Graph

values briefly dropped to 7.1 at the Patty's Rock mid-depth sonde during a hypoxic event in August when the estuary reopened (Figures 4.1.15 and 4.1.21). The Willow Creek station had a minimum pH value of 6.2, a mean pH value of 7.3, and a maximum pH value of 8.8 (Table 4.1.1). The Willow Creek station also had pH values that were observed to vary with increases and decreases of DO concentrations, as well as with fluctuations in salinity associated with reduced freshwater flows, tidal influence, and Estuary closures (Figures 4.1.16 and 4.1.22).

Upper Reach pH

The Freezeout Creek bottom sonde recorded a minimum pH value of 6.8, a mean pH value of 7.6, and a maximum pH value of 8.3 (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 4.1.23).

The Brown's Pool bottom sonde had a minimum pH value of 7.0, a mean pH value of 7.6, and a maximum pH value of 8.2 (Table 4.1.1). Minimum pH values occurred at the bottom sonde during anoxic conditions when the Estuary was closed (Figures 4.1.18 and 4.1.24).

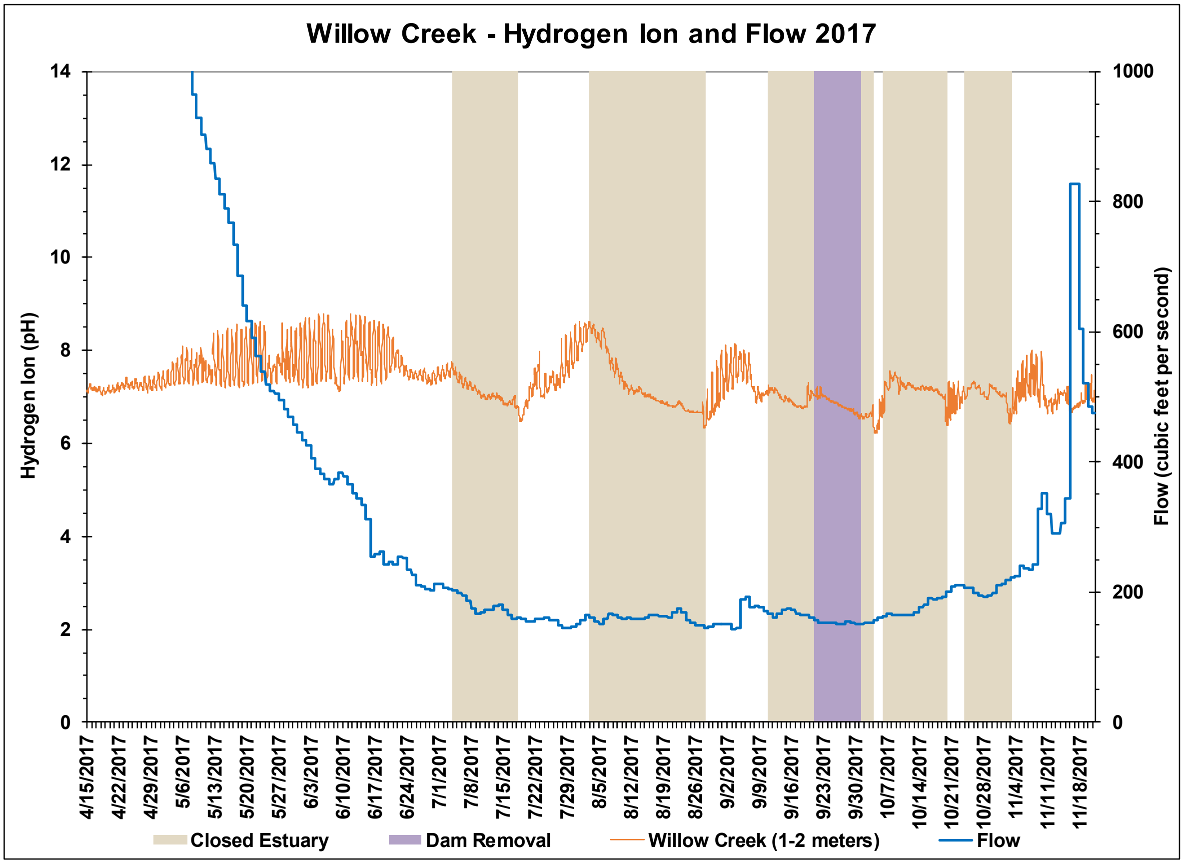


Figure 4.1.22. 2017 Willow Creek Hydrogen Ion and Russian River Flow Graph

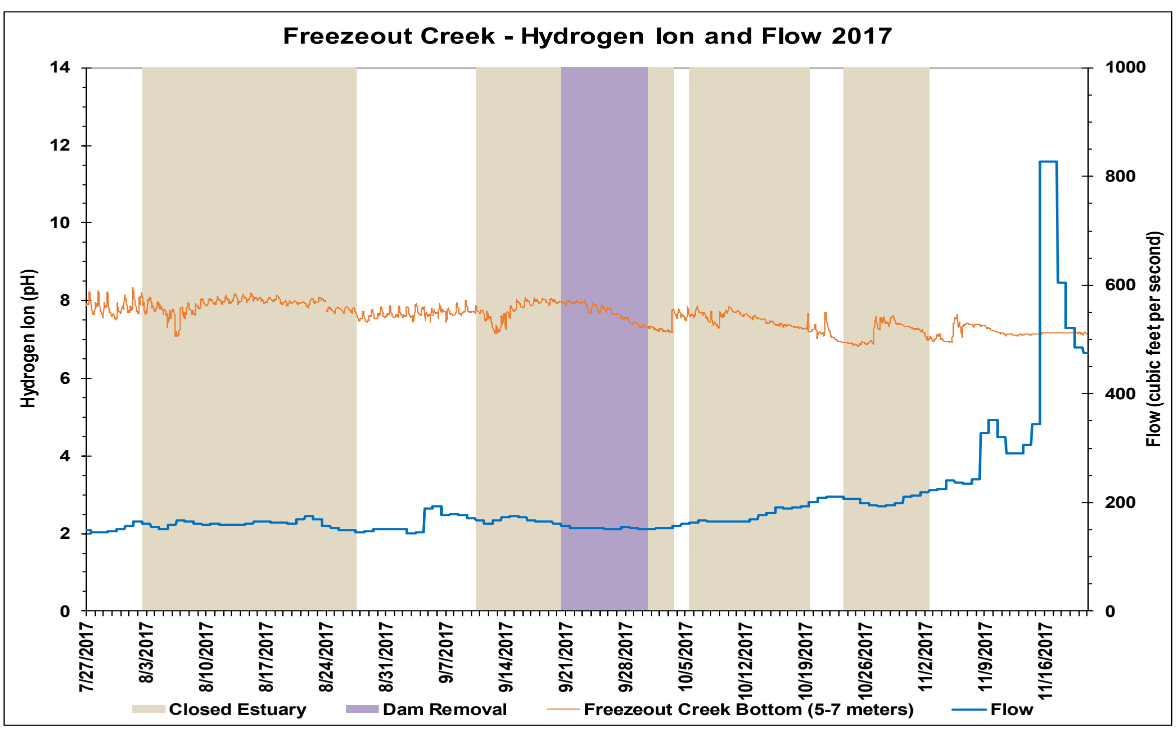


Figure 4.1.23. 2017 Russian River at Freezeout Creek Hydrogen Ion and Flow Graph

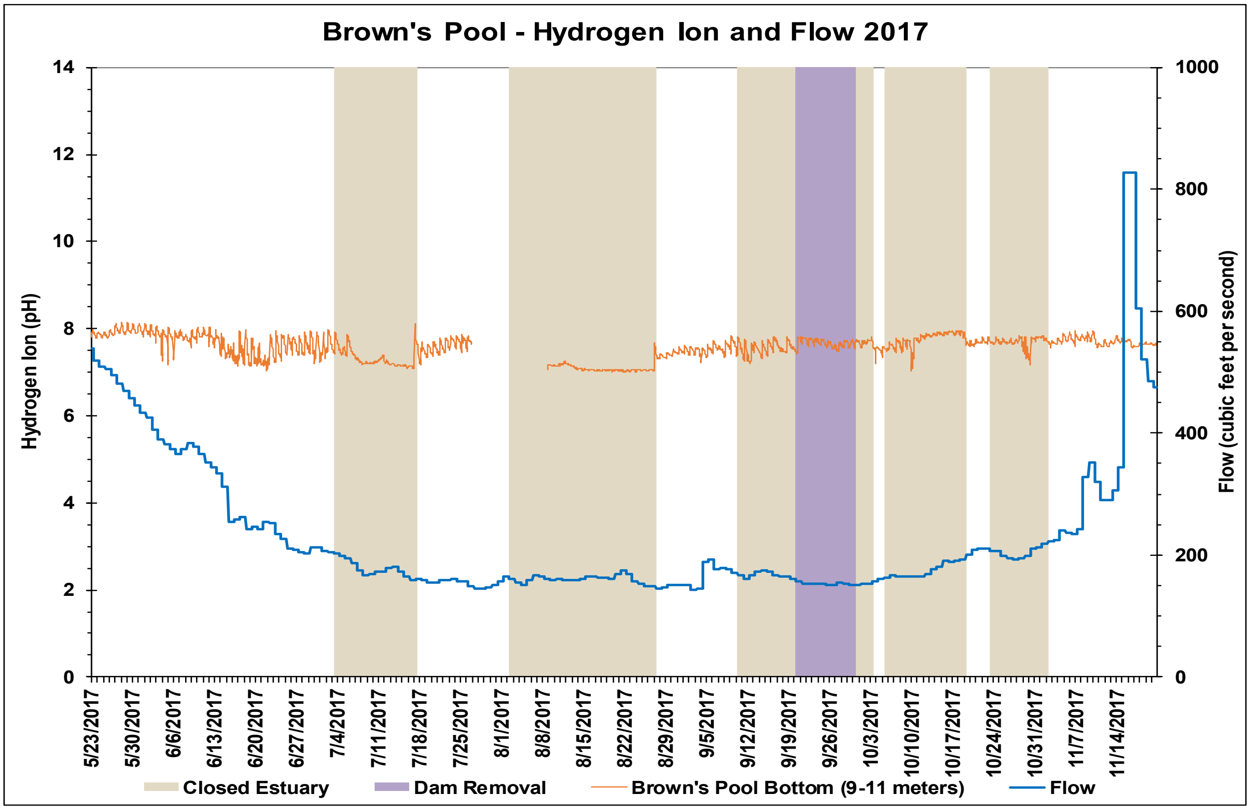


Figure 4.1.24. 2017 Russian River at Brown's Pool Hydrogen Ion and Flow Graph

Maximum Backwater Area pH

The Austin Creek sonde had a minimum pH value of 6.7, a mean pH value of 7.2, and a maximum pH value of 7.8 (Table 4.1.1). The Austin Creek sonde also had pH values that were generally observed to vary with increases and decreases of DO concentrations (Figures 4.1.19 and 4.1.25).

The Patterson Point bottom sonde had a minimum pH value of 5.3, a mean pH value of 7.1, and a maximum pH value of 8.1 (Table 4.1.1). The Patterson Point mid-depth sonde had a minimum pH value of 7.2, a mean pH value of 7.6, and a maximum pH value of 8.1 (Table 4.1.1). The Patterson Point sondes also had pH values that were generally observed to vary with increases and decreases of DO concentrations (Figures 4.1.20 and 4.1.26). Minimum pH values were observed during hypoxic and anoxic DO concentrations under both open and closed conditions.

Grab Sampling

Sonoma Water staff conducted weekly grab sampling from May 16 to October 17 at three freshwater stations in the mainstem of the lower river including Patterson Point, Monte Rio, and Vacation Beach (Figure 4.1.1). Additional focused sampling was conducted during or after Estuary closures, as well as during summer dam removal in late September, where Agency staff would collect three samples in ten days (Tables 4.1.2 through 4.1.4). Samples collected and analyzed for nutrients, turbidity, *chlorophyll a*, and indicator bacteria are discussed below. Other sample results including organic carbon, and dissolved solids are not discussed, but are included as an appendix to the report.

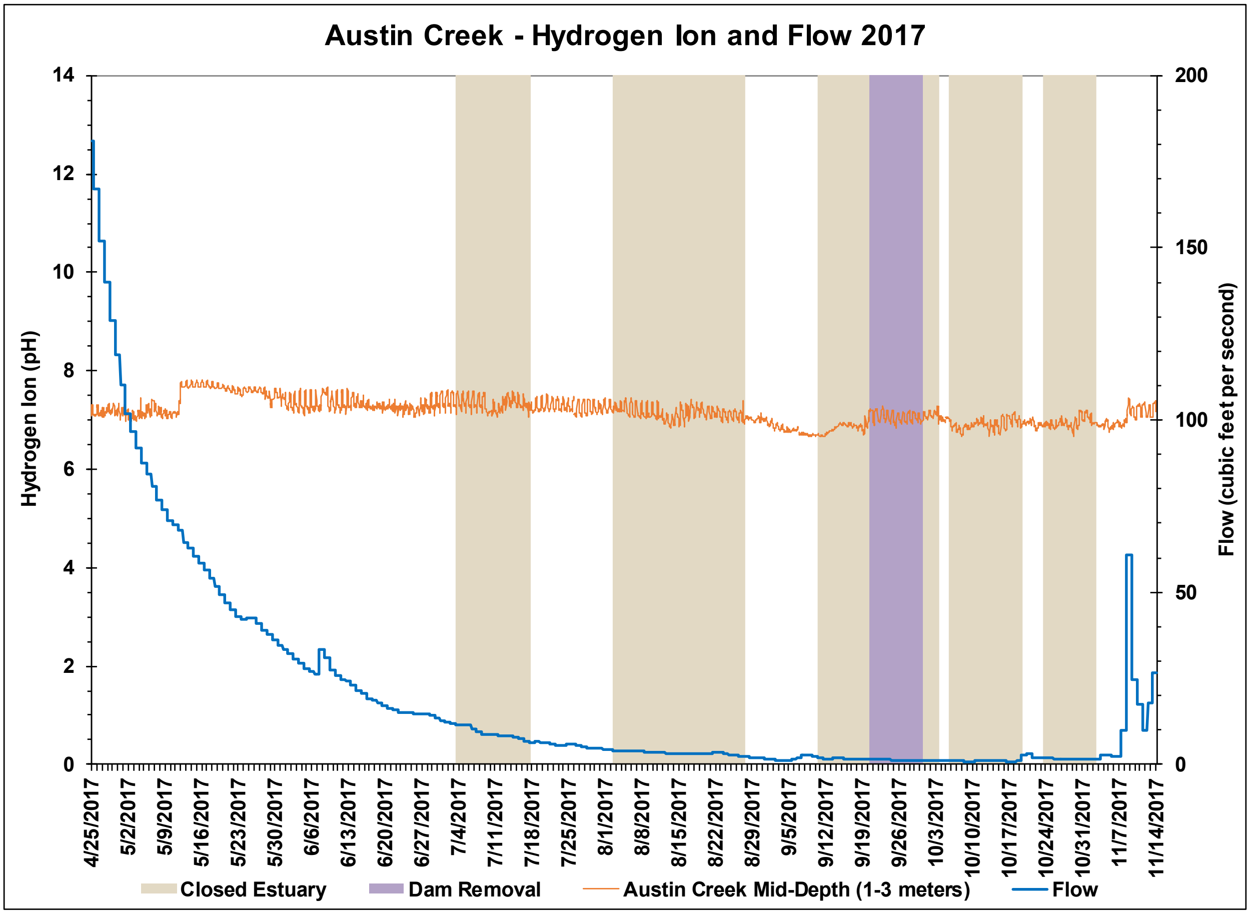


Figure 4.1.25. 2017 Austin Creek Hydrogen Ion and Flow Graph

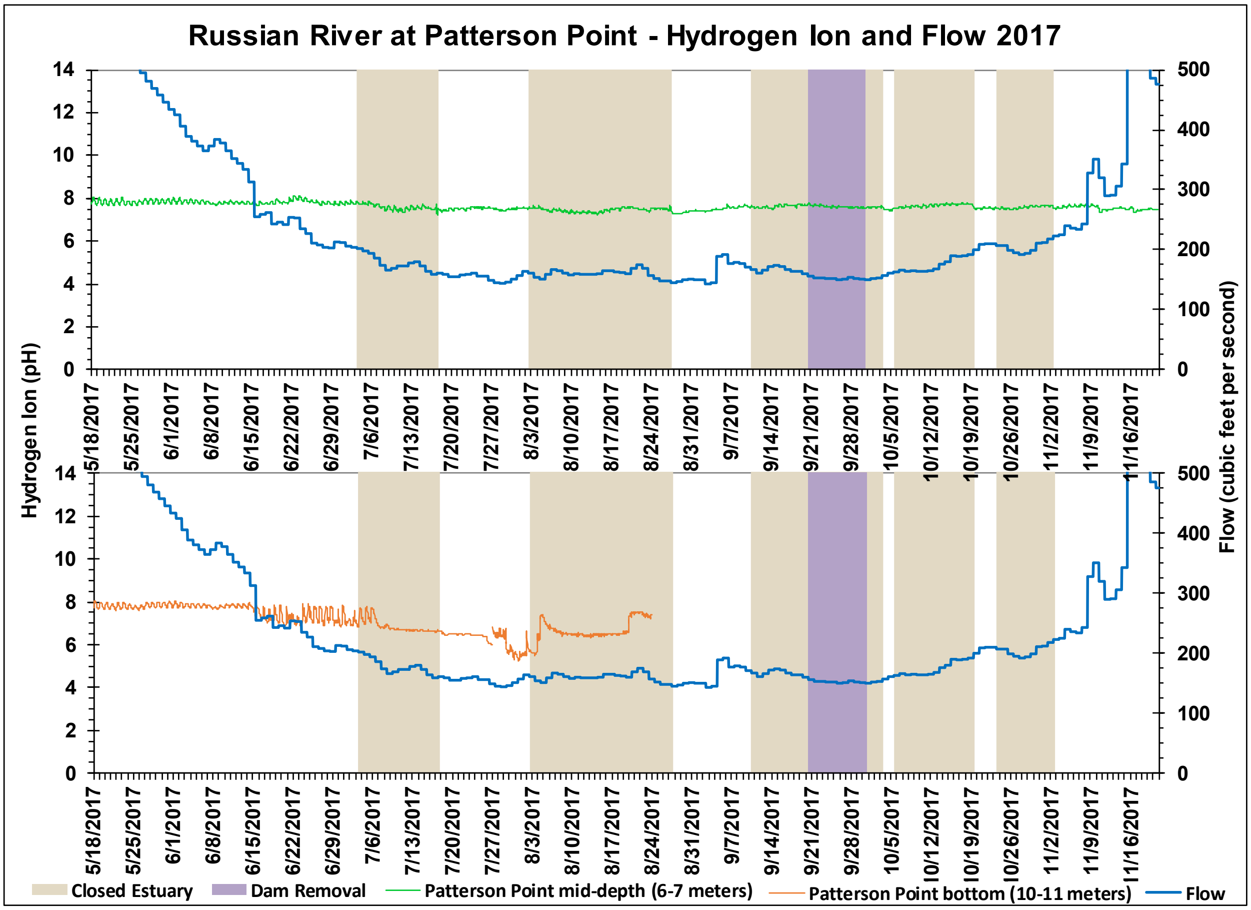


Figure 4.1.26. 2017 Russian River at Patterson Point Hydrogen Ion and Flow Graph

Table 4.1.2. 2017 Russian River at Patterson Point Station Grab Sample Results

Patterson Point*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	Total Coliforms (Colilert)	Total Coliforms Diluted 1:10 (Colilert)	E. coli (Colilert)	E. coli Diluted 1:10 (Colilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)***		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/16/2017	16.1	0.24	**0.034**	**4.4**	**0.0035**	686.7	383	12.0	10	3.0	777	Open	1.09
5/23/2017	19.6	0.37	**0.030**	**2.4**	**0.0038**	1119.9	706	11.0	20	<1.0	561	Open	1.90
5/30/2017	19.2	0.32	**0.032**	**2.5**	**0.0038**	344.1	457	110.0	**310**	3.0	483	Open	0.84
6/6/2017	22.1	0.32	**0.032**	1.7	**0.0029**	727.0	987	14.6	<10	1.0	400	Open	1.85
6/13/2017	19.4	**0.47**	**0.034**	2.2	**0.0023**	770.1	857	12.1	<10	3.1	364	Open	1.26
6/20/2017	25.1	**0.51**	**0.037**	1.7	**0.0061**	1732.9	2481	11.0	<10	13.4	243	Open	2.19
6/27/2017	23.2	0.23	**0.035**	1.4	**0.0044**	1413.6	1246	11.0	10	6.1	207	Open	3.50
7/5/2017	22.7	0.26	**0.044**	2.0	**0.0047**	>2419.6	8664	18.7	20	6.2	197	Closed	4.38
7/11/2017	24.1	0.18	**0.038**	1.4	0.0014	>2419.6	7701	12.1	20	35.0	175	Closed	6.36
7/13/2017	23.7	0.18	**0.039**	1.3	**0.0018**	>2419.6	7270	23.3	20	13.1	179	Closed	6.95
7/18/2017	23.9	0.10	**0.040**	1.6	0.0016	>2419.6	9804	27.9	10	20.9	164	Open	3.03
7/25/2017	23.4	0.035	**0.042**	2.1	**0.0030**	>2419.6	3255	12.1	10	31.2	141	Open	2.15
8/1/2017	22.9	0.12	**0.031**	2.2	**0.0023**	325.5	2224	6.3	<10	4.1	139	Open	1.73
8/8/2017	22.6	0.12	**0.029**	**2.9**	0.0015	>2419.6	2489	29.8	52	**64.4**	144	Closed	4.80
8/10/2017						>2419.6	2613	42.6	31		136	Closed	5.44
8/15/2017	23.4	0.19	**0.027**	1.7	**0.0018**	>2419.6	**14136**	35.9	52	**>2419.6**	136	Closed	6.53
8/22/2017	21.2	0.053	**0.027**	1.1	0.0017	1986.3	1722	8.4	20	52.0	149	Closed	7.84
8/29/2017	22.2	0.16	**0.031**	2.1	0.0013	1203.3	1019	10.7	<10	14.5	135	Open	1.43
9/5/2017	23.2	0.10	**0.028**	1.4	0.0014	>2419.6	2909	14.8	<10	25.9	177	Open	1.56
9/12/2017	22.9	0.28	**0.032**	2.2	0.0012	1986.3	1989	5.2	<10	7.4	148	Closed	3.12
9/19/2017	20.1	0.20	**0.033**	**2.5**	0.00095	>2419.6	4106	25	20	**129.6**	151	Closed	5.98
9/21/2017	19.8	0.24	**0.031**	**5.2**	0.0013	2419.6	2909	71.2	75	**920.8**	143	Closed	6.78
9/26/2017	18.5	0.21	**0.023**	1.6	0.0007	1119.9	1291	33.6	31	**62.4**	138	Closed	7.71
9/28/2017	18.7	0.15	**0.025**	2.1	0.00099	1553.1	1137	46.4	30	44.1	142	Closed	7.97
10/3/2017	18.4	0.22	**0.022**	1.4	0.00082	1299.7	1274	20.9	20	36.4	140	Closed	8.56
10/17/2017	14.1	0.22	**0.024**	1.4	ND						189	Closed	7.16

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

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

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

Table 4.1.3. 2017 Russian River at Monte Rio Station Grab Sample Results

Monte Rio*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	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)****		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/16/2017	16.3	0.31	**0.034**	**4.9**	**0.0080**	866.4	523	9.7	10	4.1	777	Open	1.01
5/23/2017	19.9	0.37	**0.030**	**2.7**	**0.0048**	727.0	613	7.3	<10	8.5	561	Open	2.11
5/30/2017	19.3	0.28	**0.033**	**3.4**	**0.0075**	501.2	546	12.0	<10	1.0	483	Open	0.76
6/6/2017	22.0	0.27	**0.040**	2.0	**0.0072**	1413.6	1401	8.6	10	1.0	400	Open	1.81
6/13/2017	19.5	**0.39**	**0.038**	2.3	**0.0026**	816.4	1050	11.0	<10	1.0	364	Open	1.35
6/20/2017	25.3	**0.48**	**0.037**	1.8	**0.012**	>2419.6	2143	24.6	10	15.8	243	Open	2.19
6/27/2017	22.7	0.21	**0.035**	1.4	**0.0049**	920.8	1723	7.5	20	3.1	207	Open	3.37
7/5/2017	22.7	0.21	**0.044**	**2.8**	**0.0038**	>2419.6	7270	19.7	10	5.2	197	Closed	4.38
7/11/2017	24.6	0.24	**0.042**	1.6	**0.0026**	>2419.6	**17329**	52.0	63	59.8	175	Closed	6.36
7/13/2017	24.5	0.14	**0.036**	1.6	**0.0018**	>2419.6	5172	26.2	10	**62.6**	179	Closed	6.95
7/18/2017	23.9	0.035	**0.039**	1.7	**0.0020**	>2419.6	**12033**	18.5	85	19.5	164	Open	2.95
7/25/2017	23.6	0.21	**0.038**	**2.6**	**0.0021**	>2419.6	3255	31.7	52	**152.9**	141	Open	1.85
8/1/2017	23.1	0.10	**0.035**	**3.2**	**0.0020**	325.5	3076	10.9	10	4.1	139	Open	1.68
8/8/2017	22.6	0.086	**0.030**	**3.4**	**0.0019**	2419.6	2014	14.5	20	5.2	144	Closed	4.85
8/10/2017						>2419.6	3448	113.7	123		136	Closed	5.44
8/15/2017	23.5	0.16	**0.029**	1.7	0.0013	2419.6	3448	38.4	74	20.9	136	Closed	6.53
8/22/2017	21.1	0.090	**0.027**	1.3	0.00093	>2419.6	4611	**270.0**	**275**	**135.4**	149	Closed	7.84
8/29/2017	22.5	0.18	**0.030**	1.6	0.0011	1119.9	1421	7.2	10	1.0	135	Open	1.35
9/5/2017	23.5	0.14	**0.029**	1.7	**0.0021**	2419.6	1850	6.3	31	17.1	177	Open	1.90
9/12/2017	22.9	0.10	**0.031**	2.2	0.00078	1732.9	1483	9.7	20	6.2	148	Closed	3.12
9/19/2017	20.2	0.12	**0.030**	1.6	0.00057	1986.3	1553	47.3	74	**69.7**	151	Closed	5.94
9/21/2017	19.6	0.12	0.019	1.9	0.00097	1203.3	2603	73.8	85	**69.7**	143	Closed	6.78
9/26/2017	18.4	0.19	**0.026**	1.4	0.00032	1119.9	1130	37.3	20	60.9	138	Closed	7.71
9/28/2017	18.9	0.14	**0.024**	1.0	0.00033	1203.3	1566	77.1	63	**83.6**	142	Closed	8.01
10/3/2017	18.2	0.18	0.021	0.93	0.0013	1203.3	801	48.7	30	**88.0**	140	Closed	8.39
10/17/2017	14.0	0.10	**0.022**	1.4	0.00018						189	Closed	7.21

* All results are preliminary and subject to final revision

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

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

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

Recommended EPA Criteria based on Aggregate Ecoregion III

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

Total Nitrogen: 0.38 mg/L

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

Turbidity: 2.34 FTU/NTU

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

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

Total coliforms: 10,000 per 100 ml

E. coli: 235 per 100 ml

Enterococcus: 61 per 100 ml

Table 4.1.4. 2017 Russian River at Vacation Beach Station Grab Sample Results

Vacation Beach*	Temperature	Total Nitrogen***	Total Phosphorus	Turbidity	Chlorophyll-a	Total Coliforms (Colilert)	Total Coliforms Diluted 1:10 (Colilert)	E. coli (Colilert)	E. coli Diluted 1:10 (Colilert)	Enterococcus (Enterolert)	USGS 11467000 RR near Guerneville (Hacienda)****		
MDL**			0.020	0.020	0.000050	2	20	2	20	2	Flow Rate	Estuary	Jenner
Date	°C	mg/L	mg/L	NTU	mg/L	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	MPN/100mL	(cfs)	Condition	Gauge (ft)
5/16/2017	16.5	0.28	**0.034**	**4.5**	**0.0049**	727.0	435	8.6	<10	3.0	777	Open	0.93
5/23/2017	20.3	**0.88**	**0.035**	**3.0**	**0.0023**	547.5	776	12.2	10	2.0	561	Open	2.23
5/30/2017	19.4	0.33	**0.038**	**3.1**	**0.0022**	344.1	448	16.7	20	1.0	483	Open	0.72
6/6/2017	22.4	0.24	**0.036**	**2.5**	**0.0099**	980.4	1126	8.6	20	3.1	400	Open	1.64
6/13/2017	19.2	**0.52**	**0.038**	**3.2**	**0.0035**	770.1	697	5.2	<10	9.7	364	Open	1.09
6/20/2017	25.5	**0.50**	**0.037**	2.2	**0.0035**	1553.1	3255	37.9	52	39.0	243	Open	2.11
6/27/2017	23.3	0.18	**0.039**	1.9	**0.0069**	>2419.6	2909	22.6	31	10.9	207	Open	3.54
7/5/2017	23.0	0.18	**0.041**	**2.9**	**0.0050**	1986.3	1553	13.5	10	9.6	197	Closed	4.34
7/11/2017	24.6	0.18	**0.036**	1.8	**0.0034**	>2419.6	5794	3.0	31	15.5	175	Closed	6.41
7/13/2017	24.2	0.10	**0.035**	1.9	**0.0026**	>2419.6	4352	8.6	<10	10.9	179	Closed	6.91
7/18/2017	24.6	0.18	**0.033**	1.8	**0.0020**	>2419.6	5475	8.4	<10	10.9	164	Open	2.91
7/25/2017	23.6	0.070	**0.032**	2.2	**0.0030**	1986.3	3076	10.9	<10	7.5	141	Open	1.77
8/1/2017	23.5	0.16	**0.030**	**2.4**	**0.0018**	387.3	2282	5.2	10	4.1	139	Open	1.68
8/8/2017	22.7	0.19	**0.032**	**2.7**	0.0013	2419.6	1935	11	20	30.5	144	Closed	4.80
8/10/2017						1986.3	2613	3.1	<10		136	Closed	5.44
8/15/2017	23.3	0.19	**0.025**	2.2	0.0012	1986.3	2098	18.9	<10	34.1	136	Closed	6.53
8/22/2017	20.7	0.070	**0.023**	2.1	0.0011	1553.1	2014	6.3	10	20.1	149	Closed	7.84
8/29/2017	22.7	0.10	**0.12**	**2.6**	0.0015	1732.9	2359	5.2	20	21.1	135	Open	1.26
9/5/2017	23.5	0.14	**0.025**	1.8	0.0016	1986.3	1374	15.8	<10	13.2	177	Open	1.98
9/12/2017	23.0	0.10	**0.027**	**2.5**	0.0014	1553.1	1054	20.9	52	25.9	148	Closed	3.16
9/19/2017	19.9	0.19	**0.11**	**2.4**	**0.13**	1203.3	1664	14.5	63	17.5	151	Closed	5.94
9/21/2017	18.9	0.16	**0.029**	**3.3**	0.00097	1533.1	1314	21.6	10	**61.3**	143	Closed	6.78
9/26/2017	18.1	0.24	**0.031**	**4.8**	0.00065	1299.7	958	23.1	41	**73.8**	138	Closed	7.71
9/28/2017	18.4	0.15	**0.030**	**3.3**	0.0010	1553.1	624	14.8	52	57.3	142	Closed	7.97
10/3/2017	17.5	0.14	**0.026**	**3.4**	0.0016	980.4	677	23.1	52	**85.7**	140	Closed	8.47
10/17/2017	14.2	0.14	**0.030**	**4.4**	0.00018						189	Closed	7.21

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

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

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

Nutrients

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

The USEPA desired goal for total nitrogen in Aggregate Ecoregion III is 0.38 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Calculating total nitrogen values requires the summation of the different components of total nitrogen; organic and ammoniacal nitrogen (together referred to as Total Kjeldahl Nitrogen or TKN), and nitrate/nitrite nitrogen (Appendix 4.5).

Total nitrogen concentrations were observed to exceed the recommended USEPA levels two times each at the Patterson Point and Monte Rio stations, and three times at the Vacation Beach station (Tables 4.1.2 through 4.1.4). All of these exceedances occurred at the beginning of the monitoring season during open conditions with flows over 240 cfs (Figure 4.1.27). Whereas some of the lowest total nitrogen values observed at the freshwater stations occurred during open conditions in July when flows were 141 cfs, and during closed conditions in August when flows were as low as 144 cfs (Tables 4.1.2 through 4.1.4). Overall, total nitrogen exceedances constituted 9.3% of all samples collected (Figure 4.1.27).

The maximum total nitrogen concentration observed at Patterson Point was 0.51 mg/L on 20 June during open conditions with a flow of approximately 243 cfs (Table 4.1.2). The mean concentration at Patterson Point was 0.22 mg/L. The minimum concentration at Patterson Point was 0.035 mg/L, which occurred on 25 July during open conditions with a flow of approximately 141 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on 29 August with a concentration of 0.16 mg/L (Table 4.1.2).

The maximum total nitrogen concentration observed at Monte Rio was 0.48 mg/L on June 20 during open conditions with a flow of approximately 243 cfs (Table 4.1.3). The mean concentration at Monte Rio was 0.19 mg/L. The minimum concentration at Monte Rio was 0.035 mg/L, which occurred during open conditions with a flow of approximately 164 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29 with a concentration of 0.18 mg/L (Table 4.1.3).

The maximum total nitrogen concentration observed at Vacation Beach was 0.88 mg/L on May 23 during open conditions with a flow of approximately 561 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.22 mg/L. The minimum concentration at Vacation Beach was 0.070 mg/L, which occurred twice, on July 25 during open conditions and a flow of approximately 141 cfs and on August 22 during closed conditions and a flow of approximately 149 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29 with a concentration of 0.10 mg/L (Table 4.1.4).

The USEPA's desired goal for total phosphates as phosphorus in Aggregate Ecoregion III has been established as 21.88 micrograms per liter (μg/L), or approximately 0.022 mg/L, for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). Total phosphorus concentrations at the freshwater monitoring stations exceeded the U.S. EPA criteria approximately 97.3% of the time, continuing a trend of consistent exceedances observed in previous years. Exceedances occurred during open and closed Estuary conditions, and in river flows ranging from 135 cfs to 777 cfs. Total phosphorus values were observed to generally be higher in the spring and early summer, trending downward through the rest of the season (Figure 4.1.28).

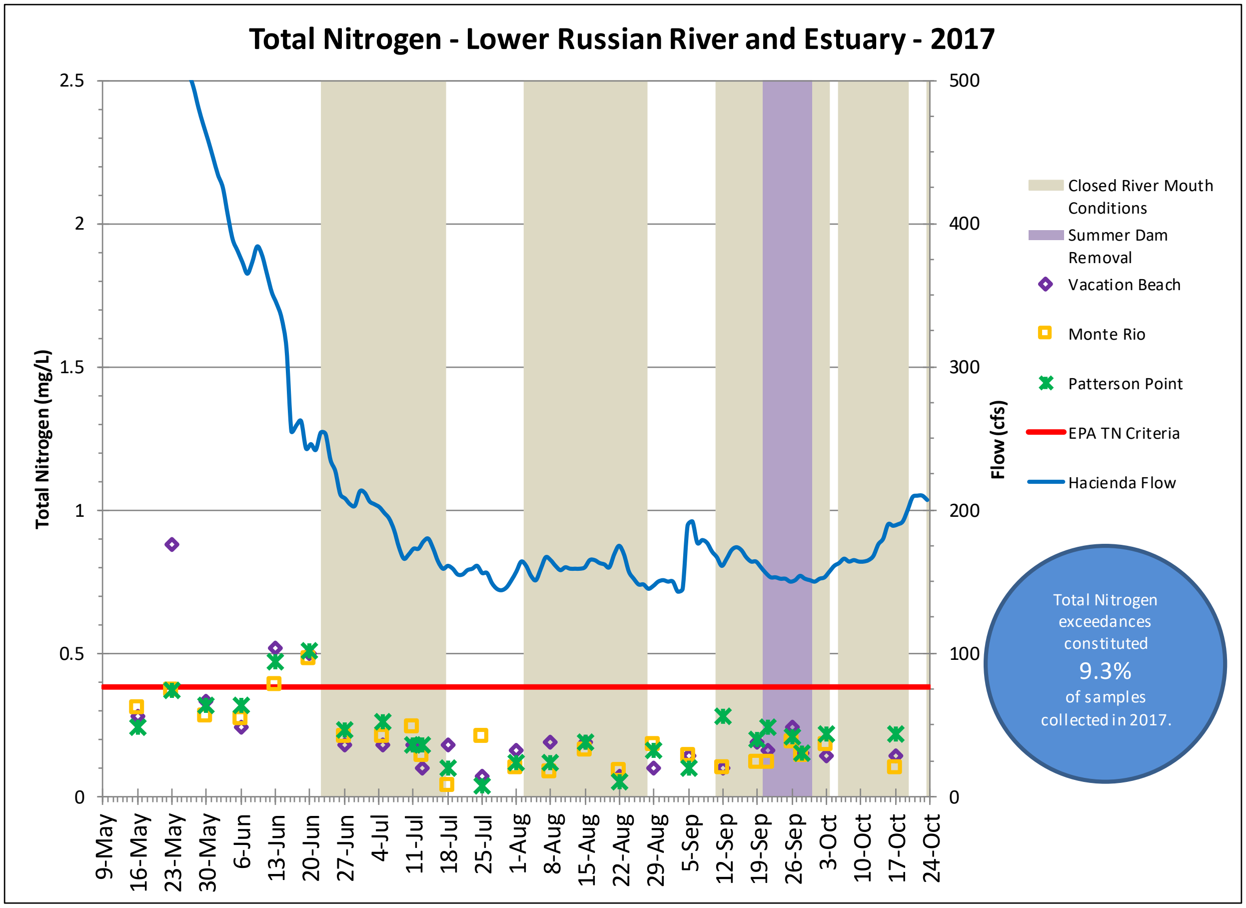


Figure 4.1.27. 2017 Russian River Grab Sampling Results for Total Nitrogen

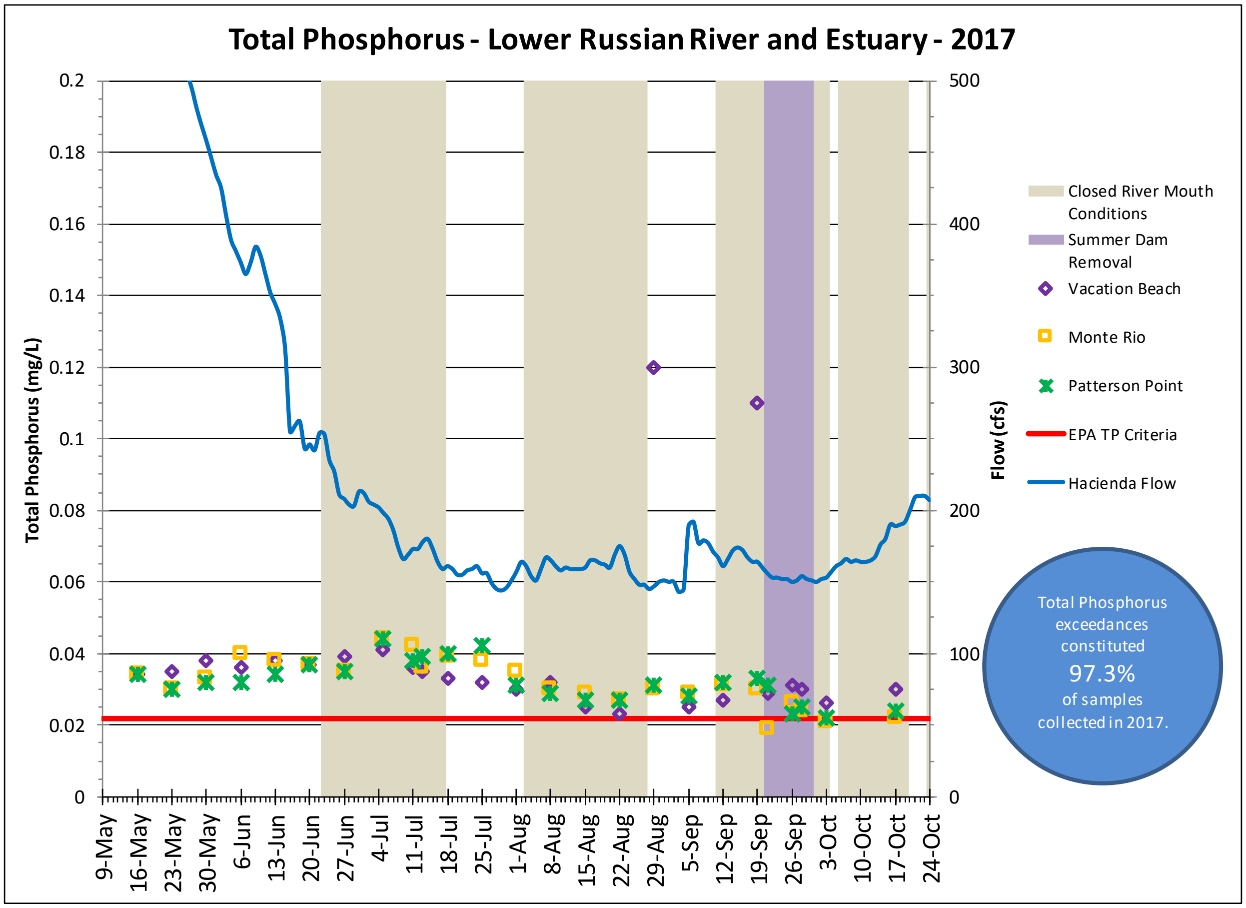


Figure 4.1.28. 2017 Russian River Grab Sampling Results for Total Phosphorus

The maximum total phosphorus concentration observed at Patterson Point was 0.044 mg/L on July 5 during closed conditions with a flow of approximately 197 cfs (Table 4.1.2). The mean concentration at Patterson Point was 0.032 mg/L. The minimum concentration at Patterson Point was 0.022 mg/L, which occurred on October 3 during closed conditions with a flow of approximately 140 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a concentration of 0.031 mg/L (Table 4.1.2).

The maximum total phosphorus concentration observed at Monte Rio was 0.044 mg/L on July 5 during closed conditions with a flow of approximately 197 cfs (Table 4.1.3). The mean concentration at Monte Rio was 0.032 mg/L. The minimum concentration at Monte Rio was 0.019 mg/L, which occurred on September 21 during closed conditions with a flow of approximately 143 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a concentration of 0.030 mg/L (Table 4.1.3).

The maximum total phosphorus concentration observed at Vacation Beach was 0.12 mg/L on August 29 during open conditions with a seasonal low flow of approximately 135 cfs (Table 4.1.4). The mean concentration at Vacation Beach was 0.039 mg/L. The minimum concentration at Vacation Beach was 0.023 mg/L, which occurred on August 22 during closed conditions and a flow of approximately 149 cfs (Table 4.1.4).

Turbidity

There were six exceedances of the Turbidity EPA criteria at Patterson Point, seven exceedances at Monte Rio, and 16 exeedances at Vacation Beach (Figure 4.1.29). These exceedances of the Turbidity criteria occurred approximately 38.7% of the time under open and closed conditions in flows that ranged from 135 cfs to 777 cfs. In addition, Vacation Beach is subject to elevated turbidity from the effects of the summer dam overflow and fish ladder outflow occurring just upstream from the station.

The maximum turbidity value observed at Patterson Point was 5.2 NTU on 21 September during closed conditions with a flow of approximately 143 cfs (Table 4.1.2). The mean value at Patterson Point was 2.1 NTU. The minimum value at Patterson Point was 1.1 NTU, which occurred on August 22 during closed conditions with a flow of approximately 149 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 2.1 NTU (Table 4.1.2).

The maximum turbidity value observed at Monte Rio was 4.9 NTU on May 16 during open conditions with a flow of approximately 777 cfs (Table 4.1.3). The mean value at Monte Rio was 2.1 NTU. The minimum value at Monte Rio was 0.93 NTU, which occurred on October 3 during closed conditions with a flow of approximately 140 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 1.6 NTU (Table 4.1.3).

The maximum turbidity value observed at Vacation Beach was 4.8 NTU on September 26 during closed conditions with a flow of approximately 138 cfs (Table 4.1.4). The mean value at Vacation Beach was 2.8 NTU. The minimum value at Vacation Beach was 1.8 NTU, which occurred three times: on July 11 during closed conditions and a flow of approximately 175 cfs; on July 18 during open conditions and a flow of approximately 164 cfs; and on September 5 during open conditions and a flow of approximately 177 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 2.6 NTU (Table 4.1.4).

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 measureable parameter of algal growth. Qualitative assessment of primary production on water quality can be based on *Chlorophyll a* concentrations. A U.C. Davis report on the Klamath River (1999) assessing potential water quality and quantity regulations for restoration and protection of anadromous fish in the Klamath River includes a discussion of *Chlorophyll a* and how it can affect water quality. The report characterizes the effects of *Chlorophyll a* in terms of different levels of discoloration (e.g., no discoloration to some, deep, or very deep discoloration). The report indicated that less than 10 µg/L (or 0.01 mg/L) of *Chlorophyll a* exhibits no discoloration (Deas and Orlob, 1999). Additionally, the USEPA criterion for *Chlorophyll a* in Aggregate Ecoregion III is 1.78 µg/L, or approximately 0.0018 mg/L for rivers and streams not discharging into lakes or reservoirs (USEPA, 2000). However, it is important to note that the EPA criterion is established for freshwater systems, and as such, is

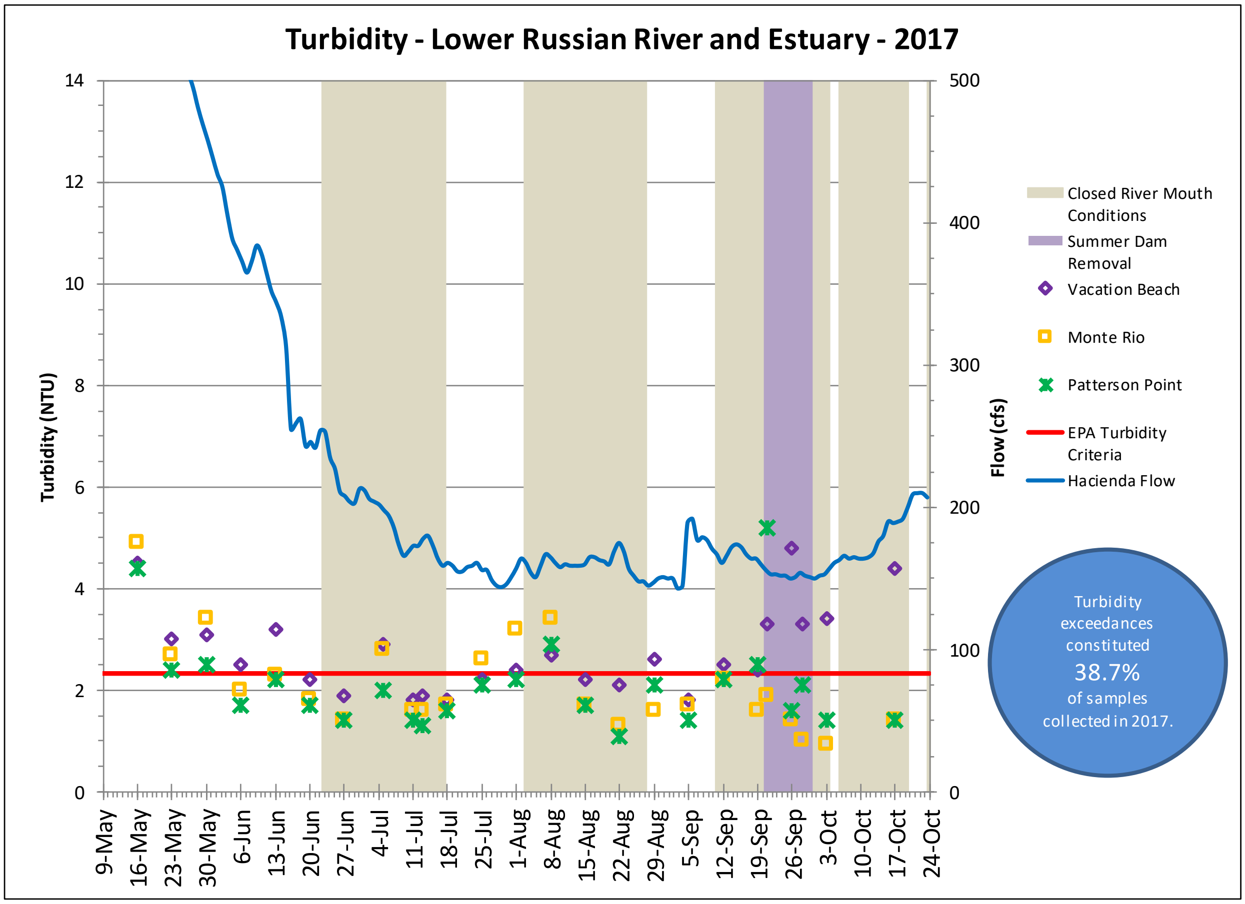


Figure 4.1.29. 2017 Russian River Grab Sampling Results for Turbidity

only applicable to the freshwater portions of the Estuary. Currently, there are no numeric *Chlorophyll a* criteria established specifically for estuaries.

Chlorophyll a concentrations exceeded 0.01 mg/L twice during the monitoring period, the level recommended to prevent discoloration of surface waters (Tables 4.1.2 through 4.1.4). Monte Rio had a maximum *Chlorophyll a* concentration of 0.012 mg/L and Vacation Beach had a maximum *Chlorophyll a* concentration of 0.13 mg/L. Additionally, *Chlorophyll a* concentrations exceeded the EPA criteria approximately 54.7% of the time at the stations throughout the season under open and closed Estuary conditions, and during flows ranging from 136 cfs to 777 cfs (Figure 4.1.30). Similar to the trend for total phosphorus, *Chlorophyll a* values were observed to generally be higher in the spring and early summer, trending downward through the rest of the season (Figure 4.1.30).

The maximum *Chlorophyll a* concentration observed at Patterson Point was 0.0061 mg/L on June 20 during open conditions with a flow of approximately 243 cfs (Table 4.1.2). The mean value at Patterson Point was 0.0022 mg/L. The minimum value at Patterson Point was ND, which occurred on October 17 during closed conditions with a flow of approximately 189 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 0.0013 mg/L (Table 4.1.2).

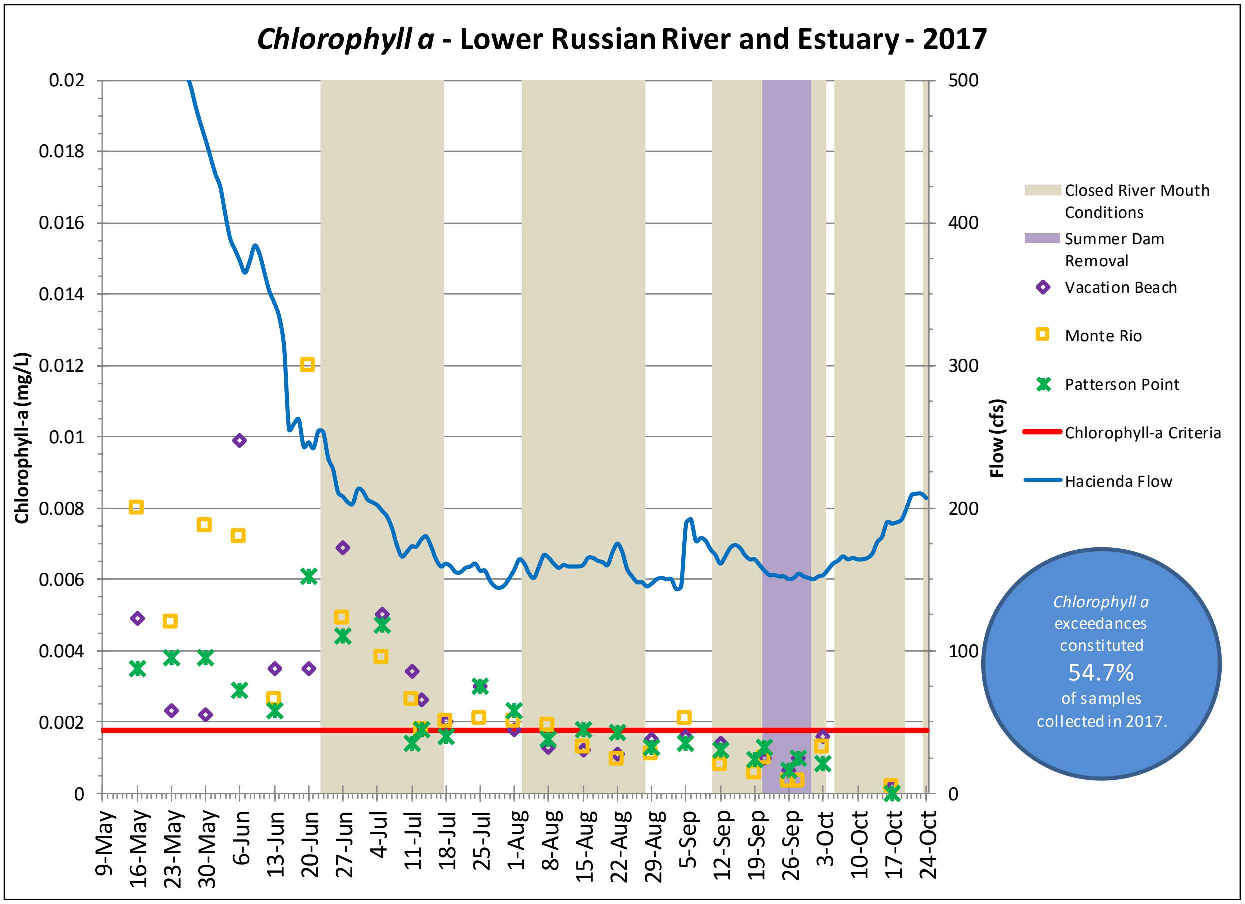


Figure 4.1.30. 2017 Russian River Grab Sampling Results for *Chlorophyll a*

The maximum *Chlorophyll a* concentration observed at Monte Rio was 0.012 mg/L on June 20 during open conditions with a flow of approximately 243 cfs (Table 4.1.3). The mean value at Monte Rio was 0.0029 mg/L. The minimum value at Monte Rio was 0.00018 mg/L, which occurred on October 17 during closed conditions with a flow of approximately 189 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 0.0011 mg/L (Table 4.1.3).

The maximum *Chlorophyll a* concentration observed at Vacation Beach was 0.13 mg/L on September 19 during closed conditions with a flow of approximately 151 cfs (Table 4.1.4). The mean value at Vacation Beach was 0.0077 mg/L. The minimum value at Vacation Beach was 0.00018 mg/L, which occurred on October 17 during closed conditions and a flow of approximately 189 cfs. Finally, the lowest flow recorded during the sampling events was 135 cfs, which occurred on August 29, with a value of 0.0015 mg/L (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) and are not currently enforceable.

Samples were collected during the monitoring season for diluted and undiluted analysis of E. coli and total coliform for comparative purposes and the results are included in Tables 4.1.2 through 4.1.4 and Figures 4.1.31 and 4.1.32. Samples collected for Enterococcus were undiluted only and results are included in Tables 4.1.2 through 4.1.4 and Figure 4.1.32. 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 4.1.32 and 4.1.31 utilize undiluted sample results unless the reporting limit has been exceeded, at which point the diluted results are utilized.

In 2014, staff at the NCRWQCB indicated that Enterococcus was not being utilized as a fecal indicator bacteria due to uncertainty in the validity of the lab analysis to produce accurate results, as well as evidence that Enterococcus colonies can be persistent in the water column and therefore its presence at a given 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 sandbar to address potential threats to public health.

The Monte Rio station was observed to have one exceedance of the RWQC for E. coli, representing 1.3% of the total samples collected (Figure 4.1.31). The exceedance was slightly higher than the RWQC with a value of 270.0 MPN. Estuary closures may have had an effect on E. coli, as values were observed to increase during closure, including the Monte Rio exceedance which occurred on 22 August with a flow of approximately 149 cfs (Table 4.1.3). Summer dam removal may have also had an effect as values were observed to increase during closed conditions and the removal of the Johnson's and Vacation beaches summer dams (Figure 4.1.31).

There was one exceedance of the RWQC for total coliform at the Patterson Point station and two exceedances at the Monte Rio station in 2017, representing 4.0% of the total samples collected (Figure 4.1.32). Estuary closures may have had an effect on total coliform as values

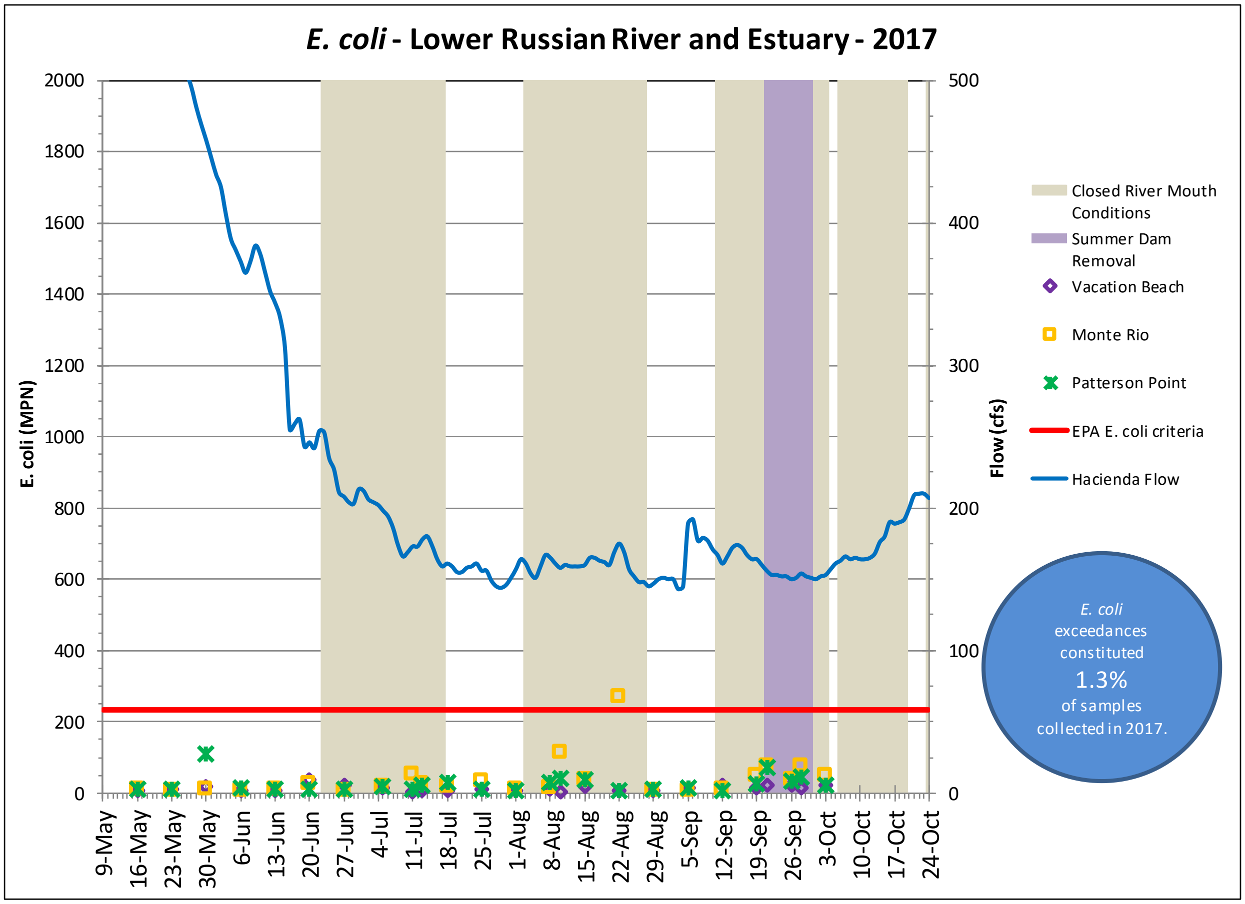


Figure 4.1.31. 2017 Russian River Grab Sampling Results for E. coli

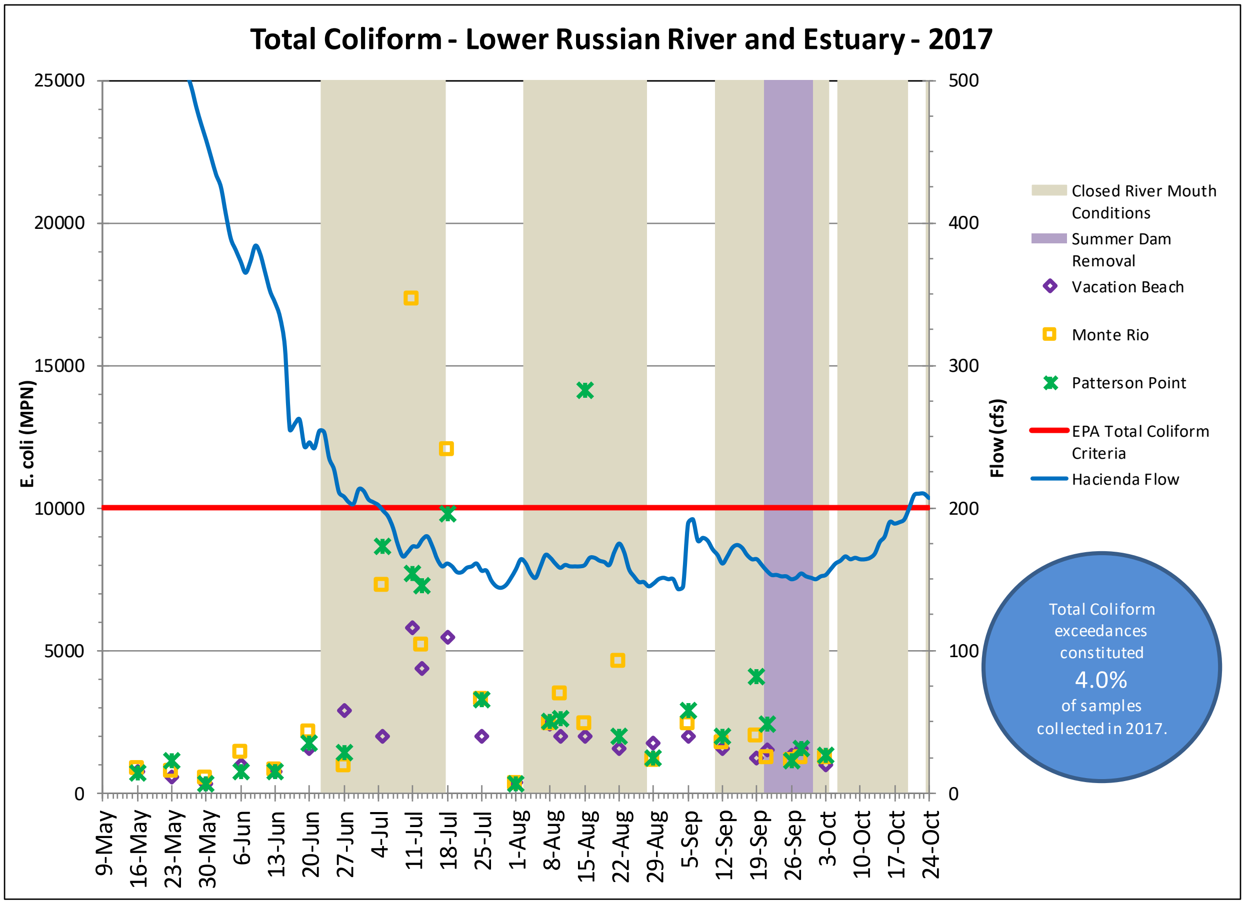


Figure 4.1.32. 2017 Russian River Grab Sampling Results for Total Coliform

were observed to increase during the July and August closures. These increases may have also been affected by increased recreational activity as they were observed during and following the Fourth of July holiday.

Based upon the recommended Enterococcus RWQC for fresh water beaches, several exceedances were observed representing 20.8% of the total samples collected (Figure 4.1.33). There were five exceedances at Patterson Point, seven exceedances at Monte Rio, and three exceedances at Vacation Beach. Estuary closures may have had an effect on Enterococcus, as values were observed to increase and exceed the RWQC during closures in July, August, and September with flows varying from 136 cfs to 179 cfs. A concentration of >2419.6 MPN was observed at Patterson Point on August 15 during an estuary closure and a flow of approximately 136 cfs. Summer dam removal may have also had an effect as values were observed to increase during closed conditions and the removal of the Johnson's and Vacation beaches summer dams, including a concentration of 920.8 MPN that occurred at the Monte Rio station on September 21 (Figure 4.1.33).

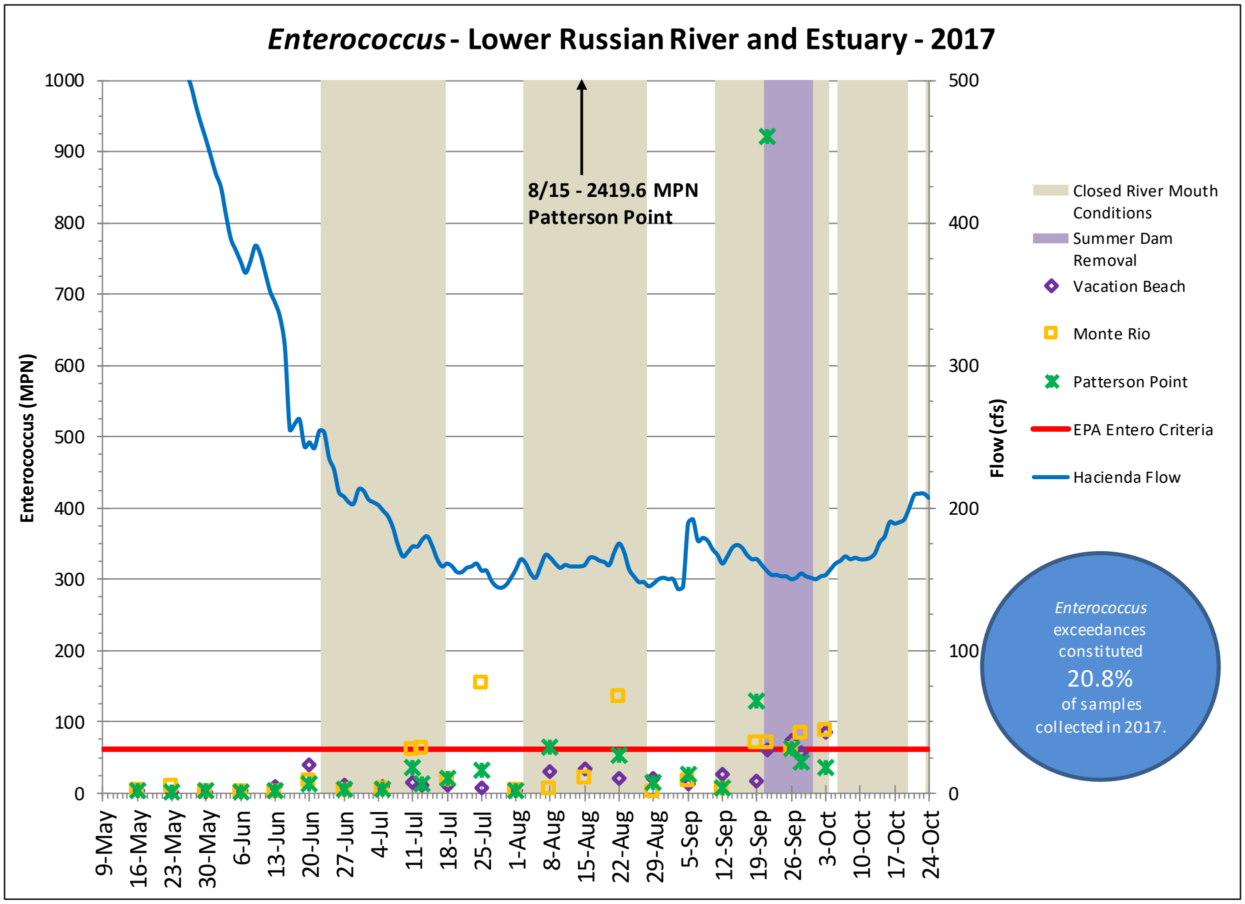


Figure 4.1.33. 2017 Russian River Grab Sampling Results for Enterococcus

Conclusions and Recommendations

Continuous Water Quality Monitoring Conclusions

Water quality conditions observed during the 2017 monitoring season were similar to conditions observed during previous monitoring seasons. 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 four closures during the lagoon management season: July 4 – 17, August 5 – 27, September 12 – October 3, and October 7 – 19 (ending in an artificial breach outside the lagoon management season. A lagoon outlet channel was attempted twice in 2017 during the lagoon management period on July 17 and September 28. The first closure of the season occurred after the mouth was naturally perched above tides from June 27 to July 4, which likely restricted the tidal prism and input of saline water into the Estuary prior to the July 4 river mouth closure. This would contribute to lower salinities during closure, such as at the Willow Creek station (Figure 4.1.4).

As freshwater flows in the Russian River decrease through spring, the salt layer typically migrates upstream. Mainstem Russian River flows decreased later in the 2017 season compared to the drought years of 2013 through 2015. Mainstem Russian River flows in 2017 were observed to drop below 200 cfs in early July, whereas mainstem flows decreased below 200 cfs in mid-May during the drought years, and mid-June in 2016. Although salinity migration patterns in the upper reach of the Estuary were fairly similar to those prior monitoring years, the Brown's Pool (RK 11.3) station was observed to remain entirely freshwater during the 2017 management period. Whereas the bottom of Brown's Pool became predominantly brackish during open and closed conditions throughout the 2016 monitoring season with concentrations as high as 6.5 ppt.

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

Monitoring conducted at the bottom of the Patterson Point station in Villa Grande continued to show freshwater conditions with a maximum salinity value of approximately 0.2 ppt in 2017. 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 and the confluence of Austin Creek provide a significant hydrologic barrier to salinity migration in the mainstem Russian River.

During prolonged barrier beach closures in 2017, overall water quality conditions were observed to be similar to those of previous years. Typically during a closure or perched event, the surface and mid-depth sondes in the lower and middle reaches of the Estuary would experience a decrease in salinity and an increase in temperature. Conversely, during prolonged closures or perched events, the mid-depth and bottom sondes in the upper reach of the Estuary typically experience increases in salinity as brackish water migrates into the area, with temperature responses that are variable. Conditions observed in the saline layer during the 2017 monitoring season were no exception.

DO response to Estuary closure events was variable in the Upper Reach and dependent on the presence and movement of salinity, the relative strength of stratification, circulation patterns, and flows in the Russian River. The presence of salinity would typically coincide with the presence of depressed DO levels, but not always (i.e. Freezeout Creek at the mid-depth sonde during the late September closure), suggesting that variability is dependent on relative DO concentrations in the migrating salt wedge, the length of time of Estuary closures, the timing of subsequent closure events, freshwater inflow rates, the DO concentration of inflowing freshwater, and subsequent tidal inundation and mixing.

Temperature, pH, and dissolved oxygen patterns during the 2017 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 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 2017 is being presented (Figure 4.1.34). 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 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 11 meter depths at the Brown's Pool station, six to eight meter depths at Villa Grande, nine to 11 meters depth at Patterson Point, and one to two meters at the Monte Rio station. In the upper reaches of the Estuary and MBA, the sondes are located on the bottom of the river because the salt layer is typically thin when it occurs at these river locations. Excluding the depth variations, the graph depicts the decrease in salinity the further upstream in the Estuary and MBA the monitoring station is located.

The graph also illustrates the variable nature of salinity levels in the Upper Estuary. For instance, in 2014 and 2016, the maximum salinity concentrations observed at Brown's Pool were nearly identical at approximately 11 ppt, whereas the maximum salinity concentration was 0.2 ppt in 2017.

Brown's Pool has been observed to have maximum salinity concentrations that range from a low of 0.2 ppt in 2017 to a high of 11.3 ppt in 2014. Likewise, the maximum salinity concentrations observed at Freezeout Creek range from a low of 4.8 ppt in 2011 to a high of 25.9 ppt in 2013, including a maximum concentration of 16.4 ppt in 2017.

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

The water quality conditions observed during the lagoon management season, particularly in the upper reach of the Estuary and in the MBA, indicates the expansion of freshwater and brackish water quality conditions during river mouth closures. These expanded aquatic habitat conditions may support additional rearing habitat for juvenile steelhead.

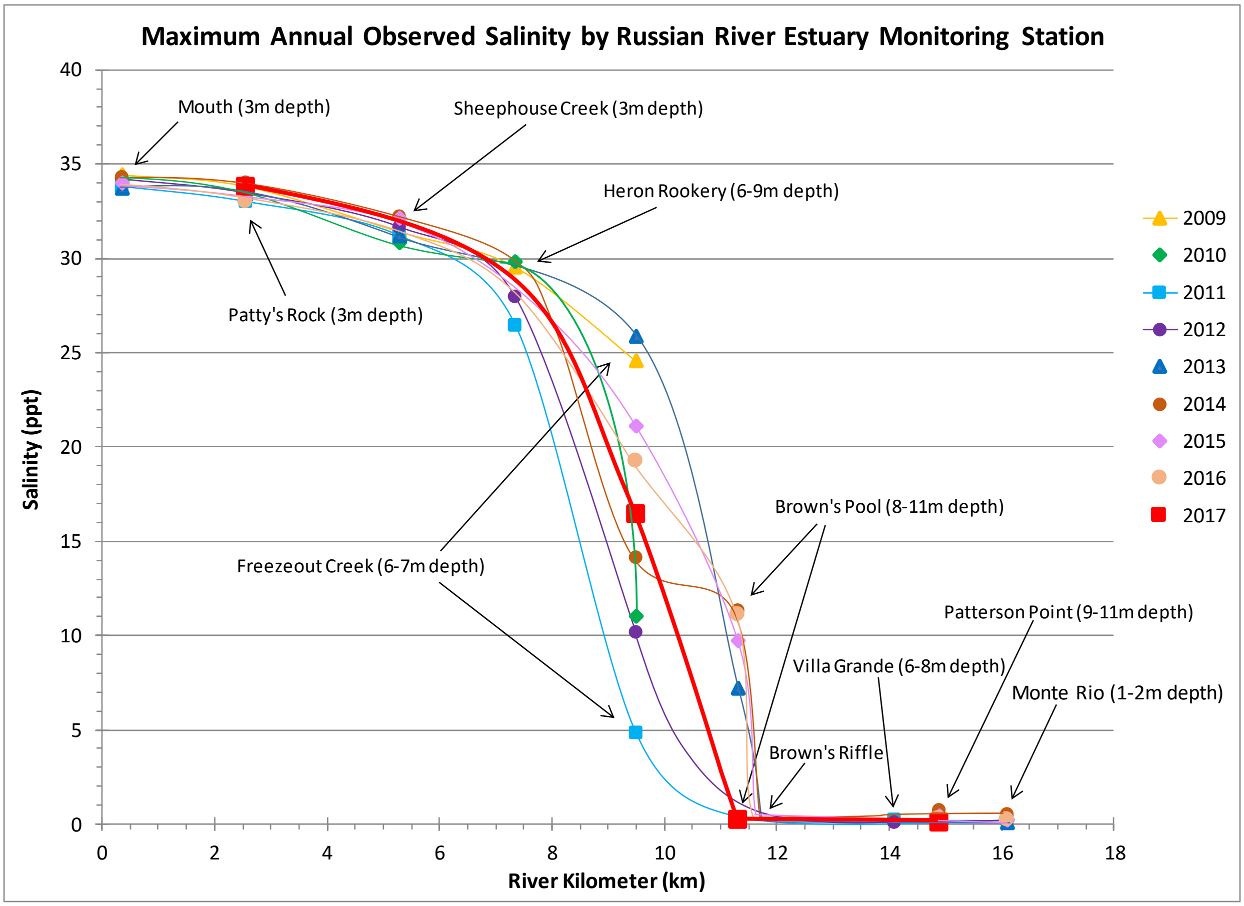


Figure 4.1.34. The maximum salinities at monitoring stations throughout the Russian River Estuary and Maximum Backwater Area between the years of 2009 and 2017.

Water Quality Grab Sampling Conclusions

The 2017 grab sampling effort in the Russian River Estuary continued to collect a robust set of data similar in effort to the 2012 through 2016 monitoring seasons. Additional focused sampling was conducted during or after Estuary closures, as well as during summer dam removal in late September. Table 4.1.5 shows the total yearly number of sampling trips and the total number of samples collected within the freshwater portions of the Russian River Estuary and Maximum Backwater Area during each monitoring season since the implementation of the Biological Opinion in 2009.

The 2017 grab sampling effort observed Total Phosphorus exceedances in 97.3% of all samples collected (Table 4.1.6). This is not uncommon in the Russian River Estuary, and similar percentages of the samples analyzed for Total Phosphorus were in exceedance during previous monitoring seasons. Table 4.1.6 shows the percentage of samples that were in exceedance each season since 2009.

The Total Nitrogen and chlorophyll a exceedances for samples taken during 2017 were also similar to percentages observed in previous monitoring years (Table 4.1.6). Year to year variability in the percentage of exceedances for these three constituents can be attributed in

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

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

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

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

part to: the frequency and timing of storm events, fluctuating freshwater inflow rates, the frequency and timing of barrier beach closures, the strength of tidal cycles, summer dam removal, topography, relative location within the Estuary, and wind mixing.

The E. coli exceedances since the implementation of the Biological Opinion in 2009 until 2017 can be seen in Table 4.1.7. However, E. coli was not sampled for in 2010, with sampling being conducted for fecal coliforms instead. Samples collected in 2009 were analyzed using the multiple tube fermentation technique, whereas samples collected from 2011 through 2017 were analyzed using the Colilert Quanti-Tray method. Percentages for total coliform samples are not shown here 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 in this case.

Data collected through the grab sampling effort in 2017 appear consistent with data collected between 2009 and 2015. 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.

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

Table 4.1.7. The percentages of freshwater samples taken that were in exceedance of CDPH Guidelines for E. coli for the sampling years 2009 through 2017. Note that for 2009, the analyzing method was multiple tube fermentation, and for 2011-2016 the method was Colilert Quanti-Tray.

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

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. Monitoring for both was conducted as soon as river flows allowed a systematic investigation of abundance, cover, and successional processes. Surveys followed spring draw down, starting in June and continuing approximately every two weeks through October 2017.

One sample location was locateded in the Estuary (Patterson Point) to evaluate newly flooded shoreline areas following river mouth closures from May 15 to October 15. Patterson Point was sampled along shallow habitat in the new littoral zone (depth light penetrates to allow for photosynthesis) that forms after water depths increase during river mouth closure. Follow up sampling was conducted at every 2 foot rise in water surface elevation following closure of the estuary. For both sampling objectives, Sonoma Water staff implemented the field based rapid periphyton sampling procedure described below.

Methods

Algal Estuary Response and Ambient Monitoring

Transects to monitor and assess periphytic micro- and macro-algal growth were established at four surface water stations selected to represent the range of algal habitats available in the Russian River. One station was retained in the maximum backwater area at Patterson Point (Figure 4.2.1) to continue data collection around the response of benthic algae following estuary closure. At Patterson Point, sampling was done along transects for estuary response as well as to collect additional baseline data from this location. Ambient algal monitoring for periphytic algae was conducted approximately every two weeks, as well as during river mouth closures at the Patterson Point station, between May 15 to October 15. Similar methods of estimating algal cover and abundance were utilized for both estuary response and ambient algal monitoring.

Estuary Response Monitoring

For closed estuary response monitoring, sampling methodology was developed based on modification of *Standard Operation Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Assessments in California* (Fetscher, et al. 2009). and *California Watershed Assessment Manual: Volume II Chapter 4*, and the *Rapid Bioassessment Protocols for Use in Wadeable Stream and River: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition* (Barbour, 1999), This methodology is intended to address monitoring periphytic algae growth in newly flooded shoreline areas. Transect endpoint 0 was established at a 1 m depth in the main stem Russian River and extended 12.5 m landward or to a 9 foot elevation as diagramed in Figure 4.2.2. Transect locations avoided locations such as tributaries, outfalls, and man-made structures to minimize influence of algal growth from contributions in nutrients, temperature, or canopy cover from such sources.

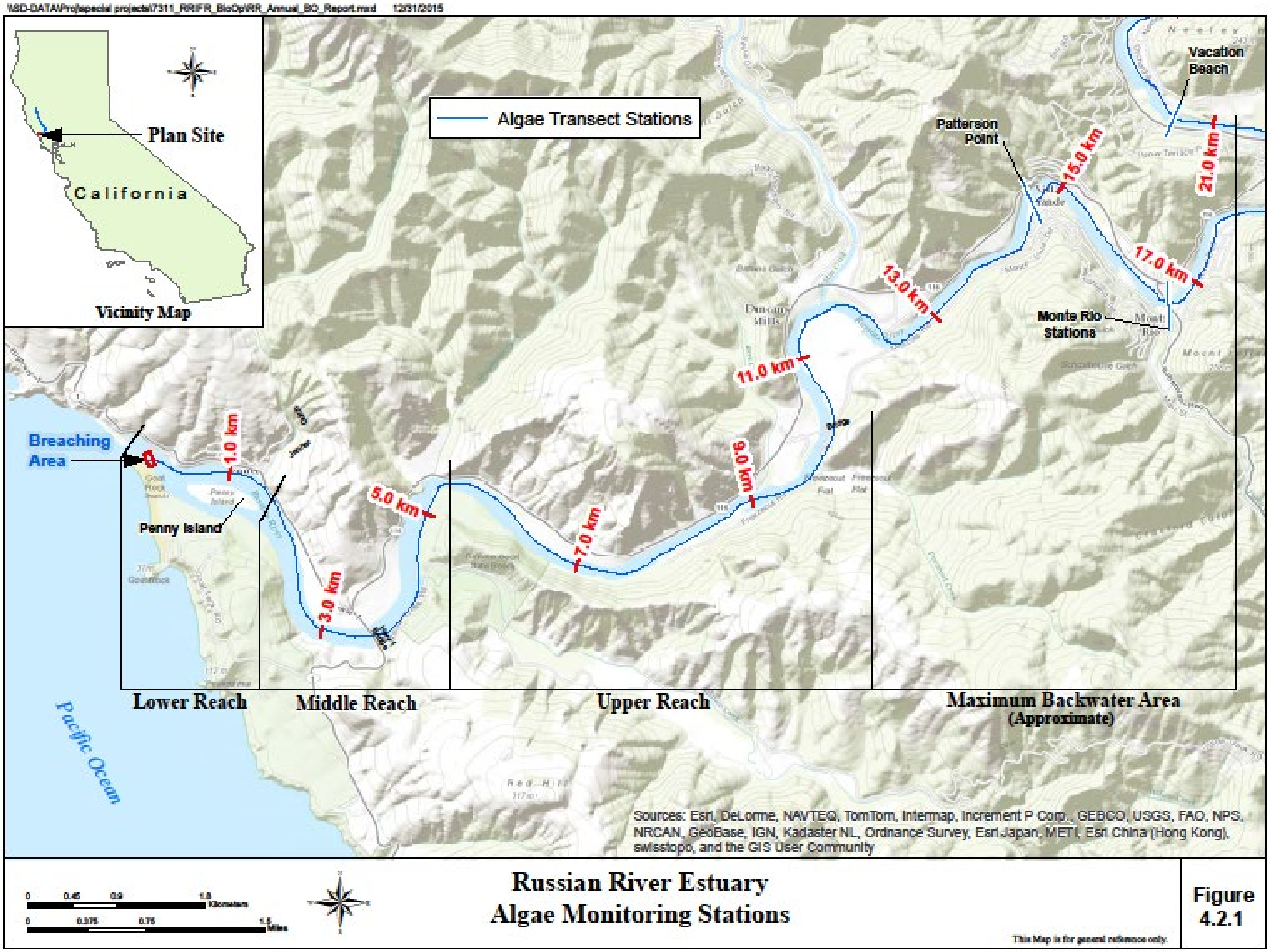


Figure 4.2.1. Russian River Estuary Algal Monitoring Stations.

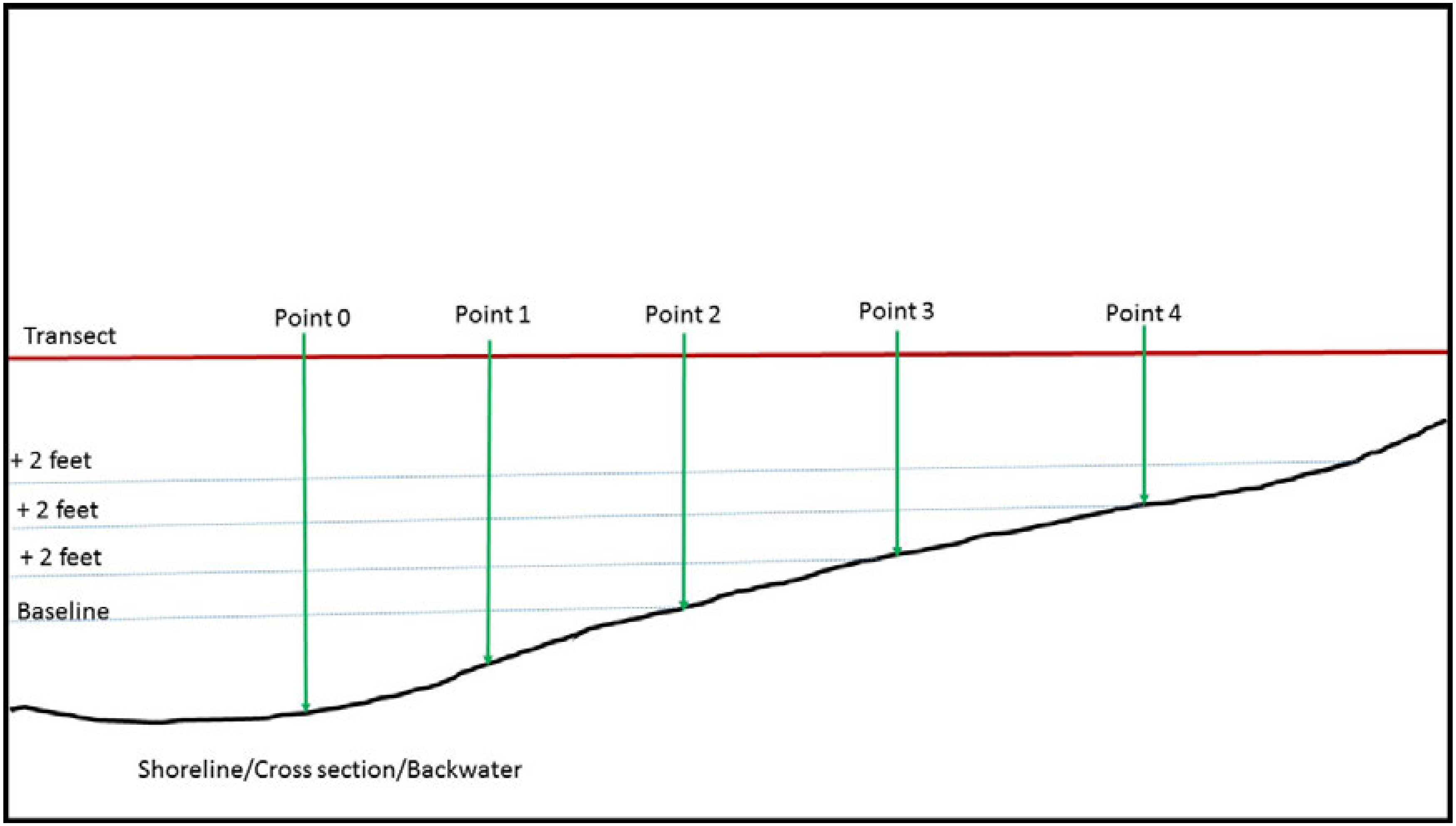


Figure 4.2.2. Transect schematic indicating transect sampling points and a representation of water levels following closure.

Transects were established during open river mouth conditions beginning in June, after flows with sufficient power to mobilize gravels and sand/silt decreased and sediments had settled and stabilized on the stream bed.

The next monitoring and sampling events occurred when the river mouth was closed, in an extended perched condition, or with an outlet channel in place and the water surface elevation at the Jenner gage was at or approaching 4.5 feet. Monitoring and sample events were repeated with each 2 foot stage change (e.g. 6.5 feet and 8.5 feet) until the river mouth returned to an open condition or at the end of the monitoring period (15 October).

Percent algal cover was calculated as an algal indicator of productivity and was measured as algal abundance using a point-intercept collection methodology. Algal cover is the amount of microalgae coating and macroalgae taken at five (5) equidistant points along each transect. The number of points collected by category (in this case the two categories are macroalgae and microalgae) divided by the total number of points collected of every category provides an estimate of percent algal cover.

The presence of algae was recorded for each point along the transect and identified as microalgae or macroalgae. Microalgae is defined as a "film-like coating" of algae. Measurement of microalgae thickness followed the method identified in Fetscher, et al. 2009, and an estimate of film-like coating followed descriptions in Table 4.2.1. Thicker microalgae layers were measured using a ruler or rod with demarcations at 1, 5, and 20 millimeters (mm). The presence or absence of attached macroalgae or unattached, floating macroalgae was recorded at each point.

Table 4.2.1. Microalgal thickness codes and descriptions (from Fetscher, et al. 2009 and adapted from Stevenson and Rollins 2006).

Code	Thickness	Diagnostics
0	No microalgae present	The surface of the substrate feels rough, not slimy.
1	Present, but not visible	The surface of the substrate feels slimy, but the microalgal layers is too thin to be visible.
2	<1mm	Rubbing fingers on the substrate surface produces a brownish tint on them, and scraping the substrate leaves a visible trail, but the microalgal layers is too thin to measure.
3	1-5mm	
4	5-20mm	
5	>20mm	
UD	Cannot determine if a microalgal layer is present	

Ambient Monitoring

For ambient monitoring, transects were located to sample the range of algae habitat available at the sampling locations. Transects were subjectively placed to collect data from areas with different conditions in the littoral zone, including but not limited to depths, velocities, substrates, insolation, and emergent vegetation. Percent algal cover was calculated as an algal indicator of productivity and was measured as algal abundance using a point-intercept collection methodology similar to the methodology used to evaluate the estuary response.

If bedload had moved significantly compared to prior monitoring, new transects were established. Sampling methodology was developed based on modification of *Standard Operation Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Assessments in California* (Fetscher, et al. 2009) and the *California Watershed Assessment Manual* (Shilling, 2005).

Following data collection along the transect, multi-habitat algae samples were collected from the range of different habitat types (riffles, pools, shade, sun, sand, gravel, cobble) present along the transect. Each sample was collected from the substrate that is uppermost within the stream and has highest possibility of sun exposure (i.e. if a thick layer of macroalgae covers the substrate, collection included the layer). Samples were placed in a cooler to protect the algae from heat and desiccation and to preserve specimen integrity. Algal species present were identified to the lowest taxa, preferably species but at least genera. Successional changes in genera over the season should provide a metric to assess species (genera) richness as well as document the stages in development of the periphyton layer. Frequency of genera encountered will be evaluated as a proxy for abundance (i.e. more frequently encountered in samples equates to more abundant in habitat.

Photographs were taken of the sites to record site conditions at the time of sampling. Photographs were taken to document the morphologies of specific colonies and algal appearance underwater using a submersible digital camera. Oblique photographs at the shoreline were taken to document cyanobacteria (blue green algae) colonies occupying the accumulated drift and other edgeline periphyton. Photographs were also taken along the transects using an underwater photo bucket with a 50 dot matrix grid pattern to assess this methodology for effectiveness and use as an additional monitoring tool.

Samples were evaluated for presence of Chlorophyta (Green Algae), Chrysophyta (Golden Brown Algae (diatoms), and Cyanobacteria. Cyanobacterial target species were identified (including species of *Anabaena*, *Microcystis*, *Planktothrix*, *Oscillatoria, or Phormidium*), monitored for changes in cover successionally over the course of the season, and evaluated for the possibility of the presence of cyanotoxins. In addition, one sample was collected along each transect at a 1 foot depth in the flowing (in active flowing channel) water column using a plankton net (deployed for five minutes) to assess the presence and abundance of phytoplankton. Water chemistry measurements were recorded near the substrate at each monitoring station using a YSI 6600 datasonde and YSI 650MDS datalogger. Conditions measured include water temperature, dissolved oxygen, specific conductance, pH, and turbidity. Water depth was recorded using a stadia rod.

Results

Figure 4.2.3 illustrates the types of algae detected at the Patterson Point station in 2017. Figures 4.2.4 and 4.2.5 illustrate the relationship and shift in relative cover by micro and macroalgae at the Patterson Point station through the monitoring season, including in response to estuary closures that occurred in June, July, and September.

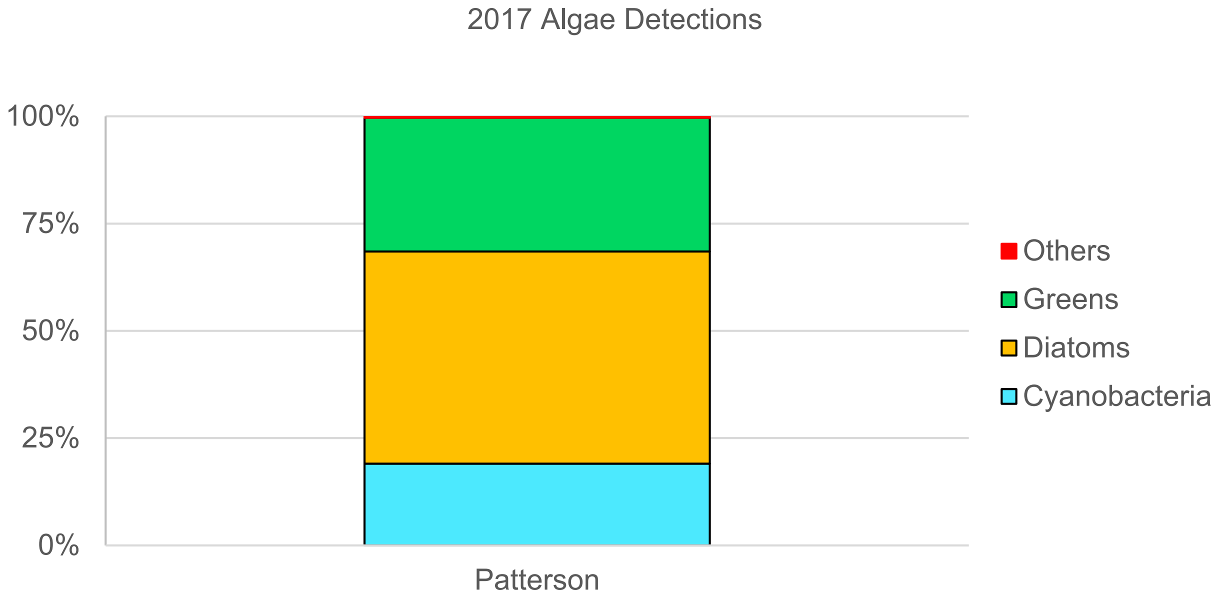


Figure 4.2.3. Algae types observed at Patterson Point in 2017.

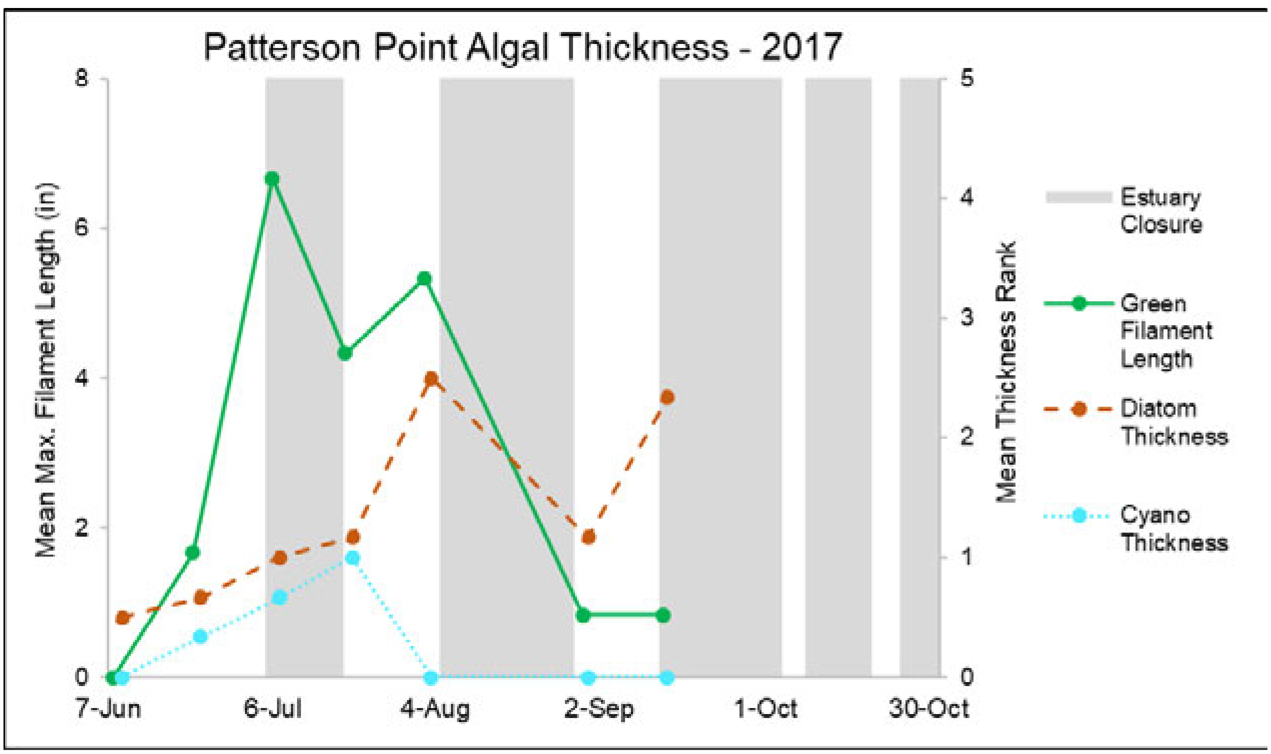


Figure 4.2.4. Change in green filament length and cyanobacterial and diatomaceous mat thickness at the Patterson Point monitoring station in 2017.

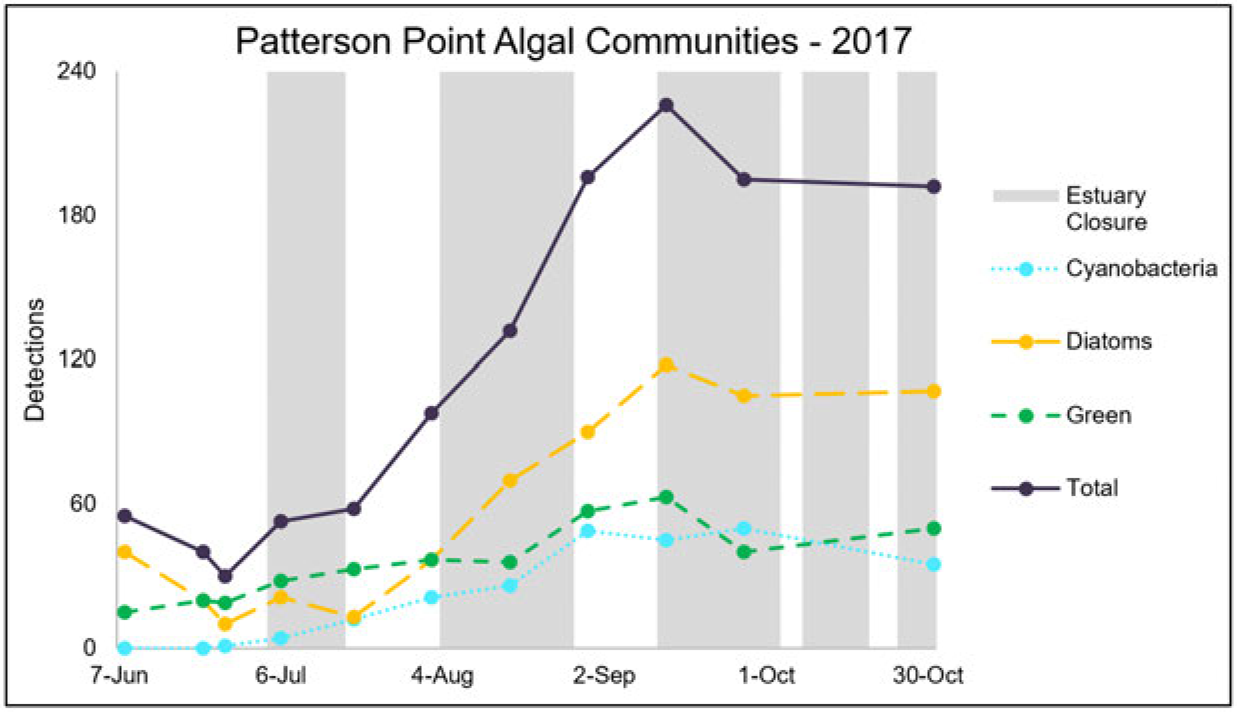


Figure 4.2.5. Change in algal communities at the Patterson Point monitoring station over the course of the 2017 monitoring season.

Green algae filaments were longest at the beginning of the season at all sites except Jimtown (June or July) and decreased in length through September and October (Figures 4.2.6, 4.2.8, and 4.2.12). Increasing diatom thickness trends were similar at Patterson, Syar, and Jimtown while diatom mean thickness at Hopland varied and did not show a clear trend or pattern over time (Figure 4.2.12). Cyanobacterial thickness was greatest at Syar in October, though Patterson and Jimtown both had the greatest number of days with visible cyanobacterial mats on the substrate visible through the viewing bucket.

The abundance of algae, as indicated by the total number of detections of algal genera on observed microscope slides, tended to increase until late August to late September for most sites and continued to increase through October at Jimtown (Fig. 4.2.11).

The diatom communities at Patterson and Syar seemed to plateau in abundance in mid-September through October while Jimtown's diatom community continued to moderately increase in abundance and Hopland's started to decrease.

The trends in abundance in the green algae communities resembled that of the total abundance of all types of algae, though the range in the number of detections throughout the monitoring period was minimal compared to that of the diatom communities.

The number of detections of cyanobacterial genera tended to be higher towards the end of the monitoring period than at the beginning for all four sites. The range in abundance over time was minimal at most sites except at Patterson where the range was larger than that of Patterson's green algae community.

Discussion/Observations

Algae occurs in the lower Russian River and Estuary under a variety of conditions and species commonly found worldwide are present in the system. Conditions supporting algal abundance are largely driven by light, temperature, stream flow, and nutrient availability. Generally the most visible type of algae are filamentous Green Algae (Family Chlorophyta) initially growing on rocks and substrate (generally cobble, gravels, and occasionally finer grained sands and silts) (saxicolous) and then becoming planktonic during their reproductive phase, which is driven by largely by season, unless another environmental parameter changes and triggers the life cycle switch (light, temperature, nutrient availability, and changes in water depth). Figure 4.2.6 illustrates a representative cross section of a water body, showing the littoral, limnetic, and profundal zones. The profundal zone is below the area of active photosynthesis, and in the Russian River, generally in areas that exceed 3 feet in depth depending on water clarity. Depending on the annual conformation of the substrate following high flow events, the littoral zone may be larger or smaller depending on where the river moved the substrate during functional flows in the winter.

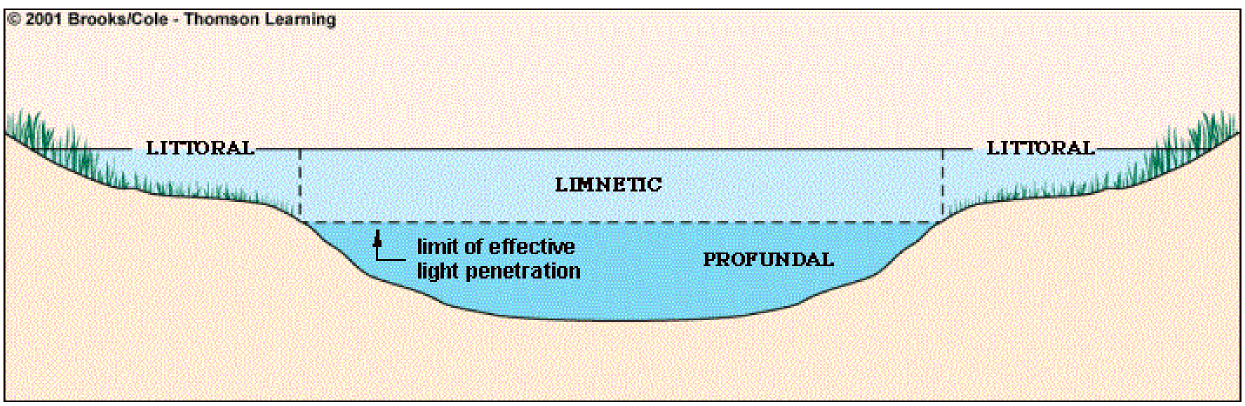


Figure 4.2.6. Diagram indicating littoral vs limnetic and profundal zones. Following river mouth closure, the profundal zone moves into the littoral zone and existing benthic algae either detach or if they have the means, move and re-colonize the newly wetted littoral zone.

In the 2016-2017 winter preceding the 2017 algae monitoring period, the Russian River experienced scouring flows resulting from record high rainfalls that had not occurred in the previous three years. The scouring effects of high flows likely removed algal paper (desiccated algae) and algal spores left behind by the previous drought seasons, thus removing a large portion of algae that could be used immediately to inoculate summer flows in the river. Compared to the 2016 monitoring period (May 2016-October 2016), algae mat thickness and cover was significantly less in 2017. Considering that environmental conditions were generally favorable for algal growth (e.g. high water temperatures and high nutrient concentrations), a plausible explanation for less algae growth er in 2017 is likely that the record setting rainfall within the Russian River watershed in the winter months preceding this monitoring period removed desiccated algae that could have otherwise kick-started its regrowth.

Estuary Closure Algal Response

Observations and cover data from 2014-2017 on the effect of estuary closure indicate that following estuary closure and the resulting increase in depth (with the corresponding change in what used to be photosynthetically active littoral zone) there is a shift in the location and composition of the benthic river algae. After spring drawdown and before any estuary closure, typical periphyton establishes in the littoral zone. Typically these are assemblages composed of micro and macroalgae growing together. Often the dominant green alga is *Cladophora* sp. which is encrusted with single cell and/or tubular or colonial diatoms and cyanobacterial colonies as well as water fungi, bacteria, and detritus. As the water depths change, some of the periphytic green algae detach and become planktonic, likely triggering a reproductive phase where numerous spores are produced to start the cycle anew or overwinter. This “drift” (the component of free floating filamentous macroalgae in a system) provides a habitat substrate for microalgae and deposits along shorelines. As the macroalgae starts to settle on shorelines or in aquatic vegetation and decompose it appears to provide an important method for dispersal of the taxa as well as providing significant shoreline habitat for colonizing microalgae, particularly cyanobacteria. As water depths change over colonies of microalgae a similar process unfolds. Microalgae that is motile (diatoms and motile greens) will simply move their cells to a more fortuitous position in the littoral zone with suitable light conditions. Non-motile colonies seem to follow a similar pattern as the filamentous greens. Whole colonies detach and become free floating. Often entraining together in the macro-drift. This shift is associated with all forms of algae and is triggered by environmental change. In this case the environmental change is the increasing water depth and the corresponding shift in the base elevation of the column of water that can be penetrated by sunlight.

Cover Shifts in the Estuary

Observations and data indicate that the shift in cover is triggered by water level increase when the Russian River Estuary mouth closes. Generally the data collected in 2017 is similar to finds in 2014-16. Generally data support the observation that water level rise causes the benthic mats of microalgae to detach from their locations in the littoral zone and through shoreline accumulation of floating colonies (and motile cells) begin to re-colonize the freshly wetted gravel bars, and other newly inundated low-lying areas. Figure 4.2.7 includes a representative cross-section from 2015 that diagrammatically illustrates conditions before a typical closure. Benthic algae is found in the photosynthetically active littoral zone but drops off in abundance quickly below the littoral zone. Figure 4.2.8 illustrates conditions following closure in 2015 and the subsequent rise in water surface elevation. In most cases, the area of habitat in the littoral zone increases as the water surface elevation increases. The benthic algae and periphyton break away from the substrate and drift onto the shoreline. Motile genera including diatoms start colonizing the new areas but were not observed re-developing into the thick crust present before estuary closure.

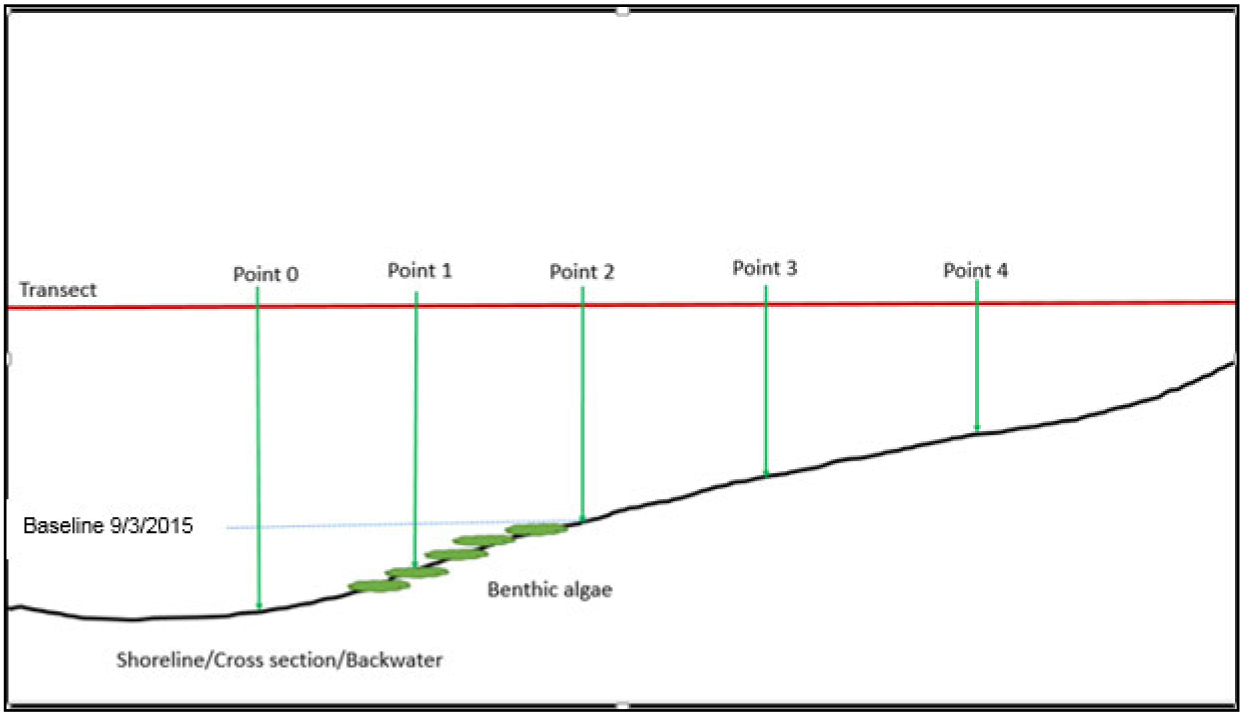


Figure 4.2.7. Before the estuary closes algae is spread relatively evenly across the littoral zone.

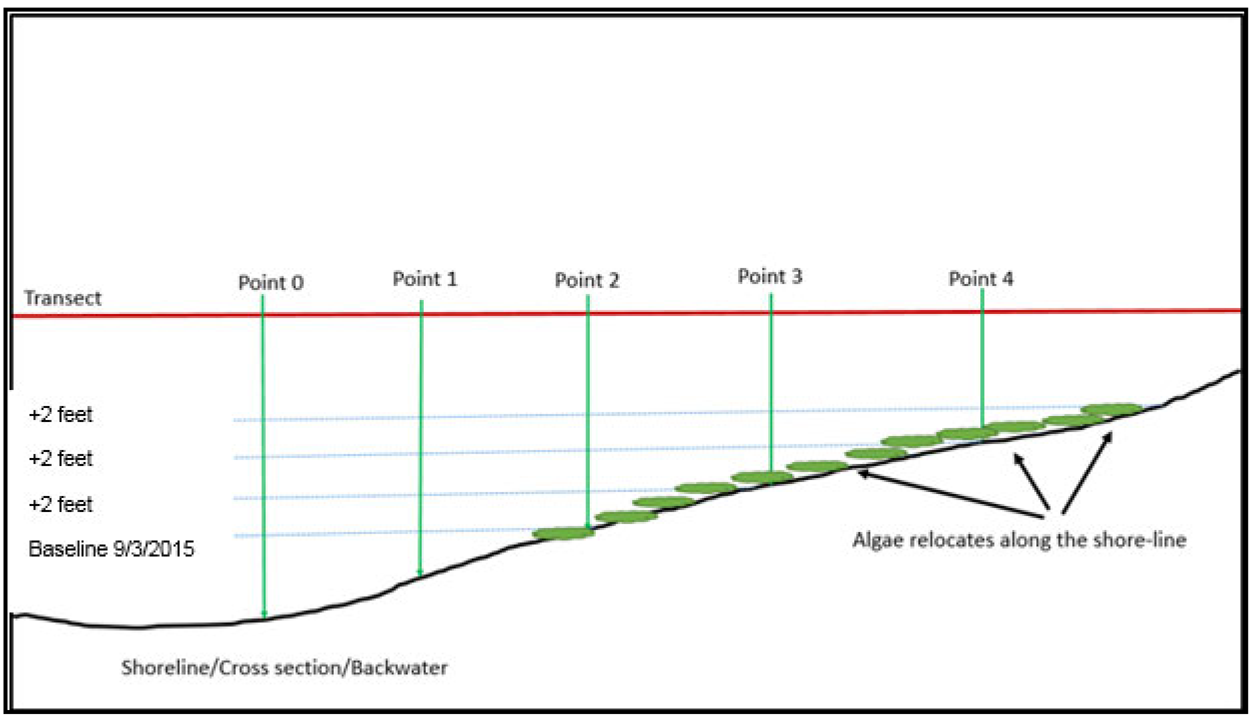


Figure 4.2.8. After the estuary closes algae moves upslope either by drift or active motility and colonizes the newly wetted littoral zone.

In 2017, the Patterson Point station had a relatively high average chlorophyll a concentration (0.0056 mg/L) and a high average number of all algal detections (120 algal units) during the monitoring period. Mean cyanobacterial detections, however, remained at a low percent of all detections and periphyton or mats dominated by cyanobacteria were minor compared to those observed in the 2016 monitoring period. Of the parameters that were monitored in 2017, the one that most closely correlated with high chlorophyll a at Patterson were higher phosphate concentrations (Figure 4.1.28). This correlation is not surprising since phosphorus is usually the limiting nutrient for all algae and may enhance the growth of all algae types.

Patterson was on average, the warmest of all four sites (Table 4.1.1, Fig.4.1.14). The water was especially warm (mean = 23.5°C) from June 20 through August 16, not far from the optimal temperature (25°C) for planktonic cyanobacterial growth rates (Reynolds 2006). Therefore, unsurprisingly, *Anabaena*, known to be capable of releasing cyanotoxins, was first detected on July 19. *Anabaena* continued to be a dominant part of the algae community throughout the rest of the monitoring season at Patterson though it was less prominent at the other sites perhaps, in part, due to the warmer temperatures at Patterson.

Recommendations

There is a clear response exhibited by periphyton to estuary closure events that was observed and measured during algae sampling/monitoring. However, utilizing a point line intercept method to characterize macroalgae (present or not) has been observed to not accurately sample macroalgae conditions in the river. It is difficult using this method to discern between the smaller filaments of green algae and micro algae crusts and colonies.

Using photographic methods utilizing a 50 dot underwater viewing bucket may have additional merit as this sampling approach will measure lengths of macroalgae directly instead of simply noting presence. Algal monitoring takes place during the lagoon management season from May 15 to October 15. Further analysis during the winter and spring would be helpful to understand the shifts in algal cover by genera over the growth season. Studying initial recolonization following spring scour through to fall reproductive blooms would be helpful to better understand both the genera and successional processes involved.

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

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

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

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

Based on prior data on the foraging of juvenile salmonids in the region's estuaries, the dominant prey of juvenile steelhead can be generally classified as invertebrate organisms that are epibenthic and benthic infauna. All of these prey sources are vulnerable to the variable conditions imposed by river mouth conditions, but taxa composition, relative abundance and production may vary as a function of both longitudinal axis (reach) of the estuary and cross-channel distribution. Another potential invertebrate component, pelagic zooplankton, has not appeared in juvenile salmon diets in either open or closed estuary conditions. Epibenthic, benthic, and zooplankton invertebrate sampling has been conducted monthly from May to October since 2010. 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.

Methods

As a result of greater focus on changes in epibenthic and benthic prey availability during estuary closures, Sonoma Water- UW-WET invertebrate monitoring protocols were revised in 2016 and were followed in 2017:

> *Monthly Estuary Surveys :*During years when no prolonged lagoon forms invertebrate surveys will be collected during May, June, and September. Under prolonged lagoon conditions surveys would be conducted monthly from May to October. This sampling schedule would be consistent with the Estuary fish seining schedule. There would be no change in the monthly number of epibenthic, benthic, and zooplankton invertebrate samples collected.
>
> *Mouth Closure Event Surveys:* Monitoring protocols will not change during estuary closure events. Samples would be collected approximately seven and 14 days after a river mouth closure and monthly during prolonged lagoon conditions.
>
> *Lab Processing:* The focus of invertebrate processing in the lab would include the primary steelhead prey taxa (based on years' results, approximately 12-15 taxa). These dominant prey would be sorted and enumerated in epibenthic and benthic samples. Zooplankton are not an important prey group and samples would not be processed. All

invertebrates from epibenthic, benthic, and zooplankton samples would be archived for further analysis if deemed important.

Sampling Sites

Sampling for fish diet and prey availability is designed to coincide with established Sonoma Water and other related sampling sites distributed in the lower, middle, and upper reaches of the Estuary during the Lagoon Management Period (May 15 to October 15). Since 2009, salmonid diet samples have been coincident with beach seining at 11 primary sites (Figure 4.3.1; modified from Largier and Behrens 2010) sampled for juvenile salmon by Sonoma Water – (1) Lower Reach: River Mouth, Penny's Point and Jenner Gulch; (2) Middle Reach: Patty's Rock, Bridgehaven and Willow Creek; and, (3) Upper Reach: Sheephouse Creek, Heron Rookery, Freezeout Bar, Moscow Bridge and Casini Ranch. When possible, samples are specifically selected for diet analysis from the overall beach seine collections at Jenner Gulch to represent the lower Estuary reach, Bridgehaven to represent the middle reach and Casini Ranch, Freezeout Bar and Sheephouse Creek to represent the upper reach. Incidental steelhead diet samples also originated from Penny Point (lower), Willow Creek (middle), and Casini Ranch (upper) sites when there are not sufficient samples from the preferred reach sites. These locations also overlap with sites established by water quality measurements—dissolved oxygen, temperature and salinity.

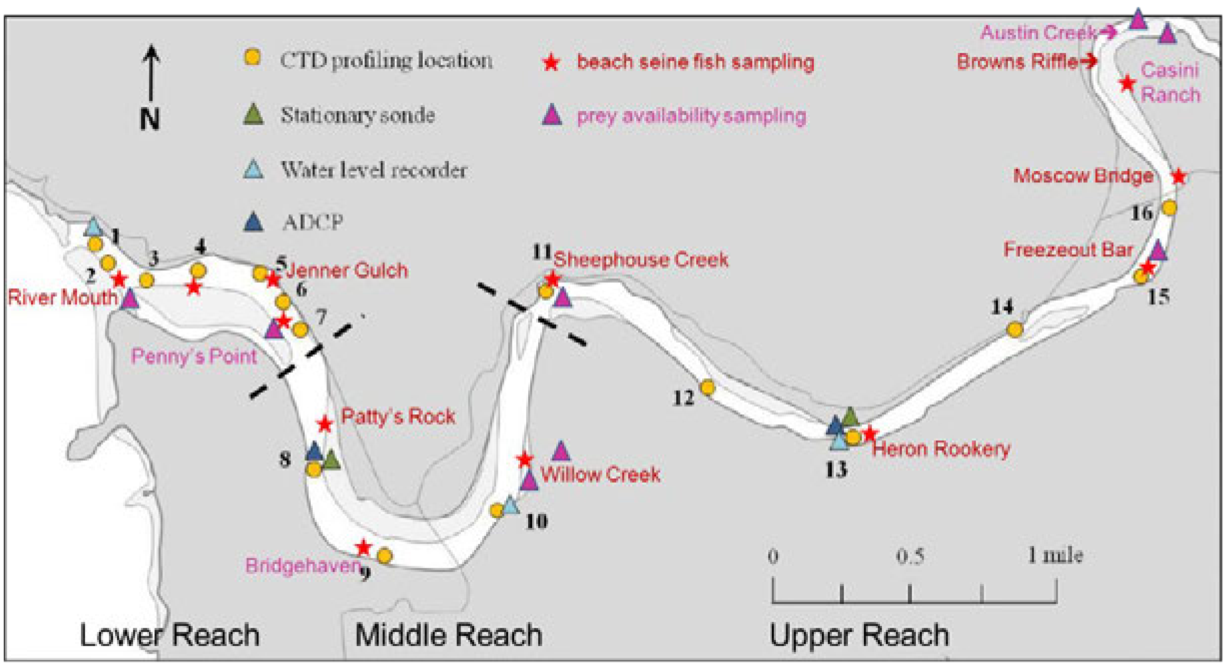


Figure 4.3.1. Locations of sampling stations for juvenile salmon diet (seining location) and prey resource availability (benthic infauna, epibenthos, zooplankton) in three reaches of the Russian River Estuary.

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

Juvenile Salmon Diet Composition

Systematic sampling of the diets of five or more (n≥5) juvenile steelhead ≥55 mm FL are derived, when available, from the beach seine sampling during the lagoon management period between May 15 and October 15. All fish designated for diet analysis are handled, gastric lavaged and released according to the University of Washington animal care protocols. If resources are available and sample sizes are less than five individual fish (n=<5) during systematic sampling, event sampling around scheduled beach management at the barrier beach are coordinated with Sonoma Water fisheries monitoring and physical measurements of estuarine response.

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

Prey Resource Availability

Benthic infauna and epibenthos prey resource sampling were conducted once per month in the lagoon management period during open, tidal (baseline) conditions. If barrier beach conditions result in a closure, epibenthos and benthic infauna are sampled seven and 14 days after closure. Following an extended closure of 14 days or more, prey resource availability sampling of benthic infauna, epibenthos, and zooplankton will begin at day 14 and continue every three weeks after until the Estuary opens. Table 4.3.1 provides a summary of the prey resource availability samples process in 2017.

Benthic Infauna

Replicate core samples (0.0024-m^2 PVC core inserted 10 cm in to the sediment) are taken at each transect of each site (Table 4.3.1). The location of each core sample is consistent with each epibenthic sled and epibenthic net to shore sample, but no core samples are taken in between transects. This sample is repeated four times per transect (twelve times per site). Additional samples would be added along the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation. The sediment cores are preserved in 10% buffered Formalin for laboratory analysis.

Epibenthos

Epibenthic organisms at the sediment-water interface are sampled with two methods: 1) epibenthic net (net to shore); and, 2) epibenthic (channel) sled (Table 4.3.1). The epibenthic net is a 0.5-m x 0.25-m rectangular net, equipped with 106-µm Nitex mesh that is designed to ride along the surface of the Estuary bottom substrate. It is deployed 10 m from shore and then pulled along the bottom perpendicular back to shore by an individual onshore. This is replicated five times per site (once at each transect and then once between Transects 1 and 2 and also between Transects 2 and 3). The epibenthic sled is equipped with a 0.125-m^2 opening, 1-m long 500-µm Nitex mesh net towed behind the boat against the current. The sled is dropped off of

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.

Table 4.3.1. Prey resource availability samples processed in 2017, Russian River Estuary.

Date	Mouth Condition	Jenner Gage Water Level (ft) (10am-2pm)	Benthic Core	Sled Channel	Epibenthic Net to Shore
River Mouth					
6/28/2017	OPEN	2.9-3.4	12	9	5
7/11/17	CLOSED (8th day of closure)	6.5	12	12	5
7/24/17	Open	1.8-3.2	12	9	5
Penny Point					
6/28/2017	OPEN	1.8-2.0	12	9	5
7/11/17	CLOSED (8th day of closure)	6.5	12	12	5
7/24/17	Open	1.8-3.2	12	9	5
Willow Creek					
6/28/2017	OPEN	1.8-2.0	12	9	5
7/11/17	CLOSED (8th day of closure)	6.5	12	12	5
7/24/17	Open	1.8-3.2	12	9	5
Freezeout Bar					
6/28/2017	OPEN	1.8-2.0	12	9	5
7/11/17	CLOSED (8th day of closure)	6.5	12	12	5
7/24/17	Open	1.8-3.2	12	9	5
Subtotal by sample type			**144**	**129**	**60**

the bow of the boat and allowed to sink to the bottom. Once the boat has finished towing the sled (in reverse) 10 m against the current, it will be retrieved back onto the boat. This is replicated five times per site (once at each transect and then once between Transects 1 and 2 and also between Transects 2 and 3). The sled is used to obtain three samples per transect (nine per site under open conditions). Additional samples would be added along the shoreward margin of the transect with increasing water level (inundation of the shoreline) during closure or outlet channel implementation (Figure 4.3.7). Captured organisms are preserved in 10% buffered Formalin for laboratory analysis.

Sample Processing and Analyses

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

In addition to individual metrics of diet composition, the Index of Relative Importance (IRI; Pinkas et al. 1971) is also calculated, wherein %Total IRI for each discrete prey taxa takes into account the proportion that prey taxa constitutes of the total number and biomass of prey and the frequency of occurrence of that taxa among in the total number of fish stomach samples:

$$IRI_i = FO_i*[NC_i + GC_i]$$

where NC is the percent numerical composition, GC is the percent gravimetric (biomass) contribution, FO is the percent frequency of occurrence for each of the prey taxa, and *i* is the prey taxa; results are expressed as a percentage of the total IRI for all prey items. We also interpret diet composition using just GC_i in order to better represent the bioenergetic contribution of prominent (from a FO_i standpoint) prey.

In accordance with a more recent revision of the IRI index, we calculated the Prey-Specific Index of Relative Importance (PSIRI) which substitutes NC and GC with their corresponding prey-specific abundances, %PNC and %PGC:

$$PSIRI_i = FO_i*[\%PNC_i + \%PGC_i]$$

PSIRI sums to 200% and therefore diving by 2 results in a version of the standardized %IRI (Amundsen et al. 1996; Cortḗs 1997), with an important distinction: the PSIRI is additive with respect to taxonomic levels, such that the sum of PSIRI for species will be equal to the PSIRI of the family containing those species.

Prey availability data are standardized to density per area or volume, i.e., m^2 for benthos and epibenthos and m^3 for zooplankton. Prior to analysis, density data are square root transformed to better equate group variances and compress positively skewed distributions to a more nearly normal distribution.

Multivariate analyses are also utilized to organize fish diet sample compositions and prey availability samples into statistically distinct groupings. Statistical analyses are performed using the PRIMER v6.0 multivariate statistics analysis package (Clarke and Gorley 2006) or the R 3.1.1 Vegan package (Oksanen et al., 2011). The primary analyses included non-metric multidimensional scaling (NMDS) and associated analyses of similarities (ANOSIM) and similarity percentages (SIMPER) of factors (in this case, organism taxa) that account for the similarity. Similarity is based on the Bray-Curtis similarity coefficient. The primary ANOSIM statistic for differences between groups is the Global R, which varies between 0 (no significant difference) to 1 (maximum difference). These analytical tools, and the PRIMER package in particular, are used extensively in applied ecology and other scientific inquiries where the degree of similarity in organization of multivariate data (e.g., species, ecosystem attributes) is of interest.

Results

Estuary Conditions

The Russian River Estuary experienced four mouth closures in 2017 during the lagoon management period (Figure 4.3.8). Samples collected before (June 28), during (July 11), and after (July 24) the first closure that lasted from July 4 to July 17 were processed. The June 28 sampling event took place five days before the river mouth closed, the next sampling date, July 11, took place eight days into the closure and then, seven days after the outlet channel breached, sampling took place on July 24.

Juvenile Steelhead Diet Composition

In 2017, 12 juvenile steelhead (78-295 mm fork length [FL]) were sampled for diet composition. Two of the steelhead (78 and 111 mm FL) were captured in May, while the other ten (122-295 mm FL) were captured in August and September. The prey composition in these samples were somewhat consistent with previous years, except for the total dominance by a single taxa. The taxa found in 11 of the 12 samples, *Eogammarus confervicolus*, contributed to about 81.3% of the total gravimetric composition (Figure 4.3.9). The next most common occurring taxa, isopod Gnorimosphaeroma insulare, contributed 7.7% to the total gravimetric composition. Although *Americorophium* spp., isopods, and gastropods were found in more than 40% of the diets, they had relatively minimal contributions to the gravimetric composition. Chironomid pupa were only found in one of the diets and composed only 2.5 % of the total numerical composition and 5.8% to the total gravimetric composition. Likely due to a small number of samples collected this year, mysids *Neomysis mercedis* and corixids, common diet taxa in previous years, were not found in any of the diets this year. These fish had a mean instantaneous ration of 0.012 (±0.01 SD). There was no relationship between fish size (FL mm) and instantaneous ration (p=0.16, $RR2$=0.10).

Due to the small sample size, we were unable to conduct other analysis for 2017. These data have been compiled into a database with the previous data and will be analyzed in a forthcoming comprehensive analysis.

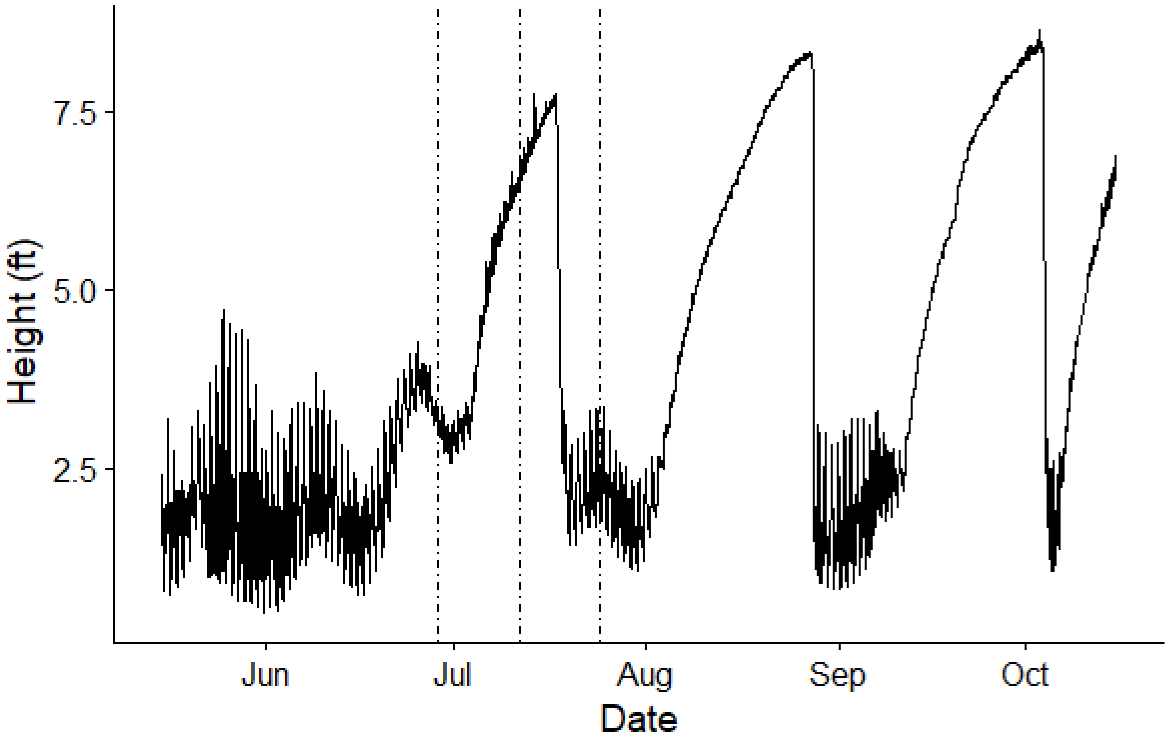


Figure 4.3.8. Dates of samples processed (dashed vertical lines) relative to Jenner Gauge water level (ft) at mouth of Russian River estuary, June and July, 2017.

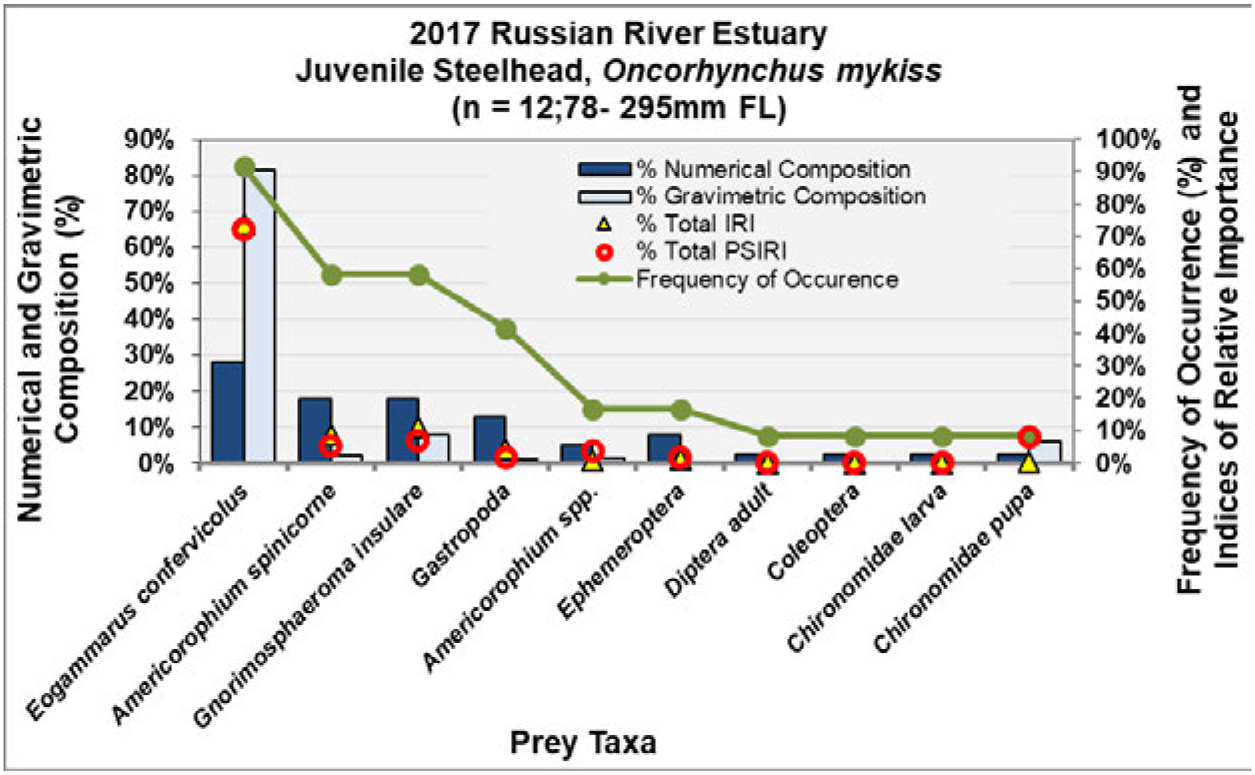


Figure 4.3.9. Percent numerical (NC) and gravimetric composition(GC), frequency of occurrence (FO), total Percent Index of Relative Importance (%IRI) and Prey-Specific Index of Relative Importance (%PSIRI) of prey taxa consumed by juvenile steelhead in the Russian River estuary, May-September 2017.

Prey Availability

Samples collected during the 2017 lagoon management period were prioritized for contrast in river mouth condition (open vs closed) and water level. This includes the aforementioned before, during, and after the July closure of the lagoon management season.

Epibenthic Net to Shore

As described in methods above, the epibenthic net to shore sampling was completed within 10 m of the high water level and could be indicative of an expansion or shift in prey organism distribution as a function of estuary water level and volume. As water elevation rises above 2.1 ft (Jenner Gage) during a closure event, the epibenthic net to shore samples organisms expand (numerical response) or migrate (distributional response) into the recently inundated shallow water margin.

The epibenthic net to shore sampling had the highest densities of prey taxa before the July 4 closure, somewhat similar or slightly lower densities eight days into the closure, and the lowest densities seven days after the outlet channel breached (Table 4.3.2). In this littoral-edge environment, the most common macroinvertebrates during the June 28 sampling were of corixid (water boatmen) beetles at the furthest upstream site, Freezeout Bar, with mean densities of 867 m^{-2} (Figure 4.3.10). Two weeks later, during closed conditions (July 11) at Freezeout Bar, corixids were found at slightly lower densities in this littoral habitat (~600 m^{-2}) (Figure 4.3.11).

Table 4.3.2. Percentage change from the first sampling event, June 28, of each taxa group from the net to shore samples for each sampling date for each site. If there were none present in the June 28 sampling a generic density of 1 per m-2 to calculate a percent change was provided.

Site	Date	*Amphipoda*	*Gastropoda*	*Hemiptera*	*Isopoda*	*Mysidacea*	*Osteichthyes*
River Mouth	11-Jul	11%	-100%	-100%	-77%	-54%	0%
River Mouth	24-Jul	-75%	-81%	100%	-84%	-95%	144%
Penny Point	11-Jul	-81%	-75%	800%	-47%	-100%	0%
Penny Point	24-Jul	-67%	-48%	-100%	-43%	-60%	144%
Willow Creek	11-Jul	-79%	-61%	-23%	3550%	-100%	500%
Willow Creek	24-Jul	76%	271%	-75%	7500%	-96%	850%
Freezeout Bar	11-Jul	-89%	0%	-25%	0%	2560%	0%
Freezeout Bar	24-Jul	33%	480%	-76%	0%	640%	0%

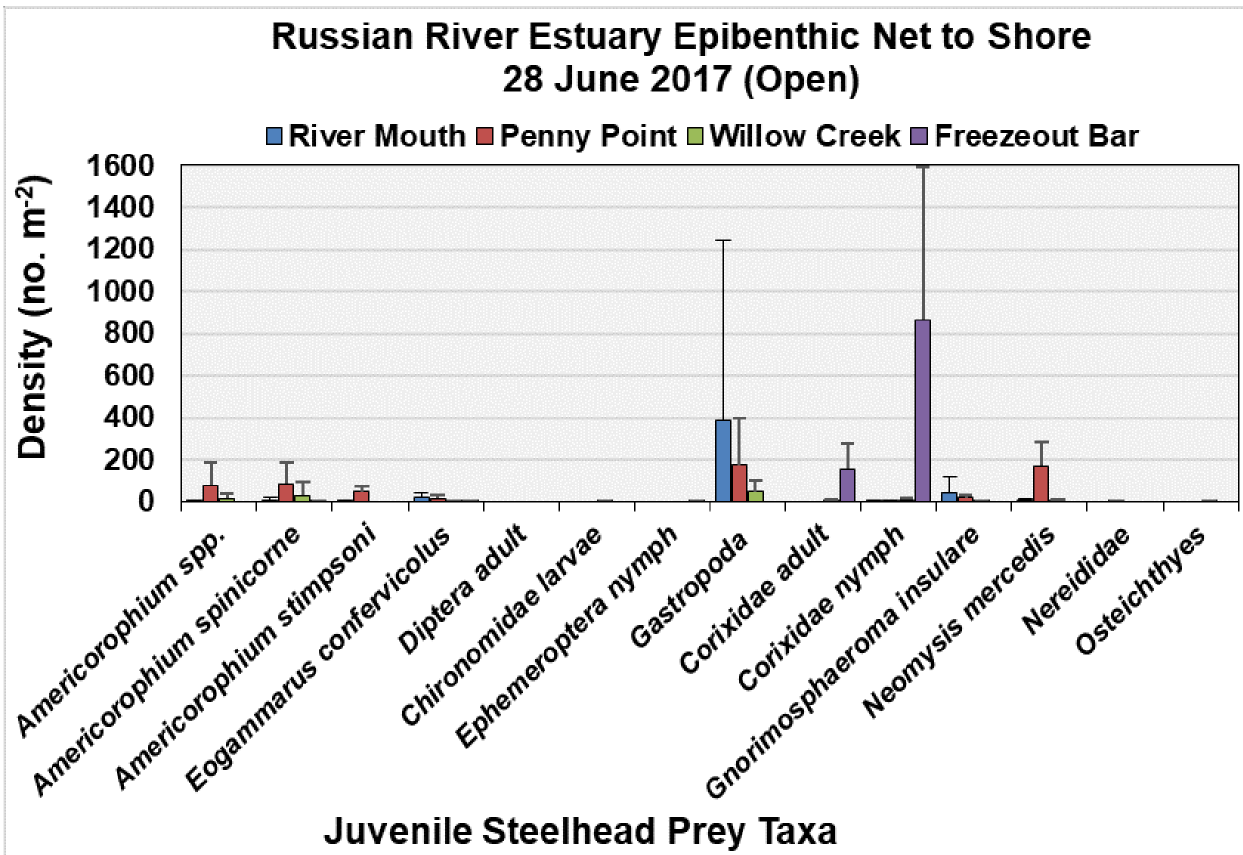


Figure 4.3.10. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic net to shore sampling at four sites in the Russian River estuary, June 28, 2017.

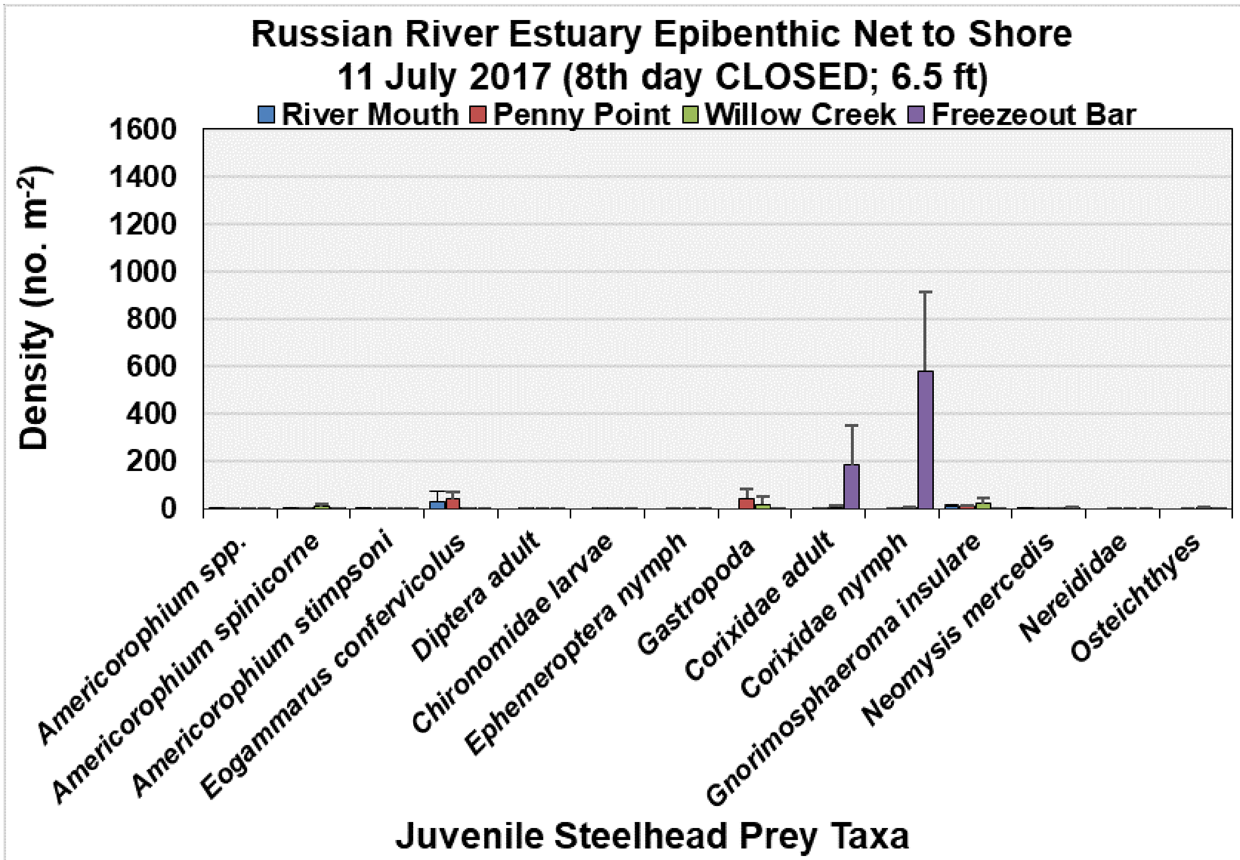


Figure 4.3.11. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic net to shore sampling at four sites in the Russian River estuary, July 11, 2017.

The July 24 sampling after the closure and subsequent outlet channel breach also found corixids but these were at the lowest densities (168 m^{-2}) (Figure 4.3.12). The next most common macroinvertebrate in the epibenthic net to shore samples were gastropods (snails) found near the River Mouth, Penny Point and Willow Creek (Figures 4.3.10 – 4.3.13). Mean densities of gastropods were highest (387 m^{-2}) during the open inlet conditions before the closure, less during the closure (44 m^{-2}) and then densities increased to as high as ~200 m^{-2} after the outlet channel breached. Other main prey taxa, such as amphipods (*A. spinicorne*, *A. stimpsoni*, *E. confervicolus*), isopods, and mysids were commonly found in the littoral zone, but at much lower densities, especially under closed conditions. For example, at Penny Point, mysids were the taxa with the third highest density prior to the closure (~170 m^{-2}), almost absent during the closure across all sites, and then occurred at a mean density of ~70 m^{-2} at Penny Point after the closure.

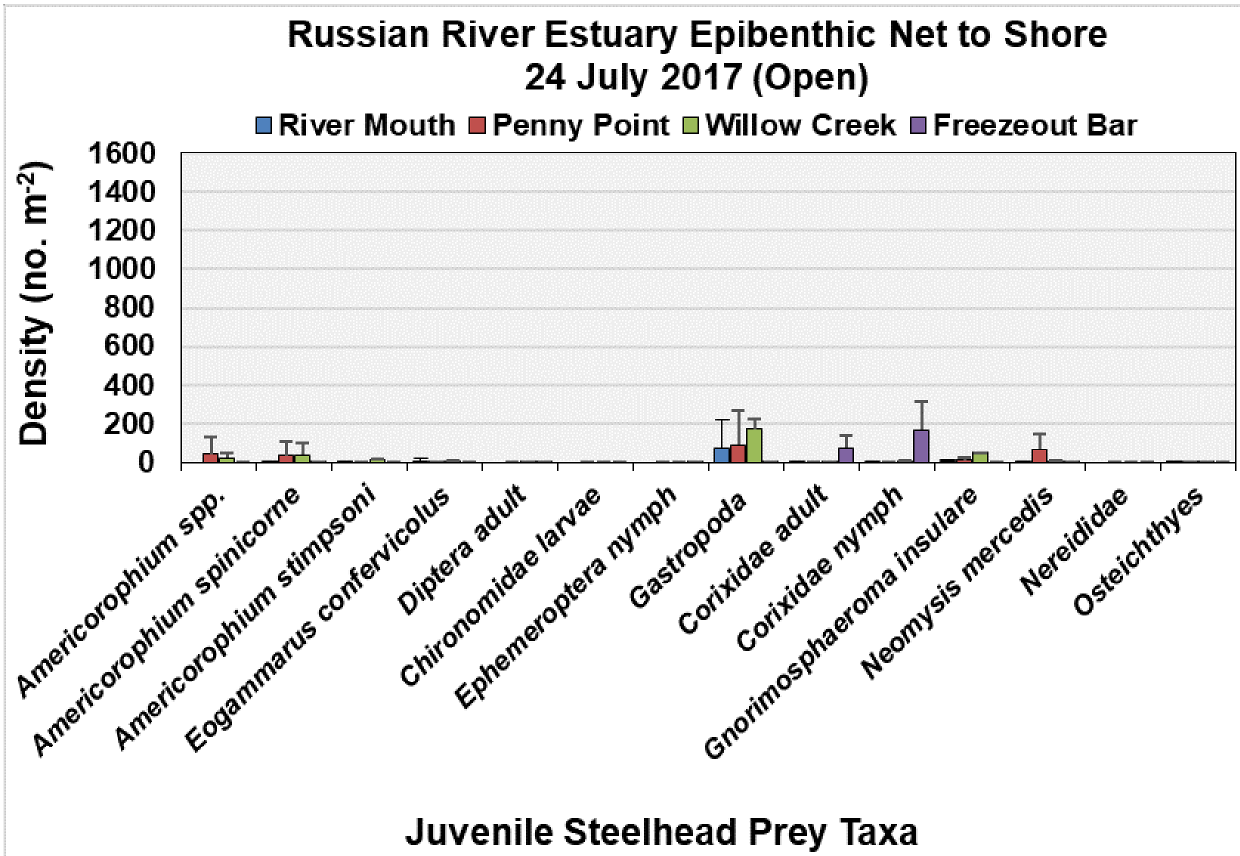


Figure 4.3.12. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic net to shore sampling at four sites in the Russian River estuary, July 24, 2017.

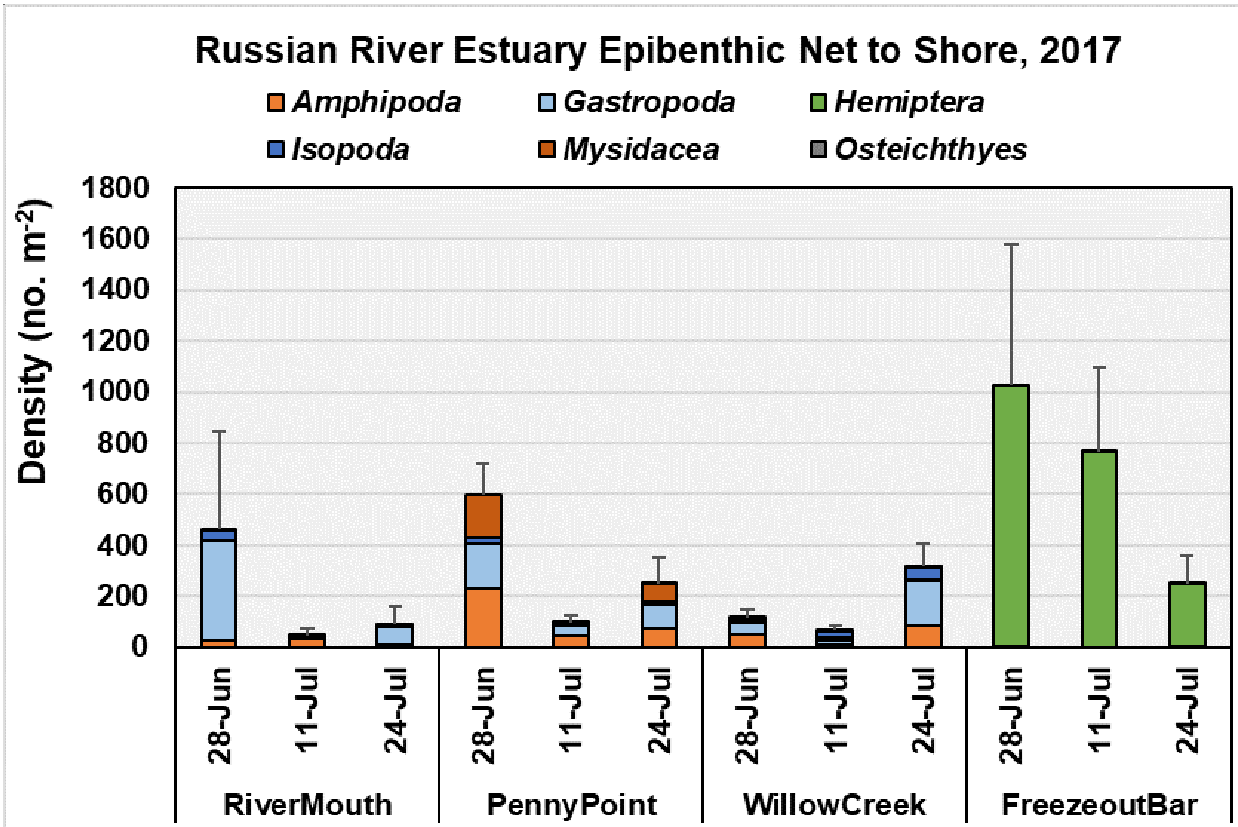


Figure 4.3.13. Cumulative density of epibenthic net to shore sampling for each of the three sampling periods for each sampling site. The July 11 dates were during closed conditions.

Multivariate analysis of the taxa density composition among the four sites over the three sampling events (Figure 4.3.14; 2D stress=0.16) indicated a significant difference between sites (R = 0.636) but not Sampling Event (R = 0.001). Freezeout Bar and River Mouth are most dissimilar while River Mouth and Penny Point had the most overlap (Figure 4.3.14).

Epibenthic Sled

Samples from the epibenthic sled distinguish potential macroinvertebrate prey availability in two respects: 1) the sled samples deeper habitats parallel to the thalweg; and 2) during prolonged closures, additional sled samples are added where newly inundated intertidal areas are available to foraging steelhead.

Other than a few exceptions, the epibenthic sled sampling analysis indicted similar general prey taxa distributions as documented in the epibenthic net to shore and relatively similar densities before and during the closure with the lowest densities after the inlet breached (Figures 4.3.15 – 4.3.17, Table 4.3.3). For all three sampling periods, the densest taxa were corixids collected at Freezeout Bar. Similar to the epibenthic net to shore, these densities were also highest before (~2,300 m^2) and during (~1,700 m^2) the July 4 closure, and lowest after the outlet channel breached (~300 m^2). Unlike the epibenthic net to shore sampling, gastropod snails were only found at notable densities (~>30 m^2) during the closure in the extra, extended habitat samples.

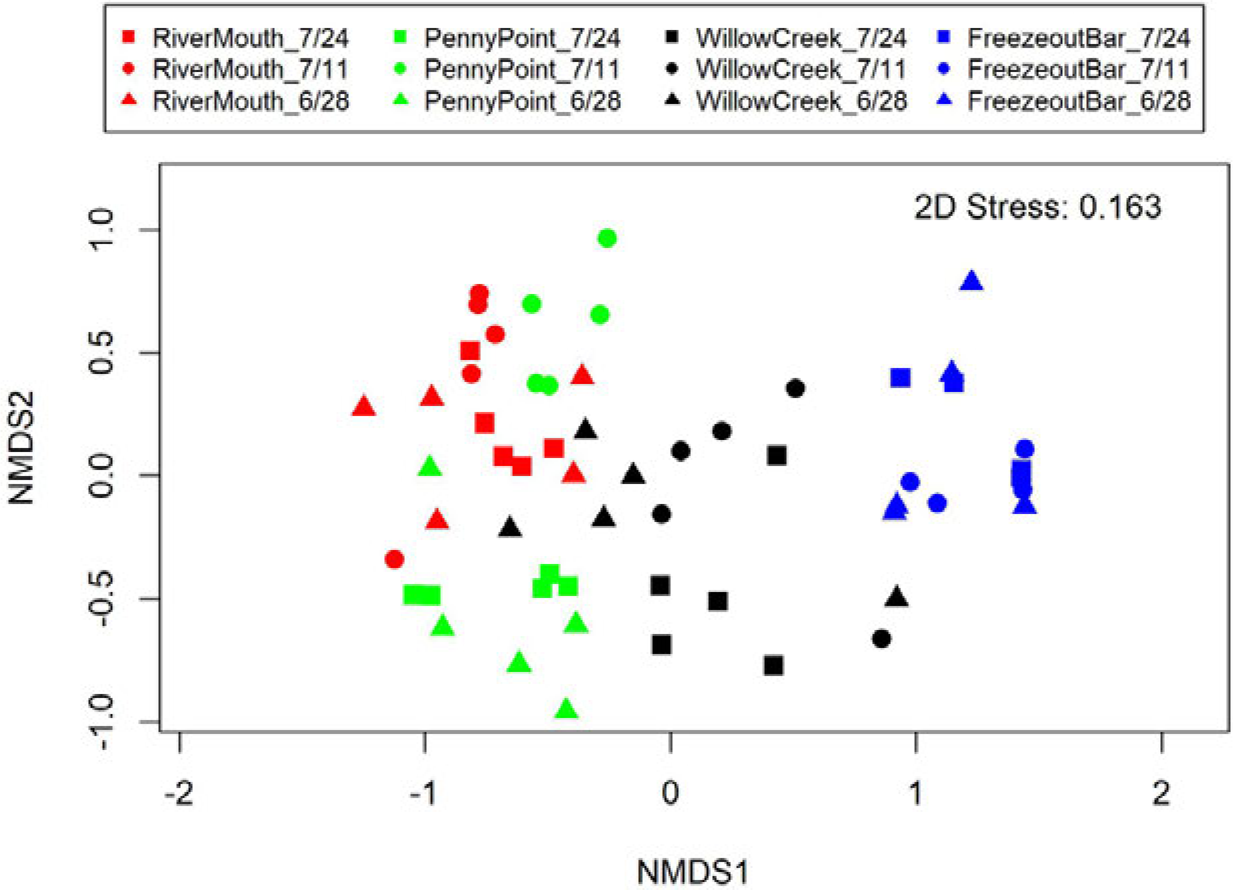


Figure 4.3.14. Multivariate analysis (NMDS) diagram of density composition of epibenthic net to shore macroinvertebrate prey of juvenile steelhead in the Russian River Estuary, 2017.

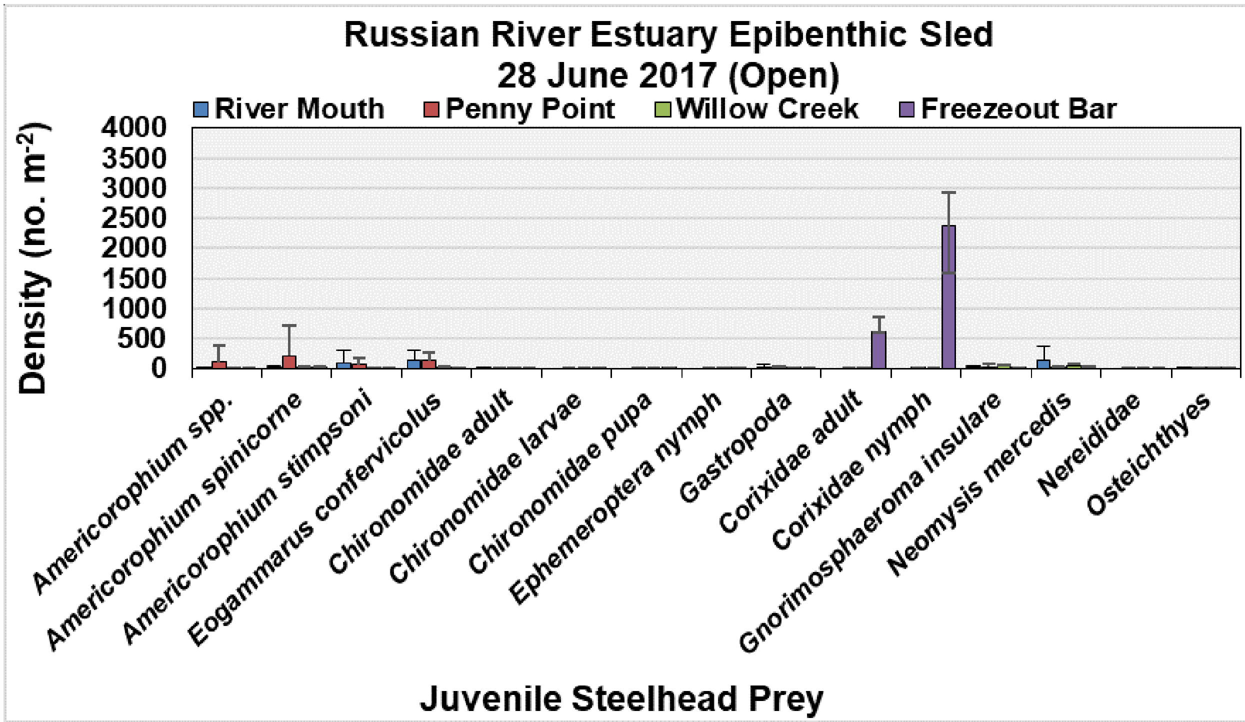


Figure 4.3.15. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic sled sampling at four sites in the Russian River Estuary, June 28, 2017.

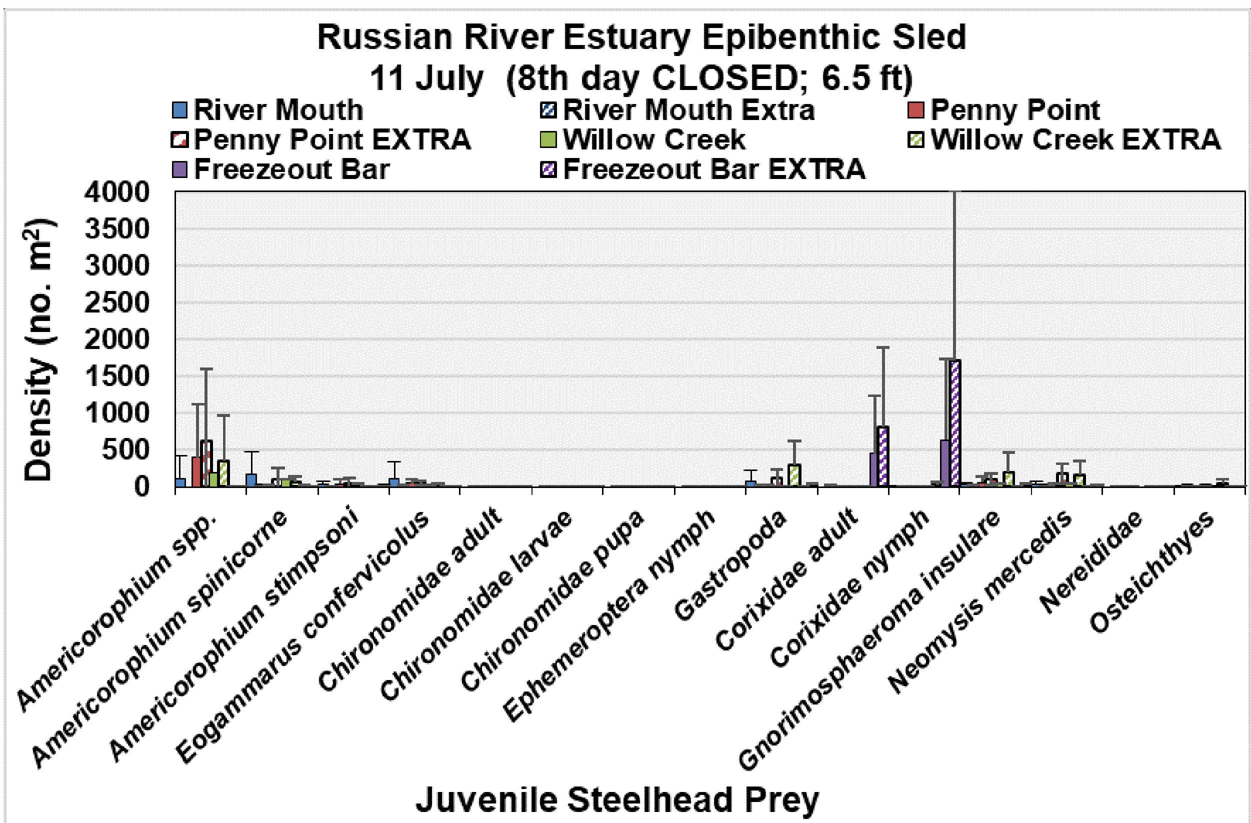


Figure 4.3.16. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic sled sampling at four sites in the Russian River Estuary, July 11, 2017.

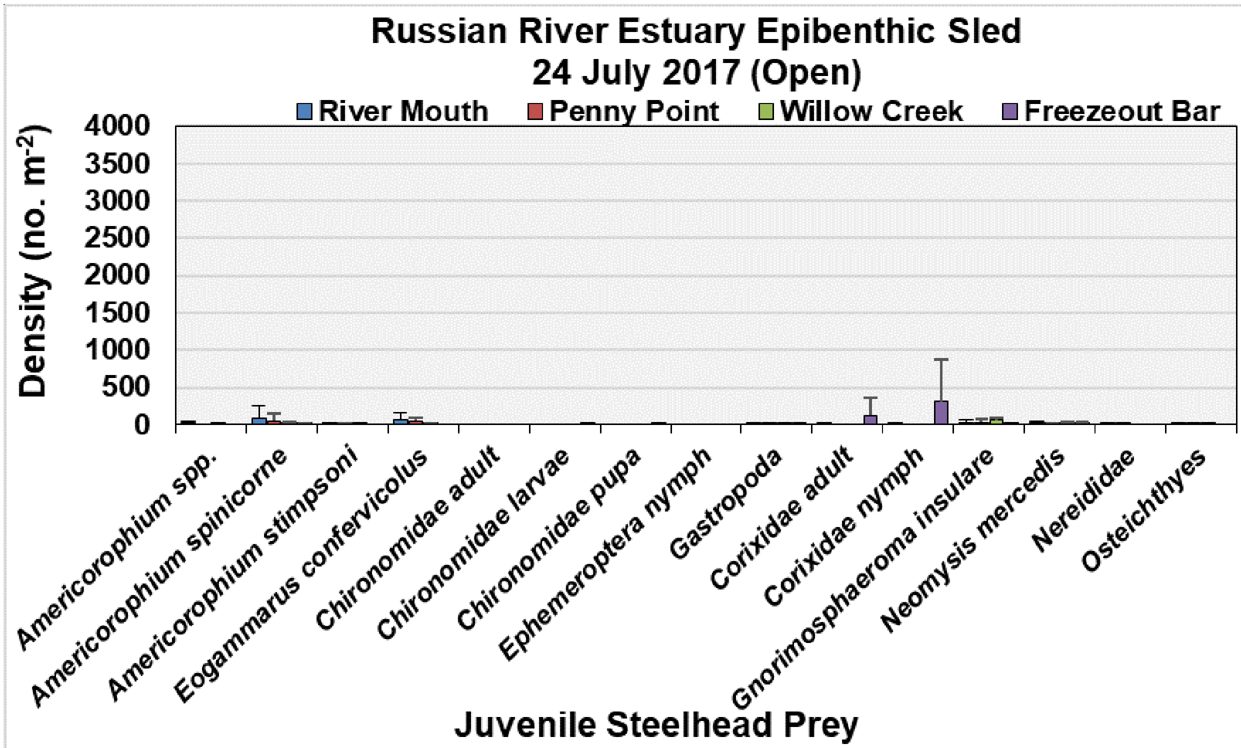


Figure 4.3.17. Density of epibenthic macroinvertebrates documented as juvenile steelhead prey from epibenthic sled sampling at four sites in the Russian River Estuary, July 24, 2017.

Table 4.3.3. Percentage change of each taxa group from the sled channel samples contributing to each sampling date for each site. Type designates location of sled channel samples; the sample type Extra were collected exclusively in the expanded closure habitat. If there were none present in the June 28 sampling we provided a generic density of 1 per m^{-2} to calculate a percent change.

Site	Type	Date	*Amphipoda*	*Gastropoda*	*Hemiptera*	*Isopoda*	*Mysidacea*	*Osteichthyes*
River Mouth	Main	11-Jul	69%	311%	6%	-1%	-85%	-8%
River Mouth	Extra	11-Jul	-94%	-43%	0%	-1%	-99%	-96%
River Mouth	Main	24-Jul	-22%	-74%	30%	52%	-89%	-97%
Penny Point	Main	11-Jul	1%	21%	-100%	67%	-45%	300%
Penny Point	Extra	11-Jul	71%	1957%	-100%	251%	891%	1700%
Penny Point	Main	24-Jul	-77%	-87%	-100%	17%	-24%	100%
Willow Creek	Main	11-Jul	529%	1350%	18%	21%	-50%	-73%
Willow Creek	Extra	11-Jul	794%	79150%	2276%	425%	223%	267%
Willow Creek	Main	24-Jul	-57%	167%	0%	54%	-70%	-74%
Freezeout Bar	Main	11-Jul	-63%	0%	-64%	-100%	-93%	0%
Freezeout Bar	Extra	11-Jul	-90%	1138%	-15%	6300%	-67%	0%
Freezeout Bar	Main	24-Jul	-57%	207%	-85%	733%	-26%	0%

Prey taxa that occurred in comparatively low densities and fewer sites in the epibenthic net to shore sampling were more dense and more widely distributed in the epibenthic sled samples. In particular, amphipods (*Americorophium* spp., *E. confervicolus*), and isopods (*G. insulare*). Chironomids and mayflies (Ephemeroptera), both main prey taxa of juvenile steelhead in previous years but were rarely consumed this year, were also absent or rarely captured in the epibenthic sled and epibenthic net to shore samples in 2017.

The extra samples collected in the expanded habitat during the clousre typically reflected what was found in the main estuary but with varying densities (Figure 4.3.18). The densities were the lowest and much lower than the normal transects in the extra samples at the site with the most drastic environmental changes, the River Mouth. Densities increased at Freezeout Bar, Willow Creek and Penny Point. At Freezeout Bar, both the regular samples and the extra samples primarily consisted of corixids. At Penny Point and Willow Creek, the higher densities in the expanded habitat consisted of amphipods (*Americorophium* spp., *E. confervicolus*), mysids, and gastropods. This would suggest that these taxa may have redistributed their populations or experienced directed immigration into the newly expanded shallows.

Multivariate analysis (NMDS) of the taxa density composition among epibenthic sled sampling stations in the four sites over the two sampling events (Figure 4.3.19; 2D stress=0.17) indicated no significant difference between dates (R = 0.011) or between the standard and extra samples (R= 0.04), but did distinguish a difference among sites (R = 0.5072). The NMDS (Figure4. 3.19) illustrates that the source of the main difference was the distinction of Freezeout Bar from the rest of the sites, likely from the presence of corixid beetles and the lack of many other microbenthic prey items.

Benthic Infauna

Among the prevalent prey of juvenile steelhead, the tubicolous amphipods *Americorophium* spp. were most abundant taxa found in the benthic cores (Figures 4.3.20 – 4.3.22). These were found at the highest densities (~25,000 m^2) during the June 28 sampling event, prior to the closure at all sites. The next most common taxa were the amphipod *E. confervicolus* at a mean density of 5,075 m^2 at River Mouth and chironomid larvae with a mean density of 3,888 m^2 at Freezeout Bar.

There was a slight decrease in the densities of prey resources found in the benthos during the closure, with *Americorophium* spp. found at the highest densities with a mean of over ~20,000 m^2. In addition, *G. insulare* were found at the next highest density at ~3,100 m^2 at Willow Creek. The benthos composition and densities after the outlet channel breached was similar to that during the closure. The highest mean density of *Americorophium* spp. was found at River Mouth (~20,000 m^2). Amphipods, isopods and nereid polychaete worms were consistently found at all sites.

Differences in assemblage structure and abundance are not evident from the multivariate analysis (Figure 4.3.23). There was not difference detected across sites (R = 0.11). Similarly, there were no differences among the dates before, during and after the closure (R = 0.102).

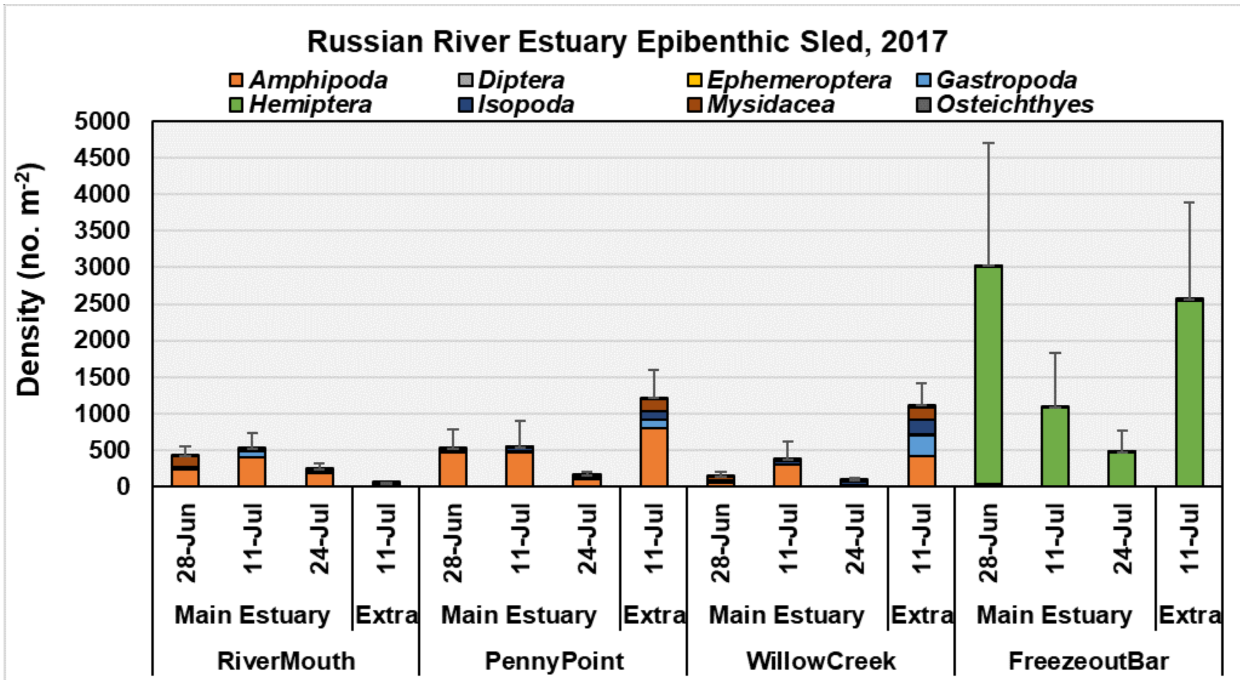


Figure 4.3.18. Cumulative density of epibenthic sled sampling for each of the three sampling periods for each sampling site. The July 11 dates were during closed conditions. The samples labeled Extra are the additional samples taken in extended habitat only accessible during the closure.

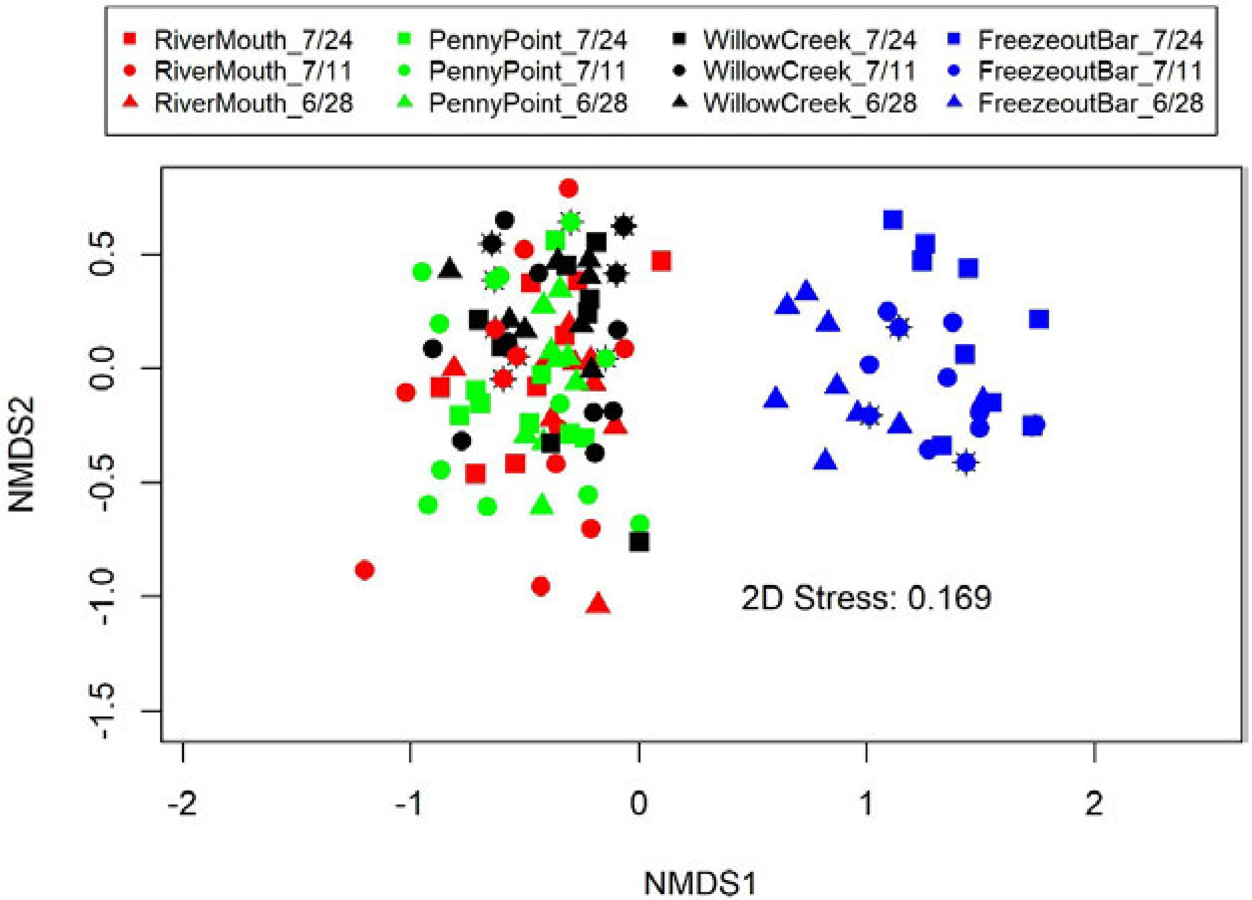


Figure 4.3.19. Multivariate analysis (NMDS) diagram of density composition of epibenthic net macroinvertebrate prey of juvenile steelhead from four sites over three sampling periods in the Russian River estuary, 2017. The asterisk symbols designate the extra samples from expanded habitat during estuary closure.

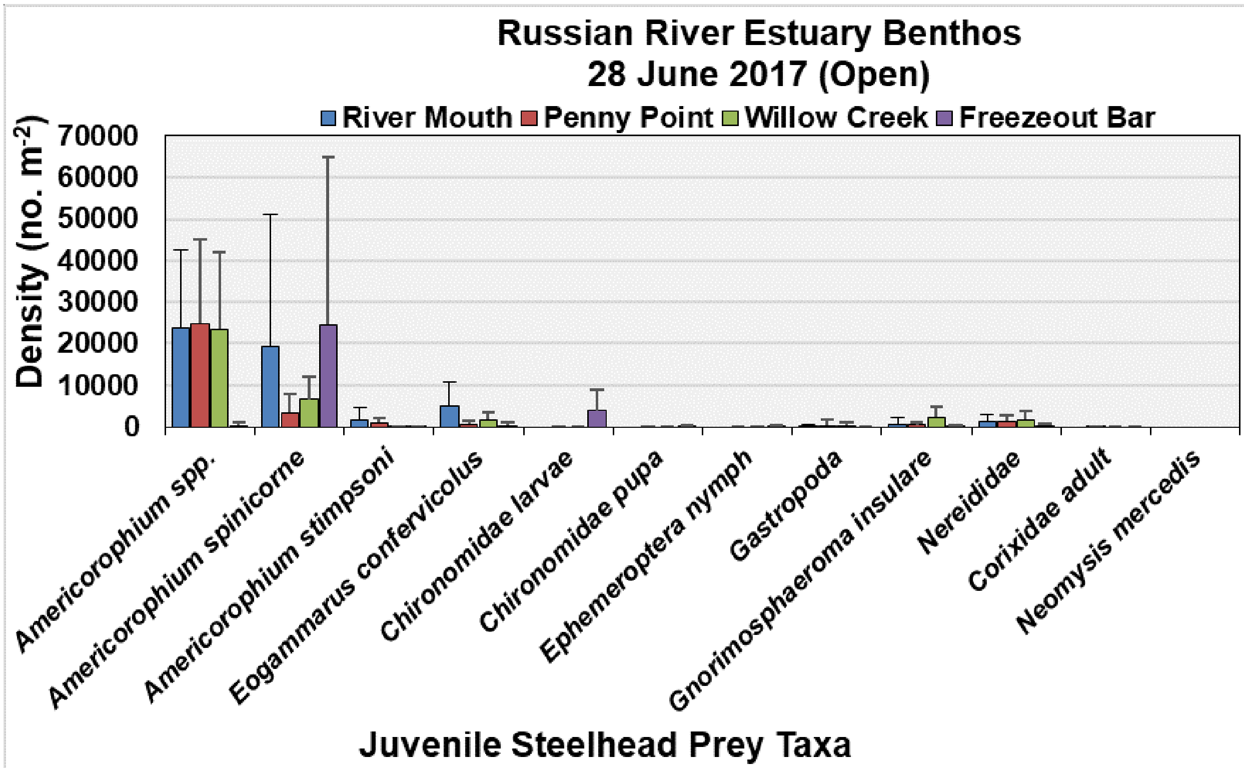


Figure 4.3.20. Density of benthic macroinvertebrates documented as juvenile steelhead prey, four sites in the Russian River Estuary, June 28, 2017.

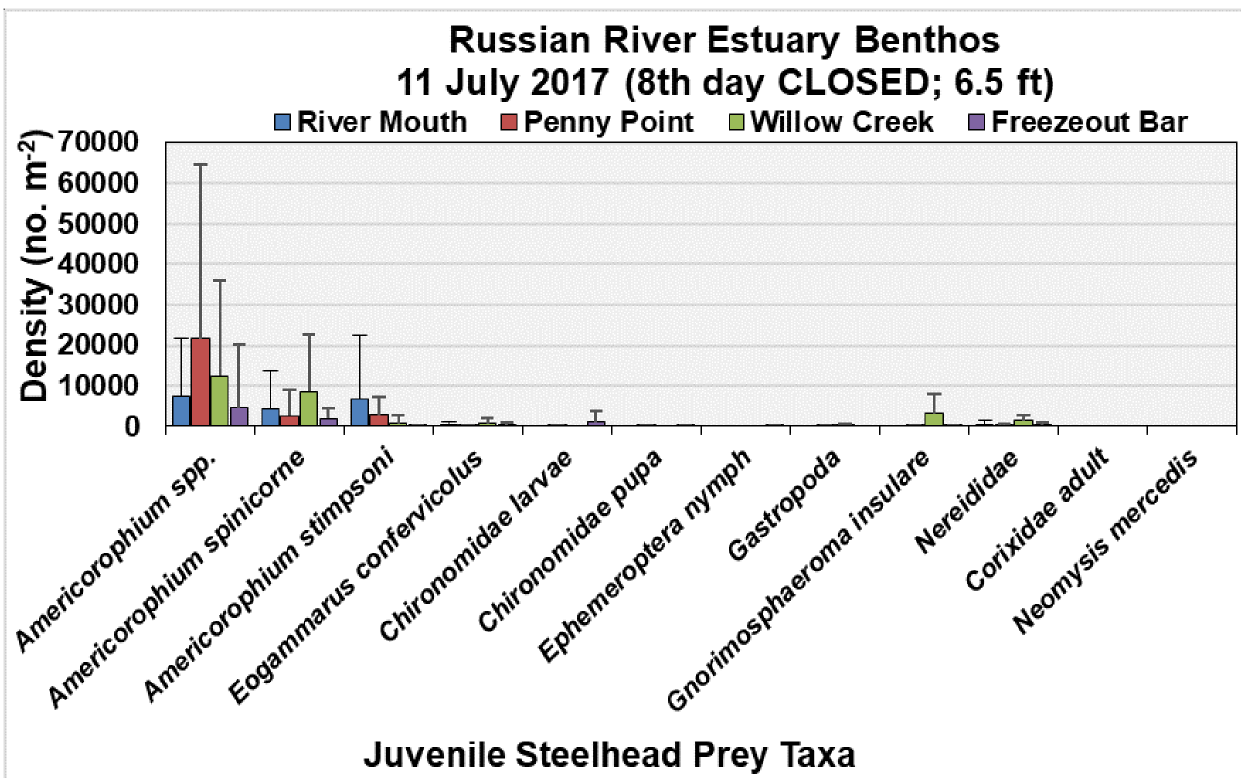


Figure 4.3.21. Density of benthic macroinvertebrates documented as juvenile steelhead prey, four sites in the Russian River Estuary, July 11, 2017.

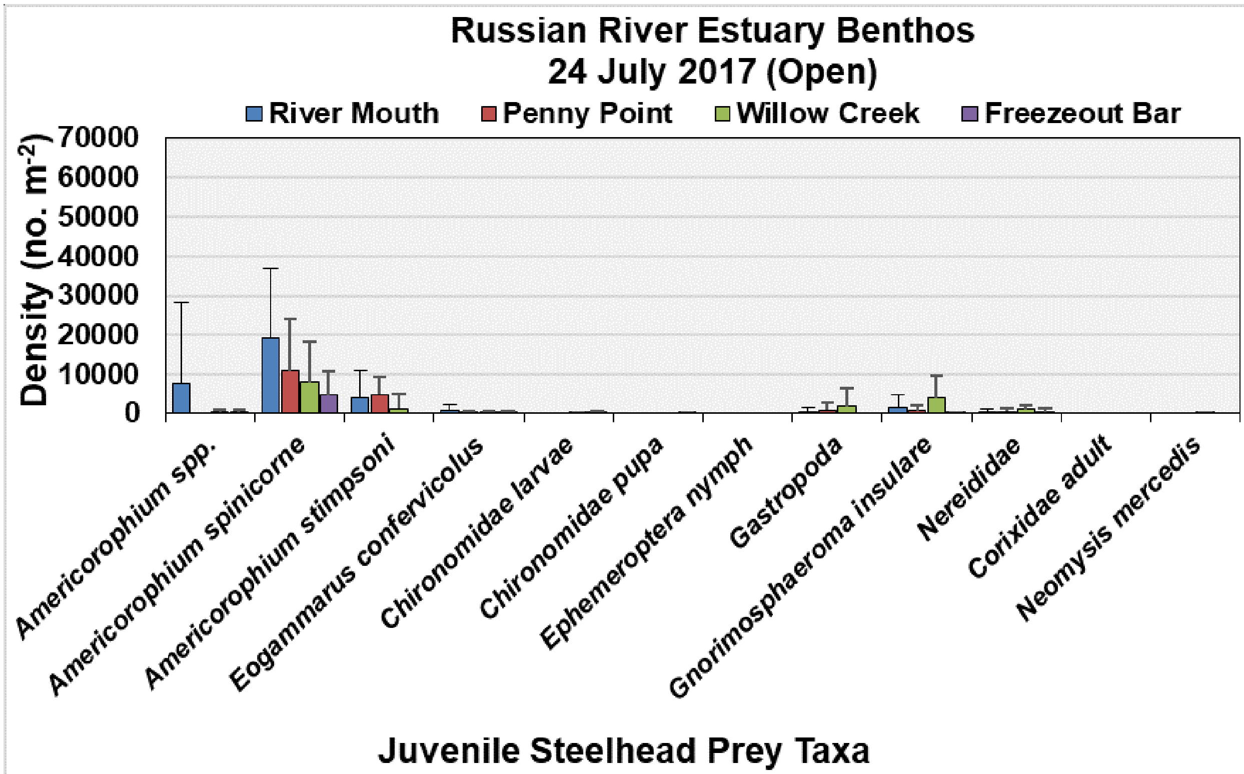


Figure 4.3.22. Density of benthic macroinvertebrates documented as juvenile steelhead prey, four sites in the Russian River Estuary, July 24, 2017.

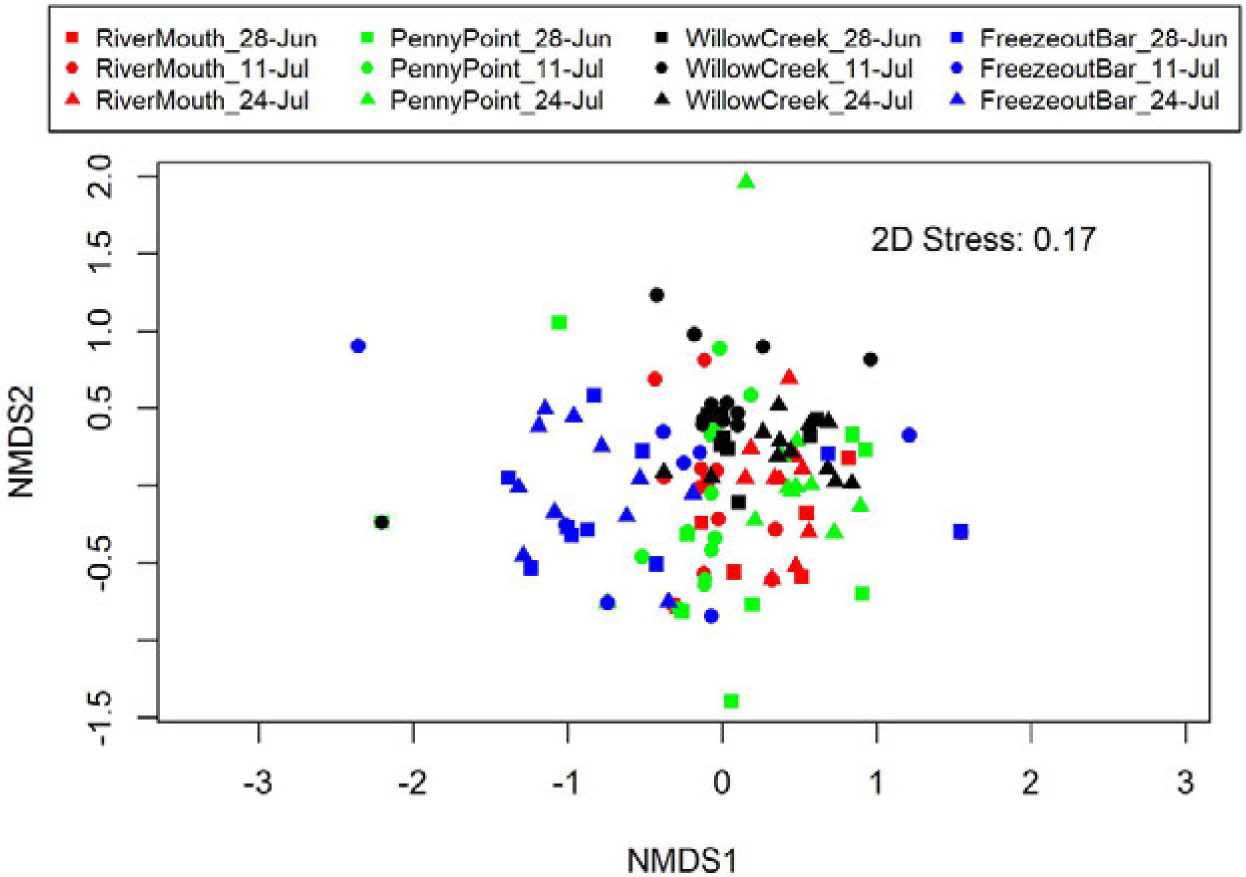


Figure 4.3.23. Multivariate analysis (NMDS) diagram of density composition of benthic macroinvertebrate prey of juvenile steelhead in the Russian River Estuary, 2017.

Point and River Mouth, *E. confervicolus* were found at mean densities an order of magnitude smaller (<500 m^{-2}). At Freezeout Bar, the only macroinvertebrates found at moderate densities were *G. insulare*, which increased to ~1,300 m^{-2} from ~450 m^{-2} in June. Except for the density of polychetes doubling later in the season at the River Mouth (from ~1,000 m^{-2} to ~2,100 m^{-2}), polychetes were consistently found at mean densities less than 1,000 m^{-2}. Multivariate analysis of the taxa density composition among the four sites over the two dates bracketing the estuary closure (Figure 4.3.17; 2D stress =0.19) indicated no significant difference among sites (Global R = 0.14) or dates (Global R = 0.20).

Conclusions and Recommendations

Findings

Relationship of Epibenthic Prey Availability to Juvenile Steelhead Diet

As demonstrated in diet composition documented throughout this study since 2009, juvenile steelhead occupying the Russian River Estuary tend to feed somewhat specifically on a limited suite of epibenthic crustaceans and aquatic insects. These prey, dominated by two species of epibenthic gammarid amphipods, tubicolous *Americorophium* spp. (*A. spinicorne; A. stimpsoni*) and *E. confervicolus*, the epibenthic isopod *G. insulare*, and aquatic insects of the hemipteran family Corixidae (water boatmen), also occur consistently in the diets of juvenile steelhead sampled in other estuaries along the northeastern Pacific, including other intermittent systems (Needham 1940; Shapovalov Taft 1954; Meyer et al. 1981; Martin 1995; Salamunovich and Ridenhour 1990; Daly et al. 2014). Unique to this year, there were no mysids or corixids found in the diets, even though these were common prey in previous years. However, the low sample size available for diet composition this year precludes interpretation of any significance to this finding. Only in a few cases, of small, persistent estuarine lagoons such a Waddell Creek, have other prey such as aquatic insects become more prominent (Needham 1940). This dominantly epibenthic feeding strategy indicates that juvenile steelhead in this, and seemingly most estuaries, are foraging along the bottom, whether in deeper channel or shallower, marginal habitats.

Prey densities were relatively comparable among the 2017 and prior years' results, implying a consistent estuarine prey community available for juvenile steelhead despite some variability in the occurrence and duration of freshwater outflow and estuary closure events. Mysids were never captured at high densities with all sampling methods in 2017, although in previous years they occurred in large swarms that are challenging to quantify. The composition and relative density distribution of macroinvertebrate prey in epibenthic net to shore and channel sled samples were similar, suggesting that there was uniform or a relatively minor gradient of prey density distribution from their deeper channel to their shallower, marginal habitats.

Similar to previous years, in 2017 prey taxa and density composition in the net to shore and sled channel samples differed among sites, but there were no differences detected among sites in the benthic cores (Figures 4.3.14, 4.3.19, and 4.3.23). This suggests that some invertebrates found in the benthos, primarily tubicolous amphipods and nereidid polychaete worms, occur throughout the Estuary despite variability in sediment structure and environmental conditions along the breadth of the Estuary. It should be noted, however, that all these prey are a component of the benthos, as sampled by cores of sediments, the nereidid worms and tubicolous amphipods are also epibenthic in that the *Americorophium* spp. amphipods and nereid polychaetes will emerge from the substrates during life cycle and ecological stages. In contrast, the epibenthos sampling (net to shore and sled channel) had spatial differences likely reflective of the taxa distributing along the Estuary's saline gradient including mysids, gastropods and especially corixids in the freshwater upper estuary. These taxa are more motile and can shift according to tidal or daily fluctuations.

The series of samples collected in 2017 bracketing the July 4-17 closure and the recent modifications to the sampling design provided the opportunity to conceptually assess this year's sampling with a Before-After Control-Impact (BACI) framework in mind (Stewart-Oaten et al. 1986, 1992). The "control" samples were collected at the same location (benthic cores, epibenthic sled) during open and closed conditions and the additional "impact" samples were from the same position relative to water level (10 m from water edge by net to shore) or from extended transects (epibenthic sled; Extra) in recently inundated intertidal waters during closed conditions. Because the unique net to shore and sled sampling sites are only inundated and sampled during closed conditions, they do not contribute to prey resources during open inlet conditions.

We can use this framework to measure the response of prey resources to changing inlet conditions and possibly determine if there is a shift in prey resources or an increase in overall abundance and availability to foraging steelhead. Based on our descriptive sampling, we hypothesized that comparisons of prey availability in open and closed estuary conditions could indicate the direction and type of response of the dominant prey organisms, where a “functional response” would involve a reorganization of the prey population as a function of changing food and habitat availability and a “numerical response” would involve a change in population abundance as a result of alteration in reproductive rate and other population regulation such as predation (Table 4.3.4). The functional response would primarily be a factor of the motility of the prey organism; our observations would indicate that all of the primary prey except gastropods (snails) have the ability to rapidly redistribute during the period of increasing or falling water elevations.

On the other hand, numerical responses might be predicted with changes in food availability or quality that would reflect in generation time and productivity, or ecological changes in mortality rates (e.g., from predation, disease, etc.). While population changes due to altered reproductive rates would require that an organism’s population regulation must occur within the period of the estuary closure (e.g., between open and closed sampling dates), many ecological responses, such as changes in predation, can occur quite rapidly. Reproductive rates are quite variable among the prominent prey taxa: various *Americorophium* spp. amphipods have generation times of 30-90 days (Davis 1978; Whitlatch and Zajac 1985); minimum gastropod development time might range between 10 and 25 days (Scheltema 1967; Reitzel et al. 2004), depending on their reproductive strategy; corixids hatch over 8-20 days (Carbonell et al. 2016); *G. insulare* isopods over 120 days (Stanhope et al. 1987); the mysid *Neomysis mercedis* 45 days or more (Johnson 1985; Hiebert 2015). Based on this July 2017 two-week period of estuary closure under study, it would appear that generation time and productivity of prey populations would not be a source of numerical response, although we cannot preclude that individual growth rates and fecundity did not increase.

Compared to prey densities found during the open inlet conditions on June 28, prey densities estimated from the net to shore and sled samples tended to either be somewhat similar or increase by July 11 during the closure, but decrease after the outlet channel breached, often below the previous open inlet conditions on June 28 (Figures 4.3.13 and 4.3.18; Tables 4.3.2 and 4.3.3).

Notable examples of the response of prey to inlet closure include relatively consistent densities of amphipods in the main sled samples at River Mouth (69% of open condition densities) and isopods at Penny Point (67%), but dramatically increased densities of amphipods (529%) and gastropods (1,350%) in the main sled samples at Willow Creek (Table 4.3.3). Concurrently, densities in the newly inundated Extra samples were dramatically higher for gastropods (1,957%), isopods (251%) and mysids (691%) at Penny Point, exceedingly high (223%-79,150%) for all prey categories at Willow Creek, but particularly high increases for just gastropods (1138%) and isopods (6300%) at Freezeout Bar (Table 4.3.3). Based on absolute densities, however, amphipods and corixid beetles (Hemiptera) demonstrated the strongest responses (Figure 4.3.18).

Table 4.3.4. Hypothesized explanations for functional or numerical responses of prey availability based on three sampling regimes before during and after inlet closure of the Russian River Estuary.

Sample Source	Functional Response			Numerical Response		
	no change from previous open estuary	significant increase in densities from previous open estuary	significant decrease in densities from previous open estuary	no change from previous open estuary	significant increase in densities from previous open estuary	significant decrease in densities from previous open estuary
Sled to Shore	redistribute into newly inundated habitat	uncertain: redistribute or concentrate in newly inundated habitat	maintain open estuary distribution	no response	recruit and reproduce	redistribute or mortality
Repeated Epibenthic Sled	maintain open estuary prey distribution	recruit into open estuary prey distribution	redistribute into newly inundated habitat	no response	increased recruitment or reproduce	redistribute or mortality
Extra Epibenthic Sled	redistribute into newly inundated habitat	concentrate in newly inundated habitat	maintain open estuary distribution; no redistributio n into newly inundated habitat	recruit and reproduce	recruit and reproduce	redistribute or mortality

Conversely, the net to shore samples indicated typically lower densities along the edge of the newly inundated habitat than when the estuary inlet was open (Table 4.3.2). With the exception of corixids at Penny Point (800%), isopods (3,550%) and fish (500%) at Willow Creek and mysids at Freezeout Bar, all other prey categories were less dense during theJuly 2017 closure. In terms of the densest taxa, only corixids at Freezeout Bar suggested approximately comparable densities (Figure 4.3.13).

Prey resources generally decreased, often dramatically by as much as -100% (e.g., corixids at Penny Point) relative to open conditions after the outlet channel breached. Only the densities of shore to net isopods increased measurably (7,500%) after the breach; however, gastropods (480%) and mysids (640%) at Freezeout Bar also appeared more dense after water levels had lowered. In addition to the elimination of resources found in the expanded habitat, the densities of prey had decreased to lower densities at all four main sites after the inlet breached (Figure 4.3.18). The largest decreases of densities were of corixids at Freezeout Bar and amphipods at the other three sites. Only gastropods (207%) and isopods (733%) at Freezeout Bar appeared in somewhat higher densities in the main sled samples after the Estuary had returned to open conditions.

Except perhaps for prey at the River Mouth site, which indicated pervasive declines or little change in prey densities sampled by all three sampling methods (Figures 4.3.13, 4.3.18, and Figures 4.3.20 – 4.3.23), evidence suggests that prey of juvenile steelhead typically increased during the Estuary's closure and then decreased dramatically after the breach returned to open estuary water levels. The increase, primarily amphipods, detected with the extra epibenthic sled transects in the expanded habitat, is possibly attributed to new availability of food resources, such as detritus, for macroinvertebrates that could mobilize to occupy the new intertidal habitat (Figure 4.3.4 functional response) or food resource and other conditions that would facilitate productive increase in their populations (numerical response). These could be increased temperatures that would speed up embryonic development or that the quiescent, non-tidal, closed conditions allow macroinvertebrates to forage or reproduce more effectively, resulting in increased development rates. However, as noted previously, the expected generation times of most prey taxa would not likely be accommodated within the two-week period of this closure. Given these results, we consider the functional redistribution and response of the prey populations upon estuary closure is a more likely explanation than a numerical response. However, return to open conditions after the inlet was naturally or artificially opened could involve both functional and numerical responses. It is likely that some of the decrease in densities, but potential population declines due to mortality factors is also possible. Due to the short interval between sampling events, most of the decrease after the closed conditions is likely attributed to the relative abrupt physiochemical changes, especially for the tubicolous amphipods. For example, it took approximately two weeks for the water level to rise to 7.5 feet during the closure and less than one day to drop back to the normal tidal range. It may be that the more subtle changes that occur after inlet closure allow these tubicolous amphipods to populate the expanded habit but the more drastic changes caused by breaches, especially potential stranding in tubes, may result in mortality from habitat loss. Alternatively, predation reduction of the populations during the closure period could also explain some of these density changes.

Recommendations

Demography and Production of Prey Populations in Response to Estuary Closure

Despite revisions in Sonoma Water and UW/WET study design and sampling protocols that are more adaptive to assessing changes in prey availability with river mouth closure, there is still considerable uncertainty about both the effects of estuary closure on prey populations, the underlying reason for the observed variability in prey responses, and the ability of juvenile steelhead to exploit them. As we have refined our understanding of the natural variability in patterns of juvenile steelhead foraging and prey availability over space and time in the normally open estuary, future monitoring and research would benefit from more concentrated, real time investigations of immediate responses to estuary closures or, conversely, barrier beach breaches reversing back to open estuary conditions. This could include dedicated, "pulse" field investigations during future periods of estuary closure. The purpose of this deeper delving into prey availability would be to address the present uncertainty about the source and consequence of functional or numerical responses of epibenthic prey immigrating or otherwise occupying shallow intertidal habitat with increasing water elevations after the estuary closes.

We are planning on conducting supplemental, closure and post-closure specific prey availability sampling May-July 2018. In addition to the standard sampling locations, this will include epibenthic sled transects at an increased temporal (daily) and spatial resolution, with adding extra transects as the water level increases at the Willow Creek site. There are two main variables that will be drawn from these samples, the timing of prey responses and calculations for the overall amount of prey resources available. The timing of prey responses will provide insight into whether the responses are a functional and a numerical response. Also, the overall prey available will be calculated by summing interpolated densities across the overall area of inundated habitat.

Enhanced Steelhead Diet and Foraging Rate Data Collection

Differences in potential consumption rate, indicated by patterns in the size-specific instantaneous ration in prior years, imply potential reach and estuary status differences in availability among the suite of preferred prey taxa. While the instantaneous ration is a viable index of consumption rate, consideration should be given to conducting periodic diet sampling of juvenile steelhead over a 24-hr or 30-hr period in order to obtain a more precise estimate of daily ration, which is a fundamental measurement for bioenergetic modeling of potential growth. We recognize that this involves periodic sampling during nocturnal hours, which may be unfeasible given Sonoma Water resources. Similarly, consideration should also be given to pulsed fish sampling during a prolonged estuary closure that enables fish samples from all four sites.

4.4 Fish Sampling – Beach Seining

Sonoma Water has been sampling fish in 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 2017, we present and discuss 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, we describe the catch of several common species to help characterize fisheries habitat conditions in the Estuary.

Methods

Study Area

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

Fish Sampling

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

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

From 2004 to 2009, eight seining stations were located throughout the Estuary in a variety of habitats based on substrate type (i.e., mud, sand, and gravel), depth, tidal, and creek tributary influences. Three seine sets adjacent to each other were deployed at each station totaling 24 seine sets per sampling event. Stations were surveyed approximately every 3 weeks from late May through September or October. Total annual seine pulls ranged from 96 to 168 sets.

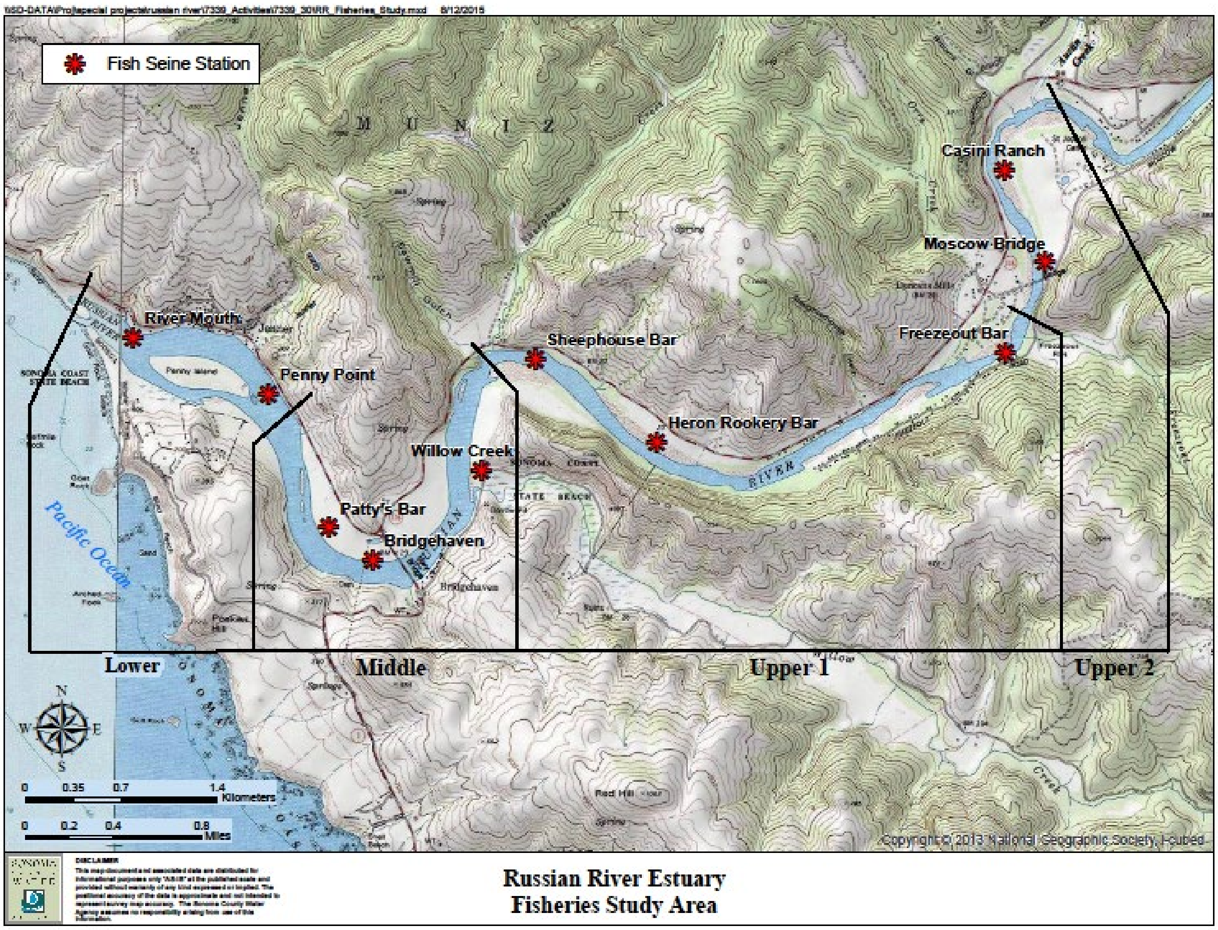


Figure 4.4.1. Russian River Estuary fisheries seining study reaches and sample sites, 2017.

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 2017, four seining events were completed in May, June, late-August, and late-September. Also, in 2014 seining was conducted in October.

For data analysis 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. For the fish seining study, the Upper Reach of the Estuary was divided into Upper1 and Upper2 sub-reaches to improve clarity on fish patterns. Fish seining stations were located in areas that could be sampled during open and closed river mouth conditions. Suitable seining sites are limited during closed mouth conditions due to flooded shorelines.

Catch per unit effort (CPUE), defined as the number of fish captured per seine set (fish/set), was used to compare the relative abundance of fish among Estuary reaches and study years.

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

- Lower Estuary
  - River Mouth (7 seine sets): sandbar separating the Russian River from the Pacific Ocean, sandy substrate with a low to steep slope, high tidal influence.
  - Penny Point (3 seine sets): shallow water with a mud and gravel substrate, high tidal influence.
- Middle Estuary
  - Patty's Bar (3 seine sets): large gravel and sand bar with moderate slope, moderate tidal influence.
  - Bridgehaven (7 seine sets): large gravel and sand bar with moderate to steep slope, moderate tidal influence.
  - Willow Creek (5 seine sets): shallow waters near the confluence with Willow Creek, gravel and mud substrate, aquatic vegetation common, moderate tidal influence.
- Upper Estuary

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

  Upper2 Sub-Reach
  - Moscow Bridge (5 seine sets): steep to moderate gravel/sand/mud bank adjacent to shallow to deep water, aquatic vegetation common, low tidal influence.
  - Casini Ranch (5 seine sets): moderate slope gravel/sand bank adjacent to shallow to deep water, upper end of Estuary at riffle, very low tidal influence.

Results

Fish Distribution and Abundance

Fish captures from seine surveys in the Russian River Estuary for 2017 are summarized in Table 4.4.1. During the 14 years of study 50 fish species were caught in the Estuary. In 2017, seine captures consisted of 19,414 fish comprised of 25 species. California halibut was a new species detected in the Middle Estuary in 2017.

The distribution of fish in the Estuary is, in part, based on a species preference for or tolerance to salinity (Figure 4.4.2). In general, the influence of cold seawater from the ocean

Table 4.4.1. Total fish caught by beach seine in the Russian River Estuary, 2017. Each station was sampled monthly during May, June, and September for a total of 200 seine sets for all sites. Monthly seine sets per station are shown in parentheses.

Life History	Species	River Mouth (7)	Penny Point (3)	Patty's Bar (3)	Bridge-haven (7)	Willow Creek (5)	Sheep-house Bar (5)	Heron Rookery Bar (6)	Freeze-out Bar (4)	Moscow Bridge (5)	Casini Ranch (5)	Total
Anadromous	American shad	1					12	15	54	131	13	226
	Chinook salmon	5	4	4	73		3			2	5	96
	coho salmon	2	18		21		4					45
	steelhead	5		5	2		3	4	2		1	22
Freshwater	black crappie									4		4
	bluegill					2	2		4	186		194
	California roach									4		4
	green sunfish									11		11
	hardhead									4		4
	hitch				2					256		258
	largemouth bass				1			4	42	177	6	230
	Russian River tule perch				5	17	19		5	658		704
	Sacramento pikeminnow	468	1010	282	1633	521	140	6	13	39	33	4145
	Sacramento sucker	9	756	65	2314	147	2892	2850	278	82	68	9461
	smallmouth bass									6	3	9
Estuarine	bay pipefish	1										1
	shiner surfperch	2	2		1							5
	staghorn sculpin	44	37	10	1		1					93
	starry flounder	89	724	111	147	62	60	192	217	23	46	1671
Marine	topsmelt	1			4		1	5				11
	California halibut				2							2
	Pacific herring	150										150
	surf smelt	4										4
Generalist	prickly sculpin	126	36	51	133	22	193	72	16	5		654
	threespine stickleback	32	382	63	257	287	144	31		38		1234
	Total	946	2969	595	4600	1119	3484	3191	701	1628	181	19414

*Prickly Sculpin counts may include small numbers of the freshwater-resident Coast Range sculpin (*Cottus aleuticus*) and riffle sculpin (*Cottus gulosus*), although neither of these species has been reported from the Estuary.

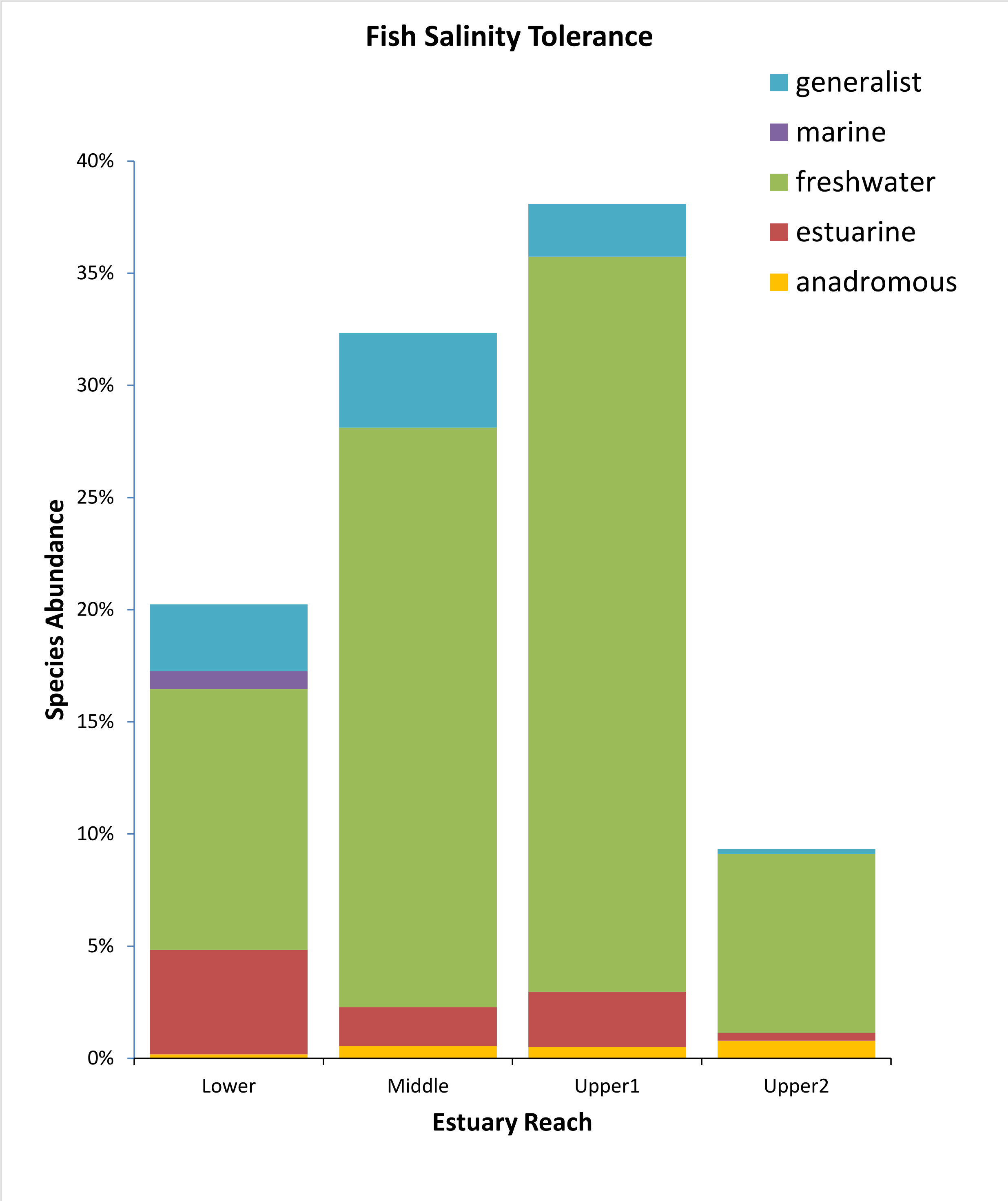


Figure 4.4.2. Distribution of fish in the Russian River Estuary based on salinity tolerance and life history, 2017. Data is from monthly seining during May, June, August, and September. Groups include: generalist species that occur in a broad range of habitats; species that are primarily anadromous; freshwater resident species; brackish-tolerant species that complete their lifecycle in estuaries; and species that are predominantly marine residents.

under open mouth conditions results in high salinity levels and cool temperatures in the Lower Reach transitioning to warmer freshwater in the Upper Reach from river inflows (Figure 4.4.3). The water column is usually stratified with freshwater flowing over the denser seawater.

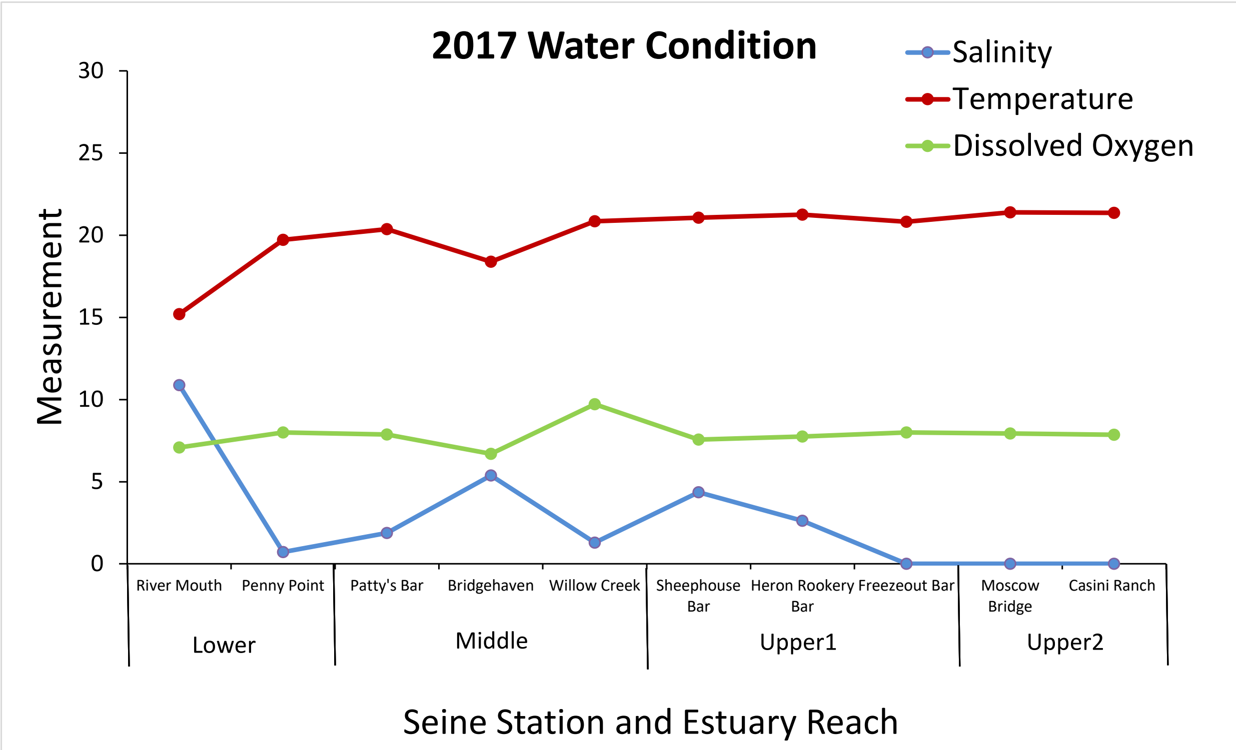


Figure 4.4.3. Generalized water conditions at fish seining stations in the Russian River Estuary, 2017. Values are averages collected at 0.5 m intervals in the water column during beach seining events from May, June, August, and September during primarily open mouth conditions. Water measurements are salinity in parts per thousand (ppt), dissolved oxygen in milligrams per liter (mg/L), and temperature in Celsius (C).

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 2017, a total of 22 steelhead were captured (Table 4.4.1) in 200 seine sets. The resulting CPUE was 0.11 fish/set (Figure 4.4.4). In comparison, during 2016, a total of 33 steelhead were captured in 150 seine sets for a CPUE of 0.22 fish/set. There has been an overall decline in steelhead abundance since 2008 when the CPUE was 1.32 fish/set. All steelhead captured in

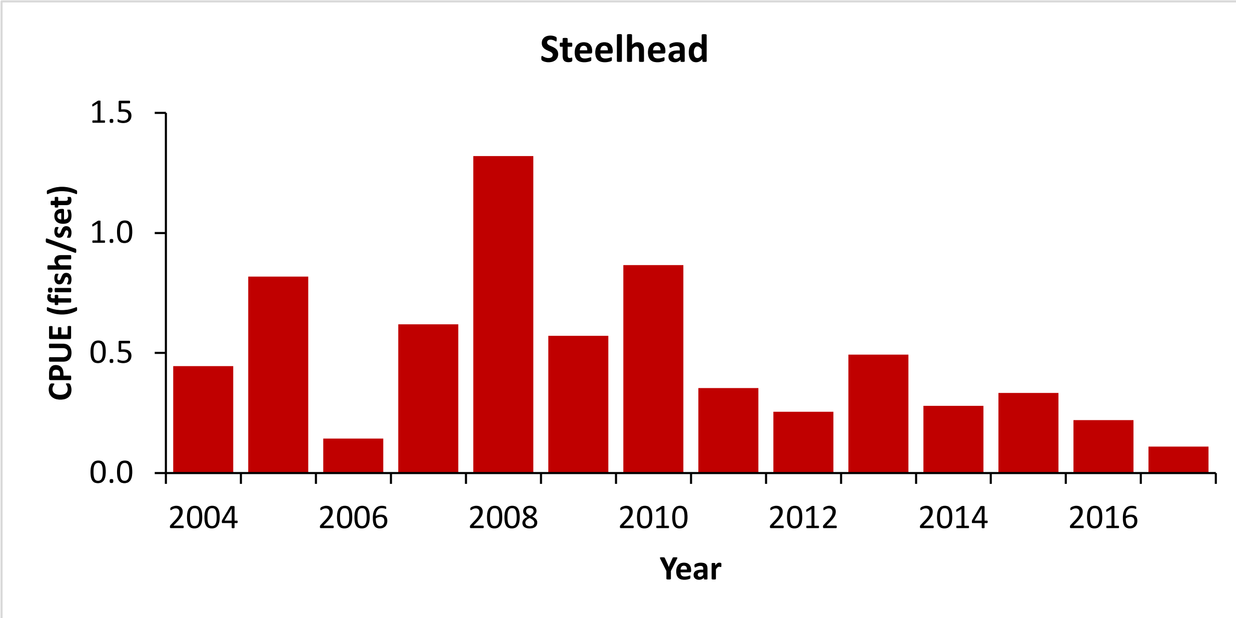


Figure 4.4.4. Annual abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2017. Samples are from 96 to 300 seine sets conducted yearly from May to October.

2017 were wild. The seasonal abundance of steelhead captures varied annually in the Estuary (Figure 4.4.5). Juvenile steelhead were captured during all four survey events in 2017. The highest steelhead abundances are typically in June and August. During 2017, steelhead captures were highest during August at 0.18 fish/set followed by June at 0.12 fish/set. The highest capture abundance among all study years was in August at 4.3 fish/set and June at 4.2 fish/set in 2008. Since seining surveys began in 2004, steelhead appear to have a patchy distribution and vary in abundance in the Estuary (Figure 4.4.6). 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 2017, which limited the temporal and spatial evaluation of steelhead in the Estuary (Figure 4.4.7). The typical pattern observed in previous study years consisted of relatively large numbers of juveniles in the upper Estuary in May and June, these fish found in the middle Estuary in mid-summer, then most steelhead found in the lower Estuary in September. Spring captures are typically parr that are residing in freshwater in the upper Estuary. Then by late summer the steelhead are mainly smolts residing to the brackish water of the lower Estuary. A similar pattern was observed in 2017; however, the largest steelhead were detected in the middle Estuary during August (Figure 4.4.7). Most juvenile steelhead captured in 2017 were age 0+ parr or age 1+ smolts and ranged in size from 32 mm to 295 mm fork length (Figure 4.4.8). One adult hatchery steelhead, fork length 510 mm, was captured in the middle Estuary on August 21, 2017.

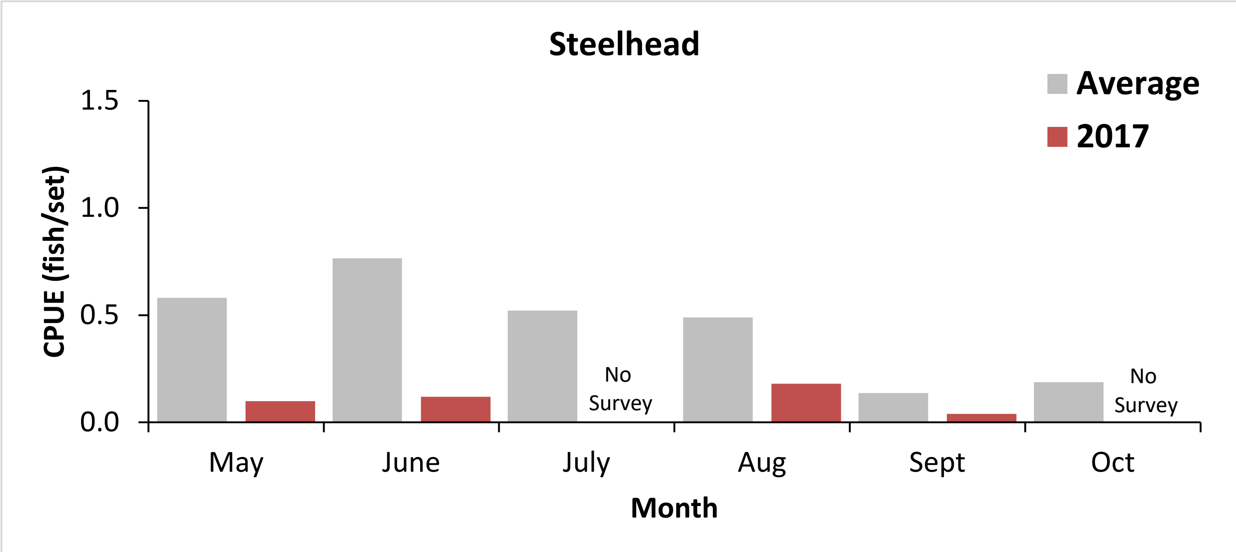


Figure 4.4.5. Seasonal abundance of juvenile steelhead captured by beach seine in the Russian River Estuary, 2004-2017. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010.

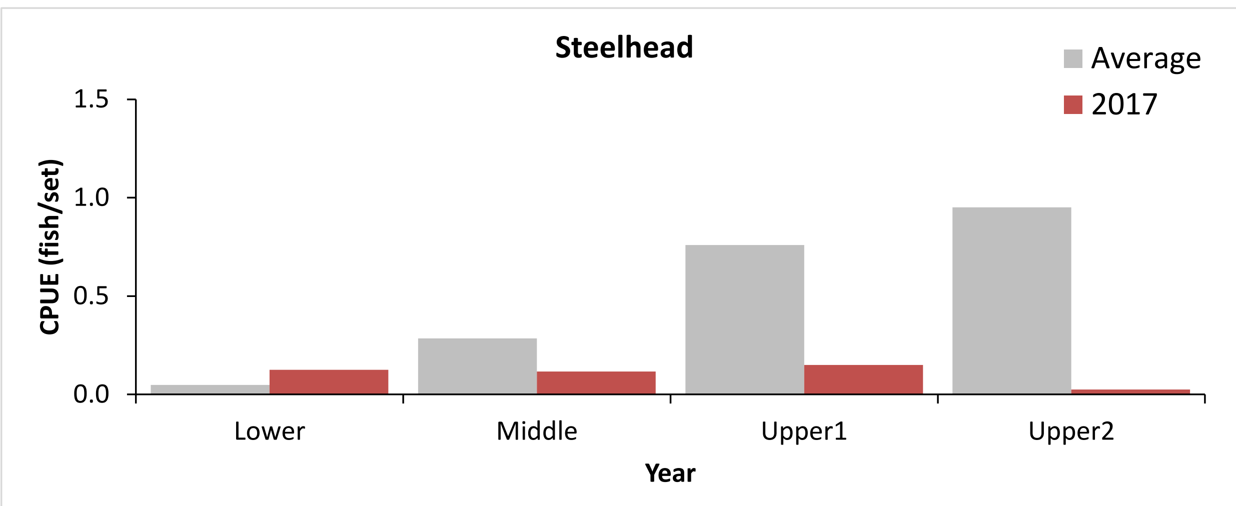


Figure 4.4.6. Distribution of juvenile steelhead in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2015 were averaged.

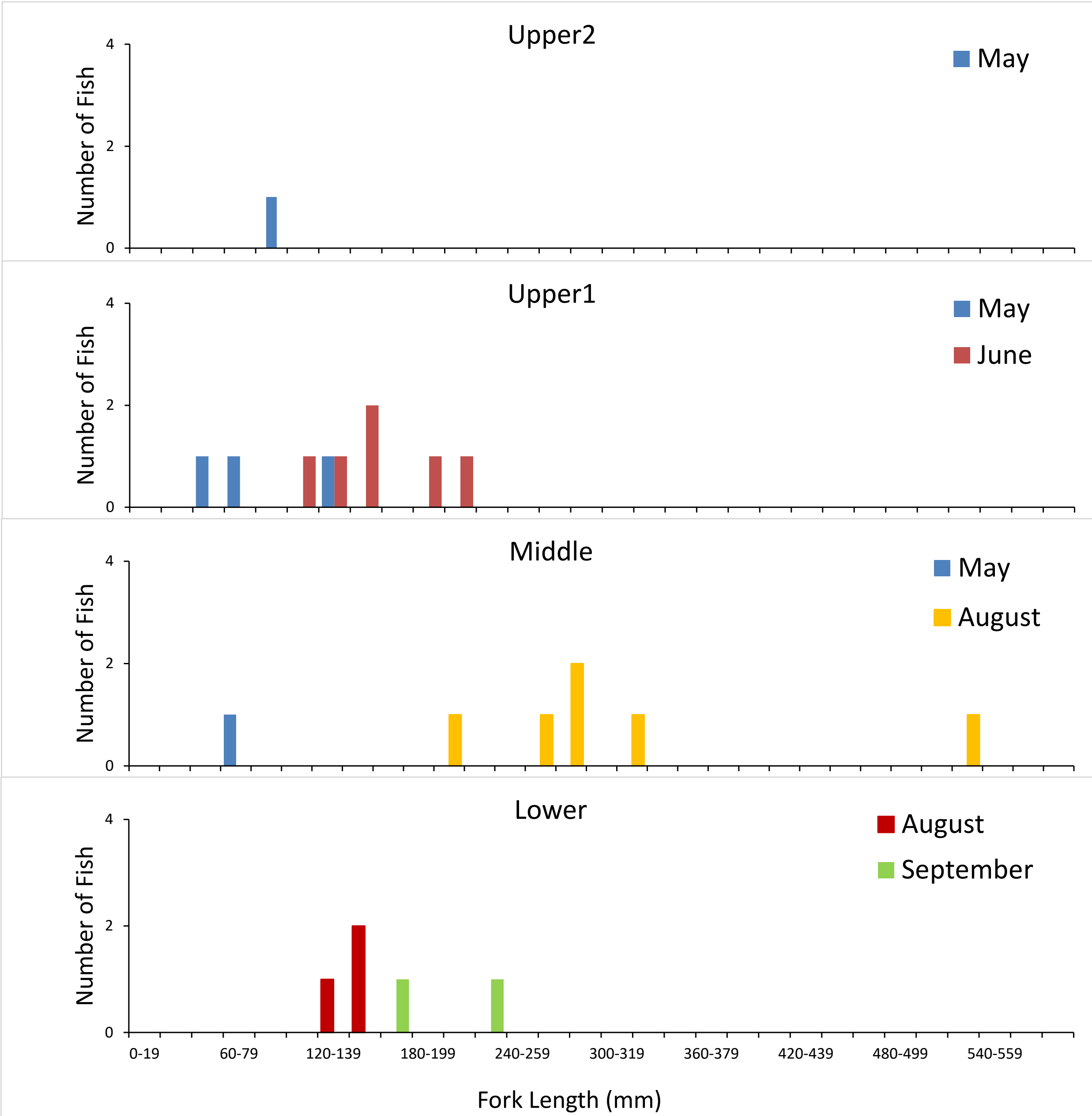


Figure 4.4.7. Length frequency of juvenile steelhead captured by beach seine in the Russian River Estuary, 2017. Fish captures are grouped by Estuary reach and month.

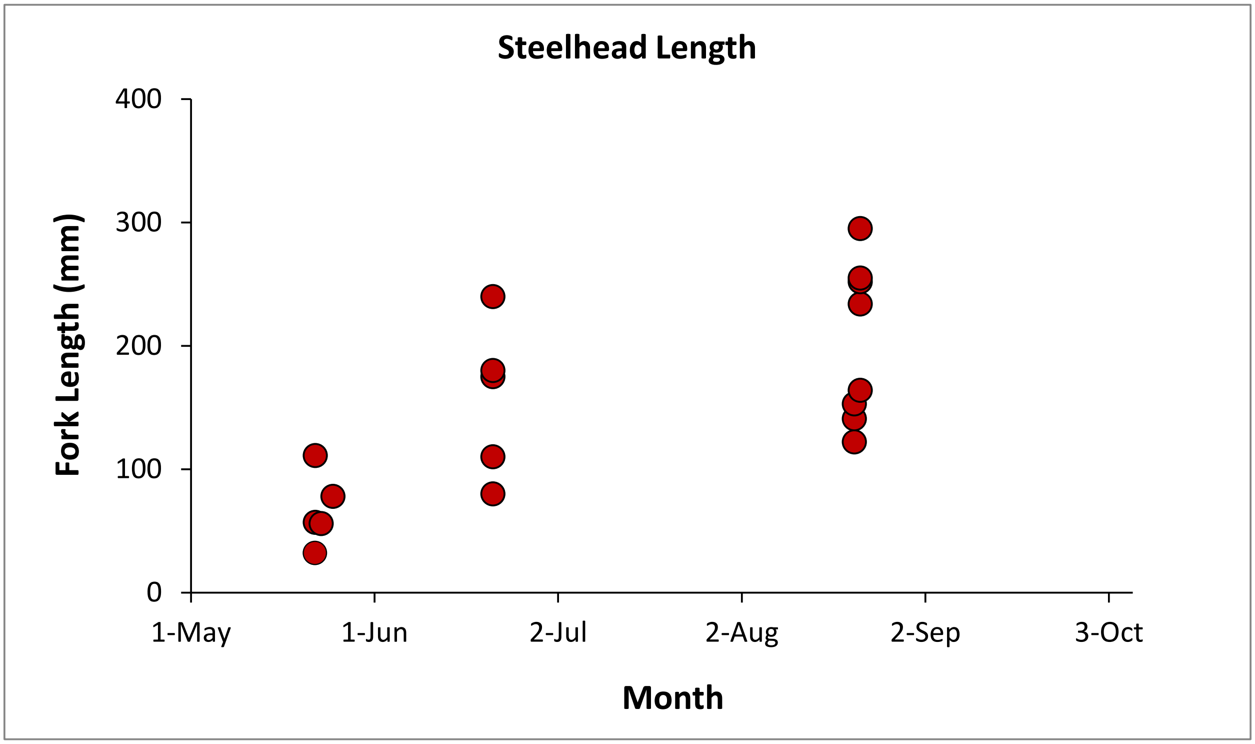


Figure 4.4.8. Juvenile steelhead sizes captured by beach seine in the Russian River Estuary, 2017. One adult hatchery steelhead with a fork length of 510 mm not shown.

In 2017, 12 juvenile steelhead captured during Estuary seining surveys were implanted with PIT tags. In addition, 790 juvenile steelhead where PIT-tagged during downstream migrant trapping studies in the Russian River and tributaries upstream of the Estuary. There were no PIT-tagged steelhead recaptured in the Estuary during 2017 seining.

Chinook Salmon

A total of 96 Chinook salmon smolts were captured by beach seine in the Estuary during 2017 (Table 4.4.1). The abundance of smolts in the Estuary has varied since studies began in 2004 (Figure 4.4.9). The highest abundance of Chinook salmon smolts was in 2008 at 5.2 fish/set. The lowest abundance of Chinook smolts was in 2016 at 0.3 fish/set followed by 0.5 fish/set in 2017. Chinook salmon smolts are usually most abundant during May and June (Figure 4.4.10) and rarely encountered after July. Monthly smolt captures in 2017 were highest during May at 0.9 fish/set. Chinook salmon smolts were distributed throughout the Estuary with captures at most sample stations and reaches annually (Figure 4.4.11).There were 2,582 Chinook smolts PIT-tagged at several downstream migrant trap sites in the Russian River and tributaries during spring 2017. Two of these smolts were recaptured in the Estuary at Bridgehaven seining station on May 25, 2017. One fish was tagged in Dry Creek at Westside Road Bridge on May 10 at a fork length of 79 mm and recapture fork length of 92 mm. The second smolt was tagged in the Russian River at the inflatable dam near Wohler Road Bridge on May 18 at a fork length of 100 mm and recapture fork length of 102 mm. The minimum transit times for these smolts was 15 and 7 days, respectively.

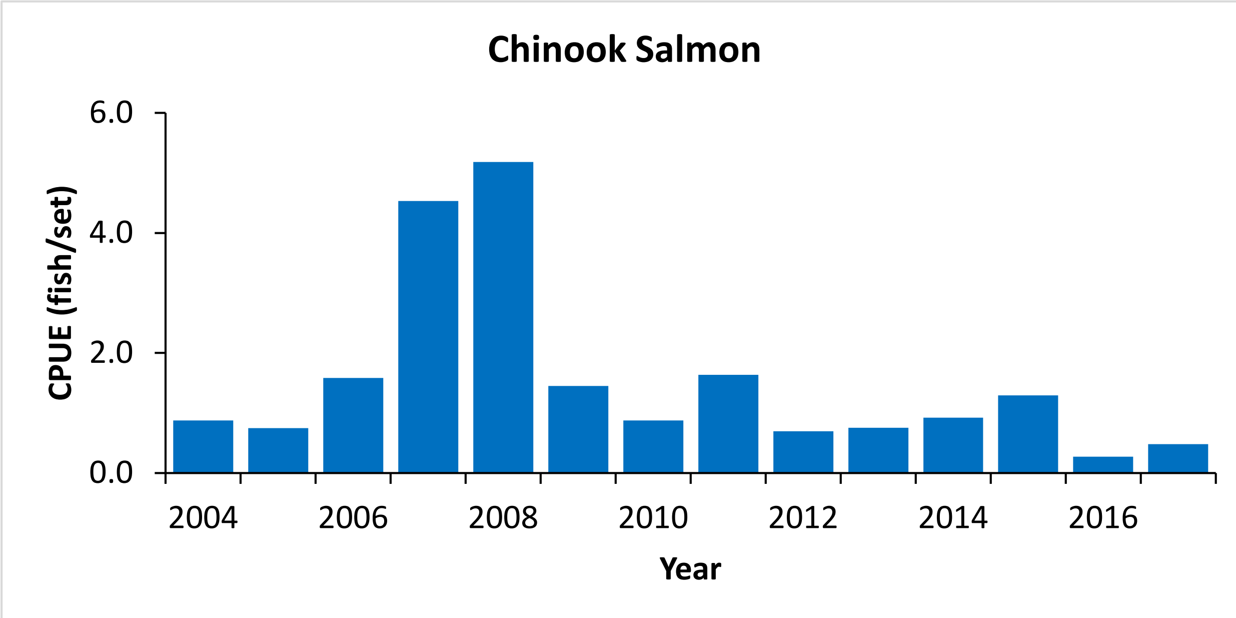


Figure 4.4.9. Annual abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2017. Samples are from 96 to 300 seine sets yearly from May to October.

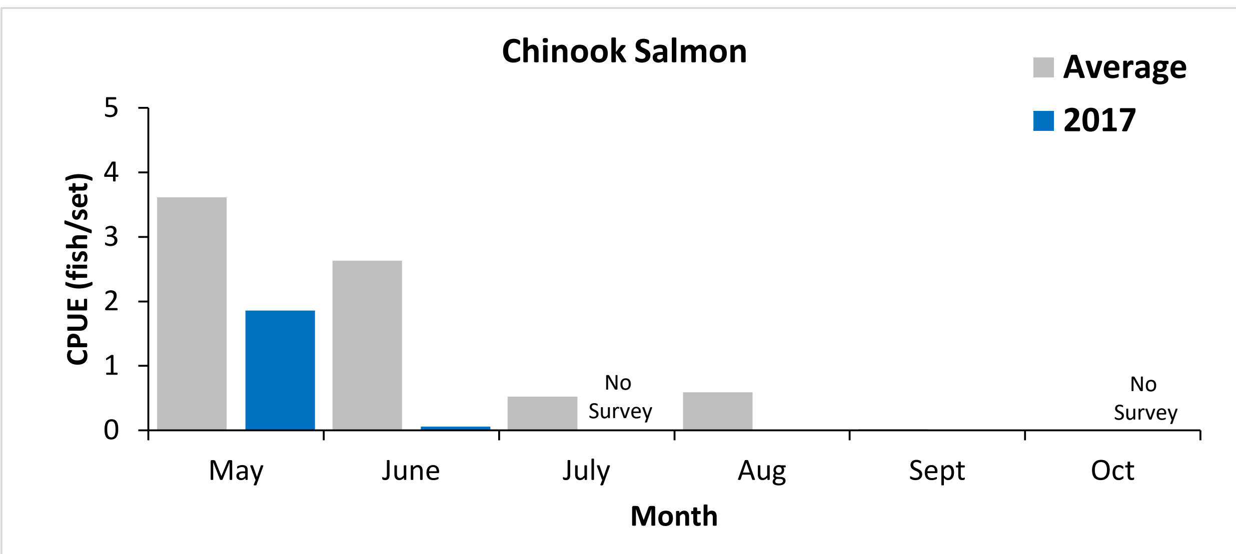


Figure 4.4.10. Seasonal abundance of Chinook salmon smolts captured by beach seine in the Russian River Estuary, 2004-2017. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2015 were averaged.

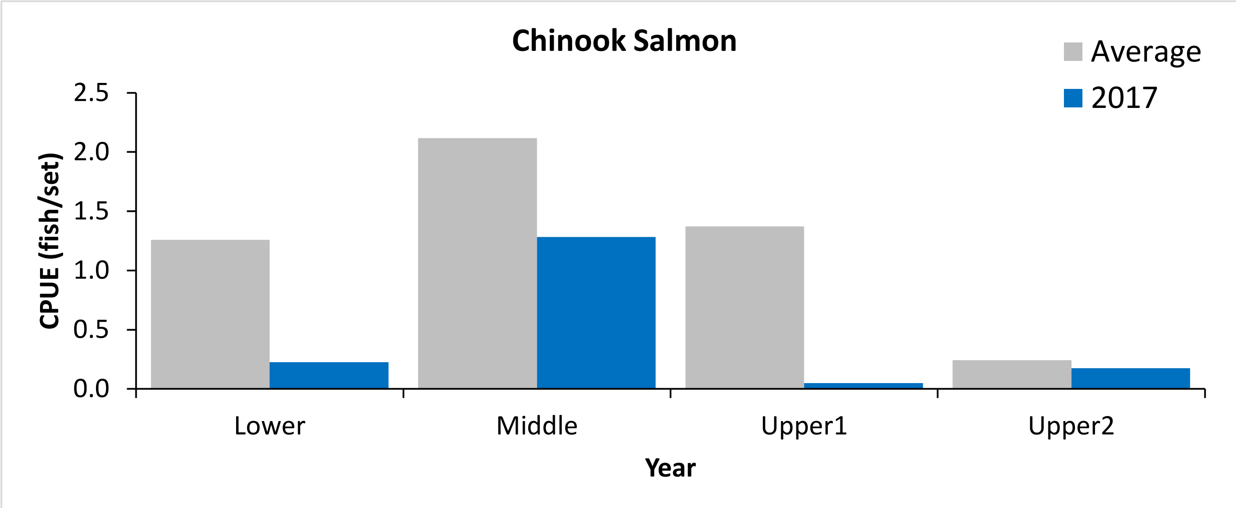


Figure 4.4.11. Spatial distribution of Chinook salmon smolts in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. Data from 2004 to 2015 were averaged. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009.

Coho Salmon

There have been relatively few coho salmon smolts captured in the Estuary during our beach seining surveys (Figure 4.4.12). The first coho salmon smolt captured in the Estuary was a single fish in 2006. In 2011 and 2015 there were marked increases in abundances of coho smolts with a CPUE of 0.9 and 0.7 fish/set, respectively. During 2017 the total capture of coho was 45 smolts, which is the fourth most since first detected in 2006. Two of these smolts were not marked and presumed wild fish. The remaining smolts were hatchery raised. Nearly all coho salmon smolts are captured by June and smolts in 2017 were captured in May (Figure 4.4.13). The spatial distribution of coho smolts has varied annually (Figure 4.4.14). In 2017 coho were captured in all reaches, except Upper2 Sub-Reach.

All hatchery coho are implanted with a coded wire tag and a portion are also implanted with a PIT tag. In 2017 there were 2,249 hatchery coho PIT-tagged. Twelve of these coho were recaptured in the Estuary. The history of these coho are shown in Table 4.4.2. These smolts were initially released or trapped at three tributaries of the Russian River, including Mill (tributary to Dry Creek), Dutch Bill, and Willow creeks. Most transit times from tributaries to the Estuary were 1-3 weeks. One fish stocked in Dutch Bill Creek in October 2017 was captured in the Estuary 7 months later in May 2018. Based on fork length measurements, most coho had low to no growth between detections, suggesting that these fish were not rearing and were migrating to the ocean.

American Shad

American shad is an anadromous sportfish, native to the Atlantic coast. It was introduced to the Sacramento River in 1871 and within two decades was abundant locally and had established populations from Alaska to Mexico (Moyle 2002). Adults spend from 3 to 5 years in the ocean before migrating upstream to spawn in the main channels of rivers. Juveniles spend the first year or two rearing in rivers or estuaries. The abundance of American shad in the Estuary during 2017 was low at 1.1 fish/set (Figure 4.4.15). This low abundance may have been influenced by the reduced seining effort in 2017 where no surveys were conducted during July.

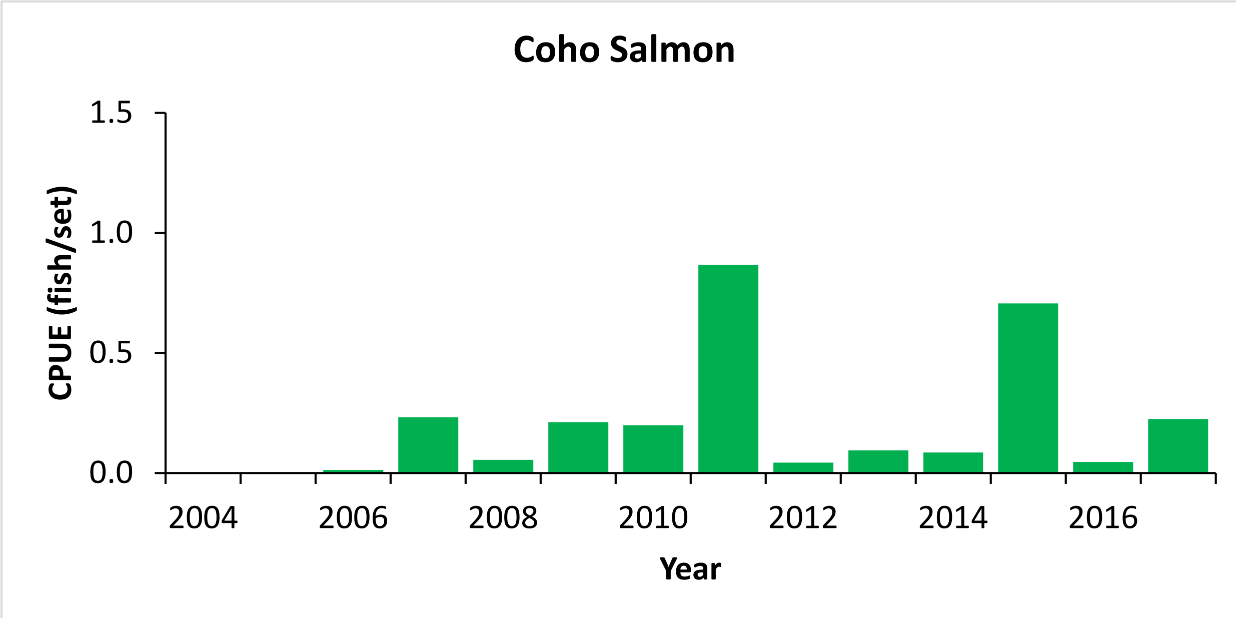


Figure 4.4.12. Annual abundance of coho salmon smolts captured by beach seine in the Russian River Estuary, 2004-2017. Samples are from 96 to 300 seine sets yearly from May to October.

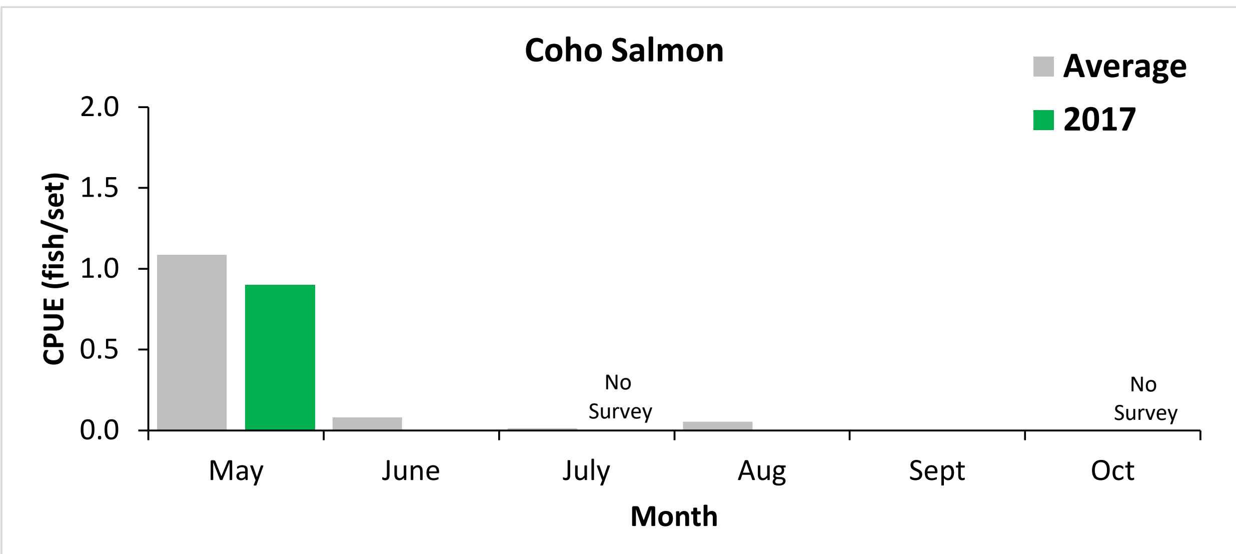


Figure 4.4.13. Seasonal abundance of coho salmon smolts captured by beach seine in the Russian River Estuary, 2004-2017. Seining events consisted of 21 to 50 seine sets approximately monthly. October surveys began in 2010. Data from 2004 to 2015 were averaged.

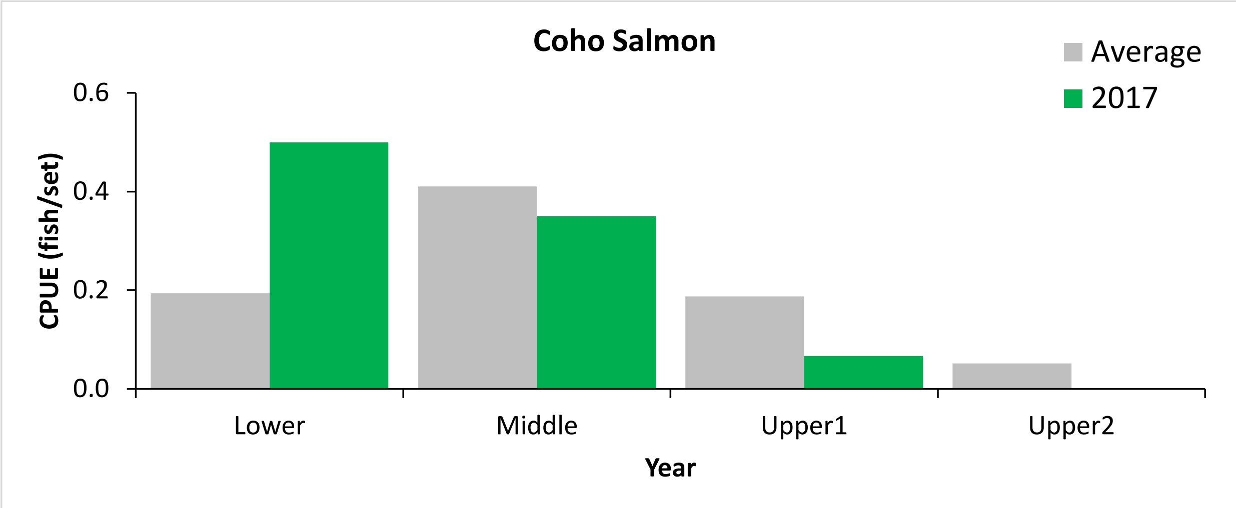


Figure 4.4.14. Spatial distribution of coho salmon smolts in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach (Casini Ranch and Moscow Bridge stations) from 2004 to 2009. Data from 2004 to 2015 were averaged.

Table 4.4.2. Hatchery coho salmon detection sites and seasons captured in the Russian River Estuary in 2017. Coho were either stocked in creeks or captured at downstream migrant traps. Fish are from the coho salmon broodstock program at Warm Springs Fish Hatchery.

PIT Tag	Release/Capture Site	Date	Fork Length (mm)	Estuary Recapture Location	Date	Fork Length (mm)
384.1B796CD274	Mill Creek	May 8	117	Penny Point	May 18	125
3DD.003BF1F828	Dutch Bill Creek	April 18	117	Penny Point	May 18	119
384.1B796CDF1A	Green Valley Creek	May 1	109	Penny Point	May 18	124
3DD.003BF2AC38	Dutch Bill Creek	Oct 8, 2017	86	Sheephouse Bar	May 22	133
384.1B796CDA67	Mill Creek	May 18	108	Sheephouse Bar	May 22	110
3DD.003BF1FF9A	Dutch Bill Creek	May 3	138	Bridgehaven	May 23	136
3DD.003BF2005C	Dutch Bill Creek	May 3	111	Bridgehaven	May 23	113
3DD.003BF2004E	Dutch Bill Creek	May 3	113	Bridgehaven	May 23	115
3DD.003BF1FFDC	Dutch Bill Creek	May 3	116	Bridgehaven	May 23	116
3DD.003BF1FF88	Dutch Bill Creek	May 3	109	Bridgehaven	May 23	109
384.1B796CE087	Willow Creek	May 15	105	Bridgehaven	May 23	107
3DD.003BF1FF45	Dutch Bill Creek	May 3	123	Bridgehaven	May 23	121

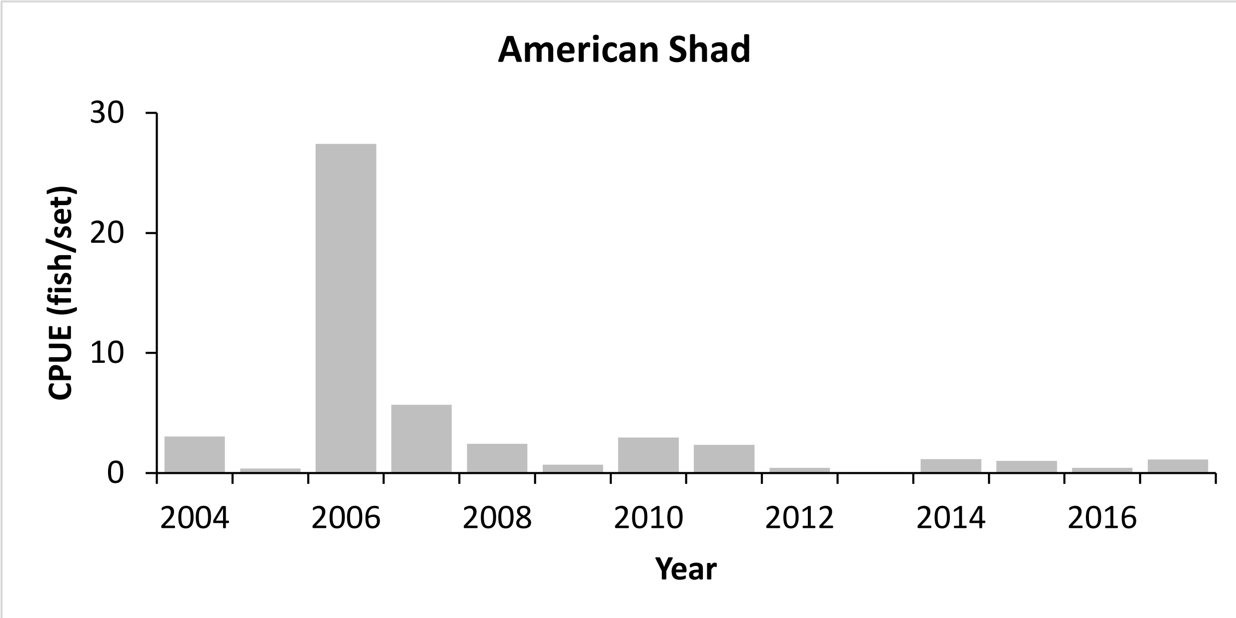


Figure 4.4.15. Annual abundance of juvenile American shad captured by beach seine in the Russian River Estuary, 2004-2017. Samples are from 96 to 300 seine sets yearly from May to October.

Typically, juvenile American shad first appear in relatively large numbers in July and the catch usually peaks in August. Shad are typically distributed throughout the Estuary, although in 2017 they were found mostly in the Upper1 and Upper reaches (Figure 4.4.16).

Topsmelt

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

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

Starry Flounder

Starry flounder range from Japan and Alaska to Santa Barbara in coastal marine and estuarine environments. In California, they are common in bays and estuaries (Moyle 2002). This flatfish is usually found dwelling on muddy or sandy bottoms. Males mature during their second year and females mature at age 3 or 4 (Baxter et al. 1999). Spawning occurs during winter along the coast, often near the mouths of estuaries. Young flounders spend at least their first year rearing in estuaries. They move into estuaries during the spring and generally prefer warm, low-salinity water or freshwater. As young grow, they shift to using brackish waters.

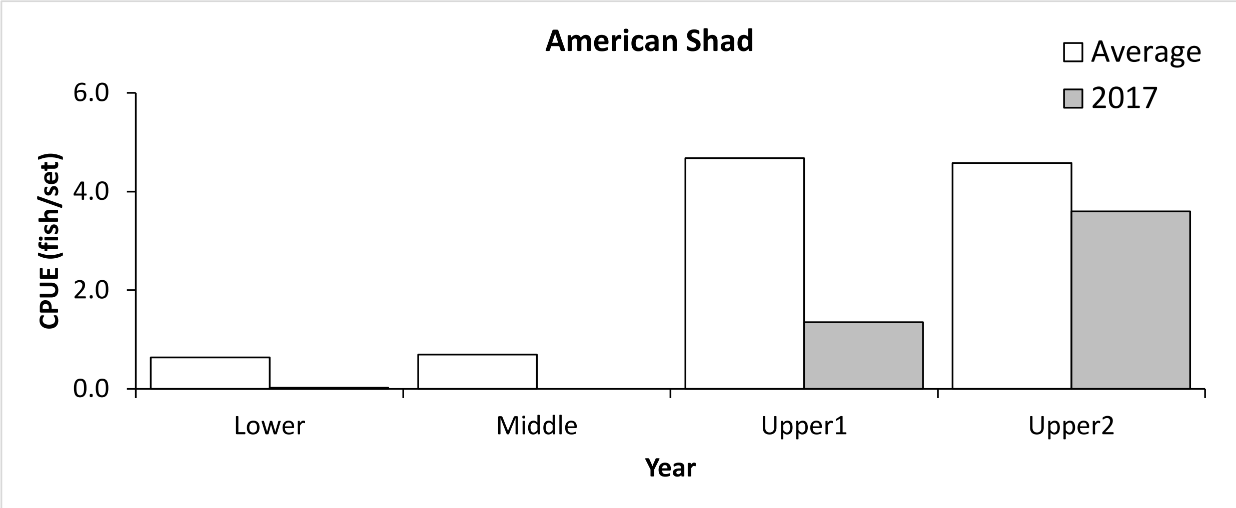


Figure 4.4.16. Spatial distribution of juvenile American shad in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Reach during 2004 and 2009. Data from 2004 to 2015 were averaged. Whiskers indicate minimum and maximum values.

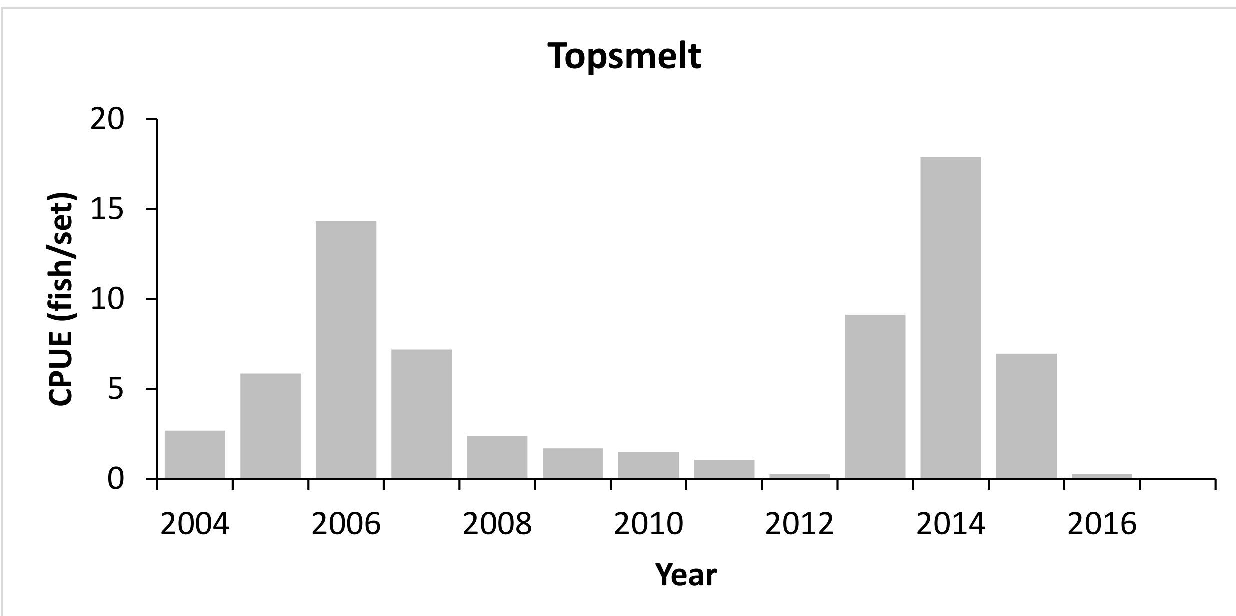


Figure 4.4.17. Annual abundance of topsmelt captured by beach seine in the Russian River Estuary, 2004- 2017. Samples are from 96 to 300 seine sets yearly from May to October.

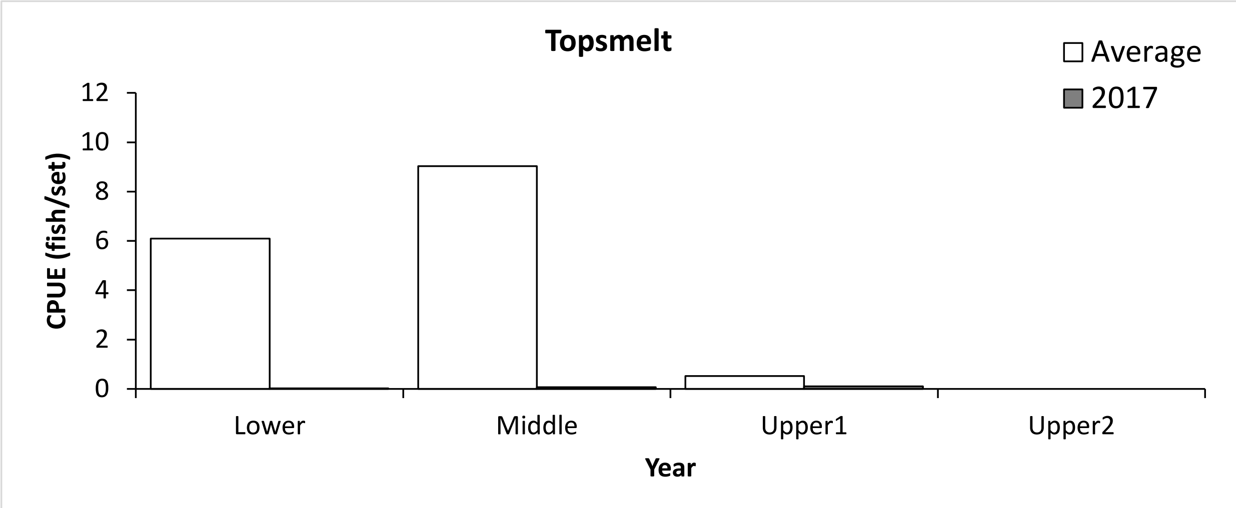


Figure 4.4.18. Spatial distribution of topsmelt in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Reach during 2004 and 2009. Data from 2004 to 2015 were averaged.

The abundance of juvenile starry flounder in the Estuary has varied since studies began in 2004 (Figure 4.4.19). Juvenile flounder were relatively abundant in 2004, 2005 and 2016 with CPUEs greater than 10 fish/set. In 2017 this flounder had the fourth highest abundance at 8.4 fish/set. During the decade period from 2006 to 2015 abundances of flounder were below 2 fish/set. The Estuary appears to be utilized primarily by young-of- the-year fish where most flounder captures are less than 100 mm fork length. The seasonal occurrence of starry flounder was typically highest in May and June, and then gradually decreased through September and October when few were caught. Starry flounder were distributed throughout the Estuary ranging from the River Mouth in the Lower Reach, with cool seawater conditions, to the Upper Reach, with warm freshwater (Figure 4.4.20). Starry flounder have been detected as far as Austin Creek at the upstream end of the Estuary (Cook 2006).

Conclusions and Recommendations

The results of Estuary fish surveys from 2004 to 2017 found a total of 51 fish species from marine, estuarine, and riverine origins. California halibut was a new species detection this year. 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 2017 fish studies contribute to the 14-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.

The fluctuation in abundance of steelhead annually is likely attributed to the variability in 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. A prolonged and severe drought that began in 2013 likely contributed to the low abundance of steelhead and salmon in the Russian River Estuary in 2017. Chinook salmon smolts spent less than half the summer rearing in the Estuary and were usually absent after July. Based on the detection of

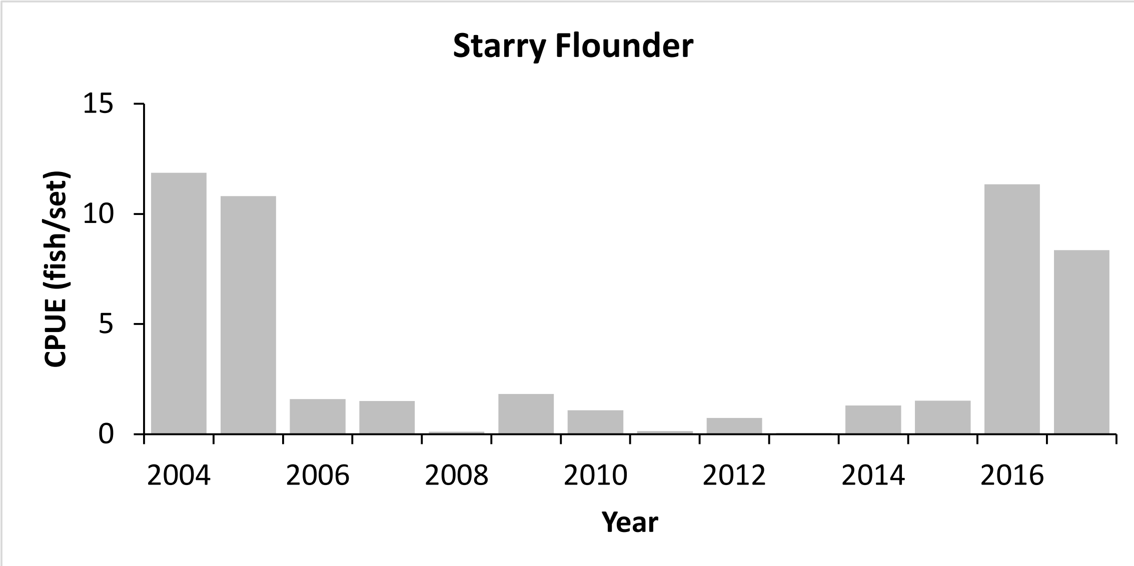


Figure 4.4.19. Annual abundance of juvenile starry flounder captured by beach seine in the Russian River Estuary, 2004-2017. Samples are from 96 to 300 seine sets yearly from May to October.

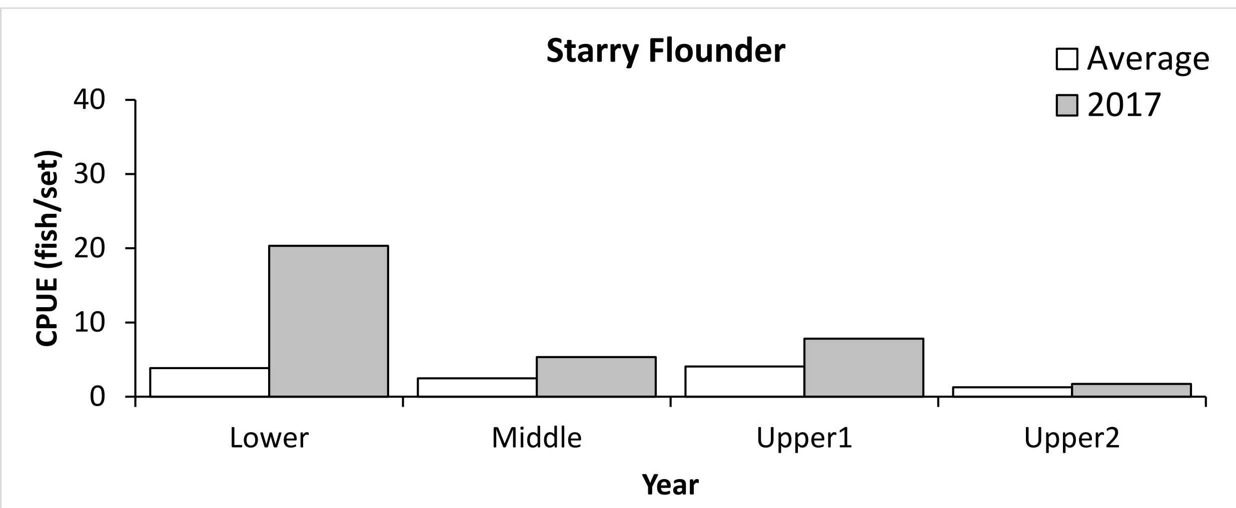


Figure 4.4.20. Spatial distribution of juvenile starry flounder in the Russian River Estuary, 2004-2017. Fish were sampled by beach seine consisting of 96 to 300 sets annually. No surveys were conducted in the Upper2 Sub-Reach during 2004 and 2009. Data from 2004 to 2015 were averaged.

these smolts at most seining stations, they appear to use most estuarine habitats as they migrate to the ocean. In comparison, steelhead were found during the entire summer and were often found in the Upper Reach of the Estuary. However, there are sites in the Middle and Lower Estuary (e.g., Jenner Gulch confluence) where steelhead are consistently found.

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 in the Russian River Biological Opinion requires Sonoma Water to provide information about the timing of downstream movements of juvenile steelhead into the Estuary, their relative abundance and the size/age structure of the population as related to the implementation of an adaptive management approach to beach management during the lagoon management season. 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):

- Dry Creek (capture only)
- Mainstem Russian River at Mirabel (not operated in 2015 or 2016)
- Mark West Creek
- Dutch Bill Creek
- Austin Creek

Stationary PIT antenna arrays were operated in the following locations:

- Mainstem Russian River at Northwood (19.16 rkm)
- Upstream end of the Russian River Estuary in Duncans Mills (10.46 rkm)
- Near the mouth of Austin Creek (0.5 rkm)

Implementation of the monitoring activities described here are the result of a continually-evolving process of evaluating and improving on past monitoring approaches.

Methods

In 2017 we again relied on downstream migrant traps (DSMT) and stationary PIT antenna arrays at lower-Russian River basin trap sites to address the objectives in the RPA. Similar to 2010 through 2016, 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. In the sections that follow, we describe the sampling methods and analyses conducted for data collected at each site.

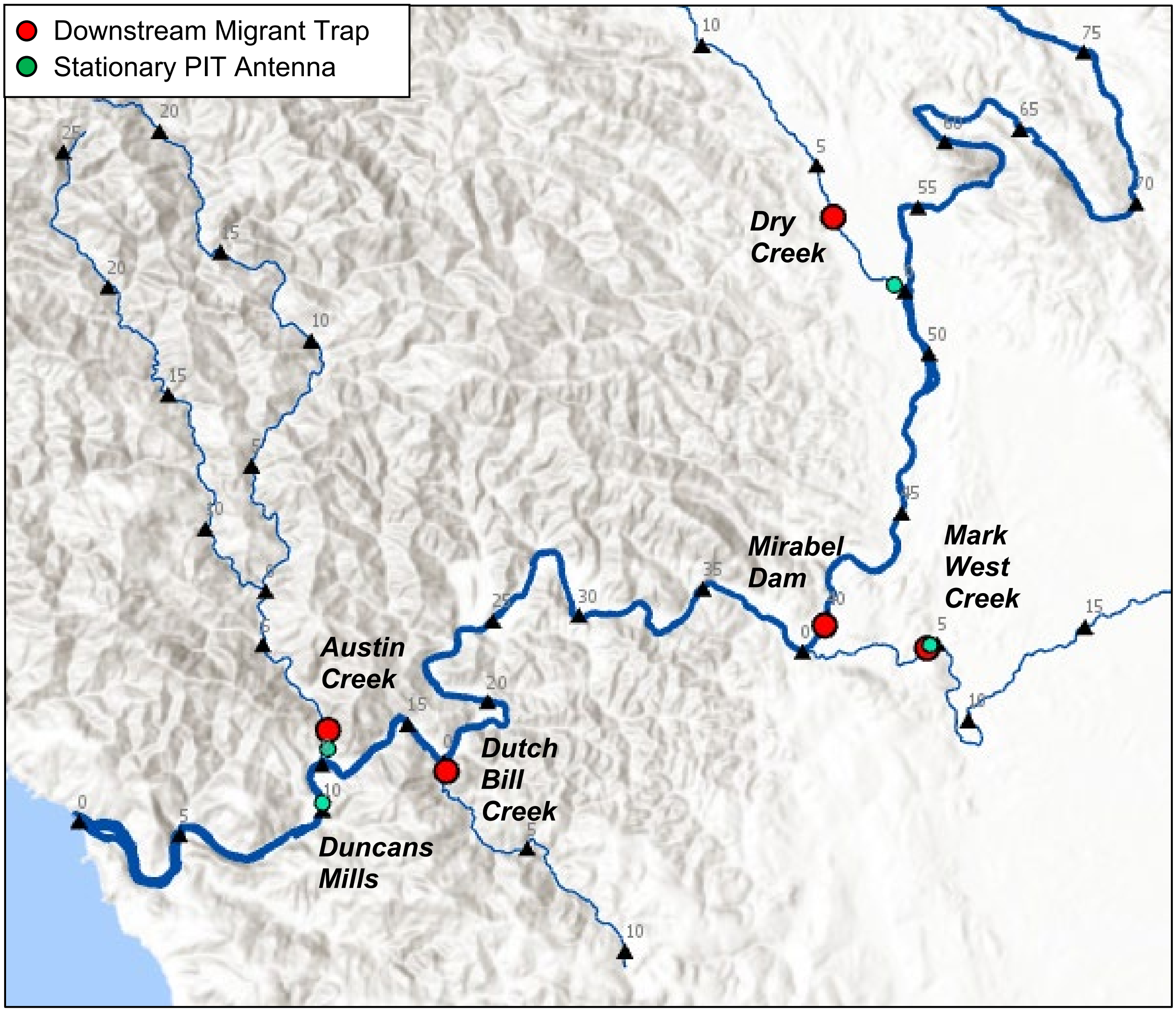


Figure 4.5.1. Downstream migrant detection sites in the lower Russian River, 2017. Numbered symbols along stream courses represent distance (rkm) from the mouth of each stream.

Estuary/Lagoon PIT antenna systems

Two antenna arrays with multiple flat plate antennas (antennas designed to lay flat on the stream bottom) were installed in the upper Russian River estuary near the town of Duncans Mills (river km 10.44, 10.46) to detect PIT-tagged fish entering the estuary (Figure 4.5.2). Generally, 12 antennas were operated continuously throughout the year. The orientation of the antennas consisted of 2 rows of antennas with one row slightly upstream of the other. Each row contained 6 antennas placed side by starting at the West river bank and extending out into the channel. However, these antennas were damaged in the winter of 2017 and not operational until after the end of the 2017 downstream migrant trapping season.

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

Lower River Fish Trapping and PIT tagging

Following consultation with NMFS and CDFW, Sonoma Water identified three lower 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. Sonoma Water operated three types of downstream migrant traps in 2017: 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 the majority of steelhead YOY and parr captured that were ≥60 mm in fork length.

Mark West Creek: Rotary screw trap (fished 4/28-5/24) switched to pipe trap (fished 5/25-6/20).

Dutch Bill Creek: Funnel net (3/30-5/15) switched to a pipe trap (fished 5/16-6/27).

Austin Creek: Rotary screw trap (fished 4/25-5/23) switched to a funnel trap (fished 5/24-6/27).

Figure 4.5.3. Photographs of downstream migrant traps operated by Sonoma Water (Mark West, Dutch Bill and Austin Creeks). See Chapter 5 of this report for details regarding operation of the Dry Creek trap.

Mainstem Russian River at Mirabel

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 Water Agency's inflatable dam site at Mirabel (approximately 38.7 km upstream of the river mouth in Jenner) (Table 4.5.1). Traps were installed on May 17 and removed on June 14.

Dry Creek at Westside Road

Sonoma Water operates a rotary screw trap at Dry Creek. The purpose of which is to fulfill a broader set of objectives in the Russian River Biological Opinion than what is described in the current section of this report.

Mark West Creek

A five foot rotary screw trap was installed on Mark West Creek approximately 4.8 km upstream of the mouth on April 28. On May 24 the rotary screw trap was removed and replaced with a pipe trap because of low water velocities. The pipe trap was removed and all trapping operations were suspended on June 20 when fish captures dropped off rapidly (Table 4.5.1).

Dutch Bill Creek

A pipe trap was installed on Dutch Bill Creek adjacent to the park in downtown Monte Rio (approximately 0.3 km upstream of the creek mouth) on March 30. The funnel net was removed and replaced with a pipe trap on May 15 because of low water velocity. The pipe trap was fished until the completion of trapping operations on June 27 when stream flow in lower Dutch Bill Creek became disconnected (Table 4.5.1).

Austin Creek

A rotary screw trap was installed in Austin Creek on April 25. Due to low water velocity this trap was changed to a funnel trap May 24. The funnel trap consisted of wood-frame/plastic-mesh weir panels, a funnel net and a wooden live box. Trapping continued until July 27 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. A dual PIT antenna array was operated 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 was assumed 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) was used to calculate antenna efficiency for the PIT antenna array located in Austin Creek.

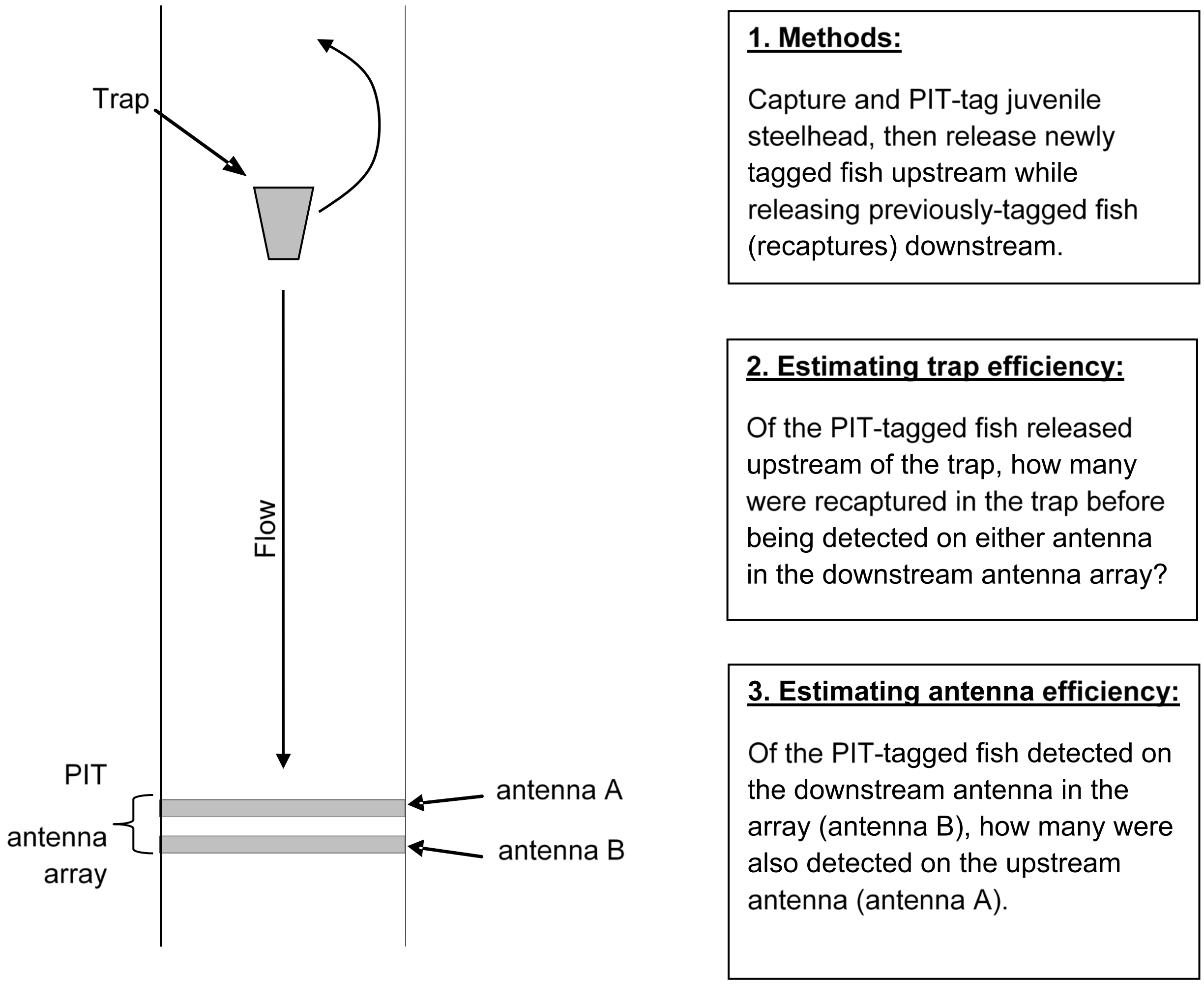


Figure 4.5.4. Diagram illustrating the relative location of the downstream migrant trap and PIT antenna array operated on Austin Creek and outline of how antenna efficiency was estimated.

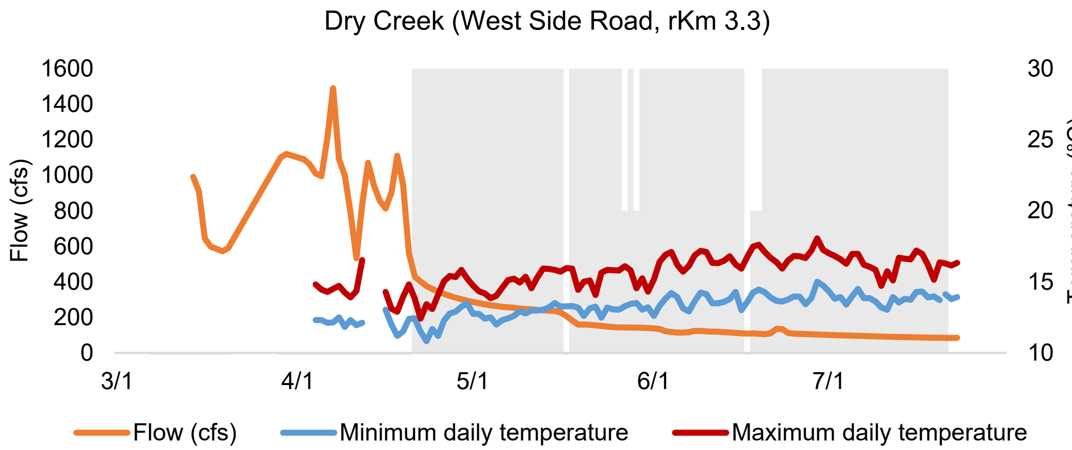
Table 4.5.1. Installation and removal dates, and total number of days fished for lower Russian River monitoring sites operated by Sonoma Water in 2017.

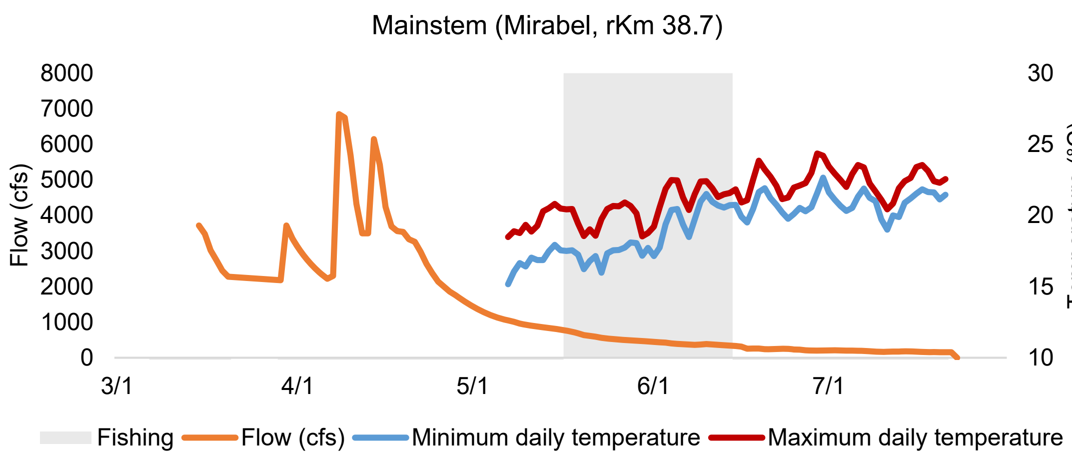
Monitoring site (gear type)	Installation date	Removal date	Number of days fished
Dry Creek (DSMT)	4/21	7/31	97.5
Mirabel (DSMT)	5/17	6/14	29
Mark West Creek (DSMT)	4/28	6/20	50
Northwood (PIT antenna array)	-	-	0
Dutch Bill Creek (DSMT)	3/30	6/27	77.5
Austin Creek (DSMT)	4/25	6/27	63
Duncans Mills (PIT antenna array)[1]	Not operational	Not operational	Not operational

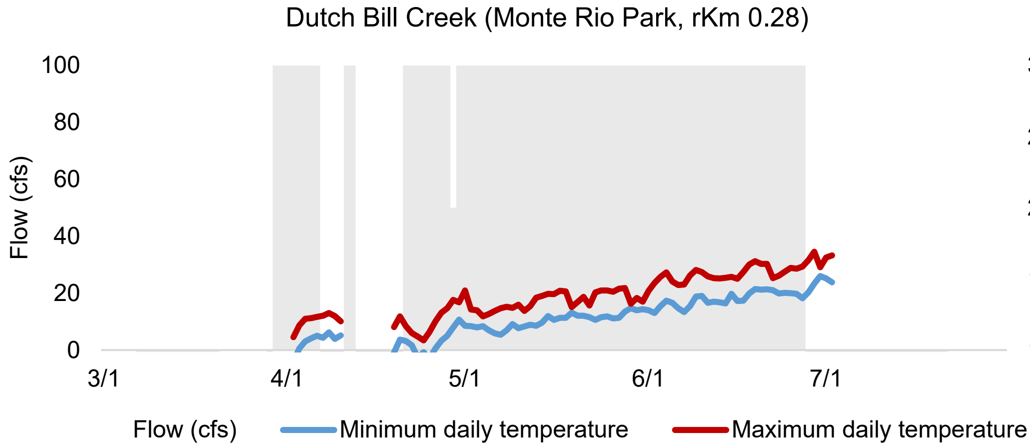
[1]See text for details on changes to PIT antenna array throughout the season.

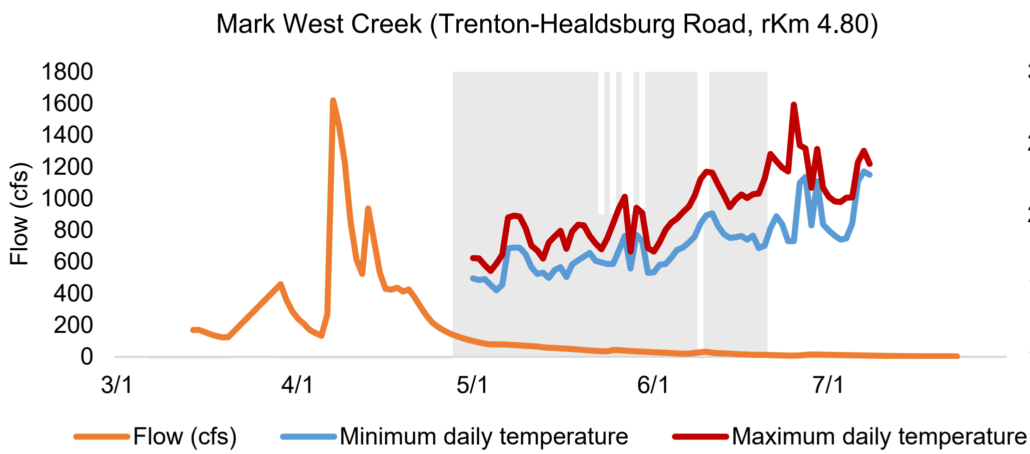
Results

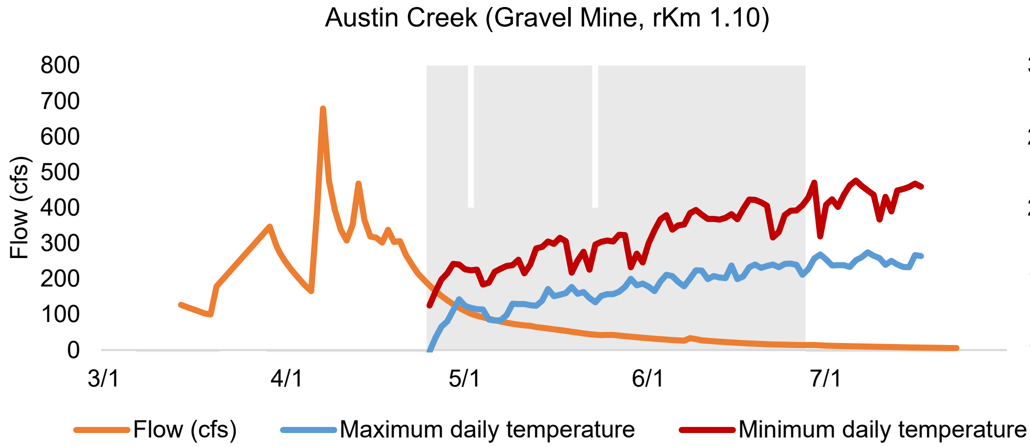
Stream flow largely dictates when downstream migrant traps can be installed (Figure 4.5.5). The sampling period most likely encompassed a high portion of the juvenile steelhead movement period, but a substantial portion of the steelhead smolt migration period may have been missed since it occurs before downstream migrant traps can be safely installed.






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


Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
1800
1600
1400
1200
1000
800
600
400
200
0
Flow (cfs)
30
25
20
15
10
Temperature (°C)
3/1
4/1
5/1
6/1
7/1
Flow (cfs)
Minimum daily temperature
Maximum daily temperature



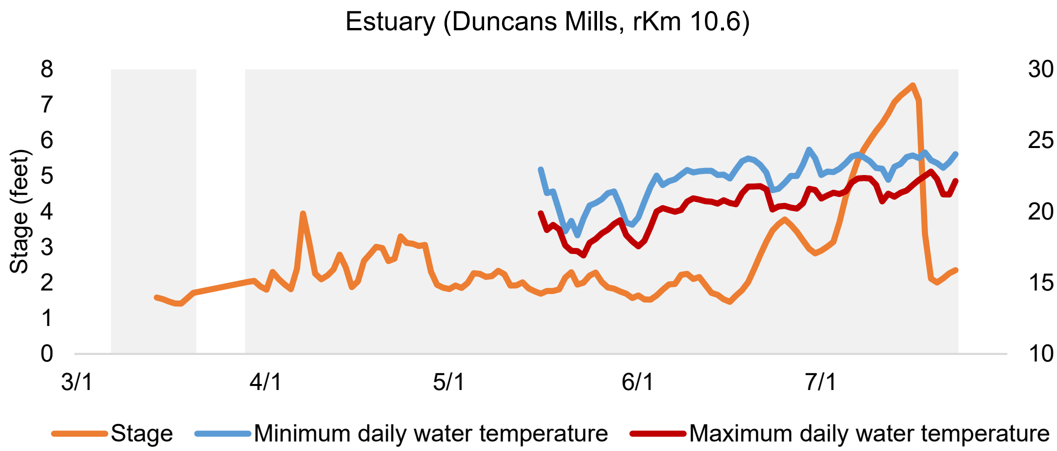


Figure 4.5.5. Environmental conditions at downstream migrant detection sites from March 1 to July 31. Gray shading indicates the proportion of each day that each facility was operated. Discharge data are from the USGS gage at Healdsburg (mainstem Russian, 11464000), the USGS gage at Trenton-Healdsburg Road (Mark West Creek, 11466800), a gage operated by CMAR on Dutch Bill Creek (data unavailable in 2017) and the USGS gauge at Cazadero (Austin Creek, 11467200). Stage data for the estuary are from the Jenner gage. Temperature data are from the data loggers operated by Sonoma Water at each monitoring site.

Steelhead

Steelhead were most frequently encountered at Dry Creek than any other trap. In total 3,966 YOY and parr, and 50 smolts were captured at the Dry Creek trap. In Austin Creek 677 juveniles steelhead were captured while 524 YOY and parr and 6 smolt steelhead were captured in Dutch Bill Creek. At Mark West Creek 141 YOY and parr, and 46 smolts were captured (Figure 4.5.6). Steelhead were not tagged at Dry Creek. At Mirabel, Mark West Creek, Dutch Bill Creek, and at Austin Creek, 1, 49, 377, and 358 steelhead were tagged respectively (Table 4.5.2).

Table 4.5.2. Number of steelhead juveniles PIT-tagged at downstream migrant traps, 2009-2017 (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
Dry Creek	N.T.	N.T.	N.T.	N.T.	2,703	1,348	N.T.	N.T.	N.T.
Mainstem	5	96	99	315	100	101	-	-	1
Mark West Creek	-	-	-	43	135	18	19	546	49
Dutch Bill Creek	-	46	22	6	12	21	7	46	377
Austin Creek	-	996	500	1,636	1,749	590	107	1,205	358
Total	**5**	**1,138**	**621**	**2,000**	**4,699**	**2,078**	**133**	**1,797**	**785**

Many steelhead juveniles were captured in Austin Creek in 2017. Over the course of the season, 677 steelhead were captured of which 469 were YOY (284 of the 469 YOY were ≥60 mm, Figure 4.5.12). Although PIT tags were applied to 358 total individuals (YOY+parr), it is estimated that, based on their size, 247 of these PIT tagged fish were YOY. In total, 244 PIT-tagged steelhead were released upstream of the trap and 2 were released downstream of the trap (Table 4.5.3). Because 80 of the 247 PIT-tagged YOY were detected on the PIT antenna array downstream of the trap in Austin Creek, there is high certainty that at least 32% (80/247) 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 55 PIT tagged individuals (YOY+parr) detected on the downstream antenna in the array (Austin Creek), 52 were also detected on the upstream antenna array (Austin Creek) resulting in an estimated antenna efficiency of 95% (52/55). In order to estimate the number of YOY out of the original 469 that actually moved downstream of the Austin antenna array, this proportion was used to expand the 52 detections to 55 (52/95%).

Of the YOY detected on either the downstream PIT antenna arrays that were also released upstream of the trap, 0 were recaptured in the trap resulting in a trap efficiency of 0%. Based on this trap efficiency it was not possible to expand steelhead YOY captured at the trap to a population estimate.

Table 4.5.3. PIT tag and trap capture metrics and values for 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
Number PIT-tagged YOY released upstream of trap	765	324	1,356	0	214	101	1,132	244
Number PIT-tagged YOY released downstream of trap	195	2	162	1,746	269	6	73	2
Number PIT-tagged YOY detected on antenna array that were tagged in Austin Creek	547	131	574	1,335	275	13	193	80
Number PIT-tagged YOY released upstream & detected on antenna array	389	131	486	0	57	13	151	80
Number released upstream & recaptured in trap & detected on antenna	47	8	196	0	2	0	60	0
ESTIMATED TRAP EFFICIENCY	**12.1%**	**6.1%**	**40.3%**	**N/A**	**N/A**	**N/A**	**39.7%**	**N/A**
Number YOY+parr detected on both antennas in array	241	93	85	399	129	34	76	52
Number YOY+parr detected on downstream antenna only	288	178	129	463	162	35	205	55
ESTIMATED ANTENNA EFFICIENCY	**83.6%**	**52.2%**	**65.9%**[1]	**86.2%**[1]	**79.6%**[1]	**97.1%**	**37.1%**[1]	**94.5%**
Number YOY captured and PIT-tagged	960	324	1,518	1,746	483	42	993	319
Total number of YOY captured (≥60 mm only)	2,617	453	2,341	4,216	541	42	2,427	319
ESTIMATED NUMBER OF PIT-TAGGED YOY EMIGRANTS (≥60 mm only)	**632**	**251**	**759**	**1,549**	**325**	**32**	**520**	**55**
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%**
ESTIMATED POPULATION SIZE OF YOY AT TRAP	**21,628**	**7,426**	**5,804**	**N/A**	**N/A**	**N/A**	**6,113**	**N/A**
ESTIMATED NUMBER OF YOY IN POPULATION THAT EMIGRATED	**14,231**	**5,755**	**2,901**	**N/A**	**N/A**	**N/A**	**2,812**	**N/A**

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

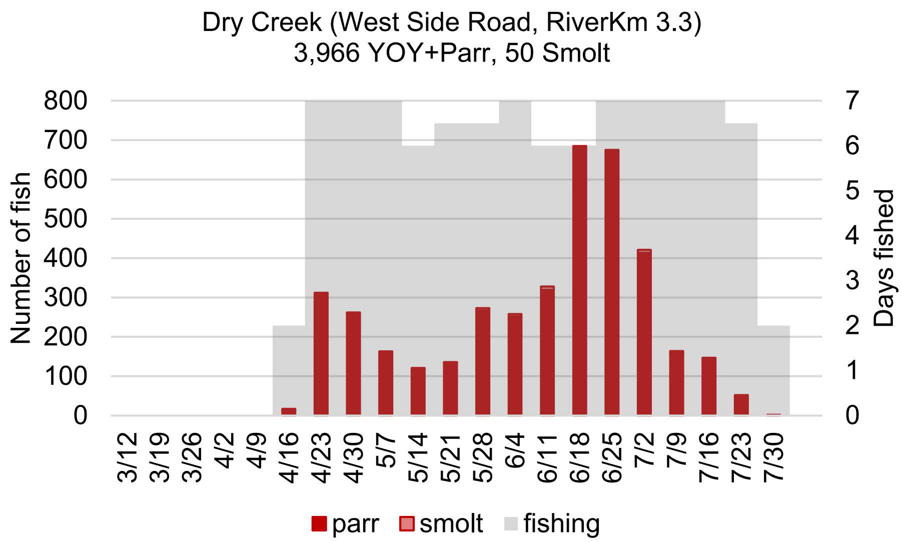
When compared to Austin and Dry creeks fewer numbers of juvenile steelhead were captured at the mainstem Russian River, Mark West and Dutch Bill creeks (Figure 4.5.6), meaning that fewer numbers of juvenile steelhead were PIT-tagged at these locations (Table 4.5.2). Fork lengths of fish caught at these traps show at least 3 year classes with steelhead YOY present at each of the trapping locations (Figure 4.5.7). As in other years, it is assume that the few steelhead smolts captured at any of the trap sites was likely due to a large portion of the smolt outmigration occurring before trap installation and the generally low trap efficiencies for steelhead smolts that is well-documented in the Russian River and elsewhere. The season total catches of steelhead have been variable over the course of this study (Figure 4.5.8 through Figure 4.5.12).

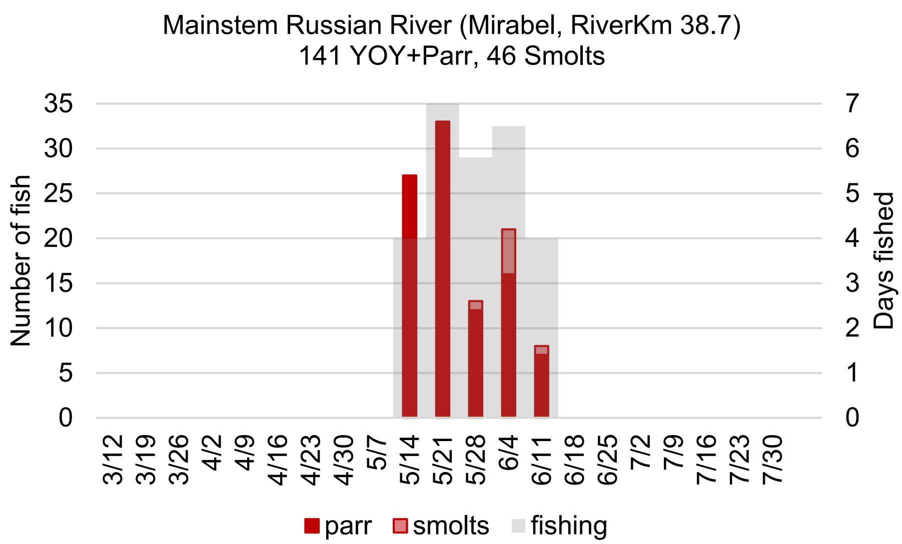
Coho Salmon

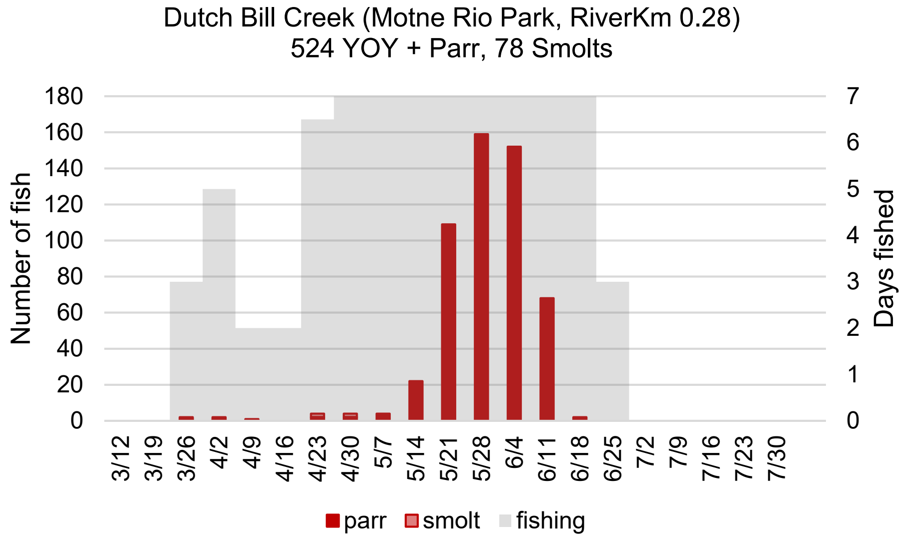
At Dry Creek 301 hatchery smolts, 35 wild smolts, and 2 smolts of unknown origin were detected at the trap (Figure 4.5.8 and Figure 4.5.13). At Mark West Creek, 1,065 hatchery smolts, 44 smolts of unknown origin, and 17 wild smolts were detected at the trap (Figure 4.5.10 and Figure 4.5.13). A total of 3,516 hatchery smolts, 11 smolt of unknown origin, and 151 wild smolts were captured at the Dutch Bill Creek trap (Figure 4.5.11 and Figure 4.5.13). At Austin Creek, 116 hatchery smolts, 1 smolt of unknown origin, 26 wild smolts, and 5 wild YOY/parr were captured (Figure 4.5.12 and Figure 4.5.13). At the Mirabel trap on the mainstem Russian River 4 hatchery smolts of unknown origin, 28 wild smolts, and 1 wild YOY/parr were captured at the trap (Figure 4.5.9 and Figure 4.5.13). Based on length data collected at the lower river traps, there were at least two age groups (YOY: age-0 and parr/smolt: ≥age-1) of coho captured (Figure 4.5.14). For a more detailed analysis of downstream migrant trapping catches of coho from other Russian River streams see California Sea Grant (CSG) Coho Salmon Monitoring Program results for spring 2017 (CSG 2017).

Chinook Salmon

Relative to steelhead and coho, few Chinook smolts were captured at the mainstem Russian River, Austin Creek, Dutch Bill Creek, and Mark West Creek traps in 2017 (632, 238, 2 and 0, respectively). While the number of Chinook captured at Austin Creek, Dutch Bill Creek, and Mark West Creek traps is typically low, the number of Chinook smolts captured on the mainstem Russian River is typically much higher (Figure 4.5.15). Chinook were captured every week that the trap was operated in 2017 (Figure 4.5.16). Fork lengths of Chinook salmon ranged from 60 mm to over 120 mm (Figure 4.5.17). Because of the low number of Chinook smolts captured it was not possible to construct a population estimate for the mainstem Russian River in 2017. For more details on characteristics of Chinook smolts captured at Dry Creek see Chapter 5 of this report.


Dry Creek (West Side Road, RiverKm 3.3)
3,966 YOY+Parr, 50 Smolt
Number of fish
Days fished
800
700
600
500
400
300
200
100
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
7/30
parr
smolt
fishing


Mainstem Russian River (Mirabel, RiverKm 38.7)
141 YOY+Parr, 46 Smolts
Number of fish
Days fished
35
30
25
20
15
10
5
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
7/30
parr
smolts
fishing



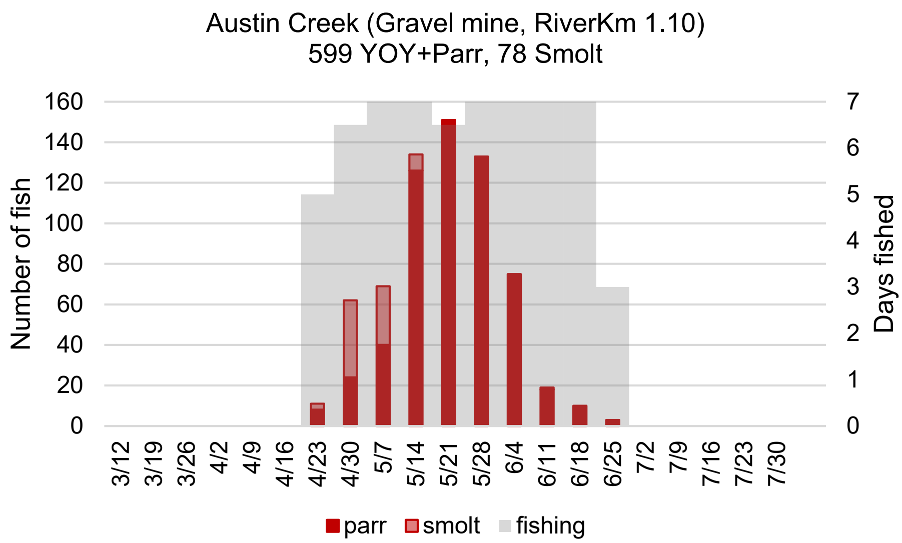
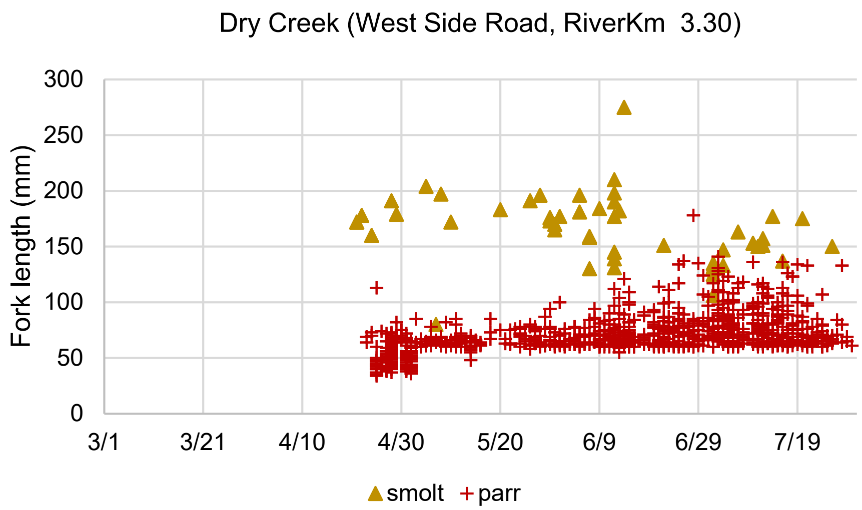
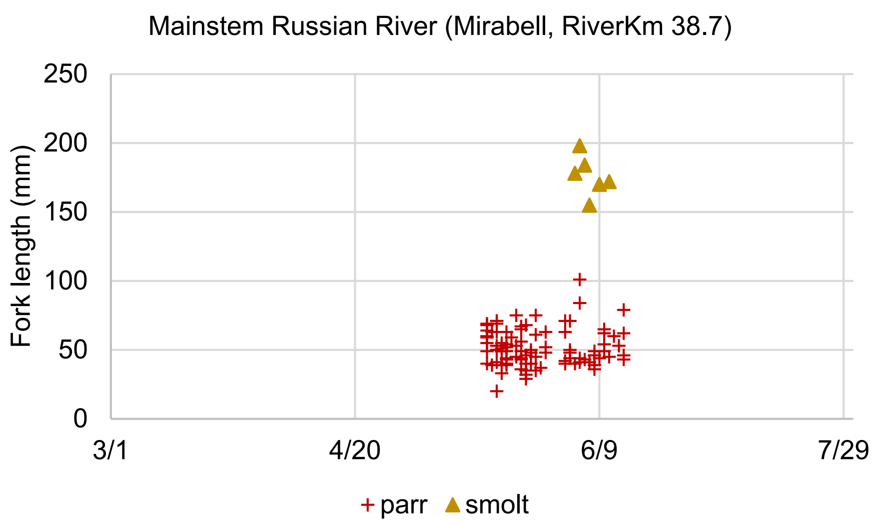
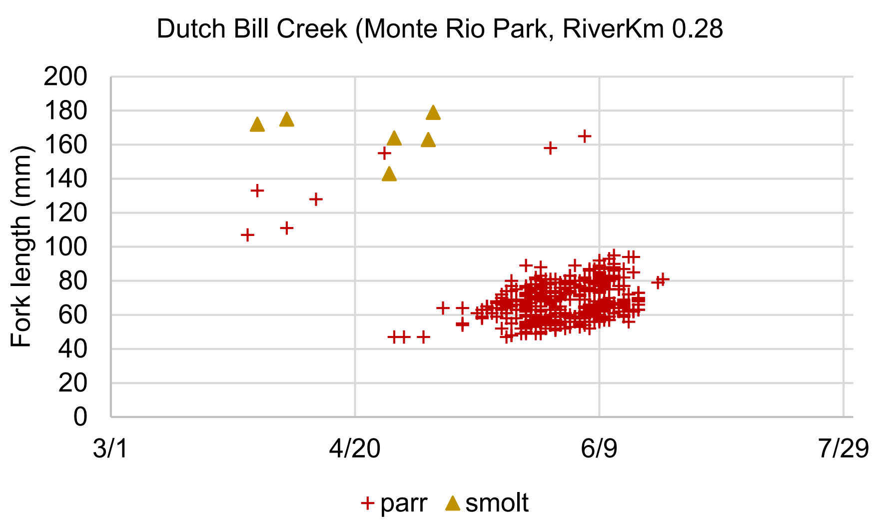


Figure 4.5.6. Weekly capture of steelhead by life stage at lower Russian River downstream migrant trapping sites, 2017. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.


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


Mainstem Russian River (Mirabell, RiverKm 38.7)
250
200
150
100
50
0
Fork length (mm)
3/1
4/20
6/9
7/29
parr
smolt


Dutch Bill Creek (Monte Rio Park, RiverKm 0.28
200
180
160
140
120
100
80
60
40
20
0
Fork length (mm)
3/1
4/20
6/9
7/29
parr
smolt

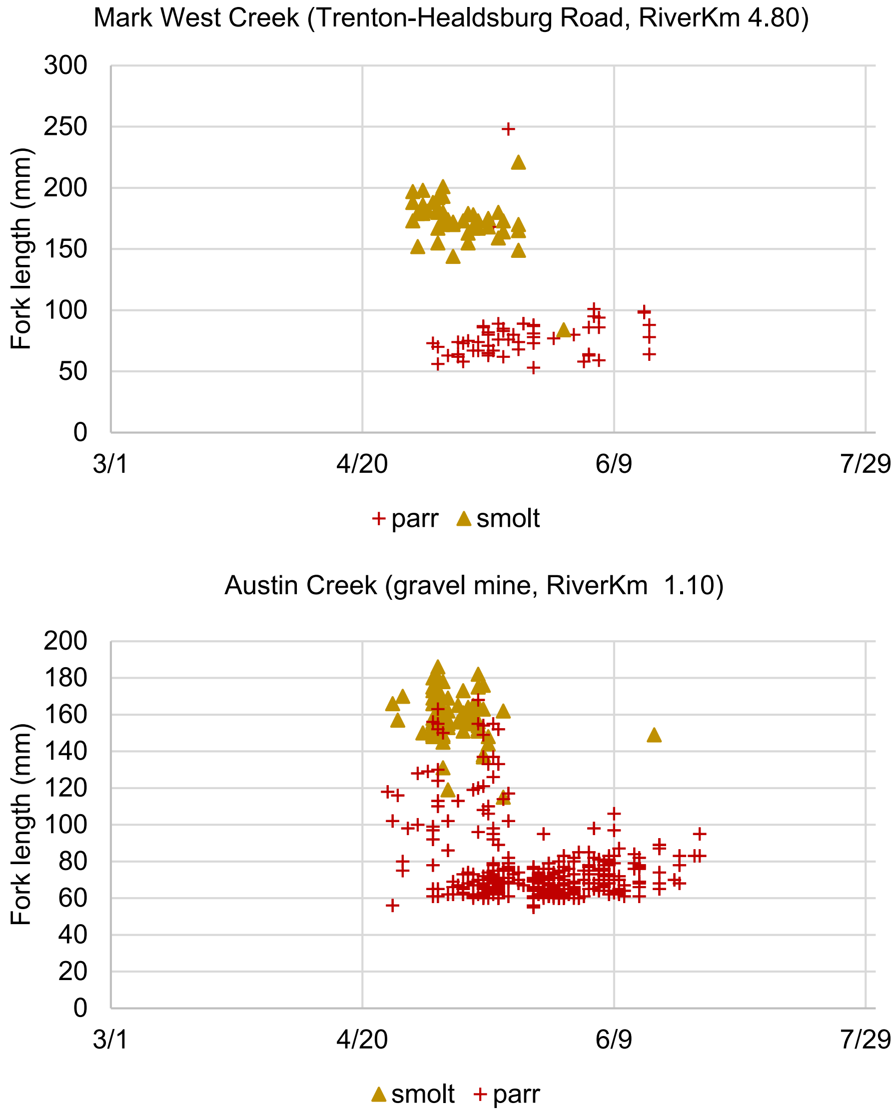
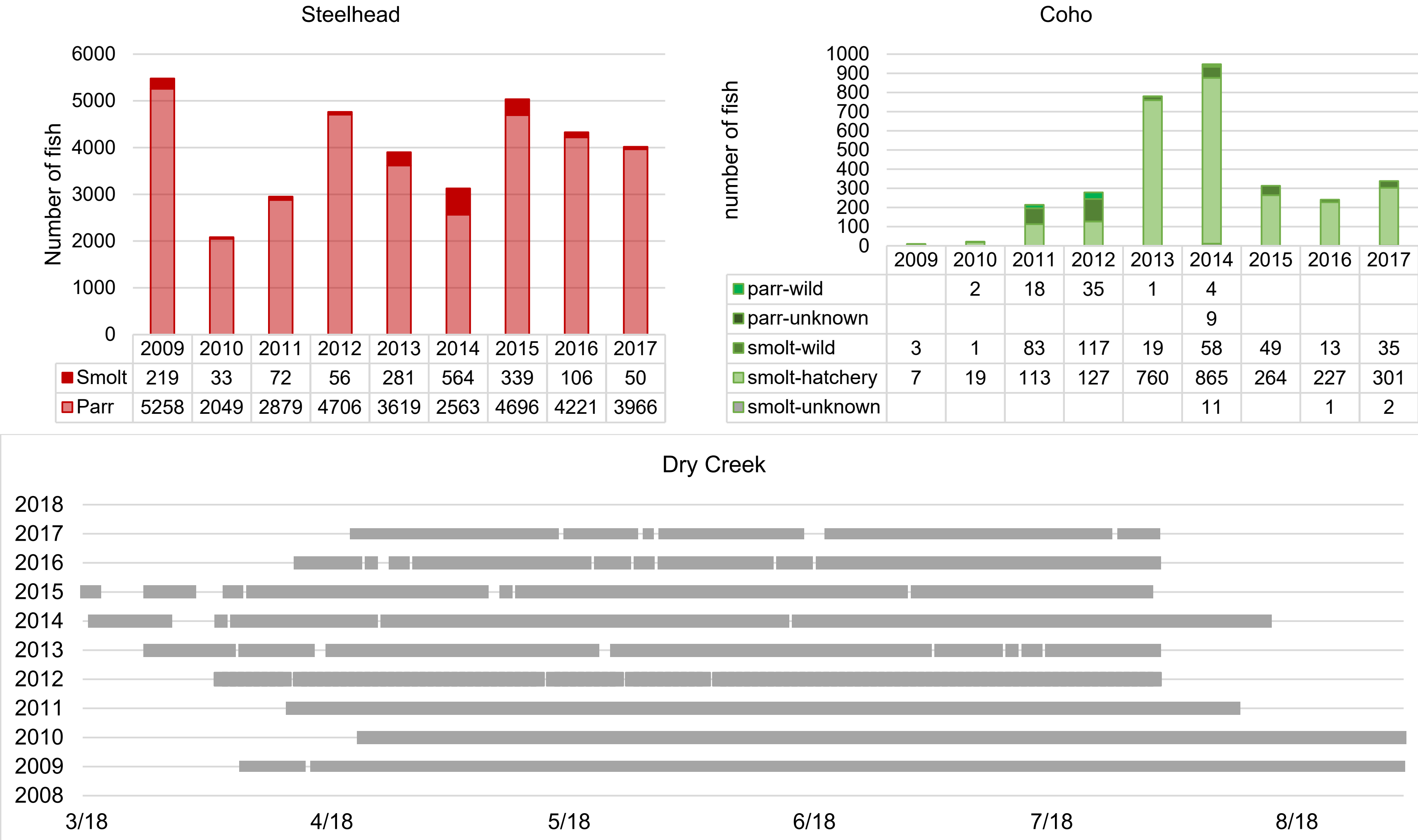


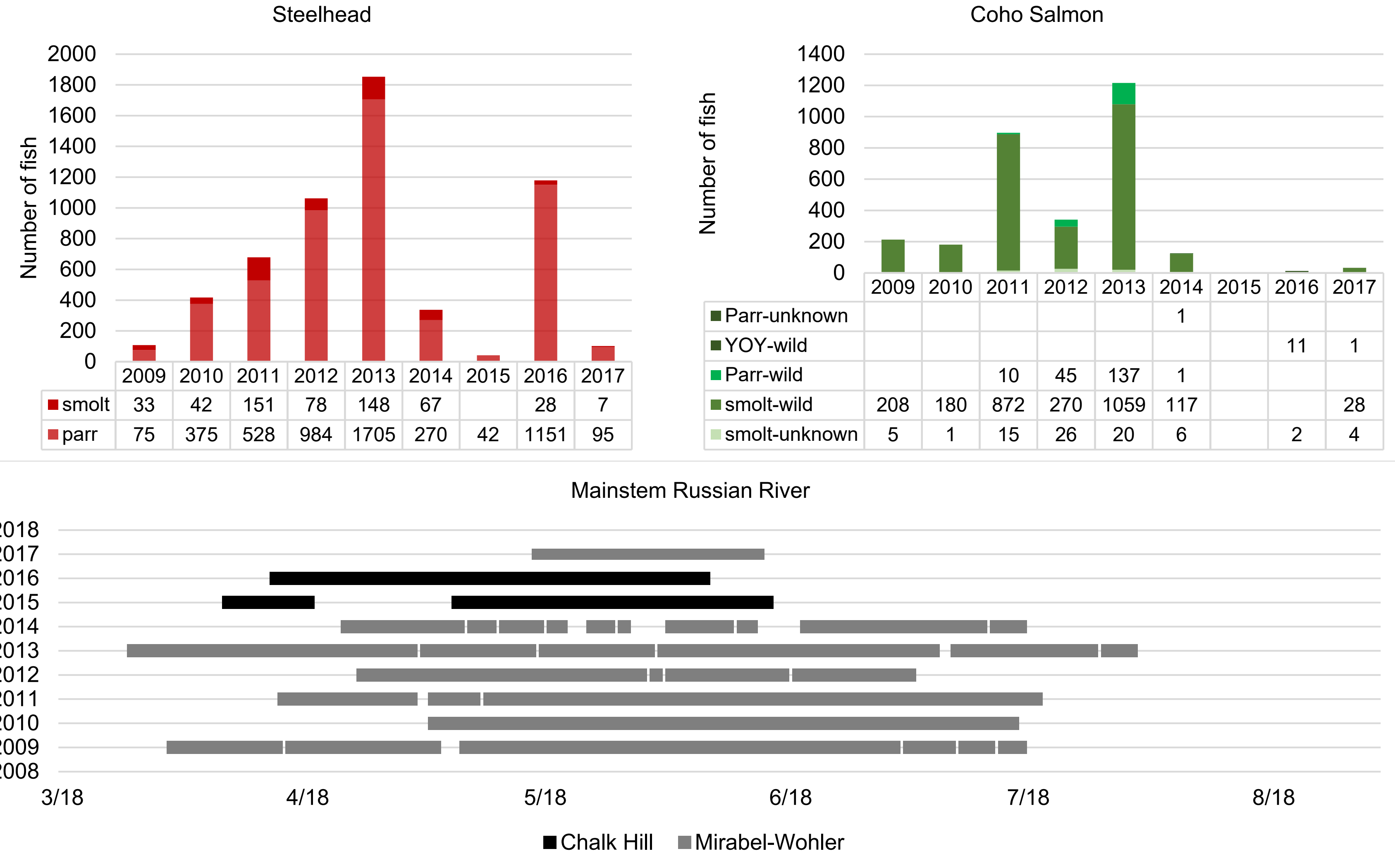
Figure 4.5.7. Weekly fork lengths of steelhead captured at lower Russian River downstream migrant trap sites, 2017.



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

	2009	2010	2011	2012	2013	2014	2015	2016	2017
parr-wild		2	18	35	1	4			
parr-unknown						9			
smolt-wild	3	1	83	117	19	58	49	13	35
smolt-hatchery	7	19	113	127	760	865	264	227	301
smolt-unknown						11		1	2

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), 2009-2017.



Steelhead

	2009	2010	2011	2012	2013	2014	2015	2016	2017
smolt	33	42	151	78	148	67		28	7
parr	75	375	528	984	1705	270	42	1151	95

Coho Salmon

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Parr-unknown						1			
YOY-wild								11	1
Parr-wild			10	45	137	1			
smolt-wild	208	180	872	270	1059	117			28
smolt-unknown	5	1	15	26	20	6		2	4

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), 2009-2017.

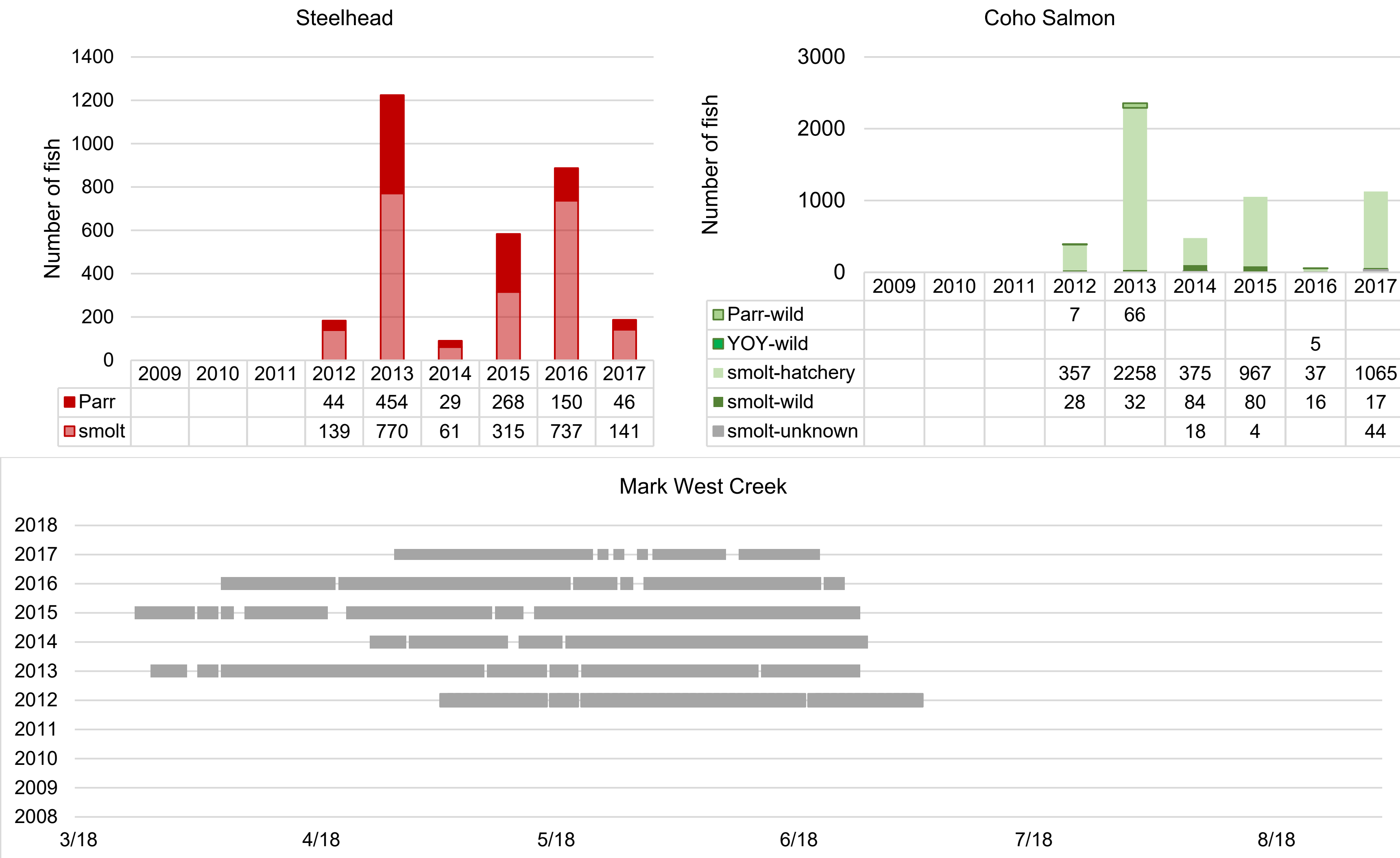
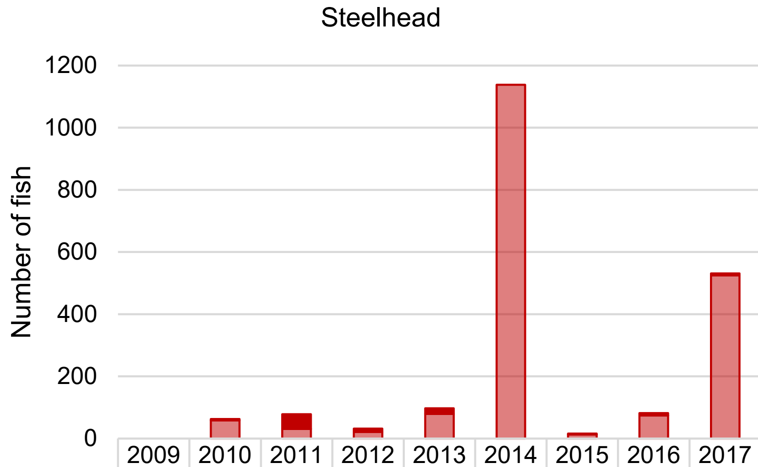
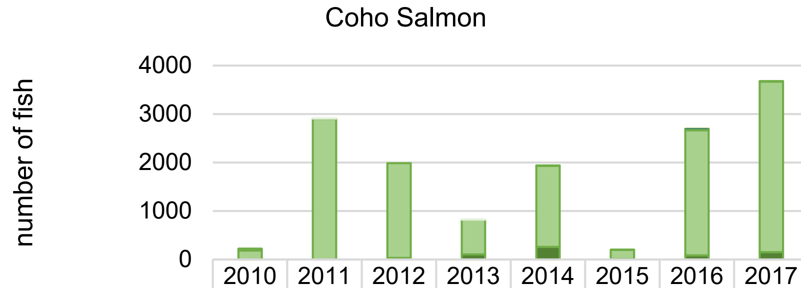


Figure 4.5.10. Number of steelhead and coho salmon captured by life stage and origin at the Mark West Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2017.



	2009	2010	2011	2012	2013	2014	2015	2016	2017
smolt		5	47	11	18		3	8	6
parr		58	31	21	79	1138	13	74	525



	2010	2011	2012	2013	2014	2015	2016	2017
YOY-hatchery							1	
YOY-unknown							15	
parr-wild		5		2				
parr-hatchery	39							
smolt-unknown		4			9	1	15	11
smolt-hatchery	184	2904	1952	717	1668	192	2581	3516
smolt-wild	1		35	106	262	8	85	151

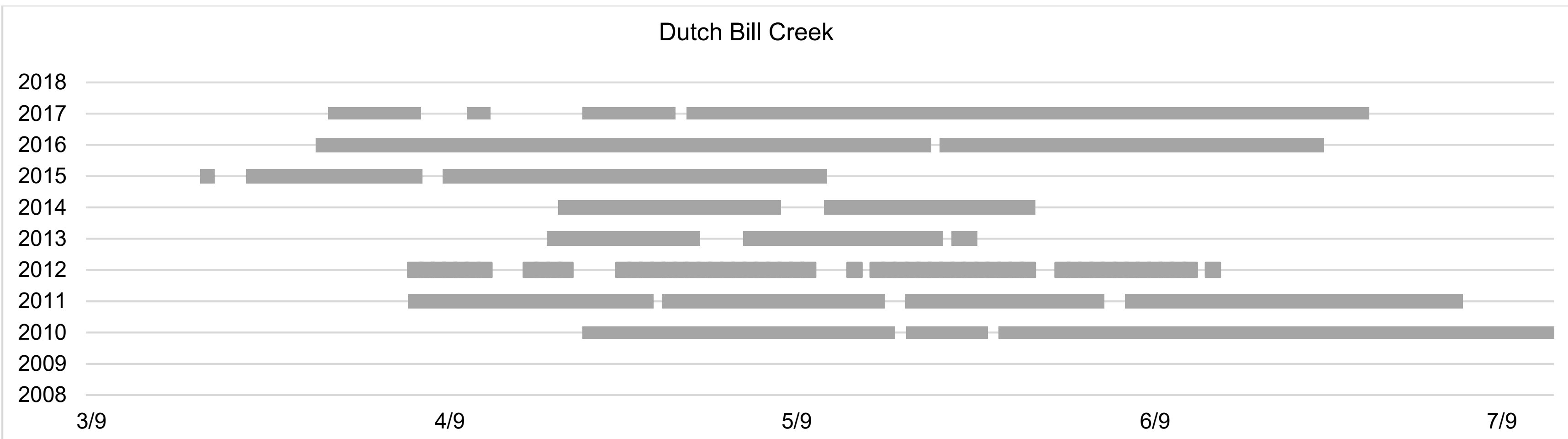
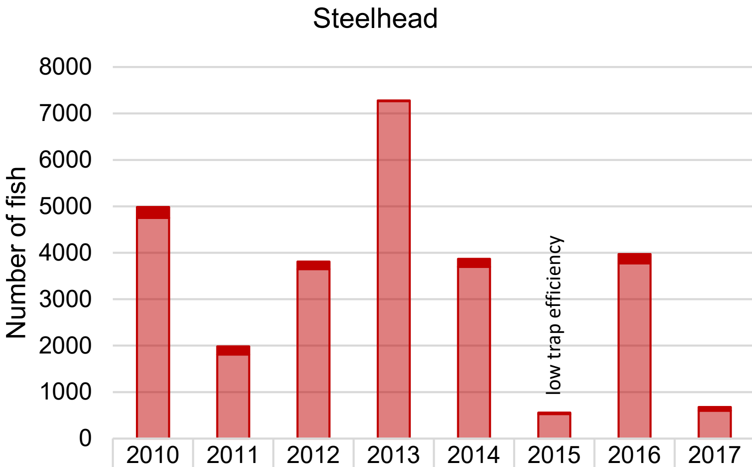
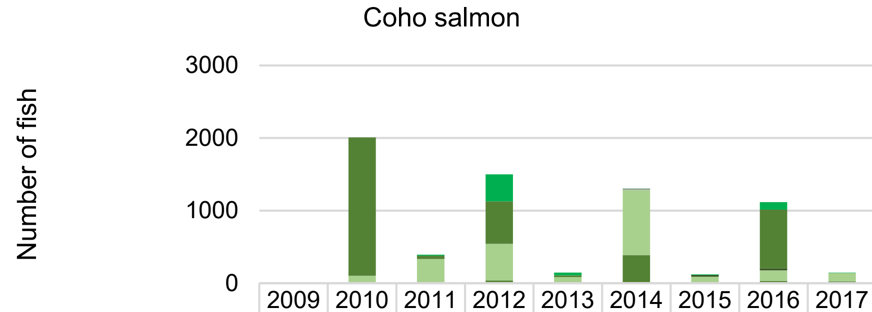


Figure 4.5.11. Number of steelhead and coho salmon captured by life stage and origin at the Dutch Bill Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2017.



	2010	2011	2012	2013	2014	2015	2016	2017
smolt	232	175	163	14	173	30	201	78
parr	4752	1809	3648	7267	3696	527	3771	599



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

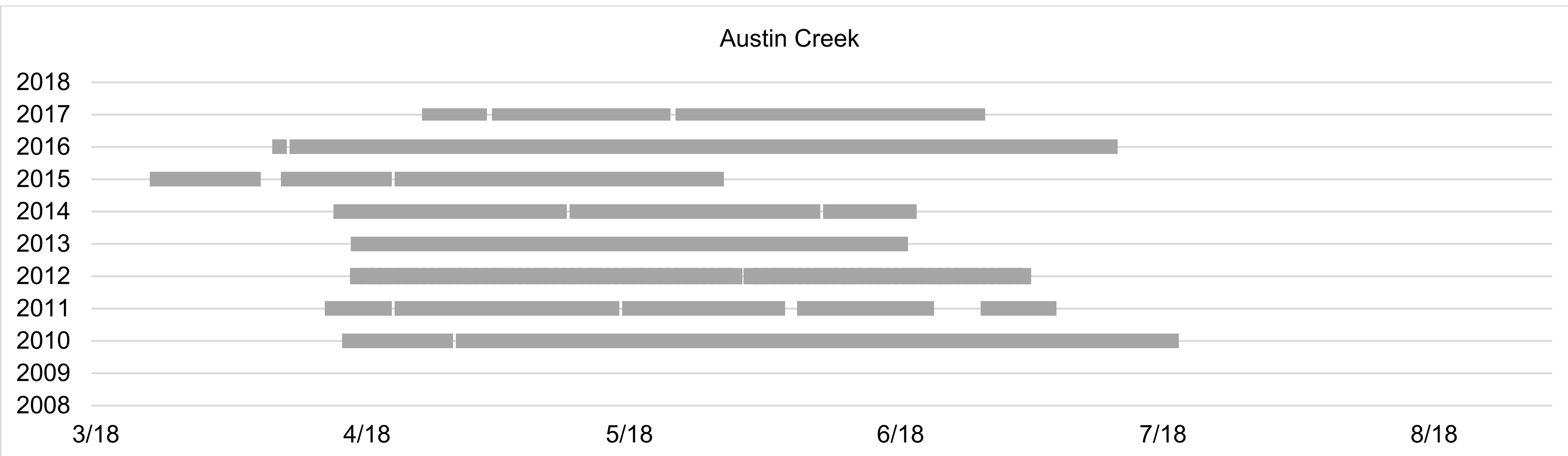
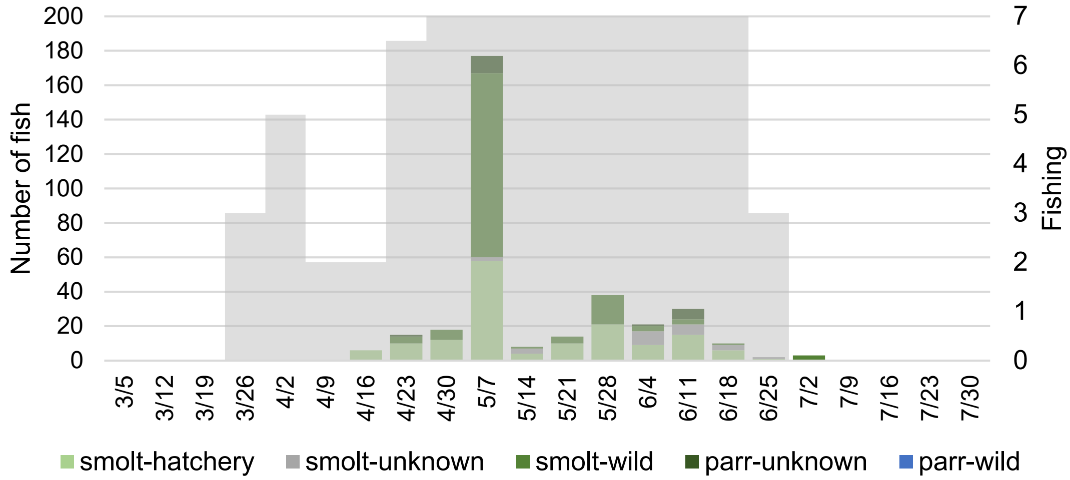
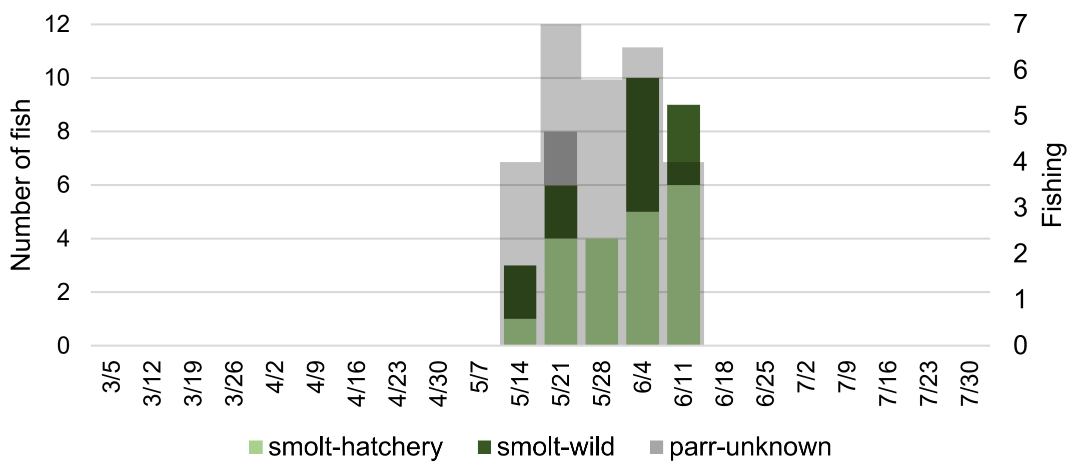


Figure 4.5.12. Number of steelhead and coho salmon captured by life stage and origin at the Austin Creek downstream migrant trap (upper panels) and duration and timing of trap operation (lower panel), 2009-2017.

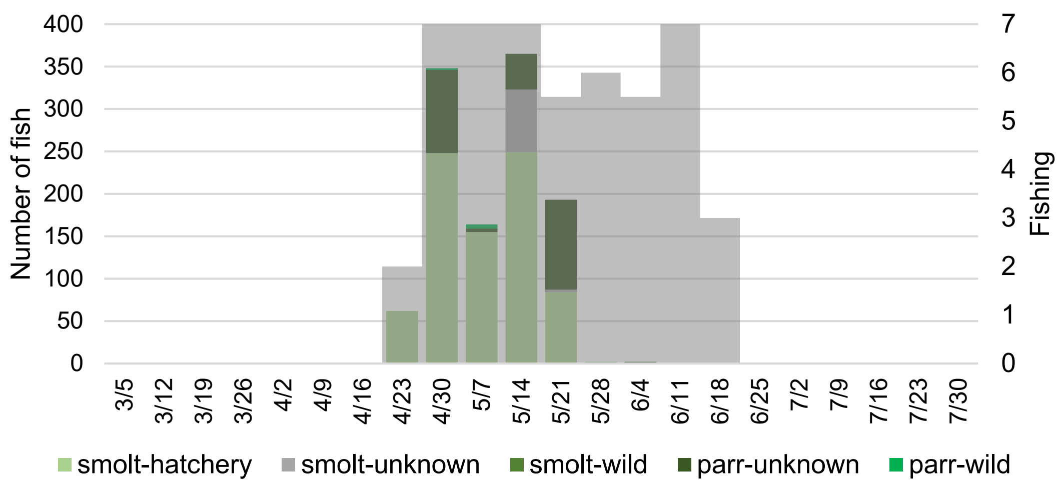
Dry Creek (West side Road, RiverKm 3.30)
301 smolt (hatchery), 2 smolt (unknown), 35 smolt (wild),
18 parr (unknown)



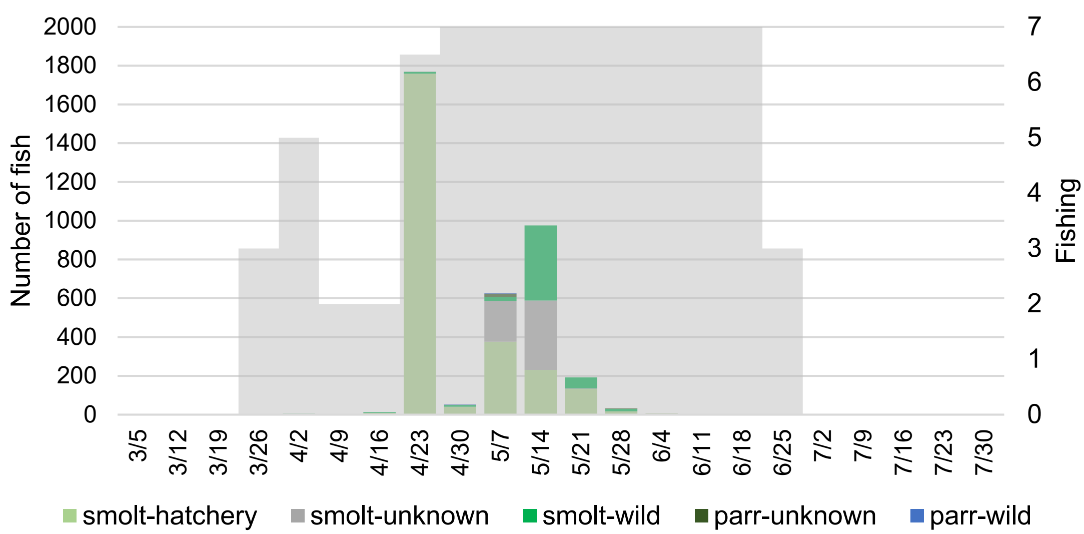
Mainstem (Mirabel, rKm 38.7)
4 smolt (unknown), 28 smolt (wild), 1 parr (wild)



Mark West Creek (Trenton-Healdsburg Road, rKm 4.80)
1,065 smolt (hatchery), 44 smolt (unknown), 17 smolt (wild)



Dutch Bill Creek (Monte Rio Park, riverKm 0.28)
3,516 smolt (hatchery), 11 smolt (unknown), 151 smolt (wild), 2 parr (wild)



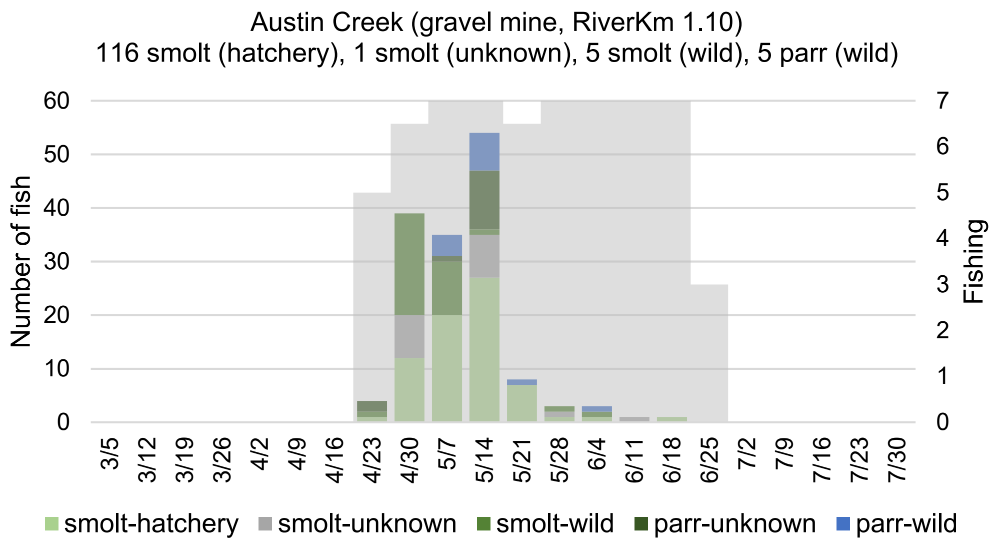
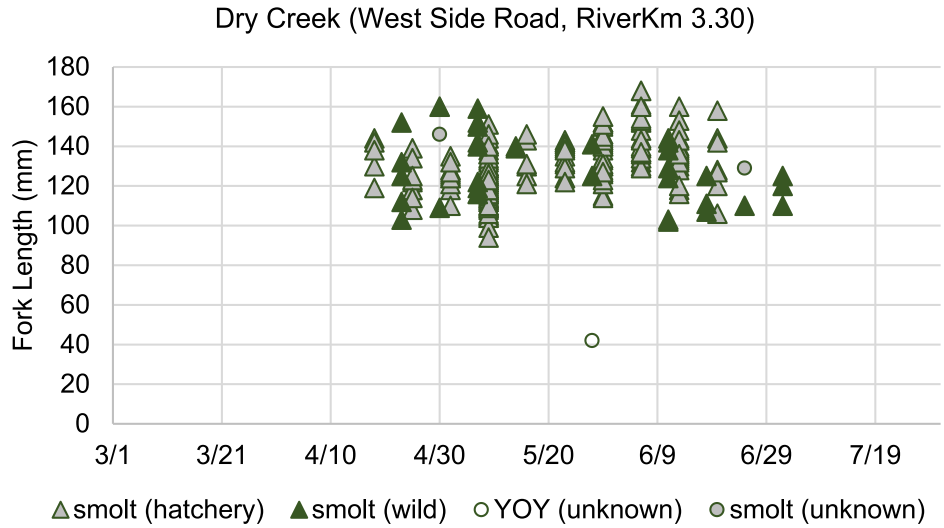
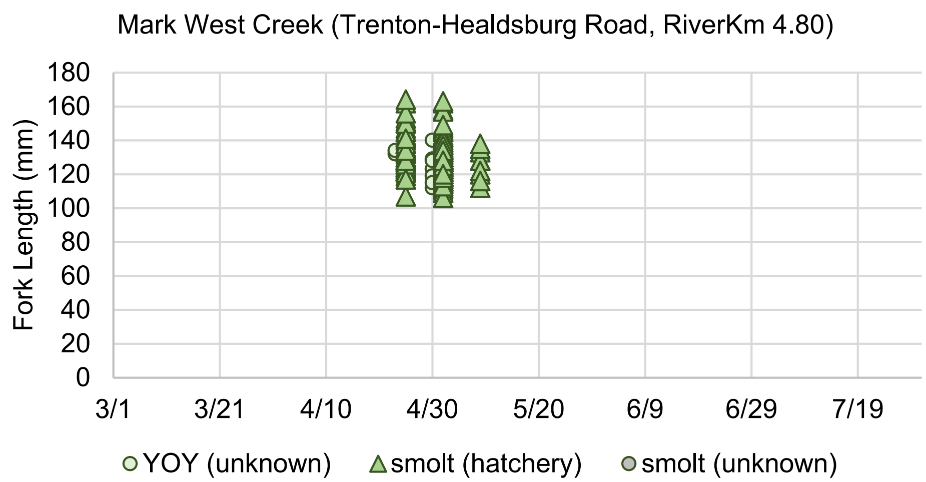
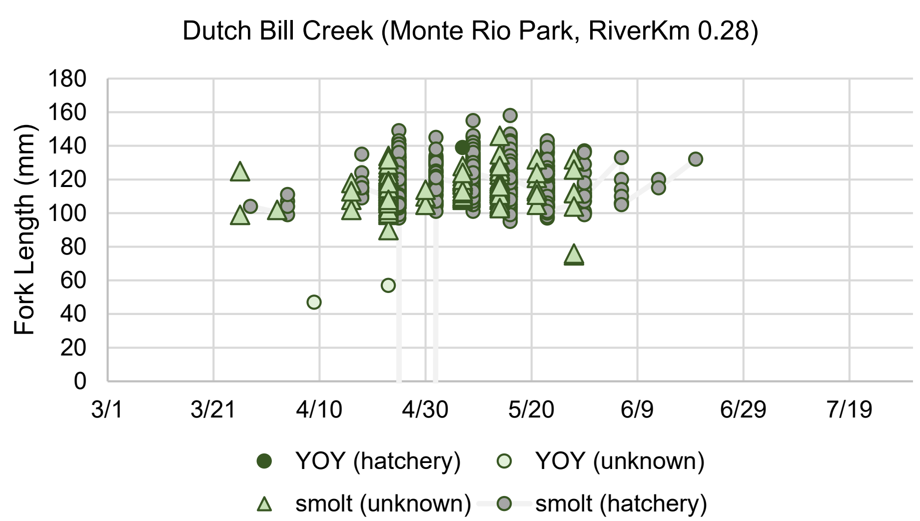


Figure 4.5.13. Weekly capture of coho salmon by life stage at lower Russian River downstream migrant trapping sites, 2017. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.


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


Mark West Creek (Trenton-Healdsburg Road, RiverKm 4.80)
Fork Length (mm)
0
20
40
60
80
100
120
140
160
180
3/1
3/21
4/10
4/30
5/20
6/9
6/29
7/19
YOY (unknown)
smolt (hatchery)
smolt (unknown)


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

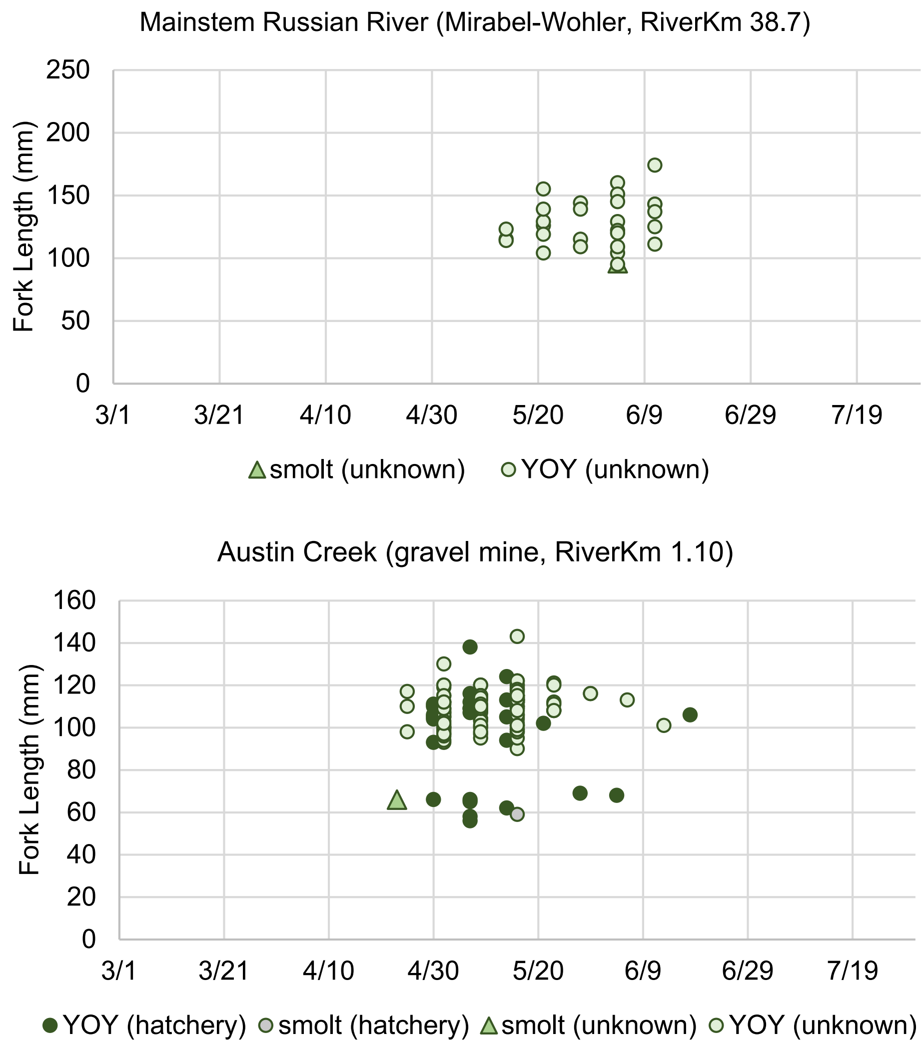


Figure 4.5.14. Weekly fork lengths of coho salmon captured at lower Russian River downstream migrant trap sites, 2017.

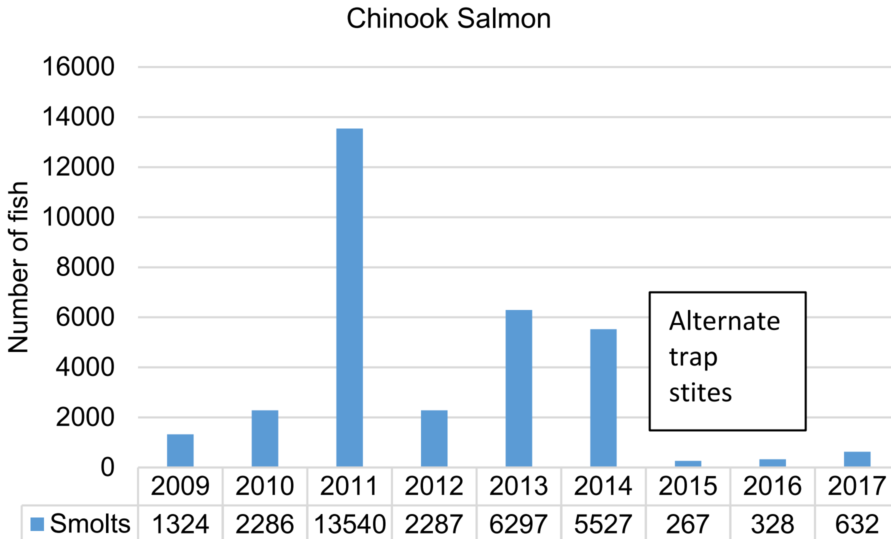


Figure 4.5.15. Number of Chinook salmon smolts captured in the mainstem Russian River downstream migrant trap from 2009 to 2017.

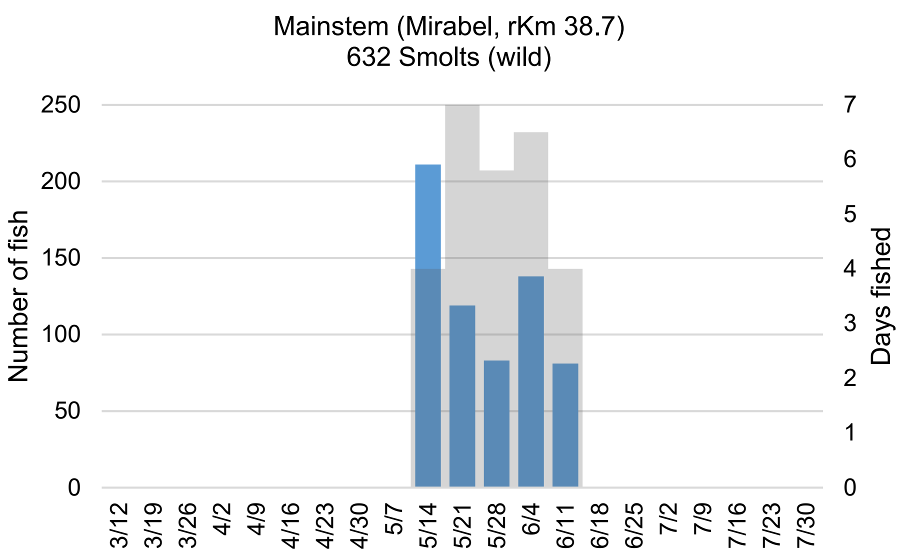


Figure 4.5.16. Weekly capture of Chinook salmon smolts at the Mirabel fish ladder on the mainstem Russian River, 2017. Gray shading indicates portion of each week trap was fishing. Note the different vertical scale among plots for each site.

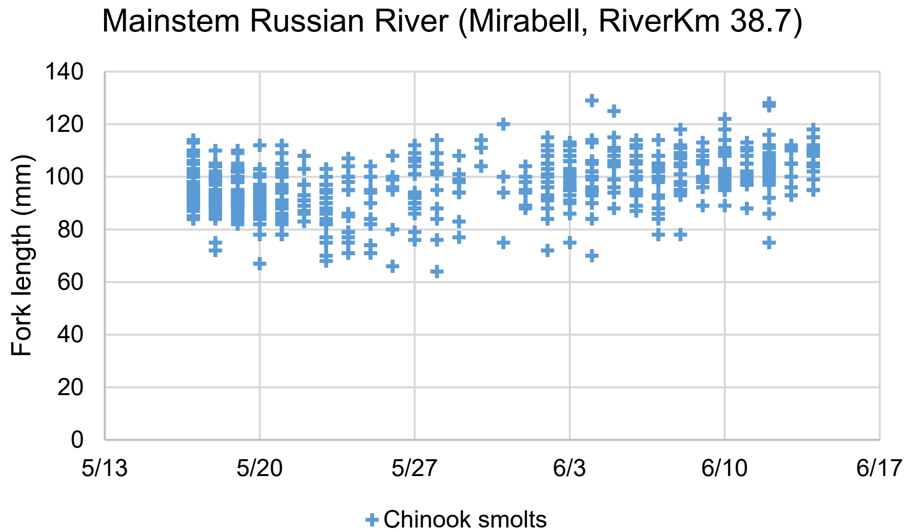


Figure 4.5.17. Weekly fork lengths of Chinook salmon captured at the Wohler Mirabel trap site on the mainstream Russian River downstream migrant trap sites, 2017.

Conclusions and Recommendations

Russian River Biological Opinion objectives regarding the timing of Russian River 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 2017, as in past years many steelhead YOY were detected leaving Austin Creek and entering the Estuary. This same pattern was not seen at the other tributary monitoring sites.

Unfortunately, operation of the PIT tag antenna at Duncans Mills that typically spans much of the Russian River was not possible for the 2017 outmigration season. High winter flows damaged the Duncans Mills antenna array and it was inoperable until after the outmigration season ended. Instead,PIT tag antennas in the tributaries were relied upon to determine if steelhead were leaving tributaries and potentially entering the Estuary. Regardless of these issues, 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) remain as the only viable method for addressing the fish monitoring objectives in the Russian River Biological Opinion. In the future, Sonoma Water will continue to attempt to operate PIT tag antennas at Duncans Mills and measure antenna efficiency so that expanded counts of PIT tagged individuals passing the antenna array can be constructed.

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CHAPTER 5 Dry Creek Habitat Enhancement, Planning and Monitoring

Introduction

The Biological Opinion contains an explicit 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, Sonoma Water 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 Chapter 6 of this report. For the mainstem of Dry Creek during this initial period, Sonoma Water was directed to perform monitoring, develop a detailed adaptive management plan, and conduct feasibility studies for large-scale habitat enhancement and a potential water supply bypass pipeline. The pipeline feasibility study was completed in 2011 and is reported in Martini-Lamb and Manning 2011.

In 2012, the 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 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). 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. Phase 2, Part 2 (Reach 14) is scheduled to start during the 2018 construction season (Sonoma Water). Phase 3, Part 2 (Reach 4a) is expected to start during the 2018 construction season (U.S. Army Corps of Engineers). Phase 3, Part 3 (Reach 5) will likely be constructed by Sonoma Water during the 2019 construction season.

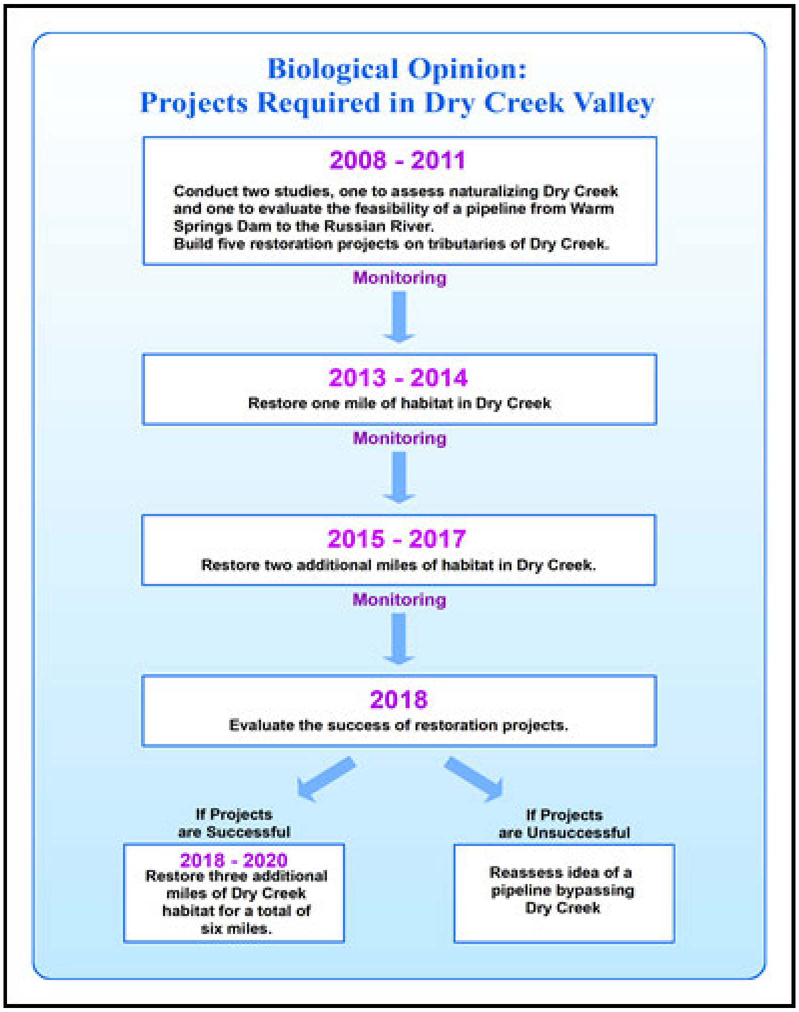


Figure 5.1. Timeline for implementation of Biological Opinion projects on Dry Creek.

2017 Habitat Enhancement Overview

In 2017, we completed construction in two new reaches: Carlson Lonestar and City of Healdsburg. We conducted pre- and post-enhancement monitoring in these two reaches as well as post-effective flow monitoring in previously completed reaches (Truett Hurst, Meyer, Van Alyea, Farrow-Wallace, and Geyser Peak (Figure 5.2).

Of the number of habitat enhancement reaches implemented to date (10), monitoring data resulted in 4 reaches rated good-excellent, 2 rated fair, 2 rated poor and 2 have not yet been fully monitored (Table 5.1). None of these overall ratings were affected by the results of validation monitoring. In future years some of the sites rated poor will be revisited to determine whether deficiencies can be corrected.

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

Enhancement Reach	2015	2016	2017	Overall Rating
Army Corps Reach 15		Excellent		Excellent
Quivera		Excellent		Excellent
Van Alyea			Good	Good
Farrow Wallace			Fair	Fair
Rued	Good			Good
Truett Hurst			Poor	Poor
Meyer			Fair	Fair
Carlson, Lonestar				--
City of Healdsburg Yard				--
Geyser Peak			Poor	Poor

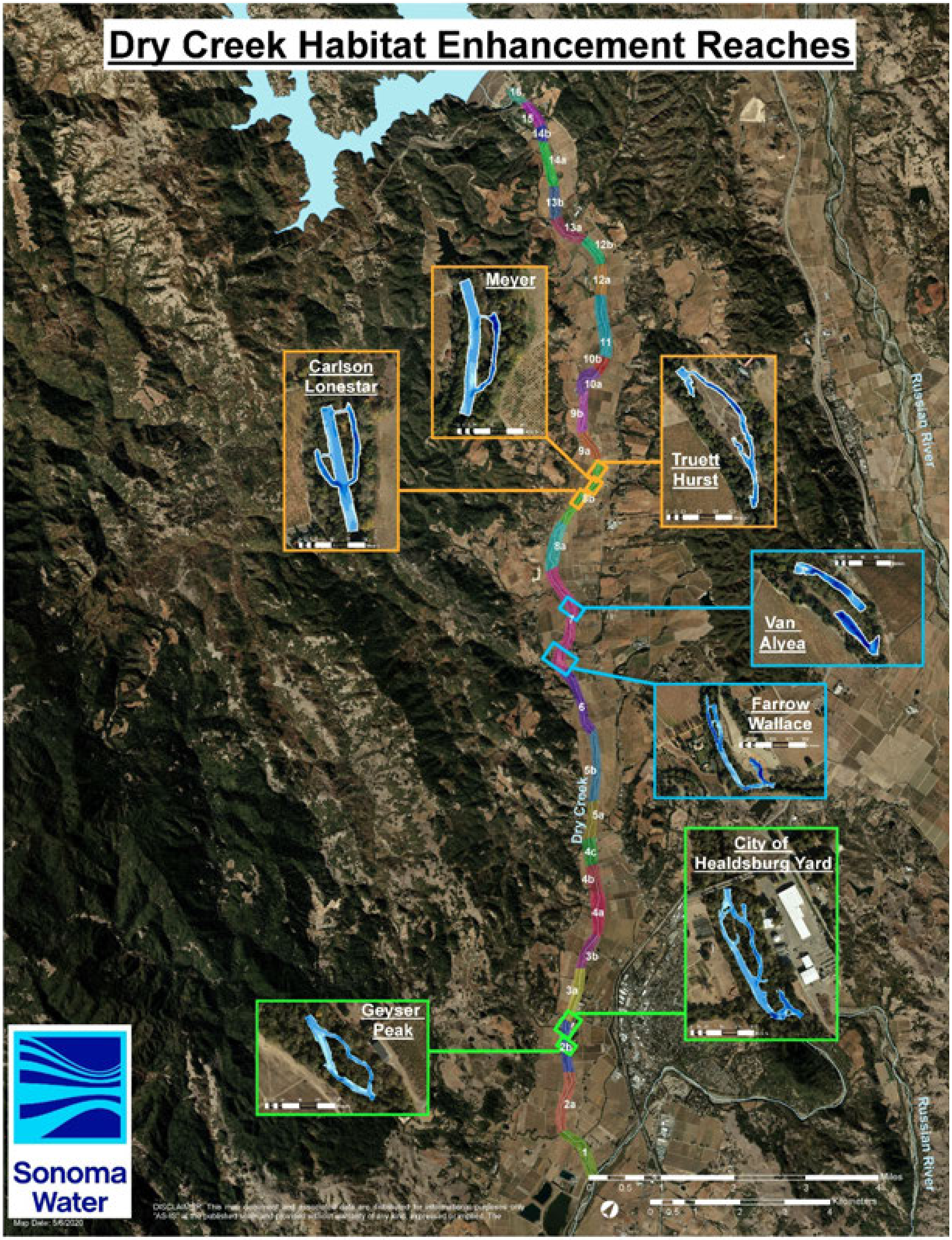


Figure 5.2. Location of Dry Creek habitat enhancement reaches monitored for effectiveness in 2017.

Dry Creek Adaptive Management Plan

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

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

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

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

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

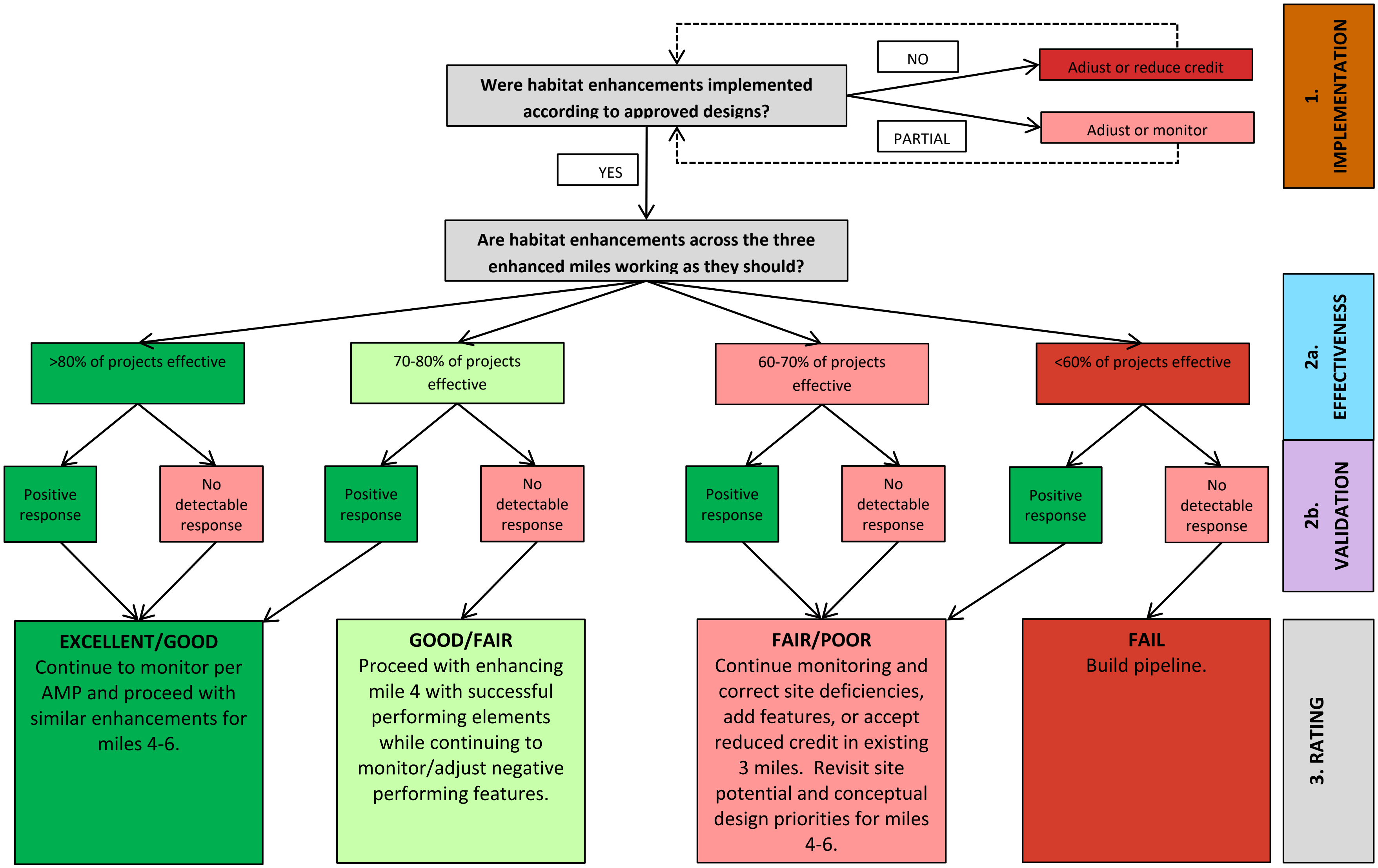


Figure 5.3. Process for determining course of action after the first three miles of Dry Creek have been enhanced. Ratings will be based on an objective evaluation in a step-wise phased monitoring approach which includes physical and biological quantitative measurements which lead to qualitative ratings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

Data Roll-up

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

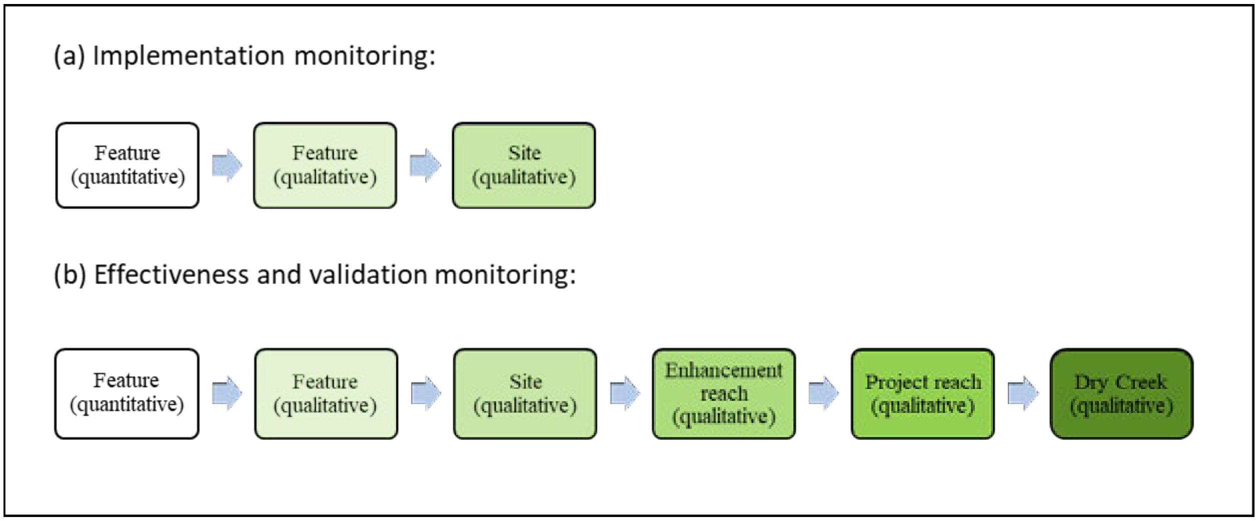


Figure 5.4. Illustration of the rollup concept for (a) implementation and (b) effectiveness and validation monitoring (from Porter et al. 2014).

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

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

The qualitative rating derived for a given group of features within a site, sites within an enhancement reach or enhancement reaches within a project reach represent the basis for overall rating of habitat enhancements. These overall ratings will influence crediting toward the total length of habitat enhanced in Dry Creek (Figure 5.3).

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

5.1 Habitat Enhancement Implementation

Phase 2 and 3

Beyond the completion of the Demonstration Project (Reach 7) work and the Corps of Engineer's Reach 15 work, Sonoma Water has continued to make progress towards construction of the next two miles of habitat enhancement. Figure 5.1.1shows the areas completed in Reach 15 and the Demonstration Project (Reach 7) and other areas either in design or under construction. These next two miles have been designated as Phase 2 and 3, with each of these phases to be constructed in parts. No construction activities occurred in 2015; however, construction of Phase 2, Part 1 (Reach 8) and Phase 3, Part 1 (Reach 2) began in June of 2016 (see photos below). The construction work for these two parts is anticipated to be completed in 2017. Design development and landowner negotiations continue for the future parts of both Phase 2 and Phase 3 design work. Phase 2, Part 2 (Reach 14) and Phase 3, Part 3 (Reach 5) are expected to be constructed in 2017 or 2018 by Sonoma Water (Figure 5.1.2). Phase 3, Part 2 (Reach 4a) is expected to be constructed in 2017 or 2018 by the U.S. Army Corps of Engineers (Figure 5.1.3).

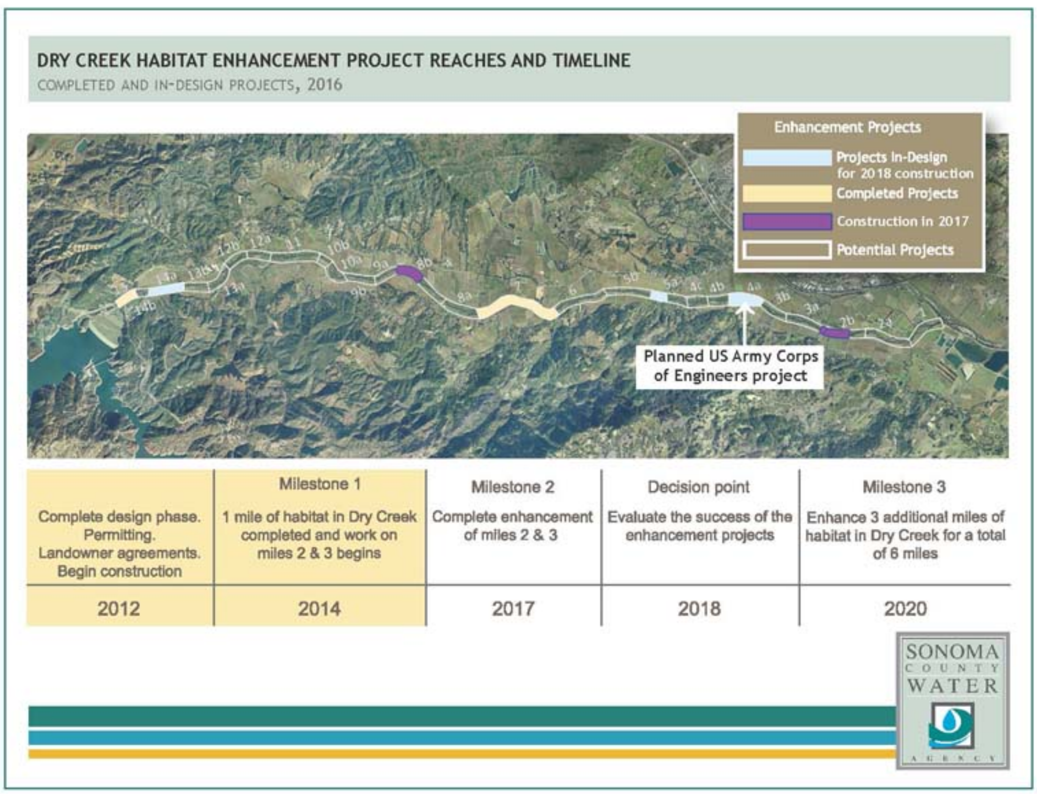


Figure 5.1.1. Projects along Dry Creek that have been completed and projects that are being designed.

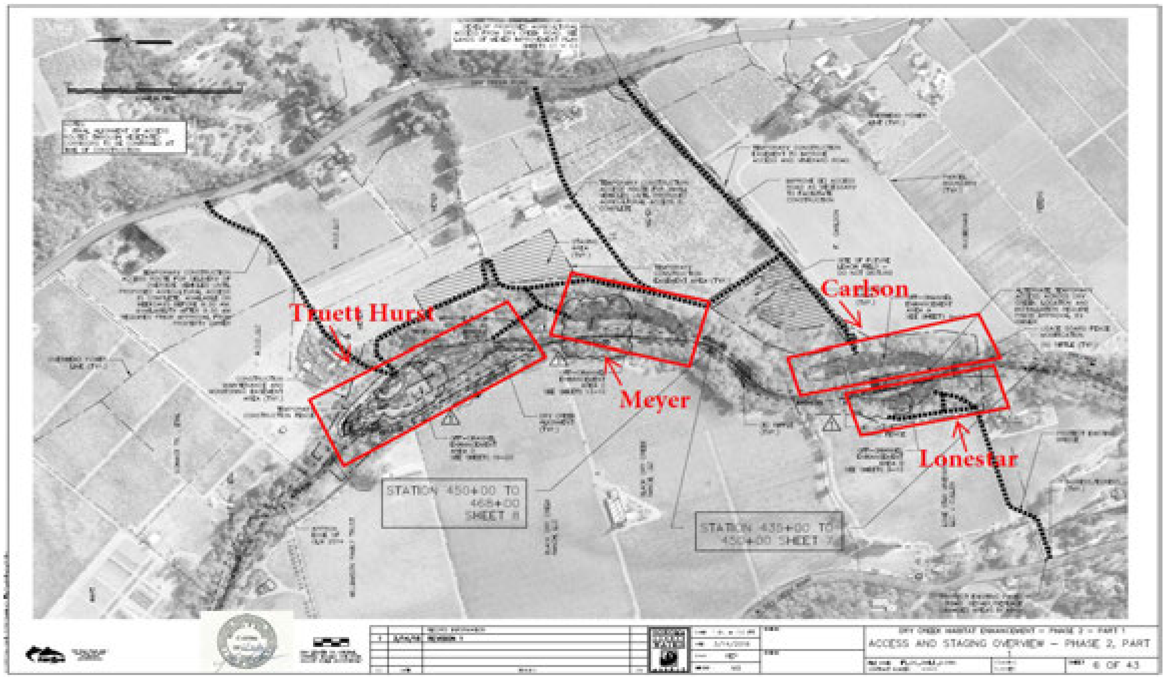


Figure 5.1.2. Work area for the Dry Creek Habitat Enhancement Project, Phase 2, Part 1, constructed in 2016 and 2017.

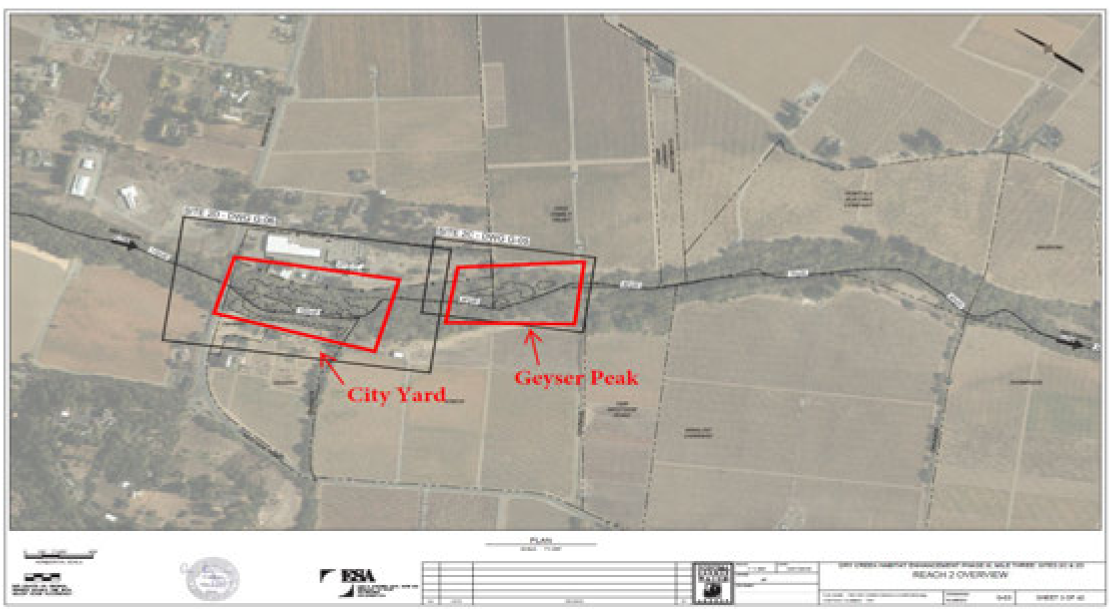


Figure 5.1.3. Work area for the Dry Creek Habitat Enhancement Project, Phase 3, Part 1, constructed in 2016 and 2017.

Between the 2016 and 2017 construction seasons, high flow events significantly altered some of the new habitat features that were construction in 2016 at both the Phase 2, Part 1 and Phase 3, Part 1 sites. Sonoma Water worked with its design team and the resource agencies on adapted designs for both of these project areas. The remaining portions of the Phase 2, Part 1 and Phase 3, Part 1 work as well as the modifications to the damaged or altered areas was all completed during the 2017 construction season. Photos of these sites are below. A detailed implementation report for the Phase 2, Part 1 and Phase 3, Part 1 work can be found in Sonoma Water Implementation Monitoring reports.

Photo 5.1.1. Dry Creek Habitat Enhancement Project Phase 2, Part 1. New side channel inlet under construction at the Truett Hurst site (Reach 8). Mainstem of Dry Creek (looking downstream) can be seen at the right hand side of the photo. August 2016.

Photo 5.1.2. Dry Creek Habitat Enhancement Project Phase 2, Part 1. New side channel backwater feature recently constructed at the Truett Hurst site (Reach 8). October 2016.

Photo 5.1.3. Dry Creek Habitat Enhancement Project Phase 3, Part 1. New side channel feature recently constructed at the Geyser Peak site (Reach 2). October 2016.

Photo 5.1.4. Dry Creek Habitat Enhancement Project Phase 2, Part 1. High flow event through the recently completed new side channel at the Truett Hurst site (Reach 8). January 2017.

Photo 5.1.5. Dry Creek Habitat Enhancement Project Phase 2, Part 1. Construction of new habitat features at the Carlson Lonestar site (Reach 8). August 2017.

Photo 5.1.6. Dry Creek Habitat Enhancement Project Phase 2, Part 1. Completed construction of new habitat features at the Carlson Lonestar site (Reach 8). Site “A” (Carlson) on Right, Site “B” (Lonestar) on Left. November 2017.

Photo 5.1.7. Dry Creek Habitat Enhancement Project Phase 2, Part 1. Newly constructed riffle at the downstream end of the Carlson Lonestar sites (Reach 8). September 2017.

Photo 5.1.8. Dry Creek Habitat Enhancement Project Phase 2, Part 1. Newly constructed side channel at the Meyer site (Reach 8, Site “C”). This site was constructed in 2016 and repaired in 2017. November 2017.

Photo 5.1.9. Dry Creek Habitat Enhancement Project Phase 2, Part 1. Newly constructed side channel and alcove at the Truett Hurst site (Reach 8, Site "D"). This site was constructed in 2016 and repaired in 2017. November 2017.

Photo 5.1.10. Dry Creek Habitat Enhancement Project Phase 3, Part 1. Newly constructed side channel at the Geyser Peak site (Reach 2). This site was constructed in 2016 and repaired in 2017. October 2017.

Photo 5.1.11. Dry Creek Habitat Enhancement Project Phase 3, Part 1. Newly constructed side channel at the City of Healdsburg Yard site (Reach 2). This site was constructed in 2017. September 2017.

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 optimal values of water velocity, depth, and cover by which to evaluate the effectiveness of habitat features, sites, and reaches (Table 5.2.1). The Joint Monitoring Team also identified secondary performance metrics that help determine the effectiveness of habitat enhancements to influence non-target, ancillary conditions (e.g., water temperature, dissolved oxygen concentration). The AMP also suggested target flows to represent seasonal variation critical to each life stage (Porter et al. 2014).

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

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

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

[1] Target coho life stage during spring is newly-emerged feeding fry which use shallower depths than would be preferred later in the summer and winter when fish would be larger. Target spring flow (discharge within the enhancement reach) is 200 cfs (approximately double the summer "base" flow).
[2] Target summer flow is 105 cfs
[3] Target winter flow is 1000 cfs

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 Reasonable and Prudent Alternative of the Russian River Biological Opinion (NMFS 2008). 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 describe the relative success of habitat enhancement measures within enhancement sites and 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
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 October during summer baseflow conditions. Daily average discharge ranged from 110 to 135 cfs over the monitoring period (as measured at the Dry Creek below Lambert Bridge near Geyserville USGS gage [gage #11465240]), and monitoring did not occur at discharges above 135 cfs to ensure accuracy and consistency when measuring depth and velocity, determining habitat types and evaluating cover.

Depth and Velocity

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

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

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

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

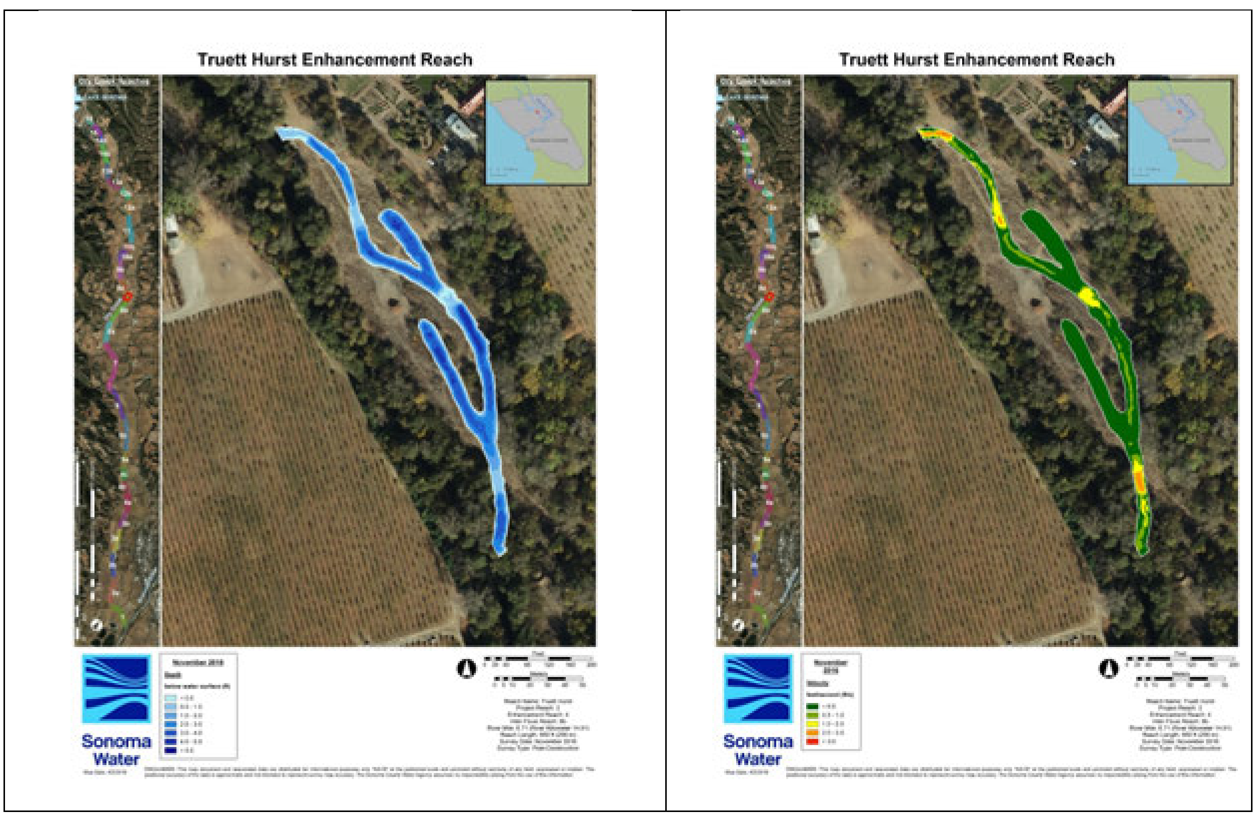


Figure 5.2.2. Digital elevation models (DEMs) created from spatially referenced depth and velocity points.

Habitat Types, Pool to Riffle Ratio, and Shelter Scores

We inventoried instream habitat units using descriptions from the California Salmonid Habitat Restoration Manual (Flosi et al. 2010). Differences in local channel gradient, water velocity, depth, and substrate size distinguish habitat types. Flosi et al. (2010) use four hierarchical levels to describe physical fish habitat, with each successive level providing greater detail. The most elementary descriptions (Levels 1 and 2) break stream channels into pool, riffle, or flatwater habitat types Successive levels differentiate habitat types by location within the stream channel (e.g., mid-channel pools, Level 3) or by cause or agent of formation (e.g., lateral-scour, log-formed pools, Level 4). In this survey, we inventoried habitat types to Level 2 and delineated upstream and downstream boundaries with nail spikes on the right and left bank. We surveyed the location of the nail spikes with a total station and processed the data within a GIS to create polygons of habitat types (Figure 5.2.3). After the inventory, we determined pool: riffle ratio to compare against the performance metric of 1: 2 (0.5) to 2: 1 (2.0) (Table 5.2.1) (Porter et al. 2014).

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

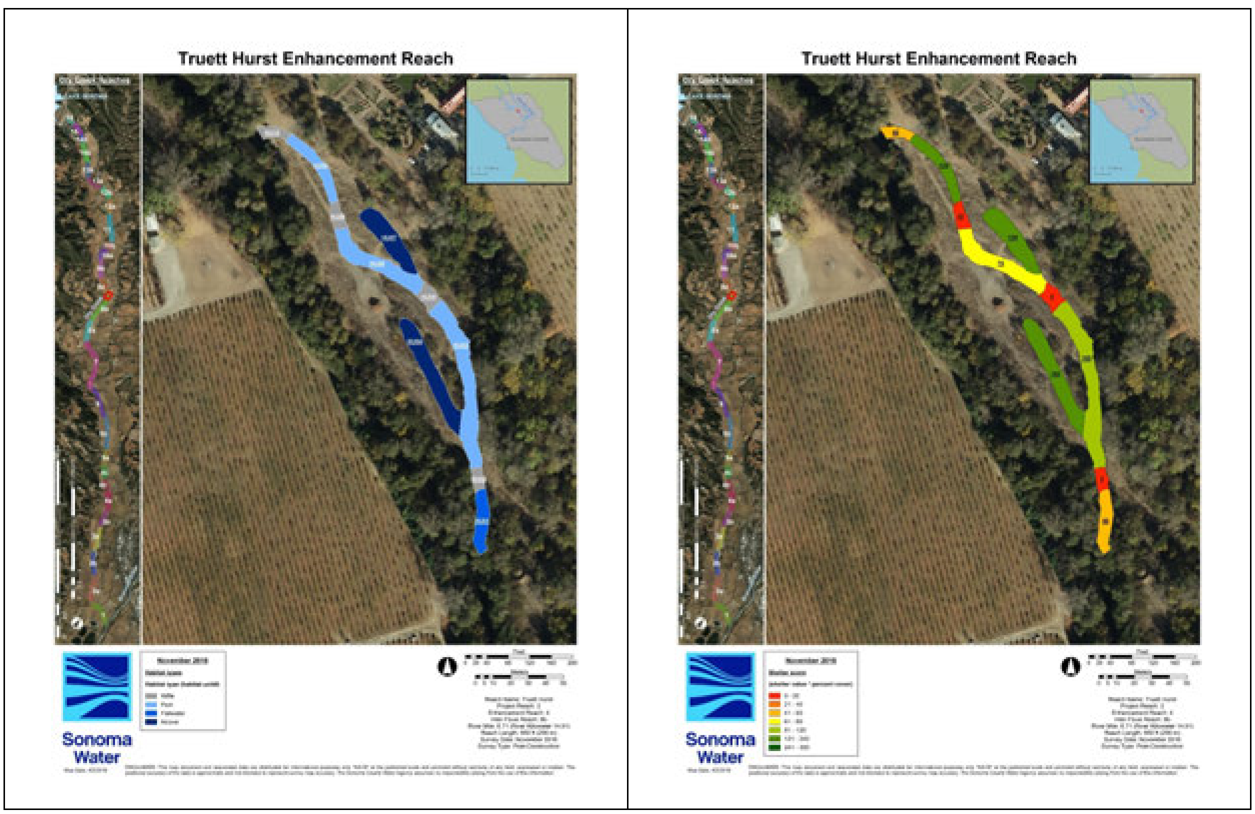


Figure 5.2.3. Example of inventoried habitat types and estimated shelter values within a Dry Creek habitat enhancement reach.

Effectiveness Ratings

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

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

Table 5.2.3. Off-channel effectiveness monitoring checklist showing original data category from the AMP (left-most column) and modified data category (right-most 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 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 DATA
	11a	MAXIMUM WATER DEPTH IN HABITAT UNIT: FT	HABITAT UNIT DATA
	11b	AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11c	AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11d	AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11e	% AREA OF HABITAT UNIT WITHIN 0.5 -2.0 FT DEPTH	HABITAT UNIT DATA
	11f	% AREA OF HABITAT UNIT WITHIN 2.0 -4.0 FT DEPTH	HABITAT UNIT DATA
	11g	% AREA OF HABITAT UNIT WITHIN 0.5-4.0 FT DEPTH	HABITAT UNIT 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 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 DATA
	15.	PERCENT OF HABITAT UNIT COVERED BY SHELTER: %	HABITAT UNIT DATA
	16a	1ST DOMINANT COVER IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT DATA
	16b	2ND DOMINANT IN HABITAT UNIT: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT 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 DATA
	18a	LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L 6-20'	HABITAT UNIT DATA
	18b	LARGE WOODY DEBRIS COUNT IN HABITAT UNIT: D >1', L >20'	HABITAT UNIT 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 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 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 DATA
	25.	DID THE FEATURE ACHIEVE THE TARGETED VELOCITY?	FEATURE DATA
	26a	MEASURED MINIMUM VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT DATA
	26b	MEASURED MAX VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT DATA
	26c	MEASURED MEAN VELOCITY (FT/SEC) IN HABITAT UNIT	HABITAT UNIT DATA
	27.	AREA OF HABITAT UNIT WITHIN TARGETED VELOCITY: (FT^2)	HABITAT UNIT DATA
	28.	PERCENT OF HABITAT UNIT WITHIN TARGETED VELOCITY (SEE ABOVE): (%)	HABITAT UNIT 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 DATA
	30b	2ND DOMINANT SUBSTRATE IN HABITAT UNIT: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT DATA
	31.	IF AN OBJECTIVE, DID THE FEATURE ACHIEVE THE TARGETED SUBSTRATE COMPOSITION?	FEATURE DATA
	32.	% CANOPY MEASUREMENT:	HABITAT UNIT DATA
	33.	PHOTOPOINT DATA COLLECTED: YES /NO	HABITAT UNIT DATA
	34.	TEMPERATURE PROFILE: YES /NO	HABITAT UNIT DATA
	35.	DISSOLVED OXYGEN PROFILE: YES/NO	HABITAT UNIT DATA
RATING	36a	TOTAL HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36b	TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36c	TOTAL HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36d	% HABITAT UNIT AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36e	% HABITAT UNIT AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36f	% HABITAT UNIT AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT 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-most column) and modified data category (right-most 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 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 DATA
	11a	MAXIMUM WATER DEPTH IN **HABITAT UNIT**: FT	HABITAT UNIT DATA
	11b	AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11c	AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11d	AREA OF **HABITAT UNIT** WITHIN 0.5-4.0 FT DEPTH: (FT2)	HABITAT UNIT DATA
	11e	% AREA OF **HABITAT UNIT** WITHIN 0.5 -2.0 FT DEPTH	HABITAT UNIT DATA
	11f	% AREA OF **HABITAT UNIT** WITHIN 2.0 -4.0 FT DEPTH	HABITAT UNIT DATA
	11g	% AREA OF **HABITAT** UNIT WITHIN 0.5-4.0 FT DEPTH	HABITAT UNIT 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 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 DATA
	15.	PERCENT OF **HABITAT UNIT** COVERED BY SHELTER: %	HABITAT UNIT DATA
	16a	1ST DOMINANT COVER IN **HABITAT UNIT**: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT DATA
	16b	2ND DOMINANT IN **HABITAT UNIT**: BED, BOL, BUB, LWD, RTW, SWD, UCB, VEG, OTH	HABITAT UNIT 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 DATA
	18a	LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L 6-20'	HABITAT UNIT DATA
	18b	LARGE WOODY DEBRIS COUNT IN **HABITAT UNIT**: D >1', L >20'	HABITAT UNIT 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 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 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 DATA
	25.	DID THE **FEATURE** ACHIEVE THE TARGETED VELOCITY?	FEATURE DATA
	26a	MEASURED MINIMUM VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT DATA
	26b	MEASURED MAX VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT DATA
	26c	MEASURED MEAN VELOCITY (FT/SEC) IN **HABITAT UNIT**	HABITAT UNIT DATA
	27.	AREA OF **HABITAT UNIT** WITHIN TARGETED VELOCITY: (FT^2)	HABITAT UNIT DATA
	28.	PERCENT OF **HABITAT UNIT** WITHIN TARGETED VELOCITY (SEE ABOVE): (%)	HABITAT UNIT 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 DATA
	30b	2ND DOMINANT SUBSTRATE IN **HABITAT UNIT**: BED, BOL, COB, GRV, SND, SLC, OTH	HABITAT UNIT DATA
	31.	IF AN OBJECTIVE, DID THE **FEATURE** ACHIEVE THE TARGETED SUBSTRATE COMPOSITION?	FEATURE DATA
	32.	% CANOPY MEASUREMENT:	HABITAT UNIT DATA
	33.	PHOTOPOINT DATA COLLECTED: YES /NO	HABITAT UNIT DATA
	34.	TEMPERATURE PROFILE: YES /NO	HABITAT UNIT DATA
	35.	DISSOLVED OXYGEN PROFILE: YES/NO	HABITAT UNIT DATA
RATING	36a	TOTAL **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36b	TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36c	TOTAL **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36d	% **HABITAT UNIT** AREA WHERE TARGETED DEPTH, VELOCITY AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36e	% **HABITAT UNIT** AREA WHERE < 0.5 F/S; 0.5 TO 2 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	36f	% **HABITAT UNIT** AREA WHERE < 0.5 F/S; 2 TO 4 FT AND SHELTER CRITERIA OVERLAP	HABITAT UNIT DATA
	37.	DOES THIS **FEATURE** NEED: DEC, ENH, MNT, REP, NON, OTH	FEATURE DATA
	38.	ARE ADDITIONAL RESTORATION TREATMENTS RECOMMENDED AT THIS LOCATION?	FEATURE DATA

Feature Ratings

From the modified checklists, we reduced the number of questions used to rate each enhancement feature to focus on feature condition, function, and apparent effect on habitat. The modified checklists for off- and in-channel areas contain up to 30 questions in the feature data category, including questions with multiple parts (e.g., Question 21; Table 5.2.3 and Table 5.2.4). We reduced the list to 11 questions with each response assigned a numeric score (Table 5.2.5). The sum of the numeric scores for each feature (up to 15 points) corresponds to a qualitative rating ranging from excellent to fail. We used the reduced list to score and rate each feature, but still answered the full list of questions for each feature (see completed checklists in Appendix 5.1). 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 (>560 as of October 2017) and the number of feature data questions in the original and modified AMP checklists.

Habitat Unit Ratings

We also reduced the number of questions used to rate habitat units to focus on area of hydraulic habitat and shelter data and to directly evaluate performance relative to primary performance measures (Table 5.2.6). The modified checklists for off- and in-channel areas each contain 40 habitat unit data questions, including questions with multiple parts (e.g., Question 16; Table 5.2.3 and Table 5.2.4). The reduced list of habitat unit data questions includes shelter value, percent overhead cover, and the calculated shelter score, with each response assigned a numeric score (Table 5.2.6). The reduced list of habitat unit data questions also includes the percent area of a habitat unit within optimal depth (0.5–2.0 ft; 2.0–4.0 ft) and velocity (≤0.5 ft/s) ranges, both singly and in combination, as specified in the RRBO and AMP, each assigned a numeric score (Table 5.2.6). The sum of the numeric scores for habitat units (up to 35 points) determines a qualitative rating ranging from excellent to fail. As with feature data, we still answered the full list of questions for each habitat unit (see completed checklists in Appendix 5.1). But, the reduced list directly evaluates habitat unit shelter and hydraulic habitat, which are primary performance measures in the AMP, and is more efficient given the number of habitat units evaluated for the Dry Creek Habitat Enhancement Project (>180 as of October 2017) and the number of habitat unit data questions in the original and modified AMP checklists.

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

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

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

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

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

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

Site and Enhancement Reach Ratings

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

Table 5.2.7. Spatial roll-up of site average feature and site average 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 site average habitat unit ratings determine the site quantitative rating and qualitative rating. The average of site ratings determines the enhancement reach quantitative rating and qualitative rating.

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

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

Monitoring Frequency

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

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

Results

During the summer and fall 2017, Sonoma Water effectiveness monitored seven enhancement reaches totaling over 531,000 ft^2 on mainstem Dry Creek, side channels, and alcoves (Table 5.2.8, Figure 5.2.4). Fields crews collected nearly 42,978 depth and velocity points, evaluated 305 features for their condition, and evaluated 90 habitat units for their hydraulic (depth and velocity) and shelter characteristics. The monitored enhancement reaches stretch from Reach 2b (as defined by Inter-Fluve 2012, River Mile [RM] 1.67) to Reach 8b (RM 8.71) (Figure 5.2.4). We monitored and rated the pre- and post-enhancement conditions of two newly constructed enhancement reaches (Carlson, Lonestar, and City of Healdsburg Yard) (see Pre-Enhancement and Post-enhancement results below) and monitored and rated five enhancement reaches post-effective flow. Sonoma Water constructed the Farrow Wallace and Van Alyea reaches in 2013/2014 and 2014 respectively (both last monitored in 2015), and constructed the Truett Hurst, Meyer, and Geyser Peak enhancement reaches in 2016 (see Post-effective Flow results below). Several large storms in 2016/2017, followed by sustained flood control releases from Warm Springs Dam led to substantial aggradation in Truett Hurst, Meyer, and Geyser Peak enhancement reaches and fair to poor enhancement reach ratings. Sonoma Water repaired and modified these enhancement reaches in October 2017, and crews monitored and rated the enhancement reaches shortly after (see Post-repair results below).

The results below summarize effectiveness monitoring results for each monitoring time period (pre- and post-enhancement, post-effective flow, and post-repair) 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 and shelter scores. We also summarize the feature and habitat unit ratings that inform the side ratings, and the roll-up of site ratings into the enhancement reach rating.

Table 5.2.8. Creek enhancement reaches monitored in 2017, 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	Monitoring Time Period			
	Pre-enhancement (ft^2)	Post-enhancement (ft^2)	Post-effective Flow (ft^2)	Post-repair (ft^2)
Truett Hurst	--	--	60,541	40,431
Meyer	--	--	34,927	11,340
Carlson, Lonestar	47,690	55,069	--	--
Van Alyea	--	--	60,316	--
Farrow Wallace	--	--	45,396	--
City of Healdsburg Yard	50,285	73,373	--	--
Geyser Peak	--	--	43,334	8,721
TOTAL (ft^2)	**97,974**	**128,442**	**244,514**	**60,492**
GRAND TOTAL (ft^2)	**531,422**			

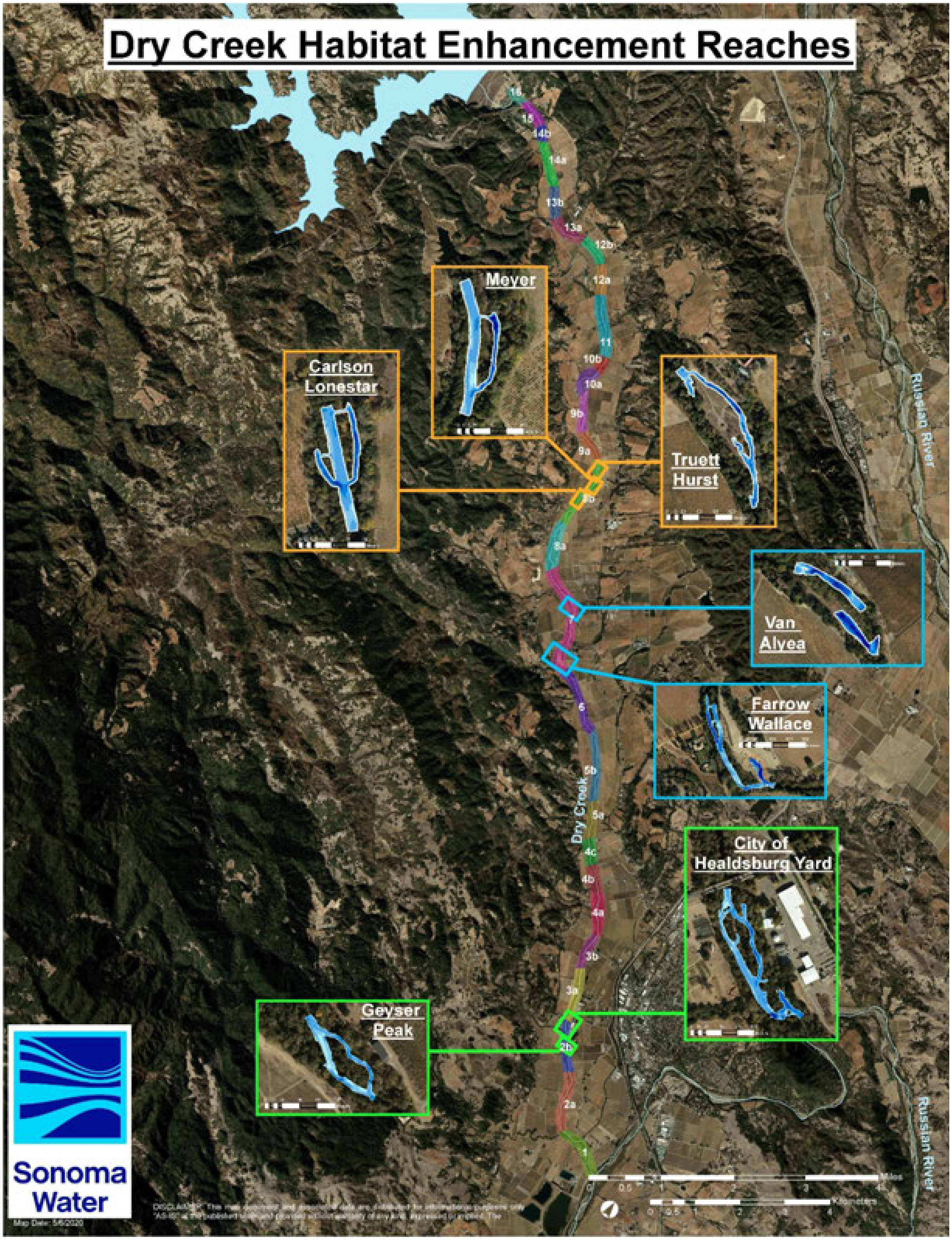


Figure 5.2.4. Location of Dry Creek habitat enhancement reaches monitored in 2017.

Pre-enhancement

Summary

Sonoma Water monitored the pre-enhancement condition of the Carlson, Lonestar and City of Healdsburg Yard enhancement reaches in 2017 (Figure 5.2.4). Overall, the pre-enhanced reaches covered 97,974 ft^2 within the main channel of Dry Creek, with 9% meeting the optimal depth and velocity criteria (Table 5.2.9). Crews recorded 14 habitat units across both enhancement reaches with a total pool to riffle ratio of 5:4 (1.25) with and a total average shelter score of 54 (Table 5.2.10). No habitat unit averaged or exceeded the optimum shelter value of 80. Pre-enhancement, the Carlson, Lonestar enhancement reach rated poor and the City of Healdsburg Yard enhancement reach rated fair (Table 5.2.11) (see below for individual enhancement reach summaries).

Depth and velocity

Table 5.2.9. Pre-enhancement areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches constructed in 2017.

Dry Creek Pre-enhancement 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	97,974	76,946	9,182	86,128	16,304	7,565	1,025	8,589
Main channel % of wetted area	100%	79%	9%	88%	17%	8%	1%	9%

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 constructed in 2017.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	4	40
Pool	5	56
Flatwater	5	62
Alcove	0	0
Pool: riffle	**5: 4 (1.25)**	**Avg = 54**

Reach ratings

Table 5.2.11. Pre-enhancement ratings for Carlson, Lonestar and City of Healdsburg Yard enhancement reaches in 2017.

Enhancement Reach	Pre-enhancement Rating
Carlson, Lonestar	Poor
City of Healdsburg Yard	Fair

Carlson, Lonestar Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the Carlson, Lonestar enhancement reach in May 2017. The reach covered 47,690 ft^2 within the main channel of Dry Creek, with 6% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.12, Figure 5.2.5). Three habitat units made up the enhancement reach, with a pool: to riffle ratio of 1:1 (1.00) and an average shelter score of 27 (Table 5.2.13, Figure 5.2.6, Figure 5.2.7). No habitat units met or exceeded the optimal shelter value of 80. The reach comprised one mainstem enhancement site with poor habitat unit ratings and poor overall reach rating (Table 5.2.14, Figure 5.2.8, Figure 5.2.9, see Appendix 5.1 for 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 Carlson, Lonestar enhancement reach, May 2017.

Carlson, Lonestar Pre-enhancement May 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	47,690	39,430	2,998	42,428	5,765	2,784	232	3,016
Main channel % of wetted area	100%	83%	6%	89%	12%	6%	0%	6%

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 Carlson, Lonestar enhancement reach, May 2017.

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 Carlson, Lonestar enhancement reach, Pre-enhancement May 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	5	10
HU02	Flatwater	2	5	10
HU03	Pool	3	20	60
Pool: riffle	**1:1 (1.00)**			**Avg = 27**

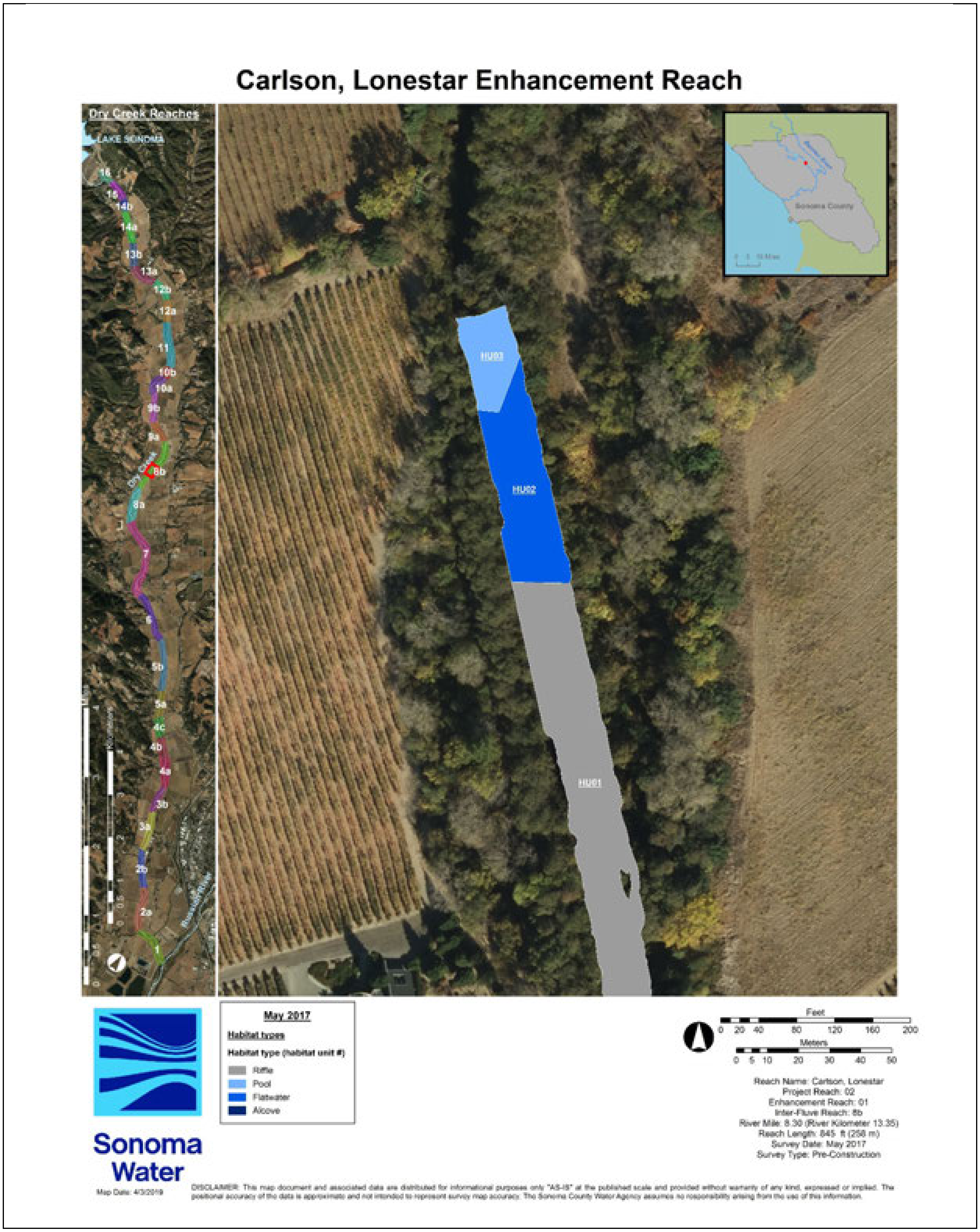


Figure 5.2.6. Habitat unit number and type within the Carlson, Lonestar enhancement reach, May 2017.

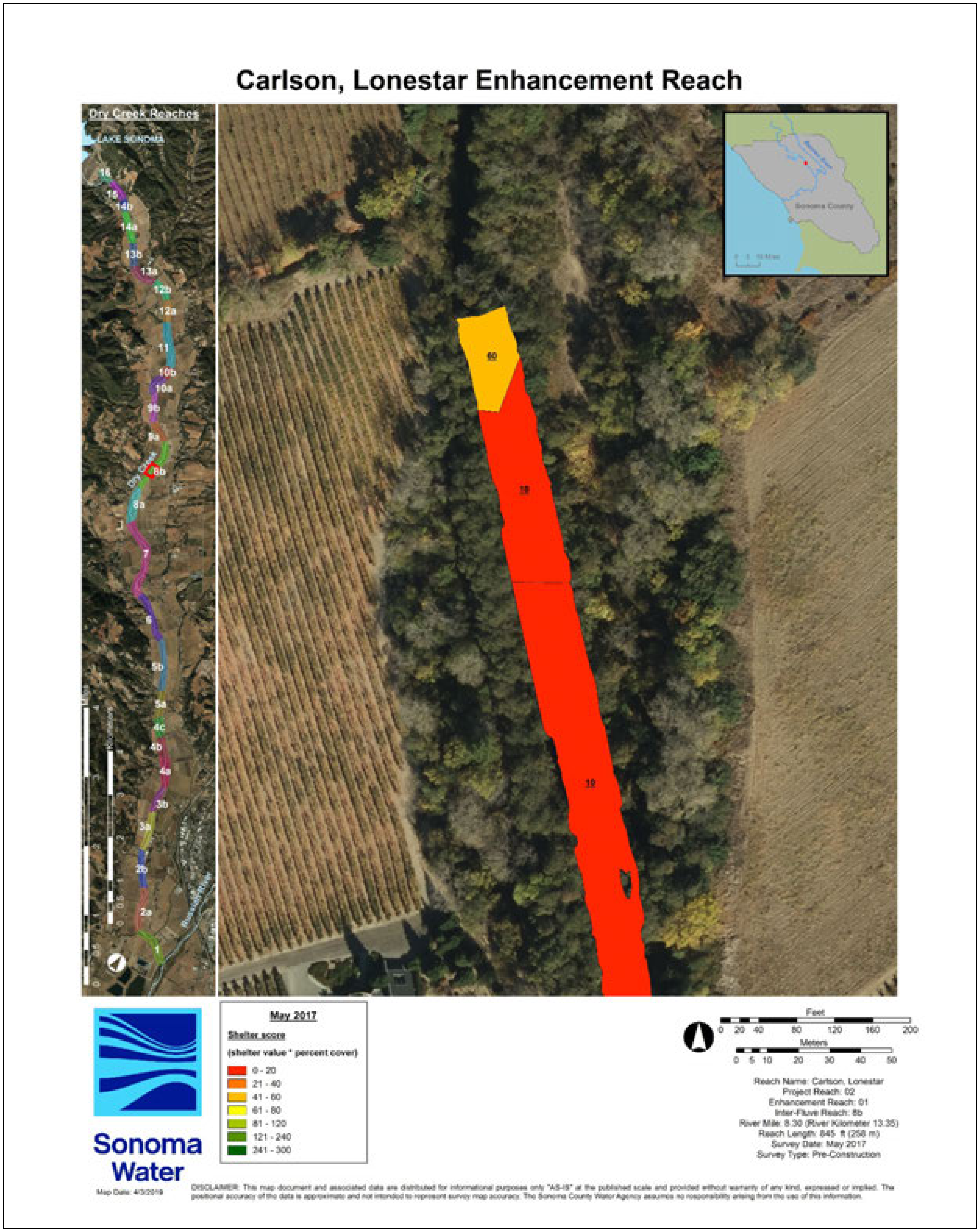


Figure 5.2.7. Habitat unit shelter values within the Carlson, Lonestar enhancement reach, May 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.14. Spatial roll-up of site average feature and habitat unit ratings for Carlson Lonestar enhancement reach, pre-enhancement, May 2017.

Site number		1			
Site type		Main channel			
Site average feature rating	Site average feature quantitative rating[a]	0			
	Site average feature qualitative rating[a]	Not rated			
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	13			
	Site average qualitative rating[b]	Poor			
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	13			
	Site qualitative rating[c]:	Poor			
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	13			
	Enhancement reach qualitative rating[c]:	Poor			

[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)

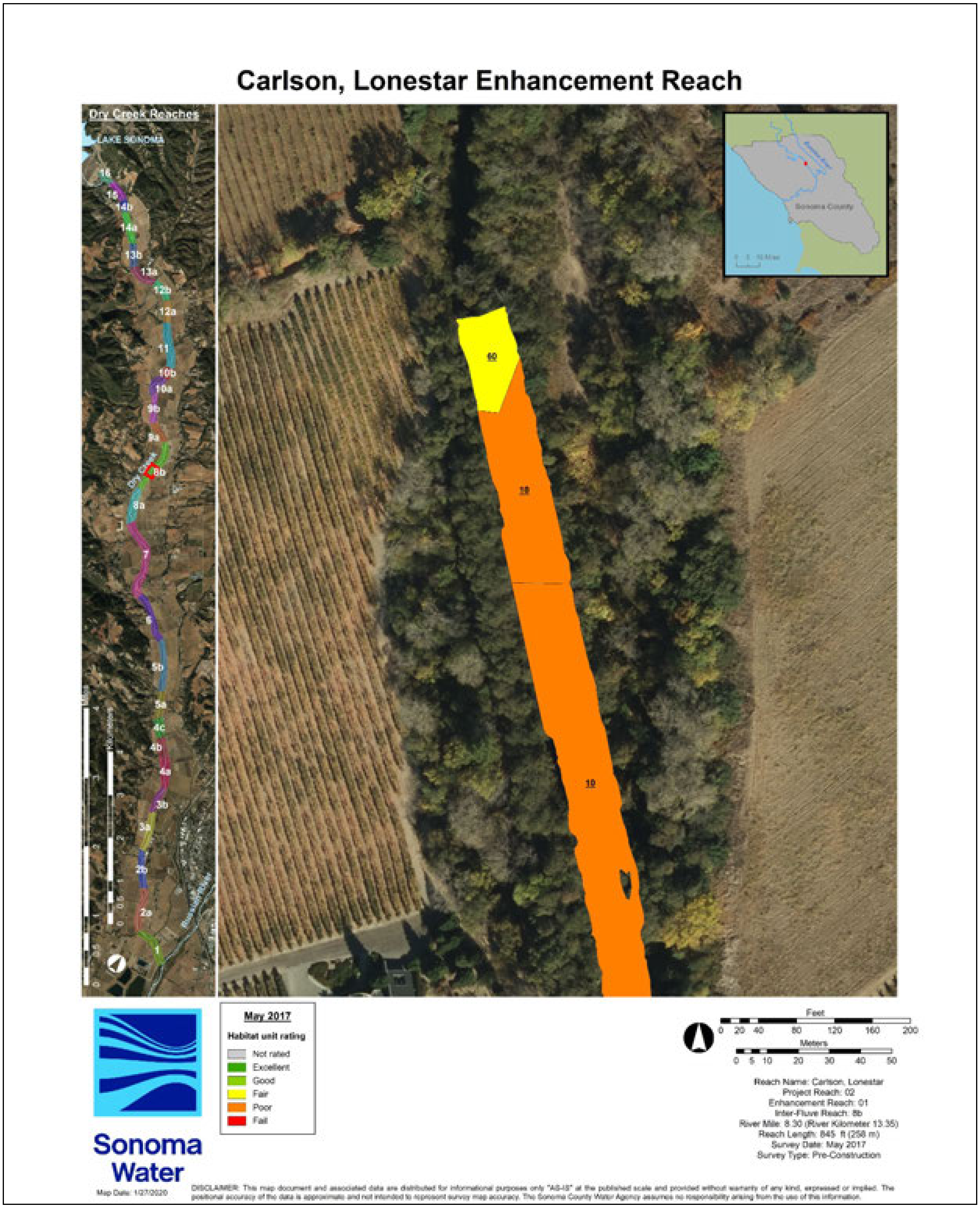


Figure 5.2.8. Habitat unit ratings for the Carlson, Lonestar enhancement reach, May 2017.

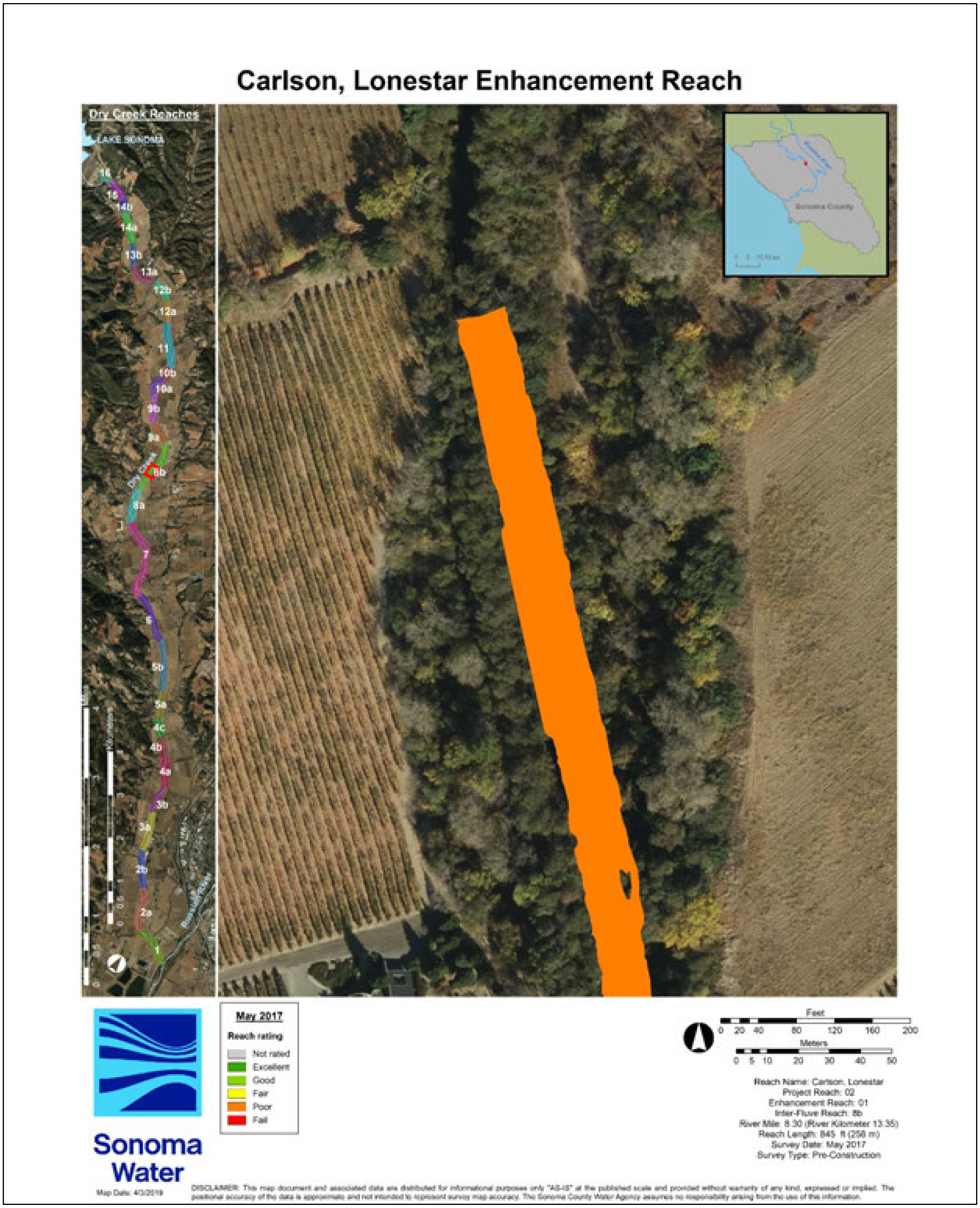


Figure 5.2.9. Pre-enhancement site and reach rating for the Carlson, Lonestar enhancement reach May 2017.

City of Healdsburg Yard Enhancement Reach

Sonoma Water monitored the pre-enhancement condition of the City of Healdsburg City Yard enhancement reach in June 2017. The reach covered 50,285 ft^2 within the main channel of Dry Creek, with 11% meeting optimal depth and velocity criteria, mostly along the channel margins (Table 5.2.15, Figure 5.2.10). Eleven habitat units made up the enhancement reach, with a pool: to riffle ratio of 4:3 (1.33) and an average shelter score of 61 (Table 5.2.16, Figure 5.2.11, Figure 5.2.12). Four habitat units met or exceeded the optimal shelter score of 80. The enhancement reach comprised a main channel enhancement site with fair habitat unit ratings and a fair overall enhancement reach rating (Table 5.2.17, Figure 5.2.13, Figure 5.2.14; see Appendix 5.1 for 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 City of Healdsburg Yard enhancement reach, June 2017.

City of Healdsburg Yard Pre-enhancement June 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	50,285	37,515	6,185	43,700	10,539	4,780	793	5,573
Main channel % of wetted area	100%	75%	12%	87%	21%	10%	2%	11%

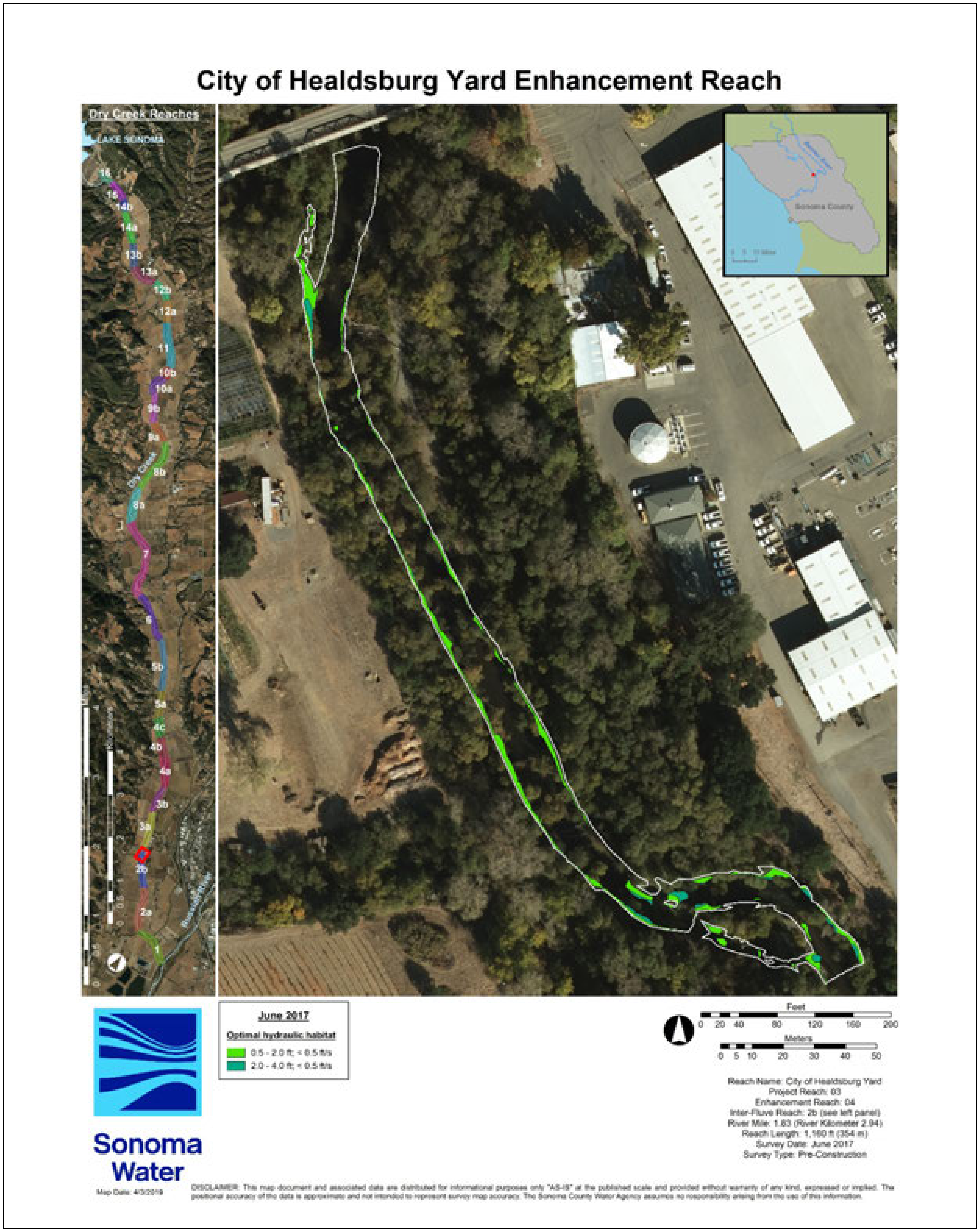


Figure 5.2.10. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the City of Healdsburg Yard enhancement reach, June 2017.

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 City of Healdsburg Yard enhancement reach, Pre-enhancement June 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	30	90
HU02	Pool	2	25	50
HU03	Riffle	2	40	80
HU04	Pool	2	30	60
HU05	Flatwater	2	15	30
HU06	Riffle	1	25	25
HU07	Flatwater	3	45	135
HU08	Pool	2	10	20
HU09	Flatwater	3	15	45
HU10	Riffle	3	15	45
HU11	Flatwater	3	30	90
Pool: riffle	**4:3 (1.33)**			**Avg = 61**

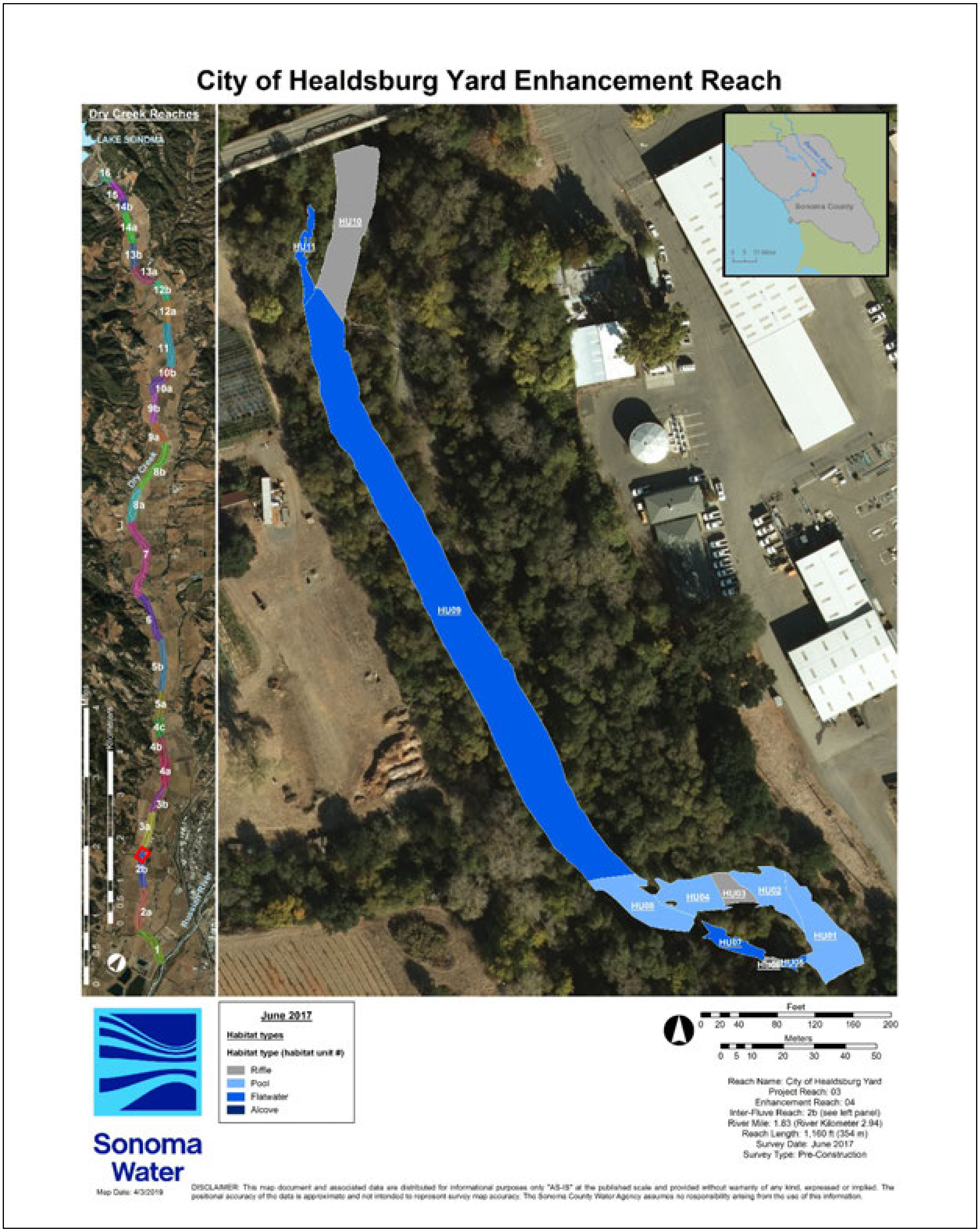


Figure 5.2.11. Habitat unit number and type within the City of Healdsburg Yard enhancement reach, June 2017.

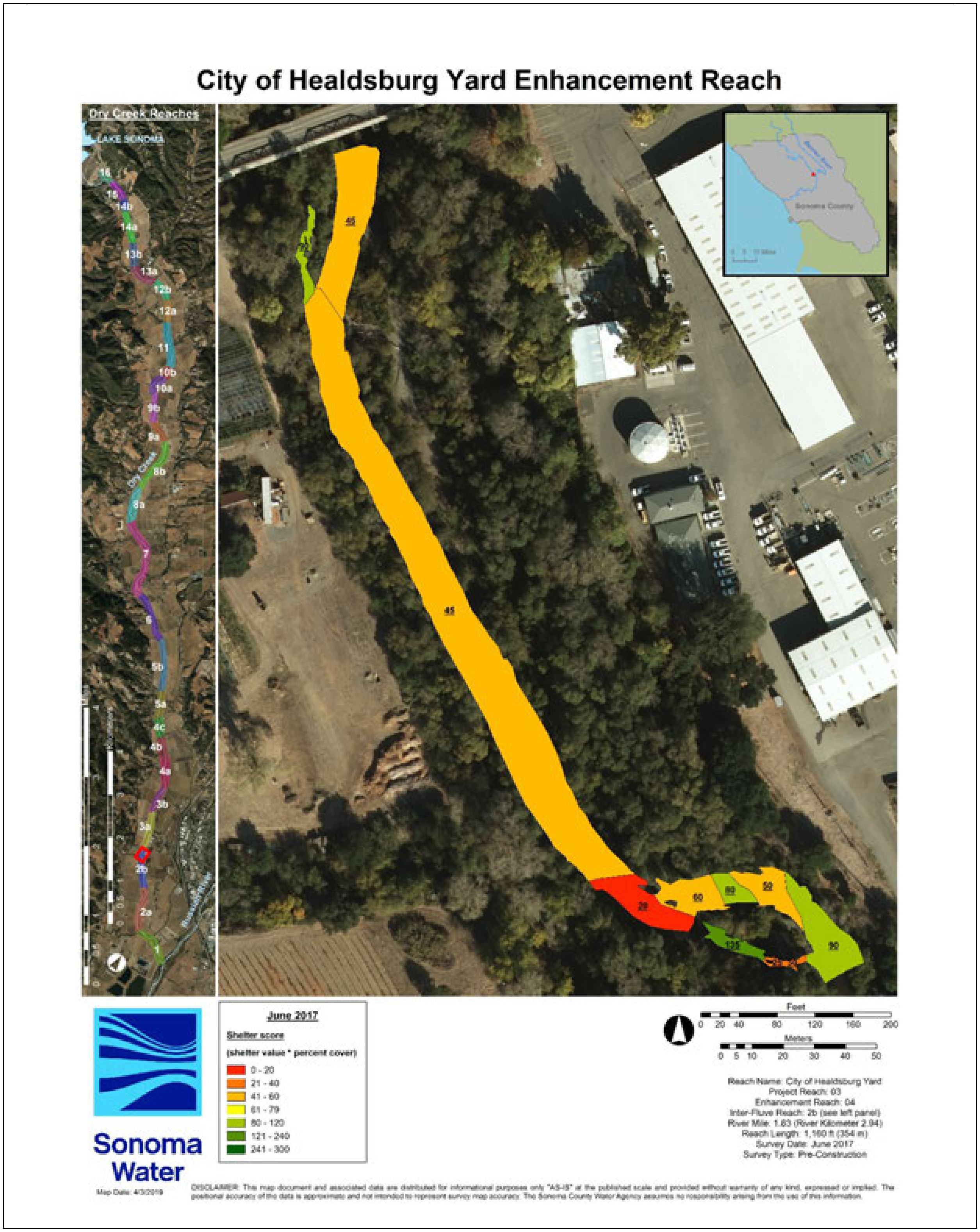


Figure 5.2.12. Habitat unit shelter values within the City of Healdsburg Yard enhancement reach, June 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.17. Spatial roll-up of site average feature and habitat unit ratings for City of Healdsburg enhancement reach, pre-enhancement, June 2017.

Site number		**1**			
Site type		Main channel			
Site average feature rating	Site average feature quantitative rating[a]	0			
	Site average feature qualitative rating[a]	Not rated			
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	15			
	Site average qualitative rating[b]	Fair			
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	15			
	Site qualitative rating[c]:	Fair			
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	15			
	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)

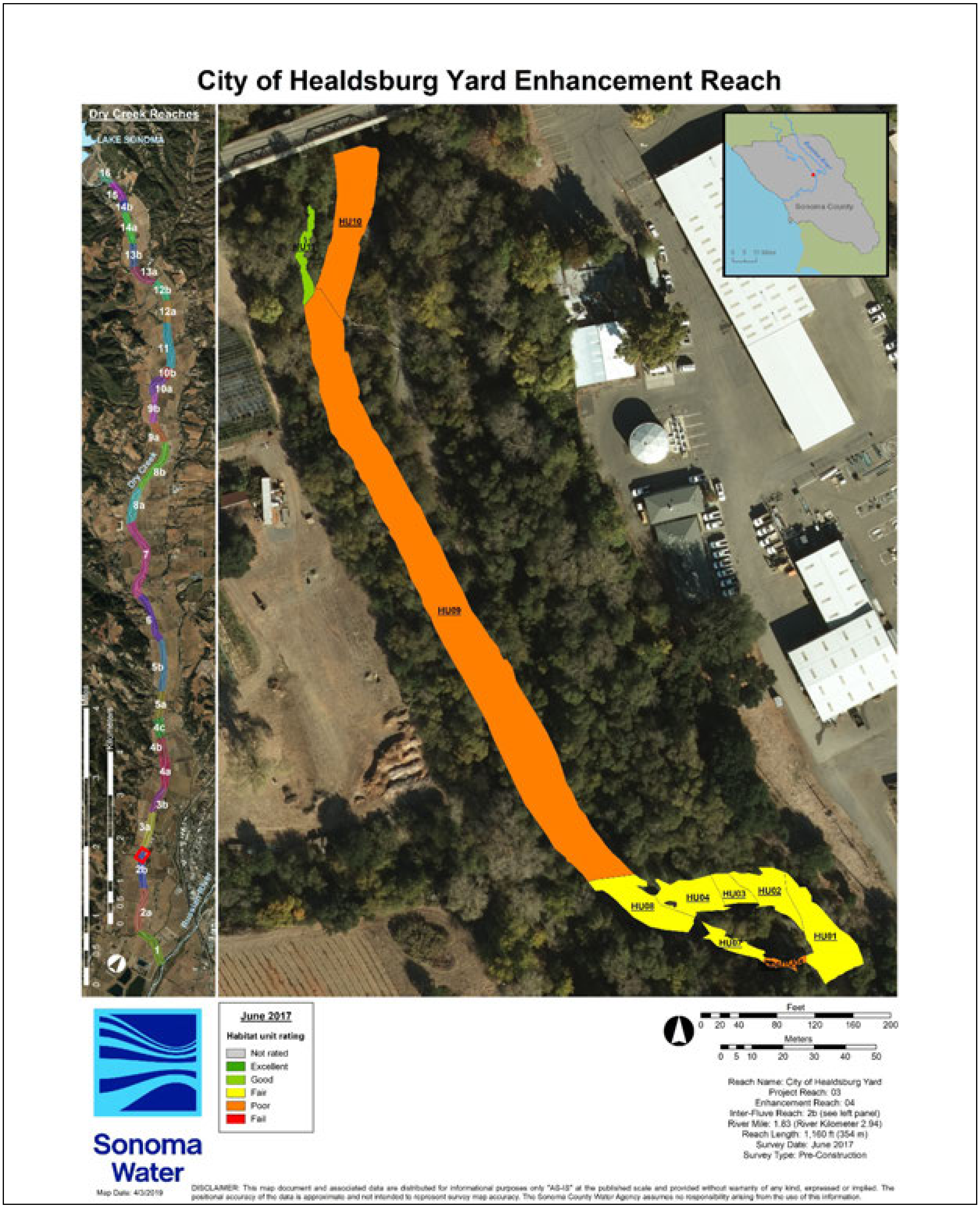


Figure 5.2.13. Habitat unit ratings for the City of Healdsburg Yard enhancement reach, June 2017.

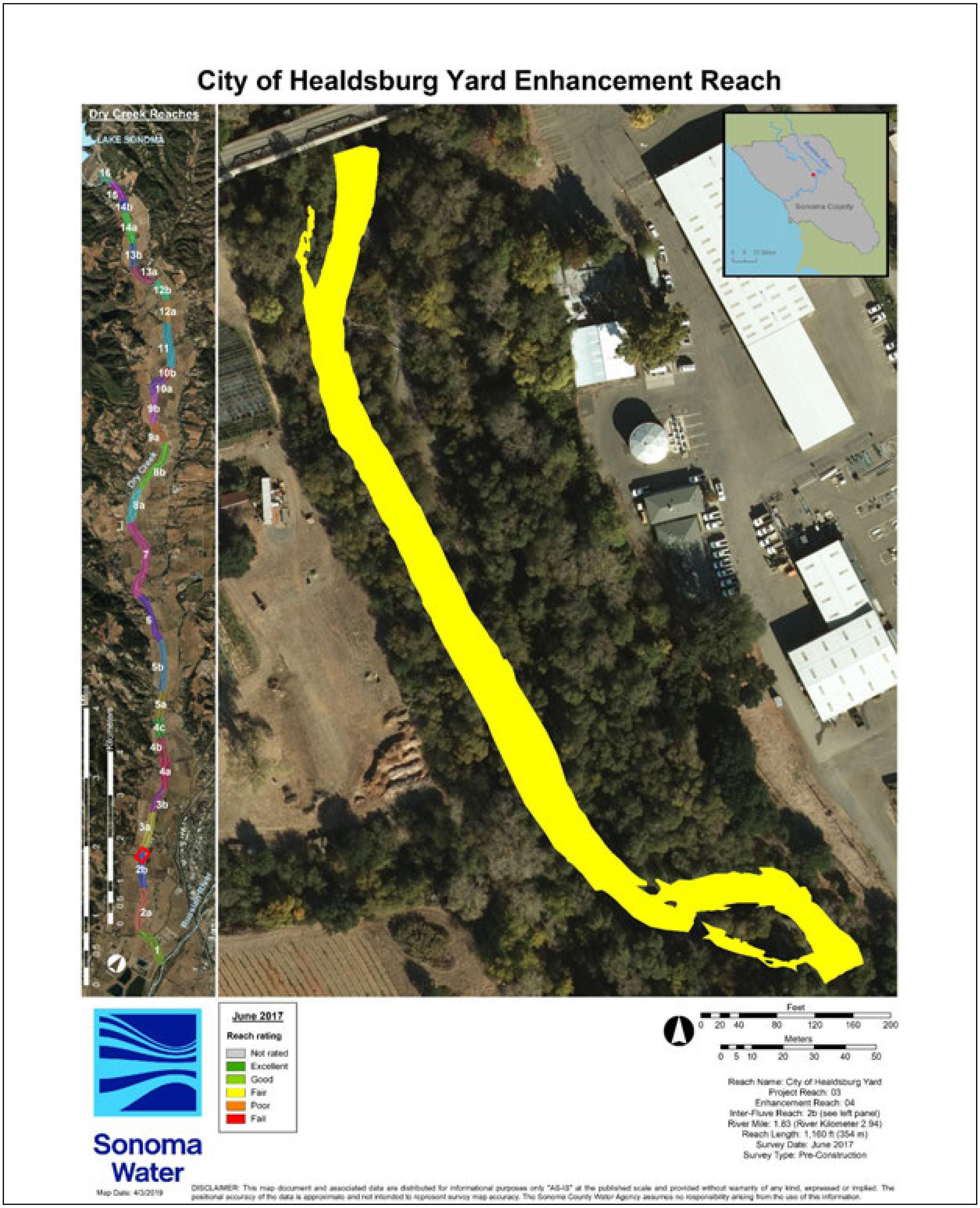


Figure 5.2.14. Pre-enhancement site and reach rating for the City of Healdsburg Yard enhancement reach June 2017.

Post-enhancement

Summary

Sonoma Water monitored the post-enhancement conditions of the of the Carlson, Lonestar and City of Healdsburg Yard enhancement reaches in 2017 (Figure 5.2.4). Overall, the enhanced portion of the reaches covered 128,442 ft^2 within main- and off-channel areas of Dry Creek, with 32% meeting the optimal depth and velocity criteria (Table 5.2.18). The enhancement added 36,628 ft^2 of off-channel and alcove area, of which 58% met optimal depth and velocity criteria, compared to 20,391 ft^2 and 22% in the main channel. Crews recorded 21 habitat units across both enhancement reaches with a total pool to riffle ratio of 5:1 (5.00) and a total average shelter score of 84. Average alcove shelter score (109) and riffle (90, n=1) exceeded the optimum shelter score of 80, followed by flatwaters (74) and pools (63) (Table 5.2.19). Post-enhancement, the Carlson, Lonestar enhancement reach rated poor and the City of Healdsburg Yard enhancement reach rated fair (Table 5.2.20; see below for individual enhancement reach summaries and Appendix 5.1 all measured values, scores, and ratings).

Depth and velocity

Table 5.2.18. Post-enhancement areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches constructed in 2017.

Dry Creek Post-enhancement 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	91,814	67,174	13,255	80,429	28,508	14,422	5,969	20,391
Off channel area	36,628	14,820	15,685	30,505	27,127	10,571	10,592	21,163
Total area	128,442	81,994	28,940	110,934	55,634	24,993	16,561	41,554
Main channel % of wetted area	71%	73%	14%	88%	31%	16%	7%	22%
Off channel % of wetted area	29%	40%	43%	83%	74%	29%	29%	58%
Total % of wetted area	**100%**	**64%**	**23%**	**86%**	**43%**	**19%**	**13%**	**32%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.19. Post-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2017.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	1	90
Pool	5	63
Flatwater	7	74
Alcove	8	109
Pool: riffle	**5: 1 (5.00)**	**Avg = 84**

Reach ratings

Table 5.2.20. Post-enhancement ratings for Dry Creek enhancement reaches constructed in 2017.

Enhancement Reach	Post- -enhancement Rating
Carlson, Lonestar	Good
City of Healdsburg Yard	Good

Carlson, Lonestar Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Carlson, Lonestar enhancement reach in September 2017. The enhancement reach encompassed 55,000 ft^2 within main- and off channel areas of Dry Creek, with 33% meeting optimal depth and velocity criteria (Table 5.2.21 and Figure 5.2.15). The enhancement added 14,237 ft^2 of off-channel and alcove area, of which 77% met optimal depth and velocity criteria, compared to 11% in the main channel. Six habitat units composed the enhancement reach, with a pool to riffle ratio of 1:1 (1.00) and an average shelter value of 113 (Table 5.2.22, Figure 5.2.16, Figure 5.2.17). Five habitat units met or exceeded the optimum shelter score of 80. The reach comprised three enhancement sites (one main channel, two side channels; Figure 5.2.18) with excellent site average feature ratings and fair to good site average habitat unit ratings (Table 5.2.23, Figure 5.2.19, Figure 5.2.20). Site ratings ranged from fair to excellent, with the main channel site scoring lower due to fair site average habitat unit ratings compared to good site average habitat unit ratings for side channel sites (Table 5.2.23, Figure 5.2.21). Overall, the Carlson, Lonestar enhancement reach, post-enhancement, received a good effectiveness monitoring rating (Table 5.2.23,Figure 5.2.22; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.21. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Carlson, Lonestar enhancement reach, September 2017.

Carlson, Lonestar Post-enhancement September 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	36,476	29,122	3,529	32,651	6,158	3,145	931	4,076
Off channel area	18,593	6,213	8,913	15,126	17,700	5,434	8,803	14,237
Total area	**55,069**	**35,335**	**12,443**	**47,778**	**23,858**	**8,579**	**9,735**	**18,313**
Main channel % of wetted area	66%	80%	10%	90%	17%	9%	3%	11%
Off channel % of wetted area	34%	33%	48%	81%	95%	29%	47%	77%
Total % of wetted area	**100%**	**64%**	**23%**	**87%**	**43%**	**16%**	**18%**	**33%**

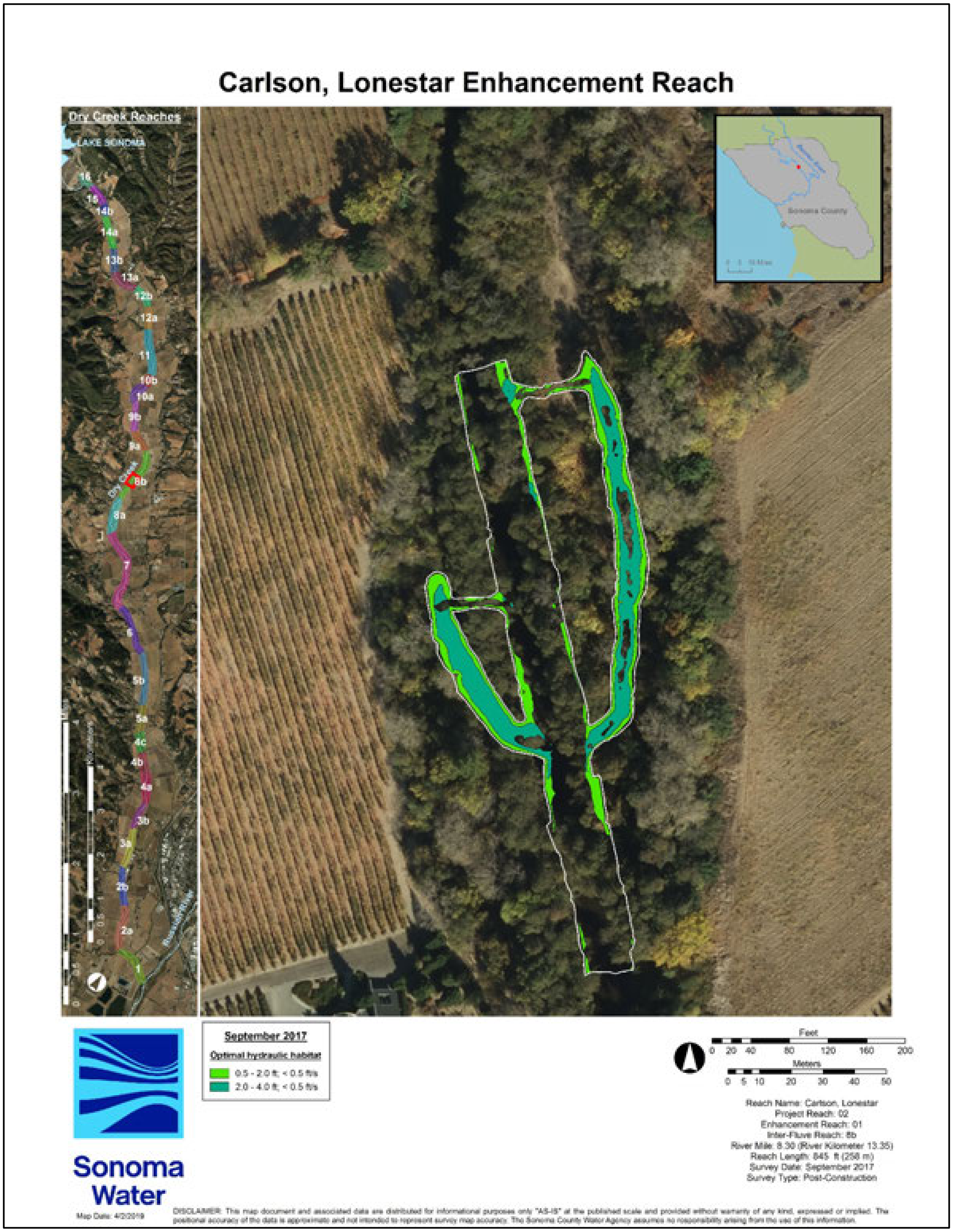


Figure 5.2.15. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Carlson, Lonestar enhancement reach, September 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.22. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Carlson, Lonestar enhancement reach, Post-enhancement September 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU02	Riffle	2	45	90
HU03	Flatwater	3	15	45
HU04	Alcove	3	50	150
HU05	Alcove	3	55	165
HU06	Flatwater	3	30	90
HU07	Flatwater	3	45	135
Pool: riffle	**0:1 (NA)**			**Avg = 113**

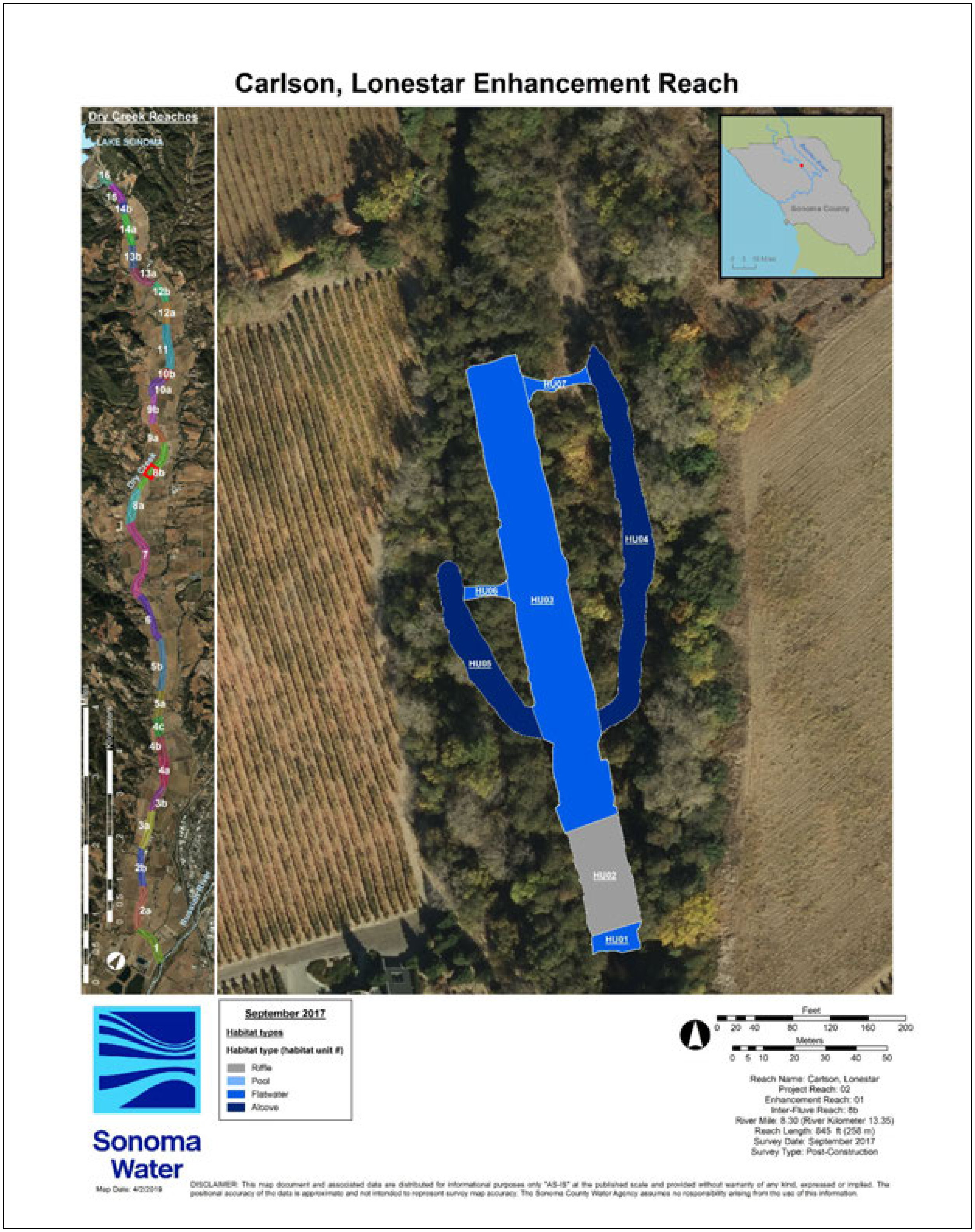


Figure 5.2.16. Habitat unit number and type within the Carlson, Lonestar enhancement reach, September 2017.

Figure 5.2.17. Habitat unit shelter values within the Carlson, Lonestar enhancement reach, September 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.23. Post-enhancement site and reach ratings for the Carlson, Lonestar enhancement reach, September 2017.

Site number		1	2	3	
Site type		Main channel	Side channel	Side channel	
Site average feature rating	Site average feature quantitative rating[a]	13	13	14	
	Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	14	26	26	
	Site average qualitative rating[b]	Fair	Good	Good	
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	27	39	40	
	Site qualitative rating[c]	Fair	Good	Excellent	
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	33			
	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)

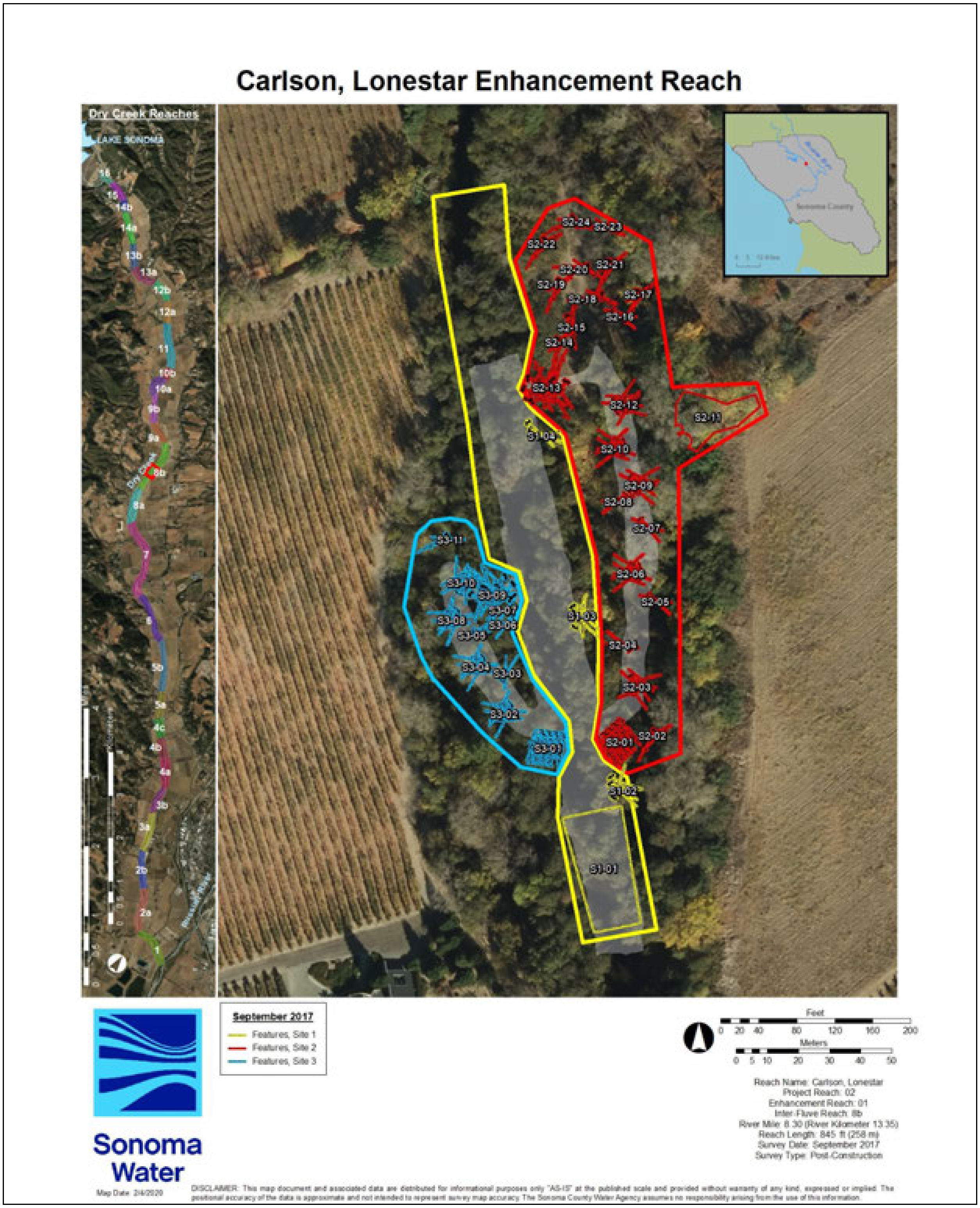


Figure 5.2.18. Enhancement sites and features within the Carlson, Lonestar enhancement reach, September 2017. Site 1 and features = yellow, site 2 and features = red, site 3 and features = blue, site 4 and features = green.

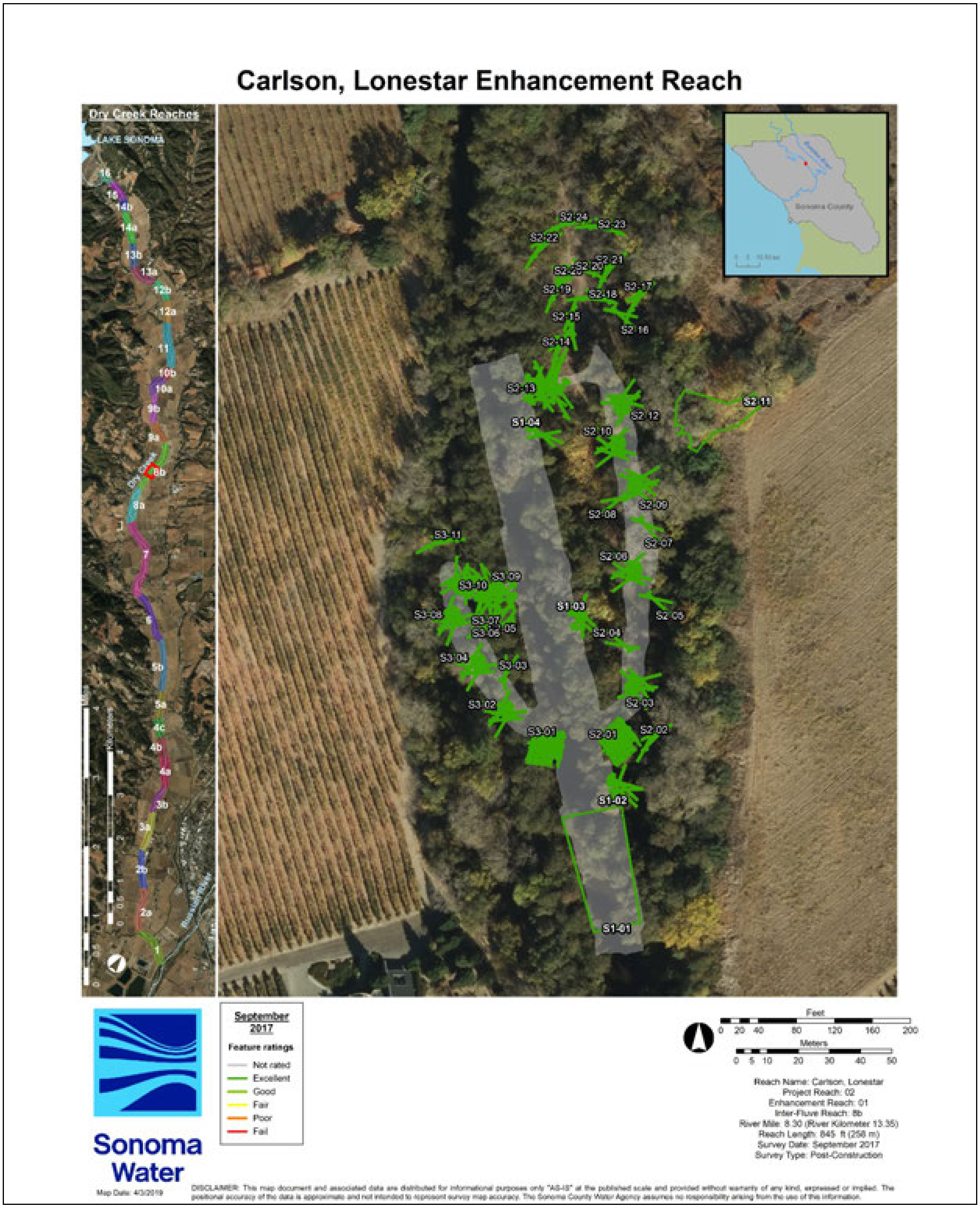


Figure 5.2.19. Feature ratings for the Carlson, Lonestar enhancement reach, September 2017.

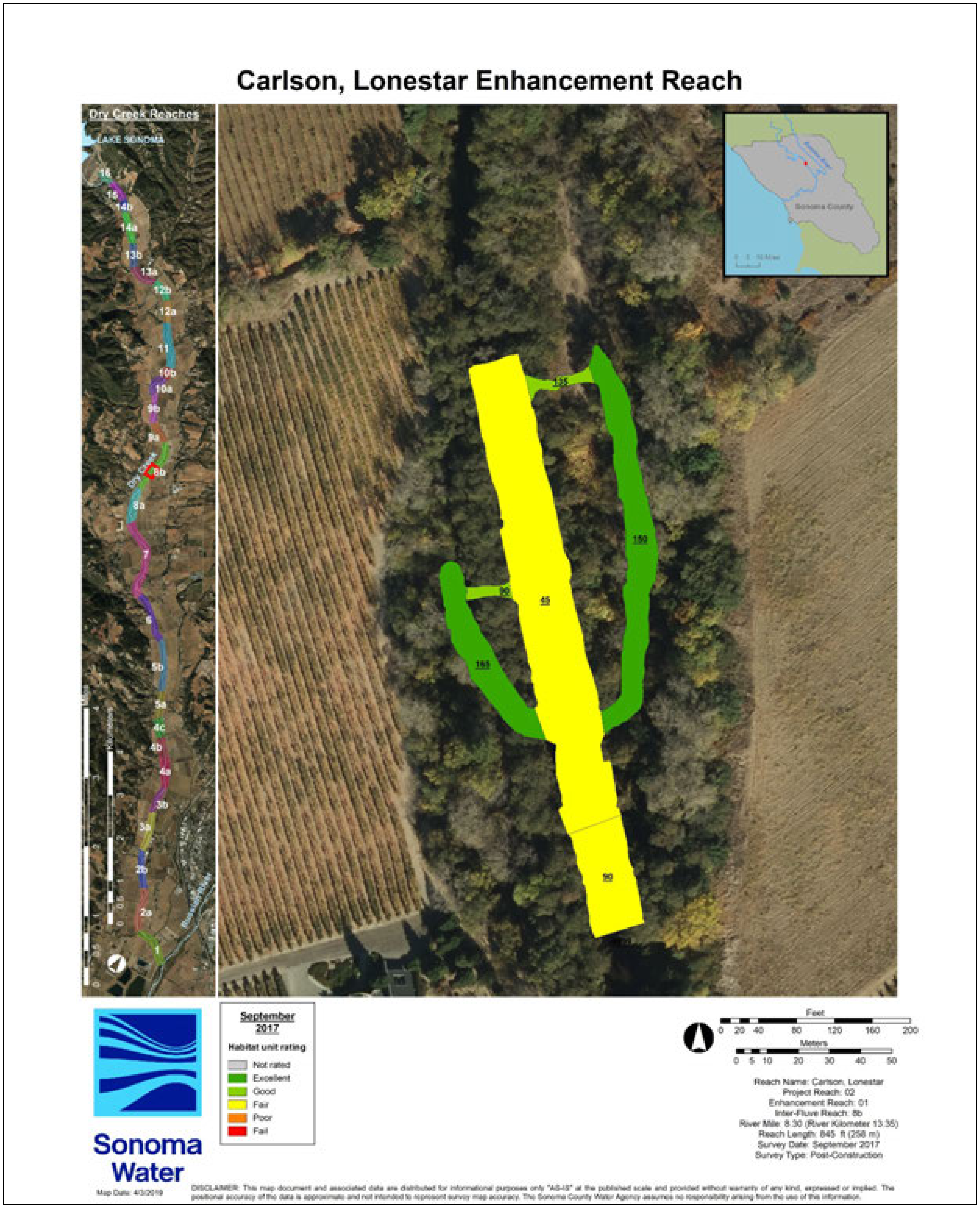


Figure 5.2.20. Habitat unit ratings for the Carlson, Lonestar enhancement reach, September 2017.

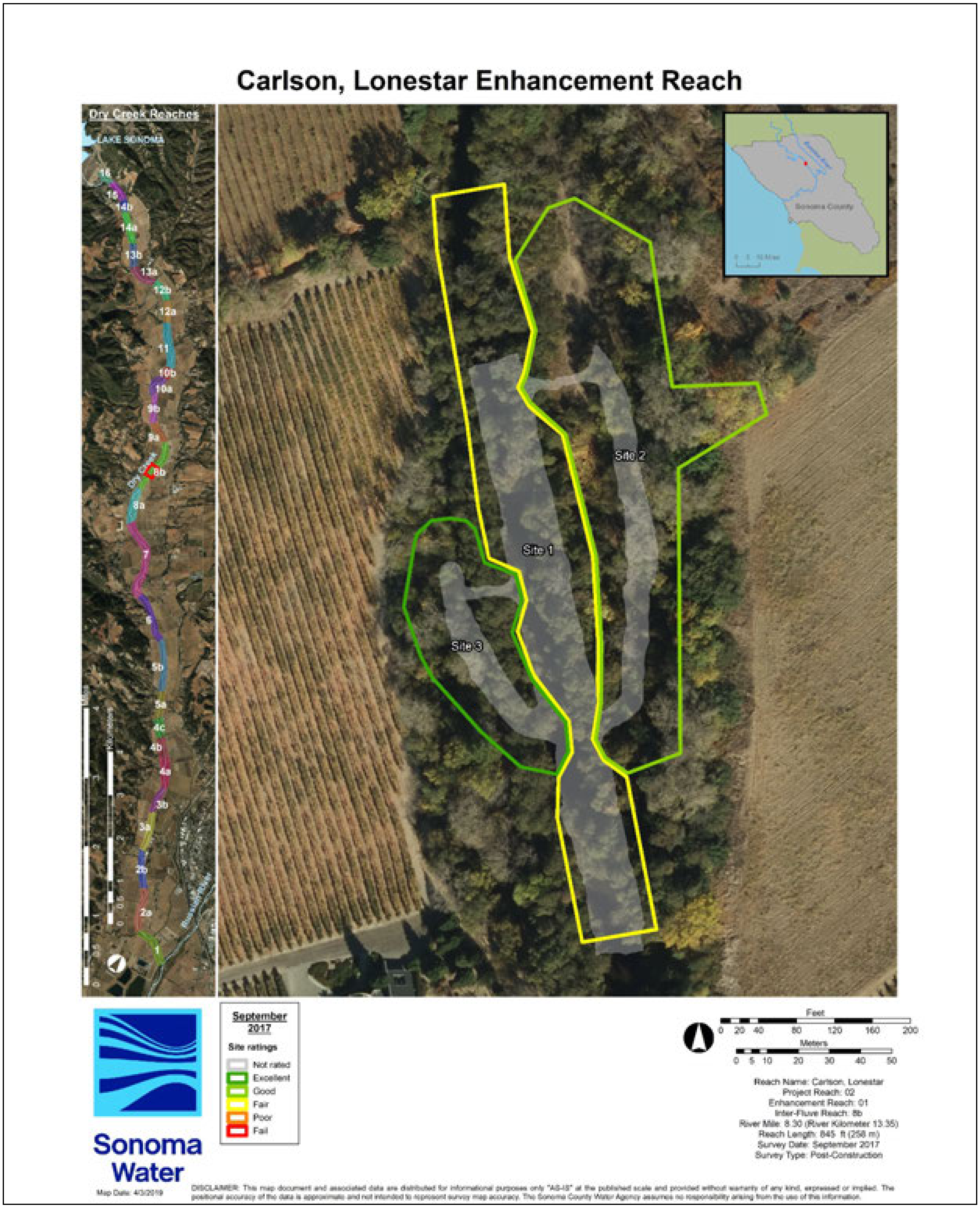


Figure 5.2.21. Post enhancement site ratings for the Carlson, Lonestar enhancement reach, September 2017.

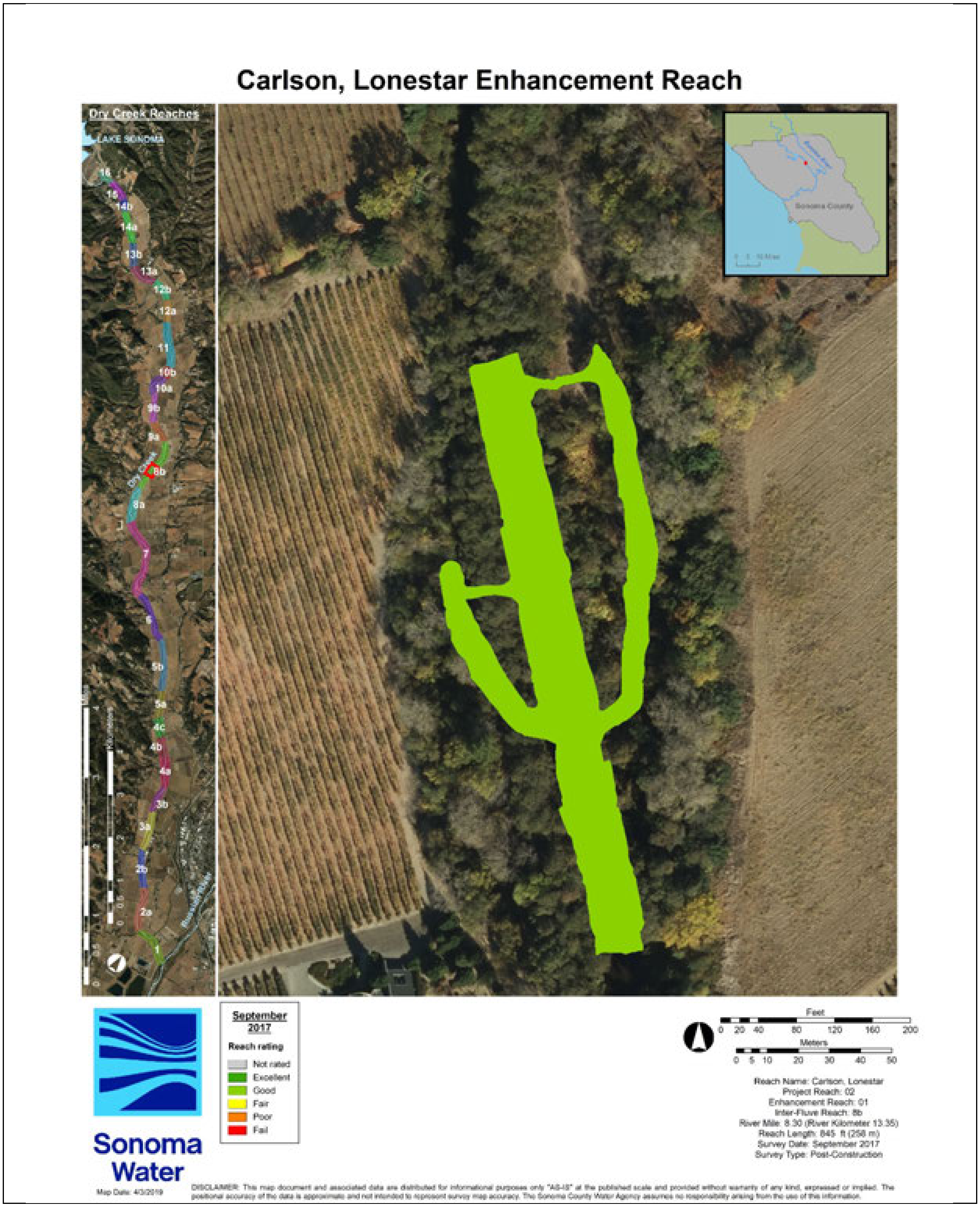


Figure 5.2.22. Post-enhancement reach rating for the Carlson, Lonestar enhancement reach, September 2017.

City of Healdsburg Yard Enhancement Reach

Sonoma Water monitored the post-enhancement condition of the Healdsburg City Yard enhancement reach in September 2017. The enhanced reach encompassed 77,000 ft^2 within main- and off-channel areas of Dry Creek with 32% of the total area meeting optimal depth and velocity criteria (Table 5.2.24). The enhancement added 7,325 ft^2 of alcove and 15,717 ft^2 of side-channel, of which 64-83% and 35%, respectively, met optimal depth and velocity criteria, compared to 26% in the main channel (Table 5.2.24, Figure 5.2.23), Fifteen habitat units composed the enhancement reach, with a pool to riffle ratio of 5:0 (NA, no decimal equivalent) and average shelter score of 68 (Table 5.2.25, Figure 5.2.24, Figure 5.2.25). Six habitat units met or exceeded the optimum shelter score of 80. The enhancement reach comprised five enhancement sites (one main-channel, two alcoves, two side channels; Table 5.2.26, Figure 5.2.26), with excellent site average feature ratings, and fair to excellent site average habitat unit ratings (Table 5.2.26, Figure 5.2.27, Figure 5.2.28). We did not collect habitat unit data for enhancement site 5 as the enhancement site and associated features occurred along the bank above the water surface elevation. Enhancement site ratings ranged from good to excellent, with the main-channel sites scoring numerically lower, but still receiving a good rating (Table 5.2.26, Figure 5.2.29). Overall, the City of Healdsburg Yard enhancement reach received a good effectiveness monitoring rating (Table 5.2.26,Figure 5.2.30; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.24. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the City of Healdsburg Yard enhancement reach, September 2017.

City of Healdsburg Yard Post-enhancement September 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	50,330	36,802	7,768	44,570	17,351	10,035	3,080	13,115
Main channel alcove area	5,007	1,250	1,957	3,207	4,999	1,242	1,957	3,200
Side channel alcove area	2,318	1,452	476	1,928	2,318	1,452	476	1,928
Side channel area	15,717	7,155	6,645	13,800	7,108	3,686	1,789	5,474
Total area	**73,373**	**46,659**	**16,847**	**63,506**	**31,776**	**16,414**	**7,303**	**23,717**
Main channel % of wetted area	69%	73%	15%	89%	34%	20%	6%	26%
Main channel alcove % of wetted area	7%	25%	39%	64%	100%	25%	39%	64%
Side channel alcove % of wetted area	3%	63%	21%	83%	100%	63%	21%	83%
Side channel % of wetted area	21%	46%	42%	88%	45%	23%	11%	35%
Total % of wetted area	**100%**	**64%**	**23%**	**87%**	**43%**	**22%**	**10%**	**32%**

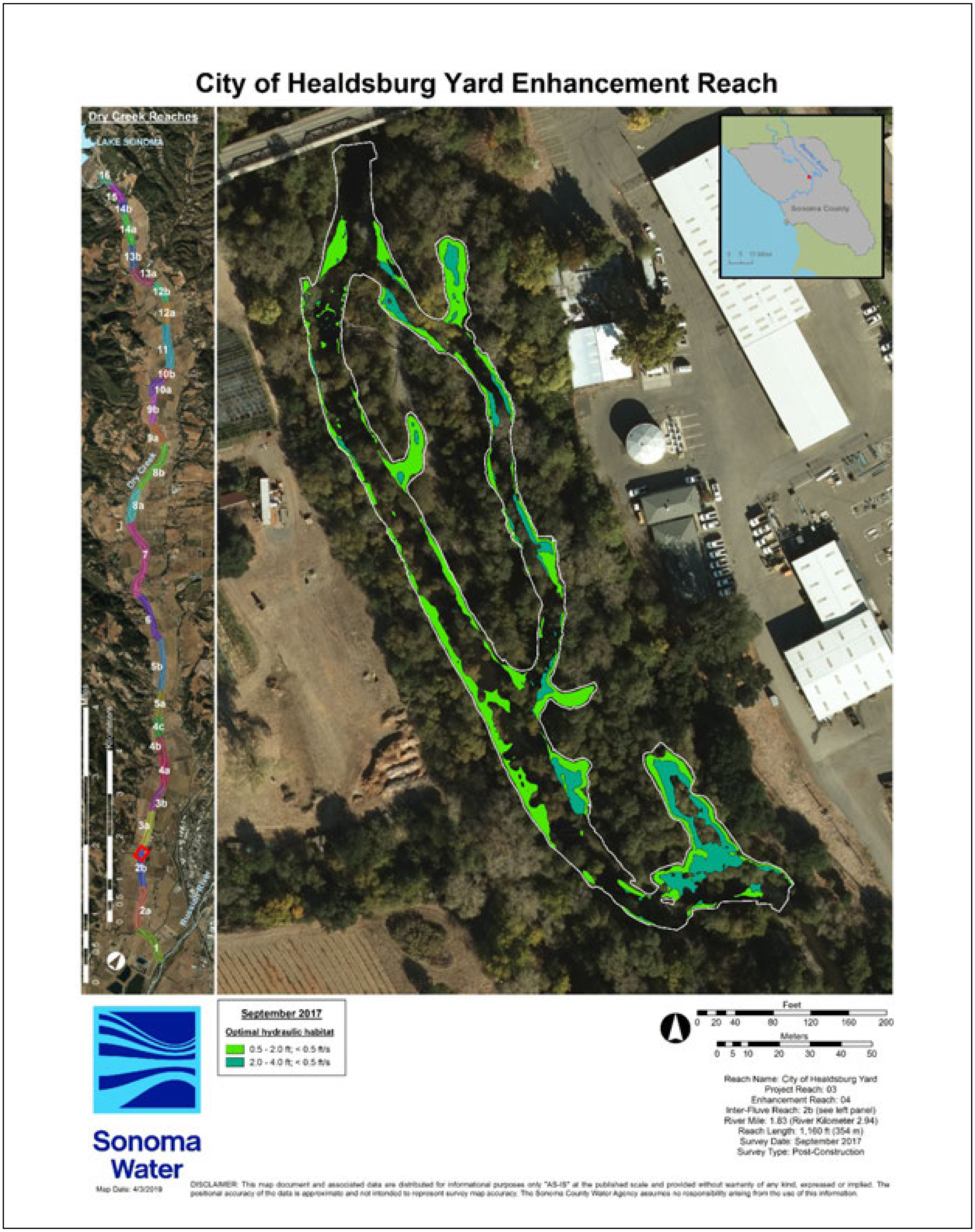


Figure 5.2.23. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the City of Healdsburg Yard enhancement reach, September 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2. 25. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the City of Healdsburg Yard enhancement reach, Post-enhancement September 2017.Main channel alcove HU 15 did not have habitat level attributes assessed.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	0	0	0
HU02	Alcove	3	30	90
HU03	Pool	3	20	60
HU04	Pool	3	45	135
HU05	Flatwater	3	25	75
HU06	Alcove	3	50	150
HU07	Flatwater	3	30	90
HU08	Alcove	3	20	60
HU09	Pool	3	30	90
HU10	Pool	3	10	30
HU11	Alcove	3	40	120
HU12	Alcove	3	10	30
HU13	Flatwater	3	25	75
HU14	Flatwater	2	5	10
HU15	Alcove	0	0	0
Pool: riffle	**5:0 (NA)**			**Avg = 68**

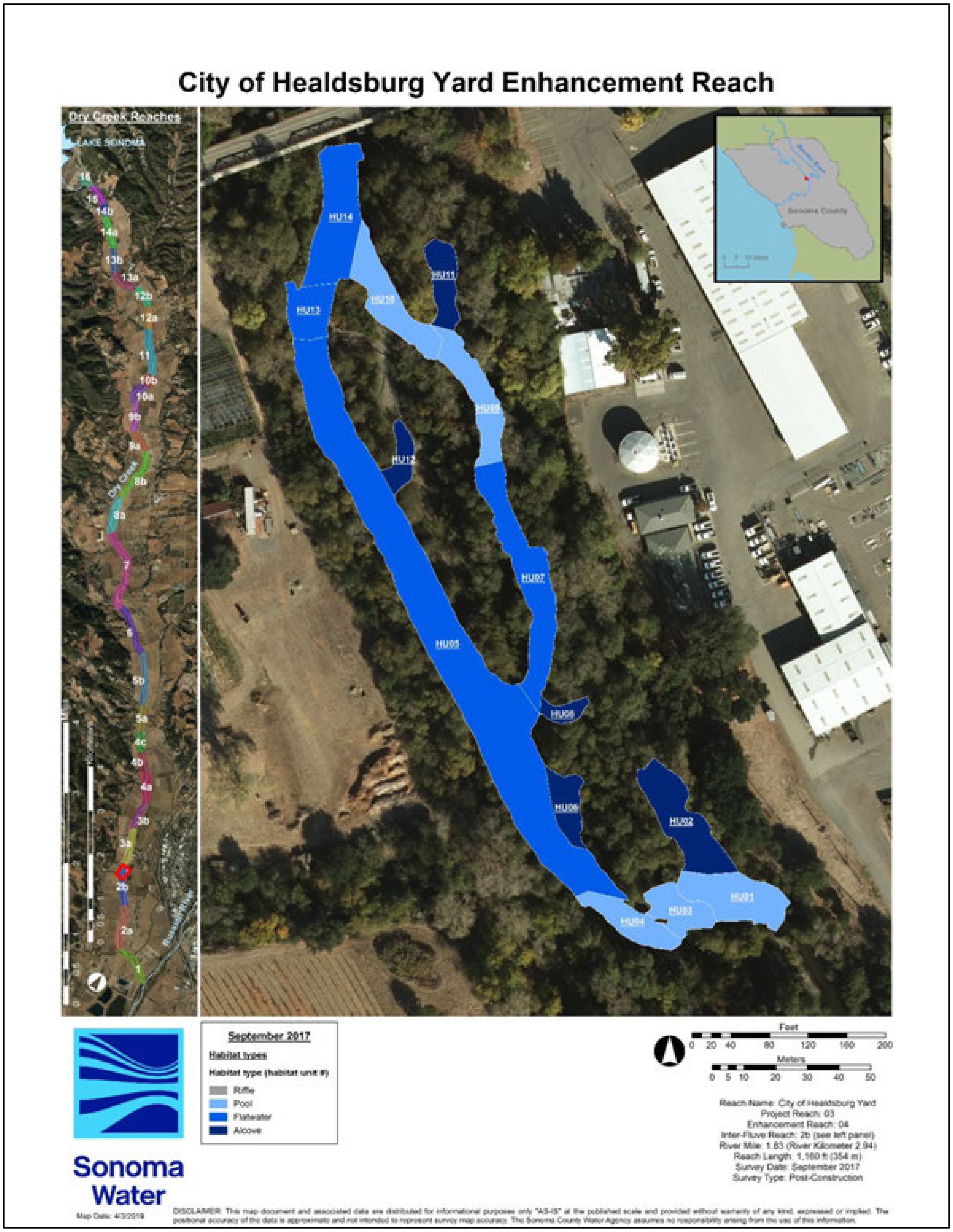


Figure 5.2.24. Habitat unit number and type within the City of Healdsburg Yard enhancement reach, September 2017.

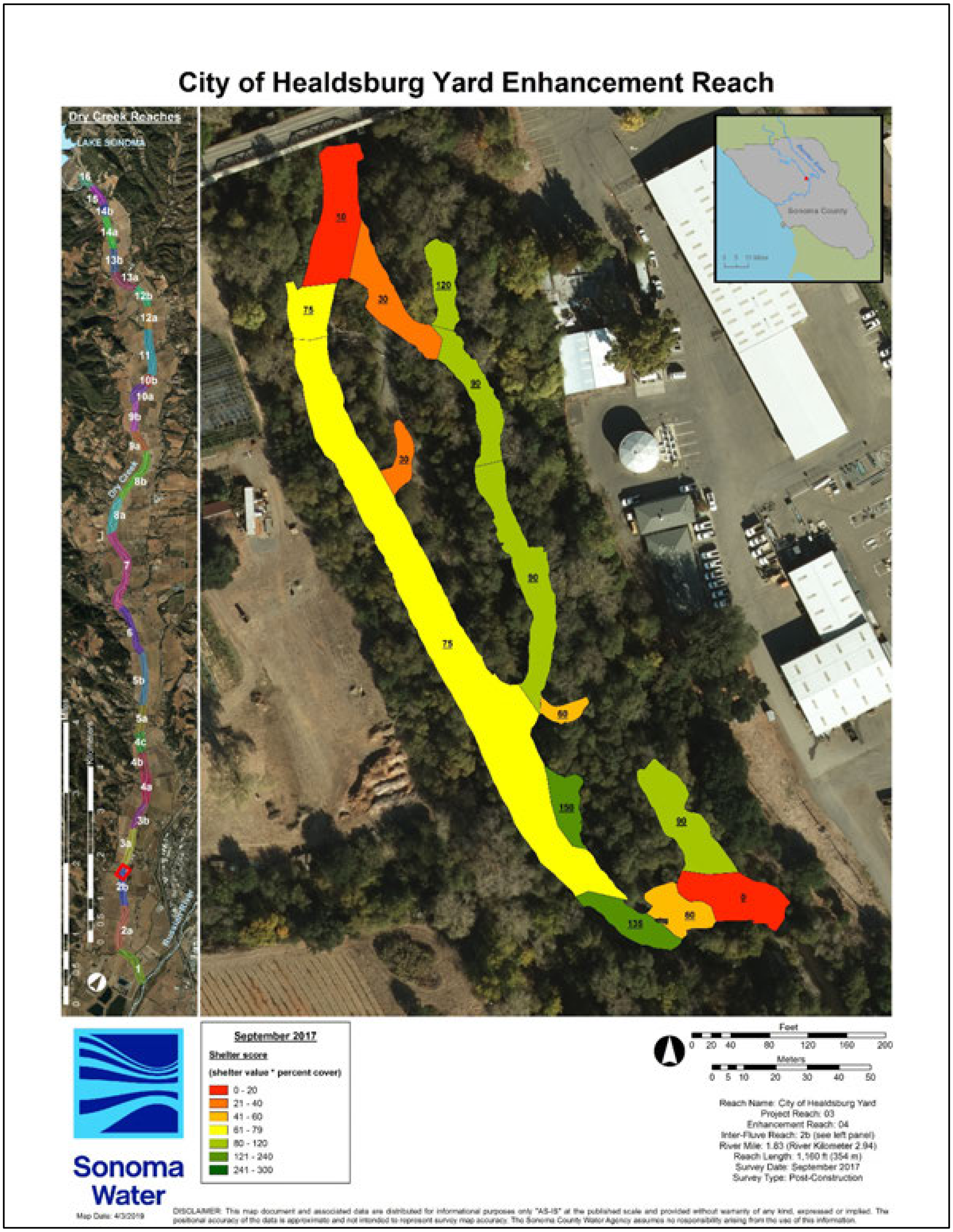


Figure 5.2.25. Habitat unit shelter values within the City of Healdsburg Yard enhancement reach, September 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.26. Post- enhancement site and reach ratings for the City of Healdsburg Yard enhancement reach, September 2017.

Site number		**1**	**2**	**3**	**4**	**5**
Site type		Main channel	Alcove	Side channel	Alcove	Side channel
Site average feature rating	Site average feature quantitative rating[a]	14	14	14	14	14
	Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	19	24	22	28	0
	Site average qualitative rating[b]	Fair	Good	Good	Excellent	Not rated
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	33 [c]	38 [c]	36 [c]	42 [c]	14
	Site qualitative rating[c]:	Good [c]	Good [c]	Good [c]	Excellent [c]	Excellent [a]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	33				
	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)

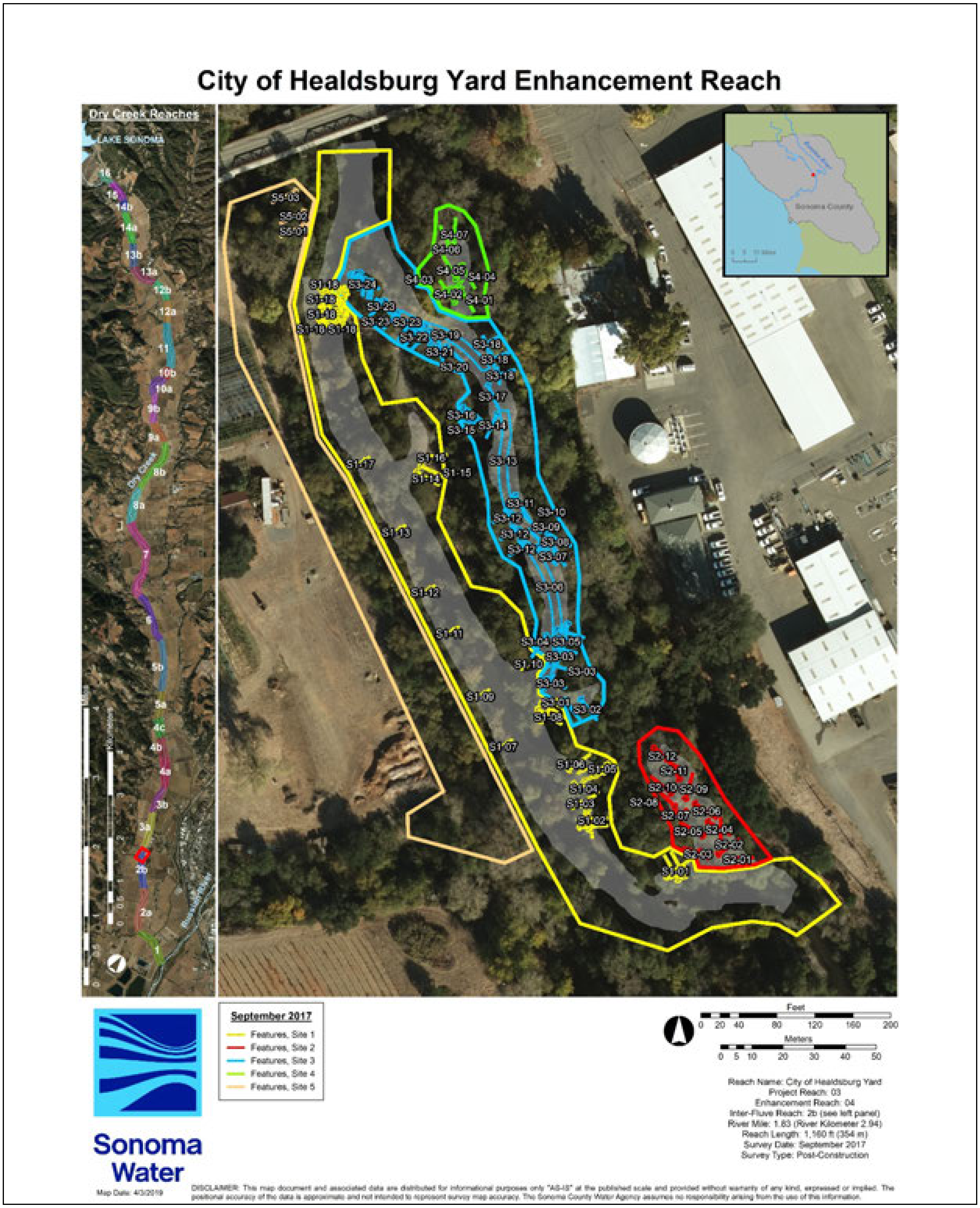


Figure 5.2.26. Enhancement sites and features within the City of Healdsburg Yard enhancement reach, September 2017.

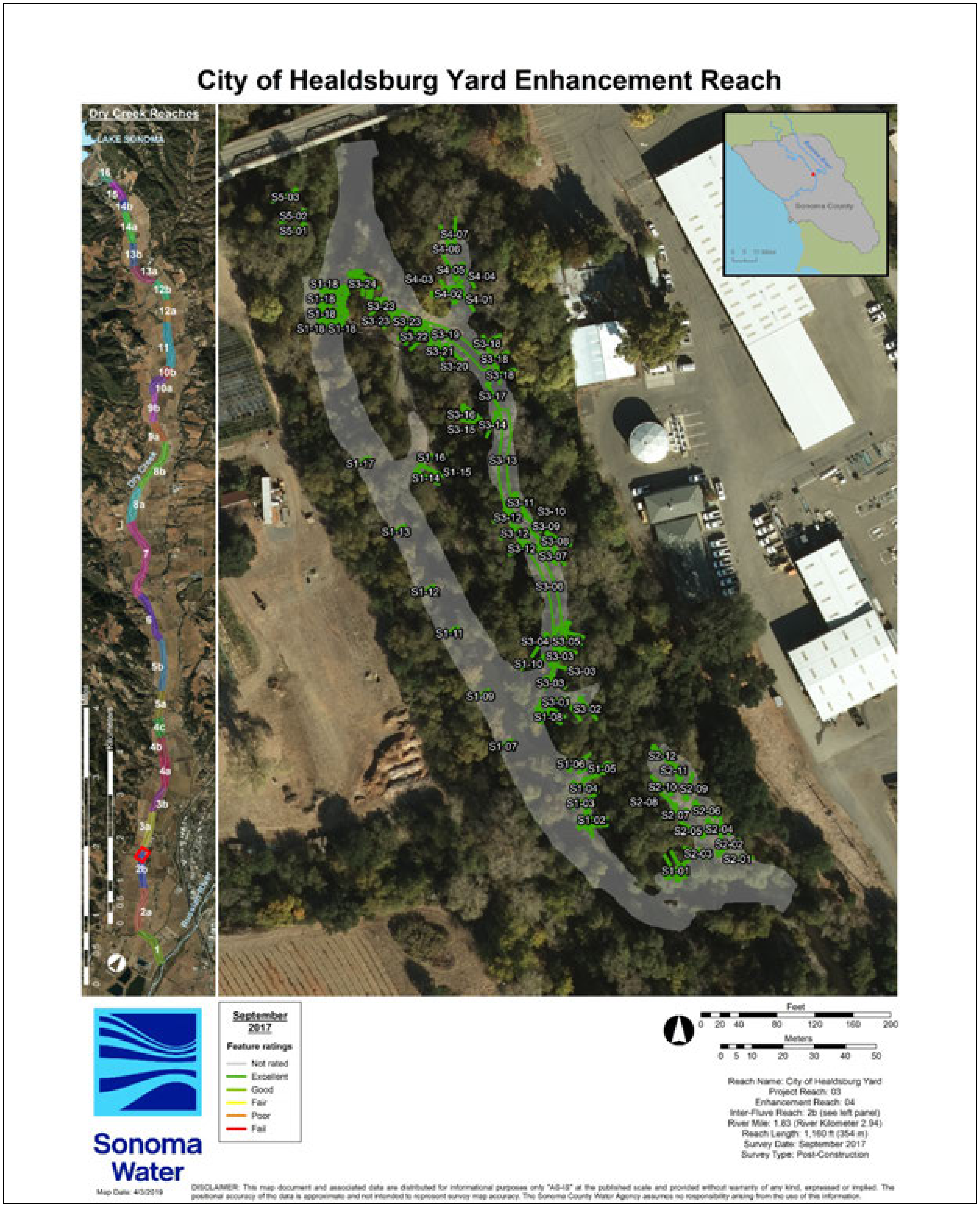


Figure 5.2.27. Feature ratings for the City of Healdsburg Yard enhancement reach, September 2017.

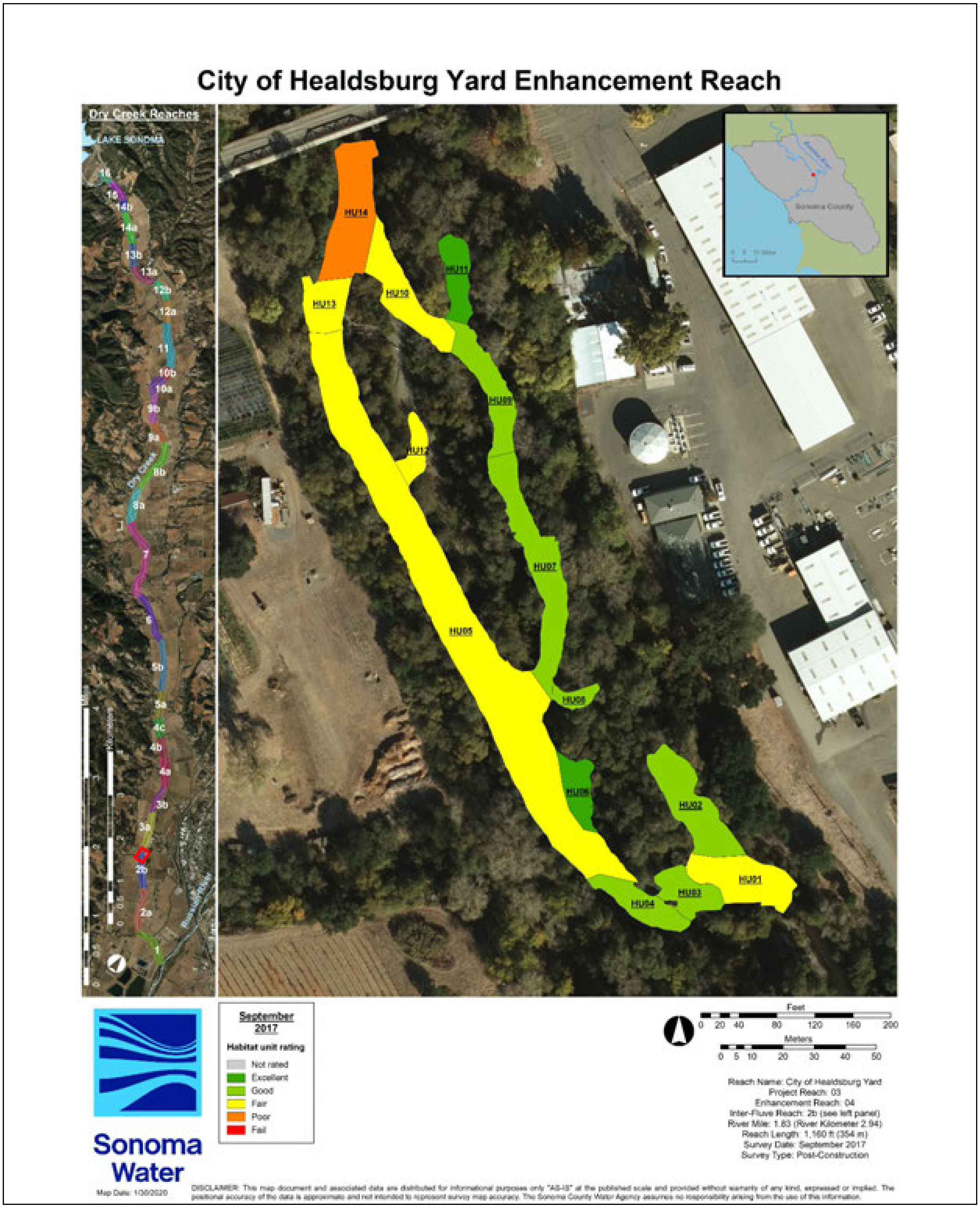


Figure 5.2.28. Habitat unit ratings for the City of Healdsburg Yard enhancement reach, September 2017.

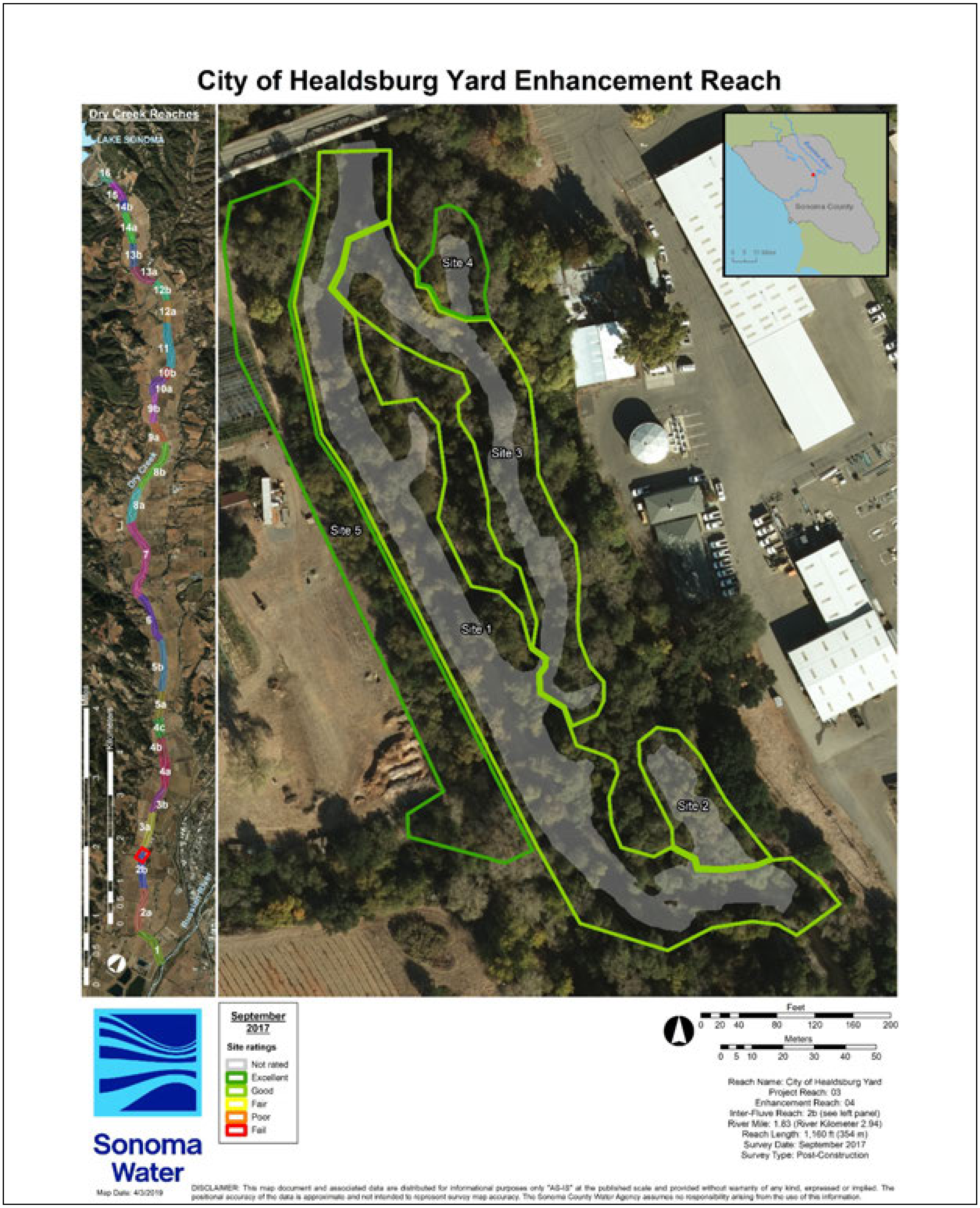


Figure 5.2.29. Post enhancement site ratings for the City of Healdsburg Yard enhancement reach, September 2017.

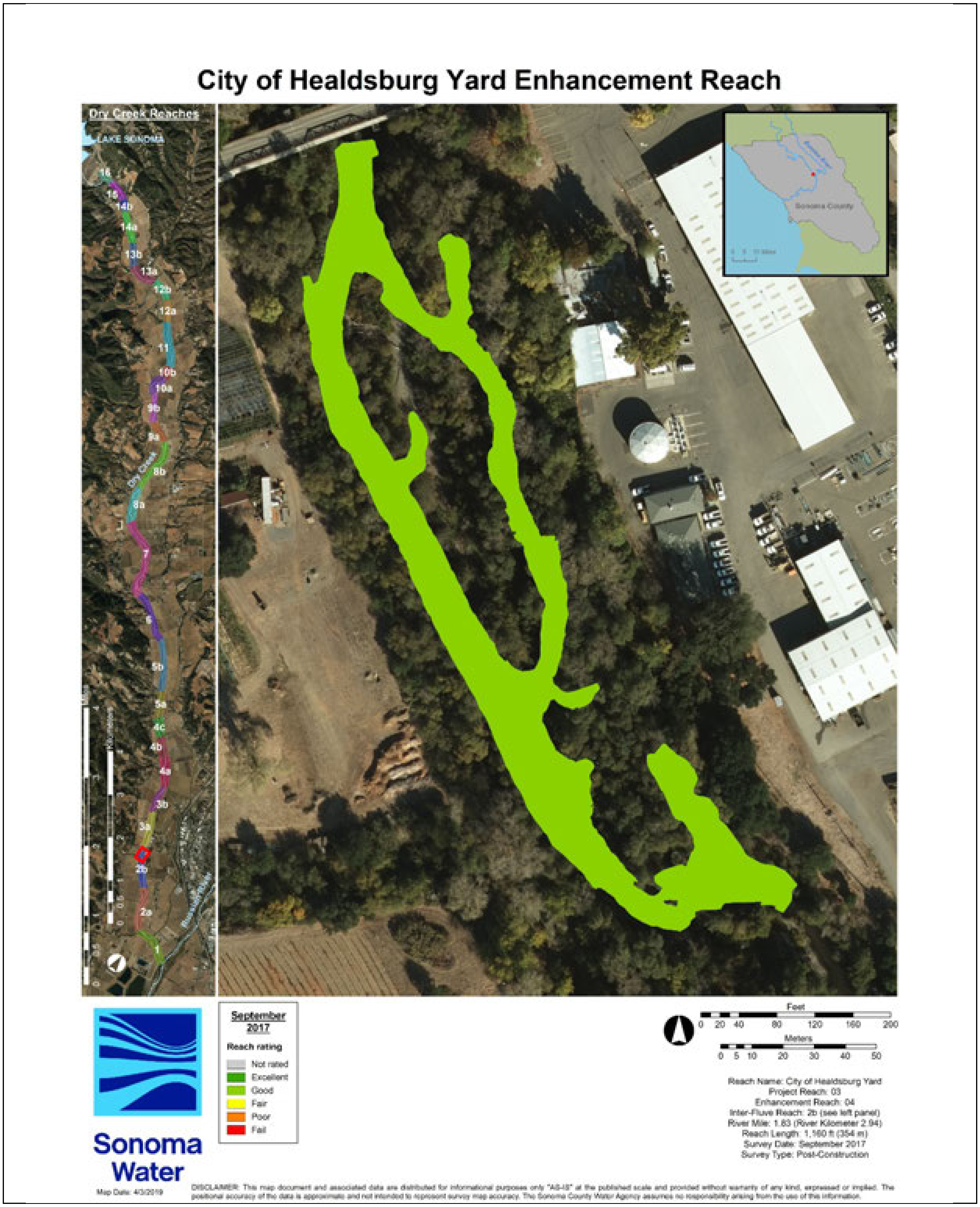


Figure 5.2.30. Post-enhancement reach rating for the City of Healdsburg Yard enhancement reach, September 2017.

Post-effective Flow

Summary

Sonoma Water monitored the post-effective flow conditions of the Truett Hurst, Meyer, Van Alyea, Farrow Wallace, and Geyser Peak enhancement reaches in 2017 (Figure 5.2.4). Overall, the enhancement reaches encompassed 244,514 ft^2 within main- and off-channel areas, with 27% of the total area meeting optimal depth and velocity criteria (Table 5.2.27). Monitoring examined 25,699 ft^2 of off-channel area, of which 69% met optimal depth and criteria, compared with 218,515ft^2 and 22% in the main channel. Several enhancement reaches constructed in 2016 (Truett Hurst, Meyer, and Geyser Peak) aggraded within off-channel areas in response to large storms that occurred over the winter from 2016 to 2017. Crews observed 35 habitat units across all enhancement reaches with a total pool to riffle ratio of 13:9 (1.44) and a total average shelter score of 61 (Table 5.2.28). Average alcove shelter score (120) exceeded the optimum shelter score of 80, followed by pools (70), flatwaters (62), and riffles (28). Post-effective flow, the Truett Hurst, Meyer, and Geyser Peak enhancement reaches rated poor, fair, and fail (Table 5.2.29) and underwent repair in October 2017 (see Post-repair below). Van Alyea and Farrow, Wallace rated good and fair, respectively (Table 5.2.29; see below for individual enhancement reach summaries and Appendix 5.1 all measured values, scores, and ratings).

Depth and velocity

Table 5.2.27. Post-effective flow areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement surveyed in 2017.

Dry Creek Post-effective Flow 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	218,515	127,326	54,206	181,532	76,897	27,133	20,241	47,375
Off channel area	25,999	11,588	6,884	18,471	23,340	12,182	5,739	17,921
Total area	244,514	138,913	61,090	200,003	100,237	39,315	25,981	65,295
Main channel % of wetted area	89%	58%	25%	83%	35%	12%	9%	22%
Off channel % of wetted area	11%	45%	26%	71%	90%	47%	22%	69%
Total % of wetted area	**100%**	**57%**	**25%**	**82%**	**41%**	**16%**	**11%**	**27%**

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.28. Post-enhancement habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2017.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	9	28
Pool	13	70
Flatwater	10	62
Alcove	3	120
Pool: riffle	**13:9 (1.44)**	**Avg: 61**

Reach ratings

Table 5.2.29. Post-enhancement ratings for Dry Creek enhancement reaches constructed in 2017.

Enhancement Reach	Post-effective Flow Rating
Truett Hurst	Poor
Meyer	Fair
Van Alyea	Good
Farrow, Wallace	Fair
Geyser Peak	Fail

Truett Hurst Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Truett Hurst enhancement reach in July 2017. The enhancement reach encompassed 15,775 ft^2 within main and off channel areas with 26% of the total area meeting optimum depth and velocity criteria (Table 5.2.30, Figure 5.2.31). The enhancement initially added 37,574 ft^2 of side channel in November 2016, but aggradation caused by large storms in winter 2016/2017 reduced off channel area to 10,682 ft^2. Within the off-channel area, sediment aggraded in the middle portion of the side channel, leaving the inlet and outlet only connected to the main channel, and aggraded two alcoves, substantially reducing alcove area (Figure 5.2.32). Still, 79% of the remaining off-channel area, largely in the side channel outlet and a portion of the downstream alcove, met optimal depth and velocity criteria (Table 5.2.30, Figure 5.2.31). Ten habitat units composed the enhancement reach post-effective flow, with a pool to riffle ratio of 4:4 (1.00) and an average shelter score of 64 (Table 5.2.31, Figure 5.2.32, Figure 5.2.33). Three habitat units met or exceeded the optimal shelter value of 80. The enhancement reach comprised four enhancement sites (one main channel, a side channel, two alcoves) that received fail to fair site average feature ratings (we did not rate enhancement site 1 as it contained no features), and fail to fair site average habitat unit ratings (Table 5.2.32, Figure 5.2.34, Figure 5.2.35, Figure 5.2.36). Site 4 (alcove) completely aggraded, burying most enhancement features, and sites 2 (side channel) and 3 (alcove) partially aggraded, burying some features leading to fail, poor, and poor enhancement site ratings respectively (Table 5.2.32, Figure 5.2.37). Site 1 (main channel) did not aggrade and received a fair rating. Overall Truett Hurst enhancement reach received a poor effectiveness monitoring rating (Table 5.2.32, Figure 5.2.38). The monitoring results and subsequent ratings led to repairs by Sonoma Water in October 2017 (See Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.30. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, July 2017.

Truett Hurst Post-effective flow July 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	49,859	36,551	11,606	48,157	11,579	6,477	835	7,312
Off channel area	10,682	5,298	1,662	6,960	10,191	6,656	1,787	8,443
Total area	**60,541**	**41,849**	**13,268**	**55,117**	**21,770**	**13,133**	**2,622**	**15,755**
Main channel % of wetted area	82%	73%	23%	97%	23%	13%	2%	15%
Off channel % of wetted area	18%	50%	16%	65%	95%	62%	17%	79%
Total % of wetted area	**100%**	**69%**	**22%**	**91%**	**36%**	**22%**	**4%**	**26%**

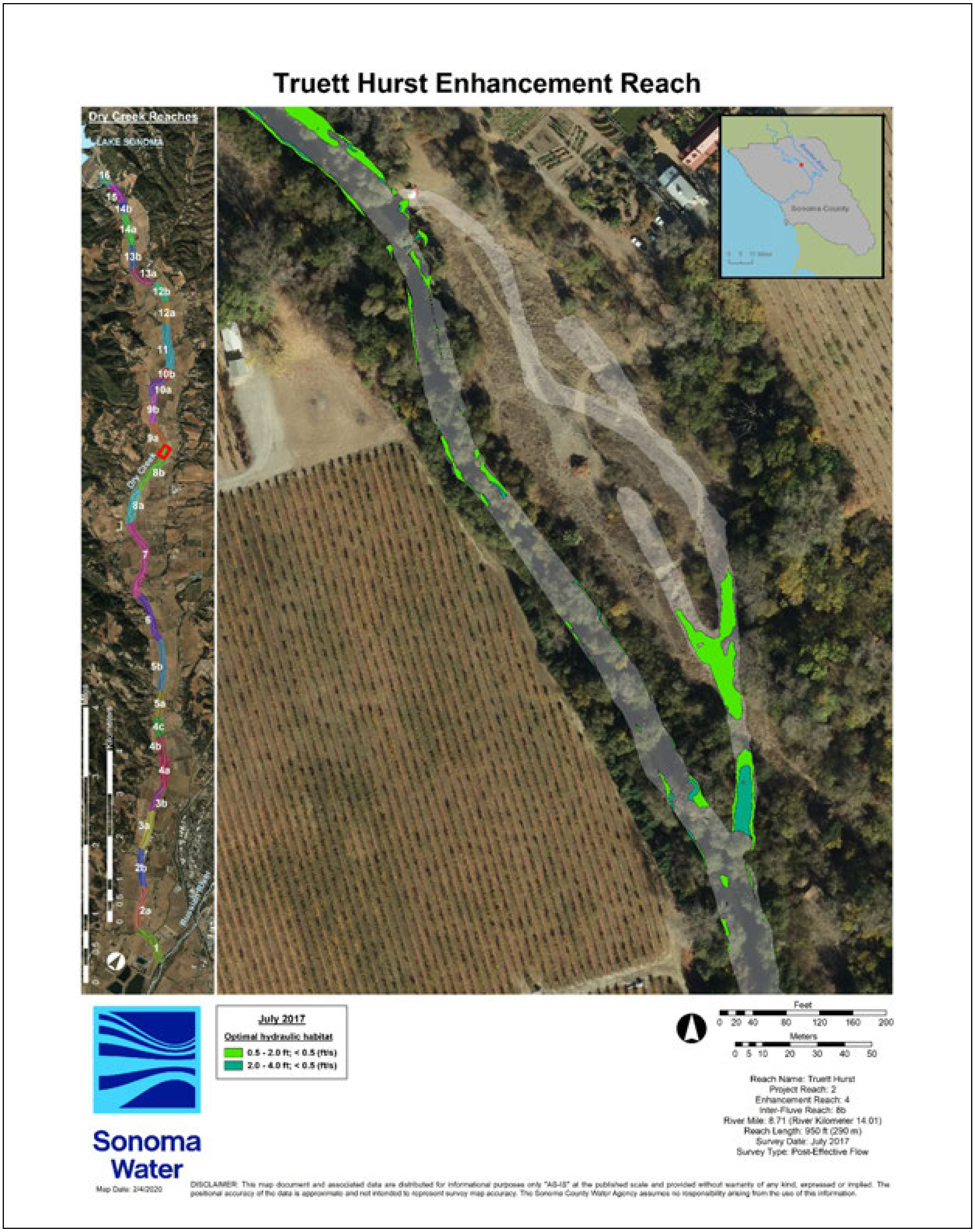


Figure 5.2.31. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, July 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.31. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Truett Hurst enhancement reach, Post-effective flow July 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	15	45
HU02	Pool	3	20	60
HU03	Alcove	3	20	60
HU04	Riffle	2	10	20
HU05	Flatwater	2	40	80
HU06	Pool	3	50	150
HU07	Riffle	3	20	60
HU08	Flatwater	3	40	120
HU09	Pool	1	25	25
HU10	Flatwater	2	10	20
Pool: riffle	**4:2 (2.00)**			**Avg = 64**

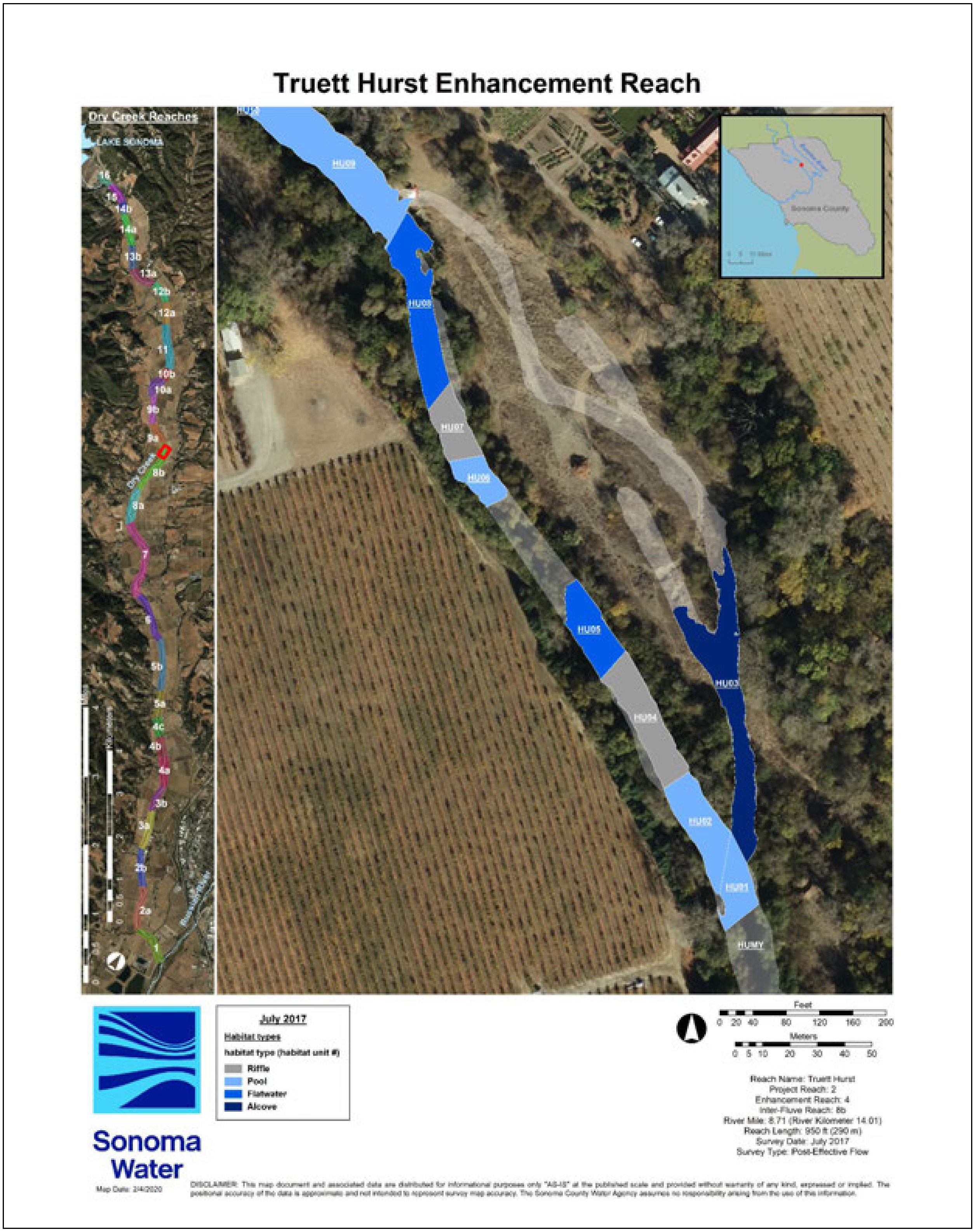


Figure 5.2.32. Habitat unit number and type within the Truett Hurst enhancement reach, July 2017.

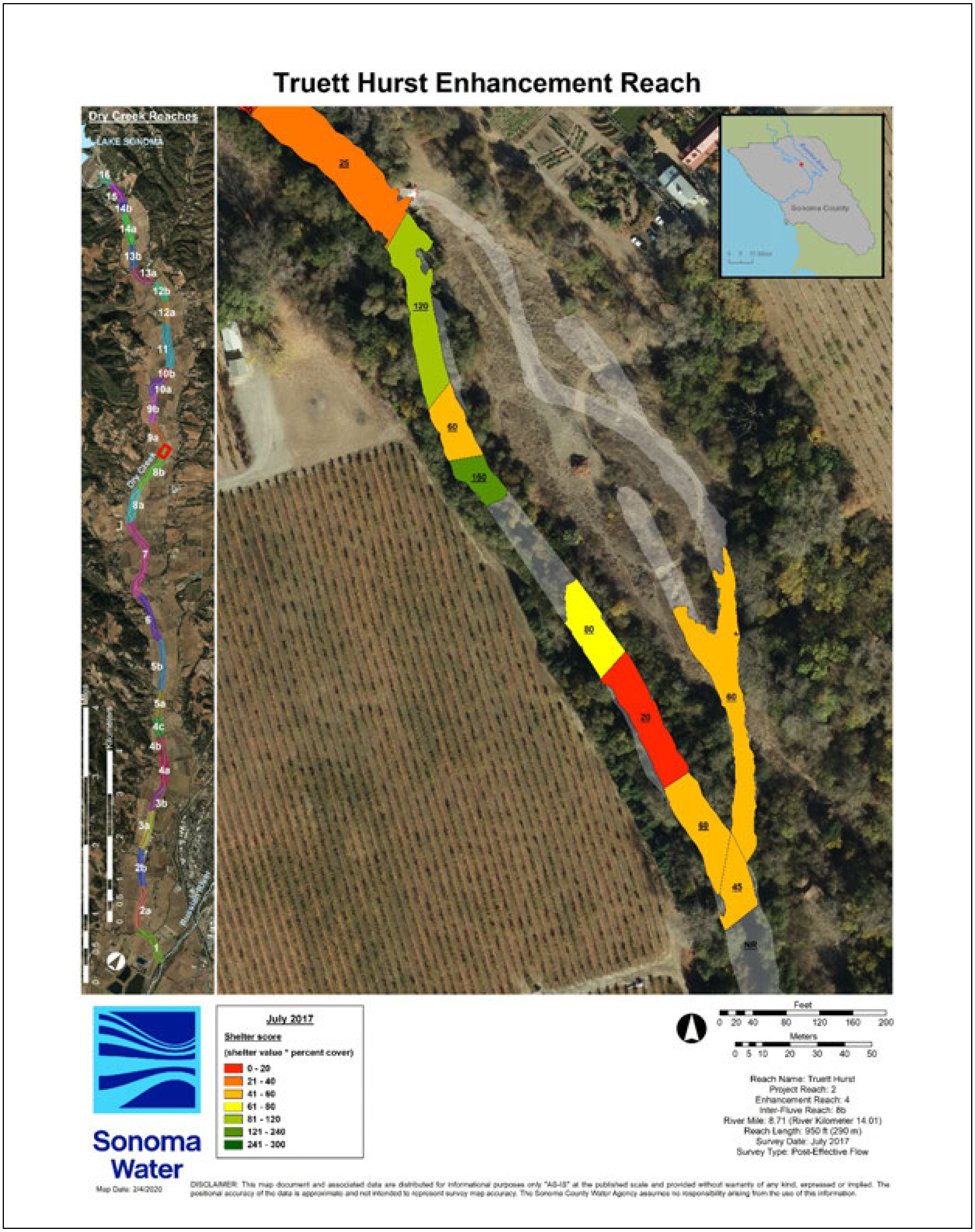


Figure 5.2.33. Habitat unit shelter scores within the Truett Hurst enhancement reach, July 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.32. Post-effective flow site and reach ratings for the Truett Hurst enhancement reach, July 2017.

Site number		**1**	**2**	**3**	**4**
Site type		Main channel	Side channel	Alcove	Alcove
Site average feature rating	Site average feature quantitative rating[a]	0	7	4	1
	Site average feature qualitative rating[a]	Not rated	Fair	Poor	Fail
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	17	12	12	0
	Site average qualitative rating[b]	Fair	Poor	Poor	Fail
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)	17[b]	19[c]	16[c]	1[c]
	Site qualitative rating:	Fair[b]	Poor[c]	Poor[c]	Fail[c]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	13			
	Enhancement reach qualitative rating[d]:	Poor			

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

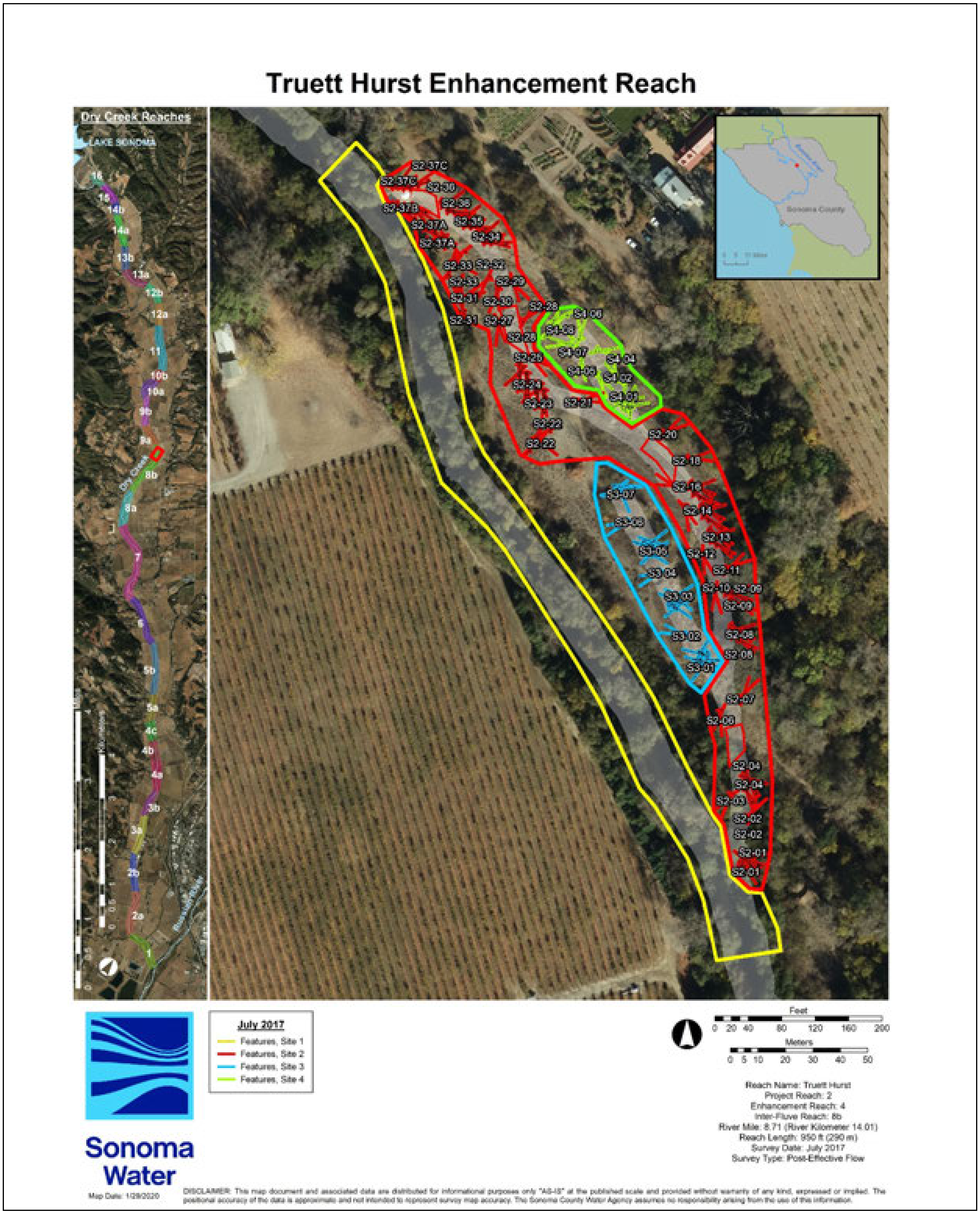


Figure 5.2.34. Enhancement sites and features within the Truett Hurst enhancement reach, July 2017..

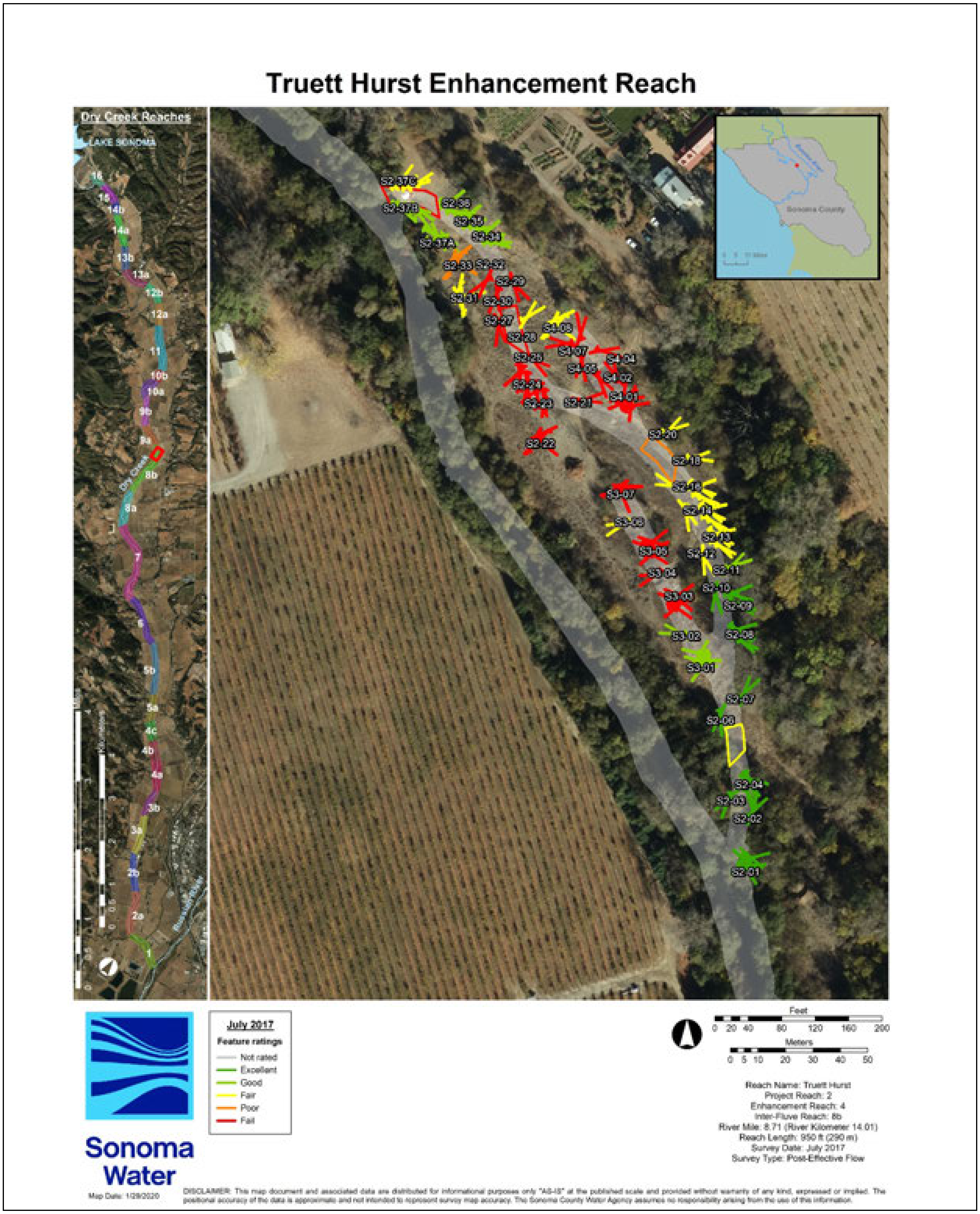


Figure 5.2.35. Feature ratings for the Truett Hurst enhancement reach, July 2017.

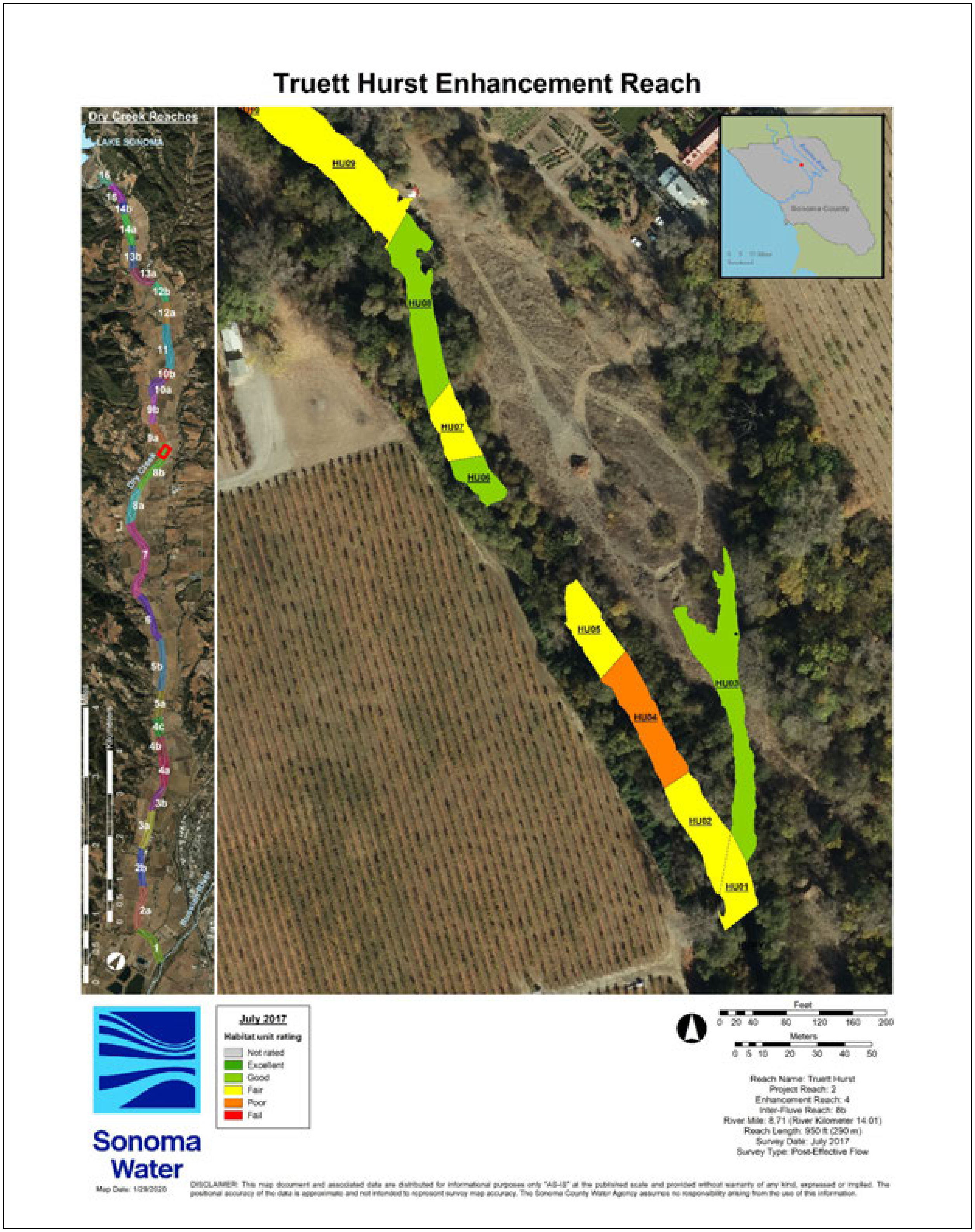


Figure 5.2.36. Habitat unit ratings for the Truett Hurst enhancement reach, July 2017.

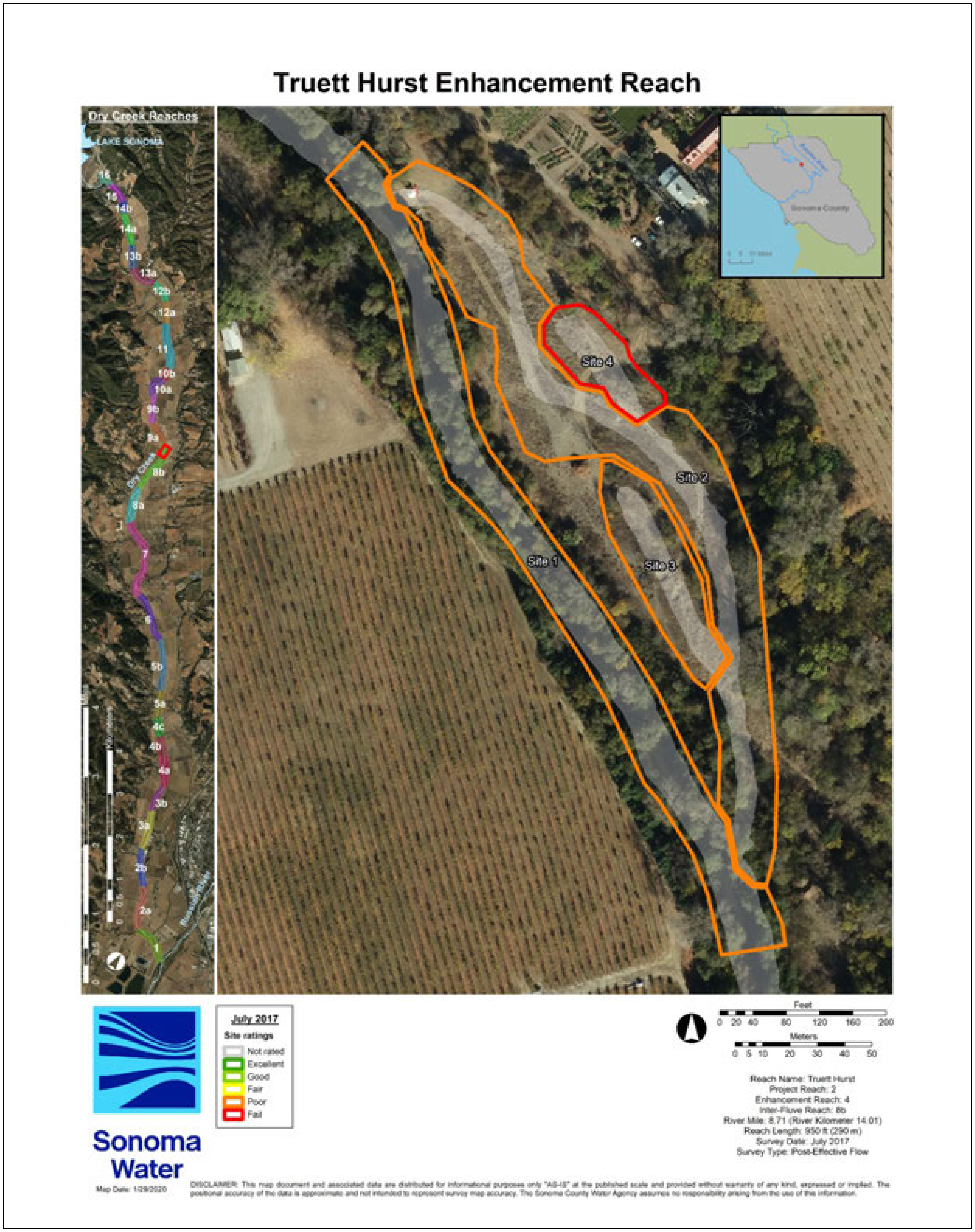


Figure 5.2.37. Post-effective flow site ratings for the Truett Hurst enhancement reach, July 2017.

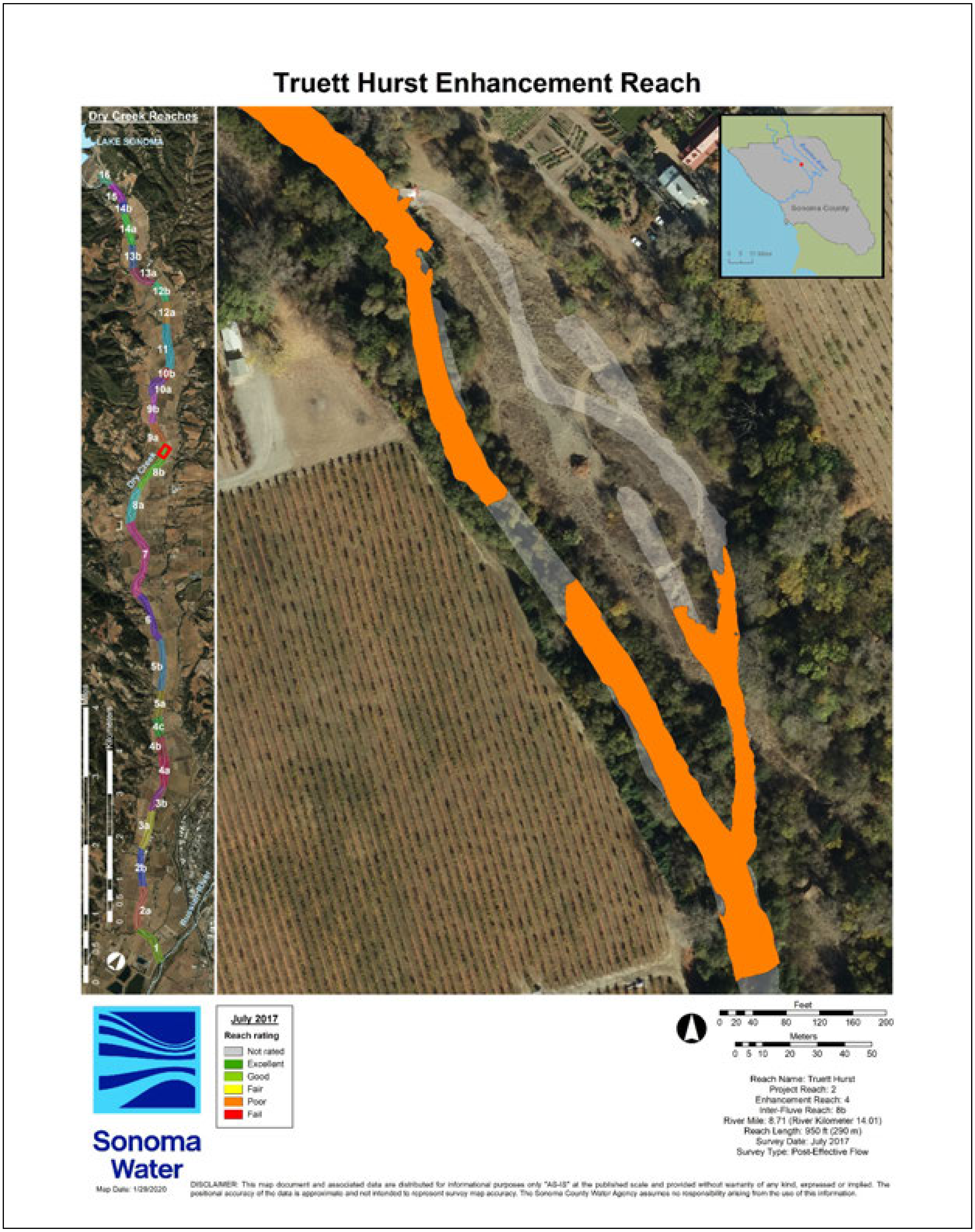


Figure 5.2.38. Post-effective flow reach rating for the Truett Hurst enhancement reach, July 2017.

Meyer Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Meyer enhancement reach in July 2017. The enhancement reach encompassed 34,927 ft^2 within main- and off-channel areas with 9% of the total meeting optimal depth and velocity criteria (Table 5.2.33, Figure 5.2.39). The enhancement initially added 14,965 ft^2 of side-channel in November 2016, but aggradation caused by large storms in winter 2016/2017 reduced off-channel area to 2,883 ft^2. Within the off-channel area, sediment aggraded nearly the entire portion of the side channel, leaving only small portions of the inlet and outlet connected to the main-channel (Figure 5.2.39). Of these small portions of inlet and outlet, 37% met optimal depth and velocity criteria (Table 5.2.33). Four habitat units made up the enhancement reach post-effective flow, mainly in the main-channel, with a pool to riffle ratio of 2:1 (2.00) and an average shelter score of 43 (Table 5.2.34, Figure 5.2.40, Figure 5.2.41). No habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised two enhancement reaches (one main channel and one side channel, Figure 5.2.42) that received a fair site average feature rating (we did not rate enhancement site 1 as it contained no features), and poor to fair site average habitat unit ratings(Table 5.2.35, Figure 5.2.43, Figure 5.2.44). Site 2 (side-channel) aggraded substantially, partially burying enhancement features, but leaving the features in good condition, leading to a fair rating (Table 5.2.35, Figure 5.2.45). Even though site 2 received a fair rating, aggradation filled nearly 80% of the side channel, which led to repairs of the enhancement reach by Sonoma Water in October 2017 (see below). Site 1 (main channel) did not aggrade, but received a poor site rating due to low site average habitat unit scores. Overall, Meyer enhancement reach received a fair effectiveness monitoring rating (Table 5.2.35, Figure 5.2.46; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.33. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Meyer enhancement reach, July 2017.

Meyer Post-effective flow July 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	32,044	26,323	594	26,916	3,574	1,381	1	1,382
Off channel area	2,883	1,062	1,397	2,459	2,032	833	776	1,609
Total area	**34,927**	**27,385**	**1,991**	**29,376**	**5,607**	**2,214**	**777**	**2,991**
Main channel % of wetted area	92%	82%	2%	84%	11%	4%	0%	4%
Off channel % of wetted area	8%	48%	85%	71%	29%	27%	56%	37%
Total % of wetted area	**100%**	**78%**	**6%**	**84%**	**16%**	**6%**	**2%**	**9%**

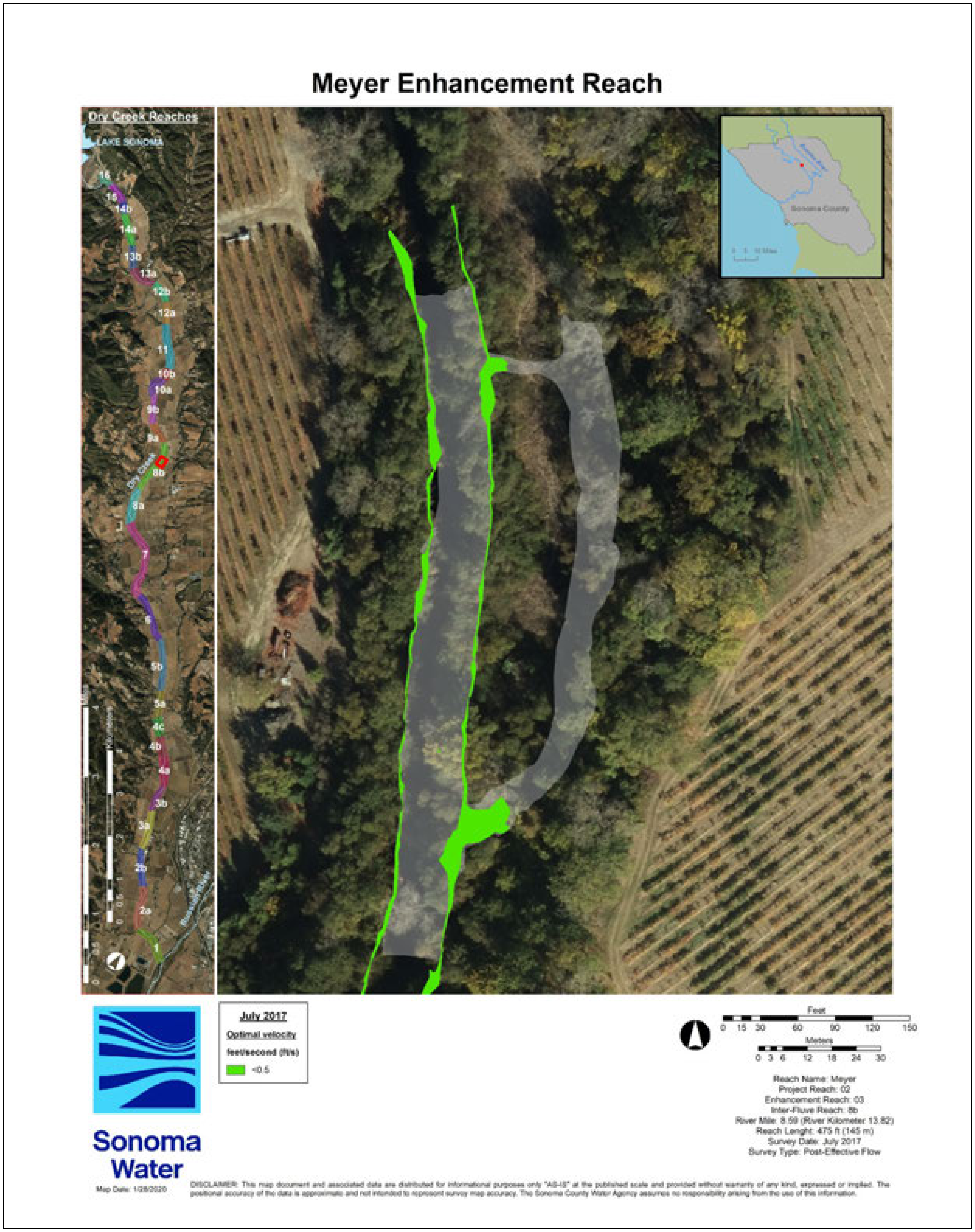


Figure 5.2.39. Optimal water velocity for fry and parr (< 0.5 ft/s) within the Meyer enhancement reach, July 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.34. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Meyer enhancement reach, Post-effective flow July 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Riffle	2	10	20
HU02	Pool	3	20	60
HU03	Flatwater	3	10	30
HU04	Pool	3	20	60
Pool: riffle	**2:1 (2.00)**			**Avg = 43**

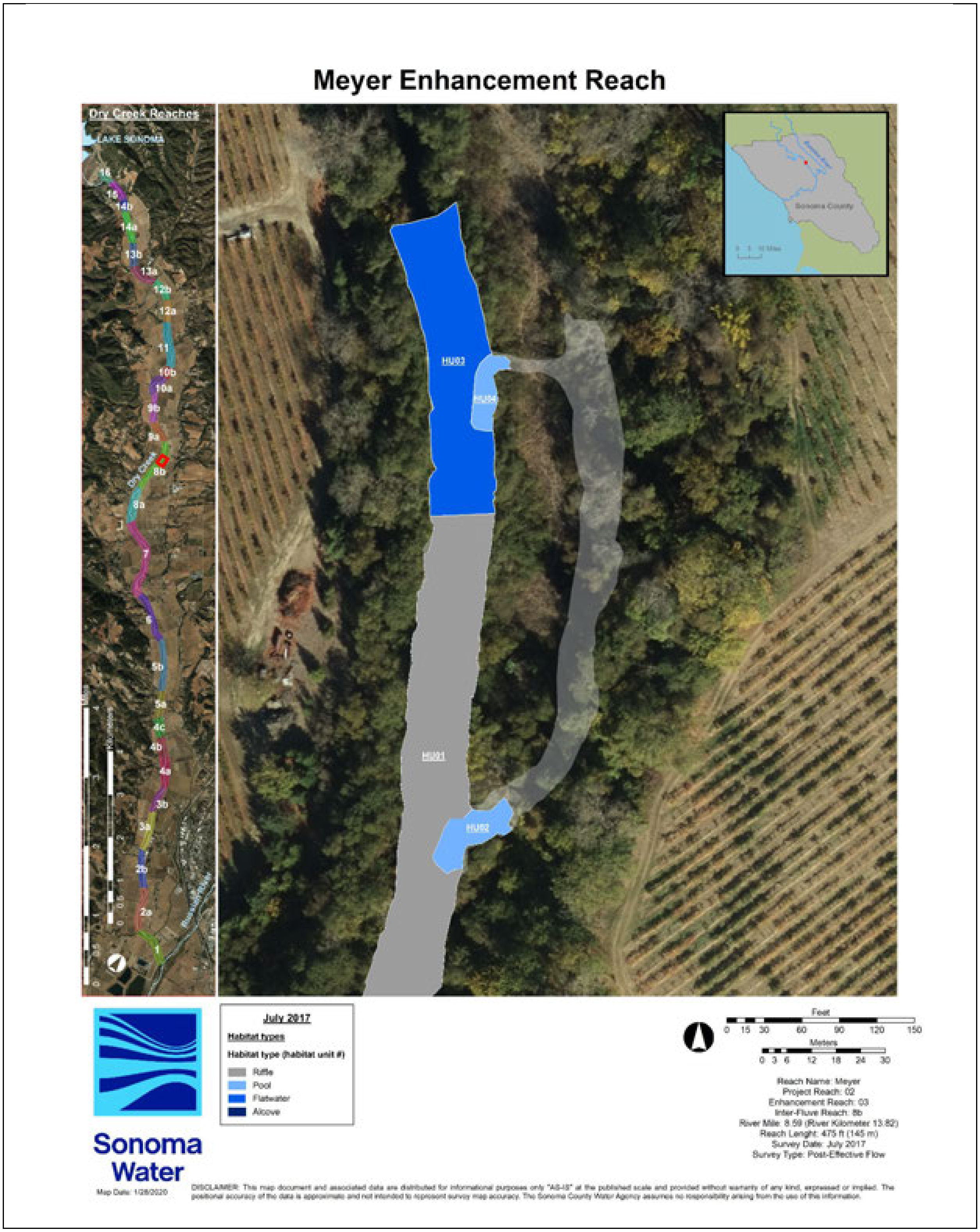


Figure 5.2.40. Habitat unit number and type within the Meyer enhancement reach, July 2017.

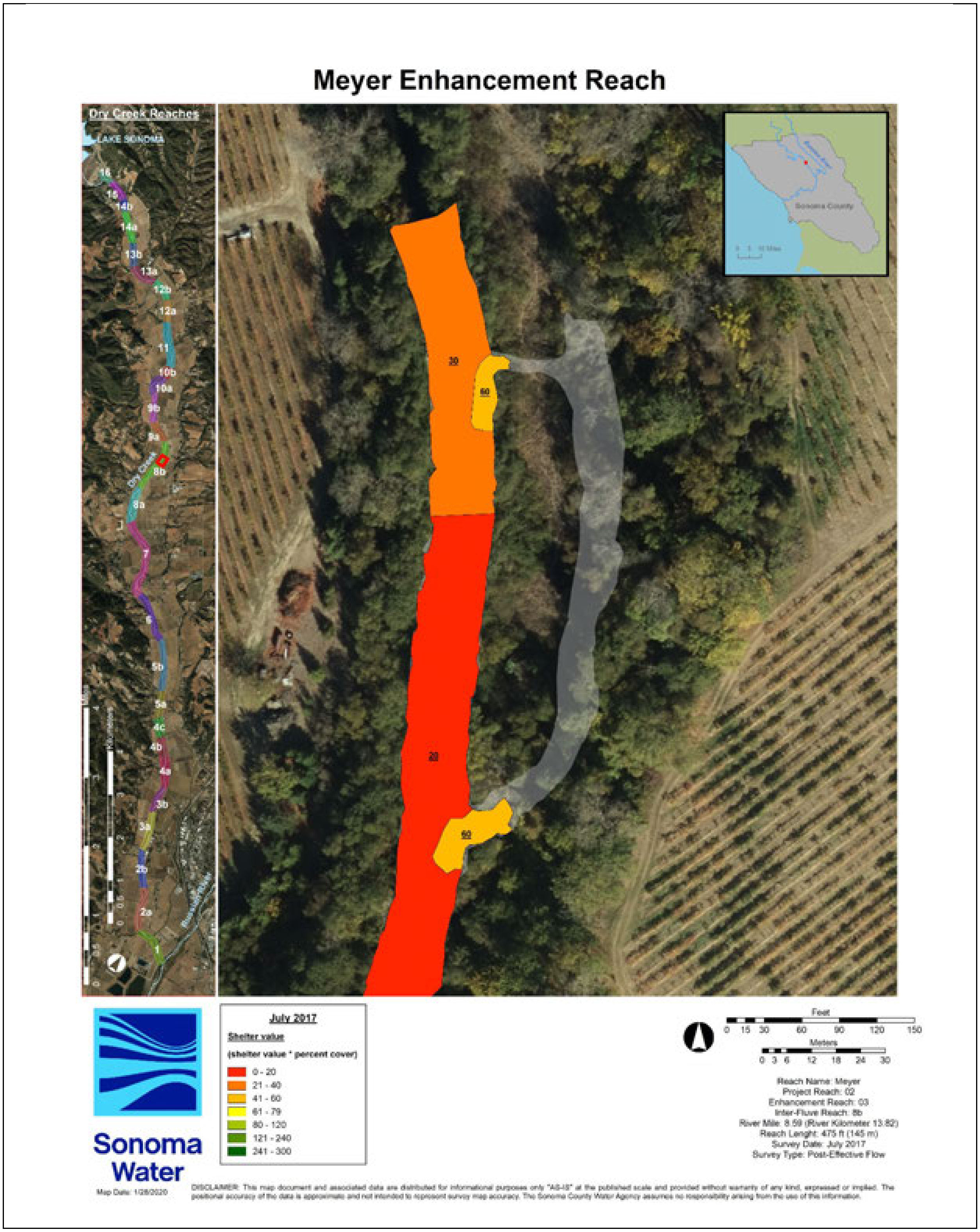


Figure 5.2.41. Habitat unit shelter scores within the Meyer enhancement reach, July 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.35. Post-effective flow site and reach ratings for the Meyer enhancement reach, July 2017.

Site number		1	2		
Site type		Main channel	Side channel		
Site average feature rating	Site average feature quantitative rating	0	8[a]		
	Site average feature qualitative rating	Not rated	Fair[a]		
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	11	16		
	Site average qualitative rating[b]	Poor	Fair		
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)	11[b]	24[c]		
	Site qualitative rating:	Poor[b]	Fair[c]		
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	17			
	Enhancement reach qualitative rating[d]:	Fair			

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

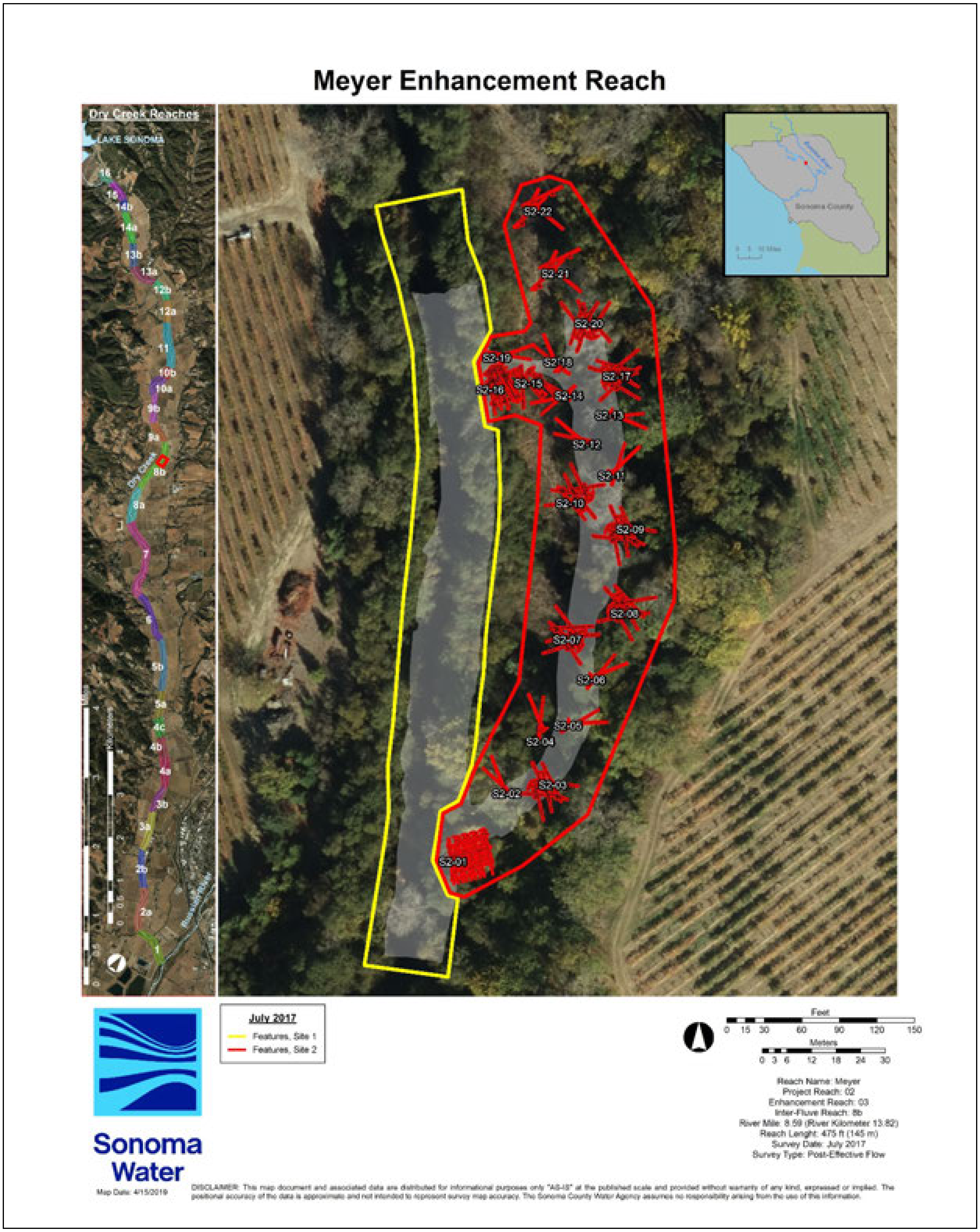


Figure 5.2.42. Enhancement sites and features within the Meyer enhancement reach, July 2017.

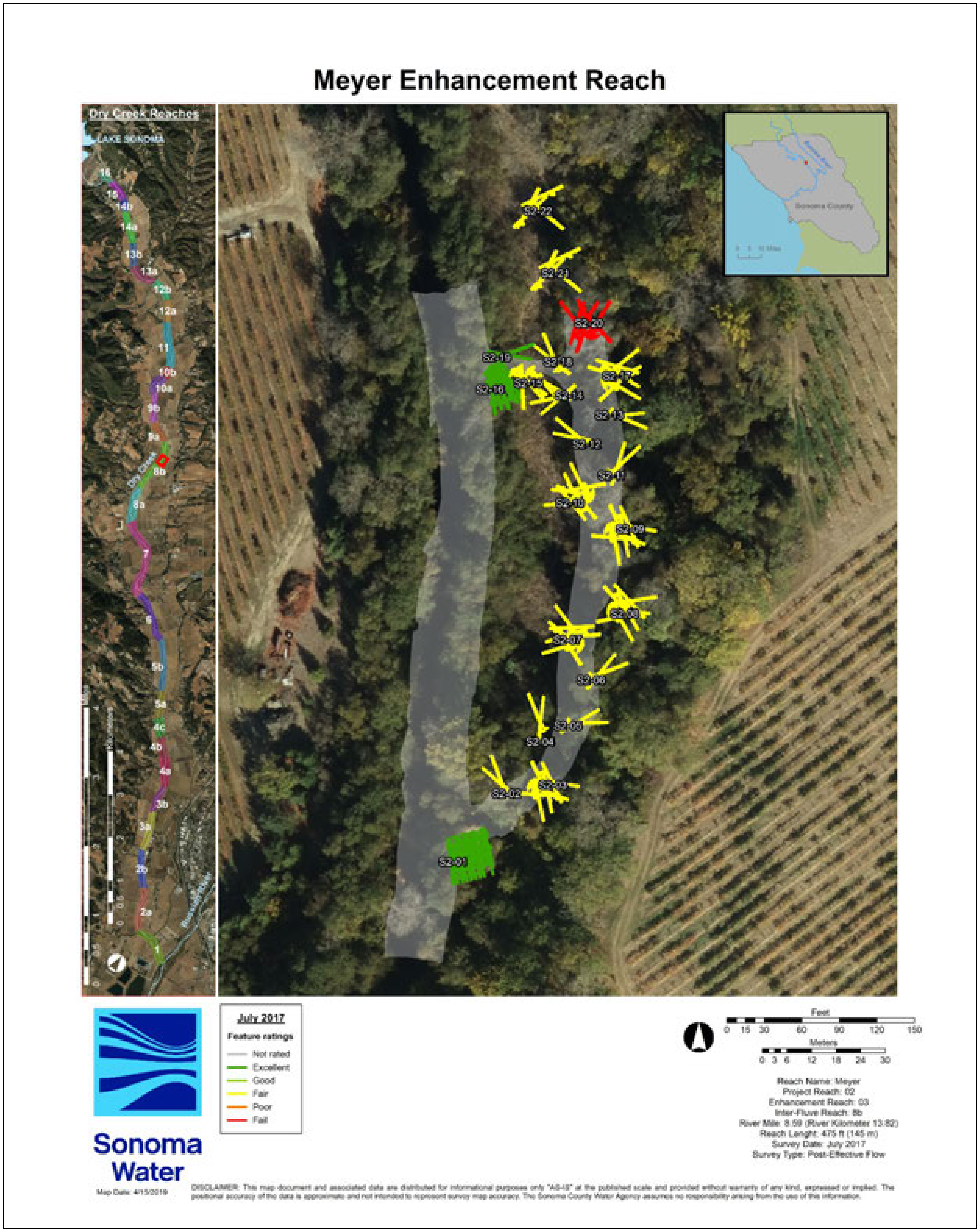


Figure 5.2.43. Feature ratings for the Meyer enhancement reach, July 2017.

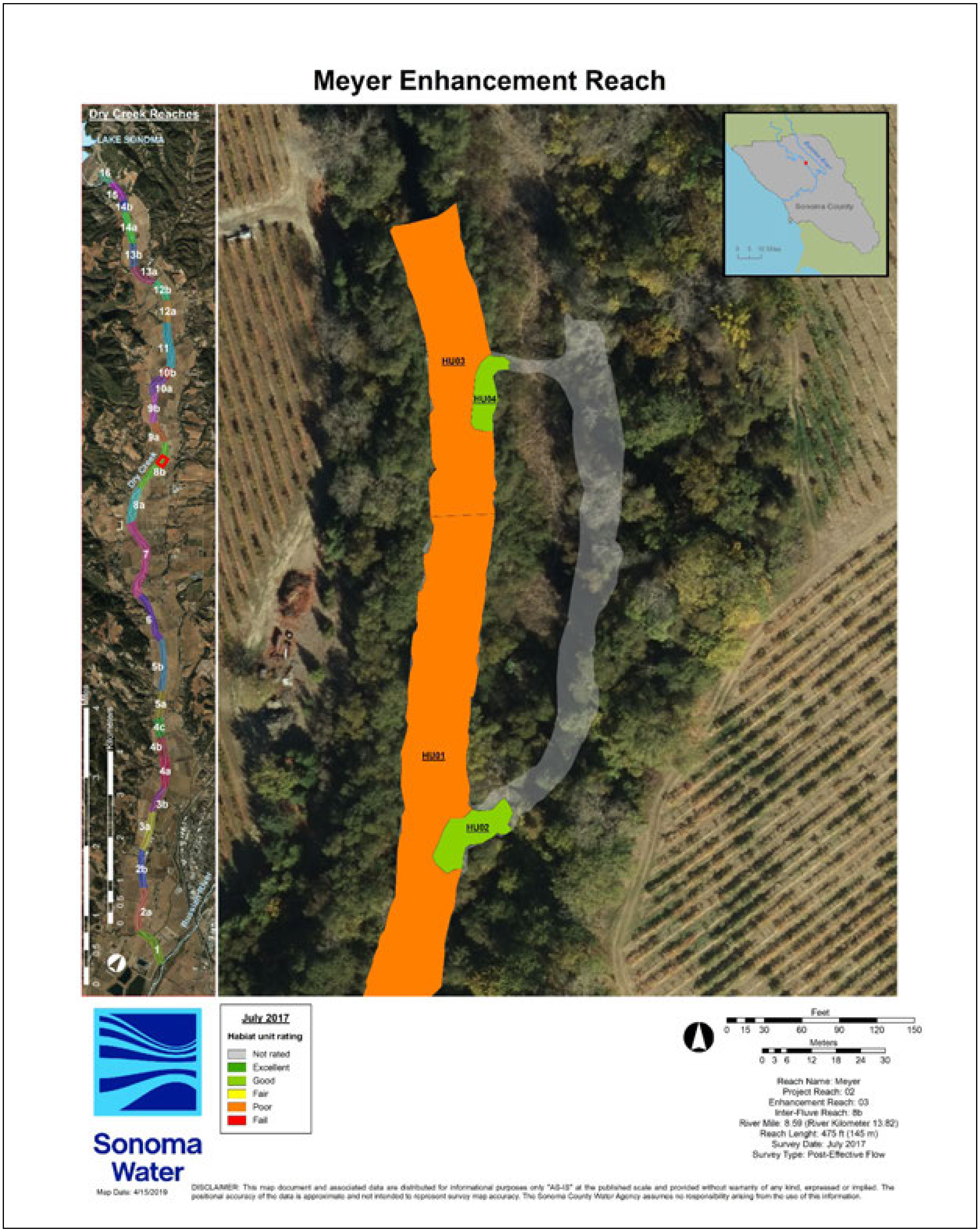


Figure 5.2.44. Habitat unit ratings for the Meyer enhancement reach, July 2017.

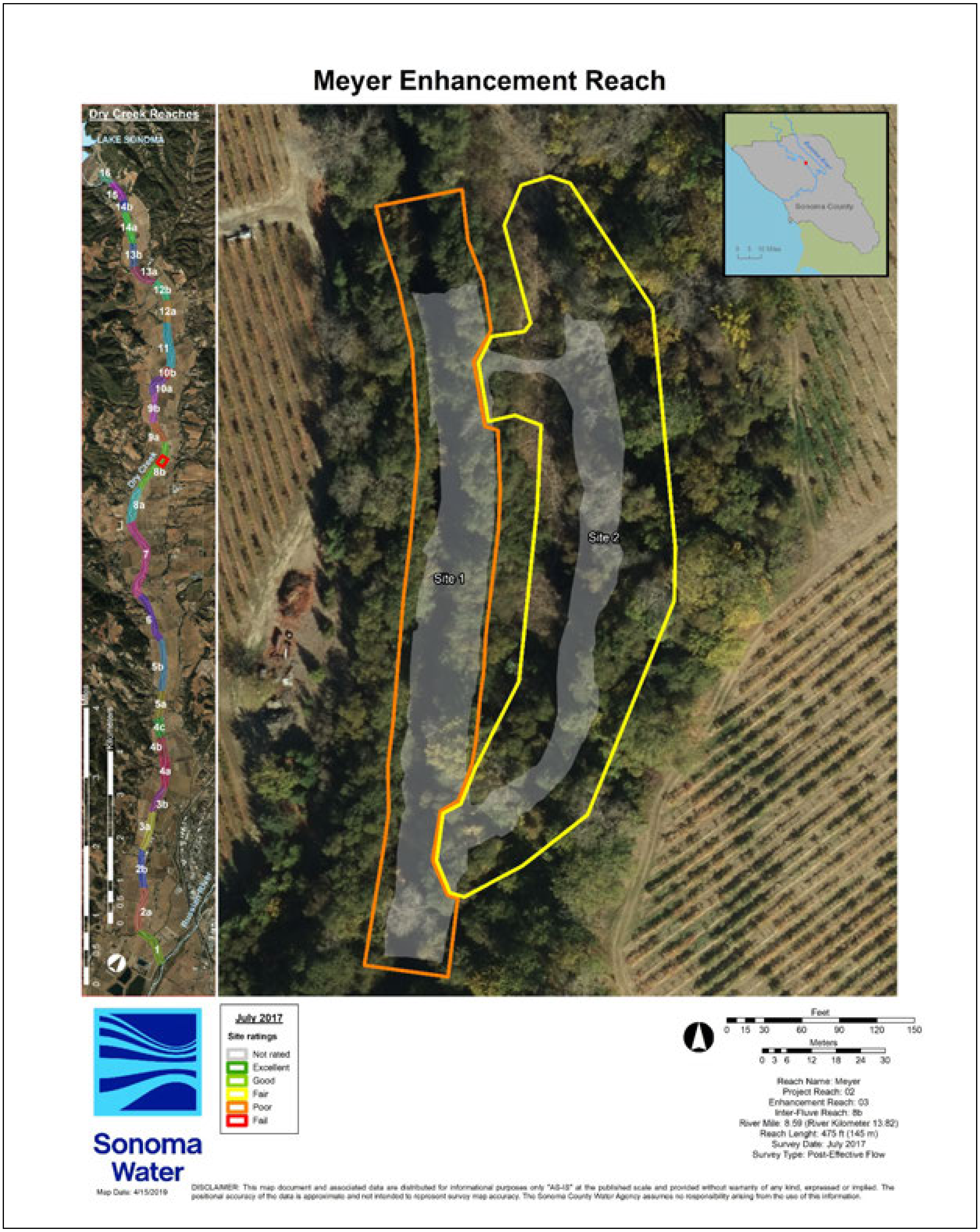


Figure 5.2.45. Post-effective flow site ratings for the Meyer enhancement reach, July 2017.

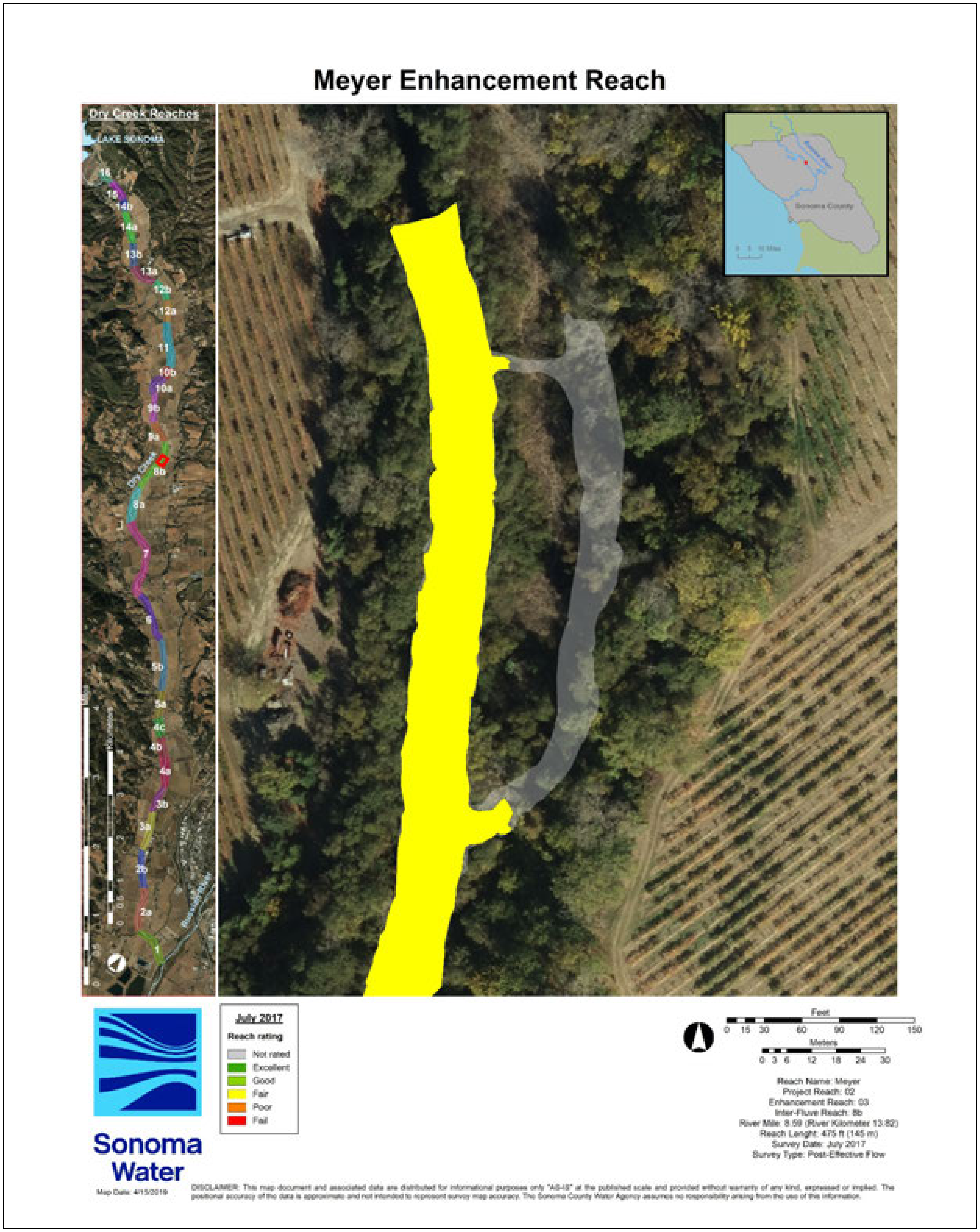


Figure 5.2.46. Post-effective flow reach rating for the Meyer enhancement reach, July 2017.

Van Alyea Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Van Alyea enhancement reach in April 2017. The monitored portion of the reach covered 60.316 ft^2 within main channel and alcove areas, with 35% of the total meeting optimal depth and velocity criteria (Table 5.2.36, Figure 5.2.47). Previous effectiveness monitoring in August 2015 recorded 24,463 ft^2 of alcove area, but aggradation, likely from recent large storms in winter 2016/2017, reduced April 2017 alcove area to 20,545 ft^2. The August 2015 effectiveness monitoring survey also recorded a greater area of main channel (51,995 ft^2) than recorded in April 2017 (39,771 ft^2) as crews could not survey a portion of the channel due to excessive depth (> 4 ft) (Figure 5.2.47). Still, 50% of the alcove area remaining in April 2017 met optimal depth and velocity criteria compared to 34% last observed in August 2015 (Table 5.2.36). Eight habitat units composed the enhancement reach post effective flow 2017, with a pool to riffle ratio of 3:1 (3.00) and an average shelter score of 64 (Table 5.2.37, Figure 5.2.48, Figure 5.2.49). Four habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised three enhancement sites (one main channel, one alcove, one bank site; Table 5.2.38, Figure 5.2.50,) that all received good to excellent site average feature ratings and fair to good site average habitat unit ratings (Table 5.2.38, Figure 5.2.51, Figure 5.2.52). All three enhancement sites received good qualitative ratings and similar numerical scores (Table 5.2.38, Figure 5.2.53). Overall, Van Alyea enhancement reach received a good effectiveness monitoring score (Table 5.2.38, Figure 5.2.54; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.36. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Van Alyea enhancement reach, April 2017.

Van Alyea Post-effective flow April 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	39,771	14,495	17,677	32,172	14,067	4,606	6,171	10,777
Main channel alcove area	20,545	3,104	7,223	10,327	20,545	3,104	7,223	10,327
Total area	**60,316**	**17,599**	**24,900**	**42,499**	**34,612**	**7,710**	**13,394**	**21,104**
Main channel % of wetted area	66%	36%	44%	81%	35%	12%	16%	27%
Main channel alcove % of wetted area	34%	15%	35%	50%	100%	15%	35%	50%
Total % of wetted area	**100%**	**29%**	**41%**	**70%**	**57%**	**13%**	**22%**	**35%**

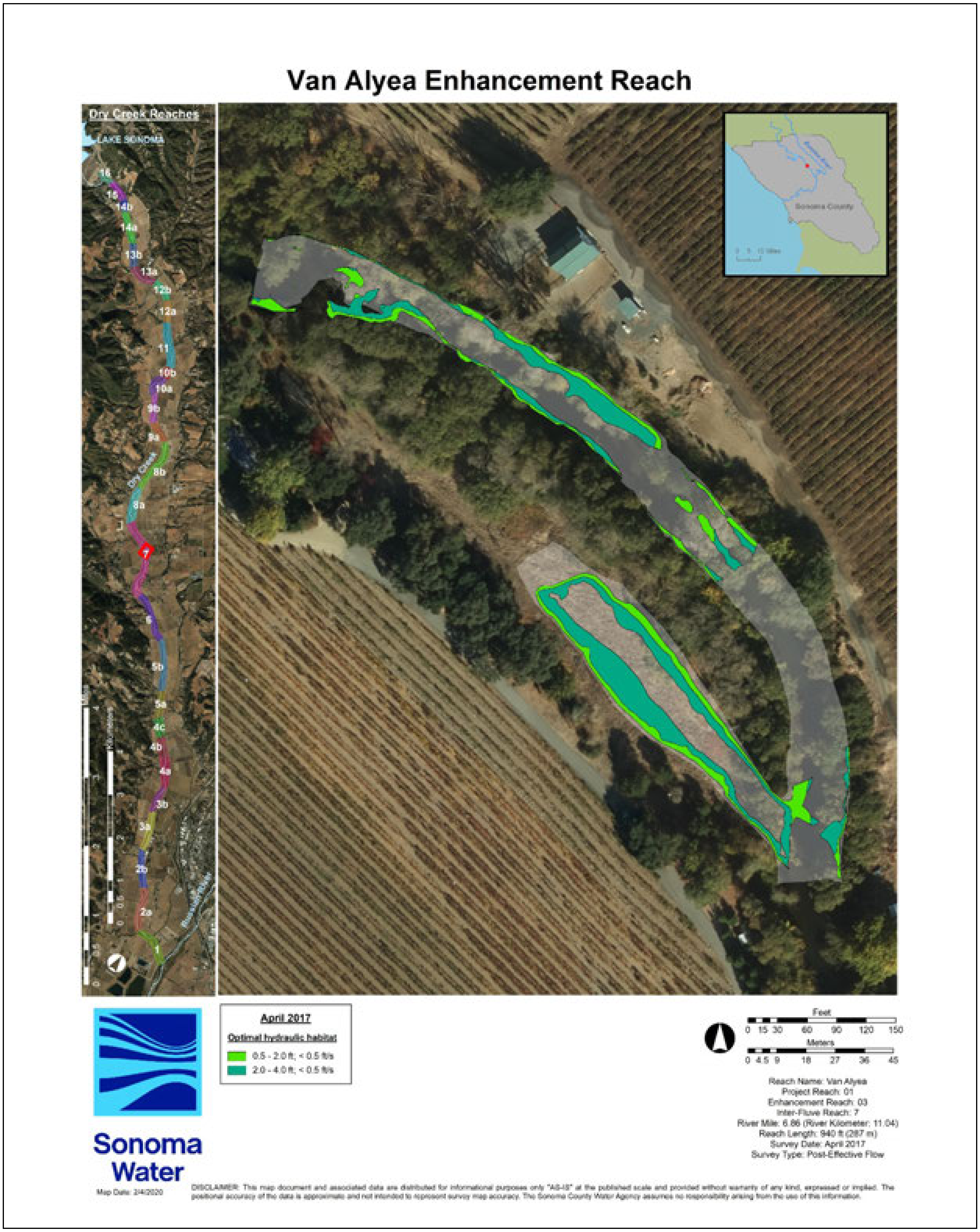


Figure 5.2.47. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Van Alyea enhancement reach, April 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2. 37. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Van Alyea enhancement reach, Post-effective flow April 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	25	75
HU02	Alcove	3	30	90
HU03	Riffle	2	40	80
HU04	Pool	3	15	45
HU05	Pool	3	30	90
HU06	Flatwater	3	35	105
HU07	Riffle	1	5	5
HU08	Flatwater	2	10	20
Pool: riffle	**3:2 (1.50)**			**Avg = 64**

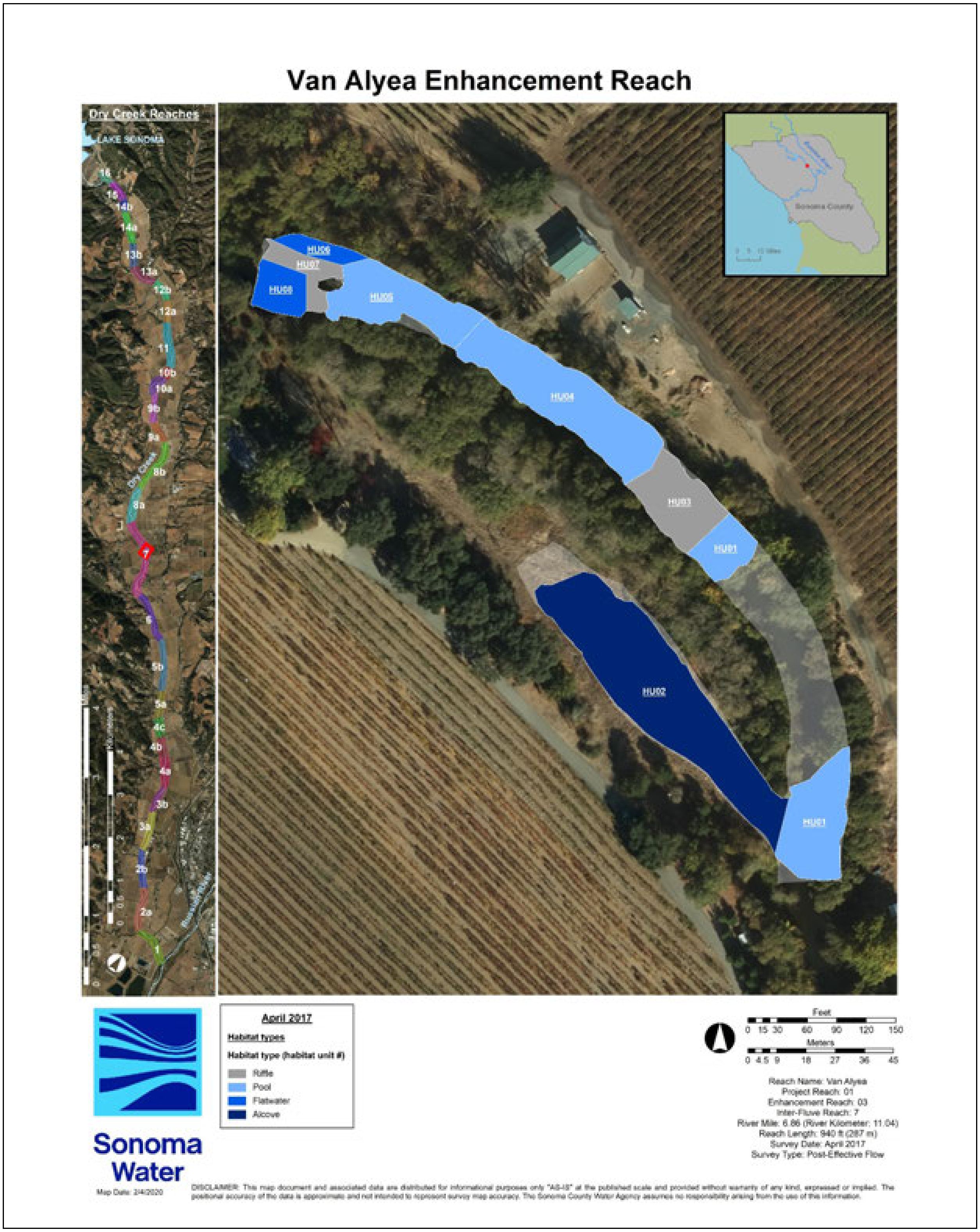


Figure 5.2.48. Habitat unit number and type within the Van Alyea enhancement reach, April 2017.

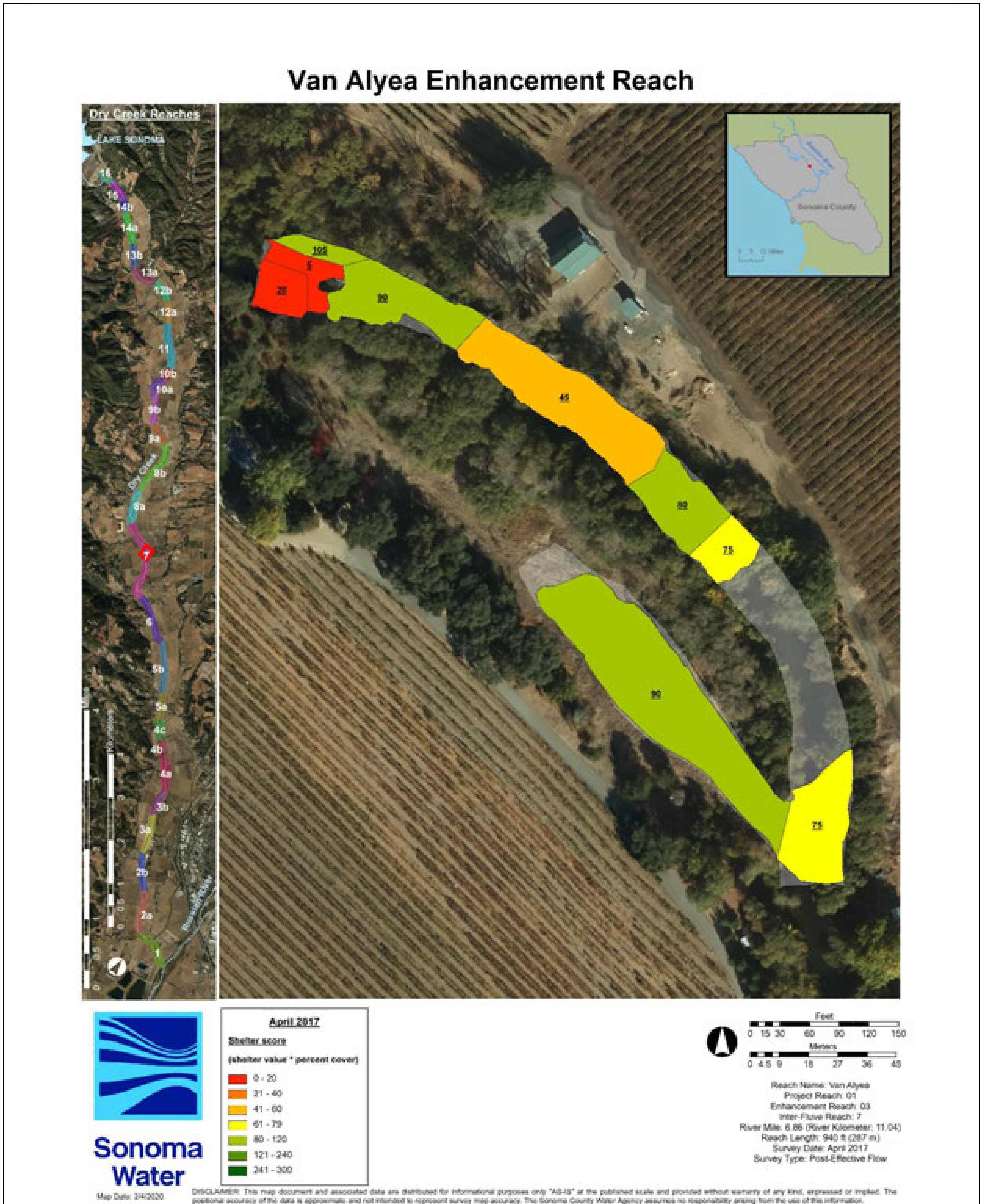


Figure 5.2.49. Habitat unit shelter scores within the Van Alyea enhancement reach, April 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.38. Post- effective flow site and reach ratings for the Van Alyea enhancement reach, April 2017.

Site number		**1**	**2**	**3**	
Site type		Main channel	Bank	**Alcove**	
Site average feature rating	Site average feature quantitative rating[a]	14	13	11	
	Site average feature qualitative rating[a]	Excellent	Excellent	Good	
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	17	22	22	
	Site average qualitative rating[b]	Fair	Good	Good	
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	30	35	33	
	Site qualitative rating[c]	Good	Good	Good	
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	33			
	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)

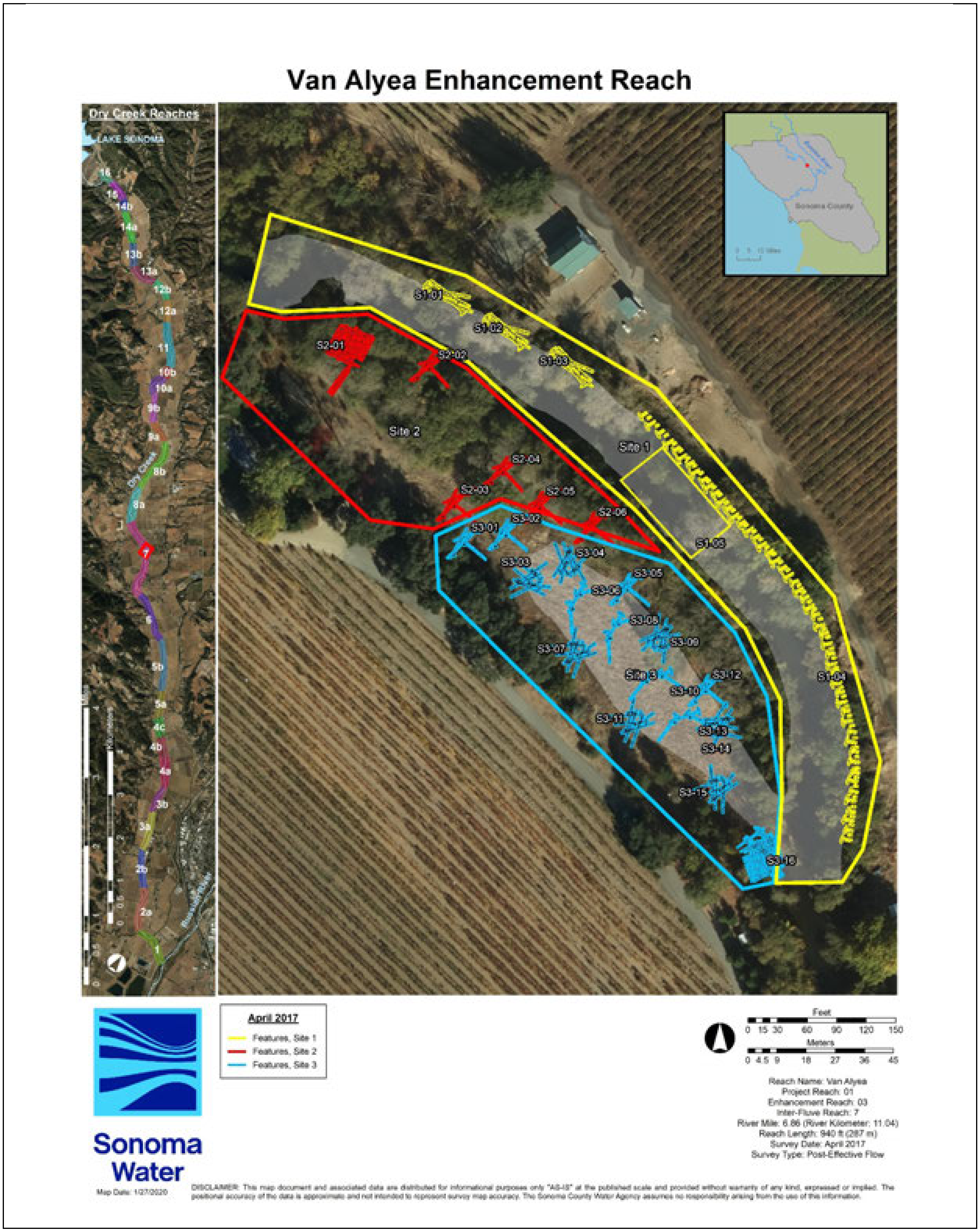


Figure 5.2.50. Enhancement sites and features within the Van Alyea enhancement reach, April 2017.

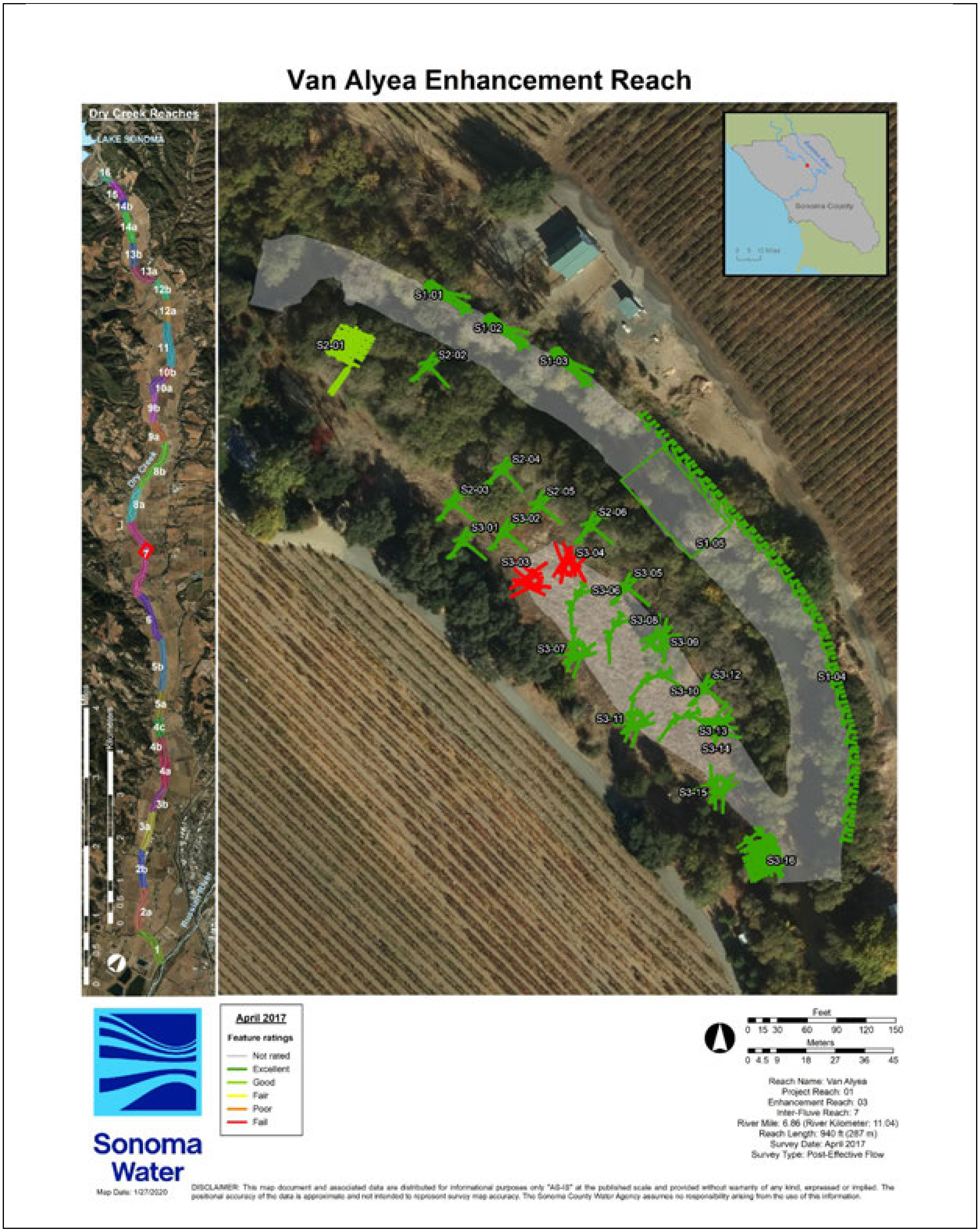


Figure 5.2.51. Feature ratings for the Van Alyea enhancement reach, April 2017.

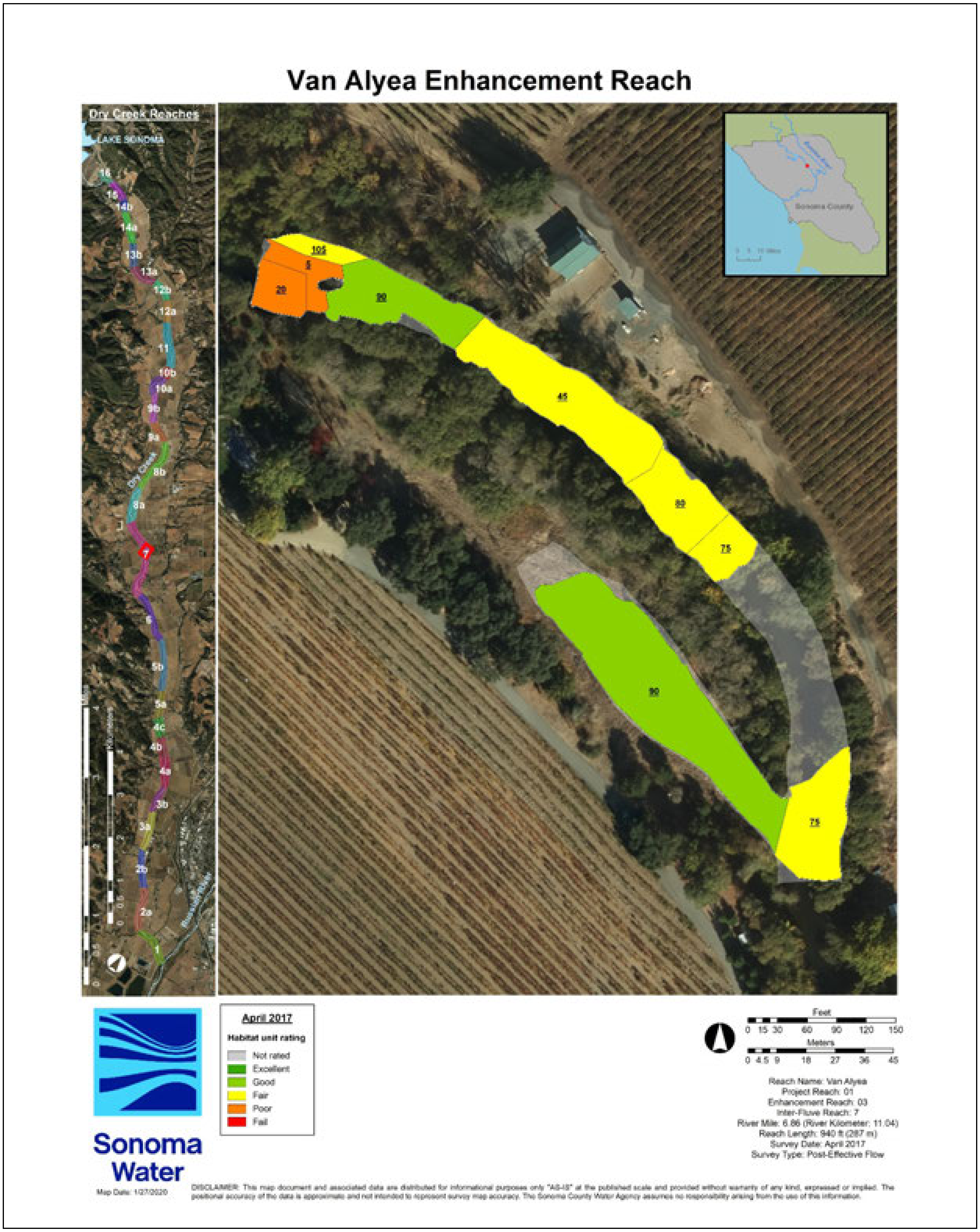


Figure 5.2.52. Habitat unit ratings for the Van Alyea enhancement reach, April 2017.

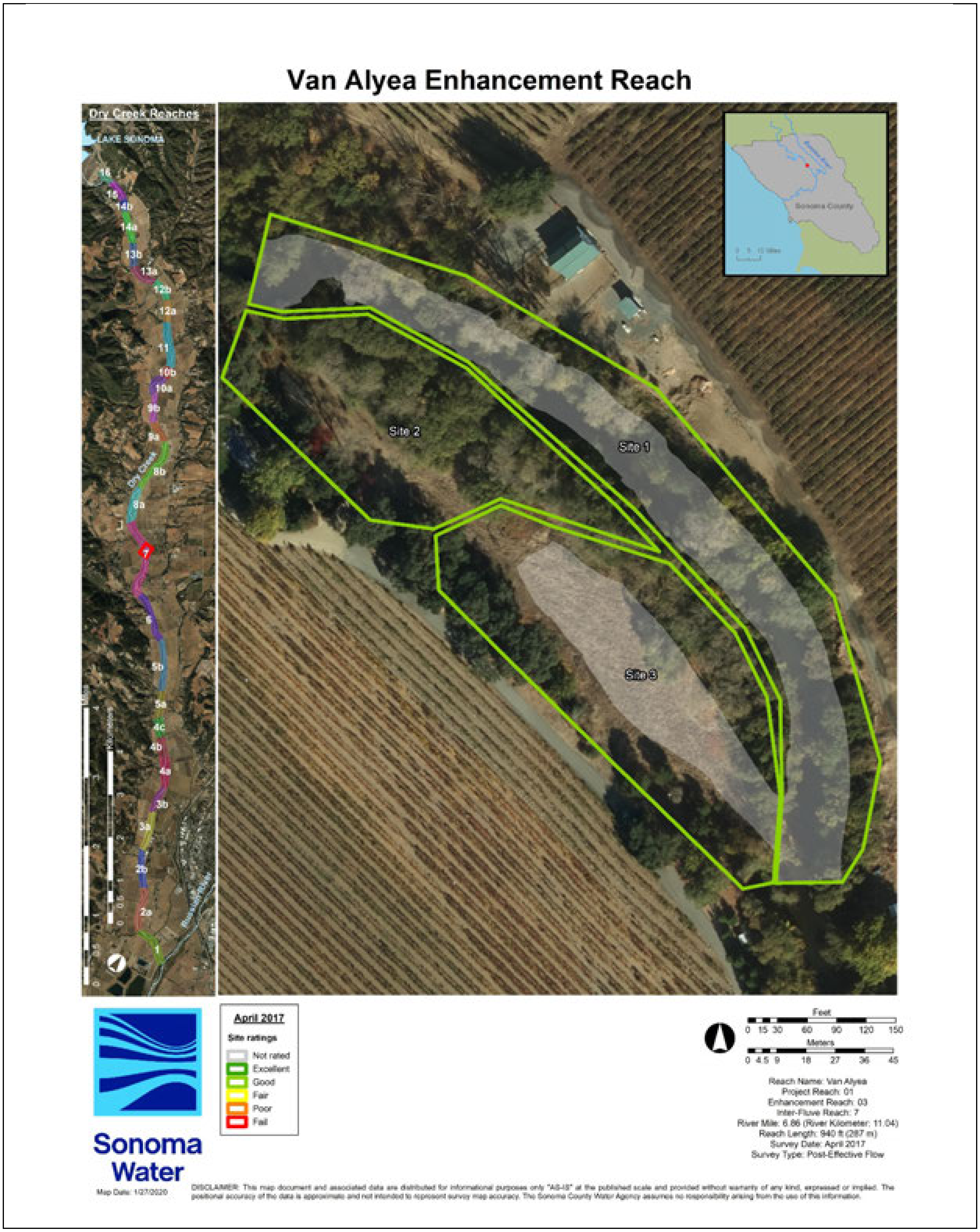


Figure 5.2.53. Post-effective flow site ratings for the Van Alyea enhancement reach, April 2017.

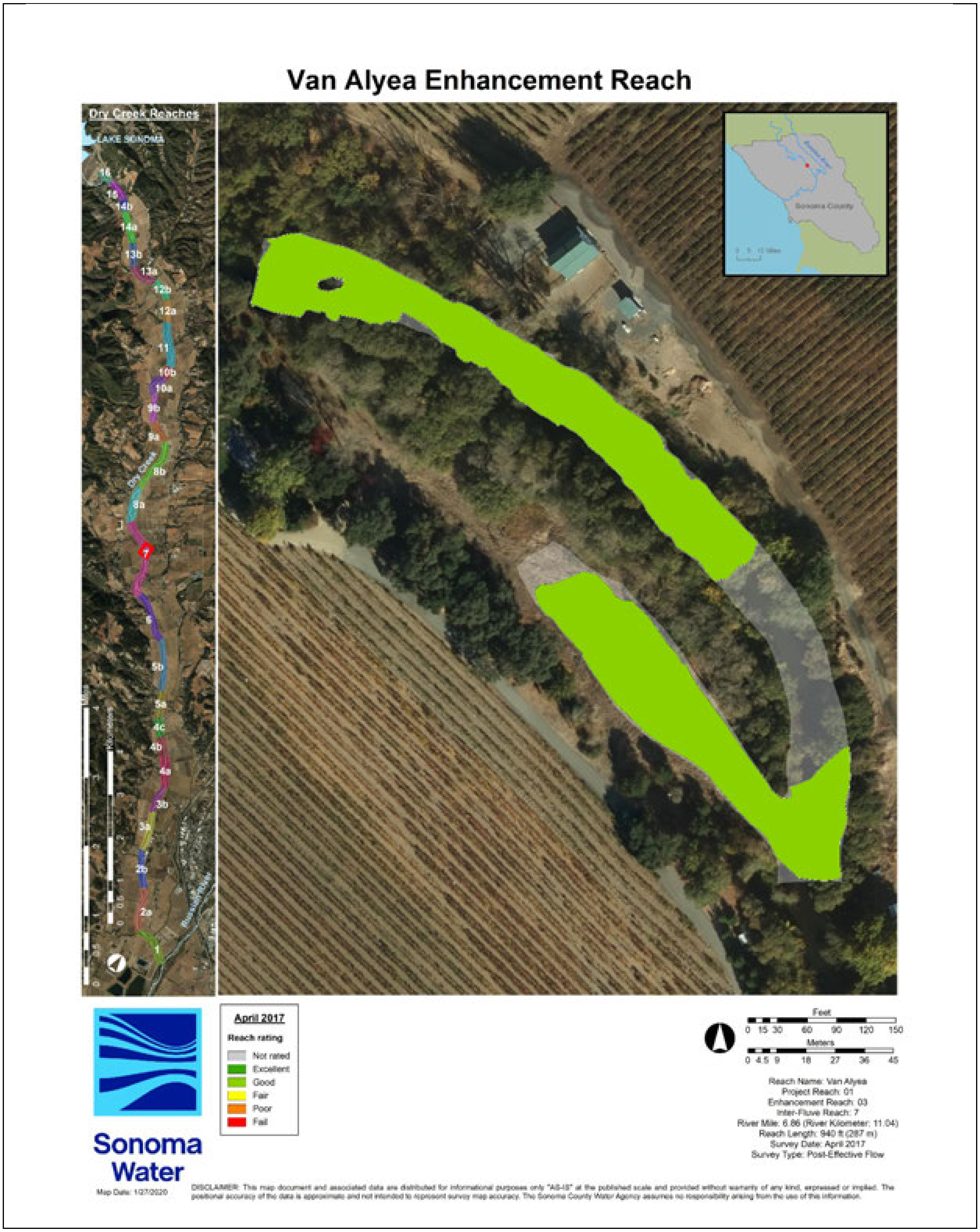


Figure 5.2.54. Post-effective flow reach rating for the Van Alyea enhancement reach, April 2017.

Farrow, Wallace Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Farrow Wallace enhancement reach in August 2017. The monitored portions of the reach covered 45,396 ft^2, with main and off channel areas, with 43% meeting optimum depth and velocity criteria (Table 5.2.39, Figure 5.2.55). Previous effectiveness monitoring in August 2015 recorded 32,452ft^2 of off channel areas, but aggradation, likely from winter 2016/2017 storms reduced off channel area to 21,695 ft^2 in 2017. The August 2015 effectiveness monitoring survey also recorded a greater main channel wetted area (55,540 ft^2) than recorded in August 2017 (23,700 ft^2) as crews could not survey portions of channel due to excessive depth (>4 ft) (Figure 5.2.55). Nonetheless, 20% and 68% of main and off channel habitat in 2017 met optimal depth and velocity criteria, compared with 15% and 60% respectively, in 2015. Five habitat units made up the monitored portion of the enhancement reach, with a pool: riffle of 0:1 (no pools found) and an average shelter score of 63 (Table 5.2.40, Figure 5.2.56, Figure 5.2.57). One habitat unit (an alcove) exceeded the optimum shelter score of 80. The enhancement reach comprised 7 enhancement sites (4 main channel, one side channel, one alcove, one bank site) (Table 5.2.41, Figure 5.2.58). We did not rate sites 2 and 3 (main channel sites) due to excessive depth, or site 4 (bank site) due to excessive vegetation growth, or features in site 6 (side channel site) due to accessibility issues (Table 5.2.41). The four rated enhancement sites received ratings ranging from fail (due to high velocity and low shelter scores) to fair and good ((Table 5.2.41, Figure 5.2.59, Figure 5.2.60, Figure 5.2.61). Overall, the Farrow, Wallace enhancement reach received a fair effectiveness monitoring rating ((Table 5.2.41, Figure 5.2.62; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.39. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Farrow, Wallace enhancement reach, August 2017.

Farrow, Wallace Post-effective flow August 2017	**Wetted area (ft^2)**	**Optimal depth (ft^2)**			**Optimal velocity (ft^2)**	**Optimal habitat (ft^2)**		
		0.5 – 2.0 ft	**2.0 – 4.0 ft**	**Total**	**< 0.5 ft/s**	**0.5 – 2.0 ft < 0.5 ft/s**	**2.0 – 4.0 ft < 0.5 ft/s**	**Total**
Main channel area	23,700	13,144	7,065	20,209	7,392	3,109	1,561	4,669
Off channel area	21,695	8,774	7,068	15,842	20,378	8,239	6,420	14,659
Total area	**45,396**	**21,918**	**14,132**	**36,051**	**27,770**	**11,348**	**7,981**	**19,328**
Main channel % of wetted area	52%	55%	30%	85%	31%	13%	7%	20%
Off channel % of area	48%	40%	33%	73%	94%	38%	30%	68%
Total % of wetted area	**100%**	**48%**	**31%**	**79%**	**61%**	**25%**	**18%**	**43%**

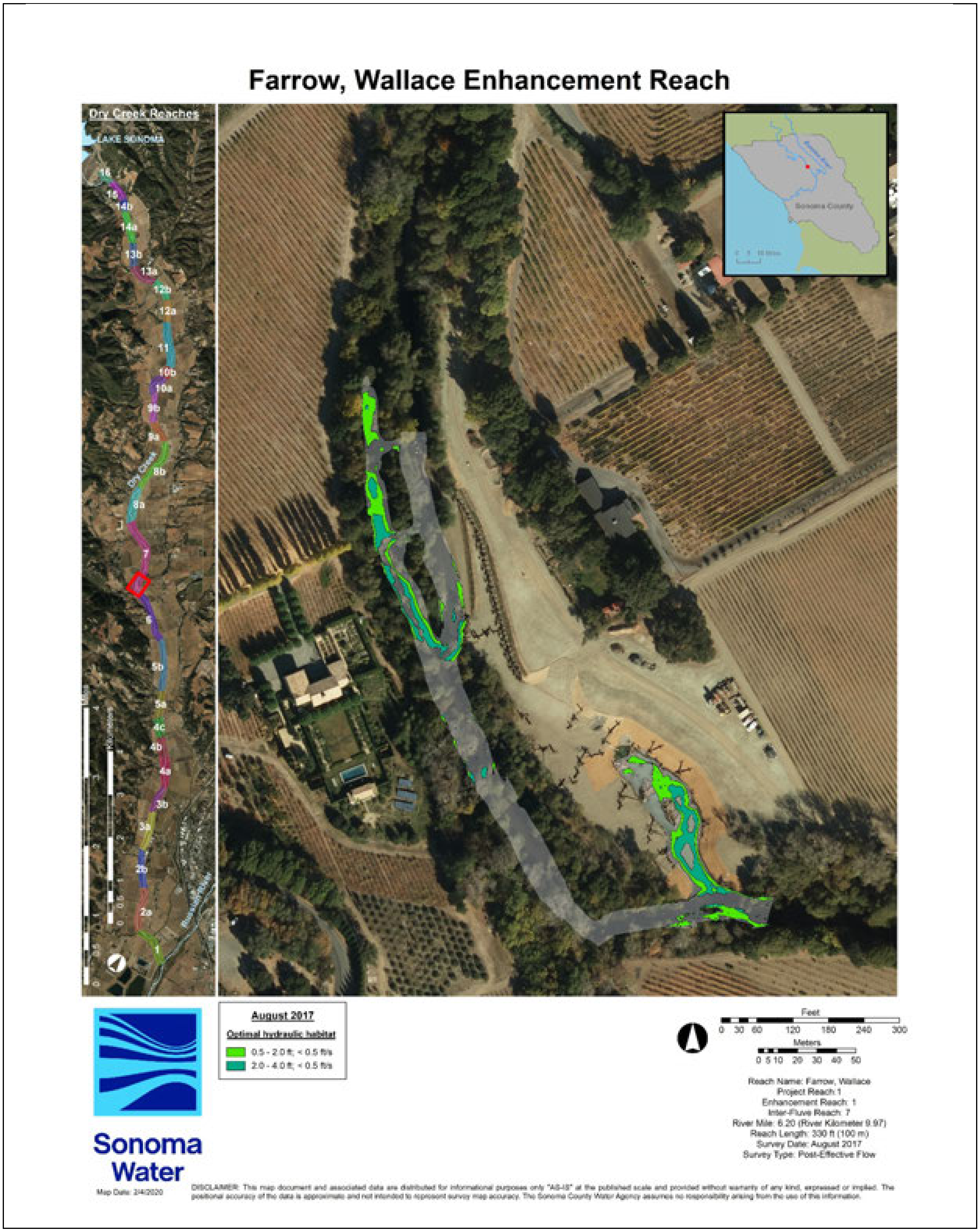


Figure 5.2.55. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Farrow, Wallace enhancement reach, August 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2. 40. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Farrow, Wallace enhancement reach, Post-effective flow August 2017. Habitat units 1, 4 and 5 did not have shelter assessed.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	0	0	0
HU02	Alcove	3	90	270
HU03	Flatwater	3	15	45
HU04	Alcove	0	0	0
HU05	Riffle	0	0	0
Pool: riffle	**0: 1 (NA)**			**Avg = 63**

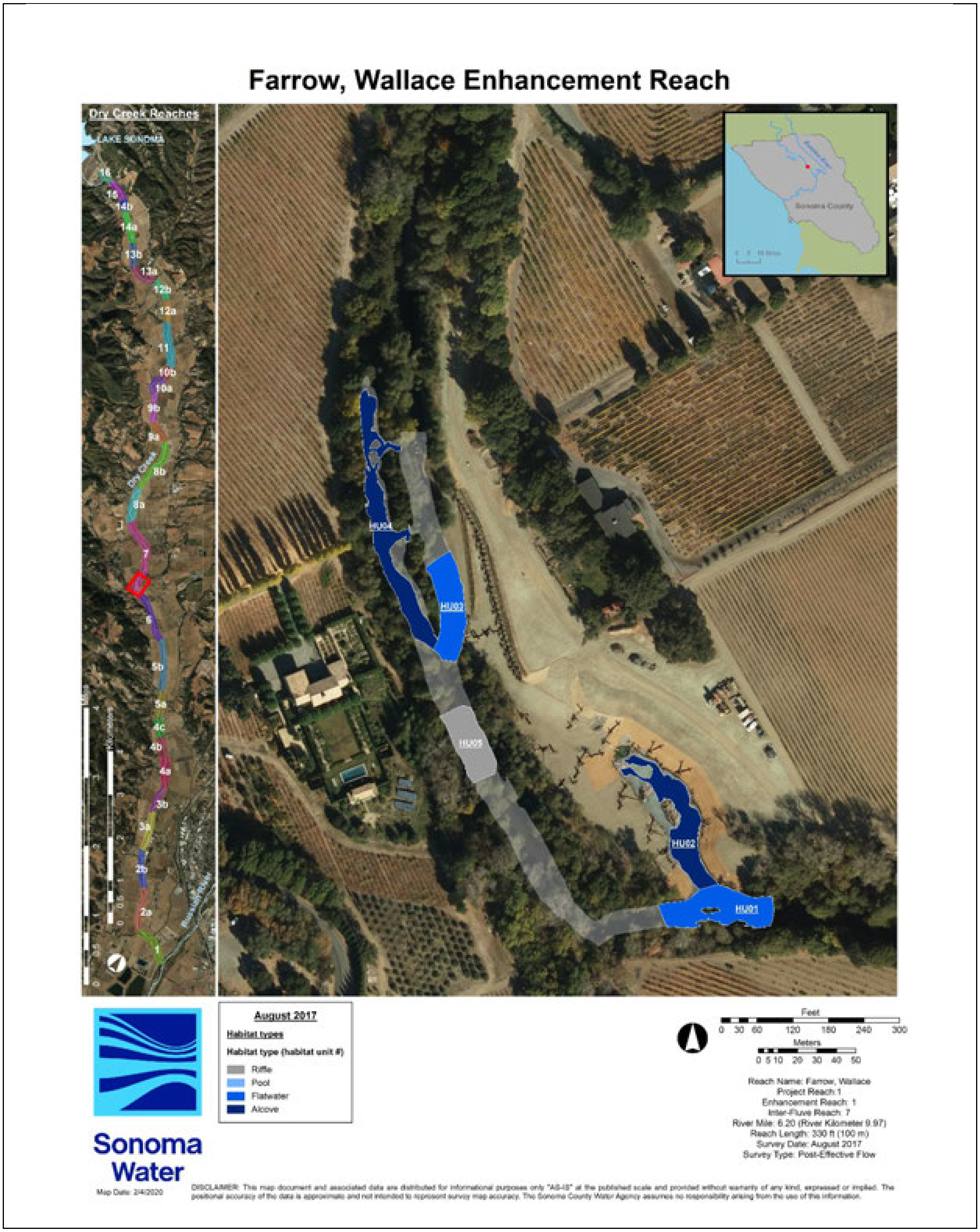


Figure 5.2.56. Habitat unit number and type within the Farrow, Wallace enhancement reach, August 2017.

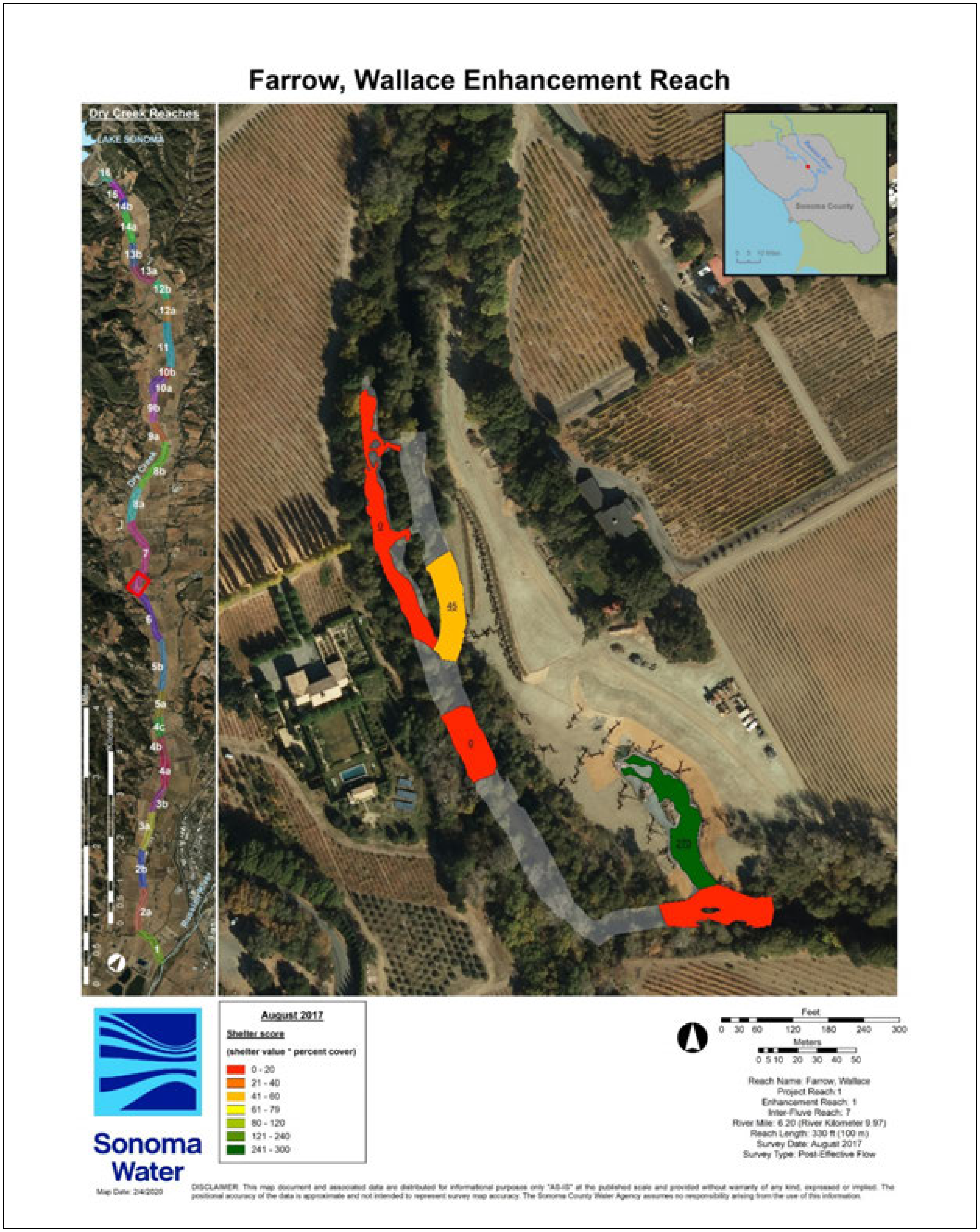


Figure 5.2.57. Habitat unit shelter values within the Farrow, Wallace enhancement reach, August 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.41. Post-effective flow site and reach ratings for the Farrow, Wallace enhancement reach, August 2017.

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 rating	Site average feature quantitative rating[a]	12	0	0	0	13	0	13
	Site average feature qualitative rating[a]	Excellent	Not rated	Not rated	Not rated	Excellent	Not rated	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	23	0	0	0	17	16	6
	Site average qualitative rating[b]	Good	Not rated	Not rated	Not rated	Fair	Fair	Fail
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)	35[c]	0	0	0	30[c]	16[b]	19[c]
	Site qualitative rating	Good[c]	Not rated	Not rated	Not rated	Good[c]	Fair[b]	Poor[c]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	25						
	Enhancement reach qualitative rating[d]:	Fair						

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

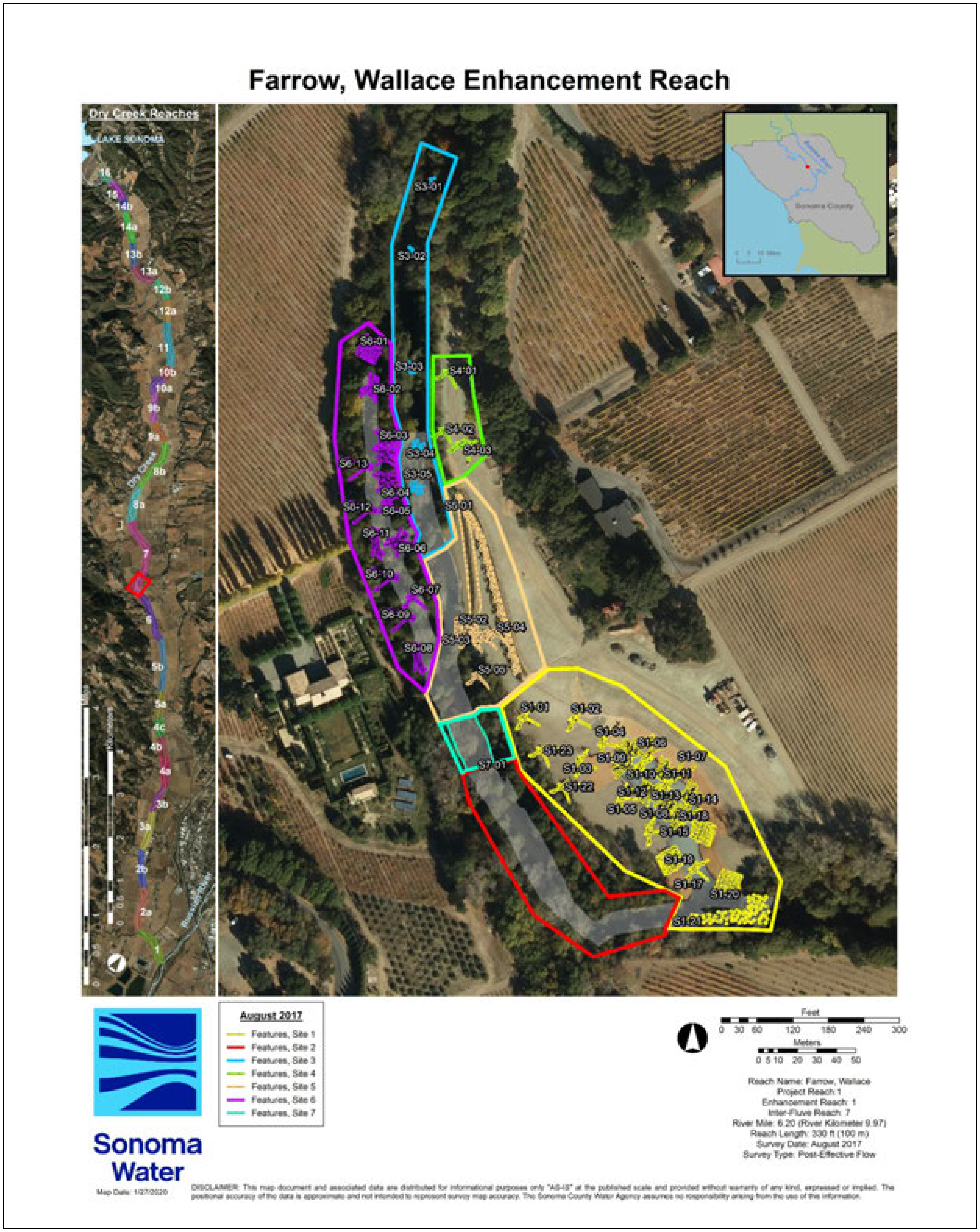


Figure 5.2.58. Enhancement sites and features within the Farrow, Wallace enhancement reach, August 2017.

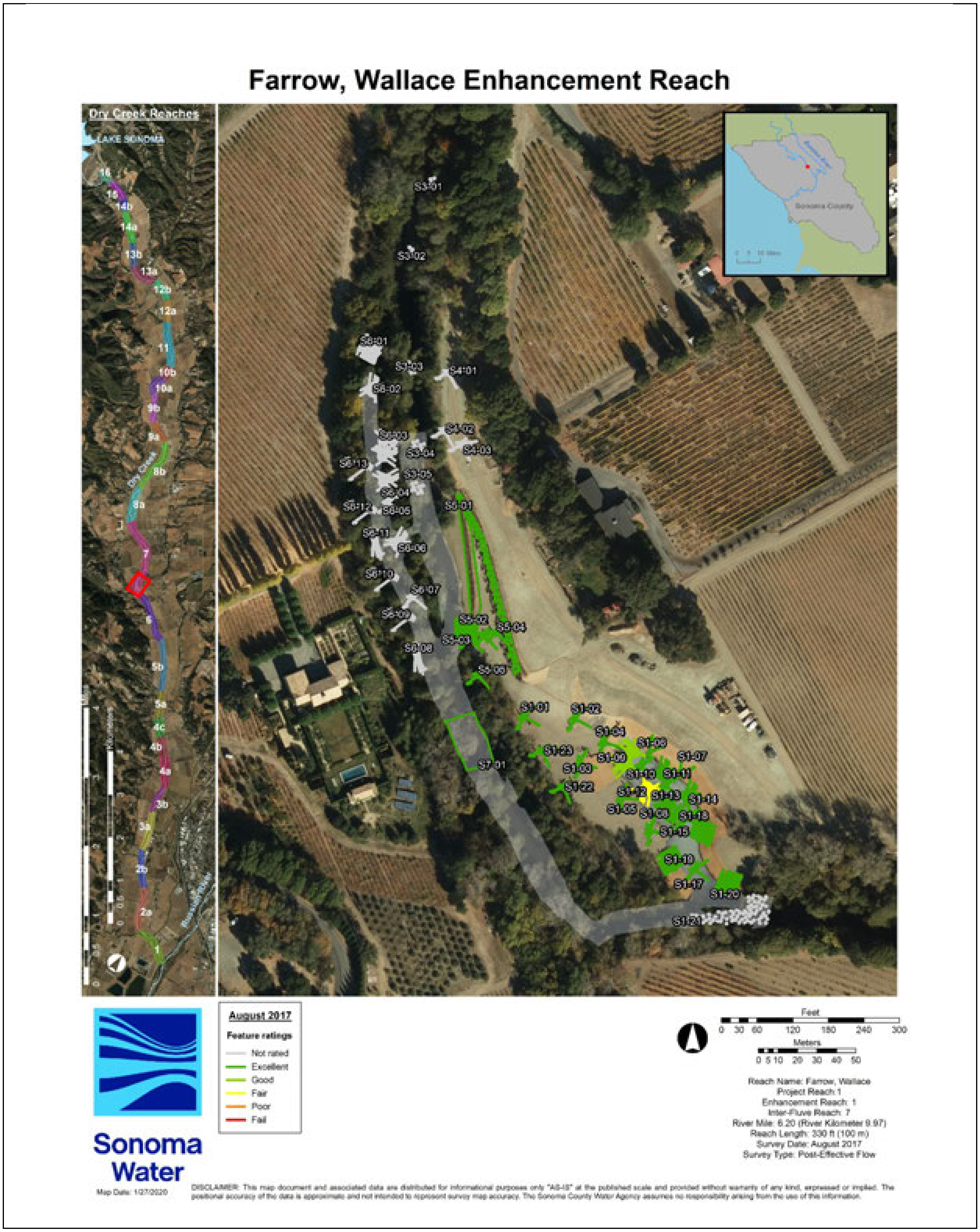


Figure 5.2.59. Feature ratings for the Farrow, Wallace enhancement reach, August 2017.

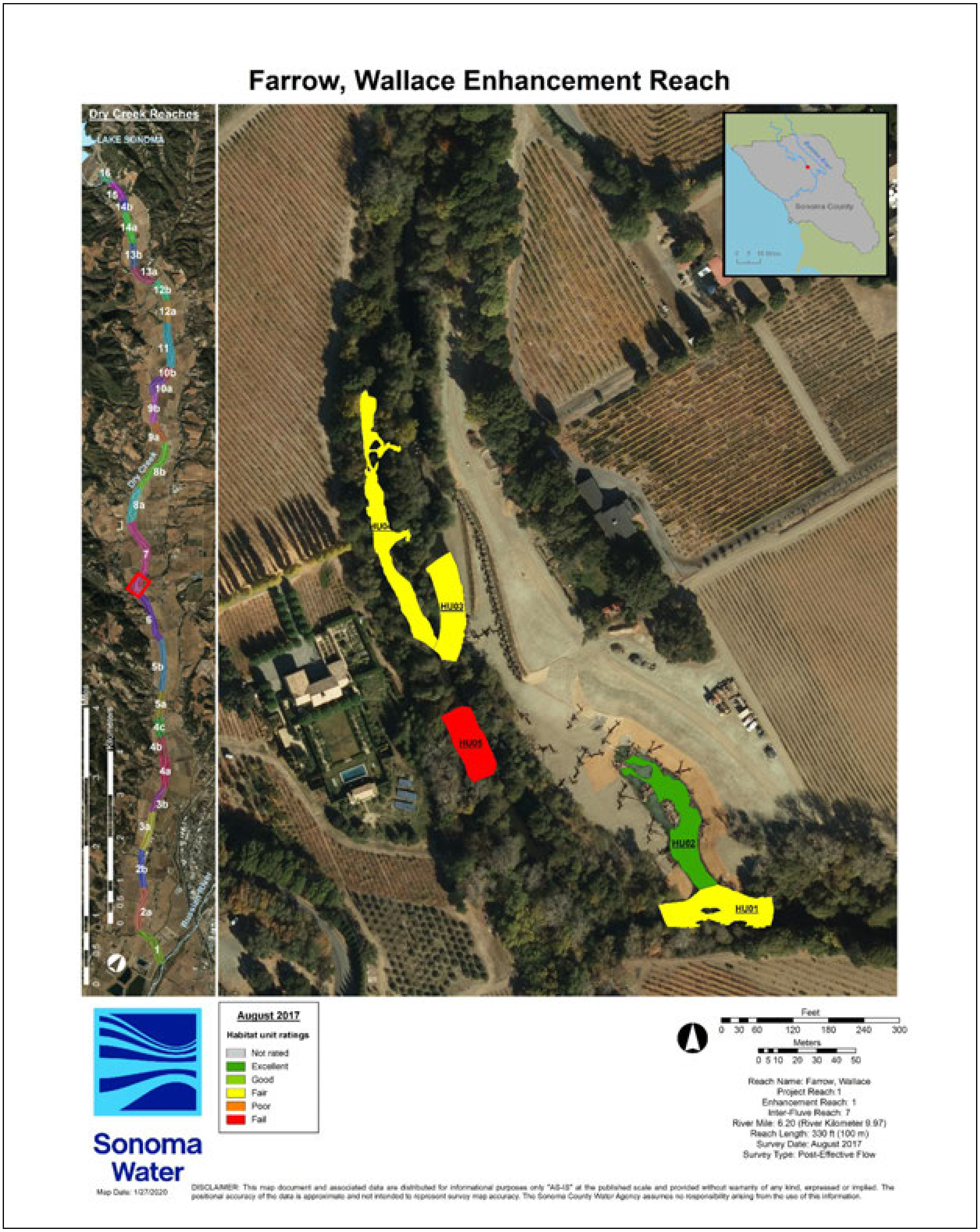


Figure 5.2.60. Habitat unit ratings for the Farrow, Wallace enhancement reach, August 2017.

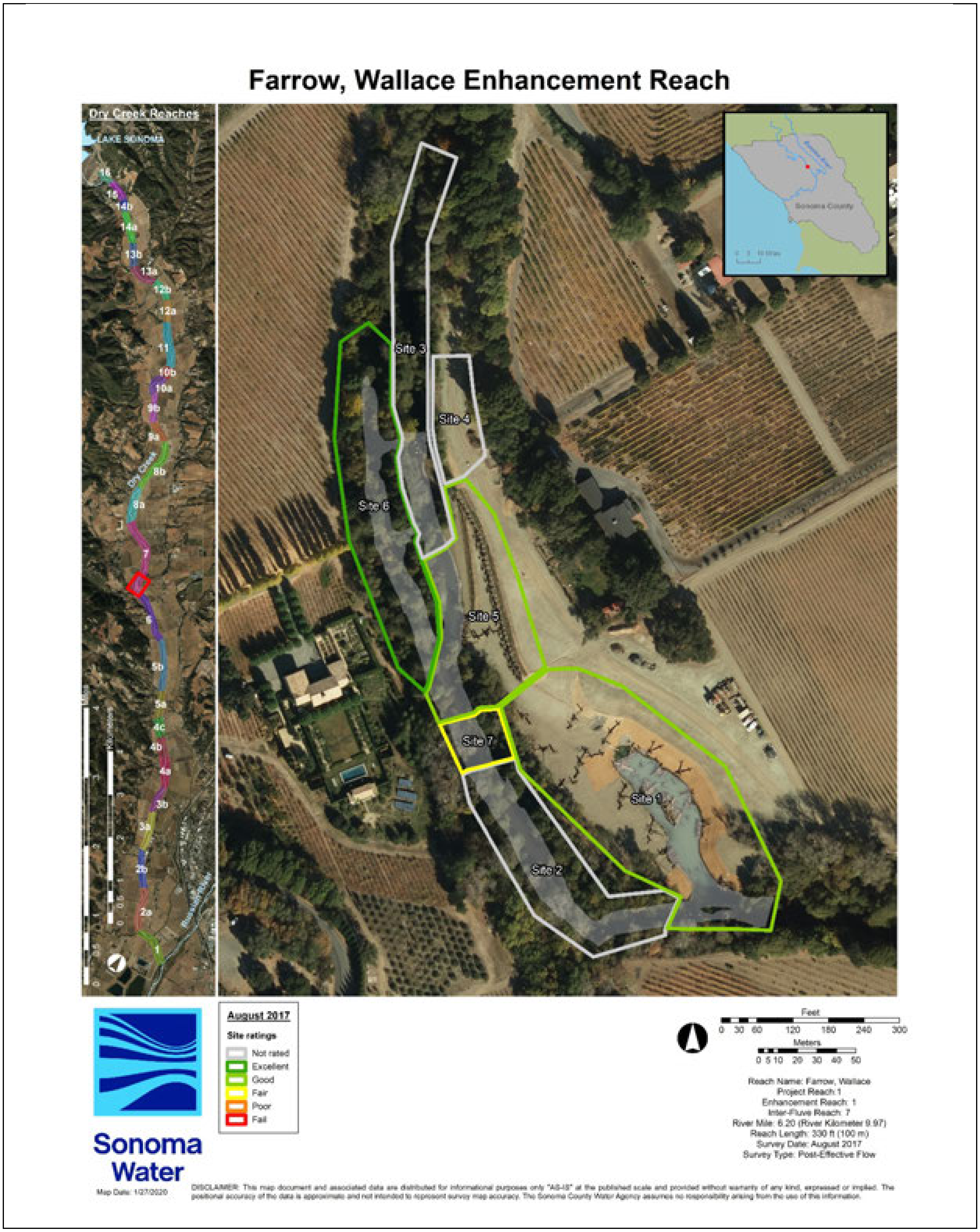


Figure 5.2.61. Post-effective flow site ratings for the Farrow, Wallace enhancement reach, August 2017.

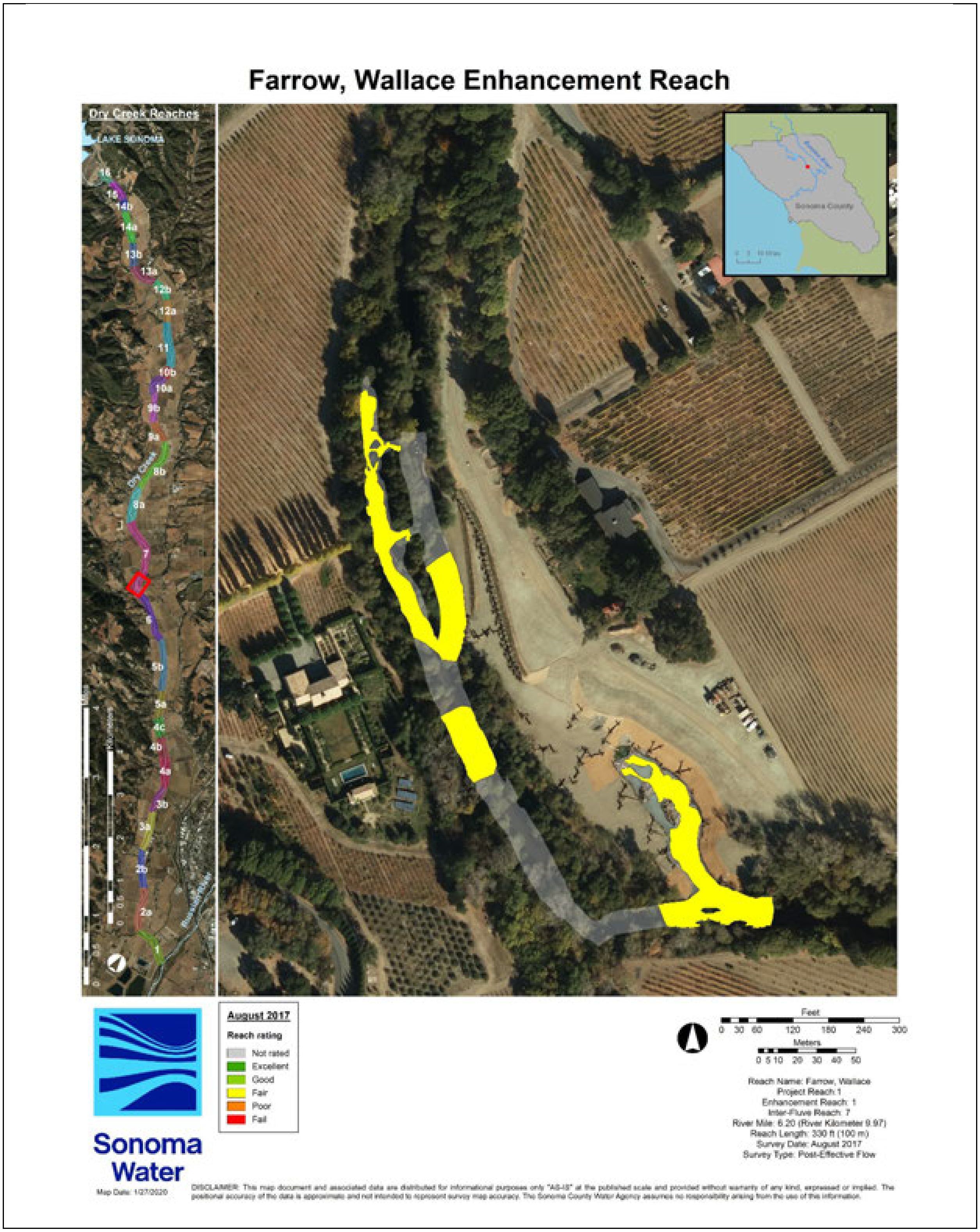


Figure 5.2.62. Post-effective flow reach rating for the Farrow, Wallace enhancement reach, August 2017.

Geyser Peak Enhancement Reach

Sonoma Water monitored the post-effective flow condition of the Geyser Peak enhancement reach in July 2017. The enhancement reach encompassed 43,334 ft^2 within main-channel area, with 14% of the total area meeting optimum depth and velocity criteria, mainly along the channel margins (Table 5.2.42, Figure 5.2.63). The enhancement initially added 8,244 ft^2 of side-channel in October 2016, but aggradation caused by large storms in winter 2016/2017 filled the side-channel and reduced off-channel area to 0 ft^2 (Table 5.2.42). Nine habitat units made up the enhancement reach post-effective flow, all in the main-channel, with a pool: riffle of 4:3 (1.33) and an average shelter score of 63 (Table 5.2.43, Figure 5.2.64, Figure 5.2.65). Four habitat units met or exceeded the optimum shelter value of 80. The enhancement reach comprised two enhancement sites (one main channel and one side channel; Table 5.2.44, Figure 5.2.66) that both received fail site average feature ratings, and fail to fair site average habitat unit ratings. Site 2 (side-channel) completely aggraded, burying most enhancement features, leading to a fail site rating (Table 5.2.44, Figure 5.2.67). Site 1 (main channel) did not aggrade, but due to a fail site average feature rating and a fair site average habitat unit rating, received a poor site rating (Table 5.2.44, Figure 5.2.68, Figure 5.2.69). Overall, Geyser Peak enhancement reach received a fail effectiveness monitoring rating (Table 5.2.44, Figure 5.2.70). The monitoring results and subsequent ratings led to repairs by Sonoma Water in October 2017 (See Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.42. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, July 2017.

Geyser Peak Post-effective flow July 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	43,334	30,162	6,799	36,961	10,478	4,910	1,207	6,117
Off channel area	0	0	0	0	0	0	0	0
Total area	**43,334**	**30,162**	**6,799**	**36,961**	**10,478**	**4,910**	**1,207**	**6,117**
Main channel % of wetted area	100%	70%	16%	85%	24%	11%	3%	14%
Off channel % of wetted area	0%	0%	0%	0%	0%	0%	0%	0%
Total % of wetted area	**100%**	**70%**	**16%**	**85%**	**24%**	**11%**	**3%**	**14%**

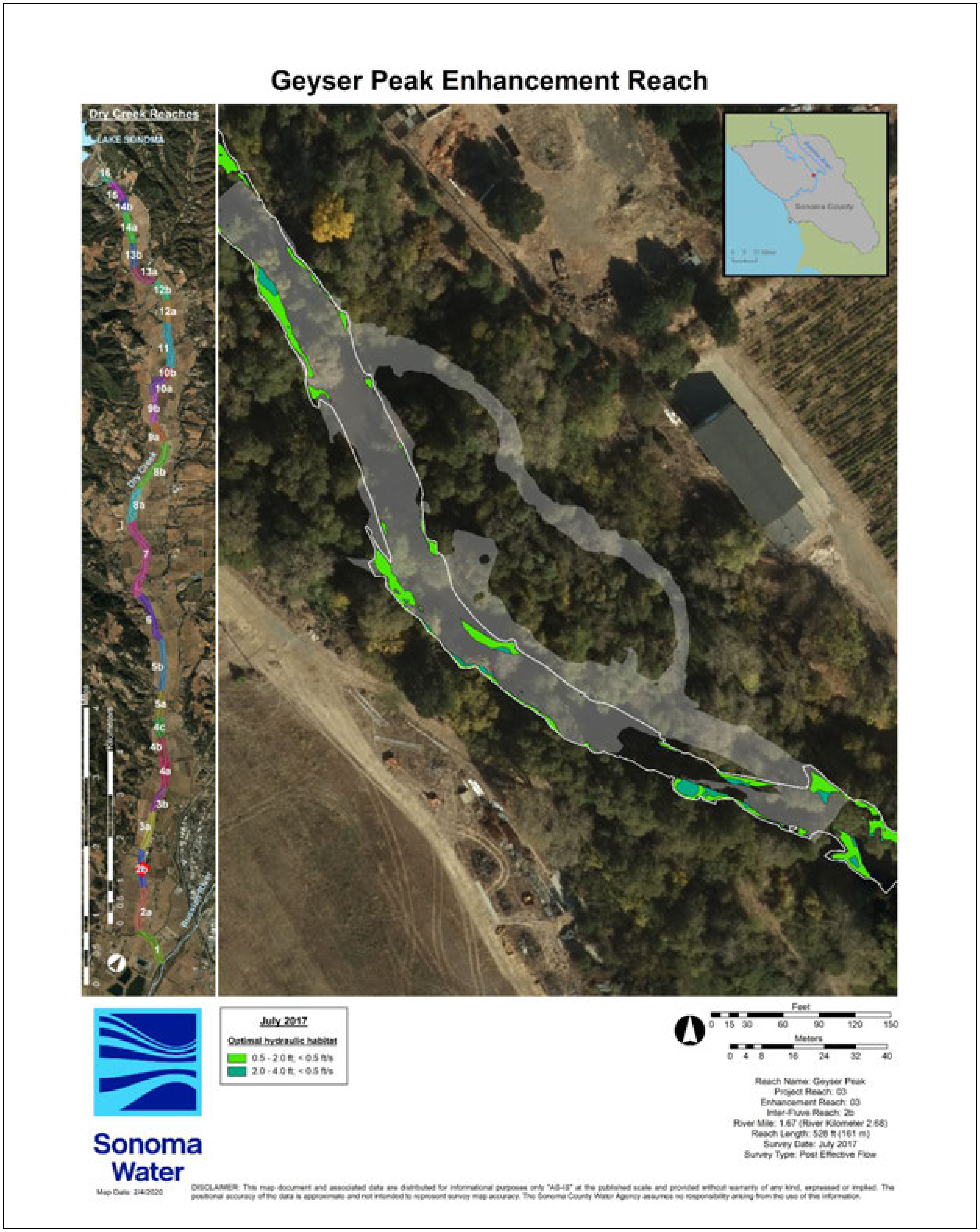


Figure 5.2.63. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Geyser Peak enhancement reach, July 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.43. Habitat, types, shelter score, percent cover, and shelter value for habitat units within the Geyser Peak enhancement reach, Post-effective flow July 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	3	35	105
HU02	Pool	3	20	60
HU03	Riffle	1	10	10
HU04	Pool	3	30	90
HU05	Riffle	2	25	50
HU06	Flatwater	3	30	90
HU07	Pool	3	15	45
HU08	Riffle	1	10	10
HU09	Pool	3	35	105
Pool: riffle	**4:3 (1.33)**			**Avg = 63**

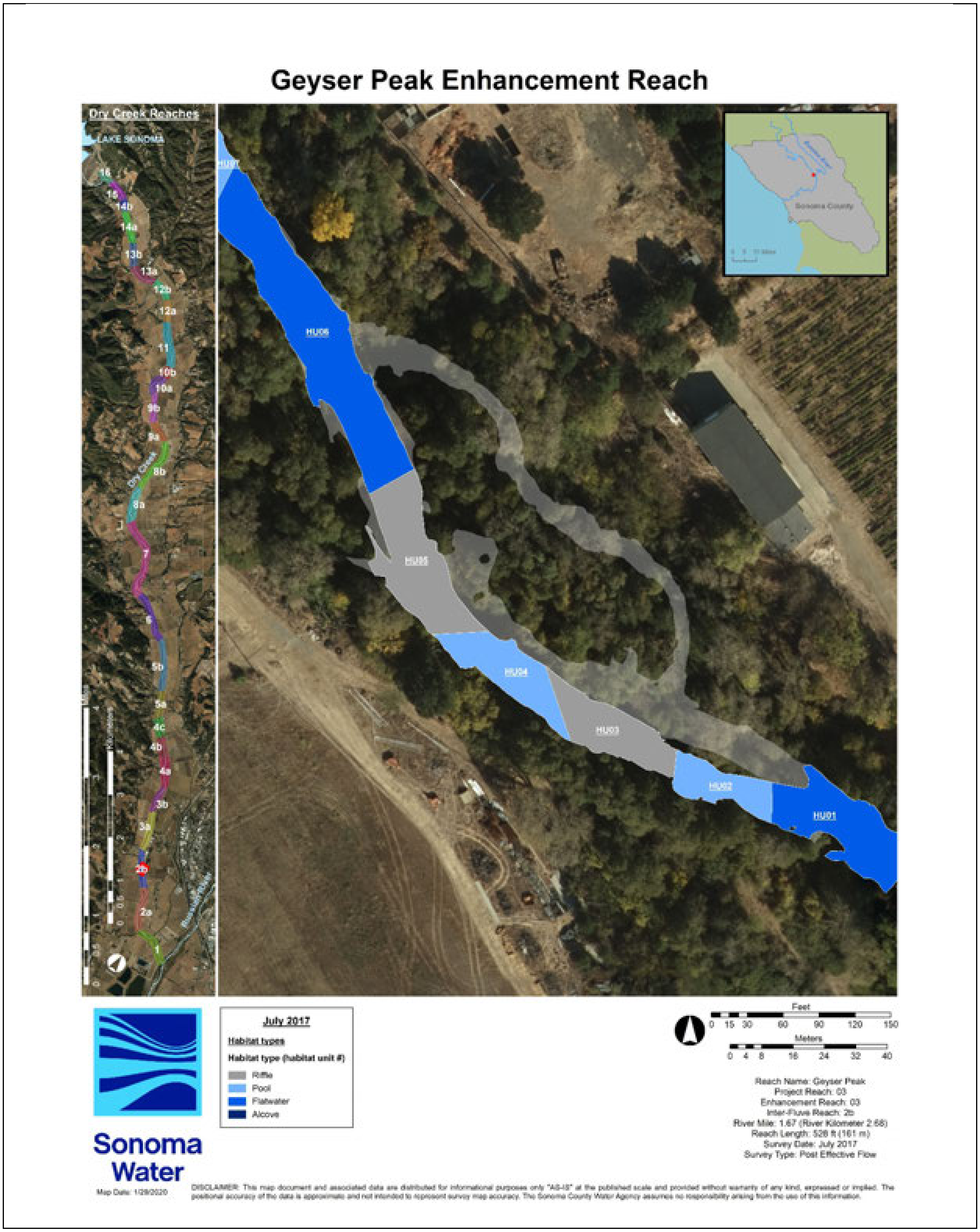


Figure 5.2.64. Habitat unit number and type within the Geyser Peak enhancement reach, July 2017.

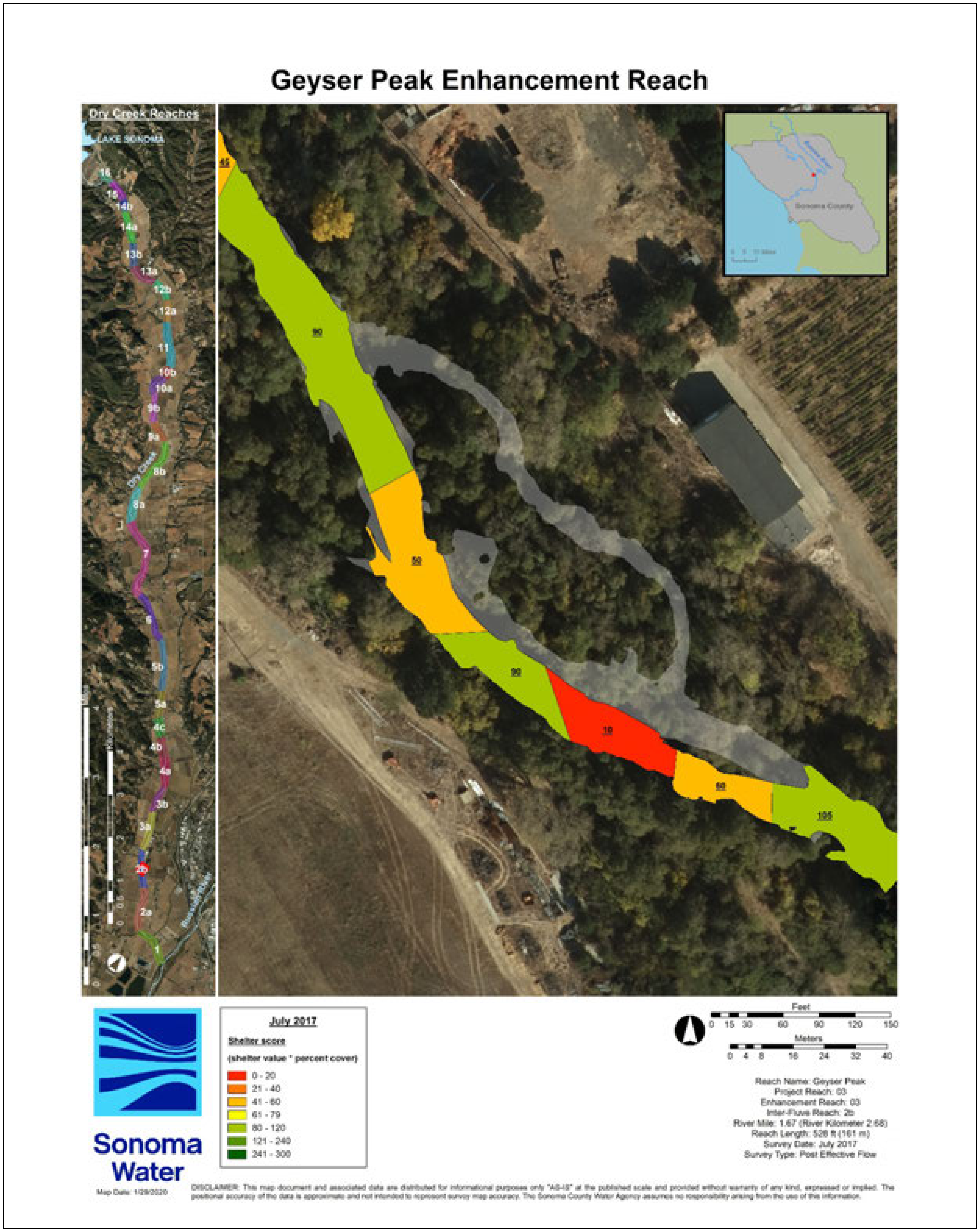


Figure 5.2.65. Habitat unit shelter scores within the Geyser Peak enhancement reach, July 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.44. Post-effective flow site and reach ratings for the Geyser Peak enhancement reach, July 2017.

Site number		**1**	**2**		
Site type		Main channel	Side channel		
Site average feature rating	Site average feature quantitative rating[a]	0	1		
	Site average feature qualitative rating[a]	Fail	Fail		
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	15	0		
	Site average qualitative rating[b]	Fair	Fail		
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	15	1		
	Site qualitative rating[c]	Poor	Fail		
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	8			
	Enhancement reach qualitative rating[c]:	Poor			

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

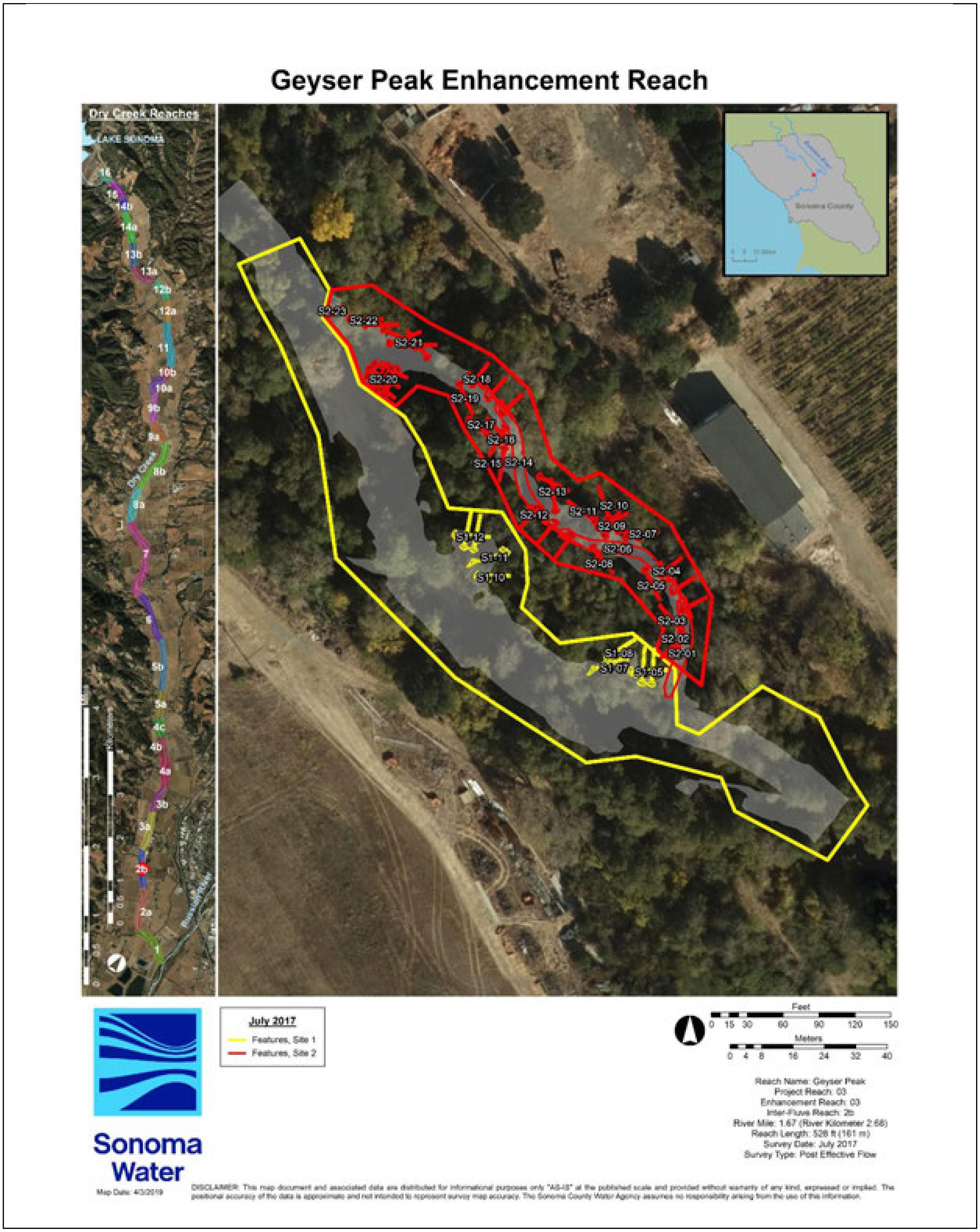


Figure 5.2.66. Enhancement sites and features within the Geyser Peak enhancement reach, July 2017.

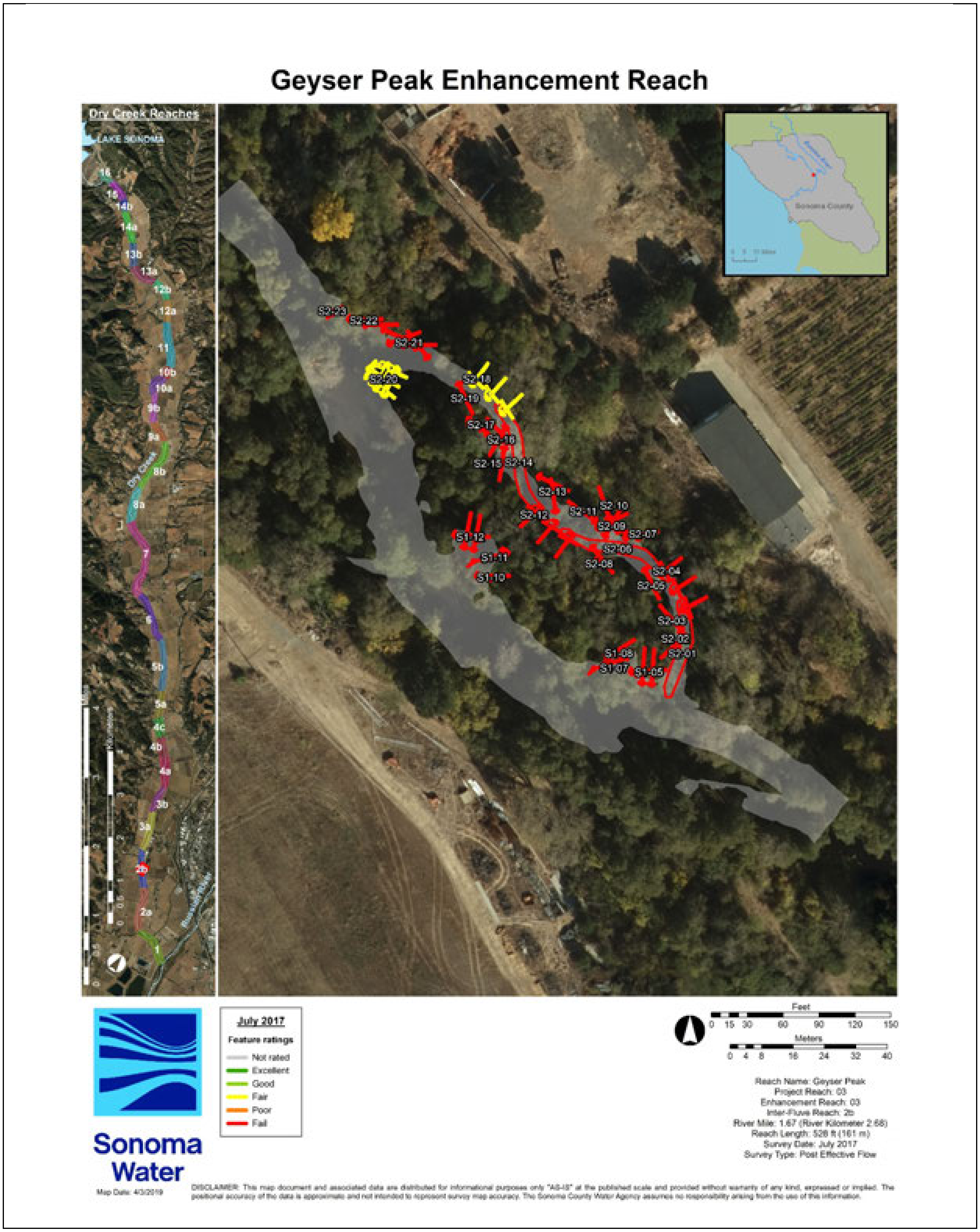


Figure 5.2.67. Feature ratings for the Geyser Peak enhancement reach, July 2017.

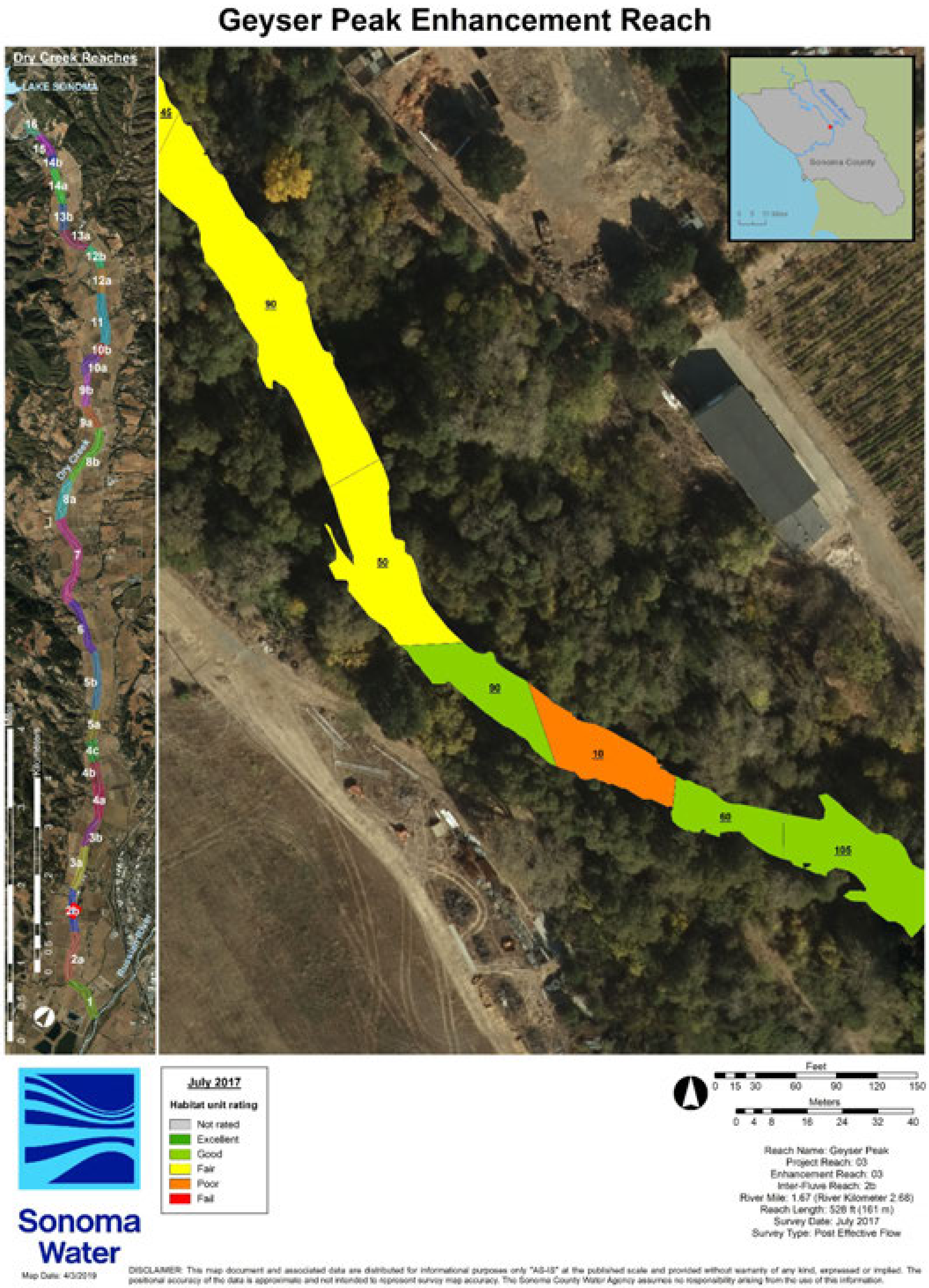


Figure 5.2.68. Post-effective flow habitat unit rating for the Geyser Peak enhancement reach, July 2017.

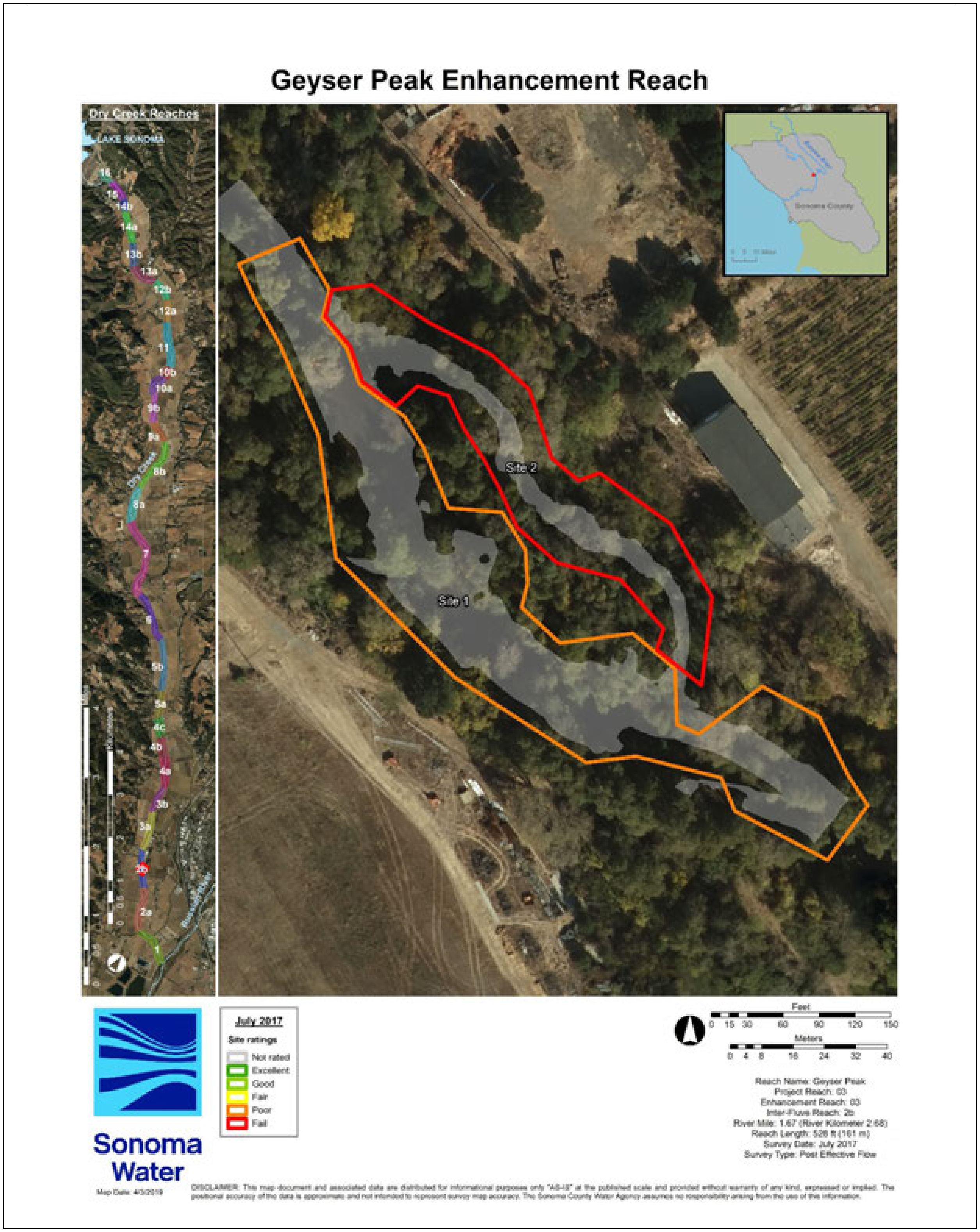


Figure 5.2.69. Post-effective flow site ratings for the Geyser Peak enhancement reach, July 2017.

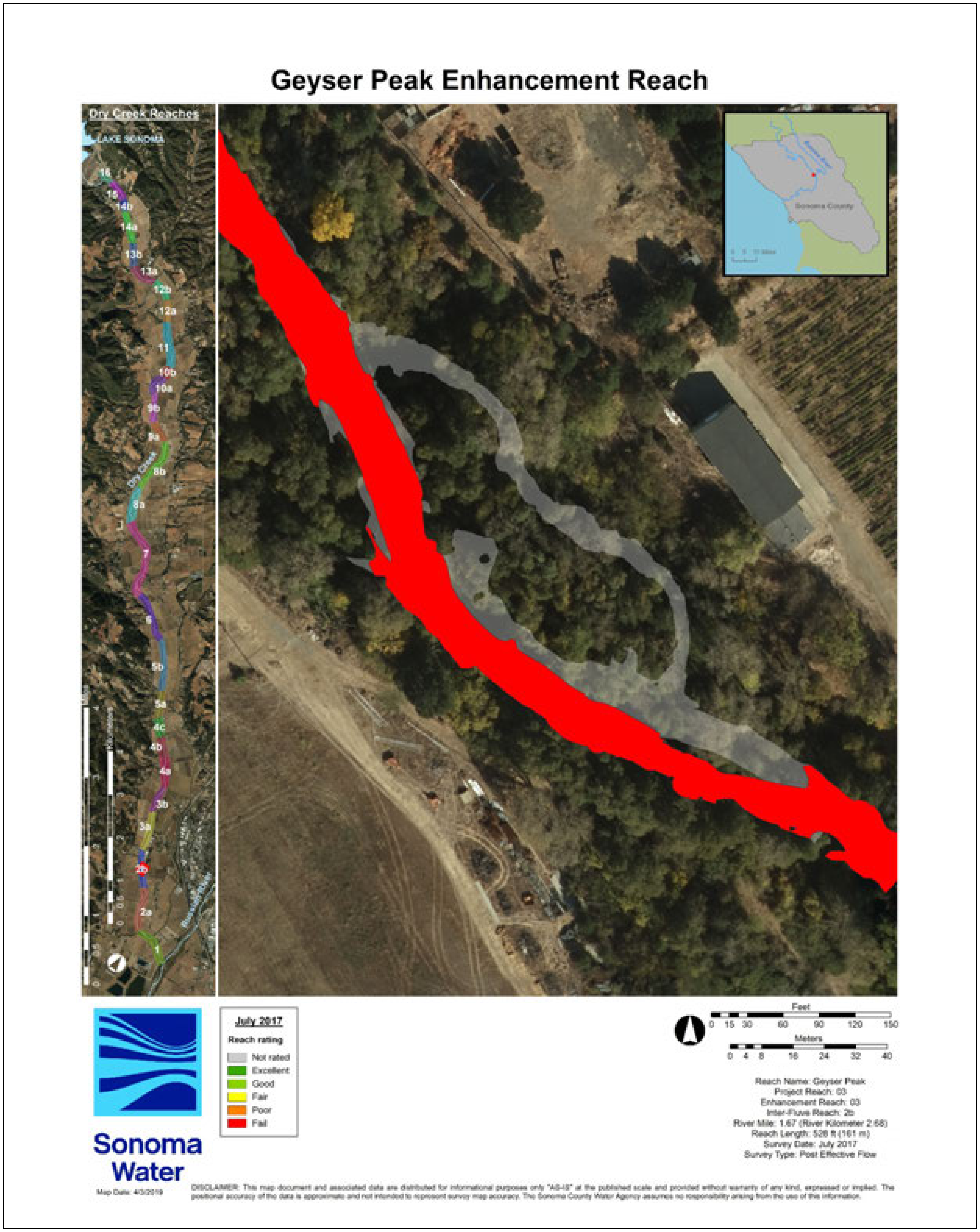


Figure 5.2.70. Post-effective flow reach rating for the Geyser Peak enhancement reach, July 2017.

Post-repair

Summary

Sonoma Water monitored the post-repair conditions of the Truett Hurst, Meyer, and Geyser Peak enhancement reaches in 2017 (Figure 5.2.4). The repairs encompassed 60,492ft^2 within main- and off-channel areas, with 31% meeting optimal depth and velocity criteria (Table 5.2.45). Repairs to the main channel covered 8,820 ft2, of which 12% met optimal depth and velocity criteria, while repairs to off-channel areas occurred over 51,672 ft2, with 35% meeting optimal depth and velocity criteria. Crews recorded 19 habitat units across all three enhancement reaches with a total poo to riffle ratio of 6:6 (1.00) and a total average shelter score of 53 (Table 5.2.46). No habitat types exceeded the optimum shelter score of 80, although the single observed alcove received a shelter score of 75, followed by pools (70), riffles (61), and flatwaters (25). Post-repair, the Truett Hurst, Meyer, and Geyser Peak rated good, good, and fair, respectively (Table 5.2.47; see below for individual enhancement reach summaries and Appendix 5.1 all measured values, scores, and ratings)

Depth and velocity

Table 5.2.45. Post-repair areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within Dry Creek enhancement reaches repaired in 2017.

Dry Creek Post-repair 2017	**Wetted area (ft^2)**	**Optimal depth (ft^2)**			**Optimal velocity (ft^2)**	**Optimal habitat (ft^2)**		
		0.5 – 2.0 ft	**2.0 – 4.0 ft**	**Total**	**< 0.5 ft/s**	**0.5 – 2.0 ft < 0.5 ft/s**	**2.0 – 4.0 ft < 0.5 ft/s**	**Total**
Main channel area	8,820	5,805	1,943	7,748	1,937	995	83	1,078
Off channel area	51,672	20,597	20,736	41,333	25,971	10,219	7,674	17,893
Total area	60,492	26,402	22,680	49,082	27,908	11,214	7,757	18,971
Main channel % of wetted area	15%	66%	22%	88%	22%	11%	1%	12%
Off channel % of wetted area	85%	40%	40%	80%	50%	20%	15%	35%
Total % of wetted area	**100%**	44%	37%	81%	46%	19%	13%	31%

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.46. Post-repair habitat types, pool: riffle ratio and average shelter score within Dry Creek enhancement reaches constructed in 2017.

Habitat Type	# of Habitat Units	Shelter Score
Riffle	6	61
Pool	6	70
Flatwater	6	25
Alcove	1	75
Pool: riffle	**6:6 (1.00)**	**Avg = 53**

Reach ratings

Table 5.2.47. Post-repair ratings for Dry Creek enhancement reaches repaired in 2017.

Enhancement Reach	Post-effective Flow Rating
Truett Hurst	Good
Meyer	Good
Geyser Peak	Fair

Truett Hurst Enhancement Reach

Sonoma Water monitored the post-repair condition of Truett Hurst enhancement reach in October 2017. The repaired reach encompassed 40,431 ft^2, including small portions of main channel area near the side channel inlet and outlet, with 28% of the total area meeting optimal depth and velocity criteria (Table 5.2.48, Figure 5.2.71). The repairs excavated one alcove in the downstream end of the side channel and re-configured the side channel, but left a portion of the upstream alcove and associated features buried, and added a site with a bank and floodplain features adjacent to the side channel. After repairs, crews recorded 4,516 ft^2 of alcove and 27,095 ft^2 of side-channel, of which 81% and 25% respectively, met optimal depth and velocity criteria, compared to 12% in the main channel. Nine habitat units composed the repaired portion of the enhancement reach, with a pool to riffle ratio of 4:2 (2.00) and an average shelter score of 53 (Table 5.2.49, Figure 5.2.72, Figure 5.2.73). One habitat unit exceeded the optimal shelter value of 80. The repaired enhancement reach comprised five originally constructed enhancement sites (one main channel, two alcoves, one side channel), and a newly added site with bank and floodplain features adjacent to the side channel (Figure 5.2.74). As noted above, the repairs left a portion of the upstream alcove and associated features buried, but reconfigured the side channel (enhancement site 4). The reconfiguration excavated and integrated a portion of the buried alcove into the side channel. While a part of the reconfigured side channel, we rated site 4 as an independent site. The five sites received excellent site average feature ratings (we did not rate enhancement site 1 as it contained no features) and poor to good site average habitat unit ratings (Table 5.2.50, Figure 5.2.75, Figure 5.2.76). Post-repair enhancement site ratings ranged from good to excellent, with the remaining alcove (site 3) scoring the highest (Table 5.2.50, Figure 5.2.**77**). Overall, Truett Hurst enhancement reach post-repair received a good effectiveness monitoring rating (Table 5.2.50, Figure 5.2.78; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.48. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Truett Hurst enhancement reach, October 2017.

Truett Hurst Post-repair October 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Main channel area	8,820	5,805	1,943	7,748	1,937	995	83	1,078
Side channel alcove area	4,516	1,884	1,784	3,668	4,509	1,883	1,778	3,661
Side channel area	27,095	11,112	11,775	22,886	9,281	4,860	1,890	6,750
Total area	**40,431**	**18,801**	**15,502**	**34,303**	**15,727**	**7,738**	**3,751**	**11,489**
Main channel % of wetted area	22%	66%	22%	88%	22%	11%	1%	12%
Side channel % of area	11%	41%	43%	84%	34%	18%	7%	25%
Side channel alcove % of wetted area	67%	42%	40%	81%	100%	42%	39%	81%
Total % of wetted area	**100%**	**47%**	**38%**	**85%**	**39%**	**19%**	**9%**	**28%**

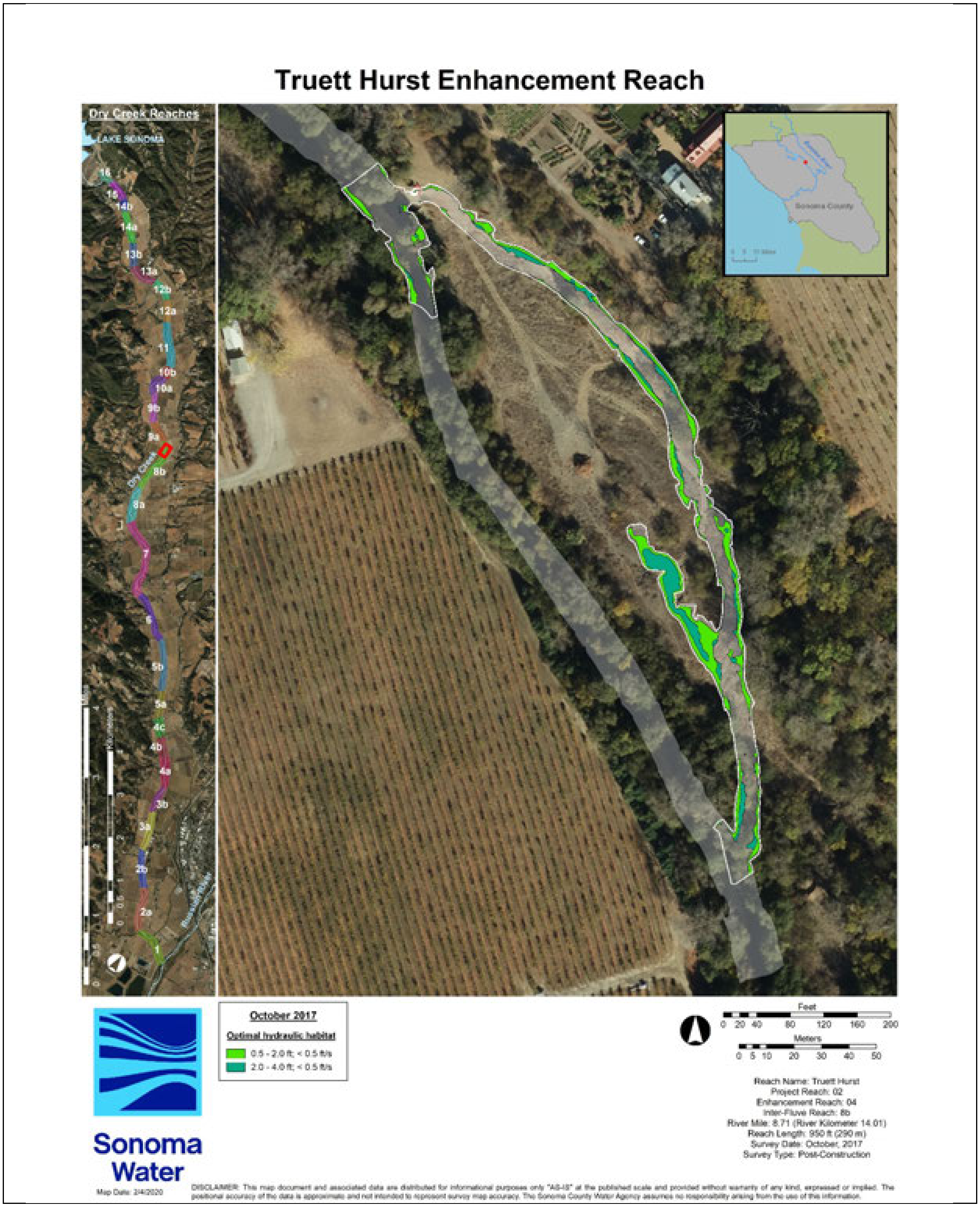


Figure 5.2.71. Optimal hydraulic habitat for fry (<0.5 f/s, 0.5-2.0 ft) and parr (<0.5 f/s, 2.0-4.0 ft) within the Truett Hurst enhancement reach, October 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.49. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Truett Hurst enhancement reach, Post-repair October 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	0	0	0
HU02	Pool	3	20	60
HU03	Riffle	2	35	70
HU04	Pool	3	40	120
HU05	Alcove	3	25	75
HU06	Flatwater	3	10	30
HU07	Pool	3	25	75
HU08	Riffle	3	15	45
HU09	Flatwater	0	0	0
Pool: riffle	**4:2 (2.00)**			**Avg = 53**

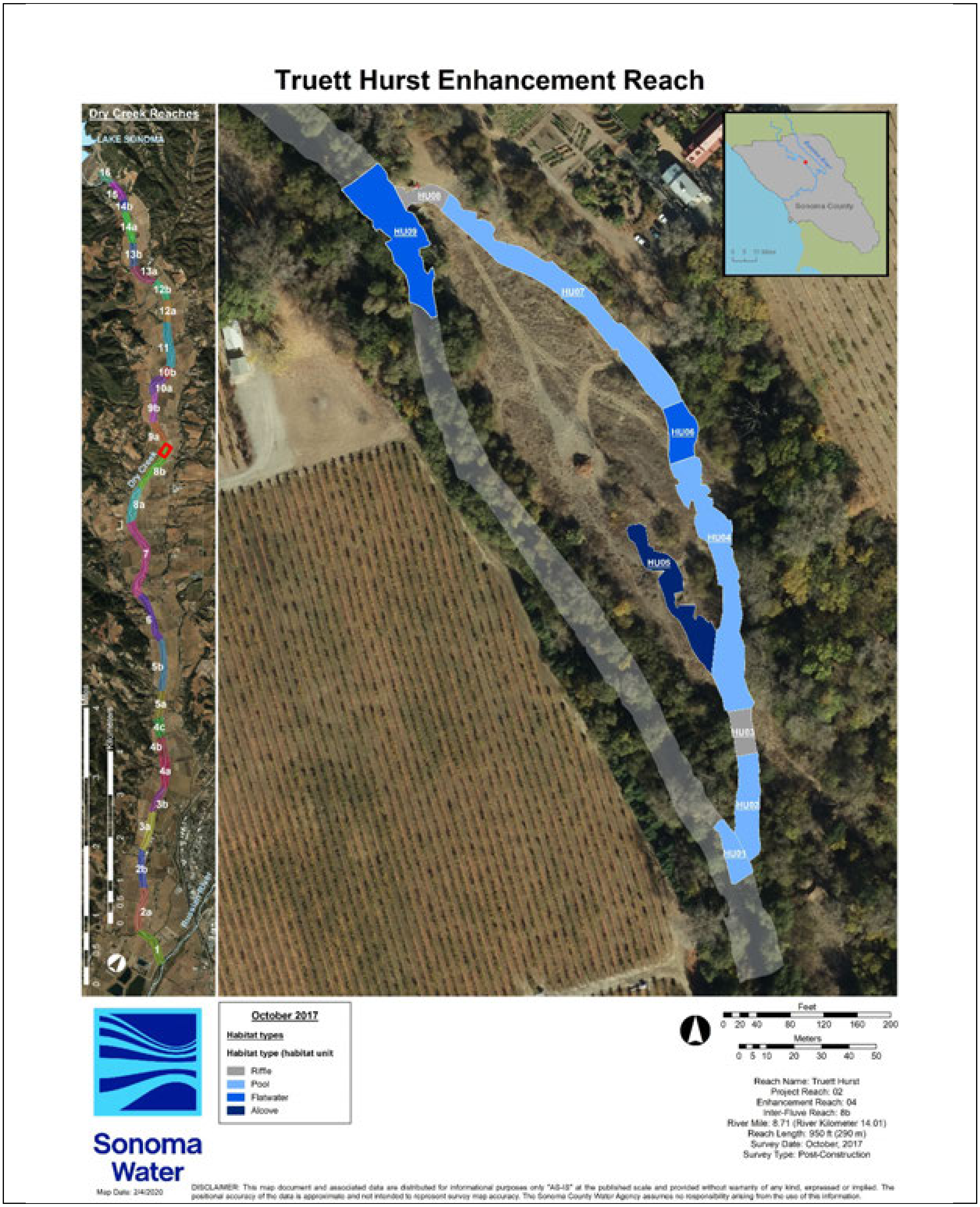


Figure 5.2.72. Habitat unit number and type within the Truett Hurst enhancement reach, October 2017.

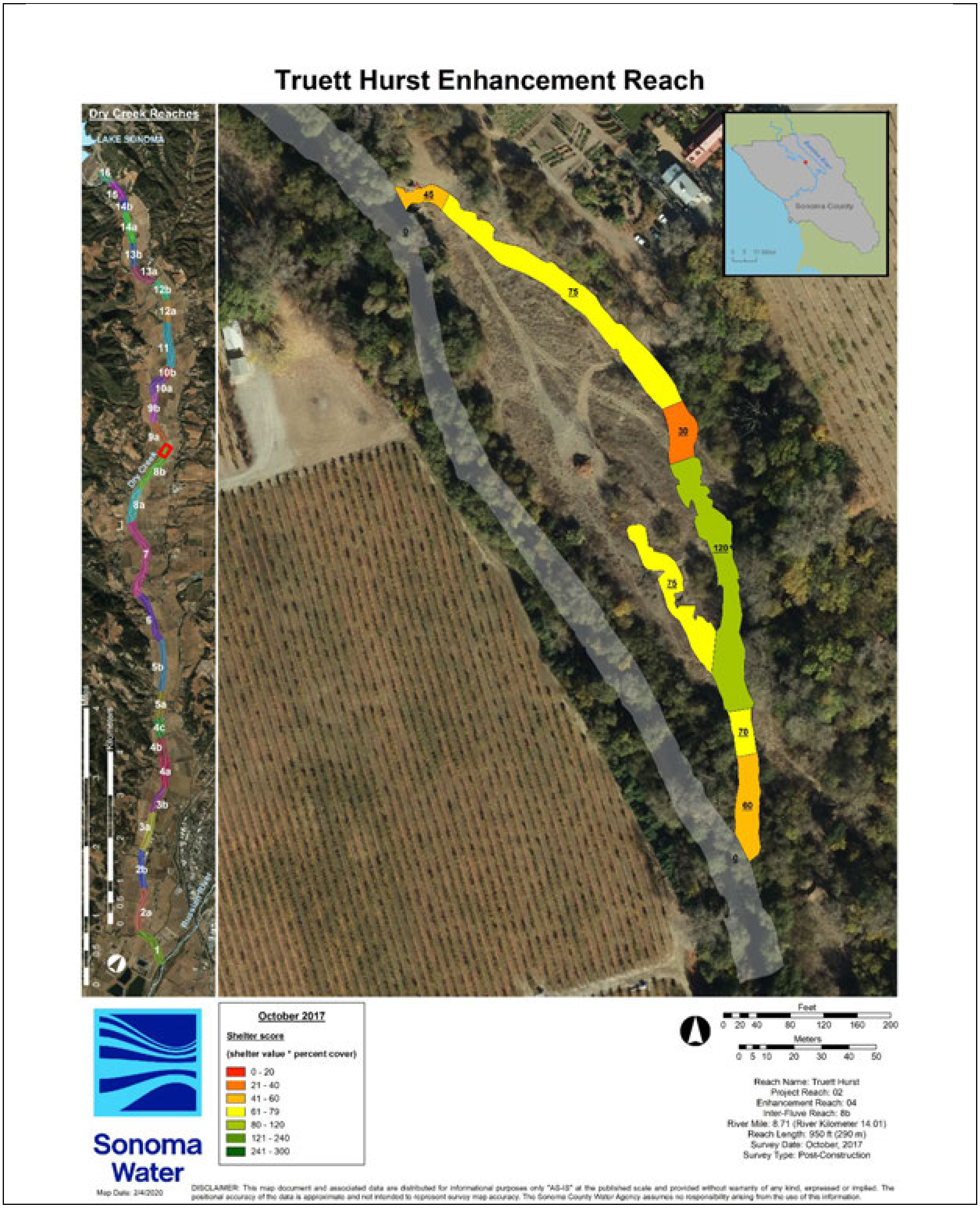


Figure 5.2.73. Habitat unit shelter scores within the Truett Hurst enhancement reach, October 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.50. Post-repair average feature, average habitat unit, site, and reach ratings for the Truett Hurst enhancement reach, October 2017. *Reach rating does not include Site 1, which was not fully assessed.

Site number		**1**	**2**	**3**	**4**	**5**
Site type		Main Channel;	Side Channel	Alcove	Alcove	Bank
Site average feature rating	Site average feature quantitative rating[a]	0	13	13	10	12
	Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	Good	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	9	18	27	20	11
	Site average qualitative rating[b]	Poor	Fair	Good	Fair	Poor
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	9	31	40	30	23
	Site qualitative rating[c]:	Not rated	Good	Excellent	Excellent	Fair
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	31				
	Enhancement reach qualitative rating[d]:	Good				

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

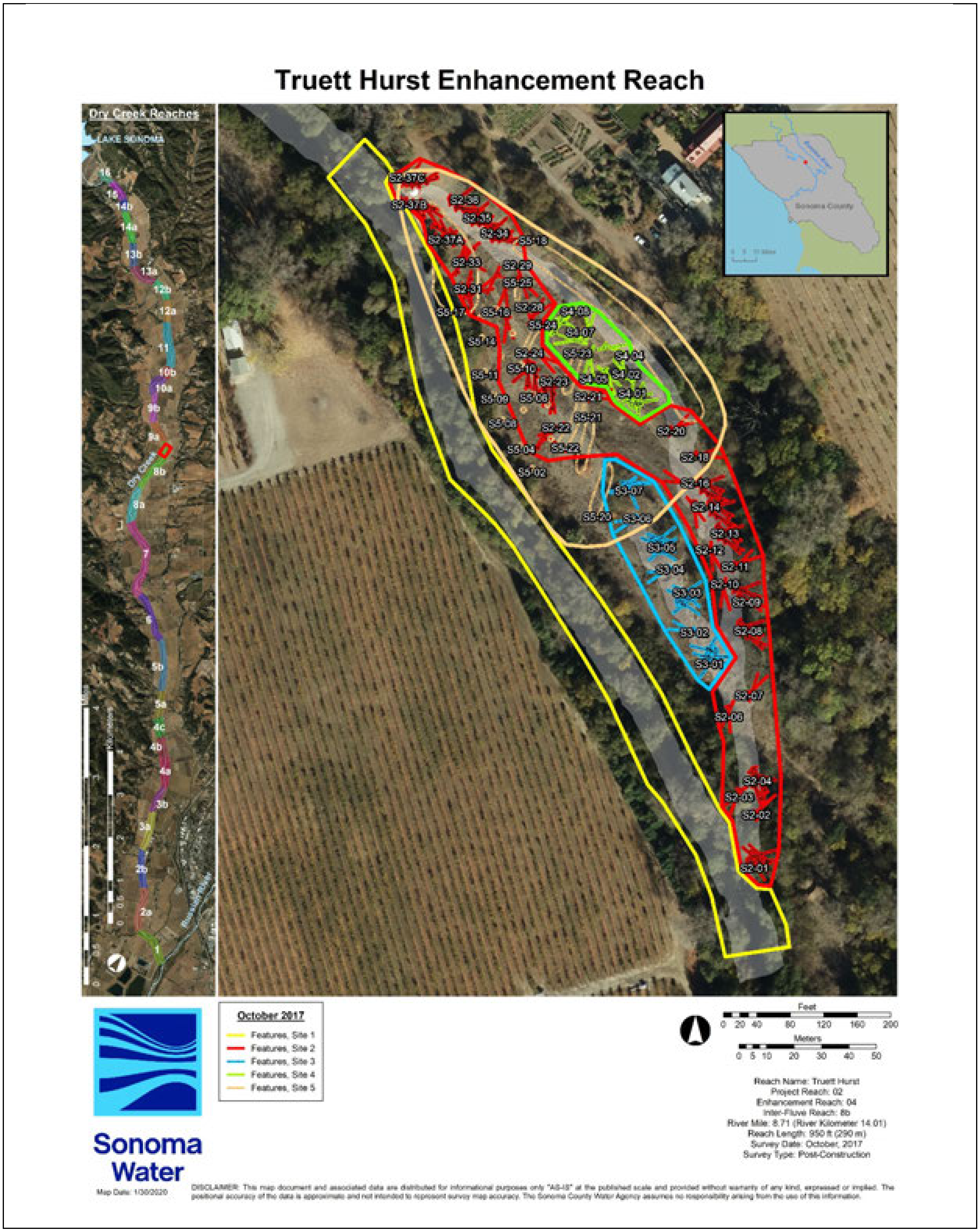


Figure 5.2.74. Enhancement sites and features within the Truett Hurst enhancement reach, October 2017.

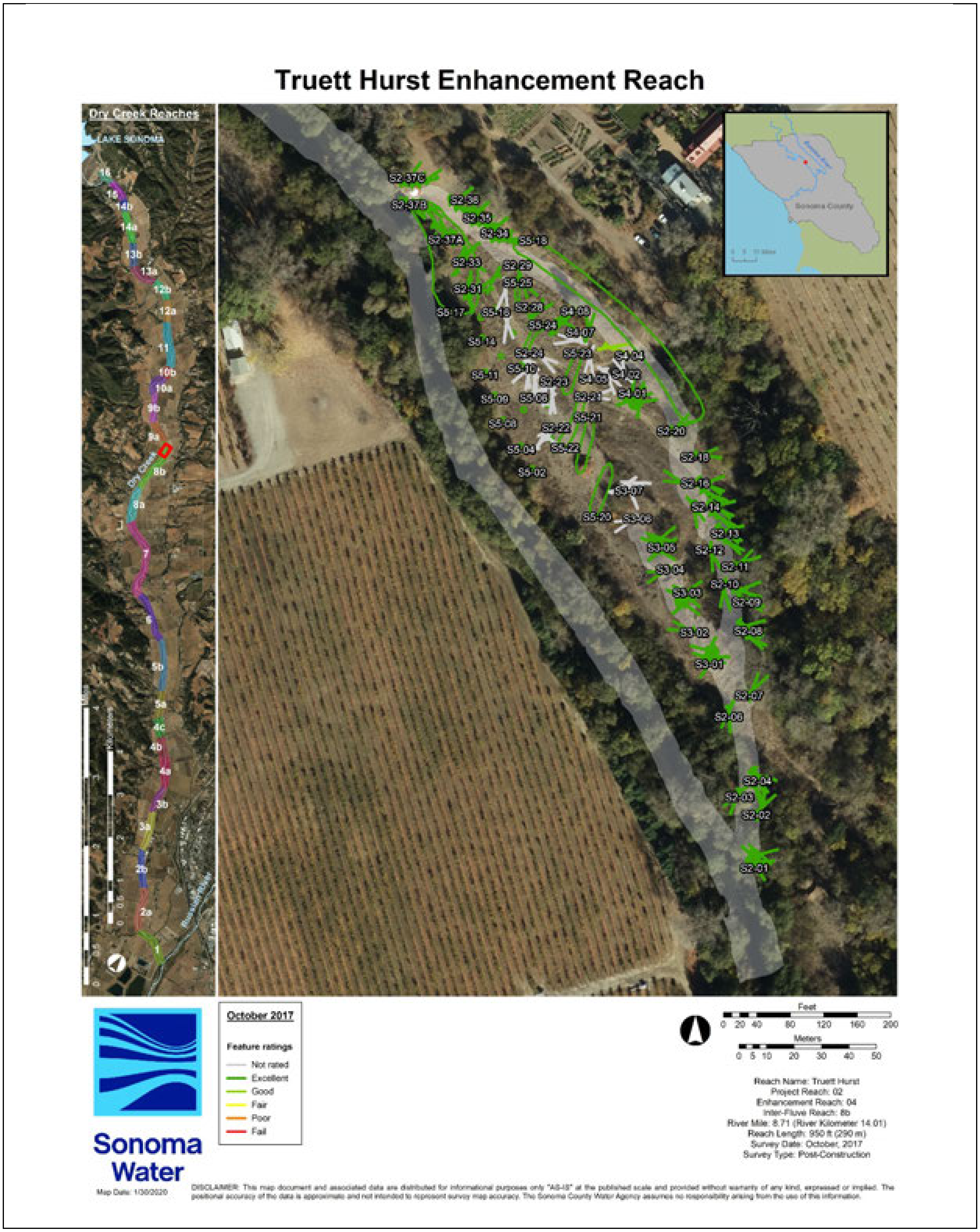


Figure 5.2.75. Feature ratings for the Truett Hurst enhancement reach, October 2017.

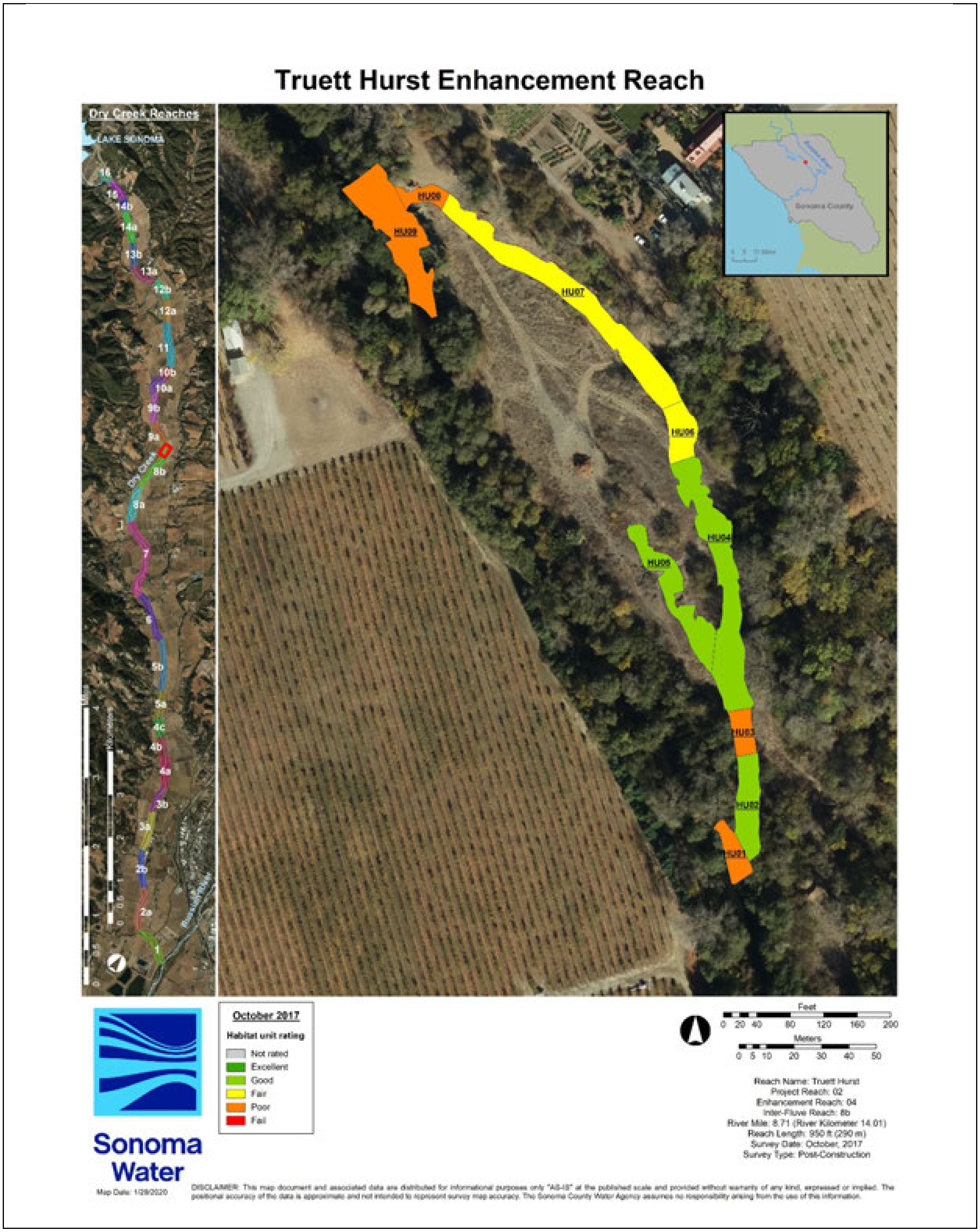


Figure 5.2.76. Habitat unit ratings for the Truett Hurst enhancement reach, October 2017.

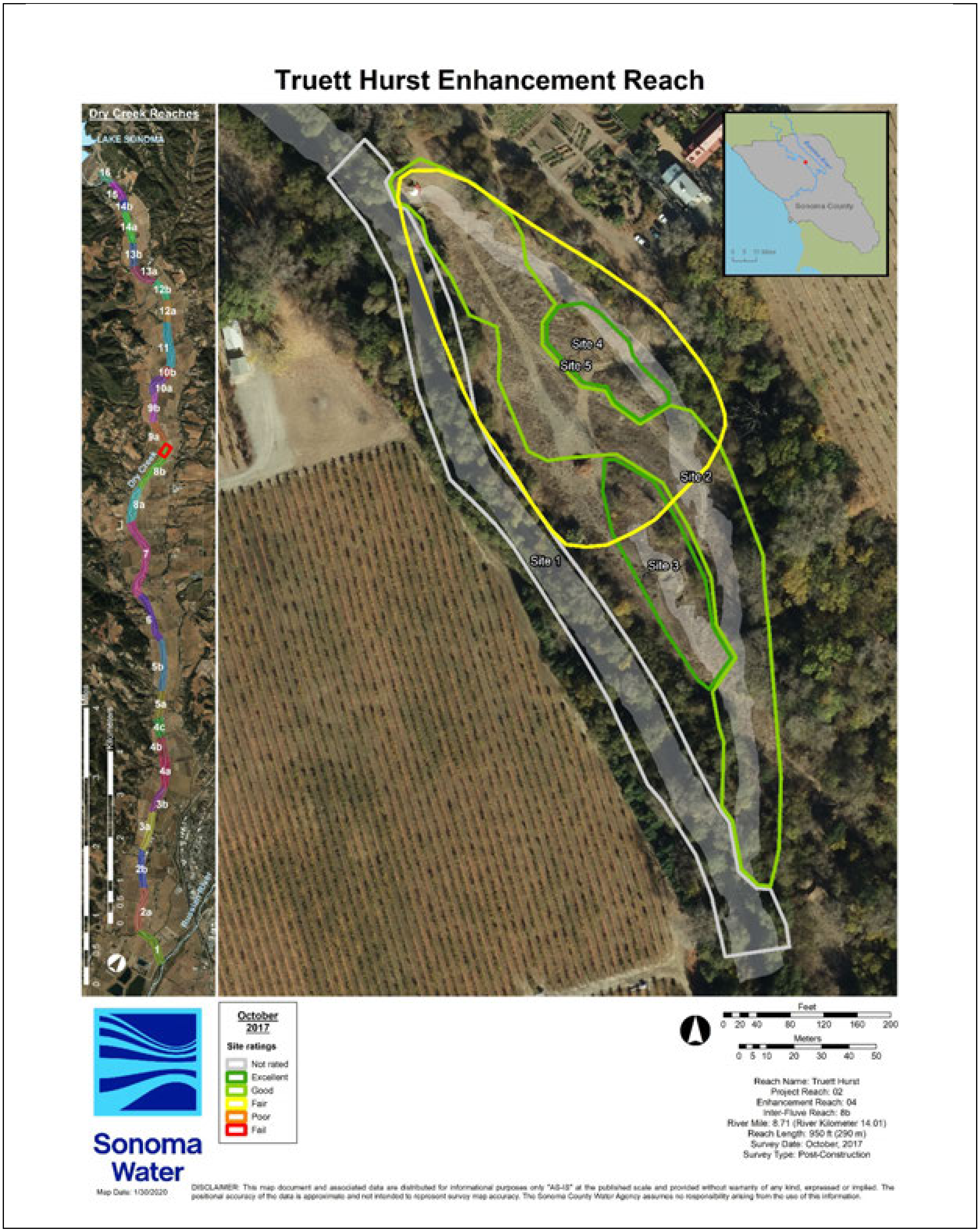


Figure 5.2.77. Post-repair site ratings for the Truett Hurst enhancement reach, October 2017.

Figure 5.2.78. Post-repair reach rating for the Truett Hurst enhancement reach, October 2017.

Meyer Enhancement Reach

Sonoma Water monitored the post repair condition of the Meyer enhancement reach in October 2017. The repaired reach covered 11,340 ft^2 of side channel area, with 55% of the total wetted area meeting optimum depth and velocity criteria (Table 5.2.51 and Figure 5.2.79). The repairs excavated the side channel constructed in November 2016, albeit to a smaller wetted area than recorded during post-construction effectiveness monitoring (14,965 ft^2). The repairs also excavated features partially buried by aggradation from winter 2016/2017 storms. Two habitat units made up the post-repair channel, with a pool to riffle ratio of 1:1 (1.00) and an average shelter value of 150 (Table 5.2.52, Figure 5.2.80, Figure 5.2.81). Both habitat units exceeded the optimum shelter value of 80. The repaired enhancement reach comprised two sites (one main channel, one off-channel), and a newly constructed side that added inlet roughness features to the upstream inlet (Table 5.2.53, Figure 5.2.82). As noted above, the repair excavated site 2 (side channel) and its features. Crews did not rate site 1 as is contained no features, did not undergo repairs, and habitat changes from the previous effectiveness monitoring (July 2017) appeared minimal. The two repaired sites received excellent site average feature ratings and good site average habitat unit ratings (Table 5.2.53, Figure 5.2.83, Figure 5.2.84, Figure 5.2.85). Overall, Meyer enhancement reach post-repair received a good effectiveness monitoring rating (Table 5.2.53; Figure 5.2.86; see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.51. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Meyer enhancement reach, October 2017.

Meyer Post-repair October 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Side channel area	11,340	2,767	4,522	7,289	9,821	2,335	3,874	6,209
Side channel alcove % of wetted area	100%	24%	40%	64%	87%	21%	34%	55%

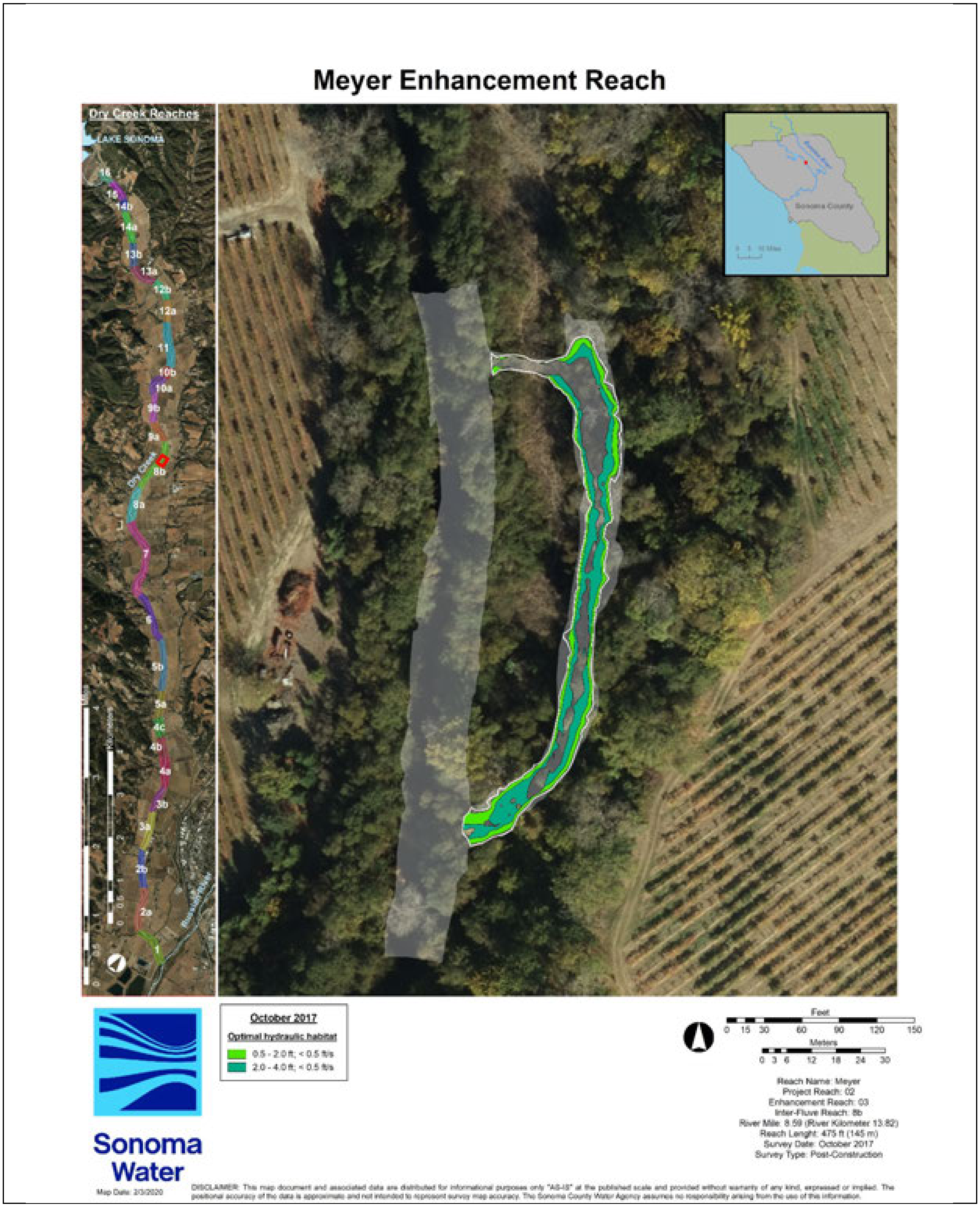


Figure 5.2.79. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Meyer enhancement reach, October 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.52. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Meyer enhancement reach, Post-repair October 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Pool	3	40	120
HU02	Riffle	3	60	180
Pool: riffle	**1: 1 (1.00)**			**Avg = 150**

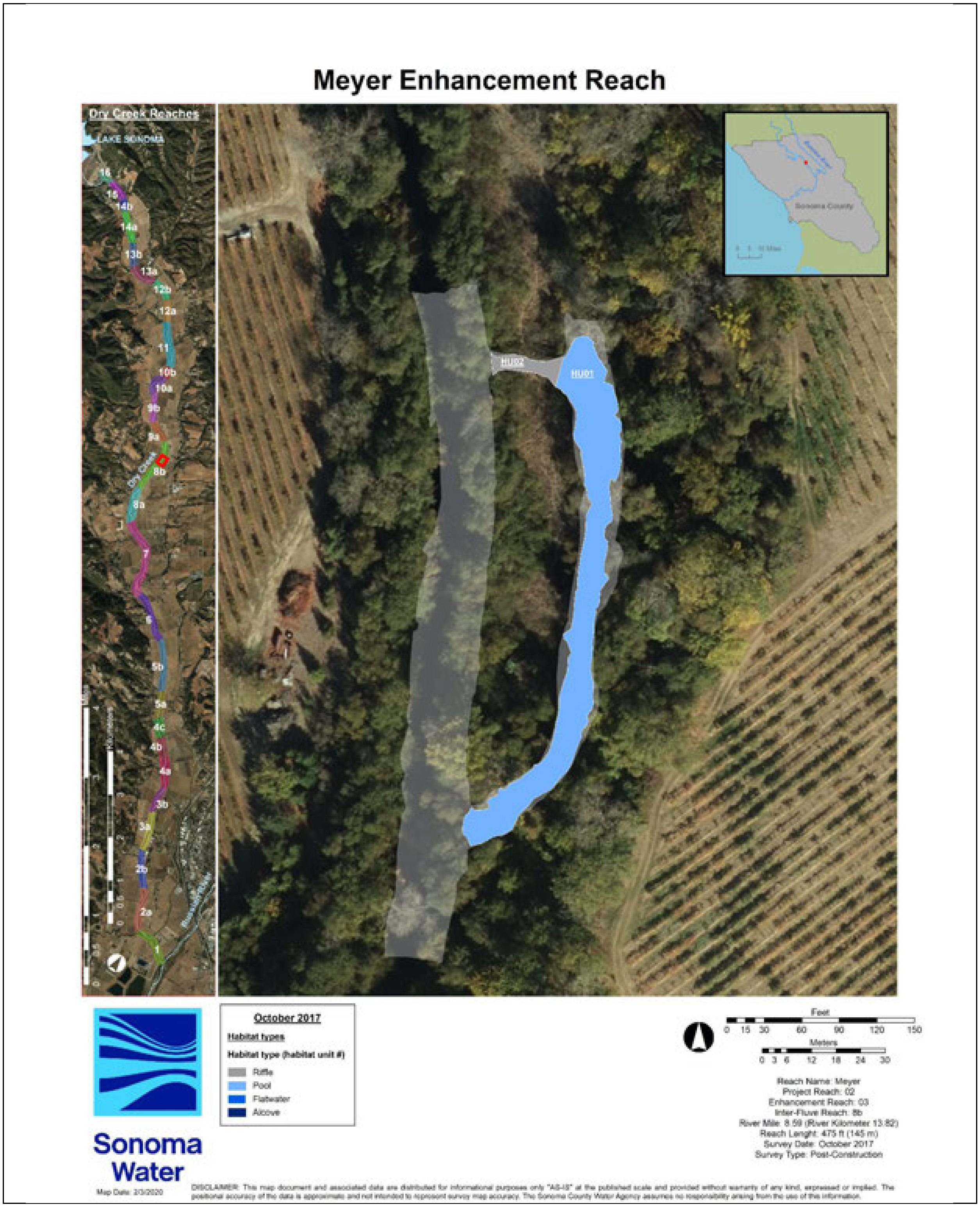


Figure 5.2.80. Habitat unit number and type within the Meyer enhancement reach, October 2017.

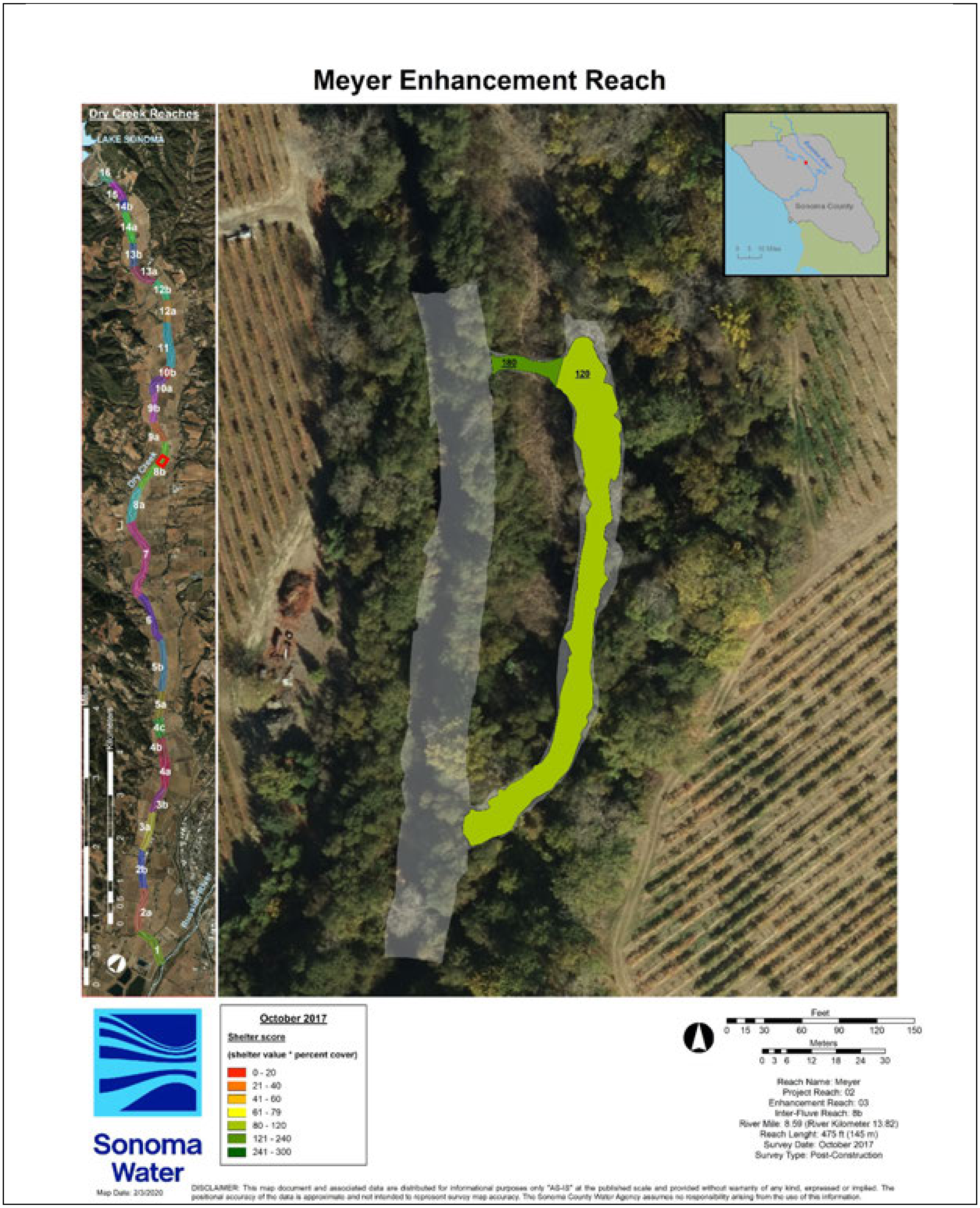


Figure 5.2.81. Habitat unit shelter scores within the Meyer enhancement reach, October 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.53. Post-repair average feature, average habitat unit, site, and reach ratings for the Meyer enhancement reach, October 2017.

Site number		**1**	**2**	**3**	
Site type		Main channel	Side channel	Side channel	
Site average feature rating	Site average feature quantitative rating[a]	0	13	13	
	Site average feature qualitative rating[a]	Not rated	Excellent	Excellent	
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	0	25	22	
	Site average qualitative rating[b]	Not rated	Good	Good	
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	0	37	35	
	Site qualitative rating[c]	Not rated	Good	Good	
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[c]	36			
	Enhancement reach qualitative rating[c]:	Good			

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

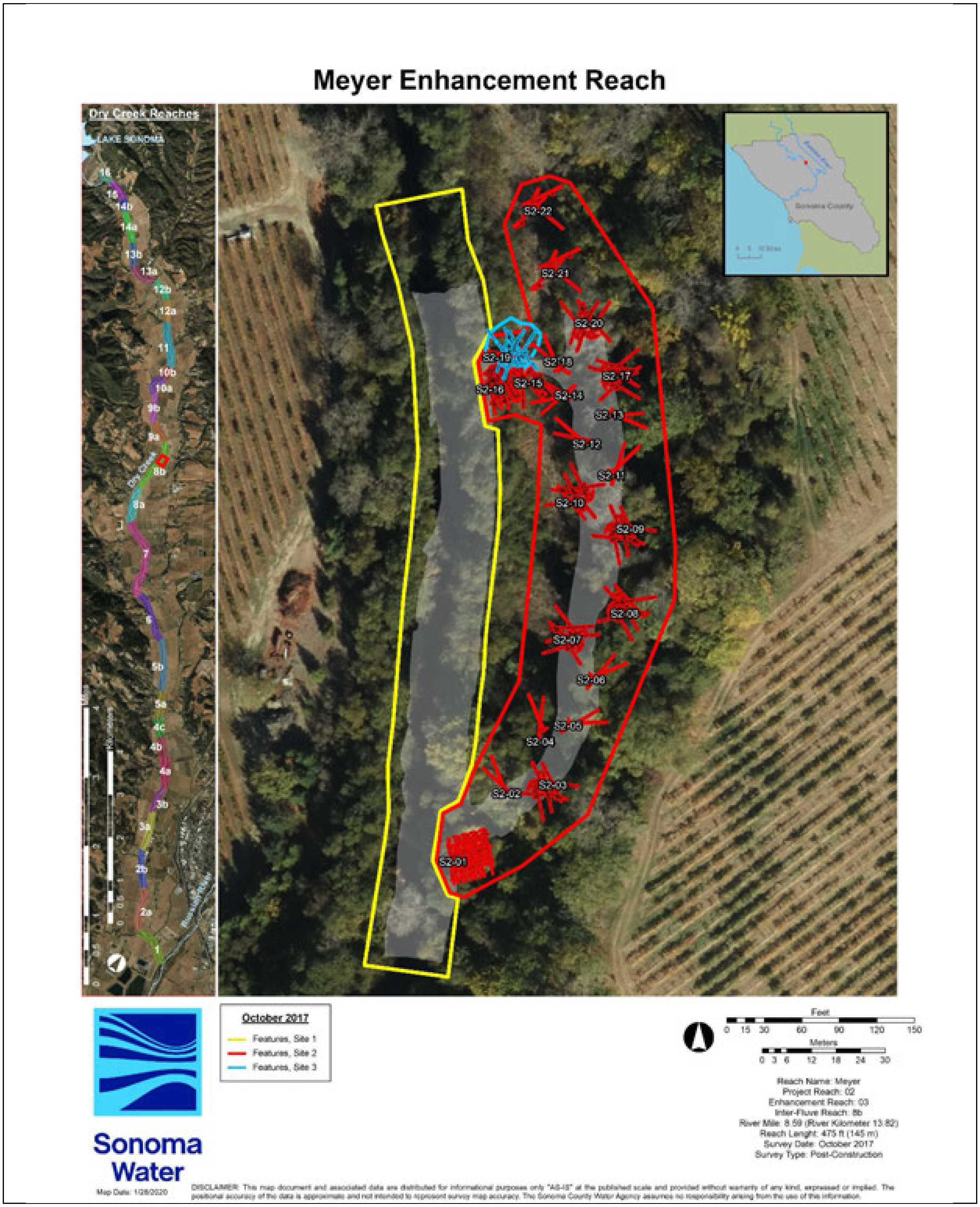


Figure 5.2.82. Post-repair enhancement sites and features within the Meyer enhancement reach, October 2017.

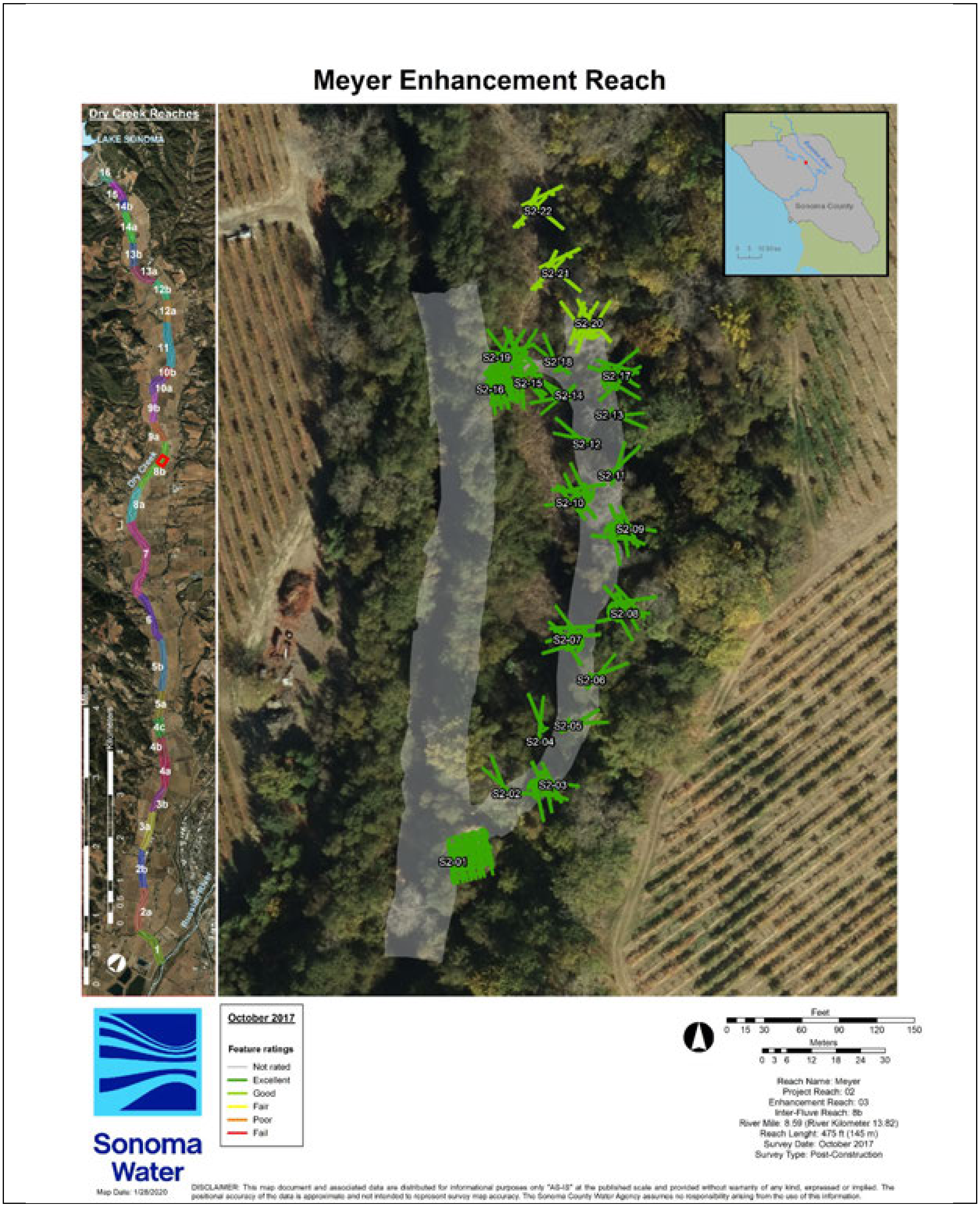


Figure 5.2.83. Feature ratings for the Meyer enhancement reach, October 2017.

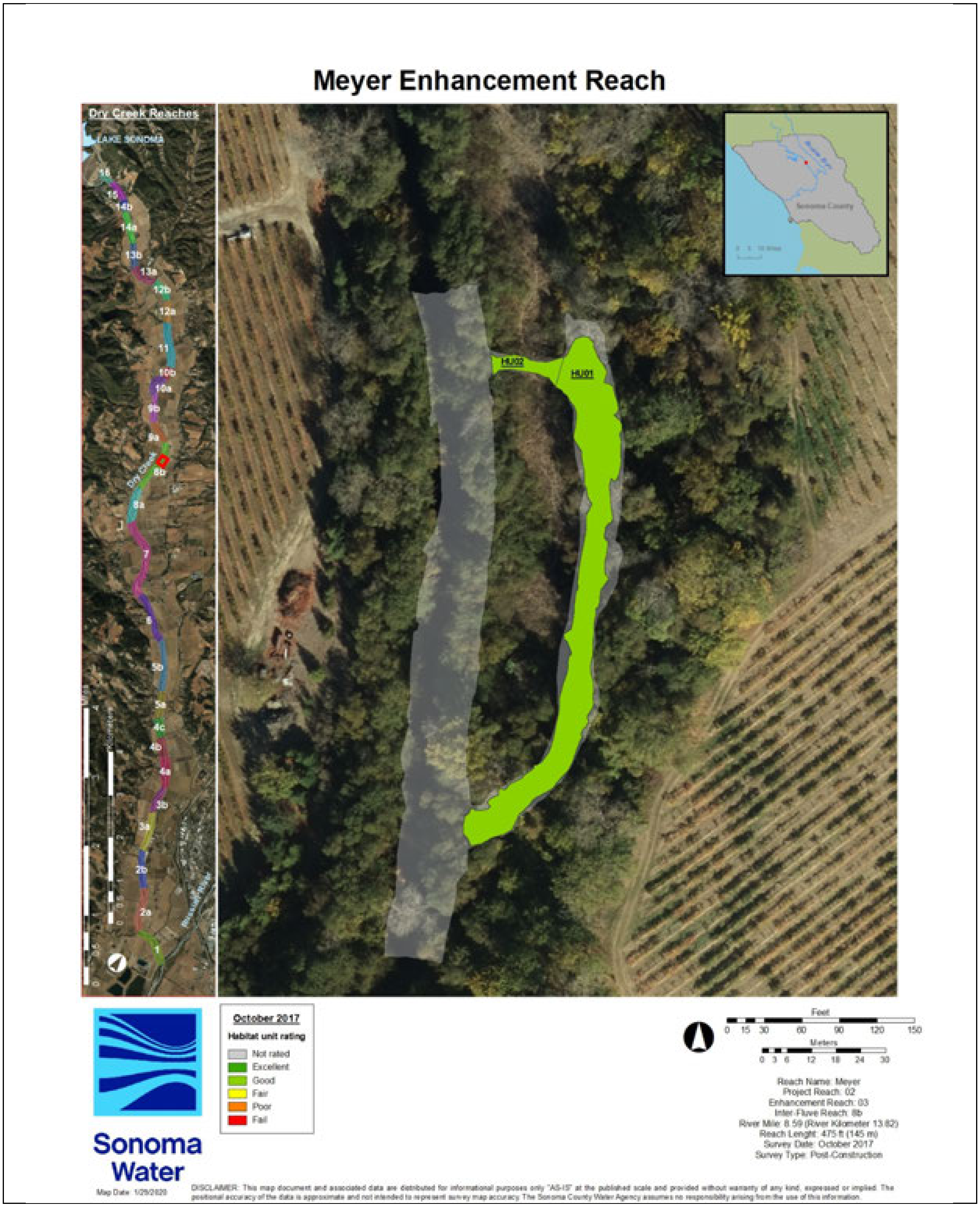


Figure 5.2.84. Habitat unit ratings for the Meyer enhancement reach, October 2017.

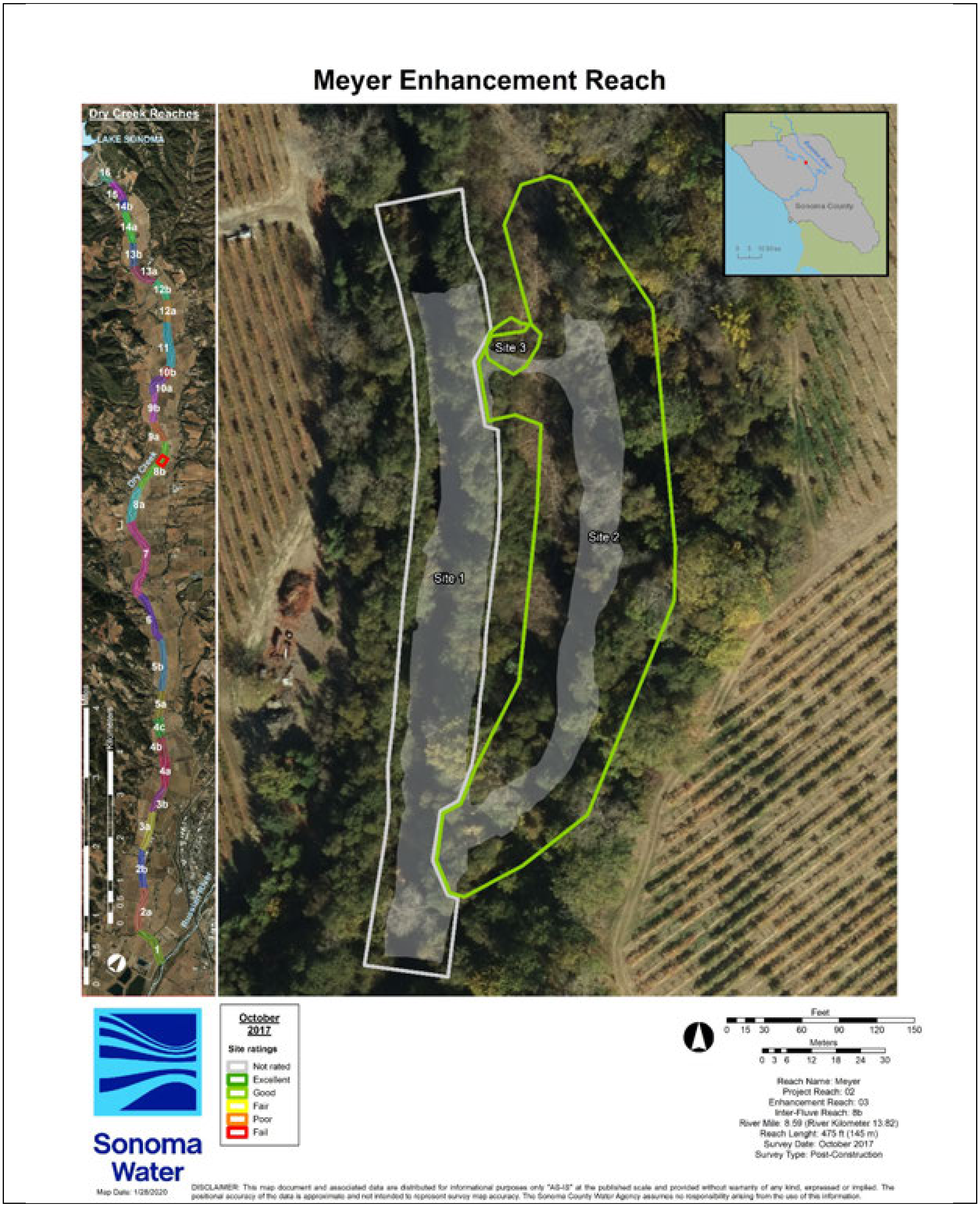


Figure 5.2.85. Post-repair site ratings within the Meyer enhancement reach, October 2017.

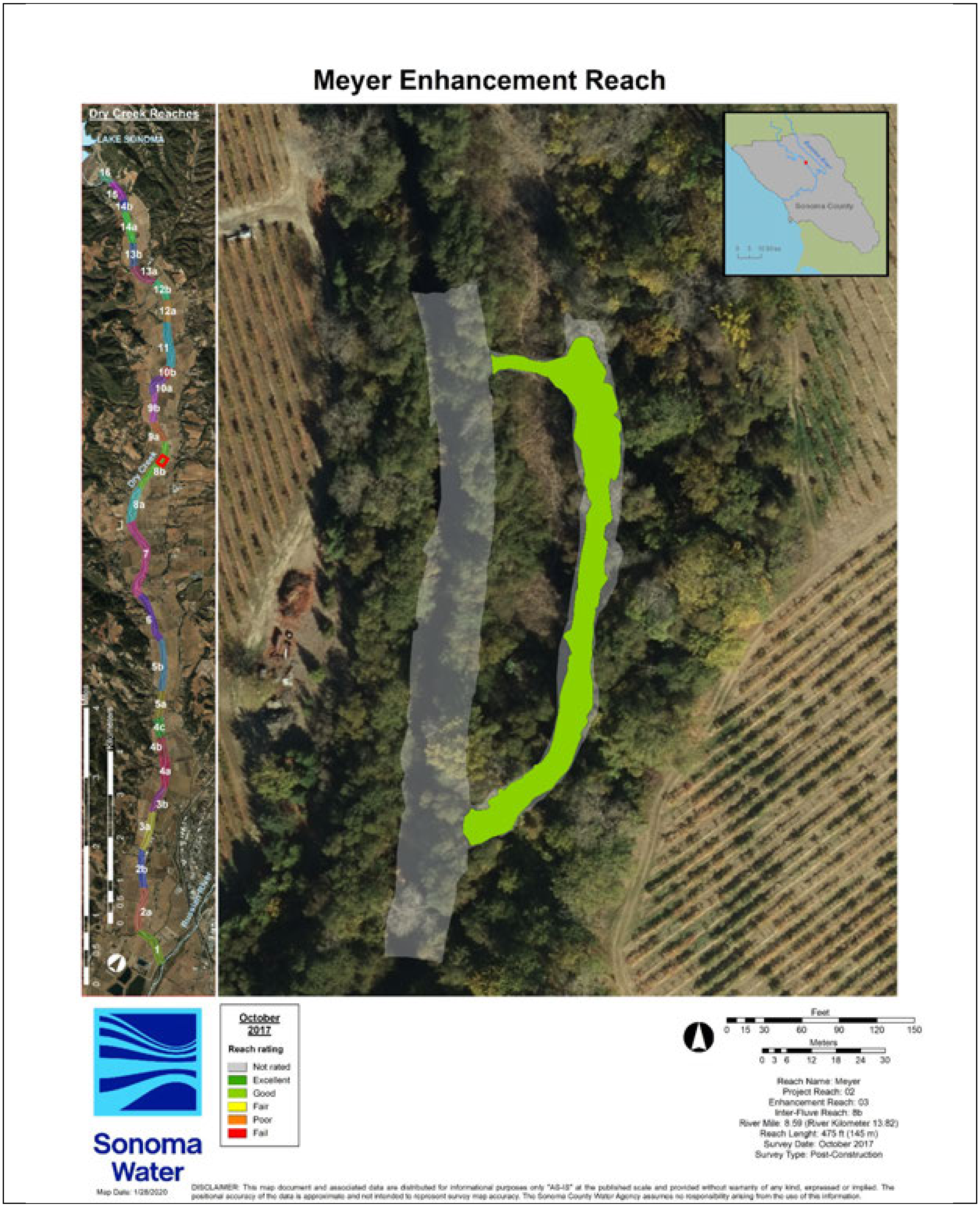


Figure 5.2.86. Post-repair reach rating for the Meyer enhancement reach, October 2017.

Geyser Peak Enhancement Reach

Sonoma Water monitored the post repair condition of the Geyser Peak enhancement reach in October 2017. The repaired portion of the enhancement reach covered 8,721 ft^2 of wetted area, with 15% meeting optimum depth and velocity criteria (Table 5.2.54 and Figure 5.2.87). The repairs excavated the side channel constructed in October 2016 to a slightly larger area, although with less percent area meeting optimal depth and velocity criteria than post-construction (57%). Eight habitat units made up the post-repair enhancement reach, with a pool to riffle ratio of 1:3 (0.33), and average shelter score of 29 (Table 5.2.55, Figure 5.2.88, Figure 5.2.89). No habitat units exceeded the optimum shelter score of 80. The repaired enhancement reach comprised two originally constructed sites (one main channel, one side channel) and two newly added sites at the side channel inlet (site 3) and along the bank within the side channel (site 4) (Table 5.2.56, Figure 5.2.90). All four enhancement sites received excellent site average feature ratings and poor to fair site average habitat unit ratings (we did not rate habitat in enhancement site 4 as it occurred along the bank above water surface elevation and contained no aquatic habitat) (Table 5.2.56, Figure 5.2.91, Figure 5.2.92). Enhancement site ratings ranged from fair to excellent, but sites including site average habitat unit scores all rated fair (Table 5.2.56, Figure 5.2.93). Overall, the Geyser Peak enhancement reach received a fair effectiveness monitoring rating (Table 5.2.56, Figure 5.2.94, see Appendix 5.1 for measured values, scores, and ratings).

Depth and velocity

Table 5.2.54. Areas and percentages of: wetted area, optimal depth and velocity, and optimal hydraulic habitat within the Geyser Peak enhancement reach, October 2017.

Geyser Peak Post-repair October 2017	Wetted area (ft^2)	Optimal depth (ft^2)			Optimal velocity (ft^2)	Optimal habitat (ft^2)		
		0.5 – 2.0 ft	2.0 – 4.0 ft	Total	< 0.5 ft/s	0.5 – 2.0 ft < 0.5 ft/s	2.0 – 4.0 ft < 0.5 ft/s	Total
Side channel area	8,721	4,835	2,655	7,490	2,360	1,140	132	1,273
Side channel % of wetted area	100%	55%	30%	86%	27%	13%	2%	15%

Figure 5.2.87. Optimal hydraulic habitat for fry (<0.5 ft/s, 0.5-2.0 ft) and parr (<0.5 ft/s, 2.0-4.0 ft) within the Geyser Peak enhancement reach, October 2017.

Habitat types, pool to riffle ratio, and shelter scores

Table 5.2.55. Habitat, types, shelter value, percent cover, and shelter score for habitat units within the Geyser Peak enhancement reach, Post-repair October 2017.

Habitat Unit #	Habitat Type	Shelter Value	Percent Cover	Shelter Score
HU01	Flatwater	2	0	0
HU02	Flatwater	3	15	45
HU03	Flatwater	3	10	30
HU04	Riffle	3	10	30
HU05	Pool	3	15	45
HU06	Riffle	2	20	40
HU07	Flatwater	3	15	45
HU08	Riffle	3	0	0
Pool: riffle	**1:3 (0.33)**			**Avg = 29**

Figure 5.2.88. Habitat unit number and type within the Geyser Peak enhancement reach, October 2017.

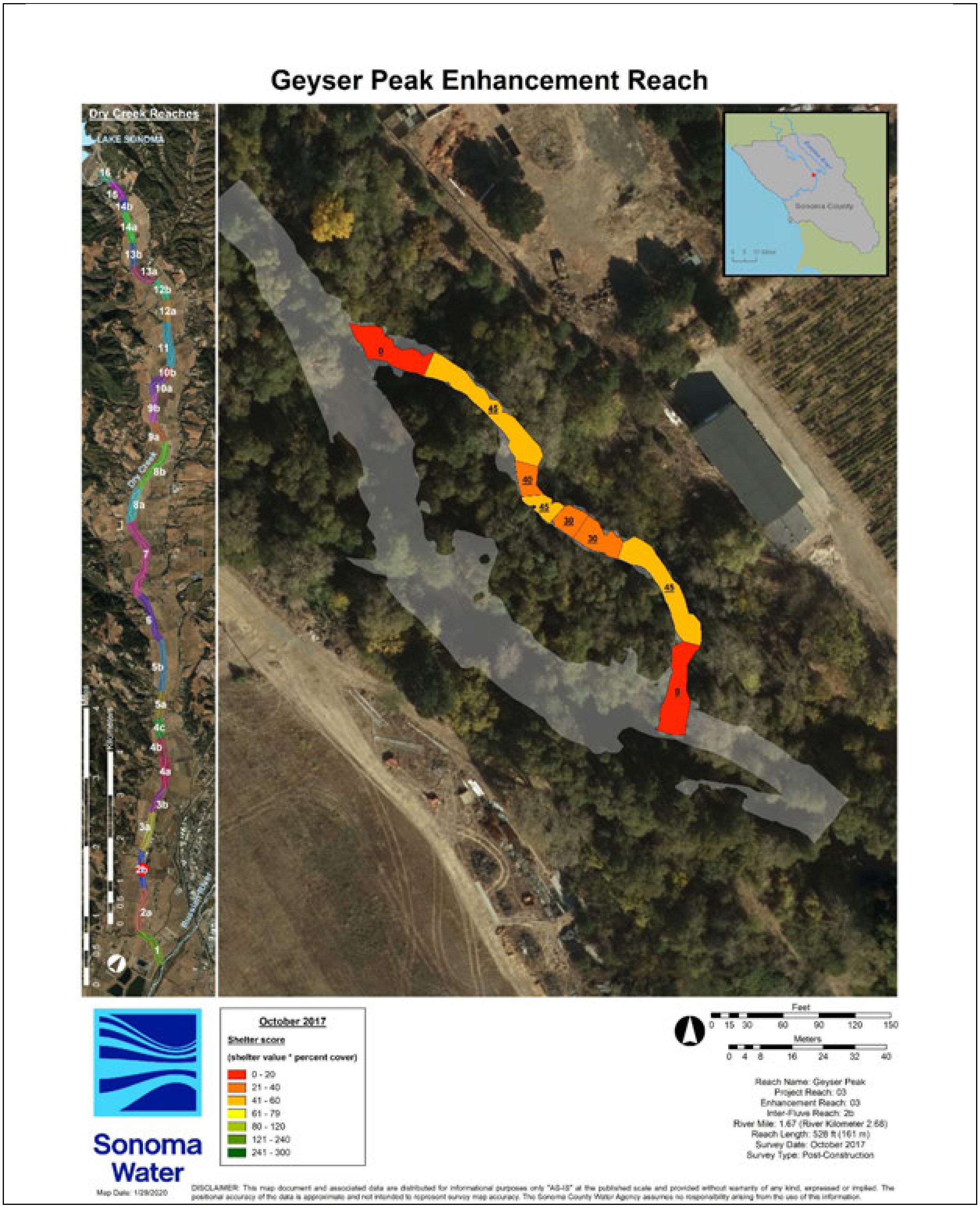


Figure 5.2.89. Habitat unit shelter scores within the Geyser Peak enhancement reach, October 2017.

Feature, habitat unit, site, and reach ratings

Table 5.2.56. Post-repair average Feature, habitat unit, site, and reach ratings for the Geyser Peak enhancement reach, October 2017.

Site number		**1**	**2**	**3**	**4**
Site type		Main channel	Side channel	Side channel	Bank
Site average feature rating	Site average feature quantitative rating[a]	13	13	12	12
	Site average feature qualitative rating[a]	Excellent	Excellent	Excellent	Excellent
Site average habitat unit rating	Site average habitat unit quantitative rating[b]	15	13	15	0
	Site average qualitative rating[b]	Fair	Poor	Fair	Not Rated
Site rating	Site quantitative rating (sum of site average feature and habitat unit rating)[c]	28[c]	26[c]	27[c]	12[b]
	Site qualitative rating[c]	Fair[c]	Fair[c]	Fair[c]	Excellent[b]
Enhancement reach rating	Enhancement reach quantitative rating (average of site rating)[d]	23			
	Enhancement reach qualitative rating[d]:	Fair			

[a]out of 15; Excellent (>=12), Good (>=9), Fair (>=6), Poor (>=3), Fail (<3)
[b]out of 35; Excellent (>=28), Good (>=21), Fair(>=14), Poor (>=7), Fail (<7)
[c]out of 50; Excellent (>=40), Good (>=30), Fair (>=20), Poor (>=10), Fail (<10)
[d]out of 41: Excellent (>=33), Good (>=25), Fair(>=17), Poor (>=9), Fail (<9)

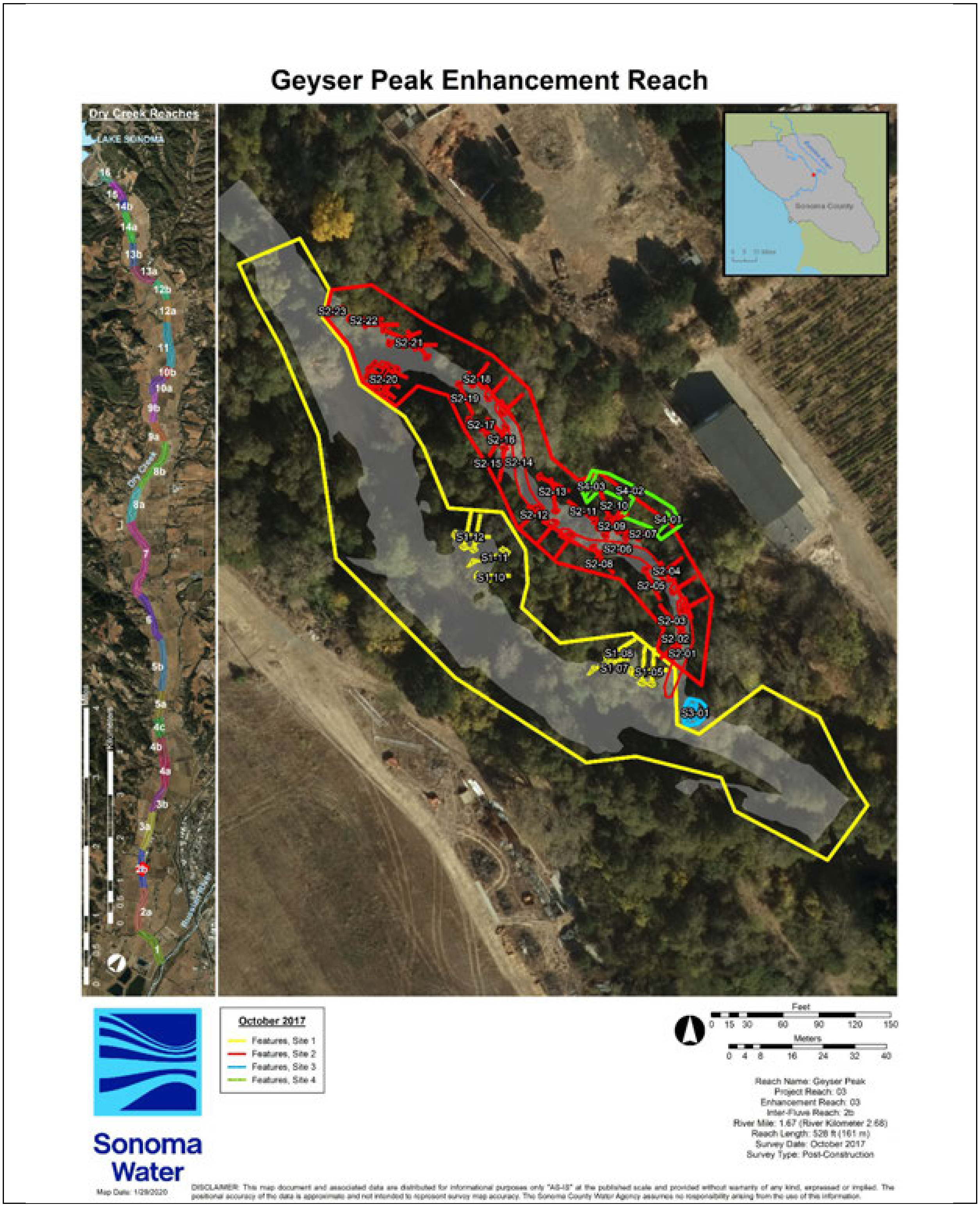


Figure 5.2.90. Enhancement sites and features within the Geyser Peak enhancement reach, October 2017.

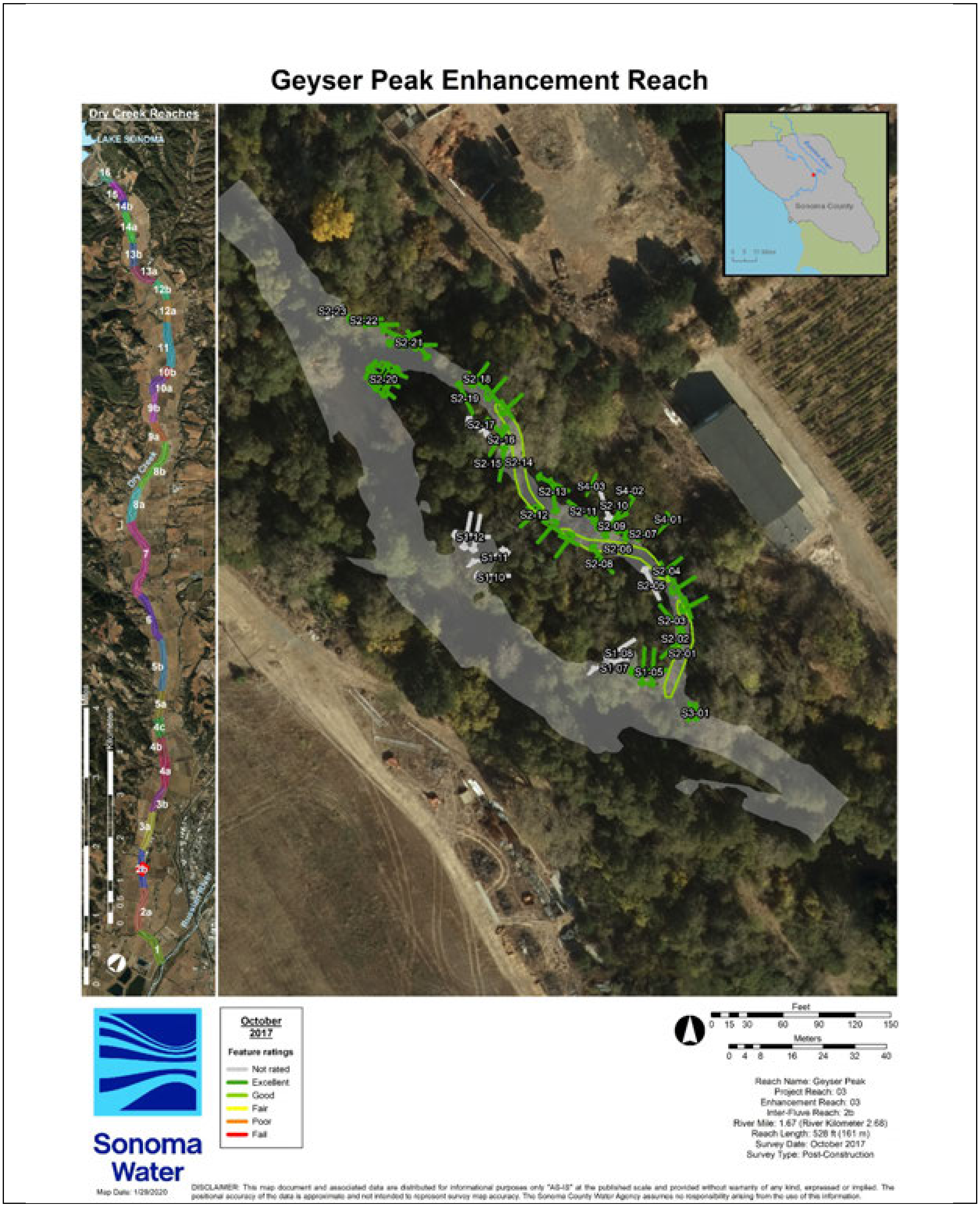


Figure 5.2.91. Feature ratings for the Geyser Peak enhancement reach, October 2017.

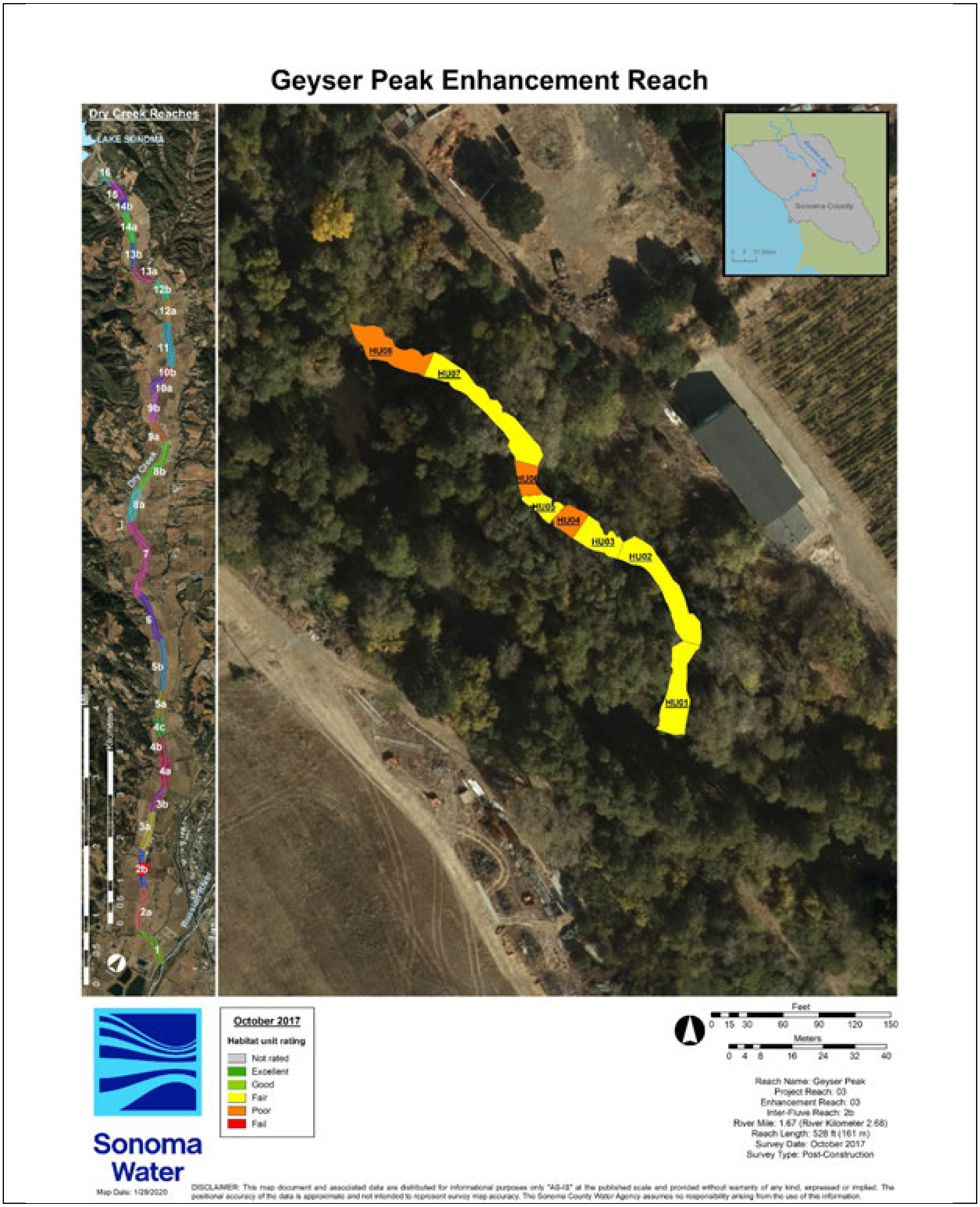


Figure 5.2.92. Post-repair habitat unit rating for the Geyser Peak enhancement reach, October 2017.

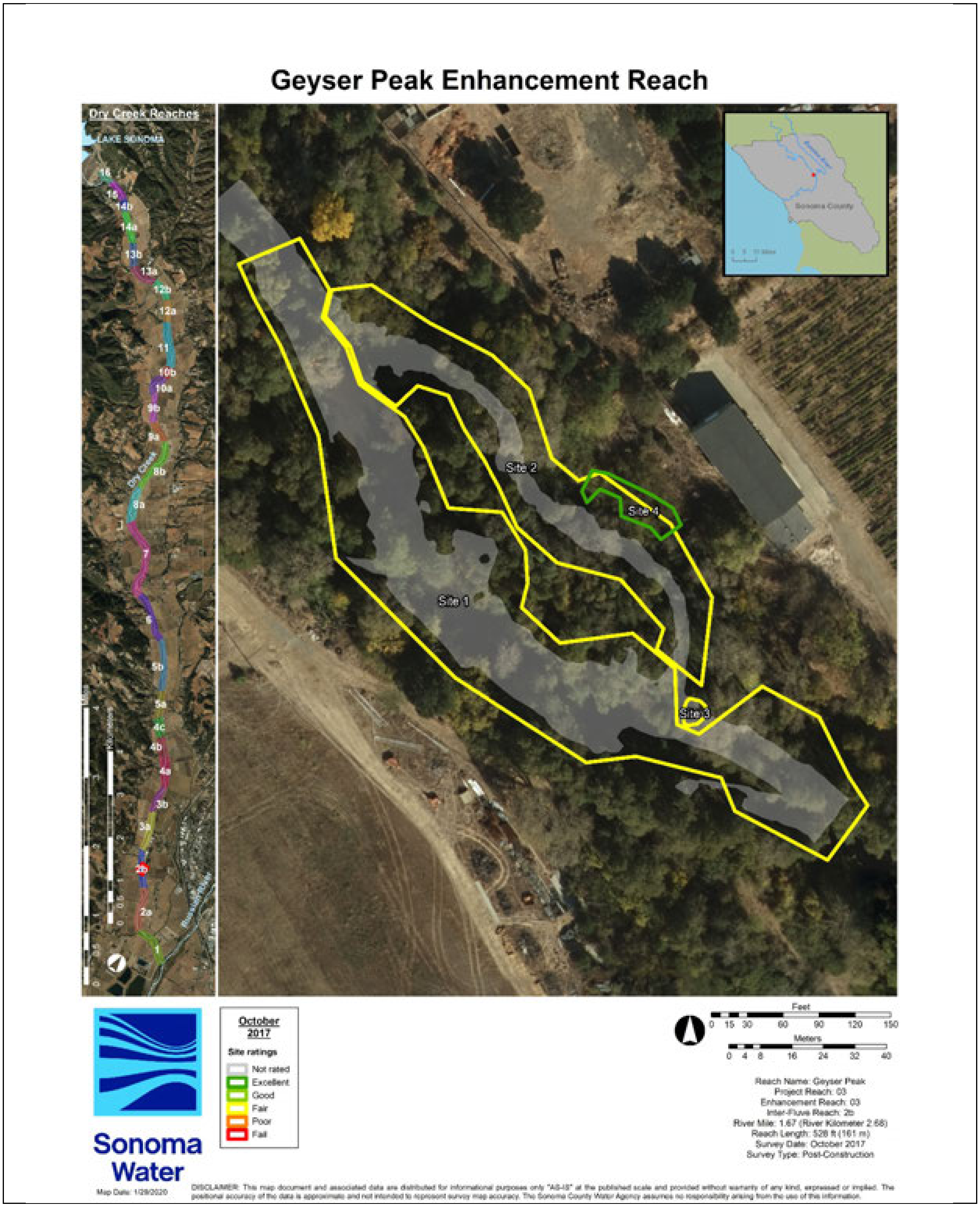


Figure 5.2.93. Post-repair site ratings for the Geyser Peak enhancement reach, October 2017.

Figure 5.2.94. Post-repair reach rating for the Geyser Peak enhancement reach, October 2017.

Discussion

Summary

Effectiveness monitoring showed an increase in the percent of optimal depth and velocity from pre-enhancement (9%) to post-enhancement (32%), post-effective flow (27%), and post-repair (31%), while average shelter scores initially increased from pre-enhancement (54) to post-enhancement (84, exceeding the optimal shelter value of 80), then decreased during post-effective flow and post repair (Table 5.2.57). The high number of riffles observed (9, Table 5.2.28) during post-effective flow surveys likely contributed to low average shelter score. Riffles are important for salmonid food production, but are typically shallow with little instream or overhead cover and subsequently receive low shelter scores. Similarly, the high number of flatwater habitat units (6, Table 5.2.46) with little overhead cover contributed to low post-repair shelter scores. Observed pool to riffle ratio remained within 1:2 to 2:1 (0.50 to 2.00) for all monitoring time periods except post-enhancement, driven by Carlson, Lonestar and City of Healdsburg project designs that included a single riffle.

Table 5.2.57. Summary of percent optimal depth and velocity, average shelter score and pool to riffle ratio for all monitoring time periods.

Monitoring time-period	% optimal depth and velocity	Average shelter score	Pool to riffle ratio
Pre-enhancement	9%	54	5: 4 (1.25)
Post-enhancement	32%	84	5: 1 (5.00)
Post-effective Flow	27%	61	13:9 (1.44)
Post-repair	31%	53	6:6 (1.00)

Depth and Velocity

Effectiveness monitoring data from all monitoring time periods in 2017 showed substantial differences in the amount of optimal depth and velocity habitat between main and off-channel areas, and between habitat types. Overall, 26% of main and off-channel area supported optimal depth and velocity, compared with 19% in main channel areas, and 50% in off-channel areas. Alcoves supported the greatest area of optimal depth and velocity, regardless of channel location (main and off-channel [69%], main channel [60%], off-channel [75%]), followed by pools (main and off-channel [30%], main channel [26%], off-channel [38%]), Figure 5.2.95). The percentage of optimal depth and velocity in flatwaters and riffles remained consistently lower than alcoves or pools through all monitoring time periods (pre- and post- enhancement, post-effective flow, and post-repair). Inter-Fluve (2010) recorded similar observations for flatwaters during pre-enhancement habitat surveys in 2010, prompting recommendations to construct low velocity habitats, such as alcoves and side channels, as a primary strategy to enhance Dry Creek. Riffles typically have higher water velocity and shallow depths at low flows, and by character do not support the optimal depth and velocity conditions recommended by the BO or the AMP, but still perform important ecological roles, such as nutrient retention and food production .

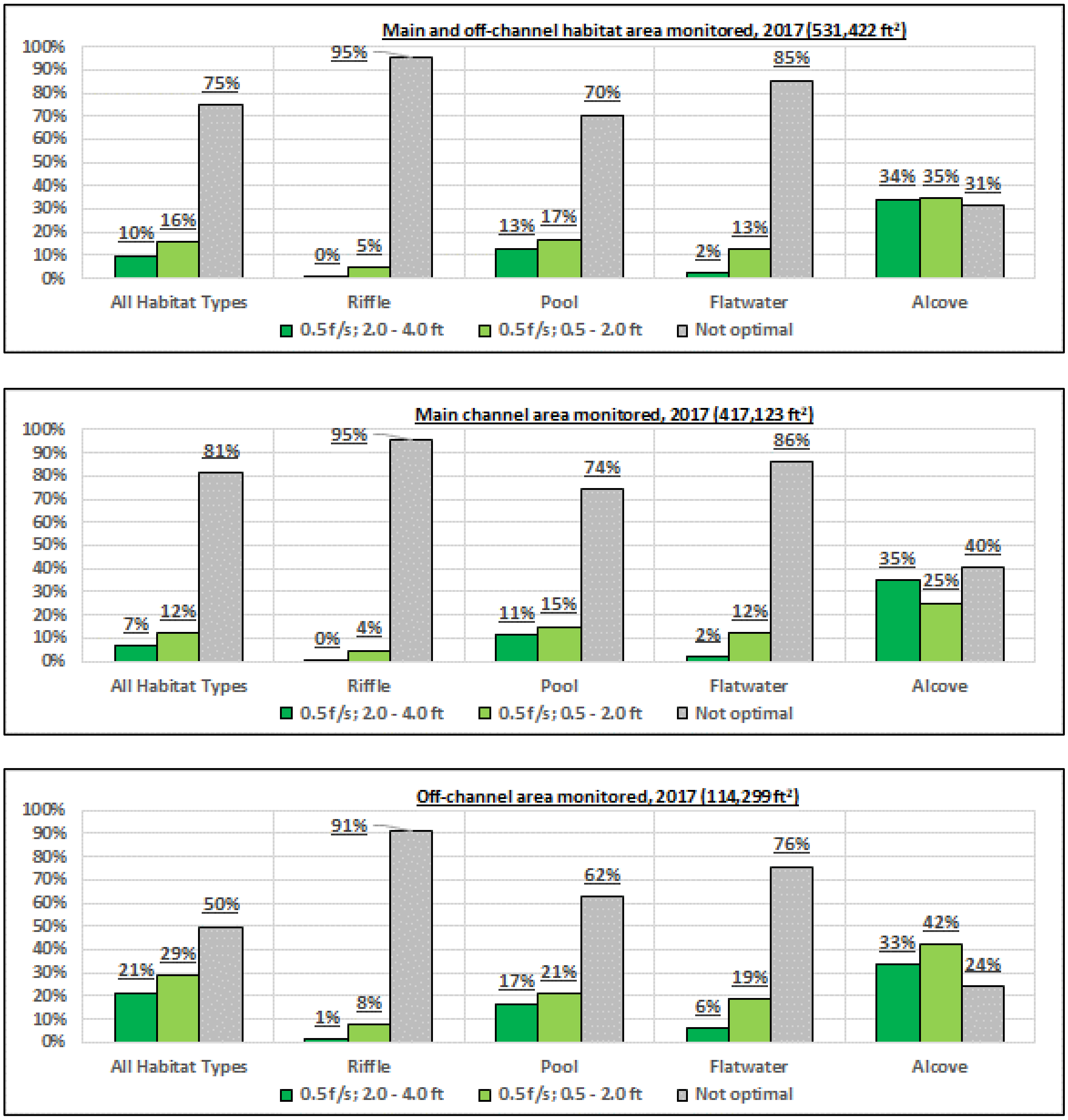


Figure 5.2.95. Percentages of optimal depth and velocity within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.

Habitat Types, Pool to Riffle Ratio, and Shelter Scores

Effectiveness monitoring data from all monitoring time periods in 2017 did not show substantial differences in average shelter score between main and off-channel areas, but did show differences between habitat types (Figure 5.2.96). Overall, main and off-channel area supported an average shelter score of 63, compared with 60 in main channel areas, and 69 in off-channel areas. Alcoves supported the highest average shelter score, regardless of channel location (main and off-channel [100], main channel [126], off-channel [81], all above the optimum shelter score of 80), followed by pools (main and off-channel [66], main channel [63], off-channel [73]), Figure 5.2.96). As with the percentage of optimal depth and velocity habitat, average shelter score in flatwaters and riffles remained consistently lower than alcoves and pools through all monitoring time periods (pre-and post-enhancement, post-effective flow, and post-repair). The results reinforce depth and velocity observations (above) that side-channels and alcoves are effective at providing habitat conditions recommended in the RRBO and in the AMP.

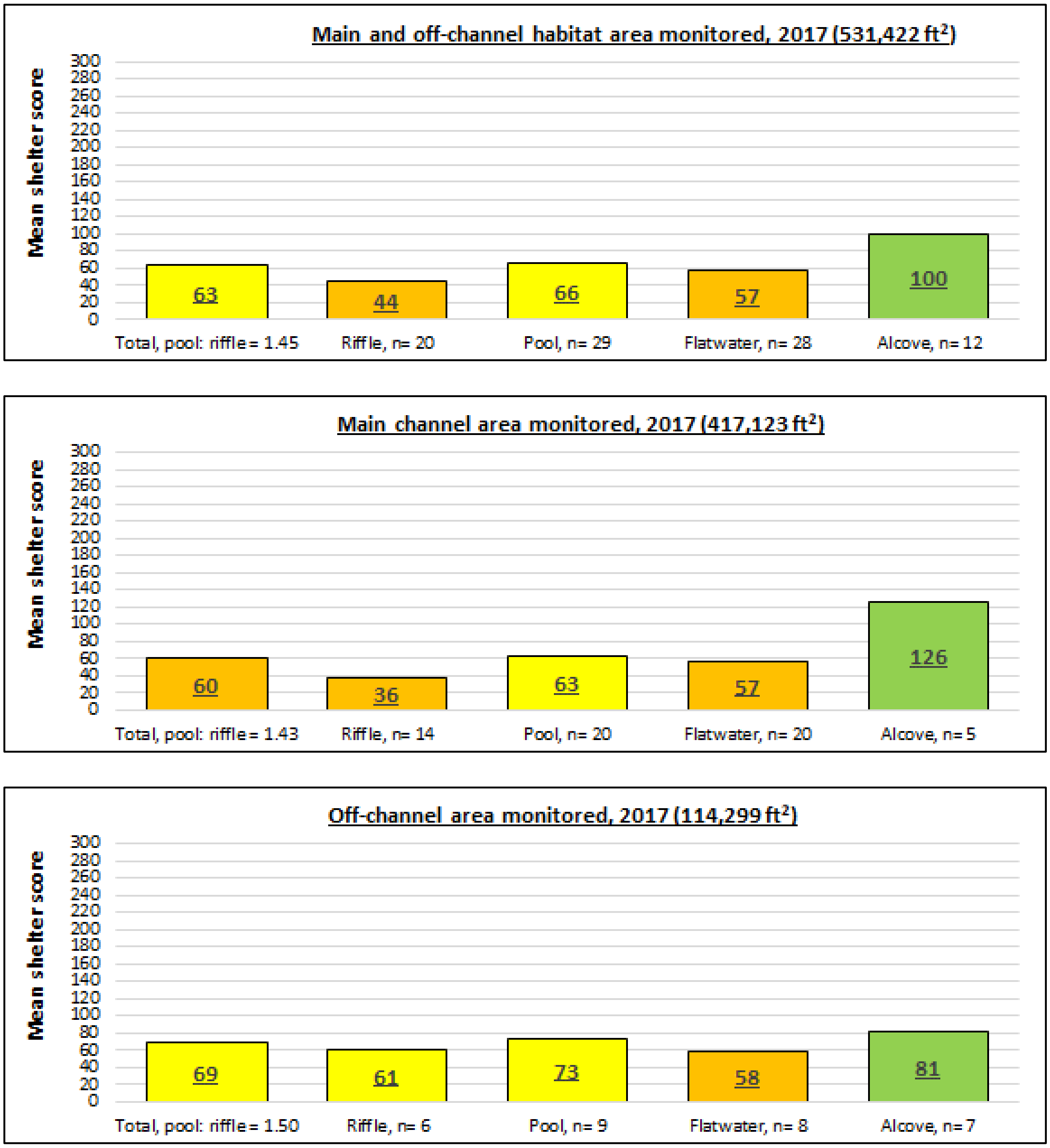


Figure 5.2.96. Average shelter scores within main and off-channel areas (top panel), main, channel areas (middle panel), and off-channel areas (lower panel), and across riffle, pool, flatwater, and alcove habitat type.

Reach Ratings

Enhancement reach ratings from 2017 effectiveness monitoring vary according to monitoring time period (Table 5.2.58). Pre-enhancement ratings of Carlson, Lonestar and City of Healdsburg Yard improved from poor and fair to good post-enhancement, consistent with the addition of off-channel areas. As described above, Truett Hurst, Meyer, and Geyser Peak enhancement reaches received poor, fair, and fail post-effective flow ratings that necessitated repairs. Post repair enhancement reach ratings of Truett Hurst, Meyer, and Geyser Peak improved to good, good, and fair. Ongoing effectiveness monitoring of Van Alyea and Farrow Wallace resulted in good and fair ratings.

Table 5.2.58. Dry Creek enhancement reaches monitored in 2017, type of monitoring conducted, and reach rating for each monitoring time period. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River) (-- indicates monitoring not conducted)

Enhancement Reach	Monitoring Time Period			
	Pre-enhancement	Post-enhancement	Post-effective Flow	Post-repair
Truett Hurst	--	--	Poor	Good
Meyer	--	--	Fair	Good
Carlson, Lonestar	Poor	Good	--	--
Van Alyea	--		Good	--
Farrow Wallace	--	--	Fair	--
City of Healdsburg Yard	Fair	Good	--	--
Geyser Peak	--	--	Fail	Fair

Conclusion

As noted above, the qualitative ratings describe the relative success of habitat enhancement measures within enhancement sites and enhancement reaches, and determine potential future outcomes (management actions). 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 (Table 5.2.2) should likely be the most recent post-effective flow ratings (Table 5.2.59). The latest post-effective flow ratings, as of 2017, show two excellent ratings, two good ratings, two fair ratings, and one poor and fail. While the latest post-effective flow ratings suggest undertaking management actions, Sonoma Water repaired the Truett Hurst, Meyer, and Geyser Peak enhancement reaches in October 2017. Further management actions should be guided by post-effective flow enhancement reach ratings that include the Truett Hurst, Meyer, and Geyser Peak enhancement reaches, which will be rated by Sonoma Water in 2018.

Table 5.2.59. Creek enhancement reaches monitored, year(s) of post-effective flow effectiveness monitoring and effectiveness rating, and latest post effective flow effectiveness monitoring score. Reaches listed from upstream (closest to Warm Springs Dam) to downstream (closest to confluence with Russian River).

Enhancement Reach	2015	2016	2017	Latest post-effective flow rating
Army Corps Reach 15	Excellent	Excellent		Excellent
Quivira		Excellent		Excellent
Van Alyea			Good	Good
Rued	Good			Good
Farrow Wallace	Good		Fair	Fair
Truett Hurst			Poor	Poor
Meyer			Fair	Fair
Carlson, Lonestar				--
City of Healdsburg Yard				--
Geyser Peak			Fail	Fail

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 2017. These data are part of an ongoing pre-construction (baseline) monitoring effort begun in 2008 and outlined in the Reasonable and Prudent Alternative section of NMFS' Russian River Biological Opinion. Validation monitoring data collected in new and previously 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), the Water Agency outlined six possible metrics that could be considered for validation monitoring of juvenile salmonids with respect to eventual habitat enhancements in the mainstem Dry Creek: habitat use, abundance (density), size, survival, growth and fidelity (Table 5.3.1). In 2009-2010, a major focus of validation monitoring in Dry Creek was on evaluating the feasibility of sampling methods to accurately estimate each of those metrics while simultaneously attempting to understand how limitations in sampling approaches may affect our ability to validate project success. These same validation metrics and associated limitations and uncertainties have been discussed in the context of the results of those evaluations and are incorporated into the Dry Creek AMP (Porter et al. 2014). The methods currently employed for validation monitoring in Dry Creek are largely based on the outcome of that work (Manning and Martini-Lamb 2011; Martini-Lamb and Manning 2011).

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

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

Methods

In order for juvenile Coho Salmon to take advantage of the habitat enhancements created in Dry Creek, fish will need to come from somewhere and although there is a substantial population of juvenile steelhead that rear in mainstem Dry Creek, Coho are extremely scarce. Therefore, our strategy for juvenile Coho validation monitoring must rely on hatchery releases coupled with visual observations of Coho in the backwaters during snorkel surveys and observations on PIT antennas within habitat enhancement sites. Because of this, much of our juvenile salmonid monitoring has been focused on steelhead. However, in 2017 we conducted a semi-natural juvenile Coho Salmon release trial in Dry Creek to evaluate the behavior of Coho Salmon post-release.

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

Evaluation of juvenile Coho Salmon releases

On November 30, 2017, approximately 6,000 PIT-tagged juvenile Coho were released into Dry Creek as part of the Russian River Coho Salmon recovery program and as a way to evaluate use of constructed side channels by juvenile Coho. We released PIT-tagged individuals in three main sites. Two of these sites (Truett Hurst and City of Healdsburg) were newly-constructed side channels while the third (Yoakim Bridge) was an unenhanced mainstem Dry Creek location. Both of these side channels as well as a third side channel (Carlson, where no juvenile Coho were released) were monitored with stationary PIT antennas (Figure 5.2) from several days prior to release until January 9, 2018 when antennas were removed because of high flows. In order to refine our evaluation of juvenile Coho post-release, we blocked off a backwater feature within the City of Healdsburg side channel with a fine mesh block net and released 1,488 (50%) City of Healdsburg fish in this backwater so they could not get out. We removed the net blocking the backwater seven days post-release on December 7 thus allowing fish in the backwater to leave volitionally. The remaining 50% not released into the backwater were released directly into the side channel and were therefore immediately allowed to leave the side channel volitionally. Similarly at Truett Hurst, all fish were released directly into the side channel (i.e., no block net) and therefore immediately allowed to leave the side channel volitionally.

Habitat utilization

Summer / Fall

We conducted two snorkel surveys in Farrow backwater in May and June 2017. Surveys were conducted with two snorkelers working in tandem. On the day of each snorkel survey we measured water temperature and dissolved oxygen at 0.25 m depth increments throughout the water column allowing us to construct vertical temperature and dissolved oxygen profiles.

Winter

Similar to previous years, we operated PIT antennas in newly constructed habitat enhancements during the winter: at the downstream and upstream openings of the City of Healdsburg (rkm 3.11, rkm 3.23), Carlson (rkm 13.48, rkm 13.59) and Truett Hurst side channels (rkm 14.05, rkm 14.30) (Figure 5.3.1, Figure 5.3.2). Although antennas did not necessarily span the wetted width of channels, they did cover the majority of the wetted width. The source of PIT-tagged fish included: (1) PIT-tagged juvenile Coho that were released from Warm Springs Hatchery into Dry Creek; (2) wild (natural-origin) juvenile steelhead that were PIT-tagged during mainstem Dry Creek electrofishing surveys; (3) adult anadromous salmonids that had been previously PIT-tagged as juveniles.

Figure 5.3.1. Approximate location of PIT antennas (yellow ovals) in Dry Creek habitat enhancements completed in late fall/early winter, 2017-18. River kilometers (rkm) correspond to the downstream extent of stream section surveyed for effectiveness monitoring. Images are "as built".

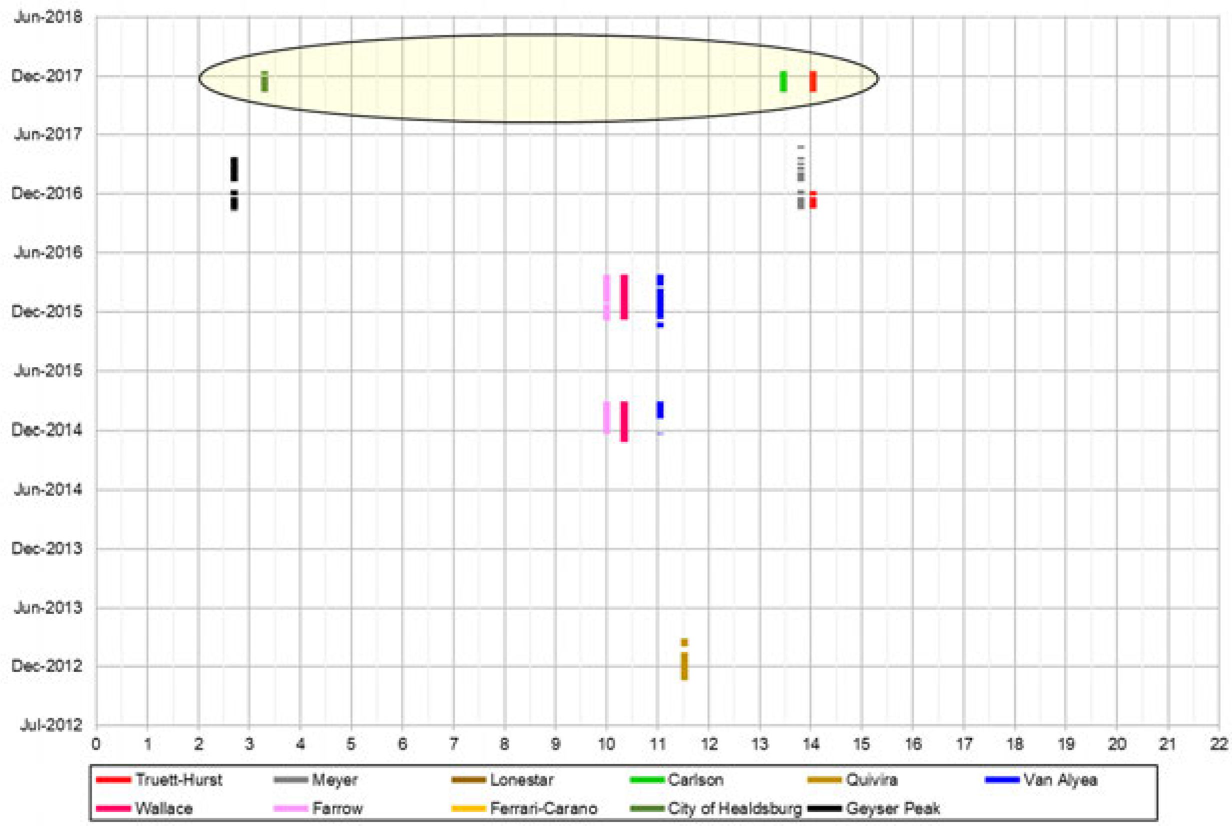


Figure 5.3.2. Dates of PIT antenna operation in Dry Creek habitat enhancement sites, November 2012 to January 2018. Sites shaded with yellow area represent the focus for the current year's data report.

Late summer population density

Site-scale sampling

We were able to conduct sampling to estimate population density in the Army Corps Reach 15 side channel (rkm ~21.4) and four constructed riffle sections: Wallace (rkm 10.17), Van Alyea lower (rkm 10.89) and upper (rkm 11.14) and Lonestar (rkm 13.44). During late August through September, we sampled with a backpack electrofisher by making a single pass through the entire side channel or constructed riffle on day 1 (the marking event) followed by a second pass two days later (the recapture event). Individuals captured on day 1 were PIT-tagged, released near their capture location and subject to recapture on day 2. From these paired sampling events, we used the Petersen mark-recapture model in Program MARK (White and Burnham 1999) to estimate end-of-summer abundance ($\widehat{N}$). Provided recapture probability, mortality and the proportion of fish leaving the section between the marking and recapture events was the same for the marked group as it was for the unmarked group, the abundance estimates from the paired mark and recapture events in early autumn will be unbiased (White et al. 1982). Density estimates were calculated as the quotient of $\widehat{N}$ and wetted area of the site.

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. Beginning in 2015, we added to our site-scale sampling that targeted habitat enhancements by employing a reach-based approach that relied on the spatially-balanced random sampling framework afforded by the generalized random tessellation stratified (GRTS) framework outlined for CMP implementation (Adams et al. 2011). Sampling reaches in this manner over time should allow us to place our results in a broader spatial context thereby facilitating more accurate validation of the effectiveness of habitat enhancement measures in Dry Creek (Figure 5.3.3). Towards that end, we sampled one randomly selected stream section in each of nine “GRTS” reaches defined in mainstem Dry Creek for CMP monitoring (Sonoma Water and CSG 2015). We sampled using methods similar to those described for the paired sample, site-scale electrofishing so that we could estimate juvenile steelhead abundance using the Petersen mark-recapture model. Stream sections (sub-reaches) were typically longer (average 618 feet, range180 - 1614 feet) than sites sampled during site-scale sampling.

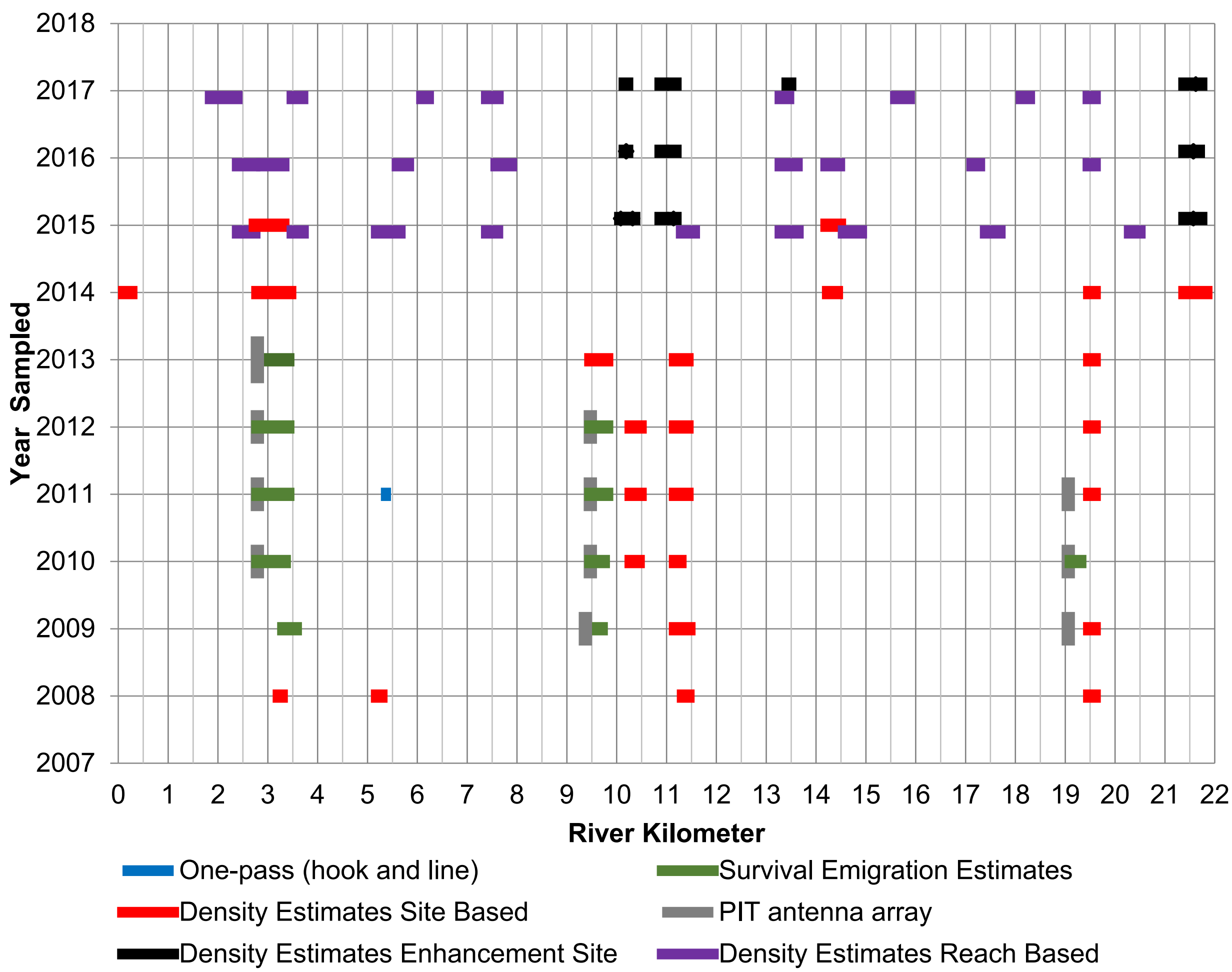


Figure 5.3.3. Years sampled and river kilometer (from the mouth) where juvenile steelhead populations were sampled in mainstem Dry Creek, 2008-2017. Line length for each site is scaled to the length of stream sampled. Data collected at the site scale were analyzed using mark-recapture (either a multiple-pass depletion or Petersen model) and reach-scale data collected in 2009 were analyzed with the core-sampling approach (see Manning and Martini-Lamb 2011 for details) while reach scale data collected in 2011-13 were analyzed with the multistate model using program MARK (White and Burnham 1999) to estimate survival and emigration.

Smolt abundance

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

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

Each day, up to 50 Chinook smolts (≥60 mm) were marked and released upstream of the trap for the purpose of estimating trap efficiency and constructing a population estimate. Both fin clips and PIT tags were used to mark fish. PIT-tagged fish provided the potential to evaluate migration mortality and migration time as fish were detected at downstream monitoring sites (i.e., Duncans Mills PIT antenna array). Marked fish (fin-clipped or PIT-tagged) that were recaptured in the trap were noted and released downstream (the lengths and weights of recaptured fish were not recorded a second time). The population estimate of Chinook Salmon smolts produced in the Dry Creek watershed upstream of the trap were based on recapture rates of PIT tagged fish only. The abundance estimate of Chinook smolts reported in 2017 applies to the period the trap was operated (April 20-July 31).

Results

Evaluation of juvenile Coho Salmon releases

Of the 1,488 PIT-tagged Coho Salmon released into Dry Creek at Yoakim Bridge in fall 2017, fish were detected in all three side channels monitored with PIT antennas in late fall/winter 2017-18 although the highest number was detected in Truett Hurst (approximately 3 km downstream, Table 5.3.2). Fish that were released directly (i.e., not blocked off) into the City of Healdsburg and Truett Hurst side channels tended to leave their respective release sites almost immediately (Figure 5.3.4) while fish that were blocked off in the City of Healdsburg showed a more even departure distribution from the side channel (Figure 5.3.5.

Table 5.3.2. Release and detection information for juvenile (age-0+) Coho Salmon released in Dry Creek, fall 2017. Note that Individuals that were detected at more than one detection site are counted more than once.. Release and detection information for juvenile (age-0+) Coho Salmon released in Dry Creek, fall 2017. Note that Individuals that were detected at more than one detection site are counted more than once.

Release (11/30/2017)		Detect		Median Days[1] (0.1, 0.9 percentile)
Site	Number	Site	Number (%)	
Yoakim Bridge (rkm 17.16)	1,488	Truett Hurst (rkm 14.01)	107 (7.2%)	3.5 (3.1, 3.9)
		Carlson (rkm 13.35)	16 (1.1%)	3 (0.5, 30.5)
		City of Healdsburg (rkm 2.49)	19 (1.3%)	1 (0.8, 5.2)
Truett Hurst (rkm 14.01)	1,486	Carlson (rkm 13.35)	70 (4.7%)	2 (1.0, 20.1)
		City of Healdsburg (rkm 2.49)	24 (1.6%)	1 (1, 2)
City of Healdsburg (rkm 2.49)	1,488	Truett Hurst (rkm 14.01)	1 (0.1%)	25 (25.0, 25.0)
		Carlson (rkm 13.35)	5 (0.3%)	27 (14.2, 33)
Total	**5,954**	**Combined**	**242 (4.1%)**	**N/A**

[1] Refers to number of days between release date and first detection date at the detection site.

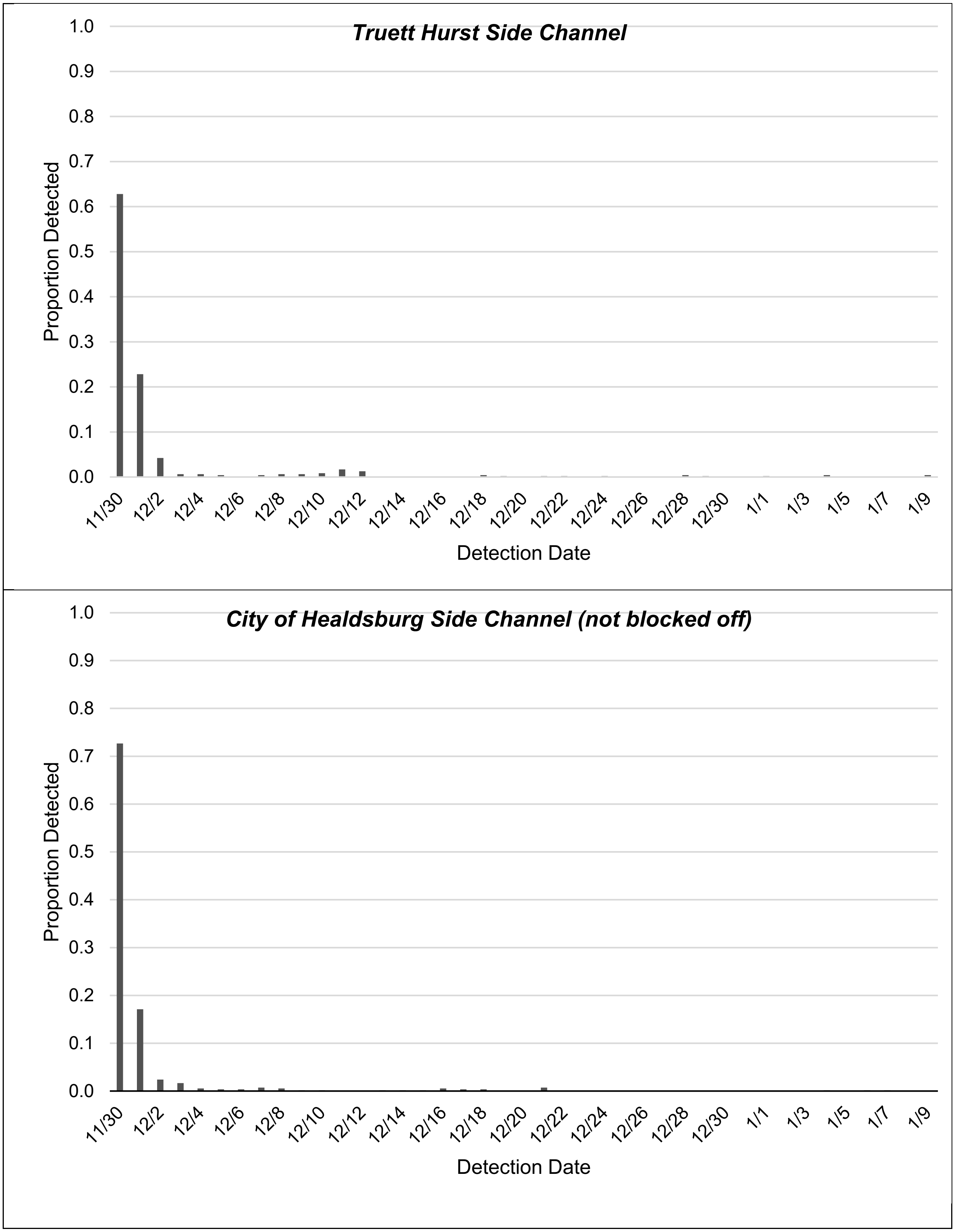


Figure 5.3.4 Proportion of juvenile Coho released into two constructed, unblocked side channels (see text for description) that were later detected leaving (most likely) the side channel of release.

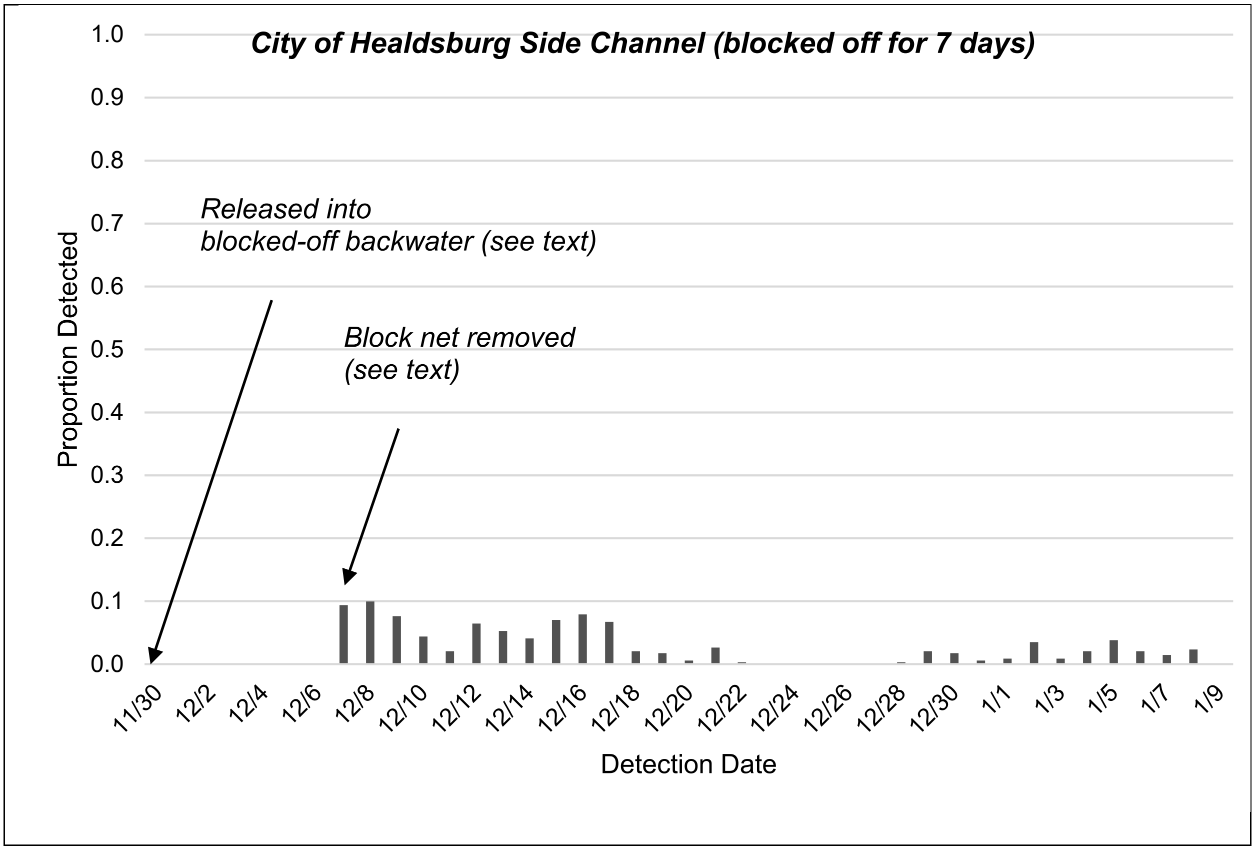


Figure 5.3.5. Proportion of juvenile Coho released into City of Healdsburg constructed side channel that was blocked for 7 days post-release (see text for description) that were later detected leaving (most likely) the side channel of release.

Habitat utilization

Summer / Fall

Counts from snorkel surveys of juvenile salmonids in the Dry Creek habitat enhancement areas were low. In 2017 high winter flows deposited large amounts of sediment in the Geyser Peak, Wallace, and Truett Hurst side channels which made these sites too shallow to survey. Surveys were conducted at the Farrow backwater on May 15 and June 21, 2017. We were unable to conduct dive surveys in the Farrow backwater after June due to poor visibility. A total of only 24 juvenile steelhead were observed in the Farrow backwater on the May 15 survey and no salmonids were observed on the June 21 survey. However, as in previous years, rooted aquatic vegetation, algae growth and high turbidity caused poor visibility (Figure 5.3.6). Evidence of vegetation impacts on snorkeling visibility is clear in light of snorkel and electrofishing surveys conducted in 2014 in the USACE side channel. The number of fish observed on October 2014 during a snorkel survey (34) was far less than the 351 steelhead captured by electrofishing in the same site a few days earlier (Martini-Lamb and Manning 2016).

Figure 5.3.6. A juvenile steelhead using aquatic vegetation in Dry Creek as cover.

Winter

Of the 1,668 juvenile steelhead that were PIT-tagged in 2017 during electrofishing surveys (Table 5.3.3), 67 were detected in the three constructed side channels where PIT antennas were operated in late fall/early winter 2017-18. Most of the detections (47) were from fish that were tagged within 2 km of the enhancement site (Figure 5.3.7-Figure 5.3.9). From these data, it is reasonable to conclude that a significant portion of all juveniles are making use of these enhanced off-channel habitats during the winter, but, not surprisingly, the highest use is by fish residing in close proximity to the habitat enhancements.

In addition to juvenile salmonid detections in the habitat enhancements, we also documented use by adult salmonids. Of the 46 PIT-tagged individual Coho detected entering Dry Creek (all Dry Creek antennas combined including the Coastal Monitoring Program life cycle monitoring antenna array at rkm 0.36), 27 entered at least one of the three side channels: 21 in City of Healdsburg; 6 in Lonestar; 23 in Truett Hurst. Seventeen individuals entered at least two side channels with 5 of those detected in all three. In addition, 1 unique adult steelhead and 14 unique adult Chinook Salmon were detected in the three side channels.

Table 5.3.3 Number of juvenile steelhead PIT-tagged during mainstem Dry Creek electrofishing surveys and subsequent number detected (and percent of total tagged in that reach) on PIT antennas in habitat enhancement side channels, late fall/early winter 2017. Reaches in bold italic text indicate reaches where constructed off channel habitats with PIT antenna monitoring were located.

CMP reach[1] of PIT applied			EF tagged (Fall 2016)	City of Healdsburg (rkm=3.11)	Carlson (rkm=13.90)	Truett Hurst (rkm=14.16)
Name	Upper (rkm)	Lower (rkm)				
DRY 1	0.00	2.82	278	0	0	0
DRY 2	***2.82***	***5.20***	***310***	***10 (3.2%)***	0	0
DRY 3	5.20	6.87	104	1 (1.0%)	3 (2.9%)	4 (3.9%)
DRY 4	6.87	9.99	124	0	0	0
DRY 5	9.99	11.62	253	1 (0.4%)	3 (1.1%)	5 (2.0%)
DRY 6	***11.62***	***13.93***	***150***	0	***22 (14.7%)***	***15 (10%)***
DRY 7	***13.93***	***17.07***	***256***	***0***	1 (0.4%)	***2 (0.8%)***
DRY 8	17.07	18.90	94	0	0	0
DRY 9	18.90	21.81	99	0	0	0
		Totals	**1,668**	**12 (0.7%)**	**29 (1.7%)**	**26 (1.6%)**

[1] Refers to GRTS reaches used for Coastal Monitoring Program monitoring in the Russian River watershed (Sonoma Water and CSG 2015).

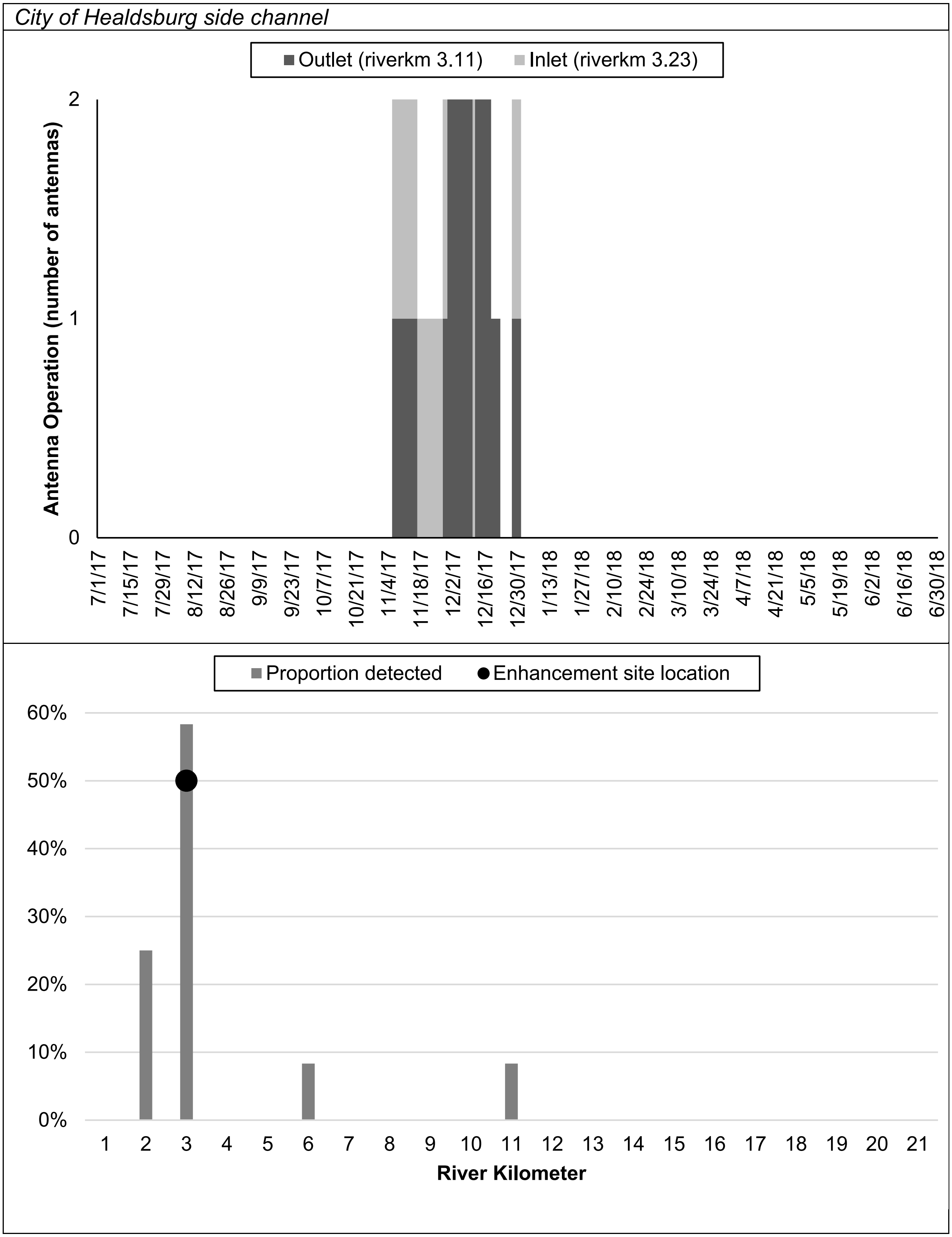


Figure 5.3.7. Proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in City of Healdsburg habitat enhancement.

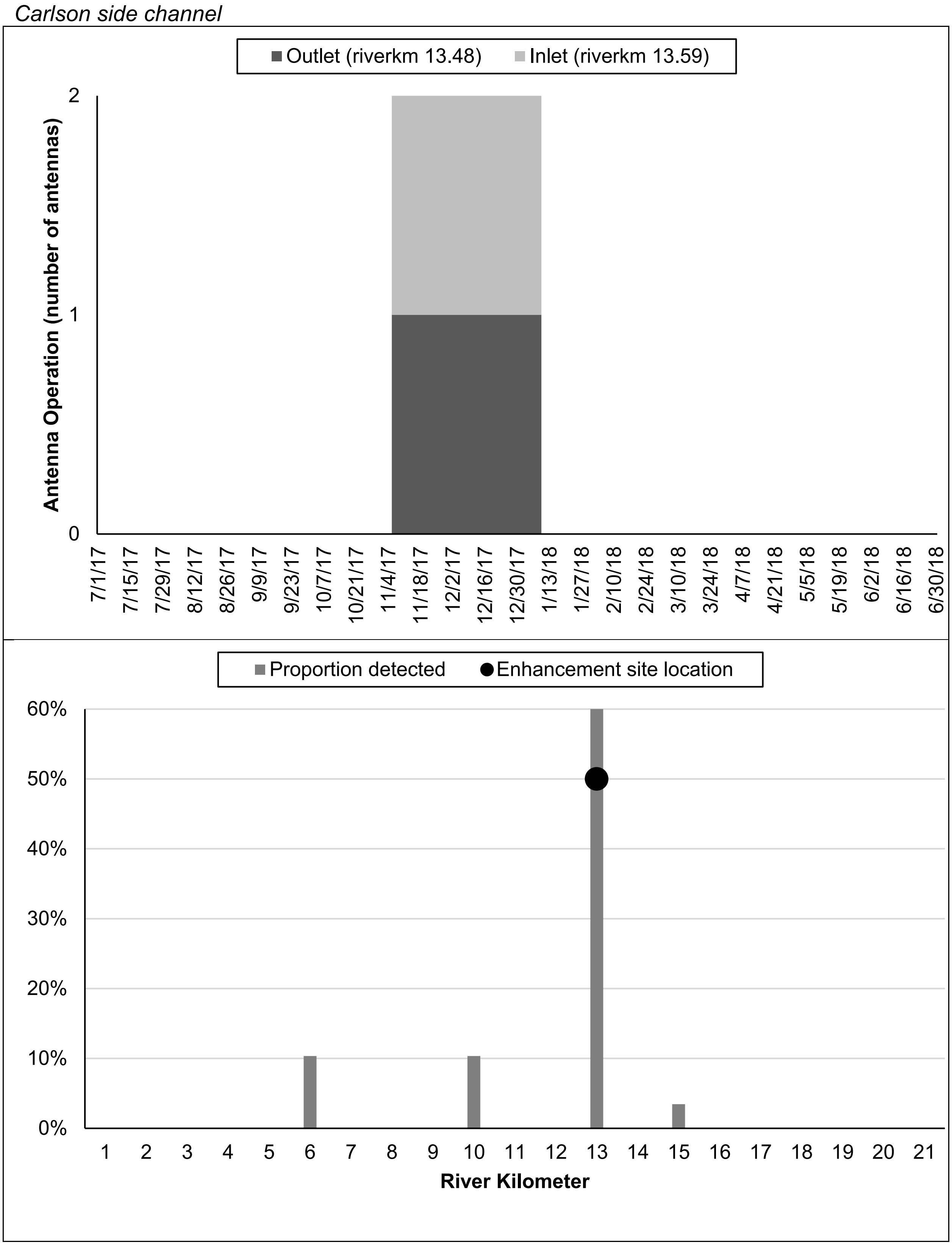


Figure 5.3.8. Proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in Carlson habitat enhancement.

Truett Hurst side channel

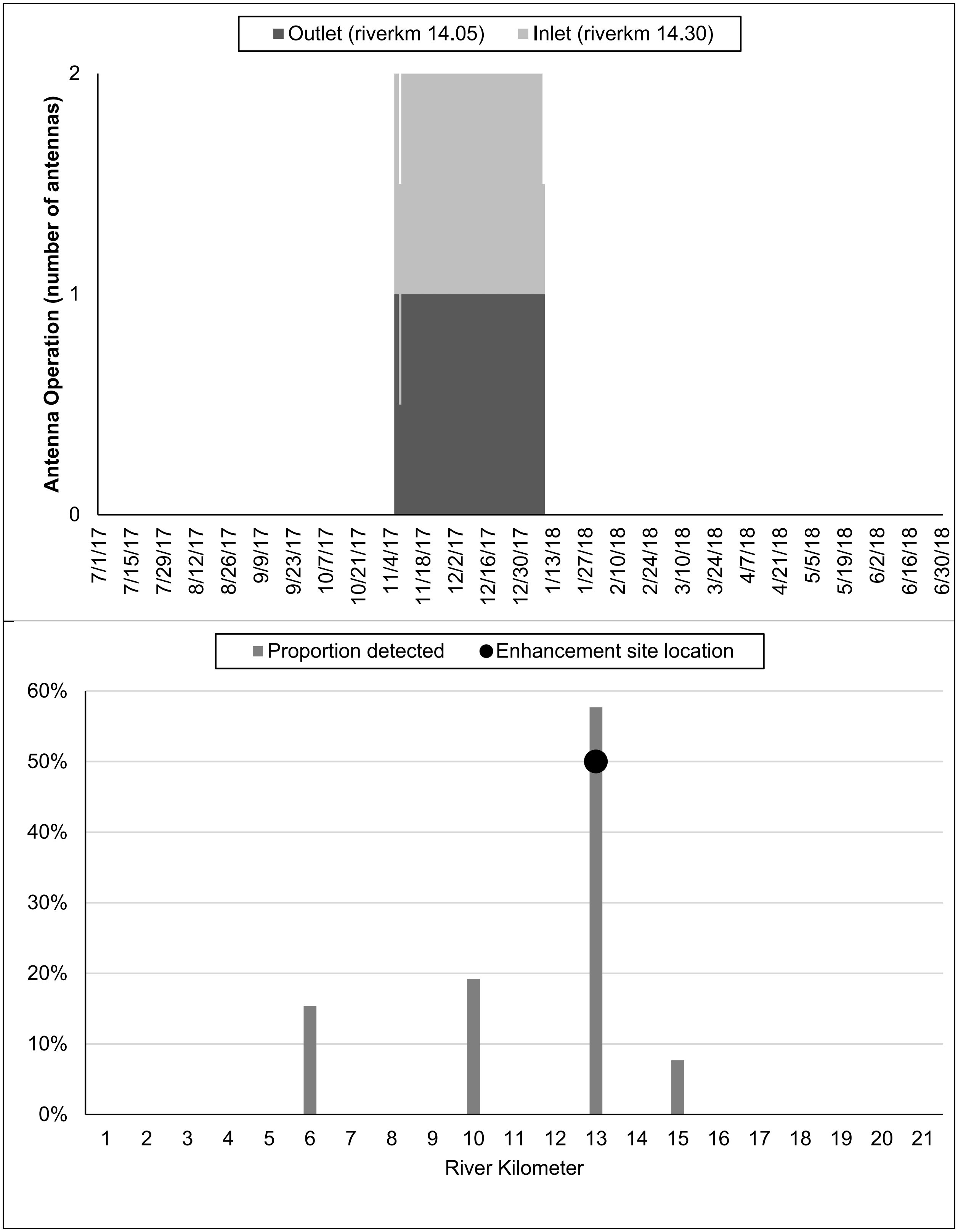


Figure 5.3.9. Proportion of juvenile steelhead PIT-tagged during electrofishing surveys in mainstem Dry Creek that were later detected in Truett Hurst habitat enhancement.

Late summer population density

Site-scale sampling

The estimated density of juvenile steelhead in the Army Corps Reach 15 side channel (0.04 fish*m^{-2}, rkm 21.4) was lower than the density estimates obtained from the four constructed riffle sections at Wallace (rkm 10.17), Van Alyea (rkm 10.89, 11.14) and Lonestar (rkm 13.44) (Figure 5.3.10). While we do not capture enough Coho to generate a density estimate, we did capture a total of 14 wild (and 5 unknown origin) Coho Salmon YOY during electrofishing sampling in the Army Corps reach 15 side channel.

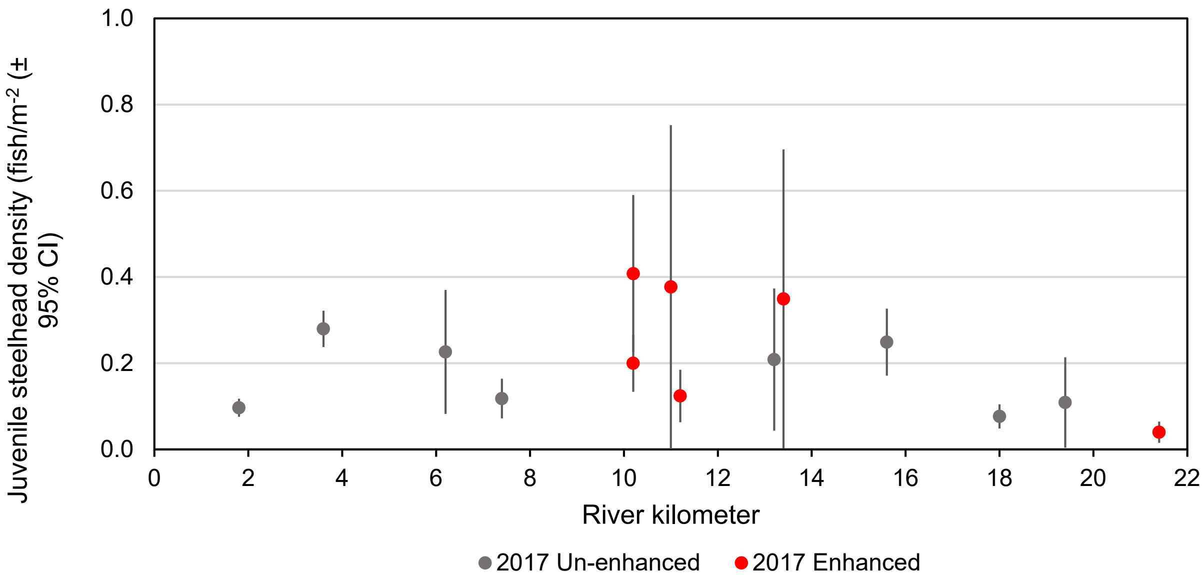


Figure 5.3.10. Estimated density of juvenile steelhead in mainstem Dry Creek, in habitat-enhanced stream sections (site-scale monitoring) and un-enhanced stream sections (reach-scale monitoring). Estimates are based on the Petersen mark-recapture model. Note there was an overlap with the GRTS reaches selected for reach-scale sampling and sections within the demonstration reach where habitat enhancements have been completed. Therefore one of the nine sites sampled for reach-scale sampling is identified as an enhanced site.

Reach-scale sampling

The average density of juvenile steelhead in GRTS sub-reaches was 0.17 fish*m^{-2} (range 0.08 fish*m^{-2} to 0.28 fish*m^{-2}, Figure 5.3.10). When averaged for all sites within a year, densities in 2017 were 0.02 fish*m^{-2} higher than the nine year average from 2008-2016 (Figure 5.3.11). The average population density for enhanced sites was greater than for un-enhanced sites (Figure 5.3.11).

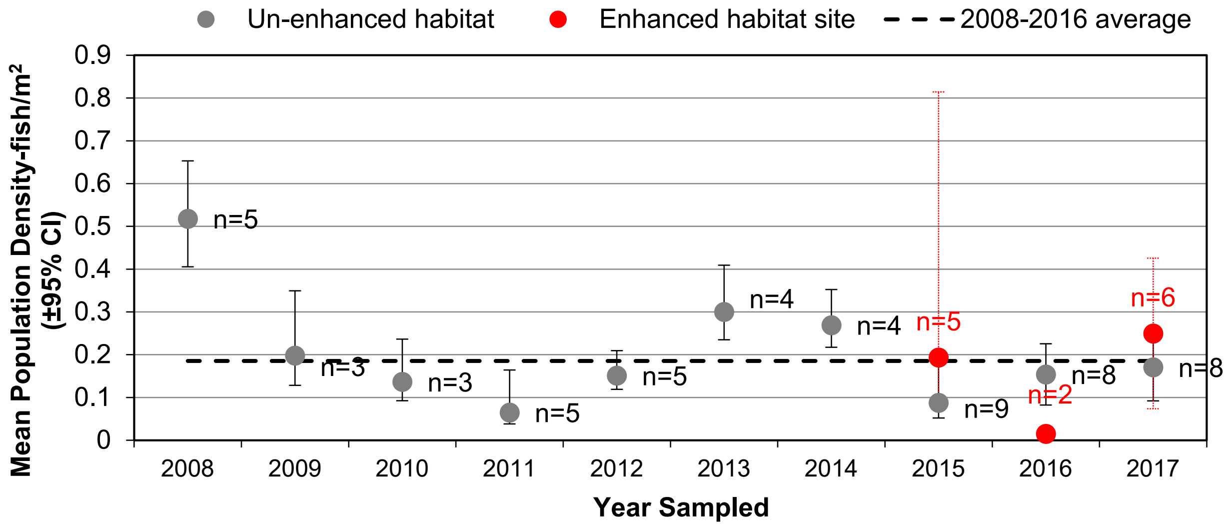


Figure 5.3.11. Mean juvenile steelhead density among all sites sampled within a year in mainstem Dry Creek, 2008-2017. "n" refers to the number of sites sampled per year.

Smolt abundance

We installed the rotary screw trap on April 20 (Figure 5.3.12). Except for brief periods when trapping was suspended because of high debris loading in the trap from high winds, the trap was checked daily during operation until it was removed on July 31.

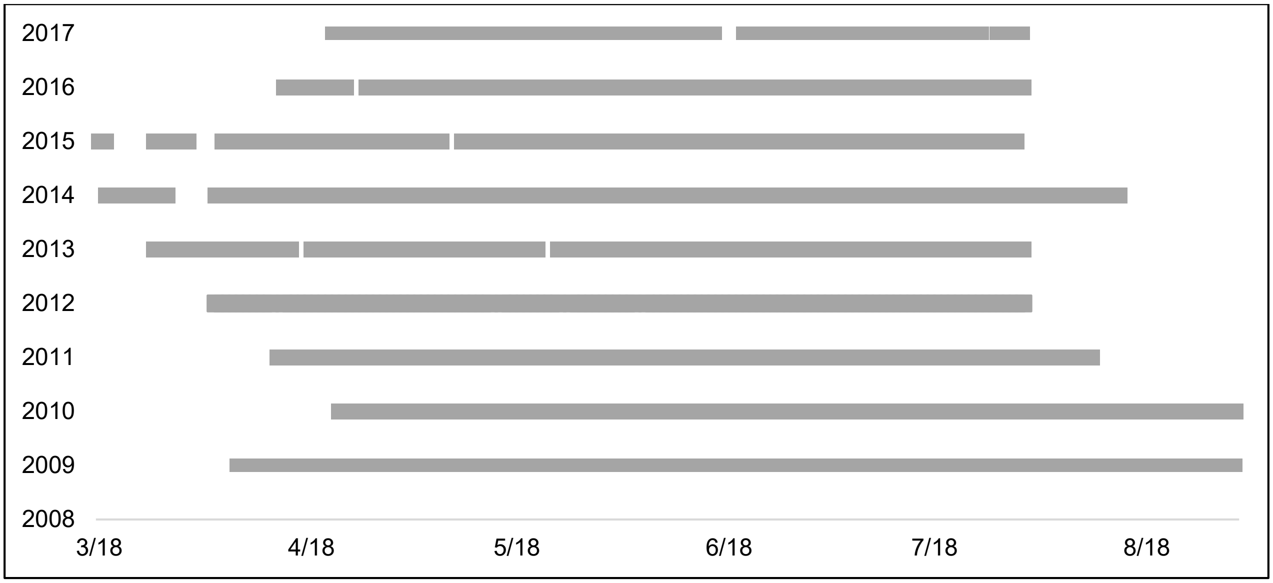


Figure 5.3.12. Begin and end dates and data gaps (spaces in lines) for operation of the Dry Creek downstream migrant trap, 2009-2017.

The peak capture of Chinook Salmon smolts (7,383) occurred during the week of 5/28 (Figure 5.3.13). Based on the estimated average weekly capture efficiency (range: 6% to 40%), the resulting population size of Chinook smolts passing the Dry Creek trap between April 20 and July 31 was 37,260 (±95% CI: 6,298, Figure 5.3.14). This is the second smallest population estimate since we began trapping Dry Creek in 2009.

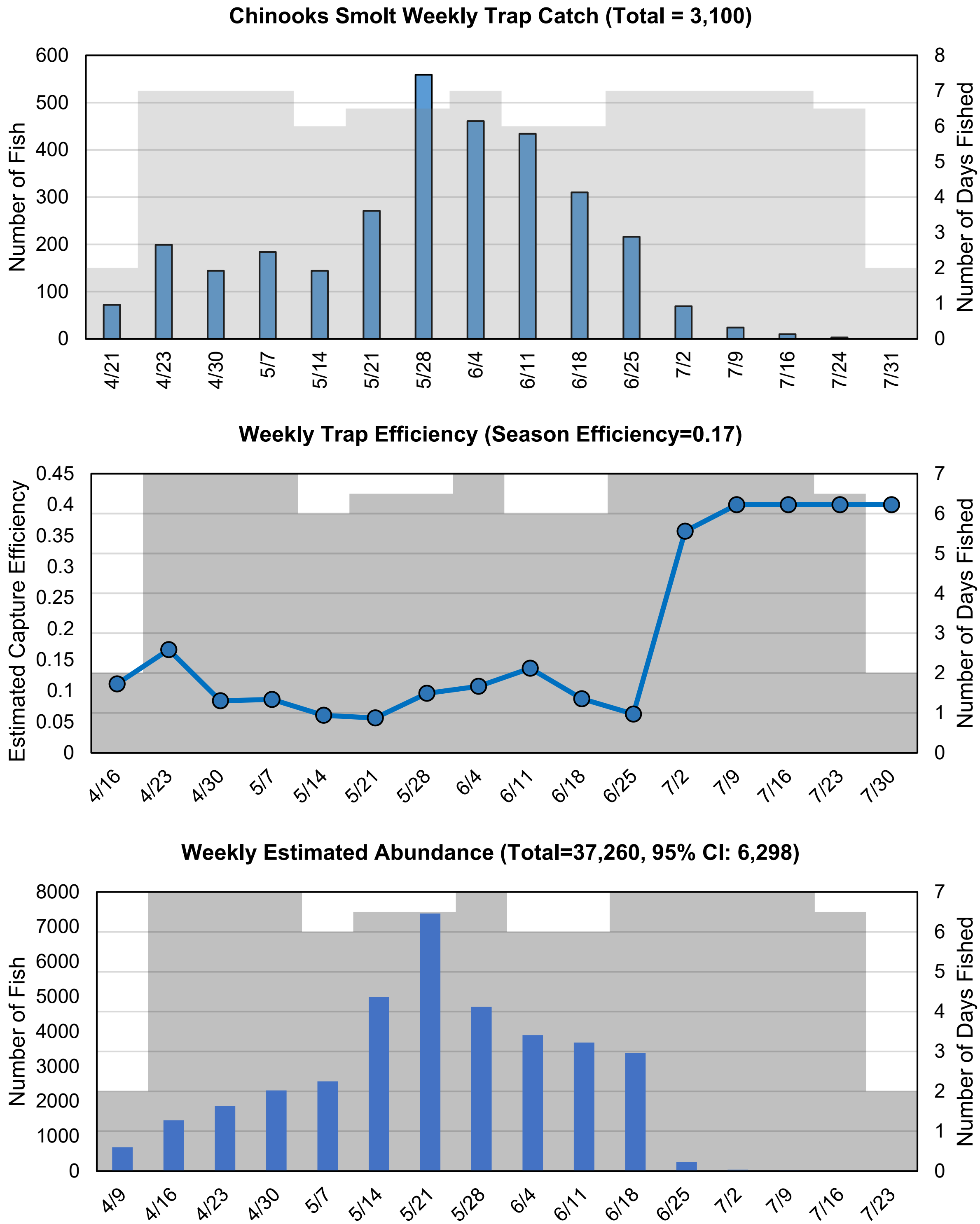


Figure 5.3.13. Weekly trap catch (upper panel), estimated average weekly capture efficiency (middle panel) and population estimate of Chinook Salmon smolts in the Dry Creek rotary screw trap (lower panel), 2017. Estimates are from DARR (Bjorkstedt 2005). The number of days each week the trap was fished is represented by the shaded area.

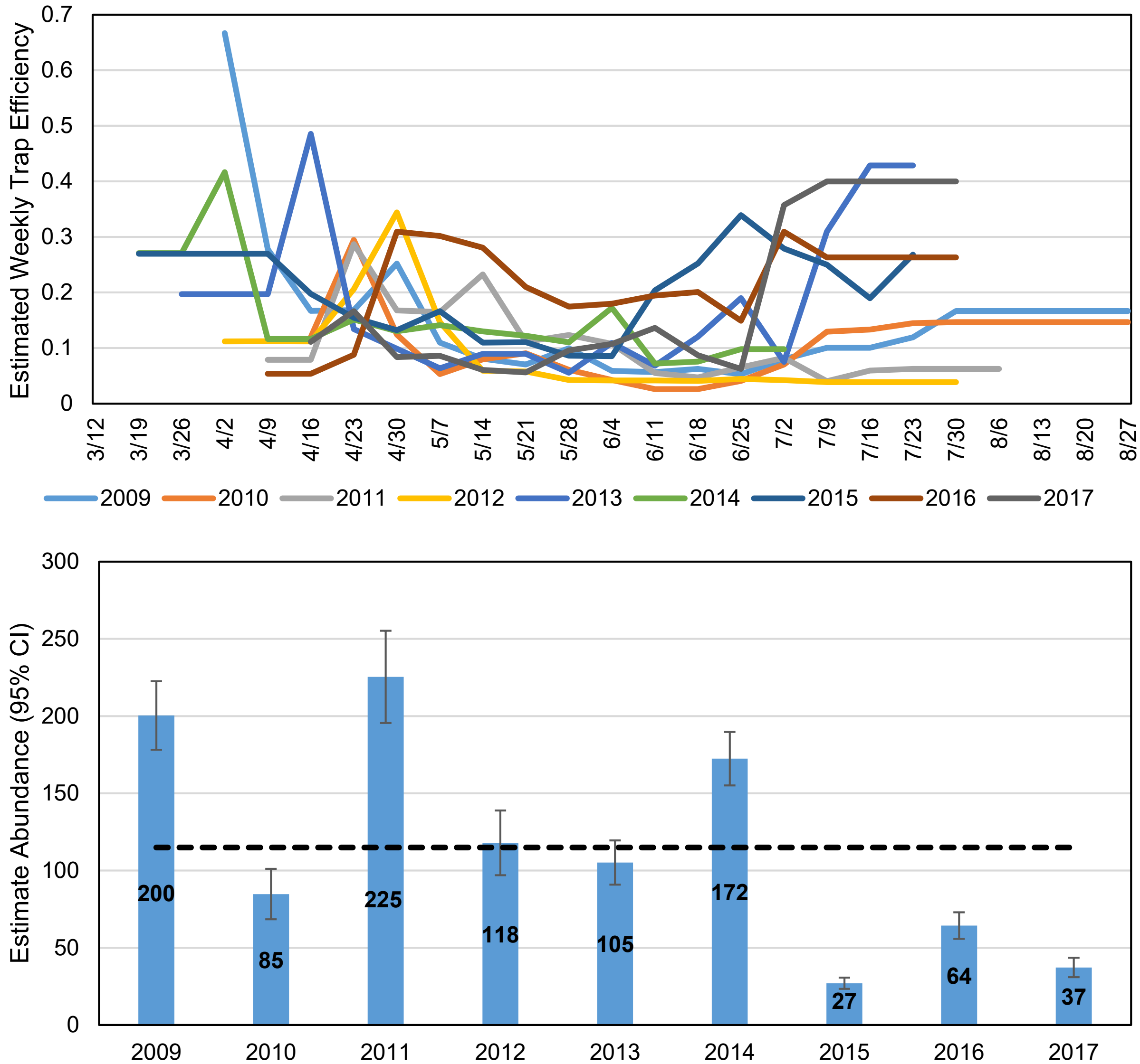
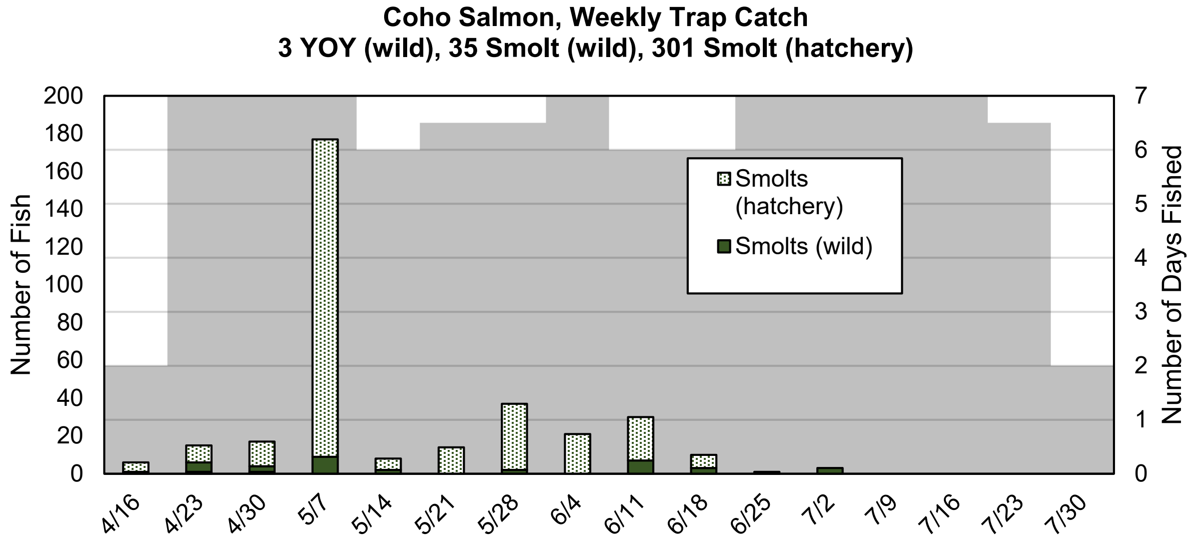


Figure 5.3.14. Estimated average weekly capture efficiency (upper panel) and population estimate of Chinook Salmon smolts (x1000) produced from the Dry Creek watershed upstream of Westside Road smolt trap site (rkm=3.3) (lower panel), 2009-2017. Dashed line is the eight year average abundance for all years combined.

Coho Salmon were the least abundant of the three salmonid species captured. Hatchery smolts dominated the catch with a total of 301 individuals captured. Steelhead parr capture was highest in June (Figure 5.3.15).



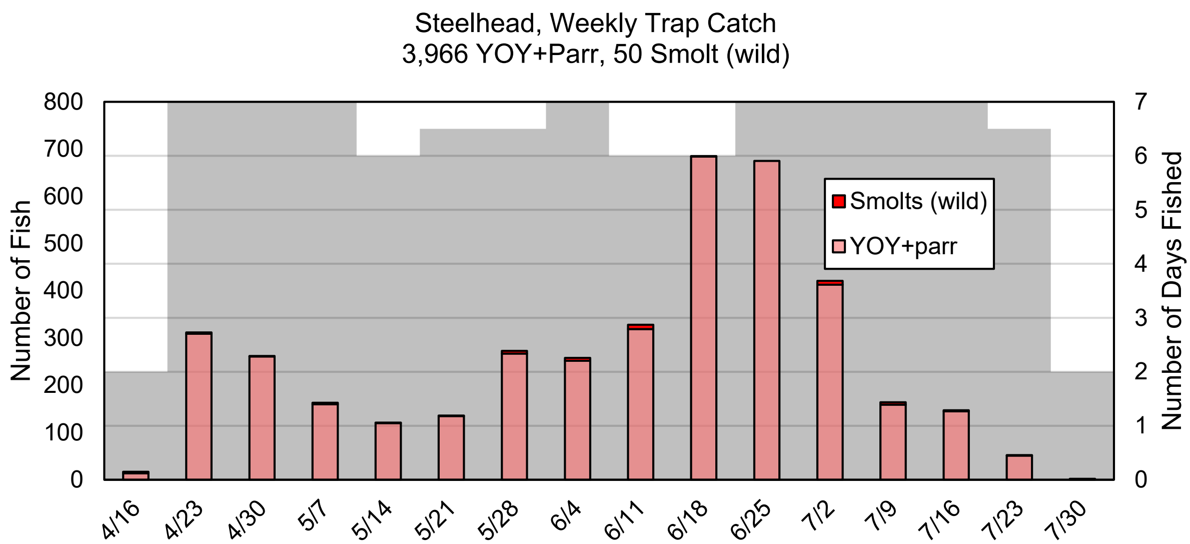


Figure 5.3.15. Weekly trap catch of juvenile Coho Salmon and steelhead in the Dry Creek rotary screw trap, 2017.

Coho smolt trap catch for the season was relatively low and similar to the catch in 2011, 2012 and 2015 (Figure 5.3.16). The capture of wild Coho smolts was still quite low at 23 individuals and is similar to previous year’s totals. Steelhead smolt and parr captures (106 and 4,221) were also similar to totals from previous years.

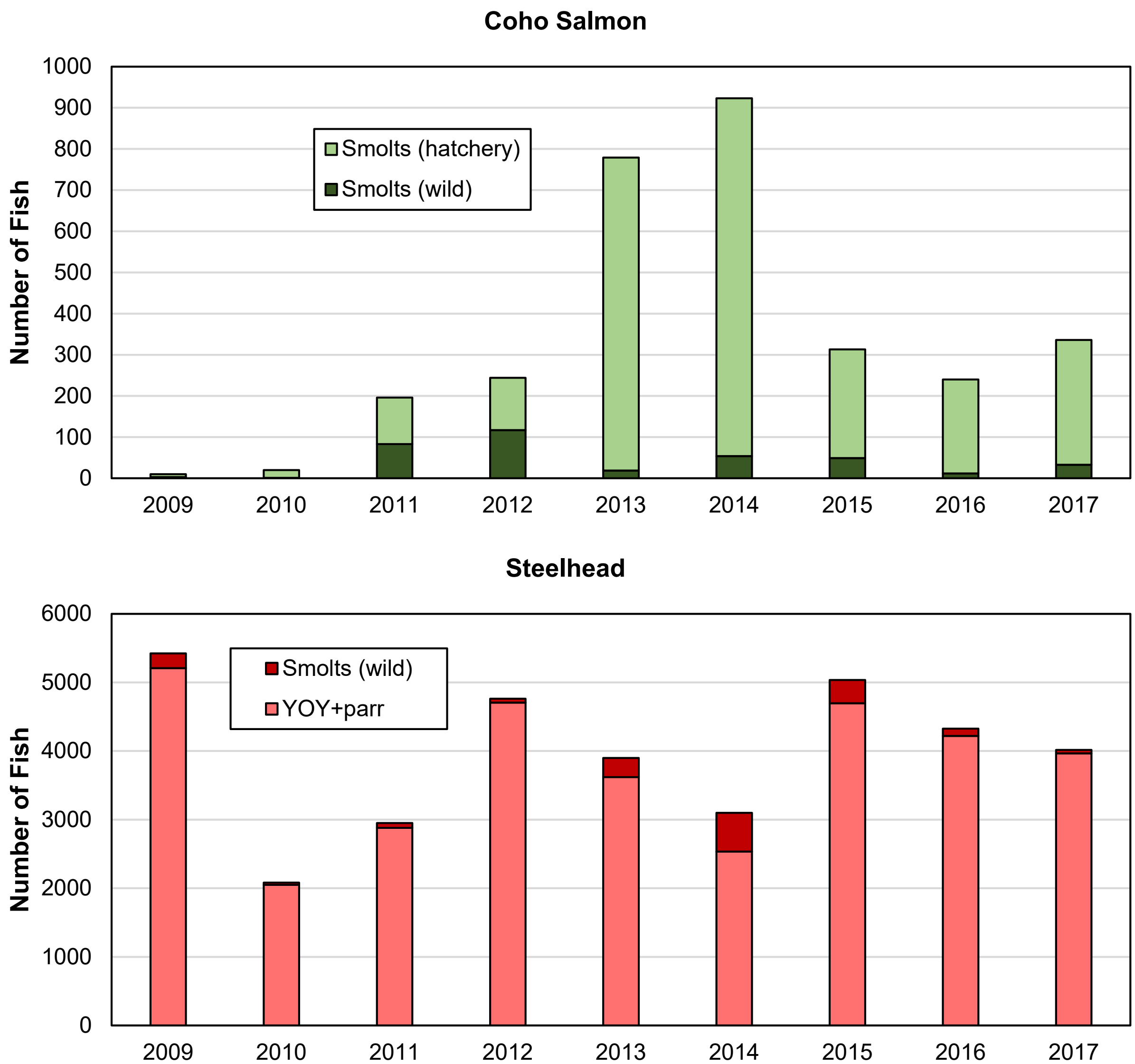


Figure 5.3.16. Trends in trap catch for Coho smolts and steelhead smolts and parr, 2009-2017.

Weekly sizes of all salmonids captured at the Dry Creek trap increased over the course of the trapping season in 2017 (Figure 5.3.17).

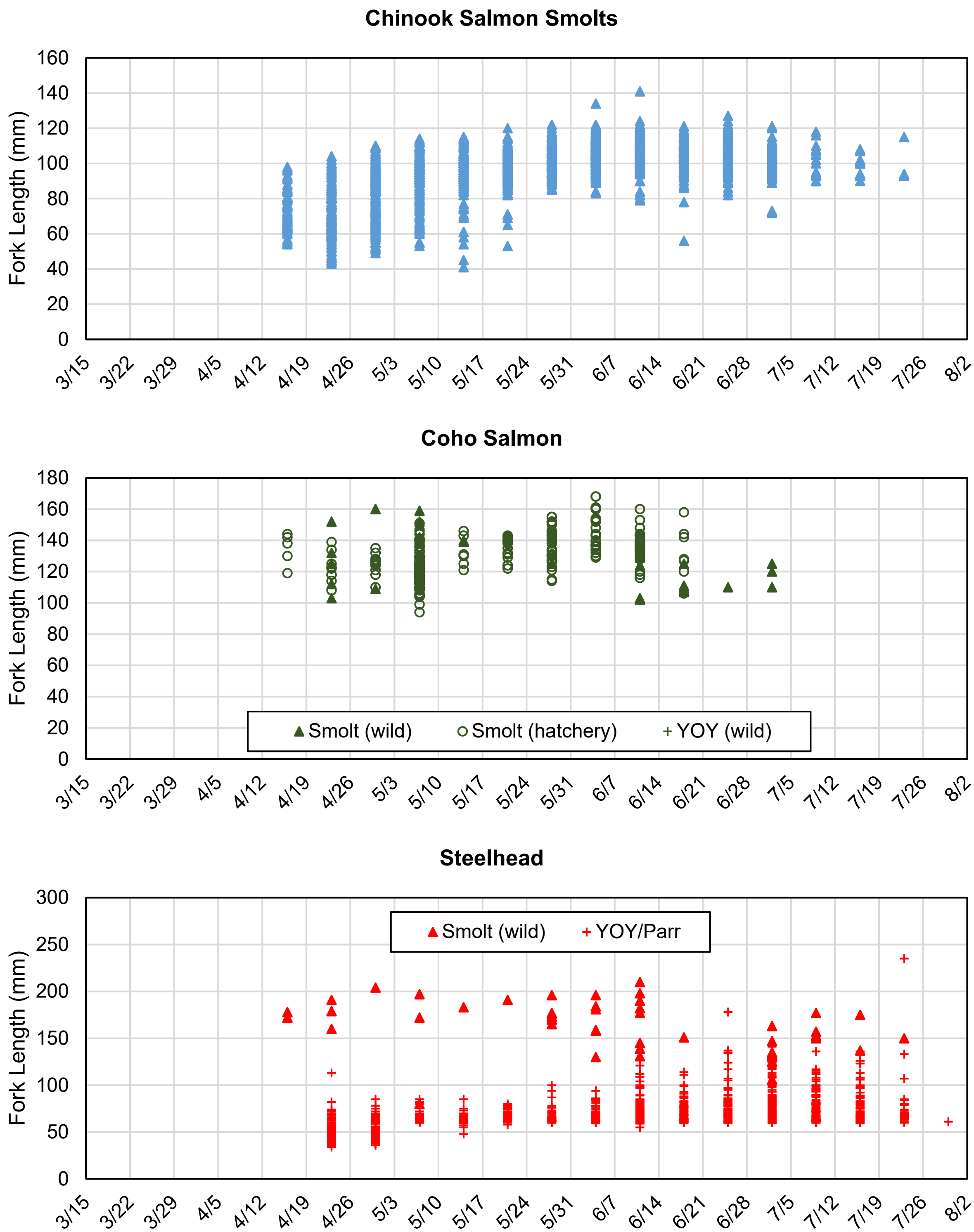


Figure 5.3.17. Fork lengths of juvenile salmonids captured in the Dry Creek rotary screw trap by week, 2017.

Conclusions and Recommendations

Based on validation monitoring conducted in 2017, there is clear evidence that juvenile salmonids are utilizing habitat enhancements in Dry Creek (Table 5.3.4). Although habitat utilization by adult salmonids is not a primary metric according to the Dry Creek AMP, presence of adults of all three species in constructed off-channel habitats suggests that benefits are likely accrued to life stages other than juveniles.

Table 5.3.4. Outcomes from validation monitoring conducted in 2017 in Dry Creek habitat enhancements.

Metric	Life stage	Species	Habitat enhancement			Method	Season	Outcome
			River km	Name	Type[1]			
habitat use	juvenile	Coho Salmon	21.40	Army Corps reach 15	SC	efish	sum/fall	present
		steelhead	2.68	City of Healdsburg	SC	PIT ant	fall-win	present
			9.97	Farrow	BW	Snorkel	spring	present
			13.35	Carlson	SC	PIT ant	fall-win	present
			14.01	Truett Hurst	SC	PIT ant	fall-win	present
	adult	Coho Salmon	2.68	City of Healdsburg	SC	PIT ant	fall-win	present
			13.35	Carlson	SC	PIT ant	fall-win	present
			14.01	Truett Hurst	SC	PIT ant	fall-win	present
		steelhead	2.68	City of Healdsburg	SC	PIT ant	fall-win	present
		Chinook Salmon	2.68	City of Healdsburg	SC	PIT ant	fall-win	present
			13.35	Carlson	SC	PIT ant	fall-win	present
			14.01	Truett Hurst	SC	PIT ant	fall-win	present
density (fish * m^{-2})	juvenile	steelhead	9.97	Wallace	CR	efish	sum/fall	0.41 ±0.18
			10.89	Van Alyea (lower riffle)	CR	efish	sum/fall	0.38 ±0.38
			11.14	Van Alyea (upper riffle)	CR	efish	sum/fall	0.12 ±0.06
			13.44	Lonestar	CR	efish	sum/fall	0.35 ±0.35
			21.40	Army Corps reach 15	SC	efish	sum/fall	0.04 ±0.02

[1]SC=side channel; BW=backwater; CR=constructed riffle

Our method of validating fish use in the late fall and winter through the use of PIT antennas in off-channel habitat continues to provide evidence that constructed habitats in the winter. Blocking off side channels (or portions of side channels) for several days following release of juvenile Coho in Dry Creek may be an effective way to overcome the apparent flight response that has been shown in other streams by the Russian River Coho Salmon Broodstock Program. The CMP sampling framework proved useful as a way of understanding our site-level data in a broader context. Unfortunately, marginal visibility due to high turbidity and vegetation growth in newly-created off-channel habitats continues to hamper our ability to effectively observe fish during summer/fall snorkel surveys and these features are largely too deep to sample with a backpack electrofisher. The difficulty in sampling specific enhancement features is highlighted by the variability observed in steelhead densities observed at enhanced versus un-enhanced areas. Overall steelhead density was higher as compared to 2016, while the density estimated at unenhanced sites were similar to last year. In the future, we will consider alternative methods for estimating summer use of these habitats by juvenile salmonids including PIT-tagging and stationary PIT antennas and, perhaps, radio telemetry.

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CHAPTER 6 Tributary Habitat Enhancements

Summary

One component of the reasonable and prudent alternative (RPA) identified in the Biological Opinion is the enhancement of salmonid rearing habitats in tributaries to Dry Creek and the Russian River. A total of ten potential tributary enhancement projects are listed in the Biological Opinion with the requirement that Sonoma Water mplement at least five of these projects by the end of year 3 of the 15 year period covered by the Russian River Biological Opinion. The five projects that Sonoma Water completed were 1) Grape Creek Habitat Improvement Project; 2) Willow Creek Fish Passage Enhancement Project; 3) Crane Creek Fish Passage Project; 4) Grape Creek Fish Passage Project; and 5) Mill Creek Fish Passage Project. A detailed summary of the tributary enhancement projects can be found in previous Russian River Biological Opinion Status and Data Reports (Martini-Lamb and Manning 2020).

References

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CHAPTER 7 Coho Salmon Broodstock Program Enhancement

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

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

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

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

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CHAPTER 8 Wohler-Mirabel Water Diversion Facility

Introduction

Sonoma Water diverts water from the Russian River to meet residential and municipal demands. Water is stored in Lake Sonoma and Lake Mendocino, and releases are made to meet downstream demands and minimum instream flow requirements. The Water Agency's water diversion facilities are located near Mirabel and Wohler Road in Forestville. Sonoma Water operates six Ranney collector wells (large groundwater pumps) adjacent to the Russian River that extract water from the aquifer beneath the streambed. The ability of the Russian River aquifer to produce water is generally limited by the rate of recharge to the aquifer through the streambed. To augment this rate of recharge, Sonoma Water has constructed several infiltration ponds. The Mirabel Inflatable Dam (Inflatable Dam) raises the water level and allows pumping to a series of canals that feed infiltration ponds located at the Mirabel facility. The backwater created by the Inflatable Dam also raises the upstream water level and submerges a larger streambed area along the river. Three collectors wells, including the Agency's newest and highest capacity well, are located upstream of Wohler Bridge. These wells benefit substantially from the backwater behind the Dam.

Mirabel Fish Screen and Ladder Replacement

To divert surface water from the forebay of Mirabel Dam, Sonoma Water operates a pump station on the west bank of the river. The pump station is capable of withdrawing 100 cfs of surface flow through two rotating drum fish screens in the forebay. The fish screens have been functioning since the dam was constructed in the late 1970's. However, they fail to meet current velocity standards established by NMFS and CDFW to protect juvenile fish. The Biological Opinion requires Sonoma Water to replace the antiquated fish screens with a structure that meets modern screening criteria. In 2009, Sonoma Water employed the engineering firm of Prunuske Chatham, Inc. to prepare a fish screen design feasibility study. The report was completed in December 2009.

The feasibility study was conducted to develop a preferred conceptual design that meets many of the project objectives while ensuring that the fish screening facilities adhere to contemporary fish screening design criteria. A Technical Advisory Committee composed of Sonoma Water engineering and fisheries biologist staff, NMFS, and CDFW provided guidance in refining the objectives and identifying alternatives. Six concept alternatives were evaluated for meeting the project objectives. Schematic designs and critical details were developed for these concept alternatives to assess physical feasibility and evaluate alternatives relative to the objectives. The preferred concept design alternative was determined through an interactive evaluation and was selected because it meets or exceeds the project objectives.

In 2010, Sonoma Water solicited qualifications from engineering firms, and a list of qualified consultants was created from the responses. Sonoma Water selected HDR Engineering

(HDR) because of its demonstrated experience with this type of work and the strength of their proposed project manager, who has a proven track record with fish passage and screening projects. Sonoma Water and HDR entered into an Agreement for Engineering Design Services for the Mirabel Fish Screen and Fish Ladder Replacement Project in June of 2011. In 2011 and 2012, HDR completed work on preliminary engineering, geotechnical analysis, hydraulic modeling, development of construction drawings and specifications. HDR's final construction drawings and specifications are anticipated in early 2013. HDR will also provide engineering support during bidding and construction. HDR's design process included consultation at different design steps with the Technical Advisory Committee described above.

Because the fish ladder enhancement identified in the feasibility study is not required by the Biological Opinion, Sonoma Water applied for funds from CDFG's Fishery Restoration Grant Program (FRGP) in 2010 to help defray costs associated with fish ladder design. The Director of CDFG awarded the grant to Sonoma Water in February 2011. Sonoma Water also submitted a second application for FRGP funds in 2012 to help defray costs associated with fish ladder construction. In February of 2013, CDFW approved $1,184,049.00 in FRGP funds towards the construction of the new fishway at Mirabel to improve fish passage at the facility.

In January 2013, the Water Agency's Board of Directors approved and adopted an Initial Study and Mitigated Negative Declaration in accordance with the California Environmental Quality Act (CEQA).

The CEQA document for the project provided a discussion of potential environmental impacts related to the construction, operation, and maintenance of the proposed fish screen and fish ladder modifications. Project construction activities require isolating the work area from the active flow of the Russian River, demolishing the existing fish screen/intake and fish ladder structures on the western bank of the Russian River, and constructing the new fish screen and fish ladder structures. The new facilities will extend approximately 40 feet farther upstream and approximately 100 feet farther downstream than the existing facilities. This larger footprint is necessary to meet contemporary fish screen and fish passage design criteria. Figure 8.1 shows a plan view of the project design. Figure 8.2 shows a conceptual design drawing of the project components.

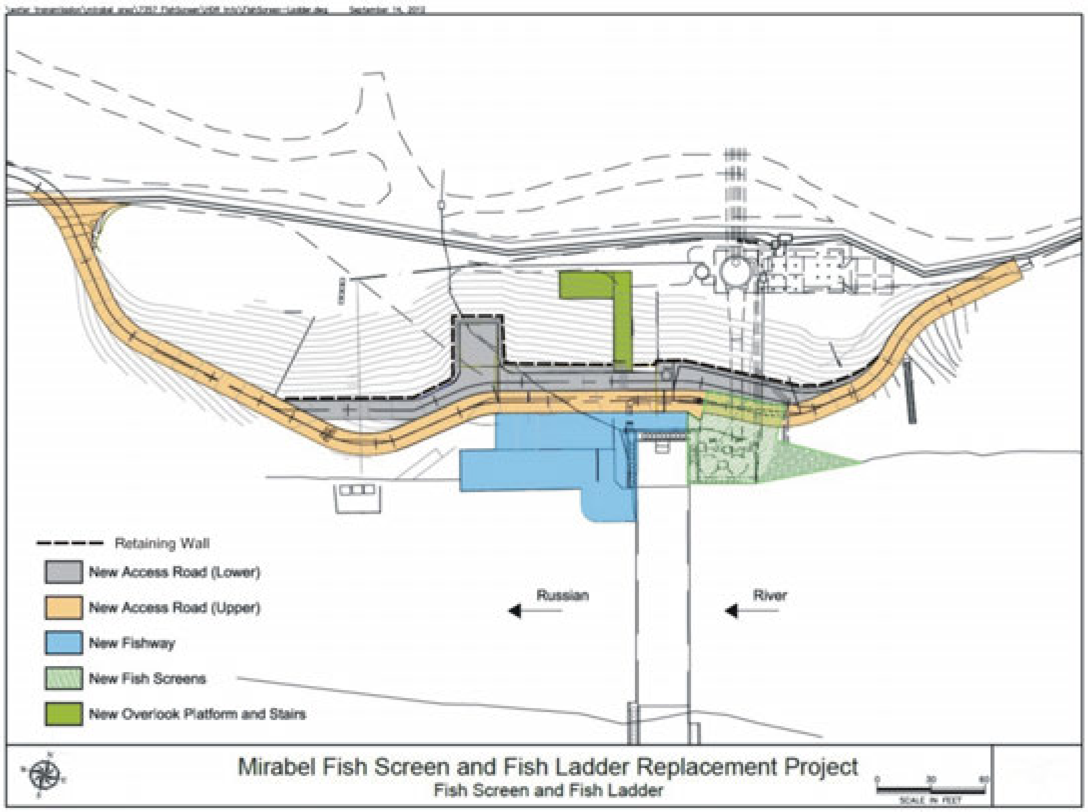

Figure 8.1. Conceptual plan view drawing of new fish screen and fishway structure at Mirabel.

Figure 8.2. Artist rendering of new fish screen and fishway structure at Mirabel.

Fish Screen

The proposed intake screen will consist of six 12-foot tall by 6-foot wide panels, with a total area of 432 square feet. The new fish screen will also incorporate a cleaning system to ensure that the screen material does not become clogged. Clogged screens result in higher flows through unclogged portions of the screen, which can lead to fish getting trapped against the screen. The cleaning mechanism is anticipated to be an electric motor-driven mechanical brush system that periodically moves back and forth to clean the intake screen structure.

Fish Ladder

A vertical slot type fish ladder was selected as the recommended design to provide passage for upstream migrating salmonids. Vertical slot fish ladders are commonly used for salmon and steelhead (among other fish species) throughout the world. A vertical slot fish ladder consists of a sloped, reinforced concrete rectangular channel separated by vertical baffles with 15-inch wide slots that extend down the entire depth of the baffle. The baffles are located at even increments to create a step-like arrangement of resting pools.

The design will be self-regulating and provide consistent velocities, flow depths, and water surface differentials at each slot throughout a range of operating conditions. It is anticipated that the ladder will be configured to accommodate a range of fish passage conditions while the Mirabel Dam is up and river flows ranging from 125 to 800 cubic feet per second. Fish passage while the Mirabel Dam is down will also be accommodated, but is not the primary focus of design. The fish ladder will extend approximately 100 feet further downstream than the existing fish ladder at the site.

Fisheries Monitoring Components

Sonoma Water currently conducts a variety of fisheries monitoring activities at its Mirabel Dam facilities. The new fish ladder design will support these monitoring activities by providing a dedicated viewing window and video equipment room and a fish trapping and holding area built into the fish ladder. The monitoring information collected by Sonoma Water staff is critical in tracking population trends and movement of different species in the Russian River system.

Education Opportunities

The existing facility at Mirabel is visited every year by approximately 3,000 schoolchildren as part of the Water Agency's water education efforts. The existing facility allows schoolchildren to see a critical component of the Water Agency's water supply system, but the views of the top of the existing fish ladder do not offer much opportunity for observing and learning about the fisheries of the Russian River system. The project includes a viewing area, separate from the video monitoring viewing window, which will allow visitors to see into the side of the fish ladder. The educational experience for schoolchildren will be improved by having the opportunity to actually see fish travelling up or down the fish ladder.

Supporting Components

The project design includes a variety of other components that support the primary fish screen and fish ladder aspects of the project. These other components consist of items such as seismic stabilization of the soils around the Mirabel dam, replacement of the buoy warning line upstream of the Mirabel Dam, modification of the existing access road to the project site, and the installation of a viewing platform to allow visitors a safe location to view the overall facility. The existing access road down to the Mirabel Dam is a steep one-way road. Vehicles going down to the Mirabel Dam area must turn around or back up the road down to the project site. The proposed project includes a modification of the access road so that the road will not be as steep and will include both an entrance and exit ramp from the Mirabel Dam site. A stairway from the top of bank down to the Mirabel Dam will allow visitor access from the upper levee road area down to the Mirabel Dam.

Construction Status

In March 2014, Hayward Baker began construction on the first phase of site improvements at the Mirabel Dam. This work consisted of the seismic stabilization of the soil area around the area of the Mirabel intake screens and fish ladder on the west bank of the Russian River. Seismic stabilization consisted of the installation of approximately 300 compacted stone columns along the levee berm at the Mirabel facility. The Mirabel seismic improvement work was completed in July of 2014 by Hayward Baker, which then allowed the second phase of construction activities to begin. Once Hayward Baker had demobilized their equipment from the work area, a second contractor (F&H) mobilized to the site in July of 2014 to begin the construction of the fish screen, fish ladder, and viewing chamber project. By the end of 2014, demolition of the original intake structure and fish ladder was complete. At the beginning of 2015, high flows in the Russian River resulted in a temporary shut-down of construction activities; however, by mid-January 2015, construction activities were once again underway and continued uninterrupted for the remainder of 2015. At the end of December 2015 and early January, 2016, high flows in the Russian River briefly slowed construction progress again, but construction activities resumed in January of 2016 and the majority of construction activities was completed in the summer of 2016. The new fish ladder and fish screens began operating for the first time in July of 2016.

Photo 8.1. One of the first groups of Chinook salmon seen through the new viewing gallery windows. October 20, 2016.

CHAPTER 9 Adult Salmonid Returns

9.1 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 located at river km 39 (rkm 39).

Methods

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

Results

In 2017, the Mirabel fish ladder cameras were in operation from September 13 to January 8, 2018 (Figure 9.1.1). With a few exceptions these cameras were operated 24 hours/day after installation until they were removed (Figure 9.1.2).

Chinook Salmon

For the 2017 video monitoring season, 2,093 adult Chinook salmon were observed passing the Mirabel fish counting station (including "unknown salmonids" prorated as Chinook) (Table 9.1.1). A total of 241 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 241 unknown salmonids 117 were partitioned to Chinook salmon.

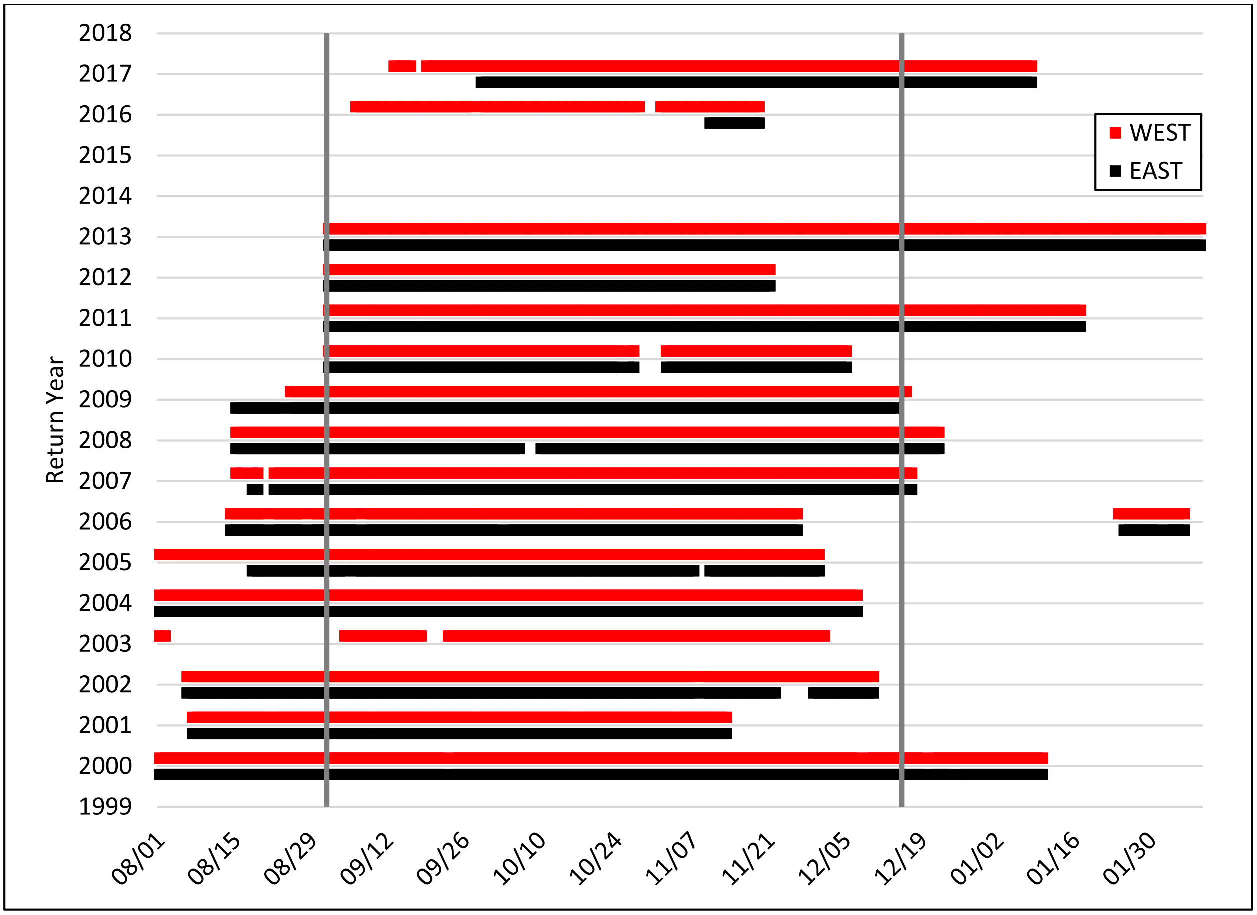

Figure 9.1.1. Period of camera operation by adult salmonid return year of video counting station at the Mirabel dam.

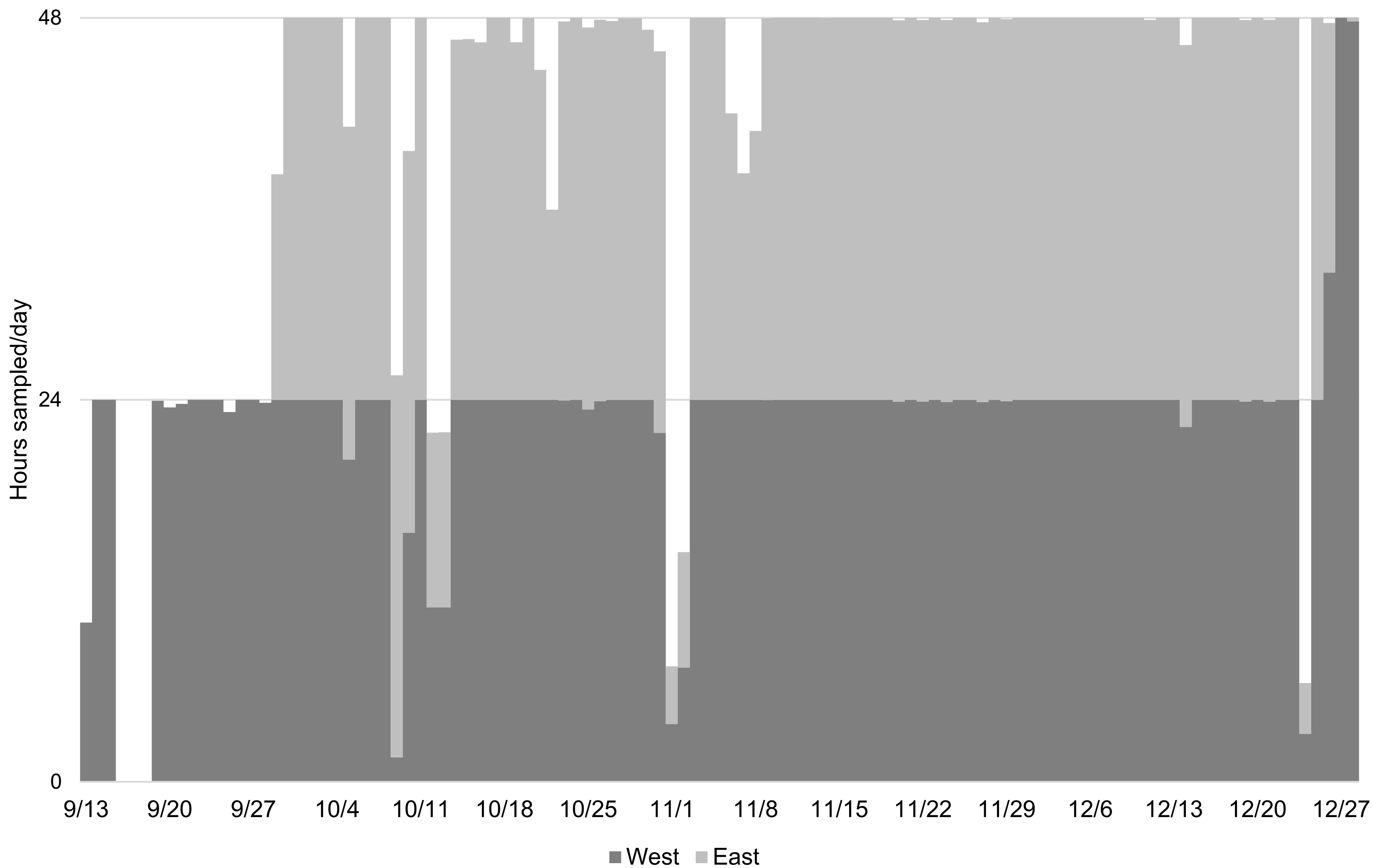

Figure 9.1.2. Number of hours/per day that the West (in dark gray) and East (in light gray) fish ladder camera was in operation at the Mirabel dam in 2017.

Table 9.1.1. Weekly count of adult Chinook salmon at the Mirabel dam fish ladders, 2000-2017. 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
15-Aug	0	0	1	--	0	0	0	0	0	0	--	--	--	--	Not Operated	Not Operated	--	--
22-Aug	1	0	8	--	0	1	1	0	0	0	--	--	--	--			--	--
29-Aug	0	3	7	2	1	4	0	0	1	0	0	0	0	1			--	--
5-Sep	9	1	18	7	1	4	0	0	0	0	0	0	1	1			0	--
12-Sep	36	7	19	20	3	14	3	0	2	0	0	0	2	2			0	0
19-Sep	25	12	65	23	8	14	4	1	17	0	3	1	0	1			0	3
26-Sep	50	17	1223	181	16	31	8	4	84	0	1	158	70	17			8	2
3-Oct	31	240	113	146	42	27	317	10	126	78	669	534	51	44			32	91
10-Oct	115	51	628	515	52	112	87	39	82	562	896	390	551	4			291	50
17-Oct	81	10	272	232	651	556	532	26	13	177	153	1070	1886	8			392	125
24-Oct	465	300	153	532	2287	309	114	106	22	285	280	273	996	27			131	81
31-Oct	64	661	505	2969	185	613	1531	250	511	135	94	223	1654	315			56	612
7-Nov	23	81	2337	1289	1189	699	298	429	174	335	169	90	619	731			50	366
14-Nov	182	--	20	47	221	127	459	154	15	38	43	120	851	1063			103	508
21-Nov	201	--	37	95	57	63	53	96	24	129	113	266	50	179			--	71
28-Nov	110	--	14	45	60	33	--	425	19	24	76	6	--	99			--	82
5-Dec	19	--	53	--	16	--	--	476	18	9	5	1	--	172			--	24
12-Dec	15	--	--	--	--	--	--	4	8	28	--	2	--	125			--	24
19-Dec	17	--	--	--	--	--	--	--	13	--	--	10	--	73			--	16
26-Dec	1	--	--	--	--	--	--	--	--	--	--	16	--	32			--	27
2-Jan	0	--	--	--	--	--	--	--	--	--	--	2	--	53			--	11
9-Jan	0	--	--	--	--	--	--	--	--	--	--	10	--	58			--	--
16-Jan	--	--	--	--	--	--	--	--	--	--	--	1	--	28			--	--
23-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	73			--	--
30-Jan	--	--	--	--	--	--	0	--	--	--	--	--	--	36			--	--
6-Feb	--	--	--	--	--	--	--	--	--	--	--	--	--	10			--	--
Total	**1,445**	**1,383**	**5,474**	**6,103**	**4,788**	**2,607**	**3,407**	**2,021**	**1,129**	**1,800**	**2,502**	**3,173**	**6,730**	**3,152**	**--**	**--**	**1,062**	**2,093**

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

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

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

Coho Salmon

During the monitoring period for the 2017 return year, we observed 135 adult coho. These images were reviewed by fisheries biologist from Sonoma Water, and California Sea Grant (CSG). Because of the timing of camera operations, which are tied to dam operations, and the location of these monitoring sites upstream of significant amounts of Coho Salmon habitat in the basin, these counts are not the best indicator of adult Coho Salmon returns to the basin. Instead, we suggest the basinwide spawner survey estimate of 85 (95% CI: 55-115) as the most comprehensive and accurate indicator of all adult Coho (hatchery- and natural-origin) returning to the Russian River basin in 2017-18. This estimate is based on spawner surveys in the Coho stratum of the Russian River Coastal Monitoring Program sample frame (see Adams et al. 2011 for details).

Steelhead

Based on hatchery returns, steelhead migrate and spawn in the Russian River primarily between December and March; however, we removed the Mirabel cameras in January and there is significant portion of the steelhead run occurs after January. In total, 557 steelhead were observed migrating through the Mirabel Fish ladder between October 1, 2017 and January 8, 2018.

Conclusions and Recommendations

In 2017 we were able to successfully operate video cameras in both fish ladder for the duration of the Chinook migration, but this was not without some difficulty. Sonoma Water decided that it is unsafe to supply 110 volt power to the east side video camera and lights by routing the cable underwater along the stream bottom. There appeared to be few alternative ways to supply power to east side of the river. In 2017 we relied on a diesel generator to supply power to the lights on the east side of the river. This required frequent refueling. In addition to the difficulties supplying power to the east side video cameras, it has become apparent that Chinook spend an unusually long time in front of the west video camera. Frequently there were many Chinook milling in front of the camera. These fish would move upstream out of view of the camera and then drop back downstream out of the view of the camera. When many fish were exhibiting this behavior at the same time double counting became a possibility. The reviewers had to watch the video at a slower speed, which made the review process more laborious.

The Mirabel video system continues to provide useful data on the Russian River Chinook run. We recommend continuing to operate the camera system in future years. In 2018 we plan to experiment with using rechargeable 12 volt batteries to power lights on the east side of the river in order to avoid using a generator for a second season.

9.2 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 issued by the State Water Resources Control Board to satisfy the Biological Opinion (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 reduced water supply releases from Coyote Valley Dam (Lake Mendocino) may affect migrating and spawning Chinook salmon (Cook 2003). Spawner surveys in Dry Creek began in 2003.

Background information on the natural history of Chinook salmon in the Russian River is presented in the 2011 Russian River Biological Opinion annual report (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 9.2.1). 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.

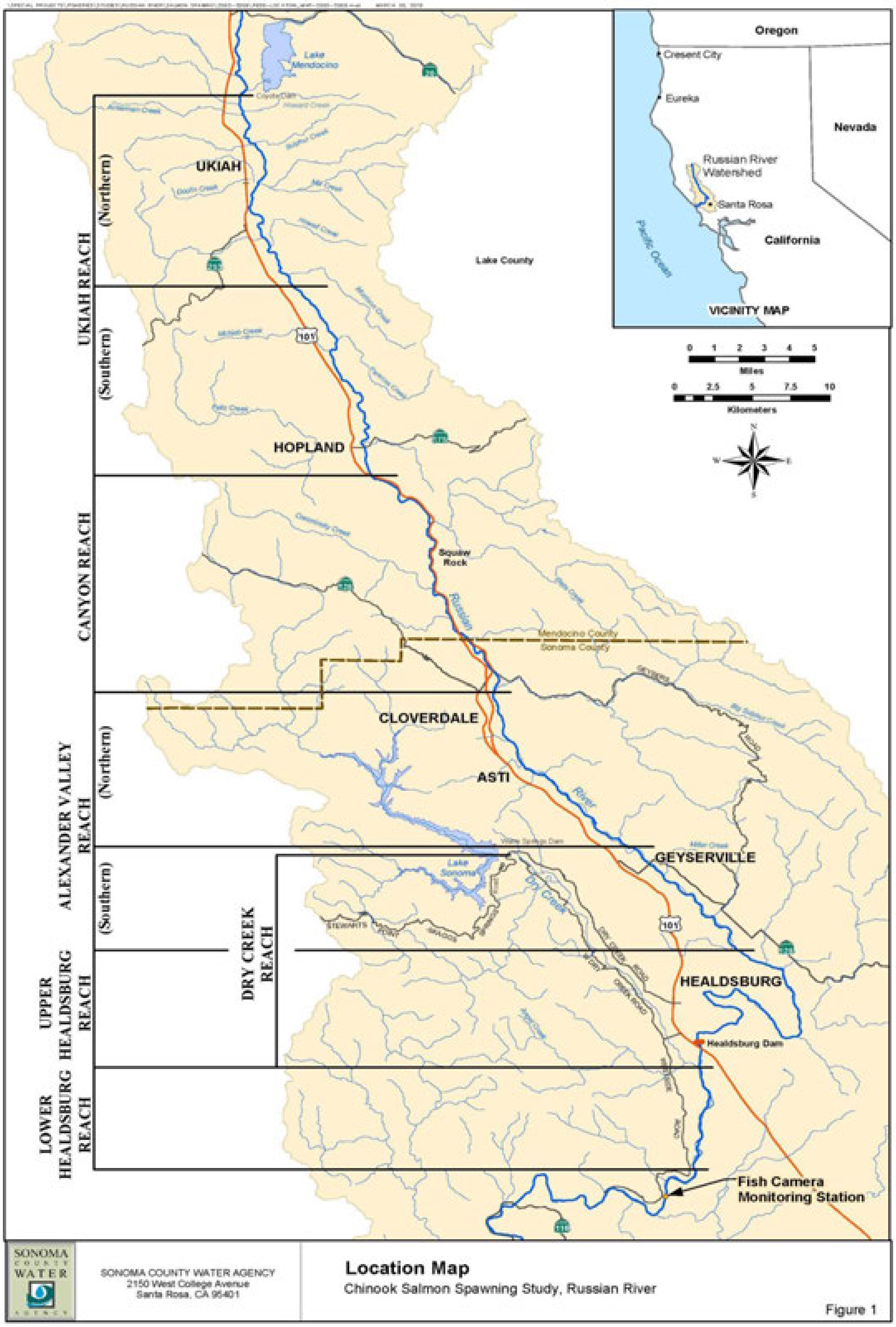

Figure 9.2.1. Chinook salmon spawning survey reaches. Only Alexander Valley, Upper Healdsburg, Lower Healdsburg, and Dry Creek reaches were surveyed in 2017.

The Chinook salmon spawning ground study consists of a single-pass survey during the estimated peak of Chinook salmon fall spawning. A crew of two biologists in kayaks visually 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 obscures the detection of redds. Spawner surveys were curtailed or cancelled during 2005, 2010, 2014, and 2015 along the Russian River. During high flows surveys are often possible in Dry Creek due to regulated, clear water releases from Lake Sonoma. Also, increases in turbid water releases from Coyote Dam at Lake Mendocino since around 2011 have prevented an accurate count of redds in Ukiah and Canyon study reaches.

The Russian River from Alexander Valley to Lower Healdsburg was surveyed on December 4-6, 2017. Chinook salmon spawner surveys were curtailed during fall 2017 due to high turbidity in Ukiah and Canyon reaches. To follow salmon spawning and determine peak activity in Dry Creek four bi-monthly surveys were conducted from November 8 to February 28, 2017. The survey conducted on November 29, 2017 along Dry Creek contained the largest count of redds and was selected as the single-pass visit to represent the abundance of redds in Dry Creek.

Results

Most of the Chinook salmon spawning typically occurs in the upper Russian River mainstem and Dry Creek (Table 9.2.1). During 2017, there were 59 redds observed in the Alexander Valley, Upper Healdsburg, and Lower Healdsburg reaches of the Russian River. The redd counts for Alexander Valley (39) and Upper Healdsburg (14) is the second year of relatively low abundance since surveys began in 2002. Lower Healdsburg typically has low detections of redds and 6 were found in 2017. During four surveys of Dry Creek 179 individual Chinook salmon redds were detected from November 8 to December 18. The highest count of redds on a single survey was 112 redds on November 29, 2017 (Table 9.2.1). This single pass number is the fourth lowest since 2003.

Conclusions and Recommendations

Although Chinook salmon surveys were restricted to four reaches in 2017 the distribution and abundance of redds appear to be similar to or within the range of other redd numbers observed during previous study years. The abundance of Chinook salmon redds have shown a sharp decline in the past three fall runs. Although there are many factors that could be driving this trend, it is likely that several years of severe drought in the region is a major contributor.

Table 9.2.1. Chinook Salmon redd abundances by reach, upper Russian River and Dry Creek, 2002-2017. Redd counts are from a single pass survey conducted during the peak of fall spawning activity. *Survey either not completed or incomplete.

Reach	River km	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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]	*
Alexander Valley	26.2	163	213	90	*	62	131	65	129	*	97	185	163	*	61[2]	41[2]	39
Upper Healdsburg	25.6	79	40	8	*	23	67	48	38	*	66	53	57	*	*	1[2]	14
Lower Healdsburg	8.2	6	0	7	*	1	2	9	30	*	7	4	18	*	*	*	6
Russian River	**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
Total	**135.6**	*	**1163**	**900**	*	**603**	**637**	**243**	**496**	*	*	*	*	*	*	*	*
Relative Contribution of Redds																	
Russian River (%)	84.0	*	78.0	62.0	*	66.7	63.7	73.3	55.0	*	*	*	52.7	*	*	*	*
Dry Creek (%)	16.0	*	22.0	38.0	*	33.3	36.3	26.7	45.0	*	*	*	47.3	*	*	*	*

[1]Redd numbers are an estimate.

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

References

Adams, P. B., L. B. Boydstun, S. P. Gallagher, M. K. Lacy, T. McDonald, and K. E. Shaffer. 2011. California coastal salmonid population monitoring strategy design and methods. CA Department of Fish and Game, Sacramento, CA.

Cook, D. (Sonoma County Water Agency). 2003. Chinook salmon spawning study, Russian River, fall 2002. Santa Rosa, (CA): Sonoma County Water Agency.

Manning, D.J., and J. Martini-Lamb, editors. 2011. Russian River Biological Opinion status and data report year 2009-10. Sonoma County Water Agency, Santa Rosa, CA. 200 p.

Sonoma County Water Agency (SCWA). 2016. California coastal salmonid population monitoring in the Russian River watershed, progress report. April 19.

CHAPTER 10 Synthesis

Introduction

Sonoma Water has collected a variety of fish and water quality monitoring data relevant to fulfilling the overall monitoring objectives in the Reasonable and Prudent Alternative (RPA) of the Russian River Biological Opinion. Those efforts have been detailed in portions of this report leading to this chapter. The objectives specific to this synthesis chapter are to illustrate the spatial and temporal extent of monitoring activities in the basin.

As in previous years of RPA implementation, we collected fish and related environmental data from a broad spatial and temporal extent in the Russian River Basin (Figure 10.1 and Figure 10.2). We collected juvenile and smolt data from multiple locations in Dry Creek, Mark West Creek, Dutch Bill Creek, Austin Creek and the Russian River estuary. We counted adult salmonids with a DIDSON at the mouth of mainstem Dry Creek and opportunistically conducted Chinook spawner surveys on the 22 km of stream length in mainstem Dry Creek downstream of Warm Springs Dam and in portions of mainstem Russian River. Juvenile salmonids were sampled throughout the watershed using a variety of techniques. In the mainstem Russian, juvenile salmonids were sampled using beach seining at 10 fixed locations in the estuary and passive integrated transponder (PIT) antenna arrays operated near the upstream extent of the tidal portion of the estuary in Duncans Mills, Sonoma Water's Mirabel inflatable dam and near the upstream extent of the river impounded by the Mirabel dam (Syar). Downstream migrant trapping for smolts and juveniles and video monitoring of upstream migrating adults occurred at the Mirabel dam. In tributaries of the lower river, juvenile salmonids were sampled using downstream migrant traps on Mark West Creek at Trenton-Healdsburg Road, Austin Creek at the gravel mine and Dutch Bill Creek in Monte Rio. PIT antennas were operated in conjunction with downstream migrant trap sites on Austin Creek and Dutch Bill Creek. In Dry Creek, juvenile salmonids were sampled using a downstream migrant trap and backpack electrofishing. PIT antennas were operated in at the mouth of mainstem Dry Creek and constructed off-channel habitat sites in Dry Creek. Complementary data on water quality were collected by means of continuously-recording data sondes at multiple sites in the mainstem Russian and throughout the estuary/lagoon. Water quality grab samples including algae samples were collected at additional sites in mainstem Russian River. Details regarding the specifics of water quality and fisheries monitoring activities are covered in individual chapters of this report.

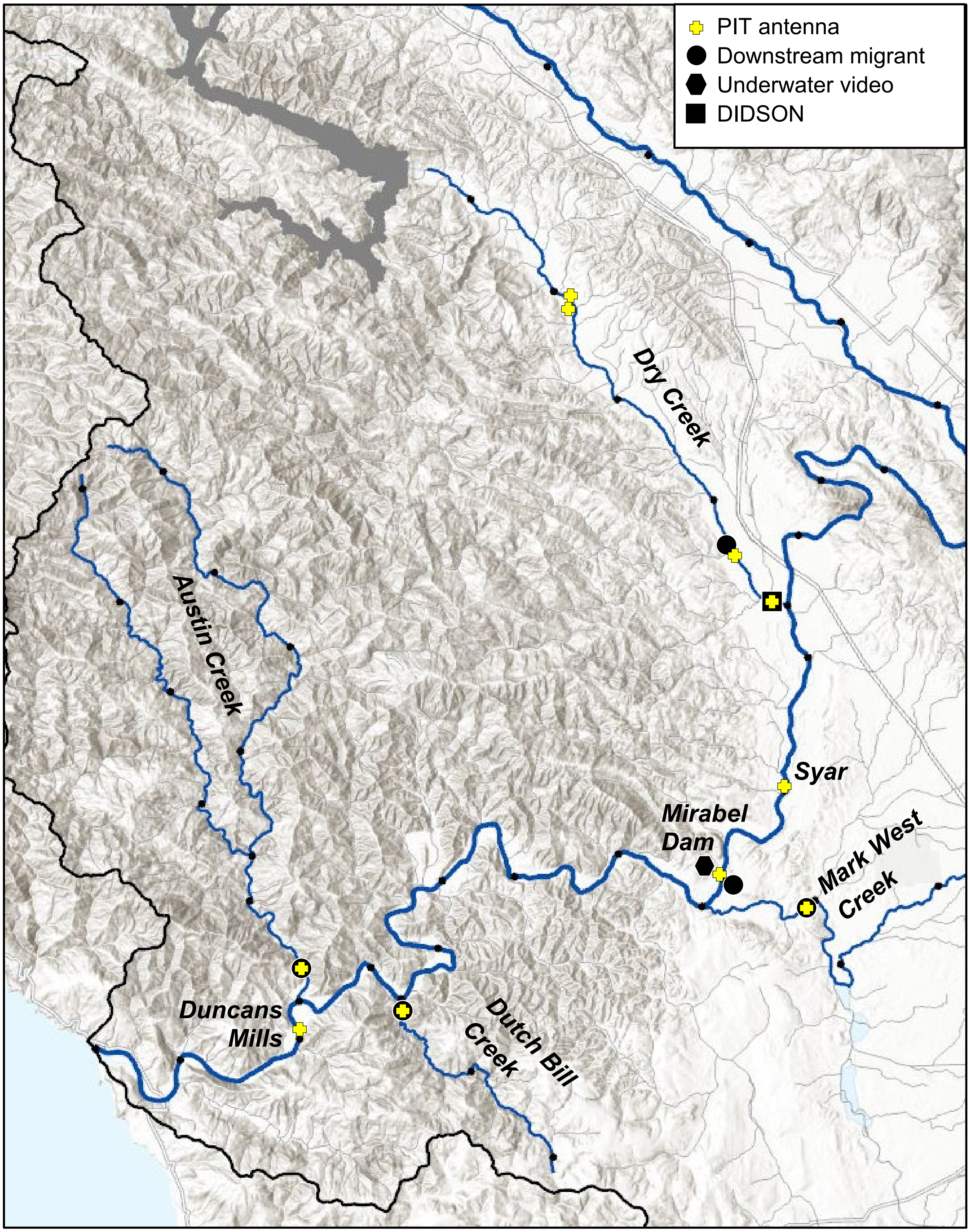

Figure 10.1. Spatial extent of fisheries monitoring related to the Russian River Biological Opinion, 2017.

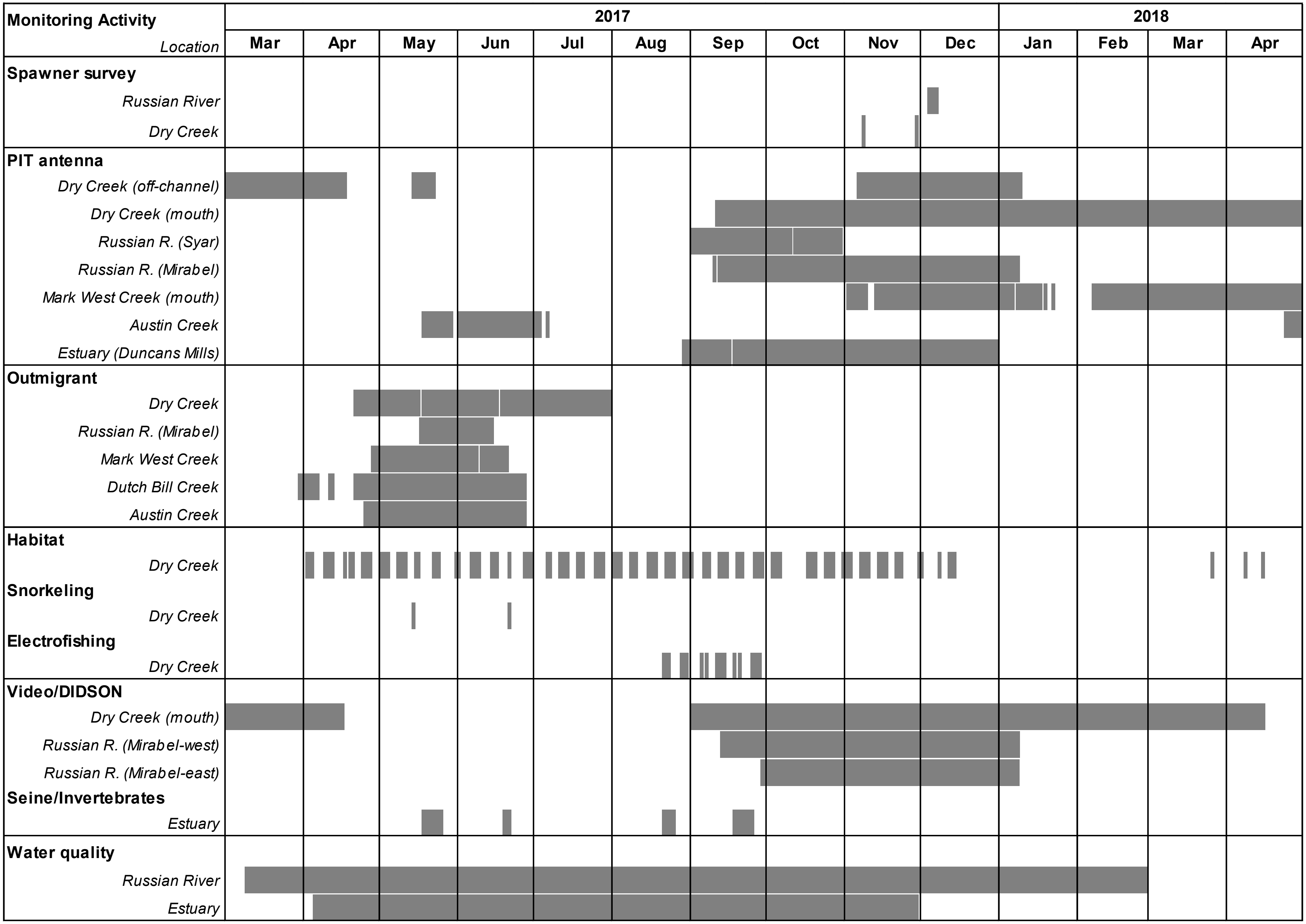

Figure 10.2. Temporal extent of fish and water quality monitoring related to the Russian River Biological Opinion, spring 2017-winter 2018.

In the sections that follow, we summarize indicators of juvenile and smolt salmonids based on data from tributary and mainstem sites sampled in 2017 into early 2018. Sonoma Water used PIT tags and fin-clipping as primary tools for characterizing fish population abundance. As described in other sections of this report and reports from prior years, PIT-tagged fish were detected during beach seining sampling in the estuary and at downstream migrant traps and stationary PIT-tag antennas located throughout the system (Figure 10.1).

Abundance

Combined juvenile steelhead downstream migrant trap (DSMT) catch at Dry Creek, Dutch Bill Creek and Austin Creek was among the lowest since Sonoma Water began implementing the RPA (Figure 10.3). The decrease was most pronounced for Austin Creek. Juvenile steelhead density from backpack electrofishing on mainstem Dry Creek showed essentially no increase relative to recent years (Figure 10.4) and the Dry Creek Chinook smolt estimate was again low compared to 2010-2014 but similar to estimates from 2015 and 2016 (Figure 10.4). Once again, Chinook smolt estimates were not possible at Mirabel due to unsuitable trap operation conditions. Captures of wild Coho smolts were low everywhere as has been the case since we began monitoring (Figure 10.4). Relative to previous years, adult steelhead returns to Russian River hatcheries were only slightly low than the average since 2000 (Figure 10.5) while the Chinook run was slightly higher than 2016 but still markedly lower than the historic average. The 2017-18 adult Coho estimate was the highest since at least 2000.

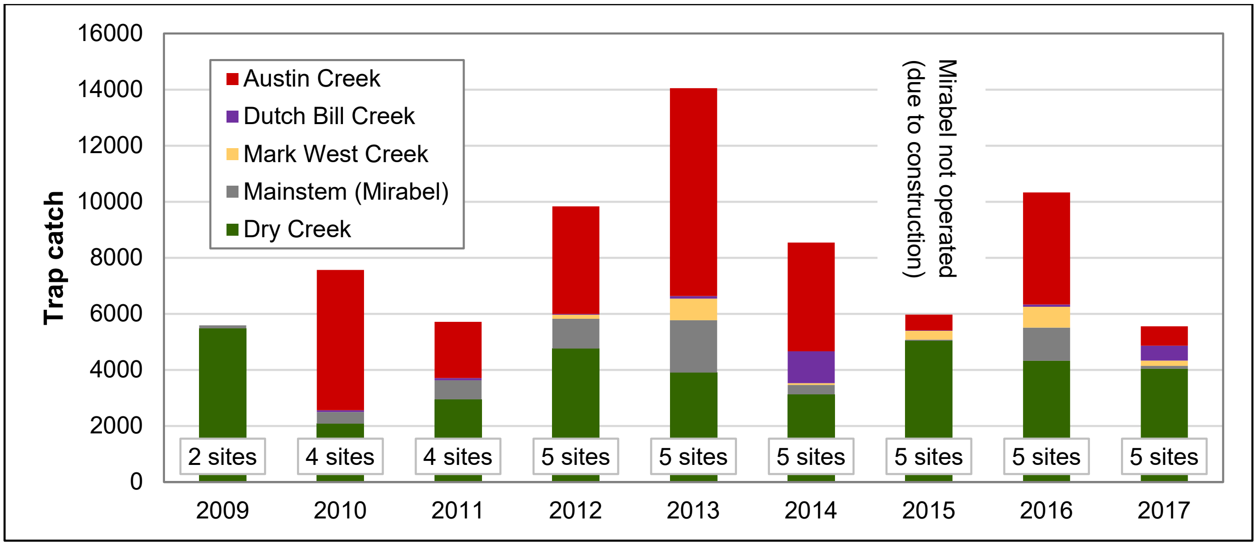

Figure 10.3. Number of juvenile (YOY and smolt combined) steelhead captured at downstream migrant traps operated by Sonoma Water, 2009-2017.

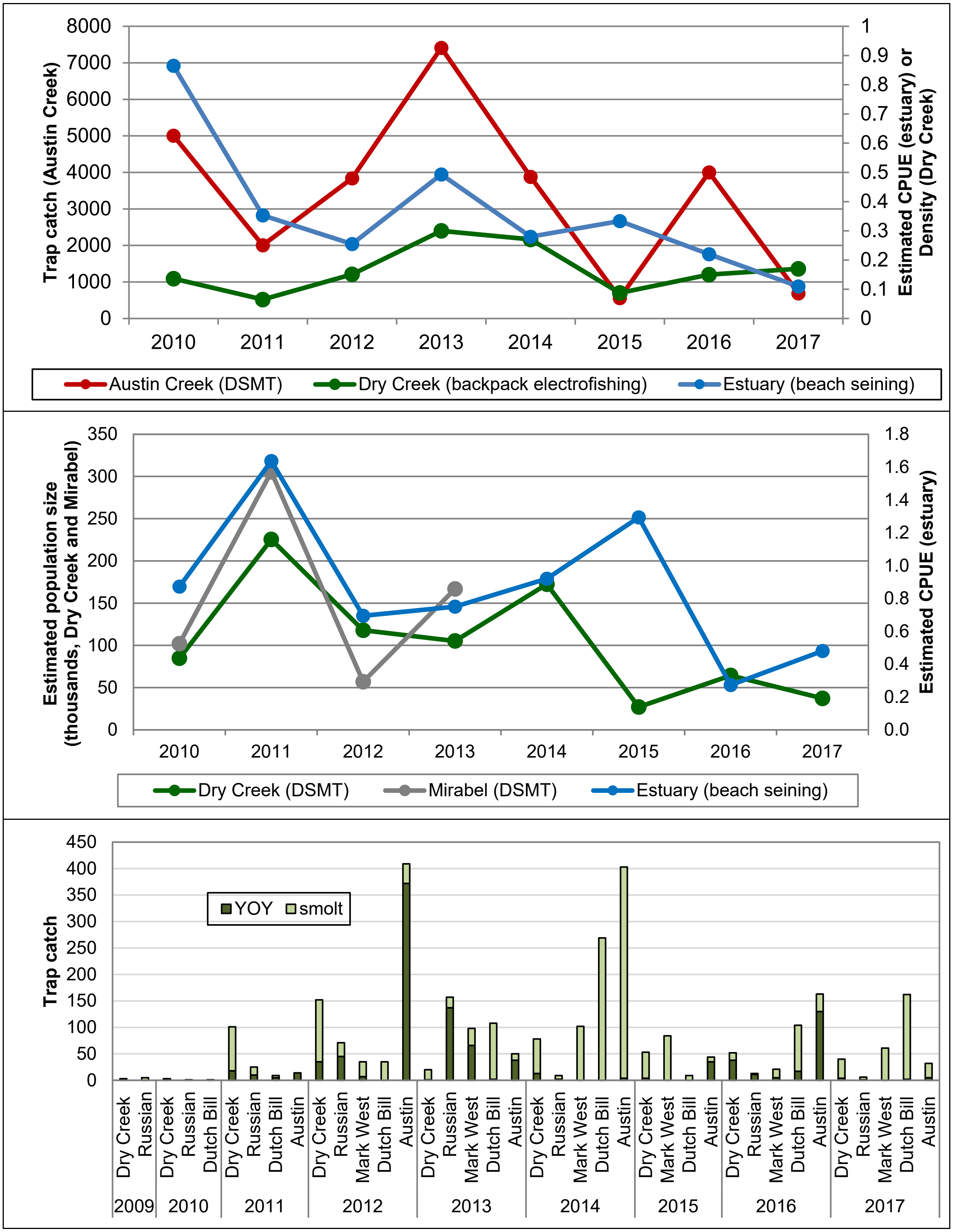

Figure 10.4. Indicators of trends in juvenile steelhead (top panel), Chinook smolts (middle panel) and wild Coho smolt/YOY (lower panel) based on monitoring conducted by the Sonoma Water, 2009-2017.

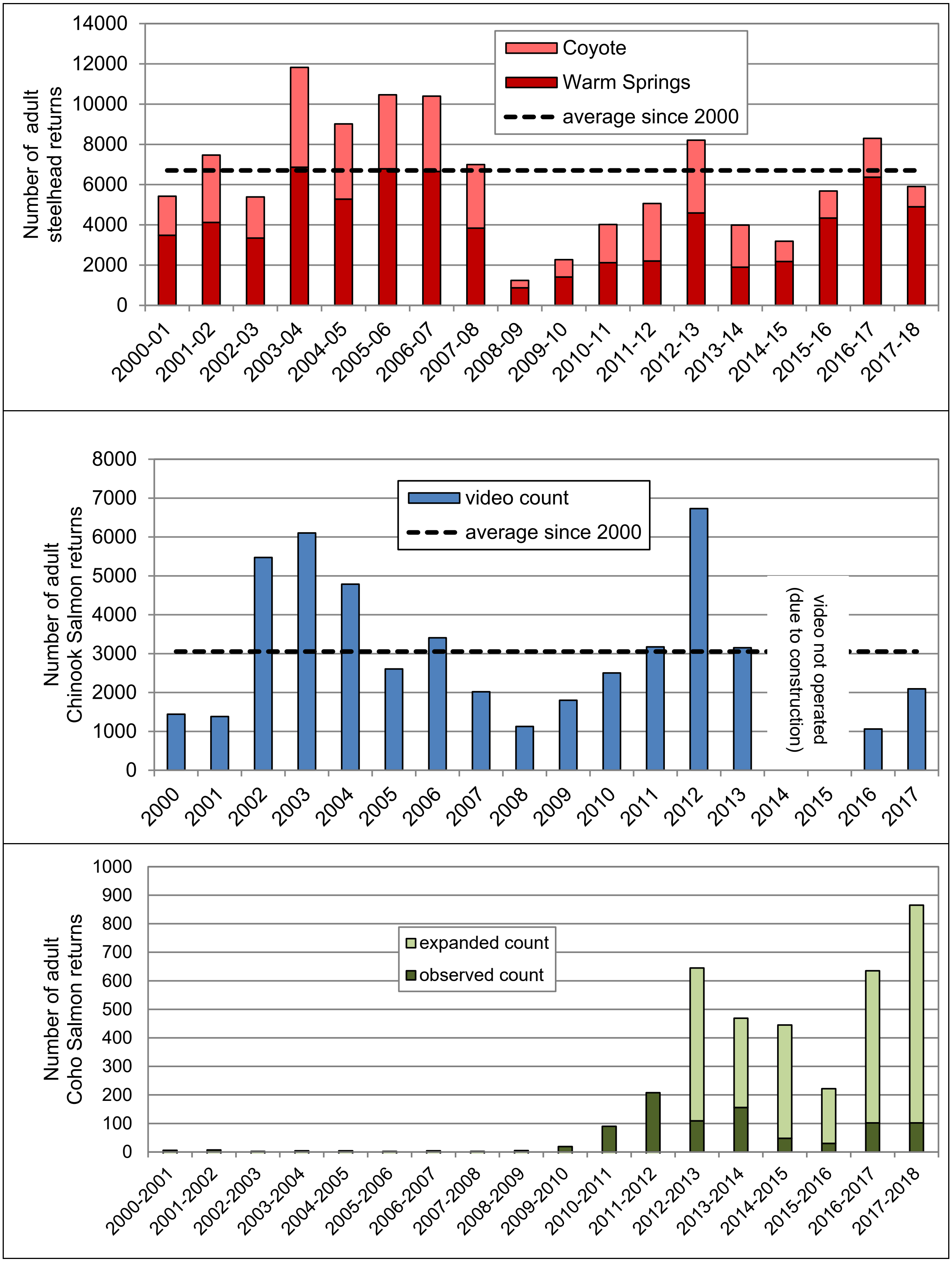

Figure 10.5. Indicators of adult steelhead (counted at Russian River hatcheries), adult Chinook (based on video counts at Wohler-Mirabel) and Coho Salmon returns (UC/CA Sea Grant).

Conclusions and Recommendations

In 2017, Sonoma Water continued to implement monitoring approaches that are beginning to show that they are serving the important need to understand the context in which salmon and steelhead populations in the Russian are being affected by RPA implementation as opposed to environmental conditions or other factors outside our control. The degree to which various measures of population abundance track each other (e.g., Figure 10.6) suggests that despite the many challenges of monitoring in a watershed the size of the Russian, monitoring that goes beyond what is required in the RPA (e.g., PIT monitoring) is paying dividends in terms of informing a broader context. Continuation of California Coastal Monitoring Program (Adams et al. 2011) implementation throughout the watershed begun in 2013 by Sonoma Water and UC/CA Sea Grant should further assist in providing that context.

References

Adams, P. B., and coauthors. 2011. California coastal salmonid population monitoring strategy design and methods. CA Department of Fish and Game, Sacramento, CA. 82 p.