South Fork Ten Mile River Basis of Design Report
Ten Mile River Habitat Enhancement Project – Phase 2

Prepared for:
The Nature Conservancy
Field Office
90 W. Redwood Avenue
Fort Bragg, CA 95437

Prepared by:
Prunuske Chatham, Inc.
103 Morris Street, Suite A-5
Sebastopol, CA 95472

June 2023

Table of Contents

1 Introduction

This basis-of-design report provides a detailed description of proposed channel and habitat enhancement elements designed for The Nature Conservancy's *South Fork Ten Mile River Habitat Enhancement Phase 2 Project* in northern Mendocino County (Figure 1). The report was prepared to accompany the draft (65%) designs and includes information on the projects' design concept, including the biological imperative, the hydrologic and geomorphic analyses underpinning the design, and an overview of the habitat enhancement design details and engineering. The draft designs were developed based on input from the Technical Working Group (TWG)[1]. Funding for the Project is from the California Department of Fish and Wildlife (CDFW) through the Proposition 1 Watershed Restoration Grant Program.

The Ten Mile River and its three subwatersheds was ranked by the Mendocino Coast SHaRP members as having the highest potential for habitat and salmonid population recovery in the HUC12 based on existing habitat integrity, potential for restoration success, and its biological importance to the diversity strata (Mendocino SHaRP presentation Feb 2021). Within the lower, alluvial valley reaches of the South Fork, the priority restoration methods recommended by the SHaRP members are off-channel/floodplain enhancements and engineered large wood structures. Maximizing rearing and foraging habitat in the alluvial valley reaches of the Ten Mile River is a key component to Coho population recovery because out-migrating smolts visit nutrient-rich seasonally flooded wetlands to bulk up before heading out to sea and young-of-the-year juveniles need accessible floodplains and low-velocity environments to survive winter high flows. Large wood structures help create and maintain deep, complex pools that provide winter base flow and summer low flow rearing habitats. With climate change bringing more frequent winter droughts and higher summer temperatures, the lower reaches of this coastal watershed has become a critical refugia zone where riparian vegetation and coastal fog maintain cool water temperatures and perennial springs sustain streamflow.

The initial premise of TNC's Lower Ten Mile Habitat Enhancement Program (Program) was that off-channel rearing habitat and winter high-flow refugia is often severely limited in alluvial valleys where the channels have become simplified and disconnected from their floodplains and that recovery of the salmon populations is dependent upon restoring this habitat and the processes that form and maintain it. In a preliminary study based on a conceptual model of Coho habitat requirements and watershed conditions, Stillwater Sciences (2011) confirmed this premise for the lower Ten Mile River. Technical Working Groups—formed during the initial planning phase (2011-2016) and continued through the Phase 1 design and implementation phases—guided design efforts towards seasonally flooded wetlands and flooded alcoves, side and split-flow channels, and large engineered log jams. The Phase 1 sites on the South Fork Ten Mile River are located in a 0.5-mile reach, and were completed in two stages: 1A was constructed in 2018 and 1B was constructed in 2020 (Figure 1). This Phase 2 Project extends the in- and off-channel enhancements another 0.4-miles immediately downstream of the Phase 1 work and into the tidally affected reach of the South Fork.

[1] The TWG is composed of staff from The Nature Conservancy (Peter van de Burgt, Jennifer Carah), California Department of Fish and Wildlife (Colin Hughes, Shadee Kohan, Sarah Gallagher), NOAA (Joe Pecharich and Brian Cluer), North Coast Regional Water Quality Control Board (Jonathan Warmerdam and Jacob Shannon), Stillwater Sciences (Abel Bruno), and Pacific States Marin Fisheries Commission (Ellory Loughridge).

The Phase 2 site designs and information presented in this report are informed by site observations, topographic analysis, hydrologic data collection and analysis, and experience gained from the Phase 1 projects. Two major references underpinning this report are the 2014 *Lower Ten Mile River Habitat Enhancement Plan* by PCI and the 2013 *Framework for Coho Salmon Habitat Restoration and Enhancement in Lower Ten Mile River* (*Framework*) technical memorandum by Stillwater Sciences. Readers should refer to these documents for more in-depth details regarding the larger watershed characteristics and land-use history, channel morphology, hydrology, and existing habitat conditions. These subjects are only briefly touched upon in this Report at a level necessary to contextualize the site-specific habitat enhancement designs.

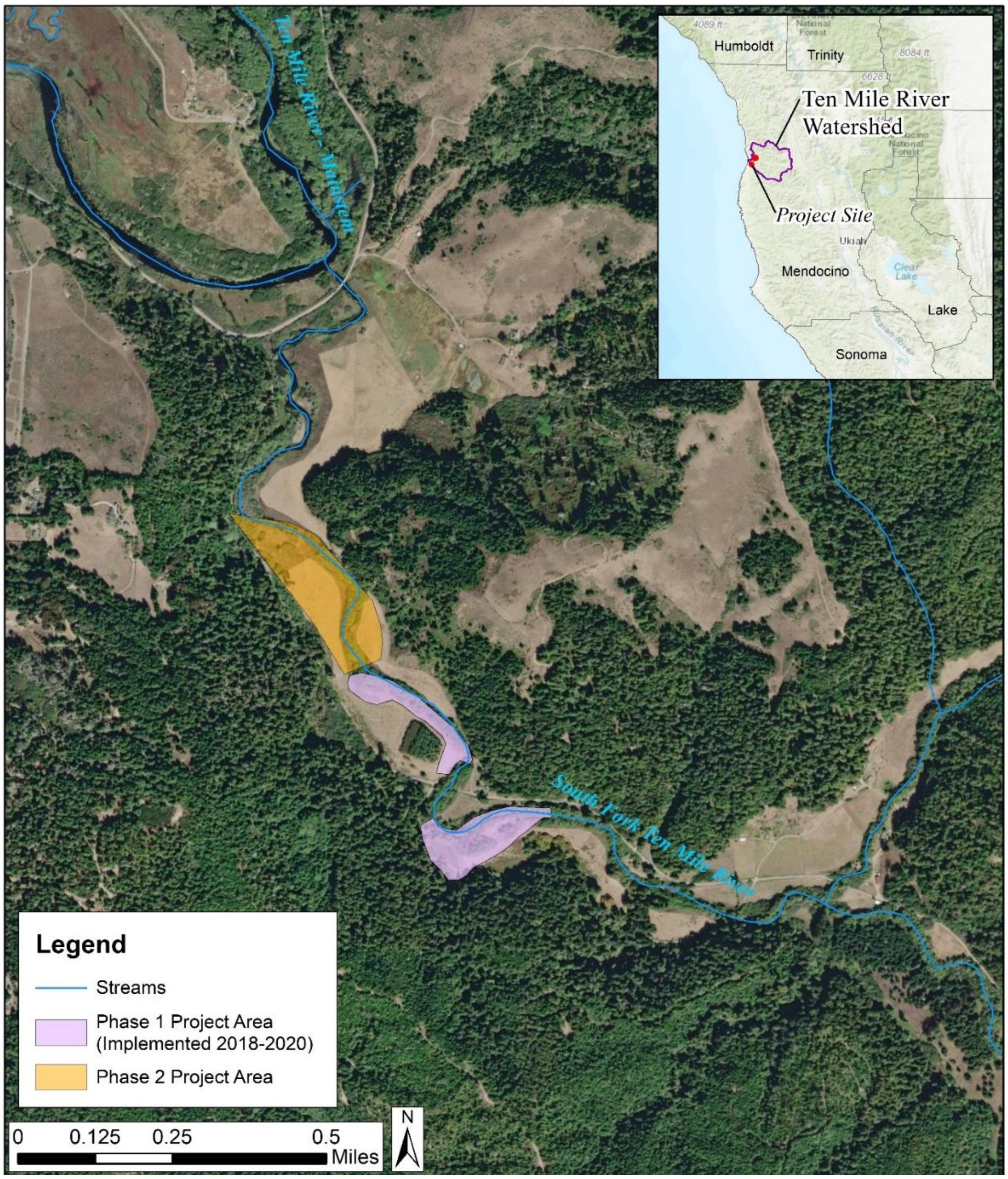

Figure 1. Site map and project location.

2 Biological Imperative

The Ten Mile River watershed currently supports a wild population of Coho Salmon, as well as Chinook Salmon and steelhead. As is the case across the entire Central California Coast Evolutionary Significant Unit (ESU), the Ten Mile River population of Coho Salmon is significantly reduced from historic numbers and is likely near or below their threshold for sustainability. Restoration actions in the Ten Mile watershed are considered to be a high priority by NOAA National Marine Fisheries Service and California Department of Fish and Wildlife, as the potential for effective restoration is high and the Coho Salmon inhabiting the Ten Mile River system are a regionally important, functionally independent population (NMFS, 2012).

Stillwater Sciences' *Framework* (2013) details the habitat factors that are thought to limit Coho Salmon populations in California, generally, and in the Ten Mile watershed, specifically. Juvenile density and distribution data for the watershed indicates that low winter habitat capacity and over-wintering survival are likely limiting smolt production and the potential for population recovery. Summer habitat quality and quantity appear to be sufficient based on flows and temperature criteria (Stillwater Sciences 2011). Visual observations of the project reach confirmed the preliminary premise that the channel is lacking off-channel winter rearing and refugia habitat elements, and that increased instream complexity for summer rearing in the lower watershed would also likely benefit the population.

Coho Salmon juveniles will migrate seasonally, when streamflows increase, to off-channel habitats in stream reaches with moderate to low gradients. Off-channel habitats, such as alcoves, ponds, and flooded wetlands, provide both velocity refuge and foraging opportunities. Juvenile Coho Salmon have been found to prefer water with velocities less than 1 ft/s (Lestelle, 2007). Furthermore, overwinter survival and growth has been shown to be significantly higher in off-channel habitats than in main channel habitats (Lestelle, 2007). While pond-type habitats produce larger fish, stream-type features such as side channels tend to have higher densities of juveniles utilizing them and they contribute significantly to smolt production (Rosenfeld et. al., 2008). Alcoves and complex channel margins (large wood, floodplains, variable bank topography, and dense vegetation) within the main channel provide shelter during high flows and, if abundant, increased rearing capacity. A well-functioning stream system that supports Coho Salmon survival and production will contain a mixture of in-channel and off-channel habitat elements along its length.

A century or more of landuse impacts, including clear cut logging, channel clearing, and valley floodplain conversions to ag fields, have reduced the extent and quality of in- and off-channel habitat in the lower South Fork Ten Mile River. In general, the high flow refugia habitat consists of small vegetated alternating bars. Channel edges have patches of undercut banks and dense overhanging willow that provide some refugia. Natural large wood accumulations are infrequent. The alder-dominated forest along the riparian corridor is young and natural recruitment from within the project reach is limited. Redwood and Douglas fir logs from the upper watershed do not make it into the project reach due to several low bridges upstream. The wide valley floodplains are only overtopped for a few hours to a few days during peak flows greater than the 2-year flood event. Although there are extensive wetlands along the valley's edges, they are not accessible to fish during high flow events. Fish are vulnerable in reaches with no high-flow refugia. Recovery Plans for the Ten Mile River call for increasing the quality, frequency, and connectivity of off-channel features along with high quality in-channel habitat, as they are expected to improve salmonid survival rates, and ultimately increase population numbers.

3 Site Conditions

The lower South Fork Ten Mile River in the project reach flows through a wide alluvial valley with broad disconnected floodplains and a narrow riparian corridor (Figure 2). The channel is entrenched and trapezoidal in shape along much of its length. Small, alternating vegetated bars and inset floodplain benches have formed within the active channel banks, and a narrow band of young riparian trees lines the streambanks. The broad floodplain pastures are flooded only during infrequent large flood events. We believe the current channel form is heavily influenced by historic logging and ranching practices. Logging practices in the late 1800s/early 1900s denuded the hillslopes of trees and understory vegetation, which led to destabilized drainages and high rates of topsoil erosion and sediment deposition in the valleys. As a result, the floodplains have become elevated five to eight feet above the channel bed and are composed of homogenous silty loam soils. What appears to be a historic valley floor surface is found 6 inches to 1 foot above the channel's riffle crest elevations, and is composed of fine gravels and sand similar to the current bed composition. Redwood logs and remains of root crowns are also found buried in this buried gravel layer.

Figure 2. Image of the project reach in 2022 (looking downstream towards the Ten Mile River estuary). The upper riverine section of the project area is in the foreground, with the tidally influenced lower section in the mid-ground left bank, beyond the fence line.

The 1965 flood-of-record carved new channel paths through the floodplains and deposited large gravel bars that to this day remain dry and largely unvegetated (Figure 3). Up until the last decade, grazing practices prevented the maturation of a riparian forest along the banks of the South Fork. With a temporary cessation of grazing and subsequent installation of exclusion fencing in the mid-2010s, a riparian canopy of alders with patches of willow and blackberry has quickly established.

Figure 3. Photo of project reach's lower area (lower left corner) immediately after the 1965 flood. Note the large gravel bar with split flows and lack of riparian forest.

Wetlands and seasonal ponds fed by winter rains and ephemeral drainages line the left edge of the valley; however, these wetlands are disconnected from the creek except during infrequent, short duration flood events. The largest and most persistent of these seasonal ponds is located within the Phase 2 project reach, and increasing its accessibility for fish is part of the project objectives.

The Phase 2 project reach is characterized by two distinct sections: the lower tidal and lagoon influenced area and the upper riverine area. The existing site conditions are shown in Figure and 5. The lower third of the project reach is tidally influenced. Water depths fluctuate by several feet daily with the tides, and the site is within the lagoon backwater when the sandbar at the mouth closes off. There are several riffles at the upper end of the tidally influenced zone and then it transitions into a long, deep run. The large, 1965-flood deposited gravel bar makes up most of the left bank in this lower section. A seasonal pond is located adjacent to the ranch road, between the 1965 gravel bar and the valley wall. This pond typically fills in early winter after significant rains and stays wet through late spring. During winter storm periods water flows down valley through the valley-wall wetlands to the pond. During infrequent, high floods, water flows across the floodplains and drains from the left bank floodplain through this lower area across the gravel bar and a drainage swale along the road. Because the gravel bar is so dry, it is not used for grazing and the landowners have given permission for broad, valley-wide restoration in this lower area.

In the upper riverine section, the channel is constrained within a 125- to 150-foot wide riparian zone between the high floodplain pastures. Within the riparian zone, the channel gently meanders between narrow vegetated alternating bars that act as inset floodplains. Bed forms range from plane bed (i.e. flat long glides with no distinguishable pools, riffles, or gravel bars) to a pool-riffle morphology with small gravel bars. In the middle of the project reach is a meander cutoff channel that formed during a flood event in the mid-2000s. This feature is now serving as high flow refugia, as it has revegetated with a dense understory. A small high flow alcove has persisted at the downstream end of the cutoff channel. The point bars, overflow channels, and alcoves in the reach provide some high flow refugia, however velocities quickly become elevated on these features during larger storm events.

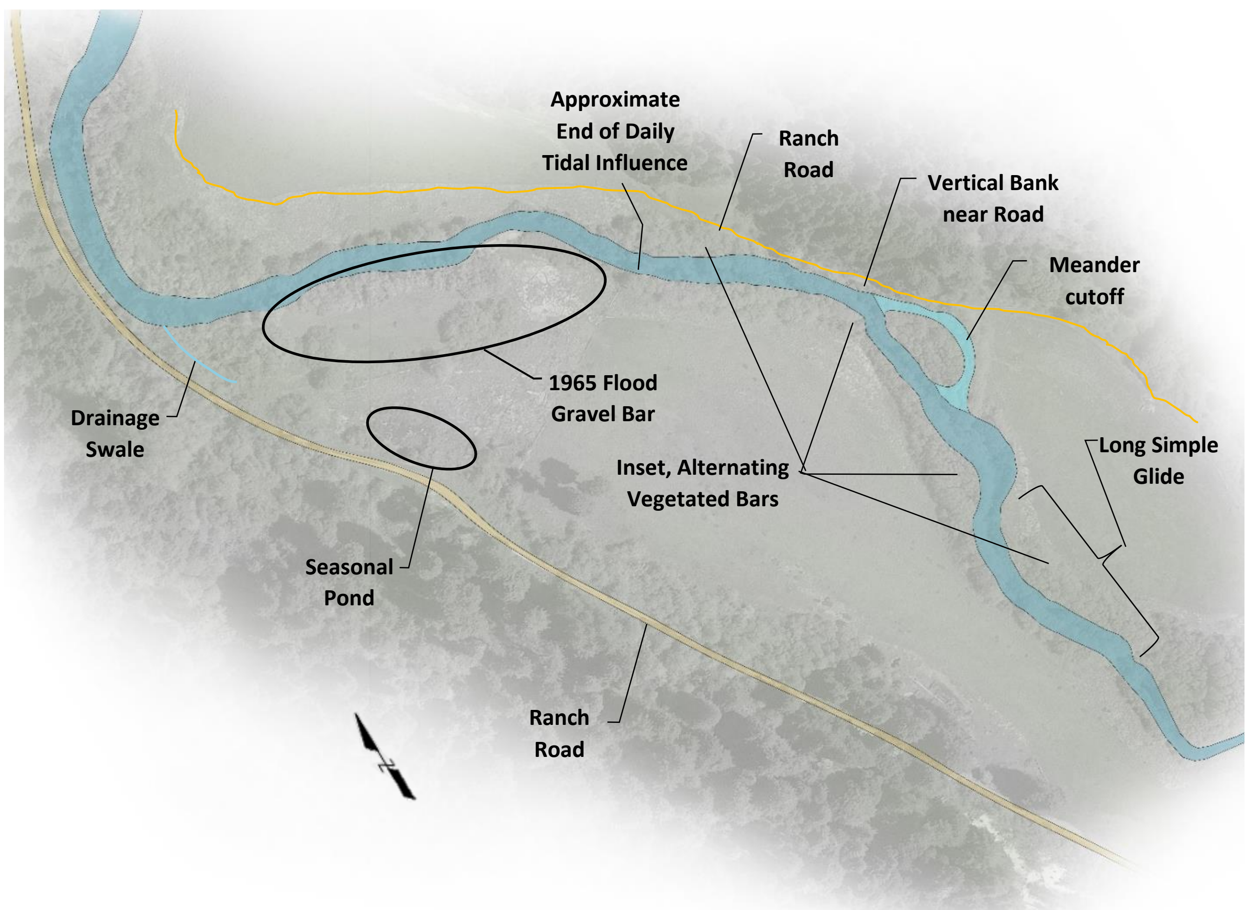

Figure 4. Existing conditions along project reach. River flow direction is from right to left.

Figure 2. Site images, clockwise from upper left: a) & b) Long glides with plane-bed channel form in upper project reach, c) tidal lagoon backwater influence in November 2022 (Normal water depth is several feet lower than shown when tidal lagoon backwater is not in effect.), d) vegetated inset gravel bar in photo center with elevated 1965 floodplain above on left bank (looking downstream), and e) existing seasonal wetland in winter (water supply to pond is via local drainage and groundwater as wetland is disconnected from river).

The following is a list of topographic and geomorphic parameters to help characterize the project river reach and provide design context.

- The South Fork project reach channel slope averages 0.1%.
- The lower half of the reach is influenced by daily tidal backwater fluctuations and late summer lagoon closure flooding.
- Winter base flow channel widths range from 15 to 25 feet.
- Bankfull (top of bank) channel widths range from 50 to 100 feet.
- Channel bed sediment is dominated by small to medium gravel.
- The floodplains are elevated 5-8 feet above the channel bed.

The project site is in an active cattle ranch and most of the floodplains are rotationally grazed pastures. The main site constraints are the ranch access roads that run along both sides of the valley. The road along the left (western) valley edge follows the historic railroad grade, is elevated, and is well-maintained with gravel road base, while road along the right (eastern) valley edge is an unimproved two-track road.

The landowner supports the stream restoration work and has expressly stated that the 1965 gravel bar, adjacent field area, and the seasonal pond in the lower portion of the project reach are available for creative and large-scale habitat restoration. Their primary concern is the stability of the ranch road on the right side of the valley, which is pinched against the valley wall by the river.

3.1 Site Morphology

Design of functioning off-channel habitat for salmonid rearing is based on understanding the terrain, the range of hydrologic and hydraulic conditions at a site, and the preferred depths and velocities for juvenile Coho Salmon. Measurement and analysis of flow depths and water surface elevations and their relation to floodplain terrain is critical. LiDAR was used for topographic analysis of the project area and as the base map for site design. Supplemental surveying was performed by PCI to refine the topography where needed, confirm the accuracy of the LiDAR, and map features such as trees LiDAR point data (FEMA March 2017) was used to create a topographic surface in Civil3D. A de-trended terrain map (relative elevation map) was then created by normalizing the elevation data by the average valley slope and a color banding scheme was applied to make it easier to discern elevation variations within the project area (Figure). This relative elevation map was used during site visits and design planning to determine low-lying areas with potential for habitat enhancement. These elevations correlated with storms seen in the reach through the 2022/2023 winter.

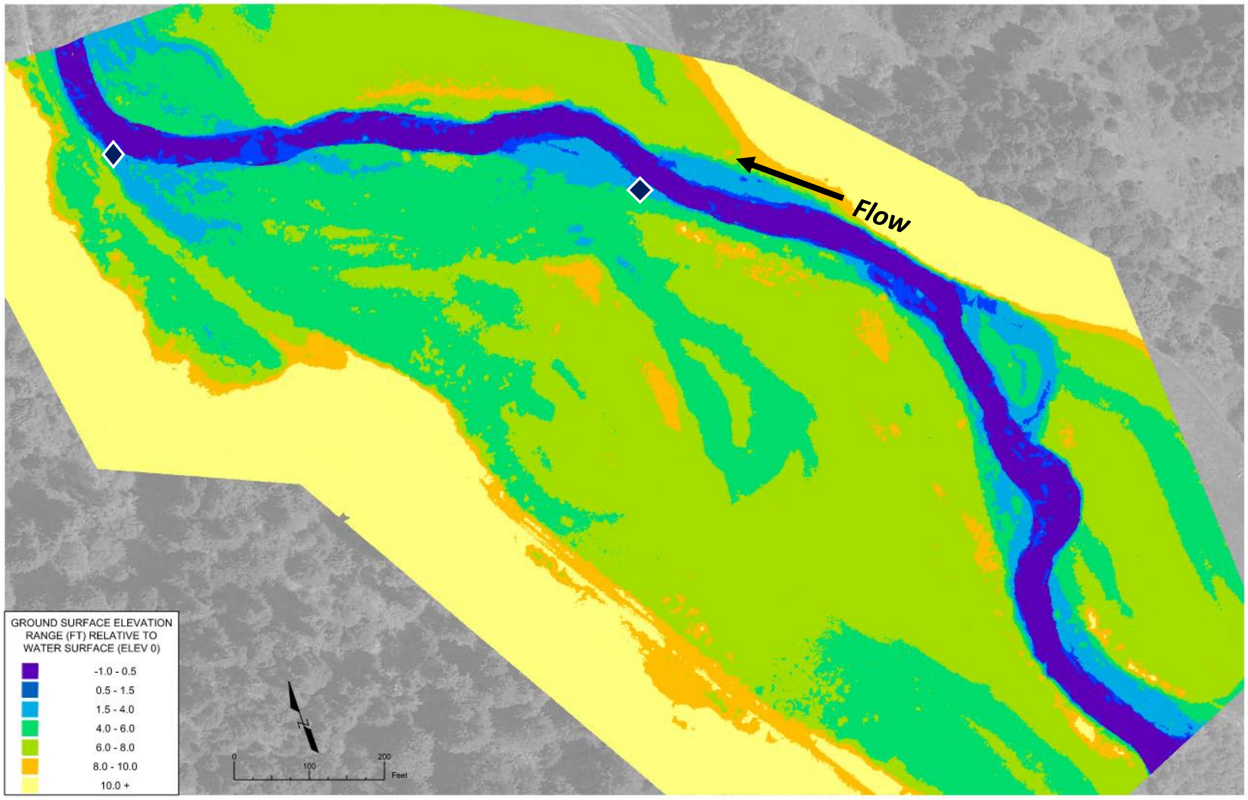

Figure 6. De-trended relative elevation map of the project reach. The color bands showing terrain feature elevations were set to relate to approximate water surfaces during the following flows: dark purple = winter baseflow/low tide, dark blue = high tide/small storm events, blue = frequent larger storm/lagoon backwater, dark green = 2-year flood, and light green = 5- to 10-year flood. Triangles indicate pressure transducer locations.Site Hydrology

PCI installed two pressure transducers in the project reach to document tidal and seasonal variations in water surface elevations in the lower portion of the project reach. The hydrograph data is used to inform alcove and Stage 0 wetland design elevations. One pressure transducer was installed at the downstream end of the reach and the other near the upper end of the tidal influence (Figure 6). The pressure transducers were installed in December 2022 and will remain in place for one year to document the range of hydrologic conditions.

The hydrograph from winter and spring 2023 (Figure 7) shows clearly how the daily tidal fluctuations backwater the site and influence water surface elevations, especially the monthly higher high tides. The tidal signal washes out during higher storm event flows. Salinity levels were also measured and are shown for the downstream PT location on Figure 7. During the winter the salinity levels hovered in the freshwater range (<0.5 ppt). A spike in salinity was observed in December prior to significant rainfall and elevated streamflows, and associated with high high tides. The measurements were taken at the bottom of a deep pool, so it is unknown whether the brackish water conditions were only found in a stratified layer at the pool bottom or were similar throughout the water column.

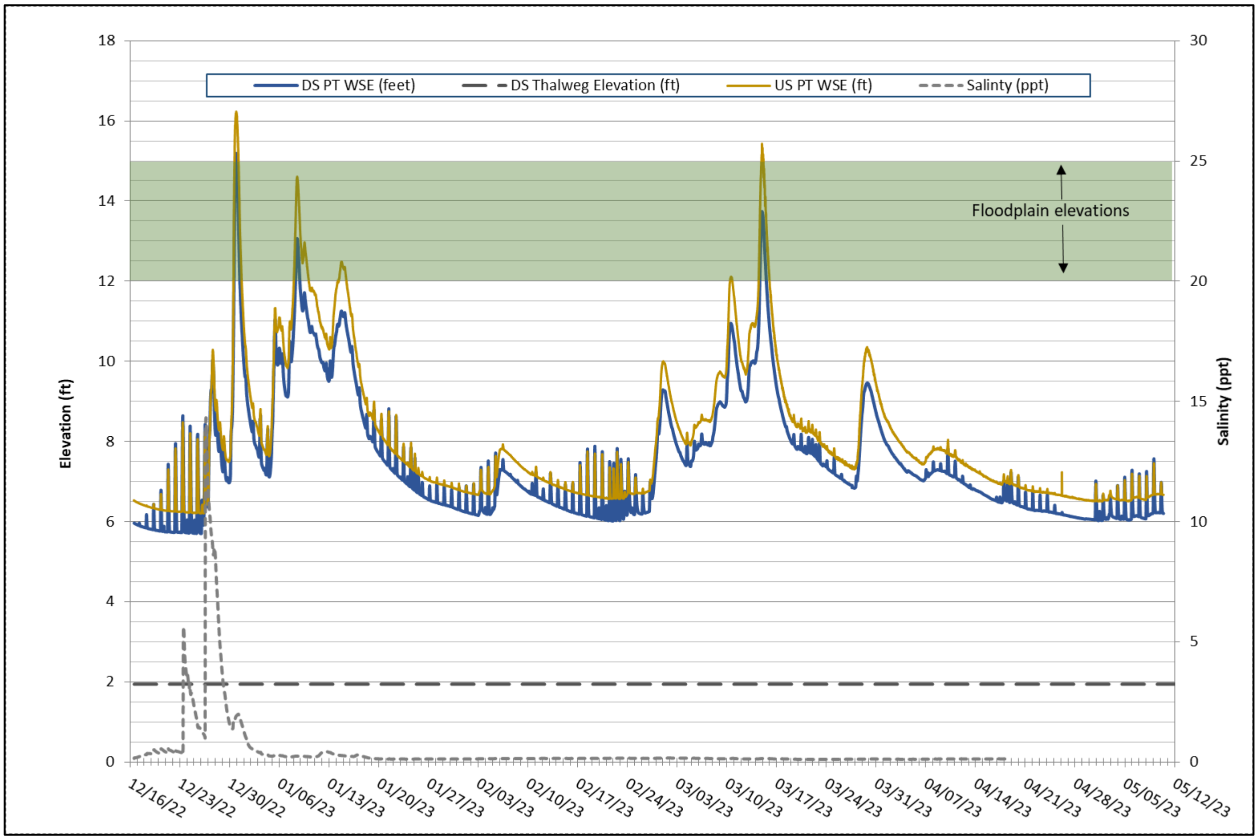

Figure 7. Hydrograph showing water surface dynamics in project reach during the 2022/23 winter. Salinity levels are also shown.

Information on groundwater (floodplain water table) levels was collected in the project reach during the winter and spring of 2015. A shallow groundwater monitoring well with a pressure transducer was installed in the seasonal pond. In-channel water surfaces were also monitored at the lower end of the project reach near the 2023 downstream PT installation. The hydrographs from 2015 (Figure 8) show that the water table level in the floodplain is elevated above channel water surfaces, though it is responsive to tidal backwater conditions, rainfall, and elevated streamflows. The floodplain water table data provides insight into the groundwater conditions that fill and maintain the seasonal pond and any designed off-channel features.

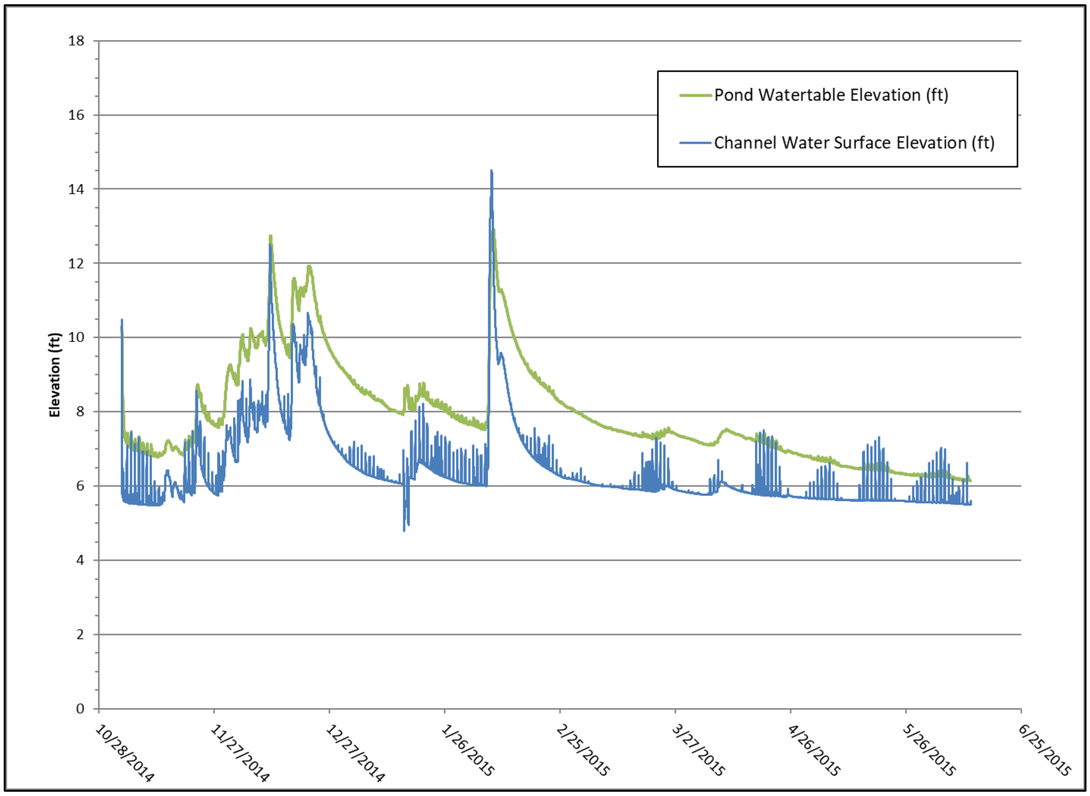

Figure 8. River and water table hydrograph from 2014/15 winter and spring, which was a much drier wet season than 2022/23 shown in Figure 7.

The South Fork Ten Mile River does not have a long-term gage established on it. We do not rely on discharge estimates or gage data for design purposes. However, for reviewers' reference, peak flows were estimated using the USGS StreamStats tool (Figure 9).

Return Interval	Flow (cfs)
2-yr	2,430
5-yr	4,390
10-yr	5,780
25-yr	7,580
50-yr	8,930
100-yr	10,300

Figure 9. Estimated discharge for design floods and the map of South Fork Ten Mile River watershed area upstream of the project area (~38 sq miles and 53.2 inches mean annual precipitation) from StreamStats (https://streamstats.usgs.gov/ss/).

4 Habitat Enhancement Concept Description

The overall project goal is to increase juvenile salmonid survival and Coho Salmon population numbers. This lower reach is utilized by juvenile salmonids for both winter and summer rearing, and ideally it provides abundant velocity and predator refugia and foraging habitats. Areas like this, where the river transitions to the estuary, should promote salmonid growth and survival. The habitat enhancement objectives for this Phase 2 project on the Smith Ranch reach of the South Fork Ten Mile River are based on guidance provided by the current and previous Technical Working Groups, as well as observations of design performance and fish utilization of the Phase 1 projects. The following are project objectives and specific design guidance:

- Create complex in- and off-channel features for salmonid winter rearing, foraging, and velocity refugia.
- Increase connectivity to and enhance existing floodplain features.
- Provide stage resilient rearing habitat (i.e. high quality, low-velocity edge habitat at a wide range of flows).
- Include deep alcoves with lots of woody cover.
- Break up long, featureless glides with simple wood structures that will initiate deeper pool scour, gravel sorting, and bar development at higher flows. The structures should also provide complex cover at low flows, and backwater inset floodplain benches at higher flows, where appropriate.
- Natural looking wood accumulation designs are preferred over engineered log jams.
- Avoid destabilizing right bank ranch road.

The Phase 2 sites and treatments were selected to 1) take advantage of existing off-channel features and unused valley land, or 2) enhance low-value, in-channel habitat areas. The intention is to provide significant uplift to the Coho Salmon rearing capacity of the 0.4-mile reach. The site elements will function together to provide high-value in- and off-channel habitats that can be utilized by salmonids across a wide spectrum of winter and spring flow conditions as they travel into the Ten Mile River estuary. Refer back to Section 3 of this report for existing site conditions and features.

Figure 10 shows the four sites (SF6, SF7, SF8, and SF9) that comprise the Phase 2 project. The naming convention is based on the concept designs nomenclature proposed in *Lower Ten Mile River Habitat Enhancement Plan and Concept Designs* (PCI 2014). While we have retained the number of sites and the nomenclature from that early design effort, the design details and specific locations have shifted to reflect changed site conditions and updated ideas of habitat needs and effective design approaches. The new designs are intended to work with site opportunities and constraints, and provide a wide range of habitat features. Overall, the project expands upon treatment approaches and features that worked well in Phase 1, including alcoves, seasonally flooded wetlands and ponds, complex large wood structures for cover, and accelerated recruitment-type log jams that utilize downed alders and whole redwood trees. Brief overviews of the site design concepts are provided here, with more details of the engineering design specifics and functioning provided in Section 5.

- **SF 6 – large alcove and seasonal pond complex**. At this location a long, deep alcove and shallow pond will connect to the existing seasonal pond and valley wall wetland complex along the left valley edge. Currently the seasonal pond is disconnected from the channel except during 5-yr+ flood peaks. An objective of this design is to not drain the existing pond and wetland, as they are important feature in the landscape, providing native frog and other wildlife habitat as well as promoting groundwater recharge.

- **SF 7 – Stage 0 wetland complex**. The dry, rarely flooded 1965 gravel deposit on the left bank will be excavated out to create a 1.6-acre, tidal-bore flooded wetland. The wetland surface will be set low enough to get flooded daily during high tides and every storm event. It is expected that the wetland surface terrain, vegetation composition, and channel pathway(s) will evolve over time with coarse sediment deposition.
- **SF 8 – alcove**. A small alcove set into a wide, tree-covered gravel bench is proposed for this site to provide complex, low-velocity, off-channel winter habitat in the upper project reach.
- **SF 9 – Simple large wood structures**. Four accelerated recruitment-type large wood structures are proposed to increase channel bedform and habitat complexity in the long glide reach. A mix of downed alder, willow slash, and whole redwood trees will be used to form the structures.

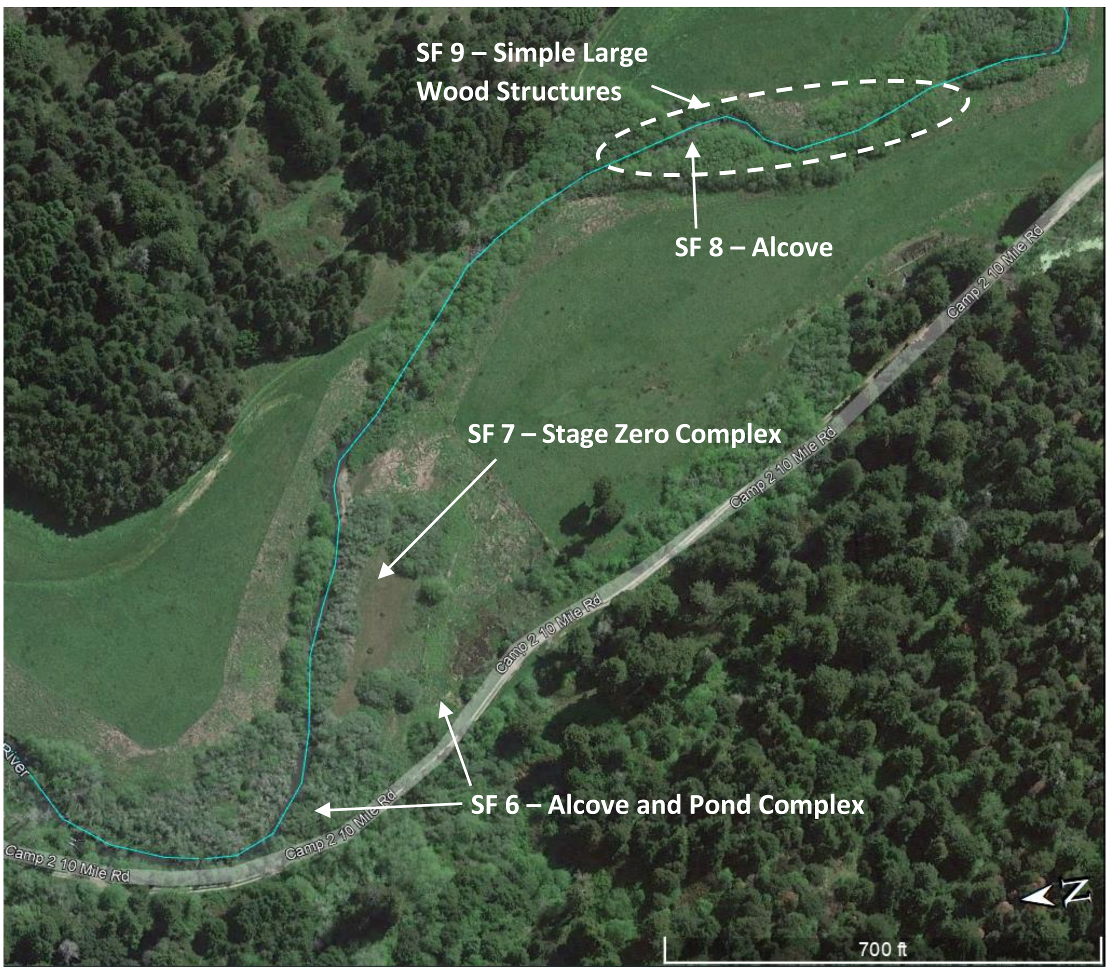

Figure 10. Site locations and description within the Phase 2 project area. South Fork Ten Mile River flow direction is from right to left.

4.1 Risk and Impacts Evaluation

The project sites are considered to be low risk locations given the adjacent and downstream land use, which includes grazed pastures, wildlands, and low-impact recreation. The floodplains where excavation is proposed are not currently used for agriculture or other activities. Upstream and downstream floodplains have a similar status, with a few having seasonal cattle grazing on them. Further downstream is the Ten Mile River Estuary and the Pacific Ocean; the estuary has large unmodified floodplains on both banks. Public access to the lower Ten Mile River estuary is possible via Mackerricher State Park and Mendocino Land Trust land. There is occasional use of the estuary by kayakers.

Two bridges are located downstream of the project site: a bridge on Georgia Pacific Industrial Rd near the confluence of the South Fork with the mainstem Ten Mile River and the Highway 1 bridge near the mouth of the mainstem. Both bridges have wide spans and they are elevated well above high flows. The large wood structures to be installed as part of the project are designed to remain in place through the expected range of hydraulic forces. They will be stabilized using log piles and pins or wedged between mature alder trees and vertical log anchors (see Exhibit A).

The off-channel enhancements and associated large wood structures have been designed to be functional over time and under a wide range of site conditions; they will work with the natural fluctuations in tide and streamflow dynamics, and will function through climate change driven shifts in sea level, flooding, drought, and temperature. The alcoves should experience minimal sedimentation, as improved timber harvest methods have reduced erosion and associated fine sediment loading to the stream channel. We do expect the SF 7 wetland complex to experience coarse sediment deposition, especially at the upstream end. It will only add to the dynamic nature of the site where deposition and scour will create variable terrain and associated vegetation patches. Sea level rise will increase the duration of inundation duration and accessibility of the project's off-channel features.

Negative impacts to biological resources will be temporary and primarily related to construction. These impacts will be mitigated during construction through biological surveys, careful species relocation, and monitoring. Nesting bird surveys will be conducted prior to brush clearing, and active nests will be avoided. Sensitive species will be excluded from the site using screening and fencing, where needed. Up to 800 feet of channel may need to be dewatered in the SF 6/SF 7 reach, however full dewatering will be difficult given the tidally influenced daily water depth fluctuations. An efficient construction approach that minimizes impacts to instream biota and water quality will be developed with the construction contractor during the next phase of design plan development. Working in the wet and using exclusion screens and turbidity curtains may provide the best solution in this dynamic environment. Turbid water from within the work area will be piped to low-lying areas in the adjacent pasture for infiltration and filtration. The SF 9 structures will be installed from the bank using long reach excavators and a crane. Fish and other wildlife in the work zones will be encouraged to leave prior to wood placement.

Post construction, the projects should have a net benefit to many native species in addition to Coho Salmon (the primary target), including tidewater goby, California red-legged frog, and western pond turtle. These species also prefer wetlands and slow-moving water with complex wood structure and overhanging vegetation.

5 Site Designs and Engineering

This section describes the four site designs in more detail. The descriptions are based on the 65% designs (PCI June 6, 2023), which include grading plans for the off-channel features and the large wood structures layout (Figure 11). Biological, topographical, hydrologic, and geomorphic conditions informed specific elements of the designs. In addition, the Technical Working Group (TWG) and landowners provided input on site-specific design extents and components at the 30% design phase. Each site will be described separately. However, many of the design components are similar across all sites, thus descriptions will reference other sites, as appropriate. All sites will have erosion control and revegetation plans developed in later design phases. Plantings will include native grasses as well as plug planting of wetland species within the tidally flooded zones.

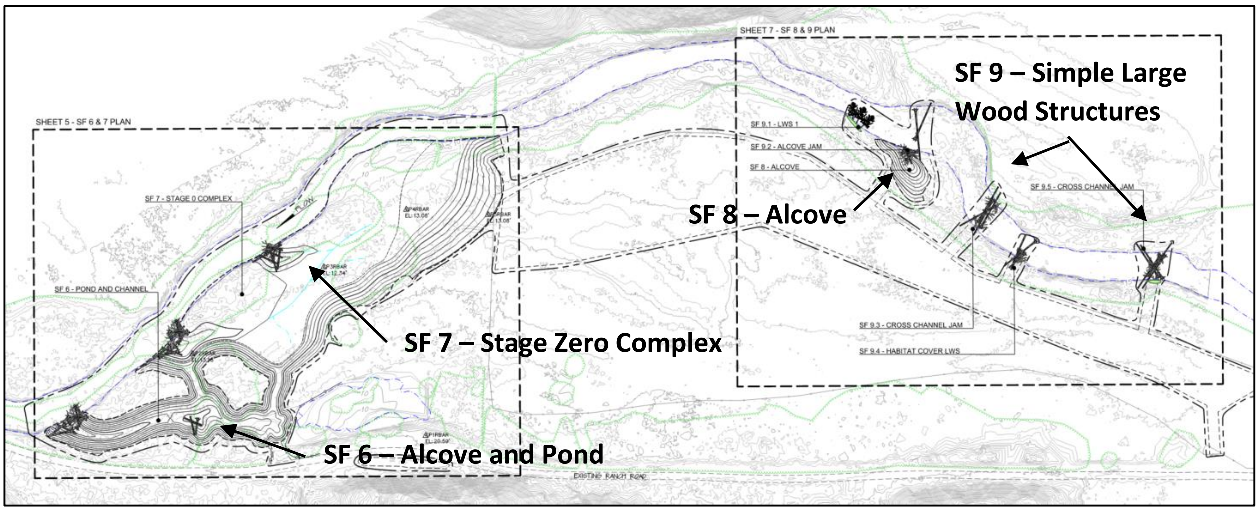

Figure 11. 65% plans overview of designs.

5.1 SF 6 – Alcove and Pond complex

This site includes excavation of an alcove that transitions into a wetland swale and small ponded area along an existing swale feature (Figure 12) that connects to the existing seasonal pond. The alcove is 150-feet long with depths ranging from 3- to 0-feet during low tide periods (water surface at ~ 6'). During the monthly higher high tides, the water surface increases to 7' and up to 8', which will extend the inundated area another 150 feet up the wetland channel. A 0.03-acre depression (pond) is incorporated into the wetland swale; it will pond water one foot deep and be connected to the alcove during every higher high tide cycle during the summer and every flow above low winter baseflow in the winter. The alcove and wetland swale will gradually transition to an existing seasonal pond at its upstream end. Connector channels from the upper portion of the wetland swale and pond to the SF 7 Stage Zero wetland complex will connect these features during winter storm events. These connector channels are set at elevation 9', approximately 6-inches above the maximum high high tide elevation, so that the two sites (SF 6 and 7) are only connected during high flows. Refer to the hydrograph in Section 3 (Figure 7) to see water surface elevations and evaluate the inundation patterns and durations of the proposed features. Section 6 presents information on changes to low velocity habitat extent pre- and post-project for SF 6 and SF 7.

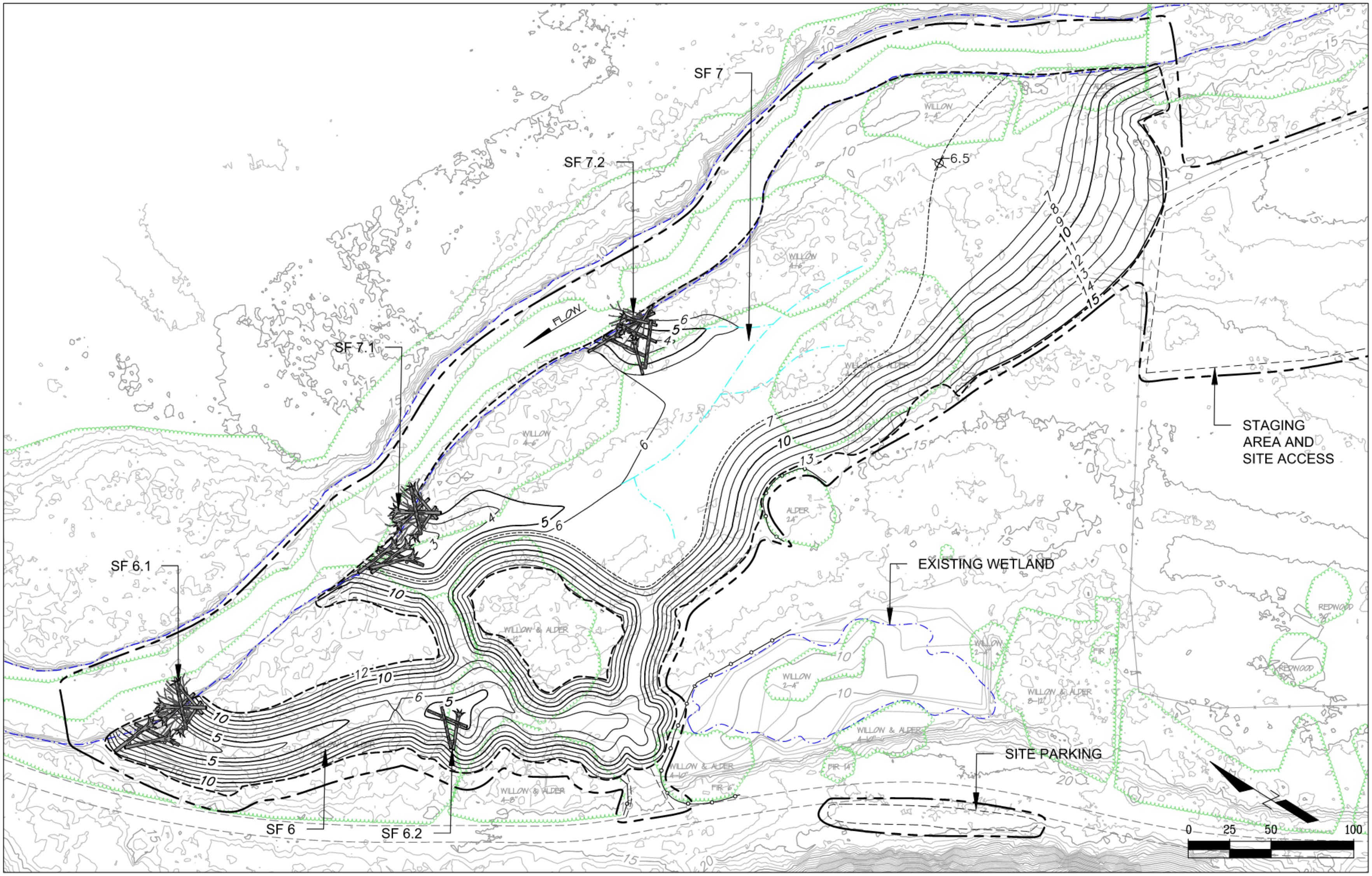

Figure 12. Site plan for SF 6 and SF 7 showing grading, large wood structures, and site access.

A large wood cover structure would be placed at the outlet of the alcove to attract fish and provide complex shelter from predators. The six redwood rootwads and two to three logs and salvaged willow and alder will also help stabilize the excavated slopes of the alcove. Vertical log anchors and pins will be used to provide the needed ballast and engineering stability (Exhibit A). Large wood would also be placed in the pond feature to provide habitat and cover for both fish and western pond turtles. In addition to water flux from the tidal backwater, the alcove, pond, and wetland swale will likely be fed from groundwater through the winter and spring. In the late summer/early fall sandbar closure at the estuary mouth creates a lagoon condition, and water will back water into SF 6 and SF 7, creating flooded wetland habitat.

All excavated areas would be revegetated with native seed and plants; specifically, in the wetted areas, native plants would be wetland sedges and rushes. We expect the 2,000 cubic yards of silty loam spoils will be hauled to a quarry up on the mainstem Ten Mile River, where it will be used to reclaim the site.

5.2 SF 7 – Stage Zero Wetland Complex

The dry 1965 gravel deposit will be converted to a 1.6-acre multi-threaded channel wetland complex (Figure 12). The entire surface of the gravel bar will be lowered to just above low tide/winter baseflow elevation (6.5' at the upstream end transitioning to 5.5' at downstream end). Small, shallow pilot channels will be excavated into the new surface to initiate channel formation and provide pathways for fish to navigate through the wetland.

We expect the 14,000 cubic yards of sandy gravel to be hauled to a yard in Fort Bragg and reused for aggregate needs. Or it will be hauled to the quarry location up the mainstem Ten Mile River. Proposed dewatering and/or water management details for this site will be worked out in the next phase of design.

The lowered surface will be planted with native wetland sedges and rushes to create high-quality cover and foraging habitat for juvenile Coho Salmon. Ideally, the multi-threaded channel complex will become a marshy, anastomosing off-channel habitat. The wetland complex is designed to be inundated by the daily high tide backwater, with drying out of the wetland occurring during low tides. During winter storm periods the wetland flat will have two to eight feet of water over it for several days to a month or more at a time. During lagoon backwater periods in late summer and fall the wetland will have up to four feet of water on it. See Section 6 for HEC-RAS images of the inundation areas at different flows.

Two three-foot-deep alcoves will be excavated into the wetland where the pilot channels reconnect to the main channel. Large wood habitat structures will be installed in the alcove to provide deep cover habitat. Like the structure at the SF 6 alcove, these will also be composed of redwood rootwads and logs, with additional salvage material to increase habitat complexity, and vertical log anchors providing the ballast connections (Exhibit A).

Over time, we expect the surface of the wetland to be modified and elevated by gravel and sand splays. Especially at the upstream end, as the wetland excavation creates a sudden, wide expansion zone that will reduce stream power at higher flows. This sudden reduction of stream power will cause bedload and some suspended material to drop out. The main channel may aggrade in the section adjacent to SF 7 wetland flat. If this occurs, the channel may avulse, and carve a new path through the wetland. Or it may become multi-threaded in this reach. None of these possibilities are considered problematic, as the channel will be dynamic and providing a complex array of micro habitats.

5.3 SF 8 – Alcove

A small alcove is planned in the upper portion of the project reach at the downstream end of an inset gravel bar bench (Figure 13). The inset floodplain bench has mature alders established on it that maintain its stability and provides shade. The bench gets overtopped at approximately the 2-year flow event. At winter base flows the water depth in the alcove will be 1.5- to 2-feet deep.

Large wood structures will be installed at the inlet mouth to provided complex cover for rearing salmonids, and to maintain sediment transport hydraulics. The alcove is also designed with its inlet angled downstream to reduce potential aggradation.

Example alcove with large wood structures from the Phase 1 project.

The back end of the alcove will slope gently (5:1 slope) up to the existing terrain. The slopes will be planted with wetland sedges and rush to provide stability. The vegetated, gently sloping banks provide stage resilient rearing habitat and foraging opportunities during higher flow events.

5.4 SF 9 – Simple Large Wood Structures

Four cross-channel jam structures are planned (Figure 13) that will serve several functions including backing flows up to initiate inset bench and alcove flooding and scouring and re-distributing gravels to initiate pool/riffle formation in the plane bed reach. The structures will be built using a combination of materials, including salvaged alders and willow from the lower reach's excavation areas and whole redwood trees with rootwads that can span the active channel and hold down the salvage wood. The logs will be stabilized in place by wedging them between live alders on the bank. Vertical log anchors will be vibrated into the channel bed at the downstream end of the structures to prevent loose material from floating downstream. The log anchor will stick up into the flow field and can help collect additional woody debris.

Example accelerated recruitment, cross-channel large wood structure from the Phase 1 project.

At two locations, alder trees on the left bank will be dug up and pushed into the channel. This serves to create additional complex habitat. It may also initiate localized bank widening and scour pool development, as alder roots stabilize stream banks and prevent natural erosional processes from widening the channel and creating complex edge habitat.

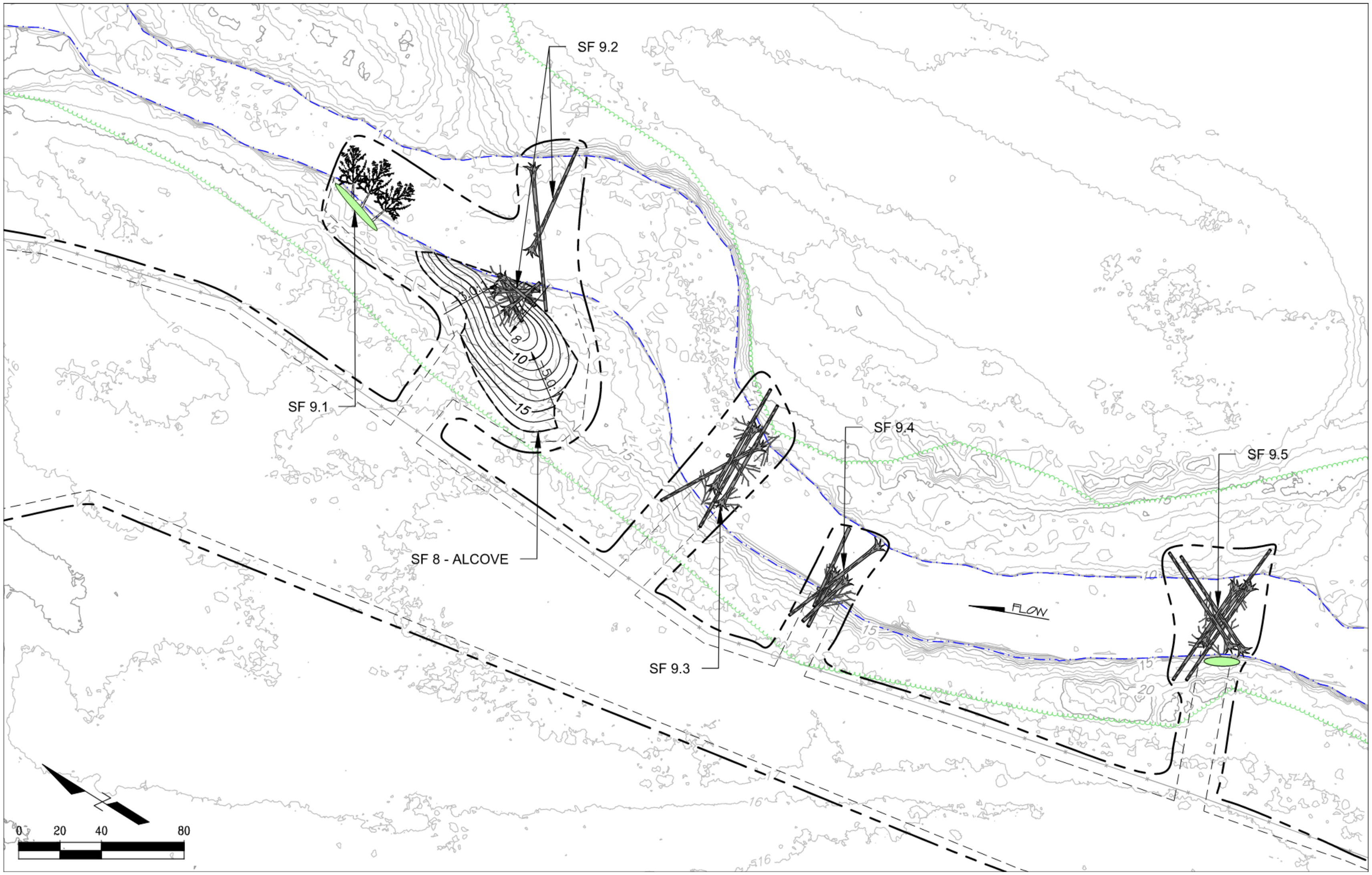

Figure 13. Site plan SF 8 and SF 9 showing grading, large wood structures, and site access. Green ovals show locations for alder removal and tipping into the channel.

5.5 Additional Design Elements

The following are design and construction elements that will be addressed in more detail in later plan sets and the project's final basis-of-design report.

- Water management during construction.
- Spoils material placement plan.
- Erosion control and revegetation plans.
- Draft monitoring plan.

6 Evaluation of Habitat Area Change

The lower project area sites (SF 6 and SF 7) were designed to create broad, connected expanses of low velocity habitat for use by juvenile salmonids for foraging and velocity refugia during winter flows. To evaluate the effect the wetland and alcove excavations have on wetted area and velocities, a 2-D HEC-RAS model (ver. 6.1, USACE 2010) was developed for the reach. The 2D capabilities of HECRAS utilizes an implicit finite volume algorithm with a digital terrain model that allows flow to travel in any horizontal direction. The diffuse wave equation option was used to depict flow down the channel, into the alcoves, and across the floodplain during several representative flows (Table 1). Vegetation and landscape features were given roughness values as shown in Table 2. The model results are considered to be approximate only, as the channel terrain was not surveyed and is based on an early spring water surface. Also, in this setting, with daily tidal fluctuations and backwater conditions from the mainstem during higher flow events, developing a downstream boundary condition that represents the range of actual conditions is not practical. Nor were we able to model the floodplain overbank flows that originate upstream where the bank is lower, or the valley wall drainages that contribute to wetland saturation and ponded water throughout the winter season. Thus, the model run results were only used to compare accessible areas and velocity patterns in existing condition versus design conditions.

Table 1. Flows modeled.

Flow event	Flow (cfs)
Winter Base Flow	40
1/2 Q1 – frequent small storm	500
Q1 – frequent large storm	1000
Q2	2430
Q5	4390

Table 2. Roughness values used.

Manning's roughness values	
RIPARIAN	0.07
CHANNEL	0.035
PASTURE	0.035
UPLAND ROAD AND FOREST	0.06
WETLAND SCRUB	0.05
WETLAND GRASSES	0.04

Images of the downstream sites, pre- and post-project, at four representative winter flows were produced from the HEC-RAS model results (Figures 14-17). At each flow the expansion of low-velocity areas is dramatic, and reflects high quality, vegetated floodplain foraging habitat. Over two acres of floodplain and deep-water alcoves will become accessible at the full range of winter flows with the proposed design.

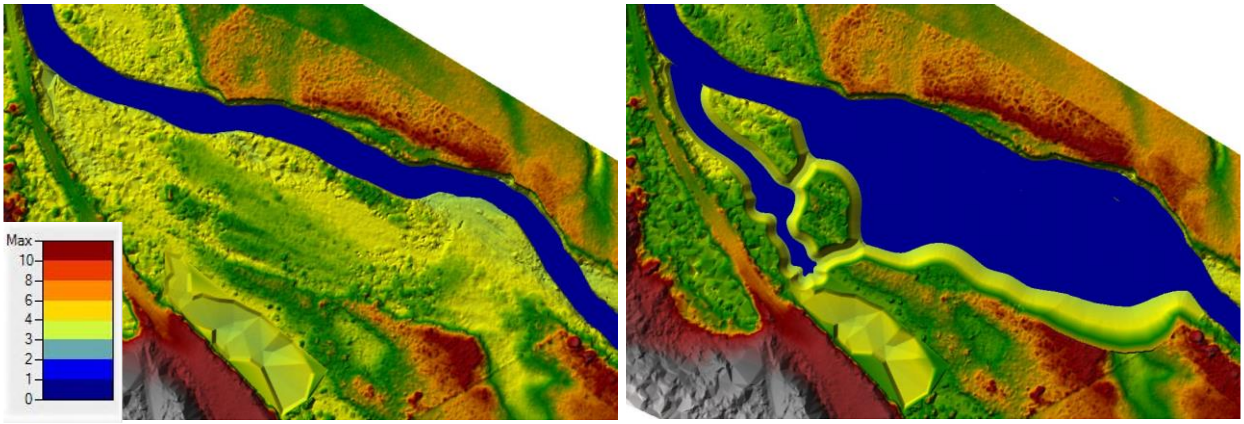

Figure 14. Inundated area and velocities in the lower project reach pre- and post-project at winter base flow (~40 cfs) and high tide conditions. Dark blue represents Coho Salmon preferred velocities of <1 ft/sec. Flow is from lower right to upper left.

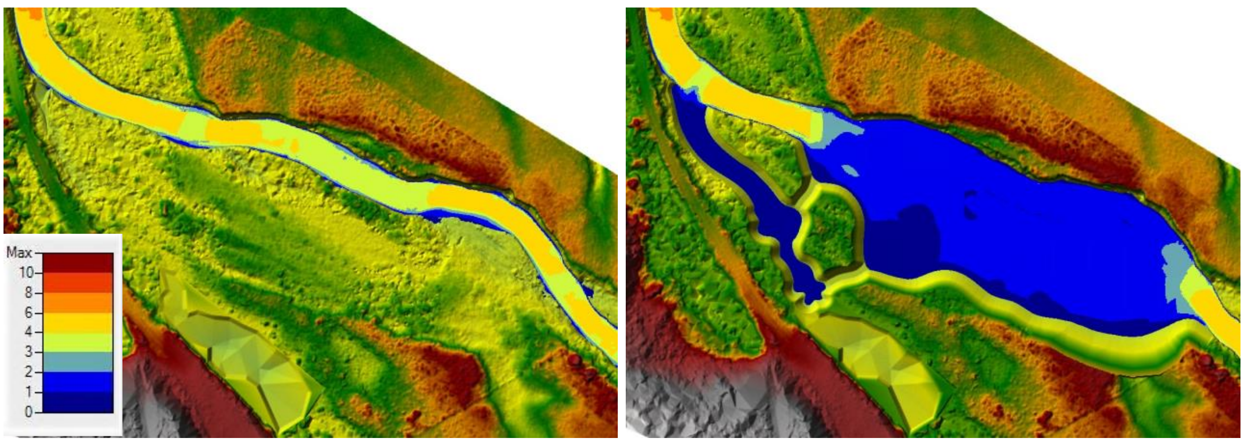

Figure 15. Inundated area and velocities in the lower project reach pre- and post-project at frequent small storm events (~500 cfs). As vegetation establishes on and gravels drop out at the head of the broad wetland bench we would expect to see more patches of optimal velocities.

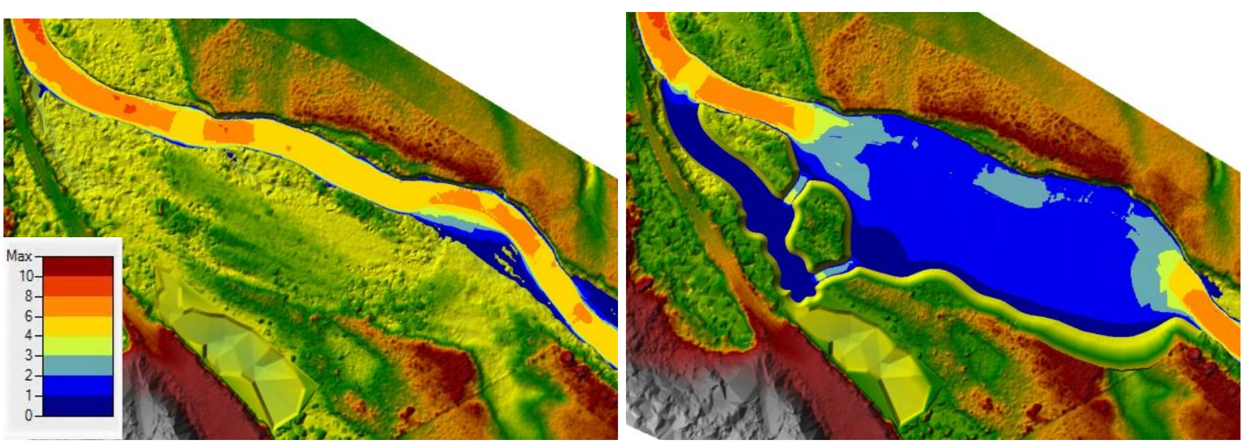

Figure 16. Inundated area and velocities in the lower project reach pre- and post-project at the 1-year RI flood peak (~1000 cfs), which also represents frequent large storm events.

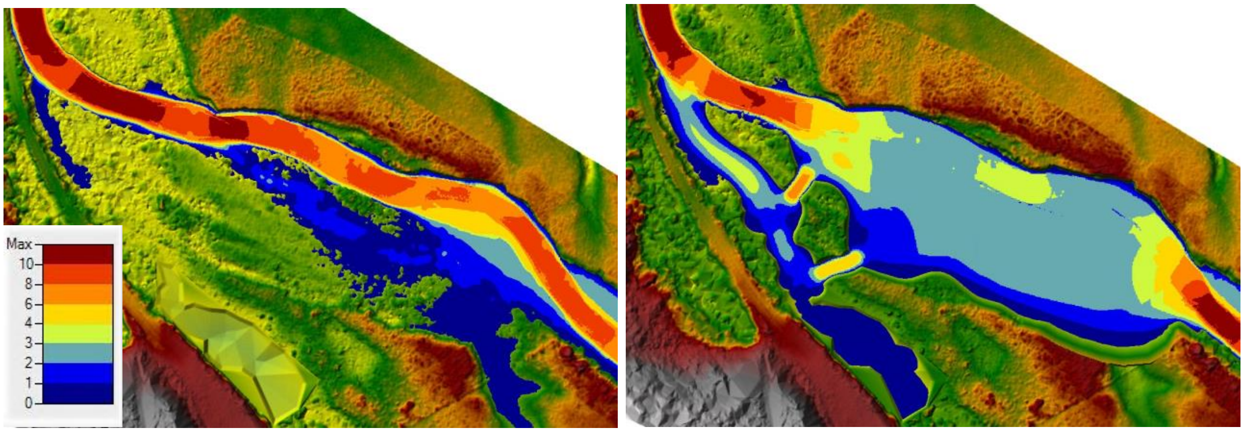

Figure 18. Inundated area and velocities in the lower project reach pre- and post-project at the 2-year RI flood peak (~2400 cfs). We would expect the velocities at the downstream end of the channel, as well as those in the alcove, Stage Zero wetland, and connector channels to be less than what is shown, as the Ten Mile River estuary will back up into this reach during flood events, slowing the flow. The high velocities in the connector channels are due to differential water surface elevations between model time steps, and are not reflective of expected actual conditions.

The SF 8 alcove will function similarly to SF 6, just at a much smaller scale. We expect it to have velocities of < 1 ft/sec at flows below the 2-year RI flood peak. At that point, the flows will be inundating the vegetated bench and riparian forest along the pasture's edge, which provide low velocity refugia areas. The large wood structures should slow surface velocities upstream of the cross channel jams and increase the extent of edge habitat available to salmonids. Their value for in-channel habitat is at winter and summer base flows after pools have been scoured and gravel reworked to create more complex microhabitats. The salvaged small wood and large and large redwood logs will provide abundant complex cover for juveniles rearing in these stream reaches.

7 References

Lestelle, L. 2007. *Coho Salmon Life History Patterns in the Pacific Northwest and California*. Prepared for U.S. Bureau of Reclamation, Klamath Area Office.

NMFS, 2012. *Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon*. Southwest Regional Office, Santa Rosa, CA.

PCI (Prunuske Chatham, Inc.). 2014. Lower Ten Mile River habitat enhancement plan and concept designs. Prepared by PCI, Sebastopol, California for The Nature Conservancy, San Francisco, California.

Rosenfeld, J., Raeburn, E., Carrier, P. & Johnson, R. 2008. *Effects of Side Channel Structure on Productivity of Floodplain Habitats for Juvenile Coho Salmon*. North American Journal of Fisheries Management, 28:4, 1108-1119.

Stillwater Sciences. 2011. Restoration opportunities for increasing Coho Salmon winter rearing habitat in the lower South Fork Ten Mile River. Prepared by Stillwater Sciences, Arcata, California for The Nature Conservancy, San Francisco, California.

Stillwater Sciences, 2013. *Framework for Coho Salmon habitat restoration and enhancement in lower Ten Mile River*. Prepared for The Nature Conservancy, San Francisco, CA.

USACE, 2010. HEC-RAS River Analysis System. US Army Corps of Engineers. *Hydraulic Reference Manual*. Davis, CA.

Exhibit A: Stability Analysis for Large Wood Structures (DRAFT)

South Fork Ten Mile River
Habitat Enhancement Project – Phase 2
Mendocino County, California

Stability Analysis for Large Wood Structures

Prepared by:

Karen Jamgochian, P.E.
Prunuske Chatham, Inc.

June 30, 2023

PRUNUSKE CHATHAM, INC.

1 Introduction

Site-specific designs for salmonid habitat enhancement were prepared by Prunuske Chatham, Inc. for The Nature Conservancy for Phase 2 of the South Fork Ten Mile River Habitat Enhancement Project. The designs include five engineered large wood structures that will be installed in new alcoves on the creek banks to increase habitat quantity and quality. The structures are complex structures with logs and rootwads connected together with steel all-thread pins to form Engineered Log Jams (ELJs). The structures have additional salvage wood wedged throughout the structure to increase habitat complexity. Main logs will be redwood or Douglas fir. Salvage material will be trees or wood removed from the site during construction that meets required project specifications. In addition to the ELJs, three accelerated recruitment large wood structures (LWS) will be constructed. These LWS structures will utilize whole redwood trees wedged between or pinned to live trees on the bank.

The structures are meant to provide a range of functions, including but not limited to:

- provide complex cover for juvenile salmonids;
- provide high-flow velocity refugia during winter high flows; and
- promote deep, slow pool formation for summer juvenile salmonid rearing.

All structures are designed so that each log has at least two points of contact with designated anchor points or will be trapped in place by fully secured logs. Anchor points include Vertical Log Anchors (vertical piles), existing trees, or other anchored logs. Vertical piles are 18" diameter (min) and are embedded a minimum of 15' into the channel bed. Log diameters in the structures range from 15 to 24 inches (at the small end) with lengths ranging from 20 to 30 feet. All main logs in each structure are connected together using 1-inch diameter all-thread rod with 4" square plate washers and a single nut on each end. Estimated structure lifespan is 25+ years and is based on wood decay rates.

Select structures have salvage material that will be wedged through or pinned beneath the structures to create additional habitat and enhance structure effectiveness. Salvage material may be complex branches taken from portions of removed trees, entire willow or alder trees removed as part of the project, or salvaged treetops normally considered slash wood during felling operations. Salvage material is generally not pinned with all-thread rod, but will be required to remain immobile under total submergence.

2 Force Balance Methodology

A vertical force-balance analysis was conducted for each type of structure to determine the total number of vertical piles or tree anchors required for stability under full submergence and flood conditions.
Horizontal (drag) and rotational (moment) forces were not calculated for these structures because of their complexity, uniformly spaced vertical resistance points, and method of anchoring. Drag forces were neglected because for the structure to drag downstream, the embedded piles would have to pull through the bed substrate. Before that occurred, they would likely shear off at their attachment point. Rotational forces were neglected in this analysis because both ends of all logs are anchored, and the VLAs are well distributed throughout the structure. In the event that moderate lateral or rotational adjustments of the structures occurred, the structures would still likely meet their design intent and would continue to provide significant habitat value.

The vertical force-balance methodology is the ratio of the various forces that cause uplift (driving forces), over the forces that resist uplift (resistance forces). The approach used for this analysis is outlined in Chapter 7 of the Large Wood National Manual (USBR and ERDC, 2016). Uplift forces include buoyancy and lift. Resistance forces include structure weight and skin frictional resistance from the vertical piles. Values for structure volume and cross-sectional area exposed to flow (used for lift force) were determined from scaled CAD drawings of individual log structures. In cases where clusters of logs did not appear to be rigidly attached to all of the logs in a structure, those logs were broken out and factors-of-safety were determined separately for each separate cluster of logs.

A scour analysis was conducted to determine maximum scour anticipated around vertical piles using methodology presented in the FHWA Hydraulic Engineering Circular No. 18, *Evaluating Scour at Bridges* (FHWA, 2012). The results indicate that up to 5 feet of scour can be expected around the vertical log anchors (Attachment A). This expected scour depth was then subtracted from the total embedment depth of the vertical piles to account for pile scour.

Because this site is located in a remote area without significant risk to downstream infrastructure, it has a low risk to both public safety and causing property damage. Under these conditions, a minimum factor of safety for buoyancy of 1.5 is recommended (Knutson & Fealko, 2014). All structures were designed to exceed this minimum factor of safety.

3 Applicable Equations

1. Buoyancy: $F_B = \gamma_w V_d$
2. Lift: $F_L = \frac{C_L A \gamma_w U_o^2}{2g}$
3. Structure Weight: $F_W = \gamma_d V_d$
4. Submerged Ballast Weight: $F_{SB} = [\gamma_B V_B - \gamma_W V_B]$
5. Pile Resistance: $F_P = x * ((2\pi R_P * D * C_A) + (P_w - P_B))$
6. Total Uplift Force: $F_{TU} = F_B + F_L$
7. Total Resistance Force: $F_{TR} = F_W + F_R + F_{SB} + Q_f * x + F_T + F_{bed}$
8. Factor of Safety: $F_{SV} = \frac{F_{TR}}{F_{TU}}$

Where:

- γ_w: Specific weight of water, lb/cf
- V_d: Volume of log. cf
- C_L: Drag coefficient, unitless
- A: Area exposed to flow, sf
- γ_B: Specific weight of ballast, lb/cf
- V_B: Volume of ballast, cf
- U_o: Approach velocity, fps
- g: Gravity, ft/sec^2
- γ_d: Specific weight of log, lb/cf
- x: # of piles, #
- R_P: radius of pile, ft
- D: Depth of pile embedment (already includes scour depth, D= total embedment depth – predicted scour depth)
- C_A: Cohesion of soil, lbs/sf
- P_W: Pile weight, lbs-f
- P_B: Pile buoyancy, lbs-f
- F_T: Log-tree resistive capacity, lbs-f
- F_{bed}: Log-bedrock resistive capacity, lbs-f

4 Assumptions

Conservative assumptions were applied where unknowns exist, to simplify the analysis, or where values were subject to change with the intrinsically dynamic nature of the stream environment. Known assumptions include:

- Constant water pressure over entire structure.
- No skin-friction between normal log members (not vertical piles) and soil.
- Ballast resistive capacity assumes no soil cohesion.
- Soil ballast volumes are for selected deeply buried members only. Not all ballast is accounted for.
- Wood density for logs assumes dry redwood.
- Wood volumes assume maximum log diameter with no end-to-end taper.

- As the structures are in a low-risk environment, approach velocities used for the lift equation are based on estimated peak flow velocity during the 25-yr return interval storm event.
- Equivalent resistance from connection of log to existing tree is 8,000lbf.
- 100% of structure log volume is submerged at design flow.
- Rootwad volumes determined from CAD assume 50% wood and 50% soil.
- Entire wood structure is fully connected and acts as a rigid composite structure.
- Piling resistance assumes 5' of scour. See scour analysis in Attachment A.

5 Vertical Force-Balance Stability Results

After the structure-specific parameters were measured or estimated, the required number of VLAs or pins to live trees to add to each structure was then manually adjusted until the desired factor-of-safety was achieved. Because each log is held in place by multiple anchor points or other secured logs and conservative assumptions are applied where uncertainty exists, there is a relatively high level of confidence in the stability of the log structures. However, uncertainty is innately present in all natural systems and all structures in this analysis have a minimum vertical factor-of-safety of 1.5 (Table 1).

6 References

FHWA. (2012, April). Evaluating Scour at Bridges, Fifth Edition. *Hydraulic Engineering Circular No. 18*. FHWA-HIF-12-003.

Knutson, M., & Fealko, P. (2014). Pacific Northwest Region Resource and Technical Services - Large Woody Material Risk Based Design Guidelines. *U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest region*. Boise, Idaho.

USBR and ERDC. (2016). National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood In Fluvial Ecosystems: Restoring Process, Function, and Structure. 628 Pages + Appendix: Available: www.usbr.gov/pn/.

Table 1. Force balance spreadsheet used to calculate required ballast for each large wood structure. Refer to Construction Drawings for the 65% South Fork Ten Mile River Phase 2 Habitat Enhancement Project (PCI 2023) for locations and design details of the referenced habitat structure types.

Structure #	# of 18"x20' Logs	# of 18"x25' Logs	# of 18"x30' Logs	# of 18"x35' Logs	# of 18"x40' Logs	# of Rootwads	Area Exposed to Flow	U_o, Approach velocity	Log to Tree Connections	# piles	Structure Volume	Structure Wood Weight	Lift	Total Pile Resistance	Structure Buoyant Force	Total Uplift Force	Total Resistance Forces	Factor of Safety
	#	#	#	#	#	#	sq ft	ft/sec	#	#	cu ft	lb-f	lb-f		lb-f	lb-f	lb-f	
SF 6.1 - alcove jam right side			**5**			**4**	50	5		3	385	10782	0	31696	24028	24028	44782	1.9
SF 6.1 - alcove jam left side			**3**			**2**		5		3	219	6133	0	31696	13668	13668	38981	2.9
SF 6.2 - pond habitat cover		**3**				**1**		3		3	189	5293	0	31696	11796	11796	37565	3.2
SF 7.1 - alcove jam right side			**5**			**4**	95	5		3	385	10782	0	31696	24028	24028	44782	1.9
SF 7.1 - alcove jam left side			**4**			**3**		5		3	302	8458	0	31696	18848	18848	41881	2.2
SF 7.2 - alcove jam	**5**	**1**	**2**			**5**	32	5		5	486	13601	0	52826	30311	30311	69307	2.3
SF 9.2 - alcove jam	**3**		**1**			**3**		8		3	249	6973	0	31696	15540	15540	40397	2.6
SF 9.3 - cross jam					**4**	**4**	400	8	2	1	403	11277	0	10565	25131	25131	40146	1.6
SF 9.4 - habitat cover			**2**	**2**		**3**	172	8	2	2	320	8952	0	21130	19951	19951	47811	2.4
SF 9.5 - cross jam					**5**	**5**	500	8	3	1	503	14096	0	10565	31414	31414	51541	1.6

Attachment A: Scour Analysis at Large Wood Structures

Hydraulic Analysis Report

Project Data

Project Title: South Fork Ten Mile River Phase 2 – Habitat Enhancement

Designer: Karen Jamgochian

Project Date: Friday, June 16, 2023

Project Units: U.S. Customary Units

Notes: Scour analysis for vertical log anchors of large wood structures. This report is automatically created by FHWA Hydraulic Toolbox for the Bridge Scour Analysis.

Bridge Scour Analysis

Notes: The "pier" is being used to model potential scour around vertical log anchors.

Scenario: Scour Scenario

Local Scour at Piers Summary

Pier Name: Pier 1

Computation Method: HEC-18

Pier Scour Depth 4.84 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Circular Cylinder

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 8.00 ft

Velocity Upstream of Pier: 10.00 ft/s

Width of Pier: 1.50 ft

Length of Pier: 1.50 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.62

Correction Factor for Pier Nose Shape (K1): 1.00

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.00

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 4.84 ft

Scour Summary Table

Local Scour at Piers

Parameter	Scour Scenario	Units	Notes
Piers			
Pier Name	Pier 1		
Pier Computation Method	HEC-18		
Pier Scour Depth	4.84	ft	
Total Scour at Pier	4.84	ft	Longterm degradation + contraction scour + pier scour