Salmonid Habitat Restoration Priorities (SHaRP) Plan for the South Fork Eel River
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Graphic narrative of watershed processes, aspects of impaired habitat, and restoration themes produced during the day long Bull Creek Expert Team meeting. Original theme interpretation and illustration produced by Mary Burke (California Trout).

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**Glossary**

**Action Group**: A portion of a focus area. The steering team sometimes split a focus area into multiple action groups for an Action Team meeting in order to facilitate group discussion of processes and limiting factors within each action group.

**Action Team**: Agency biologists, Native American tribes, researchers, restoration practitioners, consultants, private landowners, and watershed groups with specific expertise in salmonids and their habitat in one or more of the seven South Fork Eel River focus areas. The steering team invited these local experts to collectively identify site-specific restoration treatments to address the highest-impact limiting factors and threats identified by the Expert Panel for the subject focus area. Action Team members were invited to participate in the preceding Expert Panel meeting for the subject focus area.

**Basin**: An intermediate unit of the hierarchical division of the surface water of the United States (US) as managed by the US Geological Survey and organized in the National Watershed Boundary Dataset (WBD, USGS 2013). Basin is synonymous with a 6-digit hydrologic unit (HUC-6), which are on average 10,596 square miles in size. The Eel River is a basin.

**CDFG**: California Department of Fish and Game.

**CDFW**: California Department of Fish and Wildlife, formerly known as the California Department of Fish and Game.

**CDPR**: California Department of Parks and Recreation

**CMP**: California Coastal Monitoring Program. A salmonid monitoring program led by CDFW and NMFS to track the status of anadromous salmonids in California.

**Coastal Belt**: The westernmost portion of the Franciscan complex.

**Collaborative**: The SFER SHaRP Collaborative includes the members of the steering team and all representatives of Native American tribes, researchers, restoration practitioners, consultants, private landowners, and watershed groups that participated in meetings where the problems and solutions were identified for areas within the SFER. Collaborative members also reviewed the resulting documentation and continue to collaborate with members of the steering team as on-the-ground projects are developed. These members are listed under Collaborators on the previous pages and described as the Collaborative throughout this document.

**CSP**: California State Parks, formerly known as the California Department of Parks and Recreation.
**Ecological succession:** the process of temporal change within an ecological community following disturbance.

**Expert Panel:** Agency biologists, Native American tribes, researchers, restoration practitioners, consultants, private landowners, and watershed groups with specific expertise in salmonids and their habitat in one or more of the seven South Fork Eel River focus areas. The steering team invited these local experts to act as an Expert Panel and collectively consider available information documenting the condition of salmonid habitat and the extent of human threats, culminating with each panelist rating each limiting factor and threat. Expert Panel members were invited to participate in the subsequent Action Team meeting for the subject focus area.

**Franciscan complex:** A geologic unit formed from the Jurassic to Cretaceous periods composed primarily of sandstone, shale, chert, limestone, and conglomerate.

**GIS:** Geographic information system.

**HSI:** Habitat Suitability Index. The SHaRP process considered HSI scores developed using the Ecosystem Management Decision Support (EMDS) system for the 2015 South Fork Eel River Watershed Assessment (CDFW 2014).

**HUC-12:** The smallest unit of the hierarchical division of the surface water of the United States (US) as managed by the US Geological Survey and organized in the National Watershed Boundary Dataset (WBD, USGS 2013). HUC-12 is synonymous with sub-watershed. These units average 40 square miles in size.

**Landscape-scale:** The scale at which natural processes or anthropogenic impacts affect an entire sub-watershed or sub-basin.

**NMFS:** National Marine Fisheries Service.

**Reach & Reach Code:** A segment of stream, typically between 1-3 km, delineated by CDFW for surveying purposes and inclusion in the California Coastal Monitoring Program (CMP) sampling scheme. Each CMP reach has a unique numeric code (Reach Code). The steering team sometimes created new reaches and reach codes (using the same mythology as for CMP) when an Action Team identified a restoration treatment for an un-delineated reach.

**SFER:** South Fork Eel River; a sub-basin of the Eel River located in southern Humboldt and Northern Mendocino counties, California.

**SHaRP:** Salmonid Habitat Restoration Priorities.

**Sheet flow:** continuous flow of water, often stormwater runoff, over soil or rock surfaces which is not confined by a channel, rill, or gully.
**Steering Team**: A standing group of CDFW and NMFS staff that organized, guided, and documented the South Fork Eel River SHaRP process. NMFS members included personnel from NMFS’ West Coast Region, the NOAA Restoration Center, and CDFW (Region 1) that are responsible for coordinating recovery and monitoring populations of anadromous salmonids and their habitat along the North Coast of California.

**Sub-Basin**: An intermediate unit of the hierarchical division of the surface water of the United States (US) as managed by the US Geological Survey and organized in the National Watershed Boundary Dataset (WBD, USGS 2013). Sub-basin is synonymous with an 8-digit hydrologic unit (HUC-8), which are on average 16,800 square miles in size. The South Fork Eel River is a sub-basin of the Eel River.

**Sub-Watershed**: The smallest unit of the hierarchical division of the surface water of the United States (US) as managed by the US Geological Survey and organized in the National Watershed Boundary Dataset (WBD, USGS 2013). Sub-watershed is synonymous with a 12-digit hydrologic unit (HUC-12), which are on average 40 square miles in size. Hollow Tree Creek is a sub-watershed.

**Treatment Type**: Description of a commonly-understood physical modification or structure used in restoration of salmonid habitat.

**USGS**: United States Geological Survey.

**Wailaki**: Native American tribe of Athapaskan-speaking peoples residing within the Eel River basin in parts of Humboldt and Mendocino counties.

**Watershed**: An intermediate unit of the hierarchical division of the surface water of the United States (US) as managed by the US Geological Survey and organized in the National Watershed Boundary Dataset (WBD, USGS 2013). Watershed is synonymous with a 10-digit hydrologic unit (HUC-10), which are on average 141 square miles in size.

**Yager terrane**: late Cretaceous stratigraphic deposit in the Coastal Belt of the Franciscan complex, consisting primarily of argillite, sandstone, and conglomerate.
Executive Summary

The need to set restoration priorities

Over the past 150 years, Pacific salmon and steelhead populations across the West Coast have declined to the point of requiring protections. In California, many of these species have been listed under the California Endangered Species Act (CESA) and the federal Endangered Species Act (ESA). Much of this decline is due to widespread loss and degradation of aquatic habitat due to various human activities, including development and agriculture, logging and ranching, road-building and creation of fish-passage barriers.

The National Marine Fisheries Service (NMFS)’s and the California Department of Fish and Wildlife (CDFW)’s respective salmonid recovery plans describe the many actions needed to recover the Southern Oregon/Northern California Coast (SONCC) Coho Salmon, California Coastal (CC) Chinook Salmon, and Northern California (NC) steelhead in the Eel River that are listed as threatened. Given the large scale of the area described in the plans, they don’t provide the level of detail needed by practitioners to prioritize, plan, and implement meaningful habitat restoration at the project and stream-reach scale.

The vast scale of landscapes in need of watershed and fish habitat restoration, and broad scope of recovery plans, has often led to diffuse implementation of restoration projects across the landscape. While each individual project is often effective at improving conditions at the project site, the benefits of combined watershed-scale restoration efforts are often not realized given the space between projects. The resources needed to address watershed-scale impacts across the landscape outweigh those available. The Salmonid Habitat Restoration Priorities (SHaRP) process provides for a structured collaboration between representatives of resource agencies, Non-Government Organizations, California Native Tribes, academia, restorationists, landowners, and land managers to collaboratively identify the most important, reach-scale restoration actions to address first within an area of importance for salmon and steelhead recovery.

About the Salmonid Habitat Restoration Priorities (SHaRP) Process

SHaRP is a collaborative process that brings together government resource agencies, the restoration community, local experts, and landowners/stewards to collectively determine the reach-scale restoration treatments needed to address the most pressing aspects of impaired watershed processes that degrade salmon and steelhead habitat. SHaRP builds upon the restoration actions described in recovery plans for these species, resulting in a reach-scale restoration plan with broad support from the organizations and individuals that participated in the process. Additionally, recovery actions described in state and federal recovery plans must be completed elsewhere to achieve recovery of listed species, and we encourage concurrent, continued pursuit of these actions outside the focus areas identified through SHaRP.
Pillars of SHaRP

The SHaRP concept arose during conversations between NMFS and CDFW about how to best facilitate implementation of actions in recovery plans. There are key concepts, or pillars, that define SHaRP as a process and are essential to its successful implementation. The pillars describe what makes SHaRP, SHaRP, and should be used to determine whether future efforts are consistent with the SHaRP concept.

Figure ES-1. The pillars of the SHaRP process.

**Strength:** SHaRP identifies the areas with the best potential to be the source populations necessary for widespread recovery of a species across its range, and prioritizes actions that will improve habitat in these areas and therefore bolster these populations.

**Focus and Scale:** The best way to recover species quickly is to focus dollars and effort on locations and treatments that will have the most impact. SHaRP brings a finer, site- or reach-scale focus to recovery actions identified in agency recovery plans.

**Community:** SHaRP is a product of collaboration between the community of individuals that know a river: Agency biologists, Native American tribes, researchers, restoration practitioners, consultants, private landowners, and watershed groups.

**Agency Alignment:** The resource agencies are deeply involved and aligned in SHaRP efforts, resulting in agency agreement with the premise and need for the resulting projects.

**Multi-species:** All threatened and endangered salmon and steelhead occurring in the watershed are explicitly considered in the SHaRP process.
Science: SHaRP is driven by sound science. Decisions are based on collective consideration and discussion of the best available regional data, applicable literature, and the knowledge of local experts.

Decision: It is essential to make decisions, while acknowledging uncertainty, rather than waiting until the ideal information is available.

SHaRP in the South Fork Eel River

The SHaRP process was first developed and applied in the South Fork Eel River (SFER) sub-basin. The 690 square mile SFER flows into the Eel River in northwestern California approximately 170 miles north of San Francisco Bay. Recovery of the SFER populations of salmon and steelhead is necessary for recovery and eventual delisting of these species. CDFW’s SFER Watershed Assessment (CDFW 2014), which contains comprehensive data describing watershed conditions and thematic recommendations for actions to restore watershed processes and salmonid habitats, was a critical element of the success of this pilot effort, along with recent surveys, analyses, and observations from Collaborative members.

The South Fork Eel River SHaRP Collaborative

The SHaRP planning process leverages all available data and expert knowledge and opinion in a transparent and collaborative process to provide site and reach scale recommendations for restoration efforts. The SFER SHaRP pilot was led by a steering team made up of NMFS and CDFW representatives. The SFER SHaRP Collaborative includes the members of the steering team and all representatives of Native American tribes, researchers, restoration practitioners, consultants, private landowners, and watershed groups that participated in meetings where the problems and solutions were identified for areas within the SFER. Collaborative members also reviewed the resulting documentation and continue to collaborate with members of the steering team as on-the-ground projects are developed. These members are listed under Collaborators on the previous pages and described as the Collaborative throughout this document.
The South Fork Eel River SHaRP Process

Identification of Focus Areas

The SFER contains 19 sub-watersheds. The steering team compiled information that described the condition of salmonids and their habitat, as well as the extent of human impacts, in each of these 19 sub-watersheds, and scored each based on the compiled information. After gathering input on these rankings through a series of public meetings, the steering team affirmed the seven top scoring sub-watersheds and designated these as the SFER SHaRP focus areas (Figure ES-2). The SFER SHaRP focus areas, from north to south, are Bull Creek, Redwood Creek, Sproul Creek, Indian Creek, Standley Creek, Hollow Tree Creek and the South Fork Eel Headwaters (Figure ES-3).

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1 SHaRP processes occurring outside the SFER may be structured differently, as partners, the size of the area, and the extent of past planning may vary. As long as a process fulfills the pillars of SHaRP, it is a SHaRP process.
Figure ES-3: The SFER in relation to the mainstem Eel River, showing the 19 sub-watersheds evaluated during the SHaRP process. The focus areas are outlined in red.
All seven focus areas share certain attributes, which contributed to their higher scores: all occur on the western side of the basin (Figure ES-3), support populations of all three salmonid species, include areas of suitable habitat and potential to expand/improve suitable habitat, include land owners that are generally conducive to restoration planning, and have potential to maintain or improve suitable water quantity and quality.

**Collaborative Decision-Making**

For each of the seven focus areas, the steering team and other Collaborative members familiar with the focus area compiled, presented, and collectively considered all available information relevant to a reach-scale evaluation of habitat within the area. In a one-day meeting, this Expert Panel individually scored habitat conditions and human impacts, then collectively identified those that most limited salmonid populations there, which constituted the problems to solve. The same people then convened as an Action Team in a separate day-long meeting to determine the reach-scale restoration solutions to the habitat problems, which often relied on restoring watershed processes. There was one Expert Panel meeting and one Action Team meeting for each of the seven focus areas. Afterward, the steering team drafted seven action plans based on Expert Panel and Action Team discussions.

**Restoration themes**

Over the course of fourteen meetings, three general restoration themes emerged as important across many of focus areas.

The theme that drove conversations for every focus area was the overriding, urgent need to increase the complexity of instream and off-channel habitat, generally through addition of substantial amounts of large pieces of wood to streams, which will provide the necessary structure for hydrologic processes that form and maintain salmonid habitat. Summer rearing habitat needs are best met with deeper pools and enhanced in-channel structure. Winter habitat should be enhanced by structural elements that promote backwatering and reconnection of the channel to its floodplain.

A second theme was the need to reduce delivery of fine sediment to channels and to manage sediments within channels, which led to two types of restoration treatments. For reaches where an Action Team determined it was important to reduce input of fine particles from surrounding land, it identified the need to assess and treat the contributing road network and historic skid trails. To manage sediment within channels, the Action Teams generally called for placement of wood or other structure to direct flow to scour fine sediment from pools, or to sort sediment and hold back coarser particles.

The third theme was how much reduced water quantity and quality limit summer rearing potential for Coho Salmon and steelhead. The quantity of summer habitat is largely limited by stream temperature maxima, wetted channel length, and the duration of pool connectivity. These factors are influenced—if not driven by—the amount of water in the stream as the summer progresses. All
are positively influenced by restoration treatments that keep more water in the stream by restoring the connection between surface water and groundwater and increase the ability of stream banks to hold water through the summer months. Large wood is once again a key element of such restoration treatments.

How to use this plan

This document describes the SHaRP process and its pilot application in the SFER. Chapter 1 introduces the reader to SHaRP as a new collaborative endeavor, provides a rationale for focusing restoration actions, explores important principles that guided the restoration planning, and presents SHaRP as a process that may be used to focus watershed restoration in other watersheds. Chapter 2 describes the process steering team used to select focus areas of the SFER for further SHaRP planning, including public engagement. Chapter 3 describes the processes and tools used during Expert Panel and Action Team meetings and the treatment types the Action Teams considered. Chapter 4 describes the geophysical processes of the SFER sub-basin that we considered throughout the SFER SHaRP planning effort, explores historic and current land use patterns, and considers potential interactions between these processes and patterns in the context of salmonid recovery. Chapters 5 to 11 are the Action Plans for the seven focus areas. Each Action Plan describes the natural and anthropogenic history of the focus area, the problems identified during the Expert Panel meeting, and the reach-scale restoration solutions identified during the Action Team meeting (including a table and map of specific recommended projects). This plan is available for download here: https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
SHaRP is the acronym for the Salmonid Habitat Restoration Priorities process. SHaRP engages local experts to identify the most important, reach and site-scale salmon and steelhead habitat restoration actions to initiate in the next 10 years. SHaRP uses a collaborative decision-making process based on the best available information.

The SHaRP process was initiated jointly by the National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NMFS’s West Coast Region and Restoration Center), Northern California Office, and Northern Region 1 of the California Department of Fish and Wildlife (CDFW) (the agencies). The agencies are charged with conservation and recovery of threatened species under their respective jurisdictions. SHaRP was developed and piloted in the South Fork Eel River (SFER) sub-basin of the Eel River, in northwestern California. The SFER SHaRP pilot was led by a steering team made up of NMFS and CDFW representatives. The SFER SHaRP Collaborative, which created this document, includes the members of the steering team and all representatives from other local, state, and federal agencies, restoration organizations, tribal governments, environmental consulting companies, and landowners that participated in one or more Expert Panel meetings (where the major problems in a sub-watershed were identified) and Action Team meetings (where the restoration solutions for those problems were determined).

### Why the South Fork Eel River?

This watershed was selected due to the following important aspects:

- It plays a key role in salmonid recovery, as described in the respective recovery plans for Chinook Salmon, Coho Salmon, and steelhead
- Many landowners are willing to host habitat restoration projects
- Numerous restoration practitioners have been working in the watershed for decades
- A wealth of data is available that describes salmonid abundance and distribution, aquatic habitats, and watershed conditions, most collected by CDFW in support of their South Fork Eel River Watershed Assessment (CDFW 2014). The Collaborative relied heavily on the information compiled and analyzed in that document. We encourage the reader to review the watershed assessment prior to any project planning effort in the SFER; it can be downloaded at this location: [http://nrm.dfg.ca.gov/FileHandler.ashx?DокументID=175820](http://nrm.dfg.ca.gov/FileHandler.ashx?DокументID=175820)

### The Need for SHaRP

Pacific salmon and steelhead (*Oncorhynchus sp.*) have experienced a marked decline in abundance over the past 150 years. The federal Endangered Species Act addresses the protection of plant and animal species
whose populations are dwindling to critical levels.

Across the West Coast, 28 Evolutionarily Significant Units (ESU) and Distinct Population Segments (DPS) of salmon and steelhead are listed as threatened or endangered under the federal Endangered Species Act (NMFS 2019).

The California Endangered Species Act (CESA) (Fish and Game Code §§ 2050, et seq.) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the CDFW. Two species of Coho Salmon are listed under the California Endangered Species Act (CESA), including SONCC Coho Salmon (CDFG 2004). The agencies work with federal, state, and local partners in California to rebuild populations of salmon and steelhead through a range of approaches, with habitat restoration as the foremost on California’s north coast. This work seeks to repair damage done to coastal wetlands, streams and rivers. Projects are targeted at restoring the diverse habitats that these fish use at the various stages necessary to complete the salmonid life cycle.

The agencies have respectively authored recovery plans for each species of salmonids in California listed as threatened under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA). Recovery plans are “roadmaps to recovery”- comprehensive, non-regulatory documents that describe all the recovery actions needed to rebuild the target species to the point of recovery, when it no longer requires the protections provided by ESA/CESA. Recovery plans are generally written for a single species because the species are listed individually under these laws.

These recovery plans are intended to be used by anyone interested in recovering the target species. The scale of salmonid recovery plans in northern California is relatively broad, given that they address all recovery needs throughout a species range. For example, the Southern Oregon Northern California Coast (SONCC) Coho Salmon recovery plan describes the 41 populations of Coho Salmon ranging from California’s Mendocino County to Oregon’s Curry County that make up the SONCC Coho Salmon Evolutionarily

Some examples of local experts in the Collaborative:

- Agency fishery biologists that carry out salmonid monitoring every winter in the Sproul Creek sub-watershed.
- Invested landowners that have lived in the SFER watershed for decades.
- A State Parks ecologist working to protect remaining redwoods in the floodplain of Bull Creek.
- A timber company with large holdings in the area.
- A Native American tribe that has inhabited the SFER for millennia.
- A consulting geologist that designed a large-scale road-decommissioning project in the Standley Creek sub-watershed.
- Active non-profit organizations that have designed and implemented restoration projects throughout the watershed.
Significant Unit. Accordingly, the area described in a recovery action in northwest California is often a sub-basin (such as the SFER) or in some cases a sub-watershed (such as Hollow Tree Creek in the SFER). For each of these populations, the recovery plan lists the actions needed for the population of the subject species in a respective watershed. Listed actions can be numerous and may take decades to complete. It is important that recovery plans provide this comprehensive list as these actions are key to articulating how to ultimately delist a given species.

Habitat restoration, however, happens at a finer spatial scale than even the sub-watershed – such as at the scale of single site or a stream reach - and has a short planning horizon of up to 10 years. In addition, habitat restoration projects often consider multiple species simultaneously. Those interested in carrying out restoration-related recovery actions in California must consult the recovery plans but often ask the resource agencies for more specific guidance. Typically, inquiries surround site specific restoration needs and priorities in the context of population recovery (i.e. where are these restoration actions needed and what are the most important tasks to start with to increase fish numbers?). SHaRP planning is intended to provide these details.

The agencies recognize that people living in the watersheds, who have spent time studying or observing a particular area, have invaluable knowledge and insights that are key to determining:

- The most pressing problems to address first
- The best forms of habitat restoration (treatments) to address those problems
- The best reaches to apply these treatments

The agencies developed the SHaRP process to engage local experts, including their own staff, to take the planning to a finer scale within a watershed. By identifying an agreed-upon list of specific projects (treatment + location), an interested party can then develop projects and seek funding to carry them out.

By facilitating consensus of and collating recovery actions, this plan provides opportunities for multi-project collaborative funding and permitting efficiencies. We encourage stakeholders, funders and permitting entities to collectively work toward accomplishing the actions identified in this plan in order to directly affect salmonid population recovery trajectories.

The Pillars of SHaRP

The concept of SHaRP developed during agency conversations about how to best facilitate implementation of actions in recovery plans. Along the way, the agencies articulated key concepts, or pillars, that define SHaRP. These pillars guide SHaRP as a process and are key to its successful implementation. Since the SFER SHaRP is a pilot, the agencies expect it to be applied in other places to focus restoration efforts. Each analysis will be place specific and data and partners will vary. The following pillars illustrate fundamental components of the SHaRP process that we recommend be applied in future SHaRP efforts.
**The Strength Pillar:** A condition common to many species in decline is local extirpation of isolated or dependent populations, resulting in range contraction with a few areas of relative population strength remaining. SHaRP identifies the areas that currently have the best potential to be the source populations necessary for more widespread recovery of a species’ range and prioritizes actions that will continue to bolster these populations. We recognize that recovery of species is much more likely if we maintain the necessary seeds (See Salmon in Space section in Chapter 2).

**Focus and Scale Pillar:** SHaRP brings the recovery plan’s actions to a much finer, site or reach-level scale, culminating in specific projects that target a particular limiting factor. Given restoration dollars are limited, the best way to recover species quickly is to focus dollars on locations and treatments where they will have the most impact.

**Community Pillar:** SHaRP is a community planning effort. The agencies guide the process, but do not dictate or determine the outcomes. NGOs, landowners, restorationists, tribes, and fisheries and habitat experts (the Collaborative) all contribute throughout the process. For maximum engagement in the process and utility of the ultimate plan, it is critical that decisions are made in an open and transparent process.

**Agency Alignment Pillar:** SHaRP builds on agency recovery plans and watershed assessments. The agencies are heavily involved and aligned in SHaRP efforts, and as a result they agree with the outcomes of the process. Proponents seeking to implement
projects identified in the plan are assured the agencies agree with the premise and need for those projects.

**Multi-Species Pillar:** All threatened and endangered salmonid species occurring in the watershed are explicitly considered in the SHaRP process, although a single species may determine selection of the watershed where SHaRP is applied.

**Science Pillar:** SHaRP is driven by sound science. Decisions are based on the available regional data, applicable scientific literature, and the knowledge of local experts.

**Decision Pillar:** It is essential we make decisions, while acknowledging uncertainty, rather than waiting to make decisions until the ideal information is available. We proceed understanding recovery is a process, learning and adapting along the way as projects are implemented.

**California’s North Coast Salmon Project and Cutting the Green Tape Initiatives**

In 2019, CDFW launched a new initiative, the North Coast Salmon Project (NCSP), to expedite and enhance efforts to recover the threatened and endangered Coho Salmon on the North Coast of California. NCSP staff have been integral to the SFER SHaRP process and have initiated SHaRP in four other areas of the Northern California coast: the Lower Eel River, coastal streams in Mendocino County, the Russian River in Sonoma County, and Lagunitas Creek in Marin County. Together, these five pilot applications of SHaRP will demonstrate how this flexible model can be applied at different spatial scales, with varying levels of existing data and differing levels of prior partner engagement and watershed planning.

Simultaneously, CDFW, the NCSP, and other agency partners are engaged in a California Natural Resources Agency initiative known as “Cutting the Green Tape” (CGT) (California Landscape Stewardship Network 2020). Through discussion and coordination with the restoration community, CDFW is developing and adopting permitting and grant administration efficiencies to promote restoration of California’s diverse ecosystems, with an initial focus on the NCSP areas. This initiative will include a focused Proposition 1 Proposal Solicitation Notice (PSN) that will direct funding specifically towards restoration projects within the five NCSP areas listed above (including the SFER). This focused PSN and initial, associated permitting efficiencies will be released in the summer of 2021, and will focus resources to fund and permit projects described in this document. By facilitating permitting and infusing funding into priority areas, CDFW hopes to reverse the rate of species decline and restore California’s treasured natural fisheries and aquatic resources in these locations.

**SHaRP in Action in the SFER**

The SFER SHaRP pilot began with the formation of an agency steering team to guide the process. This team was composed of salmonid recovery, restoration, monitoring, and GIS specialists from CDFW and NMFS. The steering team gathered and summarized information on fish and human population
distribution, landscape character and disturbance, and aquatic habitat quality. The steering team used this information to rank the relative potential of SFER sub-watersheds for recovery and solicit stakeholder input to the decision making.

After defining the sub-watershed focus areas, the steering team identified and gathered an Expert Panel to review existing data on habitat quality and identify limiting factors and threats in each sub-watershed. The steering team then organized experts, restorationists and landowners into an Action Team to translate limiting factors and threats into site and reach-level restoration treatment prescriptions.

Lastly, the steering team organized the authorship of this document by the SHaRP Collaborative, which includes all of the local experts that participated in the process through the Expert Panel and Action Team meetings.
2. Chapter 2: Selection of Focus Areas

The SHaRP approach is based on the concept that focusing restoration in areas where steelhead and salmon still persist offers the best potential for making measurable progress toward recovery overall, and toward specific recovery needs for particular areas. The concept of larger populations maintaining a source of colonists for occupying vacant habitats, and those populations demographically connecting and supporting each other as metapopulations is well established in ecology and shown graphically in Figure 2-1. (Levins 1969, Hanski and Gilpin 1996).

![Diagram of types of metapopulations and emigration from occupied to unoccupied areas](Figure_2-1.png)

Figure 2-1. Diagram of types of metapopulations and emigration from occupied to unoccupied areas (Levins 1969, Hanski and Gilpin 1996).

Whether a species can persist in a patch or not depends on the quantity and spatial configuration of habitat within a network of connected patches. Under metapopulation models, patch occupancy is dynamic and governed by local colonization and extinction processes (Hanski et al. 1998). As habitat loss, degradation, and fragmentation are among the most serious threats to Pacific salmon, the metapopulation concept has been embraced in salmon conservation and management (Schtickzelle and Quinn 2007, McElhany et al. 2000). Salmon recovery efforts should focus not just on restoring...
habitat but also on the proximity of habitat to sources of potential colonists. As a first principle, the strongest local populations are then the most critical watersheds to secure and recover in the short term to ensure proximal habitats have the potential to be colonized over the longer term when suitable habitat becomes available. These strategies are rooted in the idea of ‘protecting the best first’ and expanding restoration outward (Beechie et al. 2008). The SHaRP process is guided by this principle to focus limited salmonid recovery dollars in patches with the highest potential for recovery of salmonids and build out restoration from these core areas. Therefore, the first step of the SFER SHaRP pilot effort was to identify the patches with the highest potential for recovery of salmonids. This chapter describes the process the steering team followed to compare the 19 United States Geological Survey (USGS)-delineated Hydrologic Unit Code (HUC) HUC-12 sub-watersheds that make up the SFER sub-basin and determine which to select for further detailed planning. Figure 2-2 depicts the SHaRP process steps, including where and when the collaborative leveraged best available science, with the first box, outlined in red to demonstrate where we are in describing the process. We also use this figure in the following chapters to highlight where subsequent aspects of process are described.

Figure 2-2. The South Fork Eel River SHaRP process, with emphasis on selection of the focus areas.
Selecting Focus Areas

The steering team compiled and evaluated data from across the South Fork Eel River (SFER) sub-basin that described the condition of salmonids and their habitat, as well as human impacts. Only data sources available for all or most of the 19 HUC-12s were included. Metrics were developed for each data source, and each metric was assigned to one of four categories inspired by Bradbury et al. (1995): Biological Importance, Habitat Condition, Optimism and Potential, and Integrity and Risk. The team used an iterative process to assign weights to each metric and added qualitative scoring criteria to account for important aspects for which data were not available.

For each category, each contributing metric was ranked relative to the distribution of values for all sub-watersheds such that the highest metric is given a percent rank of 100 and the lowest metric is given a percent rank of 0. Rank-weighted scores were then assigned by quartiles; metrics with a percent rank of 75-100 were given the highest score of 4, metrics with a percent rank of 50-74 received a score of 3, etc. These rank-weighted scores were then adjusted to account for confidence in the data. Where data was of questionable quality or representation, a confidence multiplier (1.25-0.25) could be applied to either increase or decrease the effect of that metric on the overall ranking process. An adjustment for confidence occurred only seven times in this process. All metric scores were then totaled and a final adjustment was applied to weigh the final score for each category. The scores for each category were then summed to provide a final score for each HUC-12 sub-watershed.

Data used for each category outlined in Bradbury et al. (1995), associated processing, and description of any final adjustments are described by category below. Appendix A details the data used in the SHaRP process.

Biological Importance

The steering team summarized publicly available data on the current distribution and spawning density of salmonids as a ranking metric for the biological importance of each HUC-12 watershed. Current estimated Chinook and Coho Salmon and steelhead distribution was based on data collected from a variety of sources: CDFW, NMFS, private timber companies, university research, local watershed stewardship programs, and various stakeholders. This data has largely been compiled and available in CDFW’s Biogeographic Information and Observation System (BIOS). The total length of stream (km) within the current distribution of Coho Salmon (Christy 2016), Chinook Salmon (Gavette 2005), and steelhead (Christy 2012) were summed for each HUC-12 sub-watershed. The total length of stream within Coho Salmon and steelhead distribution was adjusted based on CDFW staff assessment of the most up-to-date salmonid distribution. Some values were also adjusted to reflect removal of mainstem Eel River distribution because in most instances this habitat was used for migration rather than spawning or rearing. Chinook Salmon values were not adjusted in this way because this species uses the mainstem Eel River for spawning and rearing.
Adult salmonid spawner density was primarily determined using the CDFW CMP Adult Salmonid Spawning Ground Surveys completed annually since 2010. The CMP is designed to describe the regional status of Coho Salmon in coastal watersheds including the SFER (Adams et al. 2011). Coho Salmon, Chinook Salmon, and steelhead redd density (redds/km) from 2010-2016 (Starks and Renger 2016) were standardized by year (z-scored) and the mean redd density across all years for each HUC-12 sub-watershed was used as the final contributing metric. Standardizing by year ensured that the random samples drawn for surveying each year were fairly represented by the relative strength of each year’s salmonid return. Redd surveys followed CMP protocols and targeted Coho Salmon, so results for Chinook Salmon and steelhead are incomplete. As suggested by Bradbury et al. (1995), Biological Importance was weighted twice as high as the other categories of data to reflect the focus on salmonids in this process.

**Habitat Condition**

The steering team assembled habitat data available from SFER Watershed Assessment (SFER WA) (CDFW 2014) and CDFW habitat inventories. The SFER WA included watershed-wide ranking of stream habitat suitability for Coho Salmon using a combination of available data and professional judgment (CDFW 2014). The length of streams (km) which were ranked as either “High Quality” (i.e. relatively undisturbed habitat with the range and variability of conditions necessary to support species diversity and natural salmonid production) or “High Potential” (i.e. diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia) were summed for each HUC-12 and used as a contributing metric. Additionally, the SFER WA also included habitat suitability index (HSI) scores from an Ecosystem Management Decision Support (EMDS)-based analysis of CDFW habitat typing surveys completed in the 1990s and 2000s. Outputs of the EMDS-based analysis that were used as metrics in the SHaRP ranking process included overall HSI scores, canopy cover scores, pool depth scores, pool shelter scores, and pool tail-out gravel embeddedness scores. Standardized score values ranged from -1 (fully unsuitable) to 1 (full suitable) and HUC-12 scores are based on a length-weighted mean of the reach scores within each sub-watershed (i.e. longer reaches have more influence on the average than shorter reaches). Number of pieces of large woody debris (LWD) per stream kilometer from CDFW surveys, compiled by CDFW Fortuna for 2009-2010 and UC Hopland for 2002-2008 were also used as a contributing metric. The number of pieces of LWD in both size classes (6-20 ft. long and >20 ft. long) were summed for each surveyed reach and the final HUC-12 sub-watershed scores were based on a length-weighted mean of the reach scores within each sub-watershed.

The steering team also utilized modeled data including the Intrinsic Potential model (IP model; Agrawal et al. 2005) and the NorWeST stream temperature model (Chandler et al. 2016) to rank the current physical habitat available to salmonids based...
on methods utilized in the Nehalem Strategic Action Plan process (2020). Both models were used to subset stream reaches which were ranked as “anchor-sites,” meaning that they are expected to support all life stages of Coho Salmon. Anchor sites have mean August temperatures <17.8° degrees (NorWeST model) and either: A) 1-3% gradient with valley width of 40-100m or 100-500m; or B) 0-1% gradient with valley width of 500-1000m or 1000-4000m (IP model). The length of stream (km) which met these criteria were totaled for each HUC-12 sub-watershed and used as a contributing metric. An important adaptation from the methods used in the Nehalem SAP process was that calculations for “high-value terraces” were not included due to the lack of LiDAR data across the SFER watershed.

Optimism and Potential

The steering team summarized data to characterize the inherent potential of a watershed to support salmonids and the history of support for restoration. The likelihood values (0 – 1) available from the IP models for Coho Salmon, Chinook Salmon, and steelhead (Agrawal et al. 2005) were first categorized into three rankings: “High” (1 – 0.66), “Medium” (0.65 – 0.33), and “Low” (0.32 – 0.00). Stream lengths (km) with “High” and “Medium” IP likelihood values were then summed for each species in each HUC-12 sub-watershed and the total linear length of stream for each species and rank was used as a contributing metric. Several HUC-12 sub-watersheds included in the analysis included portions of the mainstem Eel River. IP values from the mainstem portions of the Eel River were removed from this analysis.

Data on the presence of mélange geology was also used to characterize the inherent hydrology of a watershed. Mélange layers are relatively impermeable, have a shallow depth of weathered bedrock, and store very little ground water leading to streams with naturally low summer base flows (Hahm et al. 2016). Watersheds with high percentages of mélange geology are typically vulnerable to desiccation during drought and more prone to impacts from water diversions which in turn makes salmonid populations in these streams more vulnerable to perturbations and environmental stochasticity. Based on geologic mapping data available from Langenheim et al. (2013), the percentage of mélange geology in each HUC-12 watershed was used as a contributing metric.

Land ownership was summarized to represent the conservation potential of each watershed. The area (km²) of land within each sub-watershed that is public, owned by a timber company, or designated as tribal land were all summed within each HUC-12 sub-watershed and represented as a percentage of the total watershed area. We used data compiled in the SFER WA which had a broad definition for the "Timber Company" category to capture the numerous small landowners that participate in timber operations (CDFW 2014). These lands are assumed to have a higher conservation potential than other land ownerships due to environmental regulations and conservation objectives typically associated with the ownership types listed above. Additionally, we used parcel size as an index of habitat.
fragmentation and potential for water diversions. The mean parcel size for each sub-watershed was calculated from GIS data compiled for the SFER WA (CDFW 2014) and used as a contributing metric.

The steering team also added an “Other Considerations” scoring criteria to Optimism and Potential to account for community support and past financial commitments made within each watershed. The steering team assessed each sub-watershed in three categories: 1) the history of community support for watershed health; 2) the financial resources devoted to past restoration actions; and 3) the presence of landowners with significant holdings in a sub-watershed and receptivity to restoration and conservation. By default, each HUC-12 sub-watershed received 1 point towards “Other Considerations” with additional points awarded based on expert opinions and professional judgement. If expert opinion of a sub-watershed indicated high, moderate, or low value in a category, an additional 0.15, 0.08, or 0.0 points were awarded for that category, respectively. This increased the overall score for Optimism and Potential by up to 1.45 points.

**Integrity and Risk**

The steering team summarized data to characterize the apparent anthropogenic threats and disturbances across the landscape of each sub-watershed including water temperature, road density, population density, and land ownership. Both measured and modeled temperature data were used to assess the amount of suitable cold-water habitat available for salmonids. The percentage of stream miles of small to medium-sized streams (drainage area <300 sq. km) with measured Mean Weekly Maximum Temperature (MWMT) less than 20 degrees Celsius was used as a contributing metric for each sub-watershed. This metric was calculated from the Eel River Recovery Project (ERRP) database of 1980-2015 stream temperatures in the Eel River basin which was compiled from multiple sources (Asarian et al. 2016). The NorWeST stream temperature model data (Chandler et al. 2016) were used to calculate the length of stream with mean August temperatures less than 17.8 degrees Celsius in each HUC-12 sub-watershed and used as a contributing metric. Temperature thresholds were developed based on a literature review of temperature requirements for rearing juvenile Coho Salmon (reviewed in Asarian et al. 2016).

Road networks often contribute large amounts of sediment to the SFER or cause large land disturbances that lead to sedimentation of waterways (Stillwater Sciences 1999). The steering team summarized available road data to characterize this threat. Source data was compiled by CalFire from various sources, including topographic maps and timber harvest plans (CDF 2015). Road density was calculated as the miles of road per square mile of land for each HUC-12 sub-watershed and used as a contributing metric. It should be noted that many unmapped roads exist for areas that have not had timber harvest plans filed in several decades and the steering team was not able to account for this.
Population census and parcel data were used to characterize the threats associated with increasing human population size including land development, increased water demands, and habitat fragmentation. We used census data from the 2010 U.S. Census which was first modified to better characterize the wildland-urban interface and effects of human development on natural areas (Radeloff et al. 2005). The census blocks were first intersected with each HUC-12 watershed boundary using the ArcGIS intersect tool (ESRI 2017). The population density (persons per km$^2$) reported for each census block was then converted into the count of persons for each census block using the new partial-block area. The population density for each HUC-12 sub-watershed was then calculated as the sum of persons within each sub-watershed divided by the respective sub-watershed area. This population density was then used as a contributing metric. Land ownership, which was categorized as private, non-timber company land per the SFER WA was used to characterize the potential for land development and water extraction. The percentage of land within each sub-watershed that fell into this category was summarized and used as a contributing metric.

The steering team incorporated an Integrity and Risk scoring adjustment to account for undocumented water diversion pressure which has been estimated to substantially impact dry season flow (Bauer et al. 2015). The steering team reviewed the Integrated Resource Water Management Plan’s data set of registered diversions and found it to be deficient of most water diversions. In lieu of a quantitative evaluation, the steering team used information on human population, land sub-division, and expert opinion of marijuana cultivation impacts. This adjustment was based on professional judgement and expert opinion of the perceived diversion pressure within each sub-watershed. Each sub-watershed received a default adjustment of 1 and a reduced score of either 0.5 or 0.75 depending on the perceived severity of water diversion pressure. This adjustment score was then multiplied by the sum of the previously described contributing metrics (after accounting for rank and confidence), effectively reducing the final Integrity and Risk score by 25 or 50% for each sub-watershed with moderate to severe diversion pressure, respectively.

The results of the steering team ranking process are depicted in Figure 2-3. Scores ranged from 136.5 for Hollow Tree Creek to 49.5 for the Upper East Branch. The top seven ranked sub-watersheds were as follows: Hollow Tree Creek, SFER Headwaters (Elder Creek), Indian Creek, Sproul Creek, Bull Creek, Redwood Creek, and Standley Creek.
The steering team presented the initial results of the sub-watershed ranking process at public meetings in Bayside, Laytonville, and Briceland, California in late 2017. We held two meetings in Briceland to maximize the opportunity for public input. At these meetings, the steering team described the SHaRP process and sought input on the preliminary sub-watershed ranking results. Meeting participants were neutral to supportive of the SHaRP concept and generally agreed with the team’s preliminary selection of focus areas. A few participants suggested other data to include in the ranking, and the team explained that these data didn’t fit the criteria for inclusion because they did not apply to all 19 sub-watersheds. Participants didn’t suggest any other changes to the preliminary ranking methodology or results.

**Results of Focus Areas Selection**

After the public meetings, the steering team finalized the SFER SHaRP focus areas which
are, from north to south: Bull Creek, Redwood Creek, Sproul Creek, Indian Creek, Standley Creek, Hollow Tree Creek, and the SFER Headwaters. This last area was originally called Elder Creek after the name of the HUC-12, but ultimately renamed because the HUC contains many other important tributaries in the headwaters area. The location of these focus areas within the SFER sub-basin is shown in Figure 2-4.

All seven focus areas are on the west side of the SFER (Figure 2-4). This outcome reflects the spatial distribution of areas with high underlying potential for salmonid habitat in the SFER. In addition, it is influenced by the geologic and hydrologic drivers of salmonid habitat potential (detailed in Chapter 4): the underlying geology on the west side can hold water through the dry summer months that result from the region’s Mediterranean rainfall patterns, while differing geology on the east side has less water-holding capacity; and dry season coastal fog moderates temperatures and helps support west side redwood/Douglas fir forests. The distribution and relative abundance of Coho Salmon and steelhead, which was explicitly accounted for in scoring, may reflect generational success in those west-side areas where summer rearing is more successful.

After the focus areas were selected, the steering team began planning for each of the focus areas. This planning started with identifying the known “experts” with experience in a particular focus area, inquiring of these experts who else should be included, and holding an Expert Panel and Action Team meeting for that focus area. These important steps in the process are described in Chapter 3. The steering team came to refer to all the people that participated in at least one of the Expert Panel and/or Action Team meetings (which included the steering team members) as the Collaborative.
Figure 2-4. The 19 HUC-12 sub-watersheds of the SFER. The seven sub-watersheds shown in red were selected for further restoration planning using SHaRP and subsequently described as focus areas.
3. Chapter 3: Identifying the Problems and Restoration Solutions in Each Focus Area

The Expert Panel and Action Team meetings were designed to provide the maximum opportunity for Collaborative members to evaluate the available data and local observations and determine the best course of restoration in each focus area. There was one Expert Panel meeting and one Action Team meeting for each of the seven focus sub-watersheds ultimately chosen (see Chapter 3). These fourteen, one-day meetings took place over approximately one year. To begin, the steering team identified community members known to have experience in a sub-watershed. These people, along with the steering team members, comprised the participants of the Expert Panel and Action Team meetings. The Expert Panel and Action Team often included all the same people; these names describe the major task those people completed during a particular meeting. During Expert Panel meetings, panelists discussed and ranked the limiting factors and threats in a focus area. Then, during the Action Team meeting, participants defined the actions to be taken to address the most severe limiting factors and threats identified in the first meeting. Specifically, they identified each restoration treatment needed and the reach-scale locations where it was needed. Each location of a prescribed restoration treatment was listed as a “project”. The steering team used the rankings and project information developed during these meetings to draft a comprehensive restoration plan for each
Expert Panel: Identifying the Problems

Once HUC-12 sub-watersheds were identified for strategic restoration actions the steering team identified experts with specific salmonid habitat restoration experience or knowledge of the selected sub-watersheds. Experts consisted of agency biologists, Native American tribal members, researchers, restoration practitioners, private landowners, and watershed groups with specific expertise in salmon and their habitat needs. Experts were invited to attend an all-day meeting to present and discuss relevant data, observations, and studies related to the following: Native American land management, historic watershed conditions, European settlement, changing land management practices, contemporary land management, current research, habitat and salmonid monitoring data and trends, and current restoration practices. Experts were then tasked with identification of factors limiting salmon habitat productivity and threats to the persistence of these species. The Expert Panel then ranked the severity of various limiting factors and threats in that specific sub-watershed, as shown in Figure 3-3.

In preparation for each Expert Panel meeting, the steering team organized a set of maps presenting monitoring data and features of the watershed. Features were mapped at the smallest scale possible, generally at the scale of the Coastal Monitoring Program (CMP) salmon spawning ground survey reaches (1-3km). Where survey reach delineations had not been developed for the CMP, similarly sized and numbered reaches were added to create a simple, consistent location reference system. Geomorphic features included bedrock/soil type, landslides, stream gradient, and valley width. Biological conditions included the extent of known fish distribution for each species, features limiting distribution, and density of redds from spawning ground surveys. Physical stream habitat features comprised the following: ratings of pool depth, pool cover, substrate embeddedness, canopy cover, and density of large wood pieces as well as modeled and measured stream temperatures, expert opinion of stream potential to provide refugia, and the quantity of anchor sites. The final set of maps depicted land ownership, road networks and registered water diversions. In some cases, additional data (e.g. summertime streamflow) was contributed by watershed experts. Expert Panel members were provided all maps for peer review prior to the meeting to identify errors or additional data sources that could be valuable to identifying limiting factors and threats. Examples of these maps are located in Section 2 of this document within each sub-watershed chapter.

The Expert Panel meetings began with an introduction to the watershed and a general concept of the pre-colonial stream conditions followed by subsequent colonization, changes in land use, and alterations in watershed processes through the modern day. When available, local Native American tribal members presented their perspective of traditional land use and management. A history of the anthropomorphic impacts to the
watershed followed, describing the sequence of resource extraction and associated watershed degradation. This information set the stage for a review and discussion of contemporary data and watershed processes affecting instream habitat conditions, often informed by additional presentations from Collaborative members on specific restoration or research projects they had carried out in the focus area. Ecological processes such as stream shading, large wood recruitment, erosion and sediment transport are dynamic. These processes are best understood within the context of a watershed’s historical and contemporary conditions before setting goals for its future trajectory. A conceptualized life-history model of anadromous salmonids was then presented to explore how and when various portions of the steam network may be used by fish in different life-stages, how stream habitat features may be used, and what they may be lacking. This life-history model (displayed and explained on pages 3-4 and 3-5) helped guide important discussions and assisted participants in the subsequent ranking exercise.

**Life Cycle Model**

Pacific salmon and steelhead exhibit complex life histories that utilize nearly every portion of a river network, balancing risks with rewards; however, many of the habitats these fish have evolved to use have been drastically altered. Each life history faces its own challenges and risks, from habitat degradation in small tributaries to cumulative effects of watershed processes, estuarine conditions, from variable ocean productivity to predation and competition with other native and invasive species (Good et al. 2007). Given the wide range of habitats and ecological conditions that salmon and steelhead encounter, identifying the restoration actions that will most effectively aid in recovery can be extremely challenging. Understanding the life stages most susceptible to particular environmental conditions; from egg deposition in headwater stream gravels to rearing conditions through multiple seasons with various and complicated stressors, to migrations across contrasting environmental gradients has been the focus of salmonid ecology for decades.

Collecting information to inform restoration planning at any given site, reach or sub-watershed, however, can be daunting given the data requirements, resources, time scales and uncertainty in human understanding of the true nature of the river systems.

Life Cycle Modeling is a paradigm used to help to organize and understand the pressures salmon are exposed to during their life cycle (Roni et al. 2018). While there are many different flavors of salmon Life Cycle Models, they all share a similar structure and goal. In general, they organize a life cycle into subcomponents of both space and time and attempt to understand the magnitude of transition rates (movements and survival) between time periods and areas in a watershed and productivity rates (growth) achieved during each time step. By organizing the life history components of salmon and steelhead in this way, restoration planners can begin to leverage the decades of scientific inquiry into the relationships between salmon habitat and population dynamics. While Life Cycle Modeling can take a quantitative form of using data driven
values of fish survival modeled as a function of habitat values and density dependence (i.e. stage based stock-recruitment), a much more generalized and conceptual model of Coho Salmon was used in the SHaRP process (Figure 3-2). We felt that Coho Salmon, a species that spends at least one year rearing in nearly every part of a watershed, adequately represent the habitat requirements of all salmonids of the SFER and that actions to support Coho Salmon life stages would also benefit the other species despite the apparent diversity among species.

A large body of scientific literature and studies were used to inform the creation of a generalized Life Cycle Model for Coho Salmon (Figure 3-2), and then habitat data was evaluated by the Expert Panelist and Action Teams in the context of the model. While much of the data was discussed in the light of the Coho Salmon conceptual model, all species and life stages were considered separately in a limiting factors analysis to develop hypotheses about which habitats and locations were hindering salmonid production. Using the available data and expert knowledge of each focus area in the context of the conceptual model, treatments to address the hypothesized limitation were recommended in the most appropriate locations.

![Generalized conceptual Life Cycle Model of Coho Salmon](image)

**Figure 3-2.** Generalized conceptual Life Cycle Model of Coho Salmon used in the SHaRP process to organize hypotheses about limiting habitats and salmon life phases in the South Fork Eel Watershed. The y-axis describes the spatial use of habitat through a salmonid's life history from headwater streams of a natal tributary through the mainstem, estuary and Pacific Ocean. The x-axis depicts time in seasonal steps. Salmonids grow and move through time and space with differential growth and survival experienced at every transition.
Expert Panel: Identifying the Problems

The final step of the Expert Panel meeting was to rank the various limiting factors and threats. Prior to the Expert Panel meeting, the steering team developed a list of the limiting factors and threats relevant to the subject area, which was informed by the recovery plans. The steering team also identified areas within each sub-watershed that tended to differ in the conditions and threats present (e.g. headwater tributaries, mainstem tributaries, and the mainstem) in relation to the life stages of Coho Salmon, Chinook Salmon, and steelhead. During the Expert Panel meeting, the team described large paper tables that reflected these limiting factors, threats, life stages, and areas. In many cases, these tables were modified during the meeting (prior to scoring) to reflect nuances identified by the panelists during discussion. Panelists independently ranked the impact of each limiting factor on each life stage in each area, and each threat on each life stage in the entire sub-watershed. Panelists used a five-step categorical ranking from least to greatest impact to score the impact of each limiting factor. The most severe impact received a score of 1 and the least severe impact a score of 5. Once the rankings were complete, the steering team immediately compiled the data and presented the results to the group. Panelists then discussed the group’s collective rankings (Figure 3-3). If the panel believed that a limiting factor or threat was incorrectly ranked, a discussion of how the ranking was incorrect followed until a consensus could be reached. The meeting concluded once a consensus on the most severe limiting factors and threats was reached. The steering team summarized the final rankings using the mean score for each limiting factor and life stage and coalesced the results into consolidated tables (Figure 3-3).

Action Team: Developing Restoration Solutions

Expert Panelists for a particular focus area were subsequently invited to a second meeting to prescribe restoration actions to address the limiting factors and threats with the most severe impacts on the three salmonids. The steering team identified a set of generalized restoration treatments used to address various physical/biological processes that the Action Team used as a common toolbox. When a unique or novel restoration action was identified, it was described and documented along with the other treatment recommendations. The Action Team broke into small groups to suggest restoration treatments that addressed the most severe limiting factors and threats for distinct reaches within each action group. Using the available data, treatments were recommended where they would be most likely to be effective at improving habitat or watershed processes. For example, the Expert Panel identified instream complexity as a very high-impact limiting factor for summer rearing parr in a portion of a sub-watershed.
Figure 3-3. From top to bottom: (1) Expert Panel members discuss and rank limiting factors for individual life stages in specific areas of a sub-watershed using. (2) The results of Expert Panel ranking for migrating adult salmonids in the Bull Creek sub-watershed. Each black spot represents a panelist’s vote and the rows within each limiting factors are ordered according to severity (1-5). The top row (red) is most limiting and each vote receives a score of 1 and the bottom row (blue) is least limiting and each vote receives a score of 5. (3) The summarized results of Expert Panel ranking for all life stages of Coho Salmon and steelhead in the Bull Creek sub-watershed as presented in the watershed chapters (Chapters 5–11). The mean scores are presented in the center of each cell and cells are colored according to their respective score (1.0-1.9 = red, 2.0-2.9 = yellow, 3.0-3.9 = light green, 4.0-5.0 = dark green).
In response, the Action Team recommended adding large wood for summer rearing to a low-gradient headwater stream reach in this area. This reach may have adequate spawning gravel, is frequented by spawning adults, but lacks pools deep enough to persist over the summer. Existing pools may lack adequate complex cover and provide little refuge from predation. Large wood additions to this reach should scour pools and provide complex cover for rearing juvenile salmonids.

Similar to the mapping of spatial data, restoration actions were generally prescribed at the scale of spawning ground survey reaches. When site-specific information or expert knowledge was available specific actions were prescribed at precise locations (e.g. LiDAR data used to identify split channels for off-channel overwinter habitat improvements). These restoration actions were prioritized such that the actions could be implemented over a ten-year time-frame and yield the greatest benefit to salmonids. For many of these recommendations, specific project locations and the methods of implementation will require further investigation and site-specific designs. Bear in mind, a great deal of restoration planning is on-going in the SFER and SHaRP, where appropriate, encourages utilizing these already developed or nearly developed site plans.

Once every Action Team member had the opportunity to identify and review restoration treatments in each action group the steering team member who facilitated the action group presented the restoration treatments to the team. A discussion of the proposed restoration treatments followed and if there was concern regarding a particular treatment or lack of treatment, discussion ensued until a consensus could be reached. The meeting was concluded once the Action Team reached a consensus on which restoration treatments would address the high and very high-impact limiting factors and threats.

**Treatments to Address Limiting Factors and Threats**

The following describes the treatment types that the various Action Teams prescribed for their areas. The chapters for each of the focus sub-watersheds, which are the last seven chapters of this plan, refer to these treatments. The treatments are designed to improve a specific aspect of habitat conditions for one or more life stages of particular salmonids.

**Upslope Hazard Assessment/Treatment**

There are many ways in which sediments from upland slopes enter waterways, many of which are normal processes of a healthy, functioning watershed. The extent to which upslope soil particles become suspended sediment depends, in part, on properties of the landform (e.g. geology, slope, etc.), but also on disturbance activities such as timber harvest, road construction, and fire (Figure 3-4). Assessments would seek to understand the cause of acute sediment delivery locations and determine which actions to reduce excessive sediment delivery are appropriate. Potential treatments include the following: landslide stabilization, stream bank stabilization, upslope erosion control with mulching (Figure 3-5), revegetation in the riparian zone and upslope, check dam construction to control gully erosion,
waterbar construction to control erosion from unpaved roads, and exclusionary livestock fencing.

A complete road assessment would provide landowners with a prioritized list of actions to improve the road network and how to make those improvements.

**Sediment Reduction**

Sediment reduction refers to treatments addressing sources of sediment which have been assessed and identified as priority actions to improve stream habitat. Site specific treatments are typically recommended in the associated assessments, such as a road network assessment or upslope hazard assessment.

Elevated turbidity resulting from fine sediment becoming entrained in the water column can directly harm salmonids by smothering redds, reducing fertilization rates, abrading gills, and causing stress (Lake and Hinch 1999, Greig et al. 2005, Zimmermann and Lapointe 2005, Galbraith et al. 2006). It can also influence salmonid behavior, ecological interactions, and ultimately reduce the growth and fitness of rearing juveniles (Bisson and Bilby 1982, Berg 1983, Berg and Northcote 1985, Newcombe and MacDonald 1991, Korstrom and Birtwell 2006, Shrimpton et al. 2007). Turbidity can be reduced by treating anthropogenic sources of sediment including roads, stream crossings, and land disturbances (Figure 3-5).
Figure 3-5. Decommissioning roads re-establishes natural hydrology and prevents erosion, reducing the amount of sediment delivered to waterways. The roadbed above has been outsloped and mulched, grass seed, and woody slash material has been applied to rebuild and stabilize soils. CDFW

Riparian Treatment

Riparian treatment includes the application of silvicultural treatments and revegetation efforts. The long-term goal (decades to centuries) of riparian treatment is to restore properly functioning riparian zones that provide bank stability, streamside shading, and large coniferous trees that could be recruited to watercourses from senescence, channel avulsion, or land sliding. Many riparian zones in northern California have been clear-cut along with adjacent hillslopes and tall, large-volume coniferous trees are either exceptionally rare or non-existent. In addition to the clear-cut timber harvesting, many northern California watersheds were significantly degraded by two very large floods (1955 & 1964) that compounded the impacts of the unregulated timber harvesting often converting coniferous forest riparian zones to deciduous hardwood stands dominated by red alder.

Treatments in riparian zones generally fall into one of three categories.

1. In coniferous riparian zones with a high stem density, selective felling of trees with intermediate or co-dominant crown positions to favor trees with dominant crown positions will accelerate tree growth to heights and volumes that will function as sources of deep stream shading as well as key pieces and other large wood.

2. In some watersheds harvesting practices converted coniferous forest into hardwood dominated stands. In hardwood dominated stands treatments may include both silvicultural methods that favor established coniferous trees as well as thinning of hardwoods and planting of coniferous trees.

3. The final treatment is the planting of riparian zones to establish riparian vegetation and stabilize stream channels. In many cases establishment of early seral species such as red alder or willow is the first step in a succession of treatments (Figure 3-6).

Each of these riparian treatments may be viewed as a reflection of the continuum of degraded stream conditions with concomitant additional decades of recovery.
Chapter 3: Identifying the Problems and Restoration Solutions

Flow Enhancement

Flow Enhancement refers to treatments which improve the quantity and/or quality of the summer surface flow of a stream as measured by flow volume and temperature. Although other chemical properties of stream flow may be considered to improve water quality, there are no common restoration treatments for non-point source chemical pollutants to tributaries of the SFER other than community outreach and education. Instream water quantity and quality are addressed with a diversity of strategies including treatments that restore natural hydrologic processes and engineered structures that directly enhance stream flow and temperature. The variety of treatments reflects the geomorphic, hydrologic, and anthropogenic diversity of the South Fork Eel River sub-basin, and the fact that the properties of surface water are the cumulative result of water's movement through the landscape.

Improve Temperature

Maintaining cool temperatures during hot, dry summer months is essential to juvenile salmonid survival. Riparian vegetation reduces solar exposure and ensures surface water remains cold (Beschta 1997, Roth et al. 2010, Garner et al. 2017). Improving riparian cover in key locations with appropriate plantings can drastically decrease stream temperatures (Garner et al. 2017) (Figure 3-6). Temperature can also be affected by heterogeneity in depth and stream structure that allows subsurface flow (e.g. hyporheic flow) (Poole and Berman 2001, Hester et al. 2009). Instream structures, such as log jams and beaver dams (or beaver dam analogs) that impound coarse sediments and form deep pools create thermal heterogeneity and can improve groundwater infiltration (Lowry 1993, Hester et al. 2009). This can help ensure cold water refugia and stream flows persist through the arid Mediterranean summer. Additionally, projects to improve groundwater infiltration through off-channel impoundments may be considered in suitable locations. Off-channel ponds and reservoirs can be used to store winter precipitation to supplement summer stream surface water. Diverting outflow from these storage areas through the ground can ensure that these sources remain cold year-round, cooling downstream habitats during critical months.

Observed and model temperature data were categorically summarized according to temperature requirements for Coho Salmon and steelhead, of which the latter tend to have higher temperature thresholds (Richter and
Kolmes 2005, Asarian et al. 2016). Summary statistics including Maximum Weekly Maximum Temperature (MWMT) and mean August temperatures were used to represent the maximum temperatures salmonids may experience for prolonged times (> 1 week). Generally, treatments to address temperature were recommended in reaches where temperature summary statistics exceeded suitability thresholds for Coho Salmon (>18°C; Richter and Kolmes 2005, Asarian et al. 2016). Although steelhead can tolerate higher temperatures and the availability of food may moderate temperature requirements for Coho Salmon, the steering team felt it was most appropriate to make recommendations to improve conditions for the most temperature-limited species to maximize the rearing capacity for all salmonids and provide a buffer against climate change environmental stochasticity.

**Improve Flow Volume and Duration**

Salmonids rely on persistent summer flows as a source of food and habitat. If streams become disconnected during flow recession, food supplies may become limited and juvenile salmonids may lose the ability to migrate, which leaves them more prone to predation, stranding, disease, and other stressors. Treatments to improve dry season flow are primarily based on reducing water diversion pressure through water use management, education, and outreach to ensure that the impacts of summer water withdrawal are minimized (see section below). However, instream structures such as beaver dams or beaver dam analogues can improve groundwater inundation and lengthen the dry season hydroperiod (Westbrook et al. 2006). Furthermore, off-channel pond and reservoir storage, as described above, can be used to capture winter precipitation and directly supplement instream flows during summer.

**Water Use Management, Education and Outreach**

Considering the importance of water quantity and quality to salmonids and other aquatic resources, human-related activities may cause significant impact to water availability for these resources. In populated watersheds, the ongoing challenge of low water flows requires proactive steps to keep more water in the rivers, tributaries, and streams so that people and fish have enough to survive. Water conservation treatments should be designed to engage rural landowners and stakeholders in a coordinated, community-led water conservation effort. Communicating with residents about the natural resources in their area and encouraging best management practices for water use, such as storage and forbearance, will enable voluntary community actions to improve dry season flow. Voluntary water conservation programs, such as those in the Mattole River watershed have demonstrated the effectiveness of community-based efforts to minimize water consumption and maintain
stream flows during summer/early fall dry periods. In addition to water conservation efforts, treatment types should also include examining equipment and infrastructure where water is wasted or needlessly lost. Many water users may have poorly designed and/or leaky water infrastructure which continuously diverts off-channel sources such as springs. Relatively simple updates and technical assistance could improve/update existing infrastructure to ensure water conservation.

**Addition of Large Wood: Where and Why?**

Clearing of large wood from stream channels (Bryant 1983) and the anthropogenic modification of riparian forests that have slowed the natural recruitment processes has resulted in a deficit of large wood in tributaries to the SFER (CDFW 2014). Restoring riparian and upslope processes impacted by past practices is necessary to ensure long-term recruitment of wood to the stream channel. The time scale of riparian forest maturation to the point where natural large wood recruitment is sufficient to offset transport and decay is on the order of decades to centuries (Boyer et al. 2003). As fish populations are facing local extirpation at much shorter time frames, many stream rehabilitation efforts now involve the supplemental addition of large wood to streams to restore habitat forming processes beneficial to stream biota over the shorter term (Davidson and Eaton 2013). The abundance of large wood, and the role that large wood plays in channel formation, varies across drainage networks (Abbe and Montgomery 2003, Wohl and Scott 2017) to create the diverse habitats necessary for salmonids at different life stages. Geomorphic processes and channel characteristics vary with spatial position in a river network, transitioning from constrained headwater colluvial reaches to confined then unconfined alluvial reaches (Frissell et al. 1986, Bisson et al. 2006). These characteristics govern water flow, sediment inputs, and the capacity of streams to store and transport sediment and organic matter (Hynes 1970, O’Neill et al. 1986, Pennak 1979, Vannote et al. 1980). Large wood interacts with the intrinsic characteristics of valley segment slope, channel width: depth ratio and sediment supply to force a stream morphology that differs from a free-form morphology that would result in its absence (Montgomery and Buffington 1997). Because both large wood function in channel processes, and fish habitat needs differ across the drainage network and fish life history stages, SHaRP treatments utilizing large wood are separated into various types. The treatment types attempt to coalesce our understanding of watershed stream network morphology, current watershed process and stage of stream channel evolution in response to disturbance (e.g. Cluer and Thorne 2014) with habitat needs across salmonid life history stages. SHaRP treatment categories attempt to tailor the restoration action to the localized physical and biologic potential with consideration of the larger watershed processes (Beechie et al. 2010, Abbe and Montgomery 2003). Large wood within channels most often provides multiple and interactive benefits to channel process and habitat formation. Large wood treatment categorization described in this plan is a tool to communicate the intended process-based
restoration outcome relative to inferred fish habitat limiting factors of the stream reach.

**Large Wood Addition for Sediment Retention**

Sediment budgets within stream channels are governed by rates of input, transport and channel storage (Swanson et al. 1982, Buffington et al. 2004). Large wood plays a critical role in the transport rate and storage of sediments within stream channels (May and Gresswell 2003, Faustini and Jones 2003). In smaller, higher-gradient alluvial channels, in-channel sediment deposition generally occurs upstream of channel spanning wood accumulations increasing bed elevations (Gurnell et al. 2002) (Figure 3-7). Large wood additions in these reaches can aggrade incised channels and hydrologically reconnect the channel to the floodplain and create step pool longitudinal profiles that further dissipate stream energy (Figure 3-7).

![Figure 3-7](image)

**Figure 3-7.** Large wood additions perpendicular to flow in active stream channels are intended to trap gravels, connect floodplains, and dissipate stream energy with step pools. Large wood has accumulated sediment and raised the bed of a severely incised channel (left) and improve floodplain connectivity (right). CDFW

One of the most important characteristics of in-channel sediment for spawning salmonids is gravel size, with optimal range from small gravel to cobbles (Kondolph and Wolman 1993). Large wood within streams create heterogeneous water velocities that sort sediments (Powell 1998) to provide salmonids with spawning habitat (Buffington et al 2002). In the SFER tributaries, most of the salmon spawning occurs in moderate 2-3% gradients in relatively small drainage area reaches (Starks and Renger et al. 2016). Presumably, these high use areas exhibit local basin physiography (channel width to depth, hydrologic regime) to support the formation of habitat amenable to spawning. In these channel segments where salmon spawning is currently occurring (or would be expected to occur given channel segment morphology if habitat was suitable), large wood augmentation should strive to increase hydraulic roughness, promote bar formation
and sediment storing or sorting. Bankfull spanning large wood perpendicular to stream flow create steps that trap sediment upstream of the log, while also creating vertical plunges that dissipate stream energy and sort gravels in pool tail outs below. Flow-deflection jams are common natural wood jams in this size channel and function to create channel complexity with bank scour, and areas of both sorted sediment deposition and scour (Abbe and Montgomery 2003).

**Large Wood Addition for Summer Rearing**

Pool formation, depth, and size largely depend upon channel type, in-channel sediment storage and quantity of flow obstructions. The flow obstruction created by in-channel large wood affects the frequency of alternating patterns of scour and bar formation, increasing the number of pool-riffle sequences (Collins and Montgomery 2002, Buffington et al. 2002). Summer rearing juvenile Coho Salmon and steelhead prefer deep pool habitats associated with cover (e.g. Rosenfeld et al. 1999, Lonzarich and Quinn 1995). An increase in frequency of pool-riffle sequence can homogenize invertebrate drift across habitats (Leung et al. 2009) and large wood addition has been shown to increase invertebrate taxa richness and biomass (Miller et al. 2010) that increase forage opportunities for juvenile salmon (Nielsen 1992).

![Figure 3-8. Large wood additions which have scoured a deep perennial pool and created complex cover to shelter juvenile salmon. CDFW](image)

Large wood additions to enhance summer rearing conditions would influence channel morphology to increase the depth and complexity of cover in pools, increase the number of pool-riffle sequences and enhance secondary invertebrate productivity. A practical example of large wood placement intended to create summer habitat would be large wood with attached natural boles inserted into the active channel that create scour during high water, leaving a pool during summer that is associated with root wad cover (Figure 3-8). These benefits cannot be realized, however, in reaches that perennially de-water during summer or where stream temperatures surpass salmonid tolerances.
**Large wood for In-Channel Winter Habitat.**

Winter habitat is a bottleneck for Coho Salmon (see opposing text box). Small headwater stream reaches are characterized as being more constrained by steeper valley walls, though notable exceptions to this paradigm do occur in SFER tributaries (e.g. upper Redwood Creek tributary to Hollow Tree Creek, upper Dutch Charlie Creek). In these more confined reaches, in-channel large wood supplementation is one of the few strategies available to augment habitat. In-channel large wood in bankfull-spanning configurations tend to collect smaller wood pieces, creating low-velocity pools upstream of the jam at a range of stream flows (Figure 3-9).

**Figure 3-9. Large wood improving in-channel winter habitat in a confined stream. CDFW**

**Winter habitat: A bottleneck for Coho Salmon**

Overwinter survival has been identified as a critical limiting factor influencing population abundance of Coho Salmon (Tschaplinski and Hartman 1983, Quinn and Peterson 1996, Huusko et al. 2007, Nickelson and Lawson 1998) in the Pacific Northwest. Density dependent mechanisms appear to set overwinter habitat capacity for Coho Salmon in California streams (Gallagher et al. 2012, Ricker and Anderson 2011). Coho Salmon overwinter habitat is characterized by complex, low-velocity habitats (Tschaplinski and Hartman 1983, McMahon and Hartman 1989, Quinn and Peterson 1996, Johnson et al. 2005). The target of large wood restoration projects introduced to increase overwinter habitat is to create larger and deeper pools and facilitate the interaction of winter flow with the floodplain. This ultimately provides low velocity refuge across a range of stream discharges (stages) where juvenile salmonids can shelter both in the stream channel during winter base flow and access adjacent, newly connected floodplains at elevated stages (Bustard and Narver 1975, McMahon and Hartman 1989, Bradford et al. 1995, Cunjak 1996, Bair et al. 2019). Because basin geomorphology and size impose a large control over the types of slow water winter habitats, SHaRP includes two treatment types: in-channel and off-channel that both target creation and enhancement of winter habitat through different channel and flow altering mechanisms.
In-channel winter habitat structures would tend to incorporate multiple pieces and may include ‘bole down’ placements to create complex cover areas in the eddies that form behind these structures during higher discharge. In-channel wood treatments are often indicated in areas where spawning, and rearing also occur, and therefore are important to the concept of ‘natal’ life-history pathways (see SHaRP Conceptual Salmonid Life-History Model).

**Large Wood for Off-Channel Winter Habitat**

As watershed size increases, valley widths tend to increase and channel gradients decrease. Wider valley morphology lends to more channel migration, meanders and split channels which, over time, can lead to backwaters that inundate during elevated stream discharge. Large wood supplementation in these areas seeks to take advantage of these features and enhance their benefit to salmonid habitat. Large wood can be used to inundate existing channel features and/or provide flow velocity refugia in channel features that become inundated during higher stream stages.

![Figure 3-10. A large wood jam on the mainstem of this stream (right side of photo) forces higher winter flows to inundate the surrounding floodplain (dry channel on the left side of the photo). CDFW](image)

**Barriers**

**Man-Made Barriers**

The most frequently encountered man-made barriers in the SFER are culverts and road crossings. Culverts often create temporary, partial, or complete barriers for adult and/or juvenile salmonids during their freshwater migration activities, and the cumulative effect of blocked habitat in Northern California streams is likely significant (Bates 1999, Ross Taylor and Associates 2005). While numerous culverts and road crossings have been modified for suitable fish passage in the last decade or so, there are a remaining number of them that are impeding or hindering fish passage within the basin.

**Natural Barriers**

Natural barriers, including wood debris jams, boulder cascades and bedrock falls, exist throughout the SFER. Many of these barriers are associated with knick-zones which occur as the result of regional geologic uplift
These barriers typically occur in smaller headwaters and tributaries where hydraulic power is insufficient to continue up-stream propagation of the post-uplift channel incision. For example, most of the bedrock falls in the Hollow Tree Creek sub-watershed occur within smaller tributaries just upstream from the mainstem of Hollow Tree Creek (Figure 3-11).

Wood debris jams also occur naturally and tend to form taller, more robust structures at constriction points bounded by steep valley walls or rock features. A particularly large and persistent wood jam is present in Moody Creek, a tributary of the Indian Creek sub-watershed. This jam formed at a natural constriction of the valley wall which is fortified by rock features on both banks. This jam has accumulated many pieces of large wood, cresting at a height of nearly 15 feet and accumulating hundreds of yards of sediment (Figure 3-12).

Though some of these barriers are completely insurmountable by even the highest jumping adult steelhead, some may only be partial barriers, blocking some life stages of salmonids either seasonally or completely. These are also dynamic structures that change annually as pieces of wood are either lost or gained, potentially allowing fish passage some years and not others.

Alteration, removal, and management of debris jams became a particular focus for restoration in the late 1960s through the 1980s as excessive logging debris filled streams (Bryant 1983). As poorly regulated logging activities and large storms increased the instream wood supply, many of these jams grew unnaturally large and threatened fish passage, prompting their removal. However, this theme may have been too universally applied across the landscape and many jams which had not blocked fish passage were completely removed from the
system. Instream wood is now in scarce supply and hindering habitat forming processes. Current debris jam alterations or removal must carefully consider the severity of the barrier, the species and life stages blocked, the cause of the blockage, the proximity to other barriers, the amount of upstream habitat, and the potential effects to stream morphology. If careful consideration of these factors warrants alterations to the barrier, modification should be as minimal as possible to improve passage and maintain beneficial habitat characteristics (CDFG 2010).

Alterations to natural bedrock barriers and boulder “roughs” once included heavy-handed modifications including blasting with explosives or chaining boulders to rock faces to create step pools. These methods typically had poor results and modern approaches seek to modify the barrier indirectly by raising the stream bed or water surface elevation using large wood as described above (see Large Wood for In-Channel Winter Habitat). This type of treatment would improve passage over temporal or partial barriers by effectively reducing jump heights over barriers while maintaining the natural characteristics and processes associated with the barrier.

**Beaver Dam Analogs**

Beaver dams and associated ponds directly affect stream hydrology, geomorphology, and aquatic habitats for fish. Beaver ponds, wetlands and connected floodplains slow the movement of water through the watershed system, storing water to maintain flows later into the dry season (Pollock et al. 2003, Pollock et al. 2014). Beaver dams affect stream geomorphology by trapping sediments, elevating stream beds, reversing channel incision and reconnecting channels with their floodplains (Naiman et al. 1986, Butler and Malanson 1995, Pollock et al. 2014). Beaver ponds have also been shown to directly provide excellent habitat for salmonids, particularly Coho Salmon that prefer slow water velocities, ponds and stream pools (Pollock et al. 2003). The use of human-constructed beaver dams (beaver dam analogues or BDAs) is an emerging technique for restoring fluvial ecosystems based on biomimicry (Pollock et al. 2014). The goal of this technique is to assist recovery of habitat by mimicking the effects of natural beaver dams to create habitat or conditions similar to that which would be created by a natural beaver dam. Clearly defining desired outcomes in appropriate locations for BDA development in the watershed will be key to success in any future BDA project development. The Beaver Restoration Guidebook [http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp](http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp) and the Beaver Restoration Assessment Tool [http://brat.riverscapes.xyz/](http://brat.riverscapes.xyz/) have been developed to assist restorationists interested in BDA development.

**Limiting Factors and Threats with no Restoration Solution**

For several sub-watersheds, panelists identified severe limiting factors for one or more species and life stages for which no suitable restoration treatment could be applied to directly alter the impact. These factors and threats included land conversion and development, water diversion, pollution, wet season flow, invasive predators and
competitors, and climate change. These factors were extensively discussed and, in some cases indirect treatments were recommended to address the impacts of the threat or limiting factor. However, many of these factors, especially those related to environmental stochasticity and climate, are beyond our ability to control and actions to manage invasive species need to be undertaken on a basin-scale to be effective. Furthermore, it is not within the scope of this process to enact or enforce environmental laws or regulations.

The strategies developed to indirectly relieve the impacts of these factors are based on improving habitat diversity and resilience across each sub-watershed as well as encouraging voluntary community action through outreach, education, and technical assistance. By improving overall habitat quality, restoring a diversity of complex habitat, and alleviating other stressors which are within our ability to manipulate, it is our hope that sub-watersheds will have increased capacity to buffer against climatic, ecologic, and anthropogenic impacts that cannot be predicted or controlled and will favor native species over non-native competitors. Additionally, encouraging restoration actions on a voluntary basis will improve landowner relations with the surrounding ecosystem as well as with the resource agencies charged with managing these resources.
4. **Chapter 4: Physical and Land-Use Context for Aquatic Habitat in the SFER**

**Introduction**

Successful aquatic habitat restoration requires an understanding of both the natural processes that define habitat potential under unimpaired conditions as well as the effects of anthropogenic disturbance. Considering how riverscapes once supported salmon and steelhead life histories, what changes have occurred, and how they limit these species helps us determine what conditions are attainable within existing geomorphic constraints. Evaluating the historical context of land-form and land use was fundamental to the Collaborative’s thought process as we identified limiting factors and restoration treatments. The South Fork Eel River Watershed Assessment (SFER WA) conducted by the California Department of Fish and Wildlife and Pacific States Marine Fisheries Commission (CDFW 2014) served as a basis for the sub-basin setting. Throughout the SFER SHaRP planning process, Collaborative members (including representatives of a Native American tribe, government agencies, non-governmental organizations (NGOs), landowners and universities) contributed relevant information and personal experience that, when brought together, resulted in a more comprehensive understanding of the planning area. In this chapter, we summarize the geophysical processes of the SFER sub-basin that we considered throughout the SFER SHaRP planning effort, explore historic and current land use patterns, and consider potential interactions in the context of salmon recovery.

**Attributes of the South Fork Eel River**

- Mediterranean climate characterized by dry summers and wet winters
- Principle communities: Garberville-Redway, Laytonville, Branscomb (headwaters), Miranda, Weott (confluence of SFER and mainstem Eel)
- Anadromous salmonids: Steelhead, Coho Salmon and Chinook Salmon
- Watershed statistics:
  - Eel River basin size: 3,684 square miles
  - SFER sub-basin size: 690 square miles
  - Mainstem length: 105 miles
  - Total length of stream: 683 miles
Figure 4-1. Location of the South Fork Eel River sub-basin within the Eel River Basin.
Hydrologic and Geomorphic Processes

The SFER Basin exhibits a seasonally dynamic hydrology and diverse geology. These characteristics, combined with variable micro-climates, give rise to variation in land form, plant communities, land use, and the resulting habitats that influence salmonid distribution and abundance across the basin.

Prolonged winter rains and foggy to dry summer conditions are characteristic of the climate in the SFER basin. The rainy season, which generally begins in late October and lasts through April, accounts for 90 percent of the mean annual runoff in the SFER sub-basin (Monroe et al. 1974). The dry season typically lasts from May through September. The western sub-watersheds of the SFER are strongly influenced by the coastal marine layer and are defined by morning fog and overcast conditions, whereas the inland eastern sub-watersheds become very hot and dry as the year progresses. This spatial and seasonal pattern of rainfall and runoff results in ecological challenges and opportunities that have shaped the life histories of aquatic organisms.

The concept of functional flow periods is to partition the natural flow regime into elements that support important ecosystem processes for a broad range of native taxa and assemblages (Yarnell et al. 2020). The linkage of quantifiable measures of flow regime (Patterson et al. 2020) with ecosystem process provides a framework for assessing how different flow management scenarios may result in ecologic change (Lane et al. 2017). Functional flow periods in the SFER are exemplified by the following characteristics: short but important fall flow events that initiate the wet season, elevated winter base flows punctuated by extreme peaks, followed by a period of spring recession, and finally dry season low flows through the summer (Yarnell et al. 2020) (Figure 4-2). As flow regimes have shaped salmonid ecology over evolutionary timescales, each of these periods have important implications for critical salmonid life history events. The onset of fall precipitation and its wet-season initiation trigger upstream movement of adults from the estuary to mainstem staging areas while cooling temperatures and altering water quality. Winter base flows, punctuated by storm events, result in moderate increases in discharge. This allows access to and occupation of spawning grounds. These peak winter flows also mobilize substrate, form channel features that provide habitat for salmon, and prepare spawning gravels for future cohorts (Lane et al. 2018). The spring recession is understood to be a critical period for fry re-distribution and parr growth, while the summer low-flow period can constrain juvenile salmon growth and distribution as temperatures reach annual maxima and channels may dry, limiting both habitat for rearing fish and aquatic invertebrate food production.
Combinations of flow and geomorphic attributes generate hydraulic patterns that support distinct life histories, and largely dictate the timing and spatial distribution of life history events for salmon and steelhead. Where and how animals fulfill life history requirements is largely controlled by the intersection of seasonal hydraulics and the shape and composition of the river corridor and channel. Temporal water cycles are mediated through the critical zones—the vertical extent of the Earth where water is received, stored, and released to support surface flows or vegetation. Critical zones extend from the top of vegetation canopies down to the top of unweathered bedrock, where water becomes immobile on ecological time scales (Rempe and Dietrich 2018). The western and eastern portions of the basin sit upon two distinct accreted belts of the Franciscan Complex, leading to different water holding capacities of the critical zone, timing of spring recession stream discharge and dry season stream base flow. The eastern sub-watersheds are characterized by critical zones that have poorer water holding capacities than the mélangé geology in the western portion of the SFER (Hahm et al. 2019).

The combination of geologic and hydrologic forces have sculpted a diversity of channel forms in the SFER. Guillon et al. (2019) classified seven geomorphic archetypal channel types within the SFER based on watershed contributing area, valley form and
slope, bankfull width-to-depth statistics, and substrate size distributions in an effort to categorize channels into morphological types that display distinct fluvial patterns (Figure 4-3). The seven focus areas selected through the SHaRP process for further planning occur exclusively in confined valley forms (Figure 4-3 and Figure 4-4). It is notable that the west side tributaries selected by the SHaRP process contain the majority of the gravel-cobble, bed undulating channel type which is characterized by gravel and coble substrates, high depth variability with pool-riffle sequences, and include forced bed structures (Guillon et al. 2019) that are responsive to large wood.

Figure 4-3. South Fork Eel River archetypal channel types classified by Guillon et al. (2019).
Figure 4-4. The seven sub-watersheds shown in red were selected for further restoration planning using SHaRP and subsequently described as focus areas.
Watershed History and Human impacts

Time Immemorial to mid-19th century

Native American tribes have inhabited the Eel River watershed for at least 5,000 to 10,000 years (USBLM et al. 1996). Pomo Indians and Athabascan people, including aboriginal groups of Wailaki, Sinkyone and Cahto tribes occupied the SFER. They lived in small semi-sedentary villages, moving throughout the basin to take advantage of seasonally available resources. Natural resources, such as large and small game, plants, and fish (salmon, steelhead, sturgeon, and lamprey) were plentiful throughout the basin, and the population density within the SFER Basin equaled or exceeded the density seen in other North American agricultural societies (USBLM et al. 1996). Even with this comparatively high density of people, their cumulative impact on the fisheries resources and the environment was relatively small (Yoshiyama and Moyle 2010). Based on the earliest photographs, there is support however, for the hypothesis that Native Americans managed forest structure through the use of fire in the headwaters of the SFER (Dr. Sharon Edell, personal communication, SHaRP Expert Panel, December 2020).

European arrival and settlement

The first Euro-Americans came to the SFER in the 1850s. Trappers were the first to arrive, followed by homesteaders and ranchers after the passage of the Homestead Act in 1862 (HCRCD 2002). Conflict between Native Americans and settlers between 1855 and 1865 resulted in the extirpation of a substantial population of people living in the basin. The number of settlers increased rapidly, and during this period nearly all public lands were conveyed to private ownership.

Beginning in the early 1900s, settler homesteads slowly began to transition to ranches as agriculture became one of the primary economic activities in the region. Many ranches consisted of thousands of acres of converted pasture, most of it used for intensive sheep-grazing. The land conversion from forest to pasture affected the landscape by compacting soil and forever changing the vegetation type and soil pH on vast tracts of land.

The tanbark industry was the first large-scale forest management practice in the SFER, beginning in the early 1900s and ending in the 1950s with the development of synthetic tannins (JMWM 2000). Peak production of natural tannin occurred between 1900 and 1920. Tanoak bark was peeled from trees and transported out of the area or sent to a plant in Briceland where the bark was converted to tannin extract. Stripped tanoak trees were left on the ground, and nearly all of the tanoak trees in the sub-basin were harvested during this time (HCRCD 2002).

Early logging activity in the mid-19th and early 20th century resulted in the removal of all accessible old growth redwood along the

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2 Portions of the content of this section is drawn from SFER WA, CDFW (2014).
creek mouths throughout the Subbasin. Due to the long distance between the harvest areas and larger mills near Fortuna and Humboldt Bay, many trees were used for split products such as railroad ties, shingles, and grape stakes. These split products were produced at sites where trees were felled, then transported out of the basin more easily than whole logs (O’Hara and Stockton 2012).

**Intensified logging**

Prior to World War II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all Douglas-fir in the watershed was harvested in an effort to keep up with the post-war building boom (BLM et al. 1996). Mechanized road building, log skidding and additional transportation options allowed harvesters to access remote areas with steep terrain, which resulted in an increase in logging operations throughout the basin. Roads, skid trails, and landings were often located in creeks so logs could be easily skidded downhill, and instream log ponds were constructed to preserve and transport logs further downstream. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the sub-basin (JMWM 2000).

Improvements in timber harvest techniques and equipment led to increased harvest efficiency. This new ability to harvest timber was coupled with a financial incentive to harvest quickly: in 1956, the Humboldt County Supervisors levied a tax on standing timber. As a result, most landowners were forced to harvest timber for financial reasons rather than leave it standing (O’Hara and Stockton 2012); subsequently the late 1950s and early 1960s experienced peak timber harvest.

**Forest practice regulation**

Timber harvest continued relatively unregulated until the implementation of the 1973 Z’Berg-Nejedly Forest Practice Act. This legislation established a politically appointed Board of Forestry (BOF) whose mandate was the control over forest practices and forest resources in California. The Act requires that Timber Harvest Plans (THP) be prepared by a Registered Professional Foresters (RPF) and include regeneration of forested sites. In 1993 the BOF adopted rules requiring sustained yield planning, with requirements that all forest landowners develop at least 15% late-seral-stage forests on their ownership. Although timber harvest levels have declined recently; the timber industry is still an important component of the economy and harvest rates vary with individual ownership, resource management objectives and timber product market forces.

**Floods**

Floods are natural periodic occurrences that play a major role in formation of channels and have sculpted aquatic organisms over evolutionary time scales. The effect of the floods of 1955 and 1964 in the SFER must, however, be considered in the context of the human impacts with which they coincided. During the larger and more devastating December 1964 flood, the maximum mean daily flow at Miranda was 161,000 Cubic Feet/Second (CFS) and the maximum peak flow was 199,000 CFS on December 22
while just four days before the event the SFER discharge was near baseflow at 1,180 CFS.

Prior to the 1964 flood, the SFER had just experienced an intense period of accelerated logging, where poor road construction, tractor logging and skid trails combined with largely denuded riparian and upland forests generated a catastrophic event for aquatic habitats. This event unraveled the vulnerable hillslopes, washing massive amounts of sediment into channels. During the 1964 flood, it is estimated 105 million tons of suspended sediment were transported past Scotia, near the mouth of the Eel River, during a 3-day period, compared to 85 million tons transported during the previous 8 years (Brown and Ritter 1971). Many millions of tons of gravel and logging slash was transported into stream channels. Channel capacity was thus impaired, forcing water laterally and eroding streambanks which caused large streamside mass wasting events. The result of this sedimentation was highly aggraded, wide, shallow stream channels. Much of the riparian forest that had been logged was laid bare. A large volume of the sediment from tributaries deposited at tributary mouths, disconnecting them from the mainstem. As the waters receded the tributaries cut through the gravel leaving unpaired terraces and knickpoints at ecologically important hydrologic junctions (Sloan et al. 2001). Large quantities of logging slash clogged tributary channels, storing large volumes of sediment and creating barriers to upstream fish passage.

Watershed process and channel form have experienced considerable recovery, setting watershed processes on a somewhat different trajectory. Suspended sediment concentrations declined to pre-flood levels within about 5 years (Lisle 1990). Channel beds in most tributaries scoured to stable levels in years following the 1964 flood, and are currently at or above pre-flood elevations. During channel-bed degradation, some channel geometries recovered to pre-flood arrangements with reestablishment of pre-flood channel widths. (Lisle 1982). Channels in many alluvial reaches have incised into flood deposits, however, leaving a narrower channel bounded by new riparian vegetation now disconnected from its associated floodplain. The colonizing riparian vegetation has largely locked in low-flow channel margins. The resulting riparian community is also drastically altered from the historic redwood late seral stage to primarily red alder and willow. In response to the massive loss of aquatic habitat associated with the floods, a large effort to clear debris jams and restore fish passage to upper tributary spawning reaches ensued. Through much of the 1970’s through 1980’s, the first concerted restoration efforts in the SFER focused on clearing the large volume of wood from channels (R. Gienger personal communication, SHaRP Expert Panel meeting, September 2019). While many of the large debris jam barriers necessitated clearing for fish passage, it is now recognized that this effort was too vigorous. Much of the large wood that we now understand to play a beneficial role in maintaining channel form, aquatic habitat, and sediment regulation was completely removed. In the years that ensued, the lack of large wood in tributaries to the SFER has been deleterious to channel
sediment maintenance and retention, especially in large wood forced channel types, and has resulted in reduced or simplified aquatic habitat formation in much of the basin.

**Subdivision and accelerated land-use through the green rush**

By the late 1960s, aside from preserved State Parks groves, most of the merchantable timber had been removed from the northwestern SFER basin. Land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to “new settlers”, also known as “back-to-the-landers”. Significant changes to the watershed from these activities included the development of roads to access every parcel, an increase in the number of water diversions, and collectively an increase in the total amount of water diverted from streams in the basin to supply additional residences.

Many of these “back-to-the-landers” also started cultivating marijuana, and these operations slowly expanded in both size and number. Development of this underground industry beginning in the 1970’s provided an economic boost throughout the sub-basin (JMWM 2000). Illegal marijuana cultivation proliferated through the 1980’s and 1990’s, and the illicit nature of the industry resulted in unregulated development of water resources, land clearing and grading and additional road building.

California’s Proposition 215 ballot passed in November of 1996, opening the industry to legal cultivation for medical use with limits to size of operations. These regulations proved hard to enforce and spurred the quasi-illicit operations to proliferate with little regulation. By 2002-2007, large-scale growing operations or “mega grows” started showing up on the landscape. Simultaneously, financing was readily available to anyone, regardless of their financial stability, who wanted to buy real estate. By 2010, it was estimated that nearly 80% of the nation’s cannabis came from California and most of that from the Emerald Triangle within the heart of the Eel River basin (Mathis 2020). The cannabis industry (permitted and unpermitted production) nearly doubled in area under cultivation from 2012-2016 in Northern California (Butsic et al. 2018).

The quantity and magnitude of stream diversions associated with this expansion was voluminous, increasing water temperatures, reducing flow at critical times for fish rearing and migration, and altering water chemistry across the entire basin. The unregulated road building and grading was once again impacting stream channels with excessive fine sediments.

In 2015, the Governor approved the Medical Cannabis Regulation and Safety Act and by November 8, 2016, the voters of California passed Proposition 64 -the Medicinal and Adult-Use Cannabis Regulation and Safety Act. This legislation required any person wishing to commercially cultivate cannabis lawfully in California and obtain a license from the California Department of Food and Agriculture. The regulatory framework accompanying this legislation came with environmental protections including water development, land development in accordance with state and county ordinances,
and compliance with state fish and wildlife regulations, among others.

**Salmon and steelhead decline**

The Eel River watershed historically supported a significant number of salmon and steelhead, with populations present in all major tributaries (NMFS 2014). Yoshiyama and Moyle (2010) examined commercial fishery and cannery records from as early as 1854 through 1921. Extrapolating these data to minimal population estimates, these authors estimated an average annual population of approximately 93,000 fish during this period with a peak roughly six-fold higher in 1877. Chinook Salmon represented most of this commercial catch, as the timing of river entry likely made them highly vulnerable to the netting operations in the lower river. The authors also noted, “given that the cannery records result in a very conservative estimate of Chinook numbers, the records suggest that historic runs of Chinook Salmon probably ranged between 100,000 and 800,000 fish per year, declining to roughly 50,000-100,000 fish per year in the first half of the 20th century”. The winter and summer steelhead run (combined) likely numbered between 100,000 -150,000 adults per year during the late 1800s and early 1900s. Coho Salmon numbers were less than those of steelhead; nonetheless, historic numbers probably ranged in the 50,000-100,000 fish per year (Yoshiyama and Moyle 2010).

It is estimated that by the turn of the 21st century, Coho Salmon were reduced to 6 - 15% of abundance estimates from the 1940’s (CDFG 2004). Within the entire range of Southern Oregon-Northern California Coast (SONCC) Coho Salmon, only the SFER population of Coho Salmon is thought to persist marginally above its depensation threshold (NMFS 2014).

The fish ladder installed at the former Benbow Dam at river mile 40 on the South Fork Eel River was operated from 1938 to 1976 capturing and counting passing fish. Data from the Benbow fish ladder arguably provides the most robust information on population declines. The most precipitous decline in the era of post-commercial river harvest occurred during a period when habitat conditions were significantly affected by timber harvest activities and punctuated by the catastrophic floods of 1955 and 1964 (Figure 4-5). These data show declines in populations of all three anadromous fish species from highs of 10,000-20,000 fish immediately prior to the beginning of post-WWII tractor logging in 1945, to lows of less than 5,000 fish at the end of the time series in 1976. Coho Salmon, in particular, were captured in precipitously low numbers in the last few years of ladder operation.

Contemporary data collected from 2010 to 2019 by the California Salmonid Monitoring Program (CMP) indicate Coho Salmon populations have not recovered in the past 45 years. Rather, populations appear to continue to fluctuate around disparagingly low abundances that approach the critical population depensation levels outlined by NMFS (2014). Taking incomplete CMP abundance data on steelhead and Chinook Salmon, together with anecdotal information on these species, indicates these species also continue to fluctuate around critically low
levels (Figure 4-5). Most recently, in 2018-2019, California Trout partnered with the CDFW and the California Conservation Corps to estimate Chinook Salmon entering the South Fork Eel River using a sound navigation ranging (SONAR) camera. Estimates produced with this technique placed Chinook Salmon escapement in the range of 3,150 to 4,500 fish, with slightly lower steelhead estimates between 2,500-4,000 fish (Methany in prep).
Figure 4-5. Top Panel: Counts and smoothed trend line of adult salmonids at Benbow Dam (RM 40), SFER, 1938-1976. Shaded area indicates the period of increased post WWII tractor logging, and vertical lines indicate timing of major flood occurrences, and forest management legislation. Lower Panel: Number of salmonid redds (multiplied by 2.5 to scale redds to escapement) estimated by the California Monitoring Plan and smoothed trend line.
History of Habitat Restoration

Restoration efforts throughout the SFER have been ongoing since the 1970s. Similar to other areas in the region, early efforts were largely volunteer opportunistic, and primarily addressed treating symptoms caused by unregulated land use (CDFW 2014). While well intended, much of these efforts were not optimally designed. Restoration efforts have since evolved to include a systematic approach for collecting and analyzing data, assessing watershed condition, and identifying critical issues. This information culminates in project designs that address habitat deficiencies and consider natural watershed processes.

CDFW’s Fisheries Restoration Grant Program (FRGP) was established in 1981 and has provided much of the funding for aquatic habitat restoration within the SFER and across the North Coast. During the 1980s and early 1990s, limited funds were available for the program. Restorationists primarily pursued small-scale instream habitat improvement and bank stabilization projects that were spread across the watershed and were limited in their overall effectiveness. Small cooperative fish rearing facilities and rearing pond operations were undertaken in several SFER tributaries but proved to be somewhat ineffective at producing salmonids (CDFW 2014).

As salmonid populations remained depressed in the late 1980s and 1990s, restoration organizations successfully petitioned state and federal agencies to list salmonid species under their respective Endangered Species Acts. In response to species listing and the need to organize and expedite watershed restoration to support recovery of these species, CDFW developed the Stream Habitat Restoration Manual (Flosi et al. 1994). The manual provided guidance and a systematic approach to developing and implementing restoration projects. However, funding shortfalls limited the manual’s initial utilization.

Landmark legislation passed in 1997, when Senate Bill 271 provided an additional funding source for FRGP’s watershed planning, up slope erosion control, organizational support, and monitoring categories. Furthermore, the U.S. Congress established the Pacific Coastal Salmon Recovery Fund (PCSRF) in 2000 to reverse the declines of Pacific salmon and steelhead in California, Oregon, Washington, Idaho, and Alaska. NMFS administers the program and has granted California millions of dollars through PCSRF since 2000, which CDFW has allocated through FRGP.

While the FRGP has been a significant driver in funding and guiding restoration activities, other agency funding, private funds, and numerous landowner contributions have supported a diverse array of additional restoration projects in the SFER. For example, NMFS has funded SFER projects since 2001 through its Community-based, Open Rivers and Coastal Resiliency Programs. In addition, funds available through the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (commonly known as Proposition 1) has supported restoration efforts throughout the SFER sub-basin.
Role of Restoration and the SHaRP Process

As discussed, insufficient funding and emerging watershed science shaped the initial scale and scope of restoration efforts from the 1960s to the 1990s. In the 2000s, diverse and increased funding sources allowed for expanded, more systematic restoration planning and project execution. Between 2004 and 2018, FRGP funded 112 projects in the SFER and its tributaries, totaling over 14 million dollars (North Coast Salmon Project in prep). About 70 percent of this funding supported three project types: Upslope Watershed Restoration, Instream Habitat Restoration, and Fish Passage at Stream Crossings. Upslope watershed restoration received nearly half (44%) of this funding, addressing the critical need to decommission numerous miles of old logging roads. This large-scale road decommissioning improved drainage and reduced the sediment loads entering streams. Such upslope work was essential to prevent compromising the effectiveness of future riparian and instream work.

The SFER WA compared habitat suitability indices from data collected in 1990 – 1999 to values from 2000-2010 and determined that overall habitat suitability has increased in the northern and western portions of the watershed. While it is difficult to discern the relative contribution of restoration actions, improvements in environmental regulation, and natural processes to this improvement, it is noteworthy that some aspects of habitat conditions, such as canopy cover, pool-tail embeddedness, and percentage of pool habitat are improving given the fact anthropogenic threats and stressors continue to affect surrounding areas. However, pool depth and pool shelter indices, overall, have not shown improvement, which indicates sediment inputs are on-going and instream habitat complexity is still lacking. To date, about 8% of the 275 miles of tributaries in the SFER have been treated to improve instream complexity and a smaller percentage of upland habitat has been restored since 2004 (North Coast Salmon Project in prep). Scientific literature, including Roni et al. (2010) describe the need to treat a noticeably higher percentage of a stream/watershed before a population response can be detected. Considering the size of the SFER watershed, it is evident that a significant amount of restoration is still needed.

The SFER SHaRP process culminated in identification of the highest-priority restoration projects in seven focus areas of the sub-basin, as detailed in Chapters 5 through 11 of this plan. SHaRP restoration planning utilized local expertise, advanced knowledge in watershed sciences, and improved restoration techniques to collectively; identify current barriers needing fish passage modifications, incorporate updated large wood loading target metrics (Kier Associates and National Marine Fisheries Service (NMFS) 2008) to advance large wood loading effectiveness, GIS mapping exercises to integrate potential for restoration of floodplain connectivity and identify potential winter refugia (rearing habitat); and mapping of key road networks and other significant sediment sources requiring treatment to reduce sediment input.
Resiliency in the Face of Climate Change

Over thousands of years, evolution has given rise to a diverse set of life history patterns in California salmon and steelhead. Relatively short-term environmental variability leads to certain strategies having better success than others at different times and places (Bisson et al. 2009). A diverse portfolio of life history options serves to spread the risk of mortality across a population during cyclical periods of climate anomaly or acute catastrophic events (Hilborn et al. 2003, Schindler et al. 2010, 2015) when portions of the landscape or periods within the life cycle become less productive. Climate variations include the cyclical but increasing severity of temperatures and drought (Robeson 2015) (Figure 4-6), and multi-decadal patterns of ocean productivity (Mantua et al. 1997, Mantua 2015). Catastrophic events include wildfire, floods, earthquakes, and landslides that often occur in combination.

One of the most serious threats to salmon and steelhead in the Eel River is changes to the timing and location of rainfall in the basin, and the availability and temperature of surface waters. It is widely recognized that human induced global climate change is, in part, responsible for recent changes in climatic patterns (Williams et al. 2015, Obama 2017) (Figure 4-6), and increased human demand for water likely responsible for more localized dry season deficits (Asarian and Walker 2016). Shifting patterns in the onset of the wet season, and the magnitude and timing of peak flows can disrupt the timing and upstream distribution of adult anadromous salmonid spawning and subsequent juvenile rearing distribution. The timing of springtime downstream juvenile migration, however, appears relatively invariant to local spring discharge regimes (Kelson et al. 2018), but displays larger regional scale latitudinal gradients indicative of adaptation to longer term climatic trends (Spence et al. 2014). Near the southern end of distribution in North America, SFER salmon and steelhead are at the critical edge of genotypic adaptation and phenotypic plasticity that allow population persistence through periods of rapid climate change (Herbold et al. 2018).

Collaborative members recognized that climate change contributes to many of the concerning habitat conditions and disrupted watershed processes identified in the seven focus sub-watersheds, however, it was beyond the scope and authority of the Collaborative to address the proximate causal factors of climate change (e.g. greenhouse gas emissions) through the SHaRP process. Rather, the Collaborative believes that completion of the restoration treatments identified in the following Chapters 5-11 will help to both directly address acute stressors (e.g. water enhancement and conservation, habitat complexity) as well as restore watershed processes (i.e. delivery and distribution of sediments), which will collectively contribute to an increased range and diversity of habitats necessary to support a broad array of salmon life-histories.

The concept that habitat diversity leads to resiliency is in contrast to restoration approaches that attempt to engineer instream habitats to conform to an idealized condition (Bisson et al. 2009). An idyllic but over-
simplified version of what a salmon stream ‘should’ look like may result in the loss of the life-history diversity necessary to support populations through periods of change. Recovery of habitats in the SFER sub-watersheds alone cannot address the entire suite of diverse freshwater and estuarine habitats necessary to support the complex life-histories of salmon and steelhead in the SFER. Consequently, the next SHaRP planning areas of the main-stem SFER through the main-stem Eel River and estuary are necessary, and currently underway.
Figure 4-6. Top panel displays the Mean August Air Temperature in Scotia, CA from 1930 to 2020. The middle panel displays the Annual Precipitation received by Mendocino County, CA from 1890-2019. The bottom panel displays the Palmer Hydrological Drought Index (PDHI) for North Coast Basins in California. The PDHI is a standardized index based on rainfall, temperature and soil water balance and is used as an index of longer-term drought that reduces surface and groundwater supply. The magnitude of PHDI indicates the severity of the departure from normal conditions. A PHDI value >4 represents very wet conditions, while a PHDI <4 represents an extreme drought. Blue trend lines in the panels represent a LOESS (locally weighted scatterplot smoothing) trend line and the grey envelopes surrounding the trend line indicate the standard error. Sources: [https://calclim.dri.edu/index.html](https://calclim.dri.edu/index.html) Accessed: 21 January 2021.
5. **Chapter 5: Bull Creek Action Plan**

5.1 **Sub-Watershed Overview**

Bull Creek is the northern most tributary of the South Fork Eel River (SFER) sub-basin in Humboldt County ([Figure 5-1](#)). Bull Creek is a fourth order stream with approximately 21.2 miles of perennial waterways draining a sub-watershed of about 44 square miles (Merrill and Vadurro 1999). Elevations range from approximately 160 feet at the mouth of the creek to over 3,000 feet in the headwaters. The landscape is dominated by coastal redwood forest, mixed evergreen, and coniferous forests as well as a small amount of grassland and oak woodland forest (CDFW 2014). The entire sub-watershed is owned and managed by California State Parks (CSP) as part of Humboldt Redwoods State Park. To facilitate discussion of the sub-watershed’s characteristics, the sub-watershed has been sub-divided into three areas: 1) Lower Bull Creek (mainstem and Squaw, Miller, Tepee, Harper and Cow creeks), 2) Middle Bull Creek (mainstem and Albee, Mill, Cuneo, and Burns creeks, and 3) Upper Bull Creek (mainstem and Slide and Panther creeks) (see [Figure 5-2](#) for approximate boundaries).

The lower portion of the sub-watershed was purchased to preserve old growth redwood forests in 1931, while the middle and upper portions were not incorporated into the park until after 1964. By that time, over 60% of the forests had been clear cut and the sub-watershed subsequently ravaged by two devastating floods (Jager and LaVen 1981, CSP 2020). Despite early efforts to protect Bull Creek and the surrounding forests, land use practices in the upper sub-watershed and associated flood damage have degraded aquatic conditions throughout the sub-watershed and salmonid populations have declined dramatically (CDFW 2014). Despite the ecological devastation of the mid-20th century, Bull Creek still supports Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*), albeit in drastically reduced numbers (CDFW 2014). Trends in overall salmonid habitat suitability indicate conditions are improving, likely due to resource protection and restoration actions taken by CSP and supporting conservation groups (CDFW 2014, CSP 2015). Notwithstanding recent improvements in conditions, aquatic habitat in much of the sub-watershed remains degraded from legacy impacts. Significant restoration actions are needed to accelerate recovery of salmonid populations in Bull Creek.
Figure 5-1. Bull Creek's position in the South Fork Eel River sub-basin.
5.2 History of Land Use and Fish Habitat

The underlying geology of the Bull Creek sub-watershed is dominated by an extensive zone of Yager Terrane, a layered mix of well-consolidated sandstone, argillite, and pebble conglomerate. This geologic feature forms steep, crested ridges and deep valleys that are typically deeply fractured yet stable, giving rise to soils that support lush forests such as the ancient redwood groves of the lower sub-watershed (CDFW 2014, Hahm et al. 2019). Heavily faulted and sheared areas can create zones which are locally weak and prone to landslides and erosion, especially when exposed to precipitation and other surface flow (Brown and Ritter 1971, CDFW 2014). The Bull Creek sub-watershed resides within an area with exceptionally high rates of geologic uplift as well as frequent earthquakes from the nearby faults (Merrits and Bull 1989, Lock et al. 2006). While this geology supported the growth of lush forests, land disturbances associated with unrestricted logging contributed to continuous mass wasting and the rapid aggradation observed during flood events between 1955, 1964, and 1997 (Jager and LaVen 1981, Merrill and Vadurro 1999).

The Bull Creek sub-watershed is located within Wailaki ancestral territory. Prior to European settlement, Wailaki tribal members residing in the sub-watershed depended on seasonal availability of resources including numerous edible and medicinal plants, fibers used in basketry and net making, wild game, salmon, and lamprey. The land and its abundant resources provided a spiritual connection and sustenance for tribal members. The productive timberlands and prairies of the Bull Creek sub-watershed also attracted European settlers to the area. Following the removal and relocation of Wailaki people to the Round Valley reservation in the late 1880’s, European immigrants claimed lands in the sub-watershed and established cattle ranches in the open grasslands near Albee Creek.

Ranching persisted as the dominant industry in the small town of Bull Creek until 1946 when small-scale clear cutting began. While Lower Bull Creek was purchased and protected, logging and rangeland conversion continued unabated in Middle and Upper Bull Creek until the mid-1960s (Jager and LaVen 1981). During this time, taxes levied on standing, merchantable timber incentivized the rapid and widespread harvest of timber from forest lands. By 1960, 85% of the privately held land (over 60% of the entire sub-watershed) had been clear cut. Extensive road networks were built to accomplish this feat; road densities in the upper sub-watershed were as high as 20 miles of unimproved road per square mile. Additionally, 4,000 acres of previously forested land was converted to rangeland, typically using fire. Between wildfires and intentional burning, over 8,700 acres of the upper sub-watershed were burnt by 1959 (Jager and LaVen 1981). Standard logging practices of the era included little to no protective measures for waterways and almost no erosion control or reforestation efforts.

Land disturbances due to logging activities exacerbated the slide-prone landscape and left the sub-watershed more vulnerable to erosion. When the area was struck by two devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in volumes approximately three times greater than observed in the geologic record of the Eel River sub-basin.
These large flood events drastically altered the channel morphology of Bull Creek (Jager and LaVen 1981, Pryor et al. 2011). Landslides, erosion, and unprecedented stream flows during these events severely aggraded the stream channel and floodplains and damaged the town of Bull Creek. Debris from the settlements such as portions of houses, cars, logging materials, and even coffins were transported and deposited throughout the lower sub-watershed (Jager and LaVen 1981). These floods also eroded stream banks along the portions of the stream owned by the state, taking with them over 850 of the treasured redwoods (Jager and LaVen 1981). All of the tributaries in Upper and Middle Bull Creek were filled by landslide and flood debris; the cumulative aggradation from the 1955 and 1964 events reached up to 15 feet in height in tributaries such as Cuneo Creek (Pryor et al. 2011). Subsequent sediment transport carried these sediments from the higher gradient tributaries to depositional areas in Lower Bull Creek, further aggrading the lower reaches and exacerbating erosion and loss of old-growth forest (Jager and LaVen 1981).

In response, CPS developed plans to treat key sources of sediment, minimize bank erosion, encourage sediment transport through lower stream reaches, and store large volumes of sediment in channels and control its release where appropriate. Techniques employed in the mainstem Bull Creek downstream of Albee Creek included channel clearing and shaping, flow spreading, rock gabions, revetments, groins, rock riprap, sediment retention structures, and artificial cascades. Banks lined with large rock riprap after the 1955 flood effectively withstood the 1964 flood and this treatment became the chosen strategy to protect alluvial forest in the lower reaches of Bull Creek (Jager and LaVen 1981). In addition to widespread riprap bank protection, trees that fell into the stream channel were routinely removed to reduce bank erosion potential until 1997, a practice generally referred to as “stream cleaning” (Merril and Vadurro 1999). While these efforts may have been successful in conserving the surrounding forests, they are now considered detrimental to natural river channel formation processes necessary for fish habitat formation and maintenance.

The combined effects of flood damage, logging disturbances, excess sediment yield, channel alterations to improve sediment conveyance, and wood removal (e.g. stream cleaning) have all contributed to poor stream complexity and low habitat suitability scores for salmonids in Bull Creek. Stream inventories conducted between 1991 and 2007 indicate that pool quality (a metric of both pool depth and shelter) is poor throughout the sub-watershed (CDFG 1991, CDFG 2007, Figure 5-2). This is likely due to the combination of excessive sediment delivery from land disturbance, flooding, and a lack of instream structure such as large wood³, which can scour pools and sort gravels (Figure 5-3). For similar reasons, gravel embeddedness ratings are moderate to

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³ Formally referred to as large wood debris (LWD) in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.
poor throughout the middle and lower reaches of Bull Creek, but the upper reaches have shown improvement (Figure 5-4). Stream cleaning to remove large wood has likely hindered natural recovery processes leading to poor salmonid habitat (Merrill and Vandurro 1999). While large wood densities are relatively suitable in areas of the sub-watershed with robust, mature forests, most of the reaches in Middle and Upper Bull Creek have low densities of large wood (Figure 5-3). However, it was noted that while Squaw Creek has large wood densities rated at “Excellent,” the effects of stream clearing are apparent; many instream pieces of wood have been cut, leaving only the embedded stumps and trunks left in the bank (pers. comm. Brian Starks). It is possible that this has reduced the functionality of the remaining wood pieces, resulting in the poor pool depth ratings in Squaw Creek (Figure 5-2).

Following these dramatic landscape-scale disturbances in the Bull Creek sub-watershed, the upper slopes and riparian zone have been in a process of recovery. The plant community is progressing through ecological succession, aided and accelerated by revegetation projects and road decommissioning. Jager and LaVen (1981) noted after the 1964 flood, portions of the channel in this region widened to over 400 feet and were composed entirely of flood-deposited gravel (1981). Aerial photos of the sub-watershed taken in 1965 clearly show a wide, barren plain where a thickly wooded, narrow stream corridor had once existed (CDF 1942, CDF 1965, Figure 5-5). Initially, the restoration strategy for Bull Creek relied on natural revegetation and vegetation succession (Jager and LeVen 1981). This process was slow to develop and Jager and LeVen (1981) noted this delay likely increased long term monetary and environmental costs (1981).

A 1992 earthquake fractured hillslopes along the Garberville fault and a subsequent flood in 1997 further exacerbated excess sediment delivery in the sub-watershed. Remarkably, the peak flow during the 1997 flood event was higher than peak flows observed during the 1955 and 1964 floods, yet it was much less destructive and the resulting channel aggradation was substantially lower (Pryor et al., 2011). This discrepancy is indicative of progressive watershed recovery, though more proactive measures would be required to prevent further disasters from occurring. In 2012, the second highest peak flow on record (higher than 1955 and 1964) with a recurrence interval of about 25-years did not agrade the channel. Rather, incision was documented in surveyed areas (Middle Bull Creek), a further indication of an overall reduction in sediment supply and continued watershed recovery. CPS and partners’ restoration efforts, described further in the Historic and Current Restoration Efforts section, have likely prevented tens of thousands of yards of sediment from entering streams in the sub-watershed (CSP 2015).
Figure 5-2. Pool Quality Habitat Suitability Index (HSI) scores for pool quality in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
Figure 5-3. Large wood densities in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed during the following survey years: 2007, 2010, 2015 and most recently in 2018. Surveyed reaches varied each year based on funding and crew availability.
Figure 5-4. Habitat Suitability Index (HSI) scores for gravel embeddedness in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
Riparian canopy densities in Bull Creek from Burns Creek to Mill Creek are still poor, but other reaches have greatly improved (e.g. Upper Bull Creek upstream of Panther Creek) (Figure 5.6). The methods employed to measure canopy density poorly document the old growth redwood riparian forest in Bull Creek below Harper Creek due in part to the widened channel in these reaches. Poor canopy cover increases a stream’s exposure to solar radiation, and stream temperature monitoring in Bull Creek indicates reaches with poor canopy cover are associated with marginal to unsuitable water temperatures by late summer (Figure 5.7). Interestingly, in 1937 it was noted Bull Creek “normally runs dry for 3 or 4 miles above the mouth during the summer, so that only a few pools are left. It usually goes dry about July” (CDFG 1937). The continued succession of the plant community to a mature coniferous riparian forest will likely take tens to hundreds of years (Gregory et al. 1991), but active management of the plant community will likely continue to accelerate the recovery process.

Figure 5.5. Upper Bull Creek from Slide Creek to Panther Creek from 1942 (left) to 1965 (right). The extensive upland road networks, deforestation, and flood damage are shown in stark contrast to the nearly unaltered 1942 landscape. The red arrows indicate the confluence of Panther Creek and Bull Creek.

Formerly thriving salmonid populations in Bull Creek have struggled to persist in this heavily impacted environment. Surveys and records from 1934 to 1938 indicate salmonids were abundant in Bull Creek and natural propagation was “considerable” (CDFG 1934, CDFG 1937, CDFG 1938). However, by 1960 CDFG staff optimism for the salmonid population had waned. A 1956 letter stated that “the possibility of restoring a sizable salmon and steelhead run in Bull Creek appears to be remote” (CDFG 1960). Restoration efforts and protections awarded by state land acquisitions have likely contributed to the persistence of salmonids within the sub-watershed. Though redd densities are low when compared to other sub-watersheds in the South Fork Eel River, Chinook Salmon, Coho Salmon, and steelhead regularly spawn in Bull Creek (Figure 5.8).
Figure 5-6. Habitat Suitability Index (HSI) scores for canopy density in the Bull Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
Figure 5-7. Observed mean weekly maximum temperatures (MWMT), the average daily maximum temperature during the hottest seven-day period of the year (ERRP) and modeled mean August temperatures (NorWeST) for the Bull Creek sub-watershed.
Figure 5-8. Total mean density of Coho Salmon, Chinook Salmon, and steelhead redds in the Bull Creek sub-watershed, all years surveyed (2010-2018). Data were sourced from CDFW spawner surveys (Starks and Renger 2016) designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal extent of the Chinook Salmon or steelhead run.
Bull Creek placed sixth overall in the SHaRP ranking process, with high marks received in categories related to land ownership and restoration potential. Bull Creek scored sixth in Biological Importance, eighth in Habitat Condition, second for Optimism and Potential, and second in Integrity and Risk. While the history of anthropogenic and natural disturbances has acted synergistically to heavily impact salmonids in Bull Creek, the conservation and protection measure bestowed by its ownership is considered an important attribute in Bull Creek’s recovery potential.

5.3 Historic and Current Restoration Efforts

Restoration efforts in the Bull Creek sub-watershed differ from the other sub-watersheds in the SFER sub-basin due to the fact it has been under the singular ownership of CSP since the late 1960s. Portions of the sub-watershed were protected under state ownership before any major anthropogenic disturbances took effect. However, historical land uses in unprotected portions of the sub-watershed resulted and drastic changes to the entire sub-watershed, necessitating extensive actions to protect and restore the invaluable natural resources of the park.

As described in the History of Land Use and Fish Habitat section, resource protection efforts of the 1950s and 1960s focused on acquiring the entire Bull Creek sub-watershed as well as measures to prevent the loss of old-growth redwood trees along Bull Creek. This initial management response involved constructing a straight, single-thread channel away from existing infrastructure, installing rock slope protection along the channel, and disposing of instream and floodplain wood accumulations. The projects effectively seized the natural channel forming processes, affecting the morphology of the stream. This was effective in protecting the surrounding forests but ultimately degraded overall habitat suitability for salmonids.

Beginning in the mid-1990s and expanding in the 2000s, CSP and its restoration partners shifted focus towards reducing upslope erosion and improving riparian and aquatic habitats (Figure 5-9). With support and funding from the California Department of Fish and Wildlife4 (CDFW) FRGP (including former Senate Bill 271), CSP began conducting upslope restoration projects in problematic areas of the sub-watershed in order to reduce the impacts of large landslides and old, failing logging roads which were contributing large amounts of sediment to streams. CSP completed upslope and road decommissioning work in Mill Creek in the late nineties and early 2000s. These efforts included the decommissioning of 16.7 miles of abandoned logging roads and removing 113 stream crossings to stabilize approximately 80,000 cubic yards of fill/sediment (CSP 2002). During a similar time, abandoned logging roads were also decommissioned and treated in Upper Bull Creek and in the southern portion of Cuneo Creek.

Improving upslope habitat by remediating old logging roads continued through the 2000’s (Figure 5-9). During the summers of 2003, 2004, and 2005, upslope restoration projects occurred in Albee and Harper Creeks. Collectively these projects treated 561 acres of previously disturbed sub-

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4 Formerly known as the California Department of Fish and Game (CDFG)
watershed by removing 8.1 miles of abandoned logging skid and haul roads and 44 associated stream crossings, effectively stabilizing approximately 21,309 cubic yards of sediment (North Coast Redwoods District 2006). Moreover, road erosion assessment/planning efforts were also developed for Cuneo Creek, which proposed treatment efforts for abandoned logging roads and sediment sources. In 2005 and again in 2007, road rehabilitation projects were completed along Panther Creek. These projects collectively removed approximately 137,000 cubic yards from 81 stream crossings along 16.9 miles of abandoned logging roads (CSP 2008). Riparian revegetation occurred in conjunction with these efforts, focusing in areas where road crossings were removed.

From 2012-2013, the Devil’s Elbow Landslide Sediment Reduction Project occurred in the South Fork of Cuneo Creek (Figure 5-9). This project prevented approximately 58,000 cubic yards of sediment delivery to Cuneo and Bull creeks by excavating 11,000 yards of sediment perched at the head of the Devil’s Elbow landslide and reduced surface erosion by grading the final surface to promote sheet flow. In an effort to control sediment and stabilize the hillslopes, the project planted over 800 Douglas fir seedlings, 100 redwood seedlings, over 900 coyote bush seedlings, and several other plant species in smaller quantities (Merrill 2013). Prior to project implementation, revegetation of the downslope riparian area and adjacent landslide slopes occurred with matching funds provided through a grant from the State Water Resources Control Board. Several thousand Douglas fir and redwood seedlings were planted from 2008-2010 on the upper slopes and terraces of Bull Creek (Merrill 2013).

From the late 1990s into the 2000s, CSP, Eel River Watershed Improvement Group (ERWIG), and the California Conservation Corps (CCC) through the CDFW’s FRGP funding completed several instream habitat restoration and riparian revegetation projects along Bull Creek and in lower Mill Creek (Figure 5-9). CSP installed 14 instream habitat structures in Bull Creek from its confluence with Cuneo Creek downstream to the confluence of the SFER. These structures, mostly consisting of large wood and boulders, were intended to increase habitat complexity and the number of pools in this reach. In 2003, ERWIG improved instream habitat and reduced sediment in a one-mile section of Bull Creek between Burns Creek and Cuneo Creek. The project installed 20 structures consisting of boulder weirs, boulder/log structures, willow pods, and willow baffles. Approximately 1,500 native trees were planted in the riparian area along the entire section for sediment reduction and to improve future canopy conditions (ERWIG 2005). In 2007 and 2008, ERWIG in conjunction with the CCC reduced sediment delivery and improved salmonid habitat on a 1,700-foot section in lower Mill Creek and in Bull Creek (downstream of its confluence with Mill Creek). This FRGP-funded project installed 15 structures consisting of LWD, root wads, and boulders and planted 400 mixed conifers and hardwoods in the project reach (ERWIG 2007). Most recently (2016-2017), CSP removed failing riprap in Rockefeller Forest along Bull Creek and conducted riparian planting through Prop 84 funding.
Figure 5-9. Restoration projects implemented in the Bull Creek sub-watershed.
The CSP property contains large tracts of old-growth redwood forests and provides the perfect setting for community-based watershed education opportunities. CSP has led numerous interpretive programs over the years educating park visitors on aspects of salmonid ecology and watershed restoration. In addition, FRGP provided funding for over a decade (late 1990s to early 2010s) for the Watershed Stewards Project (WSP) and ERWIG to organize and host Creek Days in the Bull Creek sub-watershed. This annual week-long event recruits hundreds of local school children, providing education on salmonid biology and the dynamics of healthy watersheds. Creek Days continues to occur and often takes place in the Bull Creek sub-watershed.

5.4 Limiting Factors and Threats Affecting Salmonids in Bull Creek

The Bull Creek Expert Panelists discussed available data and personal observations of the sub-watershed on October 21, 2019. During this discussion, each participant scored the extent to which each potential limiting factor and threat impacts each life stage of each species in an interactive process. All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid; the lower the number, the greater the severity of impact. Scores less than 2 are red (very high impact (most limiting)), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact (least limiting)). The resulting limiting factor tables (Limiting Factors Table 5-1 and Table 5-2) summarize Expert Panel rankings in three areas of the sub-watershed: 1) Lower Bull Creek (Bull Creek and Harper, Tepee, Squaw, Miller, and Cow Creeks), 2) Middle Bull Creek (Bull Creek and Albee, Mill, Cuneo, and Burns Creeks, and 3) Upper Bull Creek (mainstem Bull Creek, Slide Creek, and Panther Creek). The threats table (Table 5-3) describes threats to salmonid habitat across the entire sub-watershed. When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
## Limiting Factors

Table 5-1. Average scores for the impact of each limiting factor on each life stage of Coho Salmon and steelhead in three areas of Bull Creek. The lower the number, the greater the severity of impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact).

<table>
<thead>
<tr>
<th>Coho Salmon and Steelhead</th>
<th>Lower Bull Creek</th>
<th>Middle Bull Creek</th>
<th>Upper Bull Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bull Creek Mainstem and Squaw, Miller, and Cow Creeks</td>
<td>Bull Creek Mainstem and Albee, Mill, and Cuneo Creeks</td>
<td>Bull Creek Mainstem and Slide and Panther Creeks</td>
</tr>
<tr>
<td>Limiting Factor</td>
<td>Eggs Summer Parr</td>
<td>Winter Parr</td>
<td>Migrating Adults</td>
</tr>
<tr>
<td>Barriers (anthropogenic)</td>
<td>4.5</td>
<td>4.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Bed material*</td>
<td>2.8</td>
<td>2.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Competition and predation (bullfrog, pikeminnow)</td>
<td>3.5</td>
<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Dry season flow (including aggraded channels)</td>
<td>3.0</td>
<td>2.3</td>
<td>3.3</td>
</tr>
<tr>
<td>High water temperature</td>
<td>1.8</td>
<td>1.3</td>
<td>3.0</td>
</tr>
<tr>
<td>High wet season flow**</td>
<td>2.8</td>
<td>4.3</td>
<td>2.6</td>
</tr>
<tr>
<td>In-stream channel complexity, including pool depth***</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>2.1</td>
<td>2.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Off-channel habitat (floodplain connectivity)</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Riparian inputs (organic material, insects)</td>
<td>3.9</td>
<td>2.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Suspended sediment****</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
</tr>
</tbody>
</table>

* Substrate composition and spawning gravel quality
** Redd scour and stability, not due to diversions or climate change or the onset of timing and fall rains
*** For sorting sediment, creating velocity refuge, and predator cover
**** Considered for its affects on egg and alevin life stages while residing within a redd
Table 5-2. Average scores for the impact of each limiting factor on each life stage of Chinook Salmon in three areas of Bull Creek.

<table>
<thead>
<tr>
<th>Chinook Salmon</th>
<th>Lower Bull Creek</th>
<th>Middle Bull Creek</th>
<th>Upper Bull Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bull Creek Mainstem and Squaw, Miller, and Cow Creeks</td>
<td>Bull Creek Mainstem and Albee, Mill, and Cuneo Creeks</td>
<td>Bull Creek Mainstem and Slide and Panther Creeks</td>
</tr>
<tr>
<td>Limiting Factor</td>
<td>Eggs</td>
<td>Fry</td>
<td>Migrating Adults</td>
</tr>
<tr>
<td>Barriers (anthropogenic)</td>
<td>2.7</td>
<td>3.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Bed material*</td>
<td>2.7</td>
<td>3.2</td>
<td>2.3</td>
</tr>
<tr>
<td>High wet season flow**</td>
<td>2.7</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td>In-stream channel complexity, including pool depth***</td>
<td>1.5</td>
<td>1.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>2.6</td>
<td>3.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Off-channel habitat (floodplain connectivity)</td>
<td>1.6</td>
<td>1.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Suspended sediment****</td>
<td>2.2</td>
<td>3.1</td>
<td>2.2</td>
</tr>
</tbody>
</table>

* Substrate composition and spawning gravel quality
** Redd scour and stability, not due to diversions or climate change or the onset of timing and fall rains
*** For sorting sediment, creating velocity refuge, and predator cover
**** Considered for its affects on egg and alevin life stages while residing within a redd
Many of the limiting factors with the highest impacts to Coho Salmon, Chinook Salmon, and steelhead in Bull Creek are related to a deficiency of physical habitat complexity (Limiting Factors Table 5-1 and Table 5-2). Channel complexity and off-channel habitat were rated high to very high for all life stages of all species in all areas of the sub-watershed. This reflects the history of poorly regulated timber harvest, large scale disturbance events, and subsequent actions to prevent further damage to the old growth forests (see History of Land Use and Fish Habitat above). Anthropogenic land disturbances and large flood events aggraded stream channels and destroyed riparian vegetation. Subsequent channel incision in the absence of large wood and other channel obstructions have left active channels simplified and disconnected from aggraded floodplains (Pryor 2011). Similarly, the Expert Panel also rated large wood recruitment and canopy cover as high to very high for all species and life stages in middle and upper Bull Creek, where timber extraction and floods had the greatest impact on the riparian zone, and moderate to high in lower Bull Creek. In discussion, the Expert Panel linked the loss of large wood recruitment and a mature riparian forest as well as issues with stream temperature and floodplain connectivity to the lack of instream complexity.

Other physical and biological characteristics of salmonid habitat including temperature, stream bed material, riparian inputs, and suspended sediment were rated as high to moderate impacts to Coho Salmon, Chinook Salmon, and steelhead in Bull Creek. The Expert Panel rated high water temperature as very high impact for summer parr in middle and lower Bull Creek. Widened channels and poor canopy cover in the middle reaches leave surface flow exposed to solar radiation and increased stream temperatures from this area persists through the lower reaches. Due to improving canopy cover in upper Bull Creek, high water temperatures were only rated as a moderate impact for applicable life stages in this area. The state of riparian vegetation in the sub-watershed also led the Expert Panel to rate riparian inputs, including leaf litter and terrestrial insects, as high impact for summer parr in upper and middle Bull Creek and moderate impact for summer parr lower Bull Creek. The availability of suitable spawning gravels was rated as high impact for most egg and fry life stages of all species in all areas except Chinook Salmon fry in lower and middle Bull Creek where impacts were rated moderate. In many of the mainstem reaches of Lower Bull Creek, channel simplification has led to a lack of sorting of stream bed material and armoring of the stream bed, which is often too coarse for spawning. Additionally, sediment input from large landslides and catastrophic road failures lead to chronic turbidity. This is problematic for egg and fry (alevin) life stages which depend on gravel permeability for survival. The Expert Panel rated suspended sediment as high to very high impact for steelhead and Coho Salmon eggs and fry in all locations and moderate to very high for Chinook Salmon, depending on the location and life stage.

Factors which were rated from low to high include anthropogenic barriers, wet season flow, and interactions with non-native species. Anthropogenic barriers were rated as having low or very low impact across species, life stages, and areas, reflecting the relative lack of human infrastructure in
the sub-watershed and the effect of past restoration work. In middle and lower Bull Creek, high wet season flow was rated as a high impact for eggs of all species in middle and lower Bull Creek and was rated moderate to low impact in upper Bull Creek. Large flow events regularly occur in Bull Creek and the simplified channel is conducive to scouring the stream bed, including any salmonid redds. The Expert Panel noted warmer summer water temperatures in the Bull Creek sub-watershed are attracting non-native competitors and predators including Sacramento Pikeminnow (*Ptychocheilus grandis*) and American bullfrogs (*Lithobates catesbeianus*); however, their impact on salmonid populations is perceived to be relatively small with a moderate impact in the warmer lower Bull Creek and a low impact in the middle and upper Bull Creek.

**Threats**

Table 5-3. Average score for the impact of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in across the Bull Creek sub-watershed.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Egg Coho &amp; Steelhead</th>
<th>Egg Chinook</th>
<th>Summer Parr Coho &amp; Steelhead</th>
<th>Summer Parr Chinook</th>
<th>Winter Parr Coho &amp; Steelhead</th>
<th>Winter Parr Chinook</th>
<th>Fry Coho &amp; Steelhead</th>
<th>Fry Chinook</th>
<th>Migrating Adult Coho &amp; Steelhead</th>
<th>Migrating Adult Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channelization (roads, levee, bank protection)</td>
<td>1.2</td>
<td>1.7</td>
<td>1.5</td>
<td>1.0</td>
<td>1.6</td>
<td>2.1</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change</td>
<td>2.7</td>
<td>2.6</td>
<td>1.9</td>
<td>2.6</td>
<td>2.2</td>
<td>2.7</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert</td>
<td>4.0</td>
<td>5.0</td>
<td>4.1</td>
<td>4.3</td>
<td>4.8</td>
<td>4.5</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current roads (chronic)</td>
<td>2.3</td>
<td>2.6</td>
<td>3.5</td>
<td>3.3</td>
<td>3.4</td>
<td>4.1</td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversions</td>
<td>5.0</td>
<td>5.0</td>
<td>4.7</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legacy land mgmt. (roads, timber mgmt. practices)</td>
<td>1.3</td>
<td>1.4</td>
<td>1.3</td>
<td>1.3</td>
<td>1.6</td>
<td>2.2</td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legacy riparian mgmt.</td>
<td>1.7</td>
<td>2.5</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation mgmt. (deferred maint.)</td>
<td>2.9</td>
<td>3.5</td>
<td>2.7</td>
<td>2.0</td>
<td>2.8</td>
<td>4.5</td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Expert Panel rated threats related to the effects of roads, land management, and climate change to have the highest potential impacts to salmonids in the Bull Creek sub-watershed (*Table 5-3*). Channelization due to roads and stream bank stabilization and legacy land management practices including haul road construction and timber harvest management were rated as very high impact for all juvenile salmonids and high impact for adult salmonids. Historical land uses in the sub-watershed as well as early efforts to protect the terrestrial resources of the State Park continue to impact stream habitat by maintaining simplified channels, restricting sources of large wood, and
contributing to chronic sedimentation. Similarly, legacy riparian management including efforts to protect the old growth forests of lower Bull Creek were rated as having a high to very high impact for juvenile salmonids and moderate to low impact to migrating adults. Deferred maintenance of upslope and riparian vegetation was also rated as a high impact for most juvenile salmonids as the lack of maintenance has prolonged the habitat recovery process. The impacts of contemporary roads were only rated as high impact to egg life stages where any additional sediment contributions were thought to have an impact. Generally, most of the contemporary roads in the sub-watershed are well maintained and have been improved in recent decades; thus the Expert Panel rated them as moderate to low impact for the remaining life stages.

In contrast, the remaining threats related to land development were of least concern to the Expert Panel. Water diversion, culverts, and land conversion and development were all rated as low impact to all life stages and species. The sub-watershed is entirely owned and managed by CSP for recreational use, ensuring preservation and protection from future land development and resource extraction. Diversions were rated a very low threat in the Bull Creek sub-watershed because there are no existing diversions for household water use. For the same reason, land conversion and development were rated very low. Culverts were rated a low threat due to CSP’s land stewardship efforts, upslope restoration, and fish passage improvements.

5.5 Recovery Strategy

On October 22nd, 2019, the Bull Creek Action Team discussed the outcomes of the Expert Panel meeting, as presented in Limiting Factors Table 5-1, Table 5-2, and Table 5-3, and identified restoration actions that would best address the most limiting factors and the highest severity threats. The team collaboratively identified the best locations for these restoration actions by reviewing spatial data on printed maps and identifying locations known to the experts of the panel. Figure 5-10 and Table 5-4 below show the treatment types and locations identified by the Action Team during the meeting and later interpreted by the steering team.

The recovery strategy for Bull Creek focuses on improving physical habitat complexity for juvenile fish during summer and winter, increasing dry season flow and lowering water temperature, treating upslope sources of sediment in impacted areas, and increasing available spawning habitat through gravel retention. This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids. In some cases, more specific project locations were suggested based on high resolution data or available restoration plans. For most of these recommendations, specific project locations and methods of implementation will require further investigation and site-specific designs. Where high resolution data were available or members of the Expert Panel and Action Team had precise knowledge of treatment areas, specific project locations were identified for treatments; however, partners may require further designs to appropriately implement the recommendations. Additionally, where site-
specific designs have been developed, the reports and materials which specify those designed have been identified in the text below and should be referenced for more specific guidance on locations and designs. The materials used by the SHaRP Action Team may be useful to the restoration community in more detailed project planning. As more data becomes available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 5-10. Restoration treatment actions recommended by the Bull Creek Action Team.
### Table 5-4. Recommended restoration treatments for Bull Creek.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>LWD for summer rearing (pools, sorting gravel)</td>
<td>Bull Creek, Mill Creek</td>
<td>120, 121, 122, 124, 126, 127.2, 155</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Bull Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek</td>
<td>120, 121, 122, 124, 126, 127.2, 135, 136, 140, 143, 155</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Bull Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, Mill Creek, Tepee Creek, Cow Creek, Miller Creek, Squaw Creek</td>
<td>119, 120, 121, 122, 124, 126, 127, 135, 136, 140, 143,</td>
</tr>
<tr>
<td><strong>Adult Spawning</strong></td>
<td>LWD for gravel entrainment</td>
<td>Bull Creek</td>
<td>124, 126</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Riparian Treatment</td>
<td>Bull Creek, Cuneo Creek</td>
<td>124, 126, 127.1, 156</td>
</tr>
<tr>
<td></td>
<td>Groundwater and flow enhancement</td>
<td>Bull Creek</td>
<td>127.1, 127.2, 127.3</td>
</tr>
<tr>
<td></td>
<td>Road decommissioning</td>
<td>Burns Creek Watershed, Cuneo Creek Watershed, N.F Panther Creek Watershed</td>
<td>N/A, N/A, N/A</td>
</tr>
<tr>
<td></td>
<td>Accelerated wood recruitment</td>
<td>Bull Creek, Panther Creek, N.F. Panther Creek, S.F. Panther Creek</td>
<td>127.2, 127.3, N/A, N/A, N/A</td>
</tr>
<tr>
<td></td>
<td>Bridge upgrade</td>
<td>Bull Creek</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>Habitat assessment</td>
<td>Bull Creek</td>
<td>127.1, 127.2, 127.3</td>
</tr>
<tr>
<td></td>
<td>Riprap alteration</td>
<td>Bull Creek</td>
<td>120, 121, 122</td>
</tr>
</tbody>
</table>
**Treatments to Improve Habitat for Winter Parr and Fry**

Channel complexity and off-channel habitat for overwintering juvenile salmonids were key limiting factors identified by the Expert Panel. Treatments to increase the amount of low velocity habitat and increase the frequency of floodplain inundation were recommended. Stream reaches which were typically low gradient but lacking large wood and other refugia were selected by the Action Team as locations that could support suitable in-channel winter habitat if large wood or other flow-obstructing structures were recruited or installed. These areas were also near frequently used spawning habitat and are expected to be occupied in winter by natal and non-natal parr and fry. The Action Team identified potential areas to improve in-channel winter habitat throughout the sub-watershed including Bull Creek and the downstream portions of Cow Creek, Miller Creek, Squaw Creek, Mill Creek, and Tepee Creek (reaches 120, 121, 122, 124, 126, 127.2, 135, 136, 140, 143, and 155).

The Action Team also recommended instream structure treatments in Lower Bull Creek should be done in conjunction with removal or alteration of riprap, which was installed to prevent flood damage (reaches 120-122). Riprap in these reaches is holding the form of the channel in a relatively static state and encouraging the channel to convey sediment through a constrained channel. This limits the creation of undercut banks and natural recruitment of wood to the channel. To restore natural processes of channel migration and improve instream complexity to create more low velocity habitat, it is recommended that riprap be removed or altered where it is safe and feasible, banks should be contoured to match natural grades, and in-channel structures should be installed to complement this work. This includes installing features that extend from the active channel past the top of bank to capture sediments and create naturally contoured inset floodplains. This will help restore inset floodplains and natural stream banks lost to the 1955 and 1964 floods and subsequent mechanical re-shaping of the river channel to maximize sediment conveyance. This work should be done with great consideration for the invaluable terrestrial resources on the Bull Creek floodplain.

The criteria described above were also used to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths, the presence of anchor habitat, and/or the observation of existing floodplain habitats that could be inundated more frequently or enhanced to provide suitable winter refugia. LiDAR mapping was made available to the Action Team and digital detrending of the channel slope was used to identify locations that may be inundated at average winter elevations (~1-2m). The Action Team identified potential areas to create or improve off-channel habitat on the mainstem of Bull Creek, from Cuneo Creek to Tepee Creek, and at the downstream portions of Tepee Creek, Cow Creek, Miller Creek, Squaw Creek, and Mill Creek (119, 120, 121, 122, 124, 126, 127, 135, 136, 140, and 143). Site specific locations for off-channel habitat were recommended in the mainstem of Bull Creek from just downstream of Cuneo Creek to Mill Creek and from Squaw Creek to Tepee Creek (reaches 124, 126, 127, 120, 121, and 122). Recommendations for the location in reach 126
include modification of the existing “reef barrier,” a channel-spanning boulder structure which was placed at the outlet of a large sediment basin constructed in the mid-1980’s. The construction of this feature and the alteration to the adjacent terrace have constricted the stream channel and prevented natural channel evolution. Widening the channel, lowering the terrace, and adding large wood will allow channel migration, more frequent floodplain inundation, expansion of the riparian corridor, and improve habitat complexity and connectivity. Recommendations at locations in reaches 126 and 127 include adding large wood, lowering aggraded floodplains, and construction of side channels and off-channel pond habitats. Detailed plans and design are available in documents previously completed for these areas (NHE et al. 2018, Appendix F, CalTrout et al. 2017a, 2017b, 2017c, and 2017d). Recommendations for locations in reaches 120-122 are to investigate the feasibility of creating or augmenting off-channel habitat in relic alcoves and oxbows. Based on inundation mapping, these areas are near elevations that may inundate at average winter flows but may need to be lowered or enhanced with structures to improve their suitability for salmonids.

**Treatments to Improve Summer Conditions for Parr and Fry**

The Expert Panel identified that summer parr may be most limited by the lack of instream complexity throughout Bull Creek as well as high temperatures in the middle and lower reaches of Bull Creek. To address the limitations of channel complexity, the Action Team recommended several reaches that would likely support juvenile salmonids during the summer months but would greatly benefit from greater pool depth and increased pool cover. Treatments to install instream structures which would create deeper pools under scouring flows and complex cover under summer base-flow conditions were recommended in reaches with cooler water temperatures near frequently used spawning habitat. Recommended areas typically had lower gradients prone to deposition of sediments in the absence of channel obstructions such as large wood. The recommended reaches include portions of the main stem of Bull Creek and Mill Creek (120, 121, 122, 124, 126, 127.2, and 155). The Action Team noted Mill Creek provides cold water throughout the summer months and may create a crucial refuge for fish at the confluence with mainstem of Bull Creek, which regularly exceeds temperature thresholds in the summer months. However, lower Mill Creek generally lacks the channel complexity needed to support large populations of over-summering fish.

The Action Team identified several regions of the sub-watershed where summer water temperatures are likely limiting the summer rearing potential of parr. Due to excessive solar exposure in the middle reaches on Bull Creek, water temperatures in this region may often exceed the tolerances of salmonids during the summer and limit the summer rearing capacity of the sub-watershed. Salmonid fry and parr typically redistribute from upstream natal areas in the spring to seek productive habitats downstream of spawning sites (e.g. Hall et al. 2016, Soto et al. 2016). Since temperatures in the mainstem of Bull Creek in the middle portion of the sub-watershed typically become too hot to support rearing Coho Salmon fry and parr, the Action Team
recommends treatments to lower water temperature in this important rearing reach. The Action Team recommends planting riparian vegetation along Bull Creek from approximately halfway between Albee Creek and Mill Creek to Cuneo Creek, and from Burns Creek to just downstream of Slide Creek, as well as the downstream portion of Cuneo Creek (reaches 124, 126, 127.1, and 156). Detailed plans for these treatments are available in previously completed planning documents (NHE et al. 2018). Additionally, the Action Team recommends exploring groundwater and flow enhancement in Bull Creek above the temperature impaired reaches from the headwaters to Burns Creek (reaches 127.1, 127.2, and 127.3). The Action Team suggested the installation of beaver dam analogues or similar structures where feasible as one possible treatment to increase groundwater recharge, enhance summer flows, and regulate temperature in downstream habitat. These treatments are recommended for the same locations as the large wood for gravel storage and accelerated wood recruitment in the upper portions of the sub-watershed where these treatments could all work synergistically (see Treatments to Improve Watershed Processes below).

Treatments to Improve Adult Salmonid Spawning Distribution

The Action Team recommended adding instream structures such as large wood to aid in the capture and sorting of gravels to improve spawning habitat for adult salmonids. Instream complexity, including instream wood and boulders to sort sediments and regulate water velocities, was listed as one of the most limiting factors preventing the success of egg and alevin life stages throughout Bull Creek. In response, the Action Team recommended the installation of large wood features in habitats lacking large wood with gradients suitable for spawning, accessible to migrating adults, and near suitable summer rearing habitat. There is an abundant supply of suitable spawning gravel in the sub-watershed but does not sort well and often becomes too embedded for spawning. Spawning success will improve by increasing gravel permeability and reducing embeddedness through sediment sorting using large wood and other instream structures. Recommended treatment areas include the mainstem of Bull Creek from Cuneo Creek downstream to the left bank unnamed tributary after Mill Creek (reaches 124 – 126). The Action Team also noted the success of this type of project will be more effective if combined with treatments to reduce sources of fine sediment, including improved floodplain connectivity and road network assessment. See Treatments to Improve Habitat for Winter Parr and Fry above and Treatments to Improve Watershed Process below for descriptions and locations of recommended treatments to improve floodplain connectivity and reduce fine sediment sources throughout the sub-watershed.

The Action Team also recommended in-channel treatments in Bull Creek for improving winter refuge for juvenile life stages could benefit migrating adults. Immigrating adult salmonids will utilize low velocity habitat as holding and resting areas while in route to spawning habitat upstream. See Treatments to Improve Habitat for Winter Parr and Fry above for recommended treatments and location details.
Treatments to Improve Watershed Processes

To address processes that have been drastically altered or anthropogenically disrupted, the Action Team recommended several treatments to help to restore watershed function, alleviating limitations across multiple life stages.

Channel Migration

As previously described, much of the downstream portion of Bull Creek and portions of Middle Bull Creek was armored with riprap to encourage the conveyance of sediment and prevent bank erosion. In addition, channel straightening, and installation of channel spanning boulder weir structures installed in Middle Bull Creek further stabilize the channel. These actions have largely disrupted channel migration, floodplain connectivity, and has greatly reduced the complexity and suitability of habitat in this area. As described in the Treatments to Improve Habitat for Winter Parr and Fry section above, to restore the natural processes of channel migration and improve instream complexity to create more low velocity habitat, it is recommended riprap should be removed or altered where it is safe and feasible, banks should be contoured to match natural grades, and in-channel structures that do not promote channel stabilization, except where necessary, should be installed to complement this work.

Sediment

To address chronic sedimentation, a key limiting factor across multiple life stages, the Action Team recommended conducting road network assessments in sections of the sub-watershed where legacy logging roads have not yet been treated. California State Parks has carefully analyzed the available GIS data and determined unstable slopes and numerous logging roads are interacting through altered hydrology to create very large sources of sediment and increased risk of slope failure in all untreated portions of the sub-watershed (Fiori et al. 2002). However, site-specific information on treatment locations and the appropriate treatment methods will need to be determined through field investigations and subsequent prioritization. The Expert Panel recommends conducting road network assessments in all the “plan areas” detailed in California State Parks’ sediment source module (Fiori et al 2002). These areas include a portion of middle Bull Creek upstream from Squaw Creek, the headwaters of Bull Creek, the headwaters of Cow Creek, portions of Squaw Creek, unnamed tributaries between Mill Creek and Cuneo Creek, and untreated portions of Cuneo Creek, Burns Creek, Slide Creek, and Panther Creek (reaches 126, 127.3, NA, 143-143.1, 156, 172, NA, NA, NA) (Figure 5-10). Once high and moderate priority sites are identified in these areas, the appropriate road treatment should be applied.

The Action Team also noted there are numerous unstable slopes throughout the upper portion of the Bull Creek sub-watershed and slope failures are likely in this area. Due to the lack of instream structures such as large wood, Bull Creek lacks capacity to store and meter sediments and large volumes of sediment rapidly entrain and transport downstream. Rather than being deposited on the
floodplain or stream banks, entrained sediment deposits in pools and low-gradient stream reaches where it can smother important salmonid habitat. The Action Team recommended implementing accelerated large wood recruitment methods in key areas of the sub-watershed to increase the streams’ capacity to store and meter sediments. These areas include accessible portions of upper Bull Creek and the North Fork, South Fork and mainstem of Panther Creek (reaches 127.1, 127.2, and Panther Creek) (see Figure 5-10 above for more precise locations along Bull Creek).

Assessment and Investigation

The Action Team also recommended two distinct investigations to better understand fisheries resources in upper Bull Creek and the costs and benefits associated with upgrading the County bridge over Bull Creek. The most recent habitat surveys completed in the upper Bull Creek are over 12 years old and very little is known about the fish population using this portion of the sub-watershed. The Action Team recommends conducting a new habitat assessment as well as fisheries surveys of upper Bull Creek (reaches 127.1, 127.2, and 127.3). This was identified as a large data gap in our understanding of salmonid distribution and habitat use in the sub-watershed.

To better understand and plan for restoration projects occurring upstream of the County bridge located approximately half-way through reach 126 on Bull Creek, the Action Team recommends investigating an upgrade to the County bridge. The current bridge has supporting structures within the active channel which often collect large wood. The County currently cuts free any wood which becomes lodged against the bridge, disrupting the transport process of large wood in Bull Creek. Additionally, instream restoration projects above this bridge will likely need to consider the liability of the bridge, thus increasing the cost of engineering installed features. The Action Team recommends pursuing a cost-benefit analysis of upgrading the County bridge to a stream-spanning structure considering reduced costs of future restoration projects and increased ecological benefits. Additionally, improving coordination between CSP and the County to change how wood is managed could help maintain wood transport and wood retention for stream habitat while the current bridge is in place.

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
6. Chapter 6: Redwood Creek Action Plan

6.1 Sub-Watershed Overview

Redwood Creek runs through the northwestern portion of the South Fork Eel River sub-basin (SFER) in Humboldt County (Figure 6-1). Redwood Creek is a third order stream with approximately 31 miles of perennial waterways draining a sub-watershed of approximately 23.3 square miles (CDFG 2009b). Elevations range from approximately 250 feet at the mouth of the creek to 1,300 feet in the headwaters. The landscape is dominated by mixed conifer (predominantly redwood and Douglas fir), mixed hardwood forest, and a small amount of grassland and prairie (CDFW 2014).

The sub-watershed is primarily privately owned; the northern portion is dominated by residential land use while the eastern and areas of the southern portion are managed primarily for timber production and, to a lesser extent, grazing. The Redwood Creek sub-watershed is one of the most populated areas in the western SFER and many residents have turned to cannabis cultivation to generate income (Bauer et al. 2015). Between municipal and agricultural water use, water diversion from Redwood Creek is significantly impacting summer flows (Bauer et al. 2015, Cowan 2018, Klein 2017). While land use practices of settlers and modern owners have degraded salmonid habitat in the sub-watershed, Redwood Creek supports a consistent population of Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*) (CDFW 2014). Trends in overall habitat suitability indicate conditions are improving, likely due in part to community outreach, improvement in land management including enforced regulations, and restoration actions (CDFW 2014).

The land beneath the Redwood Creek sub-watershed is a diverse and dynamic geology. The sub-watershed is bisected by the Garberville fault and bounded by the Coastal Belt Thrust fault to the north. The underlying bedrock is composed of a mix of Yager terrane and Wildcat Group punctuated by pockets of alluvium and river terrace deposits. The resulting landscape has formed steep forested slopes, cliffs, sharp ridges, and incised canyons with friable soils prone to landslides. The relatively unstable land combined with over 80 inches of annual rainfall and a history of land disturbance makes Redwood Creek prone to erosion (CDFW 2014). Numerous eroded banks and landslides were observed in every California Department of Fish and Wildlife (CDFW*) stream inventory conducted in the sub-watershed (1993 - 2017), and aerial imagery reveals numerous landslides and erosion throughout the sub-watershed (CDF 1942, 47, 1965, 1988).

\*Formerly known as the California Department of Fish and Game (CDFG)
Figure 6-1. Redwood Creek’s position in the South Fork Eel River sub-basin.
6.2 History of Land Use and Fish Habitat and Current Salmonid Conditions in Redwood Creek and Tributaries

The history of land use in the Redwood Creek sub-watershed is as variable as its geology. The sub-watershed is within Wailaki ancestral lands, and prior to European settlement tribal members inhabited areas along Redwood Creek and its tributaries. The land and its associated natural resources provided a spiritual connection to the land and sustenance for tribal members. Beginning in the 1850s, settlers and homesteaders of European descent began living in the sub-watershed and by 1878 when a county road was completed between Ferndale and Briceland, the area was the most populated region in Southern Humboldt County (Keter 2017). Briceland, a settlement centered in the Redwood Creek sub-watershed, became a hub of commerce with spur roads to both the seaport at Shelter Cove and the towns of Redway and Garberville. Tanbark extraction was also a major industry of the Southern Humboldt region, and Briceland became the home of a tanoak bark extraction plant established by the Wagner Leather Company in 1903 (Crow 1994). Over 500 employees harvested and processed tanoak bark in the region before shipping the processed material west to Shelter Cove (Crow 1994). The Briceland plant was the largest tanbark business in Humboldt County till its closure in 1920 (Horner 2007). The presence of grasslands and prairies in the sub-watershed have also made the area suitable to livestock; ranching has been consistent in the sub-watershed since the 1880s (California Rangeland Trust 2017). The logging history of the sub-watershed is not precisely known, but the general pattern for the SFER was that late 19th and early and 20th century logging was restricted to redwoods in accessible areas around creek mouths, followed by logging of upper sub-watersheds in the decades following World War II (CDFW 2014). Based on aerial photography, a small amount of logging and rangeland conversion occurred in the lower portion of Redwood Creek and Seely Creek as well as upper Redwood Creek and Somerville Creek up to 1947 (CDF 1942, 1947). By 1965, nearly every tributary in the sub-watershed had been extensively logged and a vast network of haul roads had been constructed (CDF 1965). A portion of the lower sub-watershed was spared from logging and approximately 272 acres of old-growth redwood forest is protected by the CSP at the confluence of Redwood Creek and the South Fork of the Eel River. By the 1960s, most merchantable timber was removed from the land and the timber industry waned. Except for a few family-owned and managed ranches and timber lands, many land holdings were subdivided and sold to “new settlers” (CDFW 2014). To create an income in an economically depressed area, many of these new landowners began cultivating cannabis. This practice dramatically increased in numbers and size of operations in the 2000s and is now popular throughout the sub-watershed (Figure 6-2, Bauer et al. 2015).

Historical and contemporary land uses, as well as a series of devastating floods, have impacted the physical structure of Redwood Creek waterways. The abundant haul roads constructed for timber and tanbark extraction as well as access roads to private residences can contribute substantial sediment loads to nearby streams (CDFW 2014). In a sediment source analysis conducted in the SFER, 46% of sediment loading was attributed to anthropogenic sources including road-related...
landslides and road crossings (Stillwater Science 1999). The land disturbances due to logging activities exacerbated the slide-prone landscape and left the sub-watershed more vulnerable to erosion. When the sub-watershed was struck by two devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in far greater quantities than observed in the geologic record of the basin (Sommerfield et al. 2002). Landslides and erosion during these events led to the loss of riparian vegetation and rapid aggradation of SFER tributaries (Sloan et al. 2001). In the Redwood Creek sub-watershed, these impacts are clearly visible in 1965 aerial photography of Miller Creek, a heavily logged tributary (CDF 1965, Figure 6-3). Streamside erosion, landslides, and several reaches with highly embedded gravels are still apparent in satellite imagery and stream inventories, though the degree to which these can be attributed to legacy effects or contemporary land use is unknown (CDFG 2009a, CDFG 2009b, CDFG 2009c, CDFW 2017a, CDFW 2017b, CDFW 2017c, CDFW 2017d, Google Earth 2018, Figure 6-4). This history of riparian disturbance has reduced large wood recruitment opportunities and likely contributed to the current low density of large wood throughout the sub-watershed (Figure 6-5). The lack of large wood has reduced hydraulic scouring resulting in shallower pool depths, reduced stream complexity, and vastly diminished connectivity to floodplains (Kaufman et al. 1988, Figure 6-6) that often provide critical habitat refugia during winter flows (Bair 2016).

After the 1974 prohibition on logging in riparian zones, the plant communities have been undergoing disturbance succession. In the Pacific Northwest coastal zones, this succession moves relatively quickly from colonizing herbaceous vegetation to a community dominated by hardwoods including maple and alder species and in the later stages, mature conifers dominate the forest (Naiman et al. 2000). Prior to 1965, aerial photography indicates that much of Redwood Creek’s riparian forests had large, mature conifers (CDF 1942, CDF 1947). Contemporary aerial imagery and stream inventories show that the riparian forest is typically dominated by hardwoods (CDFG 1993a, CDFG 1993b, CDFG 2007, CDFG 2009a, CDFG 2009b, CDFG 2009c, CDFW 2017; Google Earth 2018). In 1993, average canopy cover was 63% and only 34% of the riparian forest was coniferous. By 2009 canopy cover had risen to 94% and conifer represented 56% of the riparian forest. Although canopy cover was generally highly rated throughout the watershed, hardwoods generally do not grow large enough, nor remain in streams for long once recruited relative to large conifers (Naiman et al. 2000). The continued succession from a hardwood dominated riparian to a mature conifer riparian forest that can contribute substantial large wood available to alter channel form will likely take many tens to hundreds of years (Gregory et al. 1991).

A relatively dense population and the rise of cannabis cultivation has increased the demand for water during the summer months, which is often drawn directly from riparian sources, diverted

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Formally referred to as large wood debris (LWD) in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.
from springs, or pumped from wells (Klein 2017). The SHaRP ranking process identified Redwood Creek as having the greatest density of registered water diversions in the SFER sub-basin. Bauer et al. (2015) estimated that cannabis cultivation in the Redwood Creek sub-watershed could demand between 34% and 165% of the summer stream flow depending on the water year. Consistent with this estimation, annual low flow monitoring conducted since 2013 indicates a drastic decline in flow during summer months with several reaches routinely going dry in late August and September (Figure 6-7, Figure 6-8). While the causes of flow reduction are multifaceted and difficult to pinpoint, longitudinal anomalies in flow along the mainstem Redwood Creek and semi-regular fluctuations in discharge measurements throughout the sub-watershed indicate the influence of local water withdrawals (Klein 2017). Additionally, attempts to model and compare unimpaired flows in Redwood Creek to observed flows indicate that Redwood Creek carries a significantly smaller volume of water than it would be expected to (Cowan 2018). Monitoring and regulating water use and stream flow in the sub-watershed are on-going processes and crucial to ensuring salmonid life-cycles can be completed in the sub-watershed.

Despite the history of impacts to the sub-watershed, habitat suitable to salmonids has persisted in Redwood Creek and its tributaries. Based on a review of historical photos and recent stream inventories, riparian vegetation has recovered quickly and is now considered highly suitable along most of the sub-watershed (CDF 1942 - 1988, CDFW 2014, Figure 6-9). Due in part to the persistent canopy cover, stream temperatures are also likely suitable in most of the upper sub-watershed (Figure 6-10). As a result, even in reaches that are intermittently dry, Coho Salmon can temporarily survive in isolated pools (Klein 2017). Low gradient habitats are common in Redwood Creek and often utilized by spawning Coho and Chinook Salmon and steelhead (Figure 6-11). In the SHaRP ranking process, Redwood Creek tied for the highest biological importance score, a composite of all the salmonid spawning and species distribution data available for the sub-watershed.

Currently, the land in the sub-watershed is owned by over 200 private entities, each holding relatively small parcels making restoration projects difficult to implement and opportunistic as opposed to strategic. While the Biological Importance and Habitat Condition of the sub-watershed score relatively high for the SFER basin (1st and 5th respectively), the Optimism, Potential, Integrity, and Risk scores reflect the impacts of relatively high human density in the region (tied for 7th and 11th respectively). Ultimately, Redwood Creek ranked 4th overall in the SHaRP ranking process, making it a priority sub-watershed; however, the difficulties of working with numerous residents will have to be overcome to fully realize the biological potential of Redwood Creek.
Figure 6-2. Marijuana cultivation in Redwood Creek sub-watershed. Source: Bauer et al. 2015.
Figure 6-3. Aerial photography of Miller Creek from 1942 prior to most logging activities (left) and 1965 after the area was heavily logged and two major floods washed through the SFER (right). Miller Creek flows from the top center to the bottom right of each frame. A drastic increase in the width and exposure of active inner gorge failures is apparent.
Figure 6-4. Habitat suitability index of gravel embeddedness in the Redwood Creek sub-watershed from CDFW stream surveys derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
**Figure 6-5.** Wood densities for small and large wood pieces in the Redwood Creek sub-watershed derived from CDFW stream habitat surveys competed in 2009 and 2010. Large wood is greater than 1 foot in diameter and greater than 20 feet in length. Small wood is greater than 1 foot in diameter and 6 to 20 feet in length.
Figure 6-6. Habitat suitability index for pool depth in the Redwood Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
Figure 6-7. Stream flow (gallons per minute) at monitoring stations throughout the Redwood Creek sub-watershed from 2017, 2018, and 2019. Data are plotted on a logarithmic scale; at 0.1 gallons per minute, streams are effectively not flowing. The sub-watershed map in the bottom right panel displays the approximate locations of each monitoring station. Measurements are rounded to the nearest tenth. Source: Salmonid Restoration Federation; 2017 data collection funded by 319h program (State Water Board), 2018-19 data collection funded by Wildlife Conservation Board (SRF 2020).
Figure 6-8. Mean flow (gallons per minute) in Redwood Creek during low-flow monitoring seasons 2016 - 2020 (SRF 2020).
Figure 6-9. Habitat suitability index for canopy density in the Redwood Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods: 1990-1999, 2000-2010, and most recently in 2018. Surveyed reaches varied per time period based on funding and crew availability.
Figure 6-10. Observed and modeled stream temperatures and associated suitability for Coho Salmon and steelhead rearing in the Redwood Creek sub-watershed.
Figure 6-11. Total density of Coho Salmon, Chinook Salmon, and steelhead reds in the Redwood Creek sub-watershed, all years combined (2010-2018), based on CDFW spawner surveys. The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.
6.3 Historic and Current Restoration Efforts in Redwood Creek

The Redwood Creek sub-watershed has garnered support for restoration from a diverse community of concerned citizens and restoration practitioners. There have been active non-profit organizations (e.g. Salmonid Restoration Federation (SRF), Eel River Watershed Improvement Group (ERWIG), Eel River Salmon Restoration Project, and Trees Foundation), tribal members, community groups, and landowners, but due to a high percentage of private ownership it has been difficult to perform large-scale restoration necessary to have a significant impact on aquatic habitat. Of the 19 sub-watersheds in the SFER, Redwood Creek has the highest human population density and the greatest number of smaller parcels. The result of this is a fewer number of restoration projects and smaller footprint of restoration treatments on the landscape (Figure 6-12).

Due to this high population density and current land use practices (large-scale cannabis cultivation), recent restoration efforts have focused on monitoring stream flow/availability and developing solutions to minimize water extraction and keeping water flowing in streams during critical time periods for salmonids. In 2013, SRF received grant funding to begin monitoring dry season flows in Redwood Creek and its tributaries. Flow monitoring continues to the present through SRF with support of the Wildlife Conservation Board (WCB). As a part of this funding, SRF also initiated a study to determine the feasibility of transferring a voluntary water conservation program from the Mattole River watershed in Southern Humboldt County to the Redwood Creek sub-watershed. Redwood Creek Water Conservation Project was designed to engage rural landowners and stakeholders in a coordinated, community-led water conservation effort. SRF has had some success in landowner participation in these programs, but late-summer stream flows are still highly impacted and detrimental to salmonid growth and survival. In addition to this flow monitoring and conservation project, SRF has also performed other community outreach and watershed education workshops, including water conservation and flow enhancement workshops, water rights clinics, and community stakeholder meetings to build support for coordinated water management concepts and salmon restoration in the sub-watershed. SRF is currently working on two projects in the sub-watershed, both funded by WCB. These include (1) flow enhancement planning throughout the Redwood Creek sub-watershed to identify the highest priority activities needed to increase dry-season stream flow, and (2) the design and permitting of a large-scale flow enhancement project located on the Marshall Ranch near the town of Briceland.

The CDFW Fisheries Restoration Grant Program (see Chapter 4) has provided funding to support a variety of restoration projects in the Redwood Creek sub-watershed. Since 2008, the ERWIG and the California Conservation Corps (CCC) have completed about six instream habitat improvement projects in Redwood Creek from its confluence with China Creek downstream to just below Somerville Creek. These projects have consisted of constructing large wood structures and boulder features to enhance pools, increase gravel sorting and provide habitat complexity. Approximately 30 structures were constructed because of these projects. ERWIG also modified an eight-foot dam along Redwood Creek in 2008 by partially removing the dam to allow for fish
passage under various flow conditions. An additional 25 structures along a 2,000-foot reach of Redwood Creek are scheduled to be built in summer of 2020. This ERWIG project will be near the confluence with Somerville Creek and move upstream with the intention of also improving instream habitat and stabilizing stream banks. In the early 2000s, ERWIG and the Eel River Salmon Restoration Project completed separate bank stabilizations projects along Redwood Creek by installing structures at the toe of large slides. These projects stabilized the slides and prevented sediment from entering Redwood Creek.

In the late 1980s and extending through the 1990s, Redwood Creek has been host to a variety of small programs involving the hatching and rearing of salmonids. The Redwood Creek Fish Hatchery located in lower Redwood Creek conducted artificial propagation of Coho Salmon, Chinook Salmon, and steelhead to be distributed in Sproul Creek as well as within Redwood Creek with the intention of producing a greater number of smolts.

Additional restoration projects have been completed in Redwood Creek tributaries and are briefly described in Table 6-1. These projects were also primarily funded through the CDFW FRGP.

### Table 6-1. Redwood Creek Tributaries Restoration Projects from early 1990s till 2010*

<table>
<thead>
<tr>
<th>Stream</th>
<th>Project Year(s)</th>
<th>Project Type</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seely Creek</td>
<td>2006</td>
<td>Sediment Reduction</td>
<td>Restoration Forestry Inc. performed sediment reduction project completed along 300-feet of stream channel.</td>
</tr>
<tr>
<td>Teichi Fork (tributary to Seely Creek)</td>
<td>2002</td>
<td>Bank Stabilization</td>
<td>Restoration Forestry Inc. moved road (8-10ft) along Teichi Fork and performed slope work to prevent complete bank failure. Installed willow wall for increased bank stabilization.</td>
</tr>
<tr>
<td></td>
<td>2002</td>
<td>Bank Stabilization and Barrier Modification</td>
<td>Restoration Forestry Inc. installed instream structures to improve bank stabilization as well as grade control structure to improve fish passage.</td>
</tr>
<tr>
<td>China Creek</td>
<td>1993</td>
<td>Instream Habitat</td>
<td>Several pre-existing channel spanning logs modified to improve instream habitat.</td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>Bank Stabilization</td>
<td>ERWIG completed instream bank stabilization project in lower China Creek, which entailed re-sloping 100 feet of hillslope above the bank and armoring it with quarry rock and installing small deflectors and anchor logs.</td>
</tr>
<tr>
<td>Dinner Creek</td>
<td>Early 1990s</td>
<td>Instream Habitat</td>
<td>Modification of pre-existing channel scour structures to enhance rearing habitat by deepening and lengthening existing pools.</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>Barrier Modification</td>
<td>Two county road crossing (poorly designed culverts) modified to improve fish passage to over 9,400 feet of habitat.</td>
</tr>
<tr>
<td>Miller Creek</td>
<td>Early 2000s</td>
<td>Bank Stabilization</td>
<td>Bank stabilizations and riparian and hillside planting of coniferous tree species at active slide locations.</td>
</tr>
</tbody>
</table>

*Table may not reflect all projects that have been completed in the tributaries but intends to describe most of them.
Figure 6-12. Restoration projects implemented in the Redwood Creek sub-watershed.
6.4 Limiting Factors and Threats Affecting Salmonids in Redwood Creek

The Redwood Creek Expert Panelists discussed available data and personal observations of the sub-watershed on June 13, 2019. During this discussion, each participant scored each limiting factor and threat was to each life stage of each species in an interactive process. The resulting limiting factor tables (Table 6-1, Table 6-2) summarize the Expert Panel rankings in three areas of the sub-watershed: the 1) Mainstem Area, 2) Seely, Miller, and Somerville Creeks, and 3) Pollock, China, Twin and Dinner Creeks. The impact of each threat was considered across the entire sub-watershed (Table 6-3). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
### Limiting Factors

Table 6-2. Average scores for the impact of each limiting factor on each life stage of Coho Salmon and steelhead in three areas of the Redwood Creek sub-watershed. Scores less than 2 are red (very high impact (most limiting)), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact (least limiting)). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to need restoration treatment.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Life Stages and Areas</th>
<th>Mainstem Redwood Creek</th>
<th>Seely, Miller, and Somerville Creeks</th>
<th>Pollock, China, Twin, and Dinner Creeks (Upstream of Miller Creek, reach 423)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Eggs</td>
<td>Summer Parr</td>
<td>Winter Parr</td>
</tr>
<tr>
<td>Barriers</td>
<td></td>
<td>4.7</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Channel complexity, including pool depth</td>
<td>2.0</td>
<td>1.8</td>
<td>1.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Dry season flow</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High water temperature</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>1.6</td>
<td>1.4</td>
<td>2.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>2.2</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>1.9</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spawning substrate</td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet season flow (timing and volume)</td>
<td>4.0</td>
<td>3.7</td>
<td>3.3</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Table 6-3. Average scores for the impact of each limiting factor on each life stage of Chinook Salmon in three areas of the Redwood Creek sub-watershed.

<table>
<thead>
<tr>
<th>Chinook Salmon</th>
<th>Life Stages and Areas</th>
<th>Mainstem Redwood Creek</th>
<th>Seely, Miller, and Somerville Creeks</th>
<th>Pollock, China, Twin, and Dinner Creeks (Upstream of Miller Creek, reach 425)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limiting Factor</td>
<td>Eggs</td>
<td>Fry</td>
<td>Migrating Adults</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------</td>
<td>-------</td>
<td>------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>Barriers</td>
<td>4.7</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Channel complexity, including pool depth</td>
<td>2.1</td>
<td>2.6</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Large wood recruitment, canopy cover</td>
<td>2.9</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off-channel habitat</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.1</td>
<td>2.4</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Spawning substrate</td>
<td>2.6</td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Wet season flow (timing and volume)</td>
<td>3.7</td>
<td>3.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Many of the limiting factors with the highest impacts on Coho Salmon, Chinook Salmon, and steelhead in Redwood Creek are related to a relative lack of physical habitat complexity and dry season stream flow and temperature (Table 6-1, Table 6-2). Channel complexity was rated as having a high or very high impact to all life stages of all species in all areas of the sub-watershed. Similarly, the availability of suitable off-channel habitat was rated as having a high or very high impact on all life stages and species except summer parr in the Pollock, China, Twin, and Dinner Creeks Action Group. This is likely due in part to the history of resource extraction in the region, development of roads and residential areas along the riparian corridor, as well is the devastating floods of the 1950s and 60s. The Expert Panel rated dry season flow and high water temperatures as the most limiting factor to Coho Salmon and steelhead summer parr except in the Pollock, China, Twin, and Dinner Creeks Action Group where water temperatures are typically cooler. Due to the relatively dense population of the sub-watershed, as well as the water demands of the local cannabis industry, summer water diversion pressure is high and limiting the summer rearing capacity of the sub-watershed. Large wood recruitment and canopy cover were also rated as an important limiting factor across all life stages of Coho Salmon and steelhead and Chinook Salmon in fry and migrating adults in select areas (Table 6-1, Table 6-2). This is likely due to the role that riparian forests play in creating cooler summer water temperatures and forming complex instream habitat. Sediment was rated as having a high to very high impact on all life stages of the three salmonid species due to the number of heavily used unimproved roads throughout the sub-watershed.

The Expert Panel rated factors related to fish passage as having the least limiting factor on salmonid populations. Natural and anthropogenic barriers were rated as low or very low limiting factors across all species, life stages, and areas, reflecting some of the restoration work that has been completed in the sub-watershed to address fish passage requirements. The timing and volume of wet season flow, as influenced by climate change, was rated low except for migrating adult Chinook Salmon in the Pollock, China, Twin, and Dinner Creeks Action Group. Chinook Salmon, which have a relatively early and narrow spawning period and require larger flow events to occur early in the season in order to access higher reaching tributaries. Increased environmental stochasticity can restrict how often access to those areas is possible for Chinook Salmon.
Threats

Table 6-4. Average scores for the impact of each threat on each life stage of Coho Salmon, Chinook Salmon, and steelhead in the Redwood Creek sub-watershed. Scores less than 2 are red (very high impact (most limiting)), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact (least limiting)). When reviewing the ratings as a group, the Expert Panel considered limiting factors and threats scoring moderate or high impact to need restoration treatment.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Egg Coho &amp; Steelhead</th>
<th>Egg Chinook</th>
<th>Summer Parr Coho &amp; Steelhead</th>
<th>Summer Parr Chinook</th>
<th>Winter Parr Coho &amp; Steelhead</th>
<th>Winter Parr Chinook</th>
<th>Fry Coho &amp; Steelhead</th>
<th>Fry Chinook</th>
<th>Migrating Adult Coho &amp; Steelhead</th>
<th>Migrating Adult Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel, benched road beds</td>
<td>3.1</td>
<td>3.4</td>
<td>1.0</td>
<td>2.7</td>
<td>3.2</td>
<td>4.7</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert, dam</td>
<td>3.0</td>
<td>3.4</td>
<td>2.7</td>
<td>2.0</td>
<td>2.3</td>
<td>3.8</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversions</td>
<td>5.0</td>
<td>5.0</td>
<td>4.8</td>
<td>4.7</td>
<td>5.0</td>
<td>4.7</td>
<td>4.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>2.0</td>
<td>2.0</td>
<td>1.3</td>
<td>2.0</td>
<td>2.3</td>
<td>3.3</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution</td>
<td>1.6</td>
<td>1.7</td>
<td>2.7</td>
<td>1.8</td>
<td>2.0</td>
<td>4.0</td>
<td>4.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riparian zone mgmt.</td>
<td>3.3</td>
<td>3.3</td>
<td>2.1</td>
<td>2.8</td>
<td>3.0</td>
<td>3.8</td>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural and county roads (chronic)</td>
<td>2.8</td>
<td>2.4</td>
<td>2.4</td>
<td>3.1</td>
<td>3.0</td>
<td>3.1</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The effects of a relatively high population density combined with the prevalent cannabis industry in the area are reflected in the Expert Panel rating of threats in the sub-watershed. Water diversion was rated as a very high threat to summer parr in response to the apparent diversion pressure and altered flow regimes (Table 6-3). It is hoped that summer forbearance and diversion rate restrictions that are now required through the State Water Resources Control Board (SWRCB) Cannabis Principles and Guidelines Policy will soon show significant improvements to the summer flow issues in the Redwood Creek sub-watershed. Additionally, the CDFW Instream Flow Program’s Redwood Creek study may provide more robust information for the SWRCB and CDFW to apply bypass conditions to Water Right protests or Lake and Streambed Alteration permits. However, until there is a biological response from these actions, diversions remain a very high impact threat to the sub-watershed. The chronic effects of the heavily used private and county roads on watershed hydrology and sediment transport, as well as land conversion and development associated with residences and cannabis cultivation, were also rated as a high to very high impact threat to all egg and juvenile life stages. Pollution from septic systems, illegal dumping, and cannabis cultivation was rated as a high threat for more susceptible life stages including egg and summer parr. Riparian zone management, which was expanded in discussion to include meadow
encroachment and the potential effects dense, young forests might have on hydrology, was rated as a high threat for summer and winter parr.

6.5 Recovery Strategy

On June 14, 2019, the Redwood Creek Action Team discussed the outcomes of the Expert Panel meeting and identified restoration actions that would best address the most limiting factors and the highest severity threats. The team collaboratively identified the best locations for these restoration actions (Table 6-4) and delineated project locations on large paper maps of the sub-watershed. Figure 6-13 shows the treatment methods and stream reaches identified by the team, as recorded during the meeting and later interpreted by the steering team.

The recovery strategy for Redwood Creek focuses on increasing summer base flows, improving physical habitat complexity for juvenile fish during summer and winter, reducing sediment delivery, and improving riparian forest cover and composition. To a lesser degree, the strategy also includes increasing the suitable spawning habitat for adults in key spawning reaches (Figure 6-13). This strategy identifies reach-scale regions of the sub-watershed and points identified by expert opinion where treatments can be implemented and will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. As more data becomes available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 6-13. Restoration treatments identified by the Redwood Creek Action Team.
### Table 6-5. Restoration treatments for the Redwood Creek sub-watershed.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, Twin Creek</td>
<td>418, 421, 422, 423, 425, 426, 434, 453, 472, 473, 474, 475</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Redwood Creek, Somerville Creek</td>
<td>418, 422, 423, 425, 426, 453</td>
</tr>
<tr>
<td><strong>Adult Spawning</strong></td>
<td>Large wood for gravel storage</td>
<td>Redwood Creek</td>
<td>425, 426</td>
</tr>
<tr>
<td><strong>Flow Enhancement</strong></td>
<td>Flow Enhancement</td>
<td>Redwood Creek, Miller Creek Tributary</td>
<td>423, 461.2</td>
</tr>
<tr>
<td></td>
<td>Investigate for Summer Flow &amp; Flow Enhancement Opportunities</td>
<td>Redwood Creek, Seely Creek, Somerville Creek, Miller Creek, Dinner Creek</td>
<td>425, 426, 434, 435, 453, 455, 461, 462, 463, 474</td>
</tr>
<tr>
<td></td>
<td>Water Use Management, Education, and Outreach</td>
<td>Redwood Creek, Frost Creek, Seely Creek, Miller Creek, Miller Creek Tributary, Buck Gulch, China Creek, Dinner Creek, Twin Creek</td>
<td>416, 418, 419, 420, 421, 422, 422.1, 423, 425, 426, 434, 435, 461, 462, 462.2, 463, 468, 468.1, 472, 473, 474, 475</td>
</tr>
<tr>
<td></td>
<td>Beaver Dam Analog</td>
<td>Miller Creek, Dinner Creek</td>
<td>462, 474</td>
</tr>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>Large wood for summer rearing (pools, sorting gravel)</td>
<td>Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, Twin Creek</td>
<td>421, 422, 423, 425, 426, 434, 453, 472, 473, 474, 475</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Sediment Reduction</td>
<td>Frost Creek, Seely Creek, Somerville Creek, Miller Creek, China Creek, Twin Creek</td>
<td>422.1, 434, 435, 453, 461, 462, 463, 472, 473, 475</td>
</tr>
<tr>
<td></td>
<td>Riparian treatment</td>
<td>Redwood Creek, Seely Creek, Teichi Fork</td>
<td>418, 419, 420, 425, 426, 434, 439</td>
</tr>
</tbody>
</table>
Treatments to Improve Conditions for Winter Parr

To improve habitat for overwintering juvenile salmonids, a key limiting factor identified by the Expert Panel, installation of instream structures was recommended. Stream reaches which were lacking large wood and had poor shelter ratings but had low gradients which could support suitable in-channel refugia were identified as locations to improve in-channel winter habitat. The Action Team also prioritized locations near or below habitats which are frequently utilized for spawning to ensure juveniles born in these areas have nearby winter refugia. In the Redwood Creek sub-watershed, these opportunities exist mostly in the middle and upper reaches of Redwood Creek (reaches 421-423, 425, and 426) and in tributaries of the upper sub-watershed (reaches 453, 472 – 475). There are two reaches in the lower sub-watershed including a section of lower Redwood Creek (reach 418) and lower Seely Creek (reach 434) which may also provide suitable in-channel winter habitat. These lower sub-watershed areas are important for winter rearing as they can be productive for both natal fish emigrating down river and for non-natal fish seeking refuge from the South Fork Eel River (Johnson 2016, Wallace et al. 2015, Rebenack et al. 2015).

The lack of off-channel habitats, including floodplains, alcoves, and backwaters were also identified as limiting for overwintering juvenile salmonids. The Action Team used the same criteria described for in-channel winter habitat to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths and/or the observation of existing floodplain habitats that could be enhanced to ensure frequent access to low-velocity habitat during winter base flows. Based on the available data, the Action Team identified one reach in lower Redwood Creek (reach 418), four reaches in middle Redwood Creek (reaches 422, 423, 425, and 426), and one reach of Somerville Creek (reach 453) where opportunities for off-channel winter habitat may exist but field investigation are recommended to locate specific project locations.

Treatments to Improve Conditions for Eggs and Alevin

The Expert Panel identified sediment as a limiting factor affecting the survival of salmonid eggs and alevin in portions of the sub-watershed. Several tributaries in the sub-watershed have legacy logging roads, rural private roads, and bank failures that deliver fine sediment to the sub-watershed. The Action Team identified several areas where investigations are recommended to determine the effect that streamside roads and road crossings are having on sediment delivery. These areas include roads along China and Twin Creeks (reaches 472, 473, and 475), Somerville Creek (453), Seely Creek (434 – 435), Miller Creek (461 – 463), and a single road crossing on Frost Creek (422.1). It was noted that a road inventory had been completed for the China Creek area in 2000 that resulted in upgraded culverts and stream crossings; however, the roads in this area still have chronic sediment issues resulting from poor road surfaces. Because many of these roads are private and used by a diversity of landowners, the Action Team recommended that the community form a road association to pool resources and improve road conditions for all users.
In addition to treating sediment sources, the Action Team recommended installing large wood features to help trap and sort gravel to ensure high quality spawning substrate persists. The upper reaches of Redwood Creek (reaches 425 – 426), which are heavily utilized by spawning salmonids and contain moderate amounts of large wood, were identified as priority treatment locations.

**Treatments to Improve Dry Season Flow**

Summer base flows are severely impaired in Redwood Creek due in part to the number of water extractions in the sub-watershed as well as the methodology used for water extraction (i.e. the timing of withdrawal, inappropriate extraction volumes, leaky and inefficient equipment). For juvenile salmonids, including Coho Salmon and steelhead parr, a persistent flow of cold, oxygenated water in Redwood Creek is crucial for growth and survival through the summer. To increase the amount of water available for parr throughout the summer months, the Action Team identified treatments to enhance stream flow via off-channel storage and reduce water withdrawal during the summer months through education and community outreach. The Action Team also identified key reaches to focus investigations on flow enhancement feasibility through community outreach and field assessments. Treatment areas were also chosen based on expert opinions of water use in Redwood Creek, as well as the relative feasibility of effectively increasing dry season flows within each area. An additional flow enhancement approach that should be strongly considered is conservation easements and/or land acquisition to protect key areas from further development. The main areas of focus for these approaches are upper Redwood Creek and Dinner Creek, but these approaches could also be extremely beneficial throughout the sub-watershed as opportunities present themselves for reducing development and protecting cold-water inputs.

Improving water use through coordination, education, and community outreach is recommended in Miller Creek, Buck Gulch, China Creek, Twin Creek, Frost Creek, Dinner Creek, Seely Creek, and Redwood Creek (reaches 416-423, 425, 426, 434, 435, 461-463, 468, 468.1, and 472-475). Water use is relatively high along these reaches and the Salmonid Restoration Federation (SRF) have found that many water users in the Redwood Creek sub-watershed have poorly designed and/or leaky water infrastructure which continuously diverts water from springs and small tributaries. With relatively simple updates (e.g., float valves in tanks) and technical assistance, much of the existing infrastructure could be updated to ensure that residents are not diverting more water than needed from Redwood Creek tributaries. Additionally, communicating with residents about the natural resources in their area and encouraging best management practices for water use, such as storage and forbearance, will enable voluntary community actions to improve dry season flow. For instance, Frost Creek was identified as a high-quality perennial source of cold water; however, excessive water drafting from this waterway prevents Frost Creek from making significant contributions to Redwood Creek. Simply engaging the residents of Frost Creek could have immediate returns to salmonids if residents are receptive and responsive.
There is also a critical need for most landowners to increase their storage capacity to reduce their diversion needs during the dry season. While many landowners are currently storing water during the wet season and forbearing diversion during the dry season either on a voluntary basis or as required for commercial cannabis cultivation, there are many landowners in the sub-watershed that do not have the financial resources or expertise to install storage facilities (e.g., tanks or ponds). The population density and number of landowners in Redwood Creek is relatively high throughout the sub-watershed, making it difficult to secure the full cooperation needed to implement projects involving multiple landowners and in key locations that will have the greatest benefits. Therefore, comprehensive education and outreach is needed to accomplish effective restoration. SRF is currently implementing a WCB grant that is funding water conservation planning and community outreach throughout the Redwood Creek sub-watershed. The Action Team recommends continuing this outreach with a focus on key tributaries listed above. Ideally, outreach efforts should include technical assistance to aid water users in updating water infrastructure, with follow-up financial assistance where appropriate. Also, it is recommended that a more formal storage and forbearance program is initiated throughout the Redwood Creek sub-watershed using the Mattole River storage and forbearance project implemented by Sanctuary Forest as a model. It is anticipated that ongoing outreach as well as technical and financial assistance will be required over a prolonged period (decades) to significantly reduce the impacts of human consumptive use.

The Action Team identified several key locations to develop flow enhancement projects that would store wet-season runoff and release the water during the dry season to augment surface flow in Redwood Creek. Through funding primarily by the WCB; the Marshall Ranch, Stillwater Sciences, and SRF are currently collaborating to design and construct a large off-channel pond on the Marshall Ranch property along reach 423 that will deliver cold water to Redwood Creek during the 5-month dry season. The Action Team identified three other specific locations that would be suitable for developing flow enhancement projects utilizing wet-season flow retention and dry season release: two existing on-stream ponds along tributaries to Miller Creek (reach 462.1) and a site along reach 425 with no existing infrastructure. The site along reach 425 has good access, is on low-laying, stable land, and has previously disturbed areas that could be converted to a pond without significant impacts to natural resources. The Action Team recommends working with landowners in these areas to either use existing ponds or develop new off-channel storage to enhance summer stream flows.

Additionally, the Action Team discussed the potential for using beaver dam analogues (BDAs) or log/boulder weirs in small tributaries to slow runoff, facilitate groundwater recharge and increase baseflow during the spring recession and summer dry season. A location was identified on Miller Creek, the stream with the most rapid baseflow recession in the sub-watershed, to investigate the utility of beaver dam analogues. Additional potential sites for these treatment types were also identified in the headwaters of Dinner Creek. BDA structures are a relatively novel approach to restoration; implementation of such projects should carefully consider the geomorphic and hydrologic conditions of a site and designs should build upon the successes and failures of similar
projects. Implementation guidance can also be found using the Beaver Restoration Assessment Tool (BRAT), an open source model for assessing beaver restoration potential (Macfarlane et al. 2017).

Several key tributaries were identified for future investigations to identify where and when summer flows become sub-surface and where flow-enhancement opportunities may exist in the landscape. SRF has funding from WCB to conduct this assessment in the summer of 2020. The Action Team identified Redwood Creek, Seely Creek, Somerville Creek, Miller Creek, and Dinner Creek (reaches 425, 426, 434, 435, 453, 455, 461, 462, 463, 474) as areas where the timing and location of flow disconnection is not known. Understanding this pattern will improve our ability to focus instream restoration projects into areas that maintain habitat year-round and where focused community outreach to support summer flow enhancement might be most appropriate. These tributaries, along with the upper reaches of Redwood Creek (reach 426), are also important regions to investigate where springs exist within the sub-watershed and how much potential flow they could provide. Understanding this information could inspire strategic conservation easements or land acquisitions to ensure these springs contribute cold, clean water to Redwood Creek and its tributaries.

_Treatments to Improve Conditions for Summer Parr_

In addition to low summer flow, the lack of instream complexity, high water temperatures, and large wood recruitment were also identified as limiting factors for juvenile salmonids rearing through the summer months. To address these factors, the Action Team recommends installing large wood structures to augment summer habitat and improving riparian forest cover and composition through planting and conifer release. The Action Team identified priority locations for instream treatments as portions of the sub-watershed which typically provide cold, perennial flows and are in or near well-used spawning habitat. These areas include upper reaches of Redwood Creek, Seely Creek, Somerville Creek, China Creek, Dinner Creek, and Twin Creek (reaches 421-426, 434, 453, and 472-475). Adding large wood features to these locations may create or enhance pool habitat and add cover to provide shelter from predators during low flow conditions. The Action Team recommended riparian planting along temperature-impaired reaches that have poor canopy cover including lower Redwood Creek, Seely Creek, Teichi Fork, and upper Redwood Creek (reaches 418-420, 434, 439, 425, and 426).

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
7. Chapter 7: Sproul Creek Action Plan

7.1 Sub-Watershed Overview

Sproul Creek flows through the central western portion of the South Fork Eel River (SFER) sub-basin in Humboldt County (Figure 7-1). Sproul Creek is a fourth order stream with approximately 26.5 miles of perennial waterways draining a sub-watershed of approximately 24 square miles (CDFG 2009). Elevations range from approximately 320 feet at its confluence with the SFER to 1,400 feet in the headwaters. The landscape is dominated by mixed coniferous redwood and Douglas-fir forest, mixed hardwood forest, and a small amount of grassland (CDFW 2014). The sub-watershed is entirely privately owned and is managed primarily for timber production and grazing. Most of Cox Creek, a tributary in the upper portion of the sub-watershed, consists of privately-owned rural residences. Overall population density in the sub-watershed is low with approximately 3.3 persons per square mile. Although historic land use practices and large flood events have degraded salmonid habitat in the sub-watershed, Sproul Creek continues to support a population of Coho Salmon, Chinook Salmon, and steelhead (CDFW 2014). Trends in overall habitat suitability indicate that conditions are improving, likely due to lack of large-scale disturbance, improvement in land management, and restoration actions (CDFW 2014).

The underlying geology of the Sproul Creek sub-watershed is composed predominantly of Yager terrane with a portion of the West Fork of Sproul Creek draining through Coastal terrane sandstone. These Coastal Belt layers typically form steep forested slopes, sharp ridges, and deep, incised drainages which are all characteristic of the Sproul Creek sub-watershed. The resulting soils are entirely Wohly-Holohan-Casabonne series which are very deep deposits of weathered bedrock composed of loam, sand, and gravel. Coastal Belt geology is also prone to rock and debris slides, especially along sharply eroded banks or at bedding planes parallel to hillslopes. Large landslides and eroding stream banks occur naturally in the sub-watershed. Mass wasting and erosion are an inherent and essential component of the evolution of a salmonid bearing stream, helping to maintain a healthy streambed, provide a source of suitable spawning gravels, and contribute woody debris. However, chronic fine sediment delivery associated with anthropogenic land disturbances exacerbated by multiple large flood events has accelerated the delivery of sediments in the SFER sub-basin to the detriment of fish habitat (Stillwater Science 1999).
Figure 7-1. Location of the Sproul Creek sub-watershed within the South Fork Eel River sub-basin of the Eel River basin.
7.2 History of Land Use and Fish Habitat

The sub-watershed is Wailaki ancestral land. Prior to the arrival of European settlers, tribal members residing in the area foraged, hunted, and fished within the sub-watershed. The history of land use after European immigrants settled in the Sproul Creek sub-watershed is dominated by logging. Though the precise timing of timber extraction is unknown prior to the establishment of timber harvest plans, early 19th and 20th century logging in the SFER was generally restricted to redwoods in accessible areas proximate to creek mouths. Logging activities expanded to the upper reaches of sub-watersheds in the decades following World War II as new machinery became readily available (CDFW 2014). The density of roads in the sub-watershed is approximately 7.5 miles of road per square mile, the highest of any SFER tributary considered in this process (CDF 2015, Figure 7-2). Many of these roads were rapidly constructed without concern for sustainability and sediment management inherent in their design. This has led to accelerated sediment delivery rates and in some instances, contributed to more catastrophic mass wasting events. Additionally, logging debris formed multiple unnaturally large jams throughout the river which did not block fish passage completely but likely restricted movement to the extent that they nearly became complete barriers (Holman 1952). When the sub-watershed was struck by a series of devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River at three times the rate observed in the geologic record of the sub-watershed (Sommerfield et al. 2002). These floods swept away vast amounts of wood and delivered sediments from nearby landslides, leading to rapid aggradation of the channel beds in SFER tributaries. These events left many tributaries perched above the SFER atop large deposits of sediment (Sloan et al. 2001, Figure 7-2).
With no large wood remaining in the channel and little left standing on the banks, there has been a decline in channel complexity needed to slow water velocities, capture and entrain gravels, or scour pools (Figure 7-3). Many reaches have lost sinuosity, pools lack depth and frequency (Figure 7-4), and substrates are poorly sorted, or they entrain so swiftly that only material too coarse for spawning remains (Kaufman et al. 1997). Additionally, diminished floodplain connectivity has persisted, removing access to critical winter refugia habitat for juvenile salmonids (Bair 2016). Based on CDFW stream inventories, pool quality (a composite score combining pool depth and shelter) has remained consistently low in Sproul Creek from 1990 to 2019 (Figure 7-4).
Figure 7-3. Habitat Suitability Indices for large wood density in Sproul Creek derived from CDFW stream habitat inventories completed in the following time periods: 2002-2008 and 2016, and 2019. Surveyed reaches varied per time period based on funding and crew availability.
Figure 7-4. Habitat Suitability Indices for Pool Quality in Sproul Creek derived from CDFW stream habitat inventories completed during the following time periods: 1990-1999, 2000-2010, and 2016-2019. Surveyed reaches varied per time period based on funding and crew availability.
Since riparian vegetation was destroyed during large flood events and logging activities were excluded from riparian areas with the enactment of the Forest Practices Act, riparian plant communities have been undergoing ecological succession. In Pacific Northwest coastal zones, this succession moves relatively quickly from colonization by herbaceous vegetation to a community dominated by alder (Naiman et al. 2000). CDFW habitat surveys of Sproul Creek corroborate this trend; surveys conducted from 1992-2016 indicated that 86-88% of the trees providing shade to Sproul Creek were broadleaf species (CDFG 1992, CDFW 2016). While broad-leafed trees are an important component of mature riparian forests, most do not grow very large in diameter, nor do they persist once recruited to the stream channel relative to most conifers common to the region (Naiman et al. 2000). The continued succession and maturation of the riparian forest to include substantial coniferous trees which can be recruited to streams and alter channel forming processes will likely take many decades to centuries (Gregory et al. 1991). During this time native salmonid populations remain in jeopardy of endangerment and potential extirpation.

Though contemporary fisheries surveys indicate populations remain depressed in Sproul Creek and tributaries, conditions remain suitable for salmonids despite the history of anthropogenic disturbance. Flow and temperature monitoring conducted from 2015 to 2018 indicated that most of the upper reaches of Sproul Creek have persistent flows of suitably cool water, likely due in part to high canopy densities and low diversion pressure (Metheny 2018, Figure 7-5). However, the temperature in the lower mainstem becomes stressful for salmonids beginning in mid-summer. Warmer temperatures also facilitate an expansion in the range of invasive Sacramento Pikeminnow (Ptychocheilus grandis) as far upstream as the confluence with West Fork Sproul Creek (Vaughn 2007, Metheny 2018).

Canopy densities have remained high since the early 1990s and there has been a steady improvement in gravel embeddedness, with ideal spawning gravels for salmonids now dispersed throughout the West Fork of Sproul Creek (Figure 7-6, Figure 7-7). Spawning ground surveys indicate that most of the Sproul Creek sub-watershed above Warden Creek is frequently utilized by adult salmonids, with the highest spawning densities above the confluence with the West Fork (Figure 7-8). Outmigrant trapping conducted from 1999 to 2007 confirms consistent reproductive success of Chinook Salmon, Coho Salmon, and steelhead with relatively comparable numbers of both young of the year (YOY) and year old fish (1+) from both the West Fork and the mainstem of Sproul Creek above the confluence with the West Fork (aka South Fork Sproul Creek) (Vaughn 2007, Figure 7-9, Figure 7-10). The size distribution of 1+ Coho Salmon and age distribution of steelhead from this same trapping data are consistent with other Northern California tributary streams (Ricker 2002), though the size of outmigrants from Sproul Creek tributaries tends to be relatively small on average (Vaughn 2007, Figure 7-11). It is uncertain if the observed size of Coho Salmon emigrating from Sproul Creek results in poor ocean survival, but research from other areas suggests that insufficient growth rates have resulted in smolts that are not well prepared to survive the saltwater portion of their life history (Holtby et al. 1990). It is important to note that these data are from traps located relatively high in Sproul Creek, and these fish likely spend more time rearing
and growing in the mainstem of Sproul Creek or other habitats downstream of Sproul Creek before entering the ocean (Ricker 2002).
Figure 7-5. Observed and modeled stream temperature and associated suitability for Coho Salmon and steelhead rearing in the Sproul Creek sub-watershed.
Figure 7-6. Habitat Suitability Index for canopy density in the Sproul Creek sub-watershed derived from CDFW stream habitat inventories completed during the following time periods: 1990-1999, 2000-2010, and 2016-2019. Surveyed reaches varied per time period based on funding and crew availability.
**Figure 7-7.** Habitat Suitability Index for embeddedness in the Sproul Creek sub-watershed derived from CDFW stream habitat inventories completed during the following time periods: 1990-1999, 2000-2010, and 2016-2019. Surveyed reaches varied per time period based on funding and crew availability.
Figure 7-8. Total density of Coho Salmon, Chinook Salmon, and steelhead reddss in the Sproul Creek sub-watershed, all years combined (2010-2018), based on CDFW spawner surveys (Starks and Renger 2016). The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.
Figure 7-9. The number of young of the year (YOY) and one year or older (1+) Coho Salmon (bottom panels) and steelhead (upper panels) captured in downstream migrant traps on tributaries of Sproul Creek from 1999 to 2007. The South Fork tributary refers to the mainstem of Sproul above the confluence with the West Fork. Data source: Vaughn 2007.
Figure 7-10. The number of young of the year (YOY) Chinook Salmon captured in downstream migrant traps on tributaries of Sproul Creek from 1999 to 2007. Two Chinook Salmon were captured during the same period that were substantially larger, indicating an age that was greater than one year (not included in the graph above). Chinook Salmon of this size and age are typically exhibiting the “stream type” life history. The South Fork tributary refers to the mainstem of Sproul above the confluence with the West Fork. Data source: Vaughn 2007.

Figure 7-11. Fork lengths of age 1+ Coho Salmon captured on a downstream migrant trap on the West Fork of Sproul Creek (Vaughn 2007).
In the SHaRP ranking process, Sproul Creek had the fourth highest overall priority score among 19 sub-watersheds, with the third highest Biological Importance score, the eighth highest Habitat Condition score, fourth highest Optimism and Potential score, and the fourth highest Integrity and Risk score. In the CDFW SFER watershed assessment (2014), the Sproul Creek sub-watershed had the greatest length of channel providing “high quality refugia.”

### 7.3 Historic and Current Restoration Efforts in Sproul Creek

Limited restoration efforts have been made to improve salmon and steelhead populations in Sproul Creek and its tributaries relative to other SFER sub-watersheds (Figure 7-12). Past restoration projects have primarily been funded through CDFW’s Fisheries Restoration Grant Program (FRGP); however, industrial timber companies and private landowners have also completed sub-watershed restoration projects. These projects have occurred in a limited number of reaches comprising a small percentage of the total sub-watershed. While the scale of these restoration actions is not likely to lead to detectable changes in salmonid populations (Roni et al. 2010), they are an important step towards larger restoration efforts.

The first restoration projects completed in lower Sproul Creek in the mid-1980s focused on erosion control through bank stabilization. In an effort to reduce sediment input into lower Sproul Creek, riparian tree planting occurred at 11 sites in conjunction with armoring banks though the installation of rip-rap, which consists of boulders and concrete. During the early 1990s, 30 large woody debris structures (primarily boulder/root wad structures) were placed in the mid to lower sections of Little Sproul Creek to provide spawning and rearing habitat. A follow-up project in the mid-1990s added 14 more of these structures with the similar intention of improving spawning and rearing habitat. Lastly, during the late 1990s in the middle reach of Little Sproul Creek, 1,300 conifers were planted along the riparian influence zone to provide shading, bank stability, and future recruitment of large wood to the stream channel.

In 2005-2006, the corrugated metal culvert at the mouth of Warden Creek was replaced with a bottomless arch culvert, which restored access to ¾ mile of stream to salmonids. The following year, over 10 instream structures were installed in Sproul Creek between West Fork Sproul and Warden Creek. These structures, which mostly consisted of several small diameter logs (minimum of 12” as standard), were installed to increase large woody cover, pool frequency, channel complexity, and connectivity within a 4.5-mile reach of Sproul Creek (FRGP, CDFW). The installation of these smaller structures resulted in a notable improvement in pool depths at the project sites, but the infrequent spacing appears inadequate to significantly influence channel forming processes in a stream of this magnitude. This reach would benefit from additional efforts to enhance instream habitat such as point bar wood jams where channel splits exist and complex wood structures consisting of many whole trees (pers. comm. Monty Larson).
Figure 7-12. Habitat restoration projects implemented in the Sproul Creek sub-watershed.
In addition to instream restoration, several road inventories have been completed in the Sproul Creek sub-watershed since the mid-2000s with the intention of mapping and developing treatments for problematic sediment sources. While some of these sources of chronic sediment delivery have been treated (e.g. La Doo Creek), there are still multiple areas throughout the sub-watershed that would benefit Sproul Creek and its tributaries through the reduction of chronic high turbidity.

The FRGP also funded 8 years of a 9-year monitoring program in Sproul Creek with funding for an additional year provided by Barnum Timber Company. Beginning in 1999, two downstream migrant traps were operated on Sproul Creek to monitor production, run timing, and size of Chinook Salmon, Coho Salmon, and steelhead as well as collect tissue for genetic stock analysis. The results and analysis from these monitoring efforts are discussed further in Section 11.2.

Beginning in the drought period of 2014, CalTrout conducted water resources investigations and an instream flow study in Sproul Creek. Findings are summarized in the Sproul Creek Instream Flow Study Final Report (California Trout 2018). In 2019, the SRF was awarded a California Wildlife Conservation Board grant to conduct additional flow monitoring and flow enhancement planning. That work is currently underway, with continued collaboration between SRF, CalTrout and Stillwater Sciences.

7.4 Limiting Factors and Threats Affecting Salmonids in Sproul Creek

The Sproul Creek Expert Panelists discussed available data and personal observations of the sub-watershed on September 5, 2019. During this discussion, each participant rated the impact of each limiting factor and threat on each life stage of each species through an interactive process. The resulting limiting factor tables (Table 7-1, Table 7-2) summarize Expert Panel rankings in three areas of the sub-watershed: the 1) West Fork Area (West Fork of Sproul Creek and tributaries), 2) Mainstem Area (Sproul Creek and tributaries from its mouth to the confluence of the West Fork Sproul Creek), and 3) South Fork Area (Sproul Creek above the confluence with the West Fork Sproul Creek). The severity of each threats was considered across the entire sub-watershed (Table 7-3). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered that limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
Limiting factors

Table 7.1. Average scores for the severity of impact of each limiting factor on each life stage of Coho Salmon and steelhead in three areas of the Sproul Creek tributary group.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Life Stages and Areas</th>
<th>West Fork (WF) Sproul Creek Area</th>
<th>Mainstem Sproul Creek Area</th>
<th>South Fork Sproul Creek Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel complexity, including pool depth</td>
<td>West Fork Sproul Creek, Warden Little Sproul</td>
<td>Eggs: 1.8, Summer Parr: 1.9, Winter Parr: 2.6, Migrating Adults: 2.9</td>
<td>Eggs: 2.5, Summer Parr: 2.0, Winter Parr: 1.5, Migrating Adults: 2.0</td>
<td>Eggs: 1.8, Summer Parr: 1.7, Winter Parr: 1.8, Migrating Adults: 2.1</td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>Mainstem Sproul Creek downstream (north) of WF confluence</td>
<td>Eggs: 2.3, Summer Parr: 2.6, Winter Parr: 2.5</td>
<td>Eggs: 1.8, Summer Parr: 1.5, Winter Parr: 1.6</td>
<td>Eggs: 1.9, Summer Parr: 2.4, Winter Parr: 1.6</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>Mainstem Sproul Creek upstream (south) of WF confluence, Cox Creek, unnamed creek</td>
<td>Eggs: 3.0, Summer Parr: 1.7, Winter Parr: 2.8</td>
<td>Eggs: 2.6, Summer Parr: 1.6, Winter Parr: 1.7</td>
<td>Eggs: 2.6, Summer Parr: 1.7, Winter Parr: 1.7</td>
</tr>
<tr>
<td>High Water Temperature</td>
<td></td>
<td>Eggs: 4.3, Summer Parr: 2.8, Winter Parr: 3.8</td>
<td>Eggs: 3.8, Summer Parr: 2.8, Winter Parr: 3.8</td>
<td>Eggs: 3.8, Summer Parr: 2.8, Winter Parr: 3.8</td>
</tr>
<tr>
<td>Dry season flow</td>
<td></td>
<td>Eggs: 3.2, Summer Parr: 2.7, Winter Parr: 1.8</td>
<td>Eggs: 1.8, Summer Parr: 1.8, Winter Parr: 1.8</td>
<td>Eggs: 1.8, Summer Parr: 1.8, Winter Parr: 1.8</td>
</tr>
<tr>
<td>Wet Season Flow (timing and volume)</td>
<td></td>
<td>Eggs: 4.9, Summer Parr: 5.0, Winter Parr: 5.0</td>
<td>Eggs: 5.0, Summer Parr: 5.0, Winter Parr: 5.0</td>
<td>Eggs: 5.0, Summer Parr: 5.0, Winter Parr: 5.0</td>
</tr>
<tr>
<td>Barriers*</td>
<td></td>
<td>Eggs: 3.5, Summer Parr: 4.8, Winter Parr: 5.0</td>
<td>Eggs: 3.8, Summer Parr: 4.8, Winter Parr: 5.0</td>
<td>Eggs: 3.5, Summer Parr: 4.2, Winter Parr: 4.6</td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td></td>
<td>Eggs: 2.1, Summer Parr: 3.1, Winter Parr: 1.8</td>
<td>Eggs: 1.8, Summer Parr: 3.0, Winter Parr: 1.9</td>
<td>Eggs: 1.8, Summer Parr: 3.0, Winter Parr: 1.9</td>
</tr>
</tbody>
</table>

*Including natural barriers that only occur in low flow years.
Table 7-2. Average scores for the severity of impact of each limiting factor on each life stage of Chinook Salmon in three areas of the Sproul Creek tributary group.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>West Fork Sproul Creek, Warden</th>
<th>Mainstem Sproul Creek</th>
<th>South Fork Sproul Creek Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel complexity, including pool depth</td>
<td>1.7</td>
<td>3.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>3.1</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>2.8</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Wet Season Flow (timing and volume)</td>
<td>4.9</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Barriers*</td>
<td>4.7</td>
<td>4.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.2</td>
<td>3.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*Including natural barriers that only occur in low flow years.

Many of the limiting factors with the highest impacts on Coho Salmon, Chinook Salmon, and steelhead in Sproul Creek are related to a relative lack of physical habitat complexity (Table 7-1 and Table 7-2). Channel complexity rated high or very high impact on most applicable life stages of all species in both areas of the tributary group. The Expert Panel rated large wood recruitment as a key limiting factor on all life stages of the three salmonid species due to the current deficit of large wood in key areas that can help form suitable habitat (Figure 7-3). As described earlier in the Watershed Overview, canopy cover has improved in the last two decades (Figure 7-6); however, the age, size, and type of riparian vegetation is not yet suitable to replenish large wood in Sproul Creek. Similarly, the availability of off-channel habitat was rated as another key limiting factor for most juvenile salmonids, particularly for winter-rearing life stages which depend on velocity refuge.

Factors related to water quality and quantity were also rated as high or very high impact for Coho Salmon and steelhead, depending on the area. Summer rearing parr in the mainstem and South Fork areas are limited by dry season flow with several tributary reaches drying up and mainstem flow becoming low enough to limit juvenile migrations. The Expert Panel noted that residents of the South Fork area use riparian water during summer months which may have a significant impact on the dry-season flow of this area as well as the downstream mainstem reaches. Water temperatures in the mainstem area were also rated as a limiting factor to summer parr. Temperature monitoring in this area indicates that late summer temperatures can become stressful for salmonids.

The Expert Panel also noted that several areas of the sub-watershed were more heavily impacted by excess sediment than others. Sediment inputs from catastrophic road failures as well as chronic turbidity were rated as high impact to egg life stages in the Mainstem Area and to eggs and fry in
the South Fork Area. These areas are consistently more turbid than the West Fork of Sproul Creek during winter and early spring, leading to increased gravel embeddedness and presumably lower egg and alevin survival.

Barriers (culverts and natural barriers) and wet season flow were rated moderate or low impact limiting factors across species, life stages, and areas. There are no major anthropogenic barriers in the sub-watershed and relatively few natural barriers limiting salmonid distribution. Several smaller tributaries have woody debris accumulations that may form partial or temporal barriers, but Expert Panel discussions did not indicate any of these warranted modifications. The mouth of Sproul Creek is easily passable by migrating adults and the sub-watershed is positioned relatively low in the sub-basin, making it accessible to migrating adults even under lower flow conditions.

**Threats**

Table 7-3. Effect of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in the Sproul Creek tributary group overall.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Egg</th>
<th>Summer Parr</th>
<th>Winter Parr</th>
<th>Fry</th>
<th>Migrating Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channelization (roads)</td>
<td>1.8</td>
<td>2.0</td>
<td>2.1</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Climate change</td>
<td>2.8</td>
<td>2.8</td>
<td>2.0</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Culvert, levee, tide gate, dam</td>
<td>4.3</td>
<td>4.3</td>
<td>4.6</td>
<td>4.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Diversions</td>
<td>4.8</td>
<td>5.0</td>
<td>3.6</td>
<td>5.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>3.6</td>
<td>3.6</td>
<td>3.2</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Riparian Mgmt. (legacy)</td>
<td>3.0</td>
<td>3.0</td>
<td>2.4</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Rural private roads (chronic)</td>
<td>1.8</td>
<td>1.7</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Land conversion and development was rated a very low threat in the Sproul Creek tributary group, likely due to the existing ownership by timberland managers across much of the sub-watershed. Similarly, channel impingement due to streamside roads was rated a low threat, except for migrating adult Chinook Salmon which rated a moderate impact. Pikeminnow are known to occur in the lower reaches of Sproul Creek, but it is unknown to what extent Pikeminnow distribution overlaps with salmonids in SFER tributaries, which could explain why it was rated a low to very low threat.
In contrast, chronic sediment inputs of rural private roads, as well as the effects of these roads on sub-watershed hydrology, rated a high threat to most life stages and species. Vegetation and fire management (referring to densely packed young trees) were rated as moderate. Road crossings, debris accumulation, and other barriers rated a high threat to all life stages and species except summer parr, for which they rated a very high threat (likely due to their presence in the stream during the summer low-flow period when related barriers would be the most severe).

### 7.5 Recovery Strategy

On September 6th, 2019, the Sproul Creek Action Team discussed the outcomes of the Expert Panel meeting, as presented in [Table 7-1](#) and [Table 7-2](#), and identified restoration actions that would best address the most limiting factors and the highest severity threats. The team collaboratively identified the best locations for these restoration actions by reviewing spatial data on printed maps and identifying locations known to the experts of the panel. [Figure 7-13](#) below shows the treatment types and locations identified by the Action Team as recorded during the meeting and later interpreted by the steering team.

The recovery strategy for Sproul Creek is targeted at improving physical habitat complexity for juvenile fish during summer and winter, improving riparian forest composition, treating upslope sources of sediment in impacted areas, and reducing the impacts of water withdrawal through community outreach, education, and flow enhancement. This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. As more data become available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 7-13. Recommended restoration treatments in the Sproul Creek sub-watershed.
Table 7-4. Restoration treatments for the Sproul Creek sub-watershed

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>LWD for summer rearing (pools, sorting gravel)</td>
<td>Sproul Creek, Little Sproul Creek, Warden Creek, Tributary to Sproul Creek, West Fork Sproul Creek</td>
<td>514, 516, 520, 521, 533, 535, 538</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Sproul Creek, Little Sproul Creek, Warden Creek, West Fork Sproul Creek</td>
<td>511, 516, 520, 521, 533, 538</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Sproul Creek, Little Sproul Creek, Warden Creek, West Fork Sproul Creek</td>
<td>511, 514, 516, 533, 538</td>
</tr>
<tr>
<td><strong>Streamflow Augmentation</strong></td>
<td>Groundwater and flow enhancement</td>
<td>Warden Creek</td>
<td>533</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Riparian Treatment</td>
<td>Sproul Creek</td>
<td>511, 514, 516</td>
</tr>
<tr>
<td></td>
<td>Upslope erosion hazard assessment</td>
<td>Sproul Creek, W.F. Sproul Creek, Tributary to W.F. Sproul Creek, Tributary to Sproul Creek, Cox Creek</td>
<td>516, 516.1, 542, 542.1, 554, 562, 562.1, 565, 565.1</td>
</tr>
<tr>
<td></td>
<td>Water use management, education, and outreach</td>
<td>Sproul Creek, Cox Creek</td>
<td>516, 565.1</td>
</tr>
</tbody>
</table>
Treatments to Improve Overwinter Conditions for Winter Parr and Fry

Improving channel complexity and off-channel habitat for overwintering juvenile salmonids were identified by the Expert Panel as a key limiting factor. Treatments to increase the amount of low velocity habitat and increase the frequency of floodplain inundation across a range of stream discharges were recommended. Stream reaches which were typically low gradient but lacking large wood and other refugia features were selected by the Action Team as locations which could support suitable in-channel winter habitat if large wood or other flow-obstructing structures were recruited or installed. These areas were also near frequently used spawning habitat or areas that were expected to be occupied in winter by both natal and non-natal parr and fry based on the conceptual life history model of fall re-distribution (see Chapter 4). The Action Team identified potential areas to improve in-channel winter habitat throughout the basin including portions of Sproul Creek (reach 511, 514, and 516), West Fork Sproul Creek (the upper and lower portions of reach 538), Warden Creek (reach 533), and Little Sproul Creek (upstream end of reach 520 and reach 521). The Action Team also specified that treatments in the lower reaches of Sproul Creek will also benefit migrating adults which will likely utilize low velocity habitat as holding and resting areas in route to spawning habitat upstream.

Stream gradients as described above were also used to assess suitable locations for off-channel winter habitat with the additional consideration that ideal reaches should have unconfined channels, wide valley widths, the presence of anchor habitat, and/or the observation of existing floodplain habitats that could be inundated more frequently or enhanced to provide suitable winter refugia. The Action Team identified potential areas to create or improve off-channel habitat throughout the mainstem of Sproul Creek from the middle of reach 511 up to the second right bank tributary upstream of the confluence with the West Fork Sproul Creek and from the confluence with Cox Creek downstream to the confluence with reach 562. Additionally, the lowest portion of the West Fork Sproul Creek from the confluence with Sproul Creek upstream to the first tributary on the left bank and the bottom of Warden Creek (reach 533) were also identified as areas to restore off-channel winter habitats. Members of the Action Team noted a spring on Sproul Creek near the first right bank tributary above the confluence with the West Fork Sproul Creek which provides high quality habitat throughout the year and it was observed that many over-wintering juvenile salmonids have occupied this habitat in previous seasons. An off-channel pond in this region could expand the capacity of this habitat, though equipment access to the site may be challenging. The Action Team also noted that treatments influencing floodplain inundation are most appropriate in areas that will not threaten stream-adjacent roads or other infrastructure.

Treatments to Improve Summer Habitat for Coho Salmon and Steelhead Parr

The Expert Panel identified that summer parr may be most limited by the lack of instream complexity throughout Sproul Creek. To address this limitation, the Action Team recommended several reaches that support juvenile salmonids during the summer months but would greatly
benefit from greater pool depth and increased pool cover. Treatments to increase instream structures which create deeper pools under scouring flows and complex cover under summer baseflow conditions were recommended in reaches with cooler water temperatures near frequently used spawning habitat. Recommended areas typically had lower gradients which would be prone to deposition of sediments in the absence of channel obstructions such as large wood. Augmenting these reaches with large wood will likely promote and maintain more scour pools (Woodsmith and Hassan 2005). The recommended reaches include portions of the main stem of Sproul Creek (reach 514 – 516), portions of the West Fork Sproul Creek (reach 538 from the confluence with Sproul Creek upstream to approximately the third left bank tributary and from the confluence with reach 549 to the upstream end of reach 538), lower Warden Creek (reach 533), and Little Sproul Creek (the upper half of reach 520 through reach 521).

The Action Team identified several regions of the sub-watershed where summer flows are likely limiting the summer rearing potential of parr. While flows in the Sproul Creek sub-watershed are considered relatively unimpaired compared to other sub-watersheds of the South Fork Eel River, portions of upper Sproul Creek and Cox Creek have rural residential developments and associated water diversions that likely influence stream discharge in stream channels adjacent to or downstream of diversions. CDFW habitat typing surveys and observations of the Action Team indicate that portions of upper Sproul Creek and Cox Creek frequently dry back in the summer; however, it is unknown if this is due to water diversions. The Action Team recommended conducting community outreach in these regions (reaches 516.1 and 565.1) to better understand the volume and timing of water diversion, communicate the importance of maintaining summer flows, and provide information and/or technical assistance to improve water use throughout the community.

Temperatures in the downstream region of the mainstem Sproul Creek (below reach 514) can become unsuitably warm and stressful for Coho Salmon during the summer and limit the summer rearing capacity of the sub-watershed (Figure 7-5). Salmonid fry and parr typically redistribute from upstream natal areas in the spring to seek productive habitats downstream of spawning sites (Soto et al. 2016). Trapping data and observations of feeding behavior indicate age 0 salmonids in Sproul Creek also undergo a second redistribution in early summer, suggesting that as flows recede in tributaries and headwaters, fish seek more productive mainstem habitats with greater flows (Vaughn 2007, Pers. Comm. Gabe Rossi 2019). Because summer water temperatures in the lower mainstem of Sproul Creek are typically higher than optimal for rearing fry and parr (Figure 7-5), the Action Team recommends investigating Warden Creek for flow and temperature enhancement. The use of off-channel storage to augment ground water flow into Warden Creek could significantly lower summer water temperatures and increase flows in mainstem Sproul Creek downstream of Warden Creek, creating highly productive summer rearing habitat for fry and parr.
Treatments to Improve Habitat for Eggs, Alevin, Winter Parr and Fry

The Expert Panel identified sedimentation as a high impact limiting factor for salmonid eggs and alevin throughout the sub-basin. Sedimentation was also rated as a highly limiting factor for Coho Salmon parr, steelhead parr, and Chinook Salmon fry during the winter months in reaches and tributaries of Sproul Creek above the confluence with the West Fork Sproul Creek. Based on field observations and spawning gravel embeddedness ratings, the Action Team identified portions of upper Sproul Creek (reaches 516, 516.1, 562, 562.1, 565, and 565.1) and upper West Fork Sproul Creek (reaches 542, 542.1, and 554) as areas to investigate and treat sediment sources that directly impact spawning habitat. These areas have poorly constructed and/or poorly maintained legacy and contemporary logging roads which may be contributing large amounts of sediment to waterways. Additionally, upper Sproul Creek has several miles of unimproved residential roads and numerous historic and contemporary landslides that are likely contributing to the sediment-laden waters frequently observed in Sproul Creek above the confluence with the West Fork Sproul Creek. The Action Team recommends decommissioning legacy roads, upgrading contemporary roads, and remediating landslides which are delivering harmful loads of sediment to spawning habitat through connected waterways.

Treatments to Improve Large Wood Recruitment

The Expert Panel rated large wood recruitment as a highly limiting factor across nearly every species and life stage of salmonid except for egg and alevin life stages where large wood recruitment was not included in the list of factors considered. The history of logging and flooding throughout the sub-watershed has resulted in a very young forest with relatively few coniferous trees available for recruitment to waterways. Of particular concern to the Action Team were the relatively homogenous stands of alder which have colonized the flood-swept plains of the downstream reaches of Sproul Creek (reaches 514 – 516 and a portion of reach 511 near Little Sproul Creek). While these trees provide abundant shade to the stream, they do not typically contribute large, long-lasting instream structure once recruited. Succession of more suitable coniferous trees will likely occur, though on a much longer timescale than may be sustainable for the depressed salmonid populations of Sproul Creek. To accelerate the process of forest succession, the Action Team recommends strategically thinning some of these alders to encourage the growth of understory conifers and planting conifers to improve the riparian forest’s heterogeneity. Thinned alders can be recruited to the stream to provide short term habitat as recommended in the sections above.

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
8. Chapter 8: Indian Creek Action Plan

8.1 Sub-Watershed Overview

The Indian Creek sub-watershed (Indian Creek) is located along the western portion of the South Fork Eel River (SFER) sub-basin in Mendocino County (Figure 8-1). Indian Creek is a second order stream with approximately 17.8 miles of perennial waterways draining a sub-watershed of approximately 27 square miles (CDFG 2008). Elevations range from approximately 490 feet at the mouth of the creek to 1,300 feet in the area of the headwaters. The landscape is dominated by mixed coniferous Douglas-fir/redwood forest and mixed hardwood forest (CDFG 2008, CDFW 2014). Most of the land in the sub-watershed is privately owned and managed for timber production. Despite a history of poorly regulated timber harvest and poor management of aquatic resources, Indian Creek supports a consistent population of Coho Salmon, Chinook Salmon, and steelhead. Improvement in recent harvest practices and overall land management has resulted in some initial signs of salmonid habitat recovery.

The Indian Creek sub-watershed is underlain by shale and sandstone bedrock of the Coastal Belt Franciscan Complex, which forms the steep, rugged terrain characteristic of the western slope of the SFER sub-basin (CDFW 2014). This underlying geology tends to form ridges and canyons in the landscape that are steeper and more deeply-weathered relative to the eastern sub-basins of the SFER, allowing more seasonal replenishment of rock moisture and sustained base flow throughout the dry season (Hahm et al. 2019). Despite the high-gradient upland slopes surrounding the sub-watershed, many Indian Creek streams are low gradient, meandering channels with riffle/pool complexes of Rosgen type F1, F2, and F4 (CDFG 2008). Soils in the landscape include Wohly, Holohan, and Casabonne series which are composed of well-drained gravely to sandy loams formed from weathered sandstone and/or shale (NRCS 2020). Stream banks consist of 37% bedrock, 36% sand/silt/clay, 24% cobble/gravel and 3% boulder (CDFG 2008). The resulting substrates in Indian Creek are dominated by either gravel, cobbles, or boulders with ~77% of pool tail-outs exhibiting gravel and cobble embeddedness ideal for salmonid spawning (CDFG 2008, Figure 8-2).

The weathered shale and sandstone bedrock also support productive redwood, Douglas-Fir, and hardwood timberlands which have spurred several generations of timber harvesting in the area (Hahm et al. 2019).
Figure 8-1. Indian Creek’s position in the South Fork Eel River Watershed.
Figure 8-2. Habitat Suitability Index for embeddedness in the Indian Creek sub-watershed derived from CDFW stream habitat inventories completed in the following time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
8.2 History of Land Use and Fish Habitat

The Indian Creek sub-watershed is Wailaki ancestral land, and prior to European settlement tribal members inhabited areas along Indian Creek and its tributaries. The land and its associated natural resources provided sustenance and a spiritual connection for tribal members. In the 1860s European settlers began building homesteads in the sub-watershed relying on small farming and timber operations to make a living off the land.

The logging history of the sub-watershed is not entirely known, but it most likely followed the general pattern for the SFER: late 19th and early and 20th century logging was restricted to redwoods in accessible areas around creek mouths, followed by logging of upper watersheds in the decades after World War II (CDFW 2014). Beginning in 1896, a small port and railroad were established connecting the Indian Creek sub-watershed and a mill site in Andersonia to Bear Harbor, facilitating timber extraction via rail and ship (Hugh 2010). The infrastructure of this early mill site included a large log pond dam on Indian Creek near the confluence with the SFER that blocked fish passage for over 20 years. However, there were numerous, major operational problems with both the railroad and the mill (Flagherty 1931). This limited the rate and extent of timber extraction in the Indian Creek sub-watershed between 1896 and 1910 compared to that seen in watersheds near major ports such as Humboldt Bay. This operation was abruptly halted in 1906 due to damage caused by the historic 1906 earthquake (Hugh 2010) and the destruction of the dam during a large winter storm (Michaels 1999). Logging resumed throughout the basin in the decades following World War II and continued at a rapid rate until environmental restrictions began with the implementation of the Z'berg Nejedley Forest Practices Act of 1973 (Forest Practices Act) (CDFW 2014).

The legacy effects of logging and a series of devastating floods dramatically altered the habitat and hydrology of Indian Creek waterways. From the mid-1940s until the enactment of the Forest Practices Act, lands in the Indian Creek sub-watershed were tractor logged intensively by private landowners, including Pacific Coast Lumber Company and Indian Creek Lumber Company. The activities associated with this era (road building, skid roads, elimination of riparian forest etc.) have resulted in continued disrupted hillslope surface water hydrology. During this period, landowners were taxed on standing timber until 70% was cut (URFC 2016). The incentives to rapidly harvest timber combined with a dearth of protective regulations for waterways led to the construction of numerous skid and haul roads in or near low-order streams in accordance with standard practices of the era (Gienger 2017, Stillwater Science 1999). The poorly engineered roadways and the vast scale of logging activities left the Indian Creek sub-watershed vulnerable to disturbances.

When the watershed was struck by two record-breaking floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River at rates approximately three times greater than observed in the geologic record of the watershed (Sommerfield et al. 2002). Mass wasting during these events led to rapid aggradation of the channel beds of SFER tributaries, leaving many...
tributaries perched above the SFER atop large deposits of sediment (Sloan et al. 2001). Abundant debris from timber extraction as well as remnant structures including stream crossings, mill sites, and railway materials in or near waterways washed into Indian Creek and formed large debris and sediment accumulations which created significant fish passage barriers (CDFW 2014, CDFG 1938, Gienger 2017). Through subsequent decades until the early 1980s, groups including the Center for Manpower Resources, the Coastal Headwaters Association, and the California Conservation Corps cleared many of these debris accumulations to allow fish passage (CDFG 1982, Indian Creek Rehabilitation Project 1979). Despite the short-term success of stream clearing in allowing passage, removal of instream large wood\(^7\) combined with a decline in new wood recruitment contributed to the long-term lack of in-channel large wood (Figure 8-3). The reduction in new wood recruitment resulted from decades of timber harvest which converted the riparian forest from old-growth conifer-dominant to hardwood-dominant. Coniferous trees contribute long-lasting large wood to the streams, while hardwood trunks and branches decompose rapidly.

Once large wood was removed, there was little channel complexity to slow water velocities or capture and retain gravels, allowing stream energy to rapidly down-cut through the large sediment deposits left by the floods. In many stream reaches, this altered process resulted in severely incised channels which were largely disconnected from their floodplains (Sloan et al. 2001). The lack of large wood has also reduced stream complexity; many reaches have lost sinuosity, pools lack depth and frequency, substrates are poorly sorted or entrain so swiftly that only material too coarse for spawning remains (Kaufman et al. 1997, Figure 8-3, and Figure 8-4). The persistent deficiency in floodplain connectivity has eliminated access to critical winter refugia habitat for juvenile salmonids (Bair 2016).

Prior to the rapid extraction of timber following WWII, riparian shading and instream cover in Indian Creek was noted as excellent (CDFG 1938) and even in the years concurrent with extraction, instream cover was abundant in nearby Standley Creek (CDFG 1968). A 1993 California Department of Fish and Wildlife\(^8\) (CDFW) stream inventory of Indian Creek conducted after nearly all primary forests had been logged and debris jams cleared observed low overall instream and riparian cover available and the little instream cover that was available was provided by boulder structures (CDFG 1993). A more recent stream inventory indicates that instream cover has consistently remained low and is still predominantly provided by boulders (Figure 8-5).

Since the 1974 prohibition on logging in riparian zones, plant communities have been proceeding through ecological succession following disturbance. In Pacific Northwest coastal zones, this

\(^7\) Formally referred to as large wood debris (LWD) in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.

\(^8\) Formerly known as the California Department of Fish and Game (CDFG)
succession moves relatively quickly from colonization by herbaceous vegetation to a community dominated by Red Alder (Naiman et al. 2000). This trend can be seen in the increased mean canopy density of 58% from surveys conducted in 1993 to 83% 15 years later (CDFG 2008, Figure 8-6). While increased canopy cover is considered beneficial for the regulation of summer water temperatures, alder does not grow very large, nor does it persist once recruited to the stream channel relative to most conifers common to the region (Naiman et al. 2000). The continued succession from an alder-dominated riparian forest to mature conifers which provide a source for large wood recruitment needed to restore channel-forming processes will likely take many tens to hundreds of years (Stanley et al. 1991). During this time, native salmonid populations remain at risk of endangerment and potential extirpation.

Despite the history of anthropogenic impacts to Indian Creek and its tributaries, conditions have remained somewhat suitable for salmonids and other anadromous fish. Summer water temperature data compiled and analyzed by the Eel River Recovery Project (2016) from the early 1980s through 2015 (various studies and temperature data collected only for a portion of these years) indicated suitable summer water temperatures, less than 18°C, in the upper and middle portion of the sub-watershed. Unsuitable water temperatures, 22°C – 24.9°C, were recorded in the lowest reaches of Indian Creek (Figure 8-7). In addition, water temperatures measured during CDFW stream surveys in summer months from 1938 to 1993 range from good to poor for salmonids in comparable areas to those utilized in the Eel River Recovery Project report (Figure 8-7). High quality pool habitat has also persisted in the sub-watershed with 41% of stream surveyed composed of pools, 95% of which were greater than 2 feet deep (CDFG 2008, Figure 8-4). As noted earlier, pool tail-outs had a high occurrence of spawning gravels suitable for salmonids. The multi-decade analysis conducted by CDFW (2014) confers the improvement in habitat suitability for salmonids from 1990 to 2010. Anadromous fish including Pacific Lamprey, Coho Salmon, Chinook Salmon and steelhead have been consistently observed throughout the sub-watershed, often in abundance (DFG 1938, DFG 1968, CDFG 1993, CDFG 2008). Spawning ground surveys indicate that most of the Indian Creek sub-watershed is frequently utilized by adult salmonids, and spawning is especially prevalent in Anderson Creek (Figure 8-8).
Figure 8-3. Large and small wood density in the Indian Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 2002-2008 and 2009-2010. Surveyed reaches varied per time period based on funding and crew availability.
Figure 8-4. Habitat suitability index for pool depth in the Indian Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
Figure 8-5. Habitat suitability index for pool shelter in the Indian Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
Figure 8-6. Habitat suitability index for canopy density in the Indian Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
Figure 8-7. Observed and modeled summer water temperature in Indian Creek. Sources: ERRP (2016) [years included 1980-2015] and USFS v.2 (2017).
Figure 8-8. Total density of Coho Salmon, Chinook Salmon, and steelhead redds in the Indian Creek sub-watershed, all years combined (2010-2018), based on CDFW spawner surveys. The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.
Currently, most of the sub-watershed is owned by two industrial timber companies: the Usal Redwood Forest Company and Lost Coast Forestlands LLC. Since acquiring lands surrounding Indian Creek, Usal Redwood Forest Company’s parent organization, Redwood Forest Foundation Inc. (RFFI), has partnered with Trout Unlimited (TU) and Pacific Watersheds Associates (PWA) and conferred with experts from UC Berkeley, NMFS, Humboldt State University, and Cal Fire to develop and implement restoration projects. These projects are aimed at decommissioning roads and improving instream conditions through the placement of large woody debris and riparian planting (RFFI 2019). Both the Usal Redwood Forest Company and Lost Coast Forestlands continue to participate in the SHaRP.

In the SHaRP ranking process, Indian Creek had the second highest overall priority score among sub-watersheds, with the second highest score for Biological Importance, and the third highest scores in Habitat Conditions, Optimism and Potential, and Integrity and Risk. In the SFER watershed assessment, Indian Creek had the greatest length of channel providing “high quality refugia” in the SFER watershed (CDFW 2014).

### 8.3 Historic and Current Restoration Efforts in Indian Creek

A variety of restoration work has occurred in the Indian Creek sub-watershed since the late 1970s to improve salmon and steelhead populations in Indian Creek (Figure 8-9). The Fisheries Restoration Grant Program (FRGP) has awarded approximately $949,000 to habitat restoration and restoration planning projects since 2004. This accounts for roughly 6.7% of all the FRGP funding awarded to the South Fork Eel River sub-basin during that period. While the desire to improve this sub-watershed area is strong within watershed groups, agencies, landowners, and interested stakeholders, their efforts have been partially hindered by limited access to remote areas within the sub-watershed. Indian Creek contains long stretches of stream geographically situated...
in moderately steep canyons with few to no roads. Some tributaries also lack an active, developed road network. The initial restoration efforts focused on woody debris log jam modifications whose intentions were to provide stream passage through areas littered with remnants of previous logging activities. Long stretches of local streams contained enormous amounts of slash, logs, and railroad trestle remnants from historic logging operations, which was perceived to have prevented or hindered fish passage.

Using FRGP-awarded funds, the Eel River Watershed Improvement Group (ERWIG), the California Conservation Corps (CCC), and Pacific Watershed Associates (PWA), in 2011/2012 constructed 39 structures on a 4 mile stretch of Indian Creek (beginning approximately 0.5 miles upstream from the confluence with the SFER) to enhance and increase large woody cover, pool frequency, and channel complexity using FRGP-awarded funds. In 2014 TU and PWA completed a sediment assessment, and since then they have completed several road decommissioning projects. From 2014 to 2018, ERWIG and the CCC installed approximately 67 large wood structures to improve instream habitat complexity and stabilize banks in Anderson Creek. In 2019, 64 pieces of large wood, were constructed into 18 features along a 0.49-mile reach of Moody Creek. Eleven of the features were constructed using heavy equipment, seven features were constructed by directly felling timber into the channel (WebGrants 2021). Additionally, 3.08 miles of high priority streamside and inner gorge road were decommissioned in the Moody Creek watershed. A total of 34 current and potential erosion features were treated to eliminate their potential for failing and delivering eroded sediment to Moody Creek and its tributaries. Two of these features were very large stream diversions that have now been realigned back into their natural channels (WebGrants 2021). CDFW, RFFI, Lost Coast Forestlands (LCF), PWA, TU, ERWIG, and the CCC continue to collaborate on restoration projects in the Indian Creek sub-watershed. Currently planned projects are primarily focused in Anderson, Moody, Coulborn, and Sebbas creeks.
Figure 8-9. Past restoration projects completed intended to improve salmonid habitat in the Indian Creek sub-watershed.
8.4 Limiting factors and threats affecting salmonids in Indian Creek

The Indian Creek Expert Panelists discussed available data and personal observations of the sub-watershed on March 25, 2019. During this discussion, each participant scored how limiting they thought each limiting factor and threat was to each life stage of each species through an interactive process. The limiting factor tables (Table 8-2 and Table 8-3) summarize the average Expert Panel rankings in two areas: 1) Tributaries, consisting of tributaries including Moody, Coulborn, and Sebbas creeks; and 2) Mainstem Indian Creek, consisting of Anderson Creek and the mainstem Indian Creek. When rating threats, Expert Panelists considered the sub-watershed as a whole and the relative impact of each threat on all life stages and species (Table 8-4). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered that limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
## Limiting Factors

Table 8-2. Average scores for the impact of each limiting factor on each life stage of Coho Salmon and steelhead in two areas of Indian Creek.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Tributaries (Moody, Coulborn, and Sebbas Creeks)</th>
<th>Mainstem (Indian and Anderson Creeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eggs</td>
<td>Summer Parr</td>
</tr>
<tr>
<td>Barriers (culverts)*</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Channel complexity, including pool depth</td>
<td>1.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Climate change next 10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season flow</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>High water temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>1.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Spawning substrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet season flow (timing and volume)</td>
<td>3.9</td>
<td>3.4</td>
</tr>
</tbody>
</table>

* Includes natural barriers that only occur in low flow years.
Table 8-3. Average scores for the impact of each limiting factor on each life stage of Chinook Salmon in two areas of Indian Creek.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Tributaries (Moody, Coulborn, and Sebba Creeks)</th>
<th>Mainstem (Indian and Anderson Creeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eggs</td>
<td>Fry</td>
</tr>
<tr>
<td>Barriers (culverts)*</td>
<td>4.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Channel complexity, including pool depth</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Climate change next 10 years</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Dry season flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High water temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Spawning substrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet season flow (timing and volume)</td>
<td>4.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>

* Includes natural barriers that only occur in low flow years.

Many of the limiting factors with the highest impacts on Coho Salmon, Chinook Salmon, and steelhead in Indian Creek are related to a relative lack of physical habitat complexity (Table 8-2 and Table 8-3). Channel complexity and off-channel habitat were rated high or very high impact on all applicable life stages of all species in both areas of the sub-watershed. The Expert Panel rated large wood recruitment and canopy cover as having a key limiting factor for all life stages of the three salmonid species, which may reflect a lag in improvement of these forest characteristics. As described earlier in the Watershed Overview, canopy cover has improved drastically in the last two decades; however, the age, size, and type of riparian vegetation is not yet suitable to replenish the large wood in Indian Creek. Sediment inputs from catastrophic road failures and chronic
turbidity were rated as high impact for eggs, winter parr, and fry in the tributaries area, and high for winter parr in the mainstem area.

Barriers (culverts and natural barriers) and high water temperature were not determined to be limiting factors across species, life stages. Barriers have predominantly been addressed during completion of previous restoration projects in the sub-watershed, and the entire sub-watershed generally maintains suitable summer-time water temperatures (except for the lowest reaches of Indian Creek). The timing and volume of wet season flow as influenced by climate change was rated as a high impact for migrating adult salmonids in the tributaries of Indian Creek. Similarly, the Expert Panel predicted that climate change over the next 10 years would have a higher impact on migrating adult salmonids in the tributaries area.
Threats

Table 8-4. Effect of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in the Indian Creek tributary group overall.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Coho &amp; Steelhead</th>
<th>Coho &amp; Steelhead</th>
<th>Coho &amp; Steelhead</th>
<th>Coho &amp; Steelhead</th>
<th>Chinook</th>
<th>Chinook</th>
<th>Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Impingement</td>
<td>3.4</td>
<td>3.5</td>
<td>3.6</td>
<td>3.0</td>
<td>3.0</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Pikeminnow</td>
<td>3.2</td>
<td>3.0</td>
<td>2.3</td>
<td>5.0</td>
<td>4.3</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Road crossings, debris accumulation,</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
<td>1.8</td>
<td>2.3</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>and other barriers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural private roads (chronic sediment/</td>
<td>2.4</td>
<td>2.6</td>
<td>3.0</td>
<td>2.7</td>
<td>2.8</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>hydrology impacts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation and fire management</td>
<td>2.1</td>
<td>3.2</td>
<td>2.7</td>
<td>3.2</td>
<td>2.7</td>
<td>2.8</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Land conversion and development was rated a very low threat in the Indian Creek sub-watershed, likely due to the existing ownership by timberland managers across much of the sub-watershed. Similarly, channel impingement due to stream-side roads was rated a low threat, except for migrating adult Chinook Salmon which rated as a key threat. Invasive Sacramento Pikeminnow (*Ptychocheilus grandis*) are known to occur in the lower reaches of Indian creek, but it is unknown to what extent Pikeminnow distribution overlaps with salmonids in SFER tributaries, which could explain why it was rated a low to very low threat.

In contrast, chronic sediment inputs from rural private roads and the effects of these roads on sub-watershed hydrology rated a high threat to most life stages and species, as did vegetation and fire management (referring to densely packed young trees). Road crossings, debris accumulation, and other barriers rated a high threat to all life stages and species except summer parr, for which they rated a very high threat (likely due to their presence in the stream during the summer low-flow period when related barriers would be the most severe).

### 8.5 Recovery Strategy

On May 1, 2019, the Indian Creek Action Team discussed the outcomes of the Expert Panel meeting ([Table 8-2](#), [Table 8-3](#), and [Table 8-4](#)) and identified restoration actions that would best address the limiting factors and threats with the most impact to salmonid life stages. The team collaboratively identified the best locations for these restoration actions by reviewing spatial information prepared in GIS as well as identifying locations known to the experts on the panel.
Figure 8-10 and Table 8-5 show the treatment types and stream reaches identified by the team, as recorded during the meeting and later interpreted by the steering team.

The recovery strategy for the Indian Creek tributary group is targeted at improving habitat complexity for juvenile fish during summer and winter, entraining gravel to increase suitable spawning habitat and reduce stream entrenchment, assessing and rectifying upslope erosion hazards, and improving the riparian forest through active riparian management. This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. Where high resolution data were available and/or members of the Expert Panel had precise knowledge of treatment areas, specific project locations were identified for treatments; however, partners may require further designs to appropriately implement the recommendations. The materials used by the SHaRP Action Team may be useful to the restoration community in more detailed project planning. As more data become available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 8-10. Restoration treatments identified by Indian Creek Action Team.
Table 8-5. Descriptions, targets, stream name(s), and survey reach codes for treatments identified by Action Team.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>LWD for summer rearing (pools, sorting gravel)</td>
<td>Indian Creek, Moody Creek, Sebbas Creek</td>
<td>752, 754, 756, 775, 780, 781</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Indian Creek</td>
<td>752, 754, 756</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Indian Creek, Sebbas Creek, Sebbas Creek Tributary, Anderson Creek</td>
<td>747, 748, 749, 752, 753, 781, 784, 798, 799, 800</td>
</tr>
<tr>
<td><strong>Adult Spawning</strong></td>
<td>LWD for gravel entrainment</td>
<td>Indian Creek, Moody Creek, Couborn Creek, Anderson Creek</td>
<td>752, 775, 787, 797, 798</td>
</tr>
<tr>
<td></td>
<td>Natural barrier</td>
<td>Moody Creek</td>
<td>775</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Riparian</td>
<td>Indian Creek, Couborn Creek, Couborn Creek Tributary, Sebbas Creek</td>
<td>747, 780, 781, 782, 787, 790, 798, 799, 800</td>
</tr>
<tr>
<td><strong>Logistics</strong></td>
<td>Proposed road (to access restoration sites)</td>
<td>Indian Creek</td>
<td>747</td>
</tr>
</tbody>
</table>

**Treatments to Improve Overwinter Conditions for Winter Parr and Fry**

Habitat which provides refuge from high velocity winter flows, whether instream or off-channel, is crucial to the survival of juvenile salmonids (Gallagher et al 2012, Bair 2016). Adding instream large wood to increase channel complexity and provide refuge during high velocity winter flows is recommended in portions of mainstem Indian Creek and Sebbas Creek (reaches 752, 754 – 756, and 781) (Figure 8-10, Table 8-5). These reaches are low gradient and thus likely to provide low velocity instream habitat for juveniles during winter months; however, they lack enough large wood to create winter velocity refuge. These reaches are topographically confined and likely have very little suitable off-channel habitat; therefore, the availability of instream habitat is critical. It was noted that access to reaches 754 – 756 may be difficult and sources of large wood proximate to the stream may be scarce, but reverse cable yarding may be a viable option to transport large wood to the channel.
Treatments to improve floodplain inundation and access to suitable off-channel habitats during peak flows are recommended in Anderson Creek, Sebbas Creek, and Coulborn Creek (reaches 798–800, 781, and the lower half of 784) (Figure 8-10, Table 8-5). These reaches have wide valley widths and low gradients that lend themselves to off-channel winter habitat, and in reaches 781 and 784 there are existing floodplain features which could be reactivated. In Anderson Creek and Coulborn Creek (reaches 787, 798–800), treatments to trap gravel are recommended to reduce channel entrenchment first, thus increasing the frequency of floodplain inundation and access to low velocity off-channel habitat. Coulborn Creek is severely entrenched; raising the stream bed with large wood will likely improve channel complexity and reconnect the channel to its floodplain, improving access to important winter habitat. Anderson Creek is less entrenched than Coulborn Creek but has an abundance of floodplain habitat that is infrequently inundated. Adding large wood that will store gravel to raise the stream bed and surface elevation of the water will increase the frequency of floodplain inundation, providing off-channel habitat for juvenile salmonids born from the high density of redds in Anderson Creek. Specific locations for creating or improving access to off-channel habitat were identified in the middle and lower portions of Indian Creek (reaches 747–749, 752, and 753) (Figure 8-10, Table 8-5). Based on inundation mapping, these locations may have floodplains near channel elevations which could support off-channel habitat. In addition, roads along reach 747 will be opened for management purposes within the next 10 years, providing easy access for equipment to complete restoration treatments.

Treatments to Improve Adult Salmonid Spawning Distribution

Large wood can be strategically placed to retain and sort gravel and increase the amount of suitable spawning habitat in a watershed. In a similar process, it can be used to facilitate a desired stream grade or even raise the bed of a stream to reverse entrenchment. Treatments using large wood to retain spawning gravels are recommended in reaches of Indian Creek and Coulborn Creek where gradients are suitable for spawning but spawning gravel is lacking (752, 787, and 797) (Figure 8-10, Table 8-5). These reaches are near high-density spawning sites and may provide suitable rearing habitat for juveniles but currently retain very little gravel. Large wood structures have previously been installed in Reach 797, but they may require improvement to enhance their function. New structures may also be required in this reach to store gravel more effectively throughout the reach. The Action Team also recommended structures to capture gravels in Anderson Creek (the upper end of reach 798 through the lower end of reach 800) to improve floodplain connectivity through aggradation of the stream bed. Design and implementation of these structures should also allow for sorting and storage of gravels suitable for spawning to expand the spawning distribution from the already heavily utilized regions downstream. Treatments to retain gravel with large wood are also recommended in Moody Creek (reach 775) (Figure 8-10, Table 8-5); however, these treatments are recommended for use in tandem with associated modification of a large debris accumulation (LDA) to improve fish passage. The LDA, which is a significant adult passage barrier, has trapped and retained a large amount of gravel and sediment. This has created highly suitable habitat upstream of the LDA and sediment-starved, incised reaches.
downstream of the LDA. If action is taken to improve adult salmonid passage over the LDA, large wood structures should be installed to preserve the stream grade upstream of the LDA and trap mobilized sediments downstream of the LDA. Downstream structures should be installed prior to LDA modifications to allow time for stream aggradation which may lessen the severity of the LDA barrier and thus lessen the amount of modification required to improve passage.

**Treatments to Improve Conditions for Summer Parr**

Large wood can create or augment habitat used by salmonids during summer months by scouring pools and providing cover from predators. The availability of deep pools with complex cover increases the rearing capacity of a stream by providing thermal refugia, shelter from predators, and an extended hydroperiod. Treatments using large wood to create summer rearing habitat are recommended in portions of the main stem of Indian Creek and lower Sebbas Creek (reaches 752, 754, 756, and 780) ([Figure 8-10, Table 8-5](#)). These reaches are in or near high density spawning areas where salmonids will likely rear and have suitable water temperatures year-round; however, they lack high quality pool habitat. If modifications to the LDA barrier in Moody Creek occur, similar treatments are recommended to improve summer rearing conditions to restored spawning habitat.

Active riparian management, such as tree planting and conifer release can increase the rate of forest succession after disturbances, improving the riparian canopy density and composition. Healthy, mature riparian forests can improve instream conditions by providing bank and upslope soil stability, increased shade, and a source of large woody debris. Thinning treatments in the riparian forest which promote the growth of coniferous trees and accelerate wood recruitment are recommended in Anderson Creek, Coulborn Creek, and Sebbas Creek (reaches 780-782, 787, 790, and 798-800) ([Figure 8-10, Table 8-5](#)). Riparian tree planting is recommended for the lowest reach of Indian Creek (reach 747) due to low potential for large wood recruitment and high stream temperatures occurring in the late summer/early fall ([Figure 8-10, Table 8-5](#)).

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
9. Chapter 9: Standley Creek Action Plan

9.1 Sub-Watershed Overview

The Standley Creek sub-watershed is located near the town of Piercy in northern Mendocino County (Figure 9-1). In addition to Standley Creek, the SHaRP planning process included the nearby South Fork Eel River (SFER) tributaries including Piercy Creek, Bear Pen Creek, and McCoy Creek into this sub-watershed due to their inclusion within the Hydrologic Unit Code (HUC) 12 delineations used during regional prioritization. For simplicity, only the two largest tributaries, Standley Creek, representing the western portion of the sub-watershed, and McCoy Creek, representing the eastern portion of the sub-watershed, are described in detail in this overview.

Standley Creek is a first order stream with approximately 4.7 miles of perennial waterways draining a sub-watershed of approximately 7.3 square miles (CDFG 2009d). Elevations range from approximately 500 feet at the mouth of the creek to 1,200 feet in the headwaters and the landscape is dominated by mixed conifer (predominantly redwood and Douglas fir) with areas of mixed hardwood forest (CDFG 2009d, CDFG 2009e, CDFW 2014). The sub-watershed is entirely privately owned and is managed for timber production. Despite a history of poorly regulated timber harvest and poor management of aquatic resources, Standley Creek supports a persistent population of Coho Salmon, Chinook Salmon, and steelhead.

The shale and sandstone bedrock of the Coastal Belt geology that underlies the Standley Creek sub-watershed forms the steep, rugged characteristic of the western slope of the SFER watershed (CDFW 2014). This underlying geology tends to form steep ridges and canyons in the landscape. Despite the high gradient upland slopes surrounding the watershed, much of the Standley Creek is moderate gradient (2-4% gradient) but are relatively narrow, deep, and tend to erode during winter when the banks fill and the channel migrates (CDFG 2009d). Long-term geologic processes within the western half of the SFER sub-basin have resulted in a major knickzone or area of locally steepened stream channel. This knickzone manifests in multiple knickpoints which propagate up Standley Creek, likely resulting in the end of anadromy at a 5.5 foot bedrock waterfall (CDFW 2014, CDFG 2009e). Soils in the landscape include Wohly-Holohan-Casabonne series and Zeni-Yellowhound-Ornban-Kibesillah series which are composed of deep to very deep, well-drained gravely to sandy loams formed from weathered sandstone, shale, and/or mudstone (NRCS 2020). According to the 2009 California Department of Fish and Wildlife\(^9\) (CDFW) Standley Creek Stream Inventory Reports, stream banks consist of 63% sand/silt/clay, 17% bedrock, 17% cobble/gravel and 2% boulder (CDFG 2009d, CDFG 2009e). The resulting substrates in Standley Creek pool tailouts are dominated by either gravel (52-60%) or small cobble (23-35%), and 77-

\(^9\) Formerly known as the California Department of Fish and Game (CDFG)
85% of all pool tailouts had gravel embeddedness suitable for salmonid spawning with the upper reaches exhibiting more suitable spawning substrate than the lower mainstem Standley Creek (Figure 9-2).

The weathered shale and sandstone bedrock also support productive timberlands, primarily redwood and Douglas-fir as well as hardwoods, which have spurred several generations of timber harvest in the area (Hahm et al. 2019). The exact timing of initial timber harvest activities in Standley Creek is not readily accessible, but the general pattern for the SFER was that late 19th century logging was restricted to redwoods in accessible areas around creek mouths (CDFW 2014). In late 1890s, the development of a railroad line connected the adjacent Indian Creek sub-watershed and a mill site in Andersonia to Bear Harbor, a small port on the Northern Mendocino coast, allowing timber to be harvested and extracted via rail and ship (Hough 2010). This operation was abruptly halted in 1906 due to damage caused by the historic 1906 earthquake (Hough 2010). Logging resumed in the decades following World War II after a new mill was constructed in 1947 and timber could be hauled via the newly constructed highway 101 (CDFW 2014, Hough 2010). Prior to the Forest Practices Act in 1974, lands in the Standley Creek sub-watershed were tractor logged intensively by the previous owners, primarily Pacific Coast Lumber Company, with rapid and repeated extraction of timber which was taxed if left standing (URFC 2016). By the mid 1960’s, most of the merchantable timber had been extracted from the watershed.

McCoy Creek is a fourth order stream in the Western SFER sub-basin and differs from the other tributaries in the Standley Creek sub-watershed primarily in its land use. McCoy Creek has approximately 11.1 miles of perennial stream draining approximately 6.8 square miles of land (CDFG 2007a). Elevations range from approximately 525 feet at the confluence with the SFER to approximately 1,600 feet in the headwaters. Like its Western counterparts, the underlying geology of McCoy Creek is composed primarily of Coastal Belt rock which forms a landscape familiar to Western SFER sub-basin tributaries (CDFW 2014). Similarly, McCoy Creek has a mixed coniferous and hardwood forest although a significant portion of the basin also supports grasslands with approximately 31% of habitat units surveyed in 2007 containing grasses as the dominant vegetation (CDFG 2007a). Although the history of logging in McCoy Creek is not precisely known, it likely followed a similar pattern as described above. Currently, only the upper portions of the mainstem are owned by timber companies and/or managed for timber harvest with current timber harvest plans in the headwaters (CalFire 2019). The lower portions of the stream and portions of the South Fork are now primarily owned in small parcels and used for residential purposes.
Figure 9-1. Standley Creek’s position in the South Fork Eel River sub-basin.
Figure 9-2. Habitat suitability indices of gravel embeddedness in the Standley Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
9.2 History of Land Use and Fish Habitat

The legacy effects of the logging history, a series of devastating floods, and poor management of instream and riparian habitat dramatically altered Standley Creek waterways. The land disturbances due to logging activities exacerbated the slide-prone landscape and left the sub-watershed more vulnerable to erosion. When the watershed was struck by two devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in far greater quantities than observed in the geologic record of the watershed (Sommerfield et al. 2002). Landslides and erosion during these events led to destruction of riparian vegetation and rapid aggradation of SFER tributaries, leaving many tributaries perched above the SFER atop large deposits of sediment (Sloan et al. 2001). Based on aerial photography, this scenario unfolded in the destabilized Standley Creek watershed; widened channels with large gravel and sediment deposits are apparent through the stream (CDF 1965). Channel aggradation was followed by channel incision whereby downcutting would propagate from the mouths of tributaries upstream, reworking tributary valleys (Sloan et al. 2001). Numerous landslides were noted throughout Standley Creek during CDFW stream inventories carried out after these floods and surveyors have since observed logging roads contributing fill directly to waterways and an abundance of deep-seated slides through the lower reaches of Standley Creek (CDFG 1968, CDFW 1976, Kor 1976, PWA 2007, RFFI 2019). Numerous slides were also documented along the length of McCoy Creek in a 2007 CDFW Stream Inventory (CDFG 2007a). These processes have likely contributed to the occurrence of embedded gravels in the lower reaches of Standley and McCoy creeks, where approximately 23%, and 56%, respectively, of pool tailouts surveyed had substrate poorly suited to spawning (CDFG 2009d, CDFG 2007a). This is a high rate relative to the other watersheds considered in the SHaRP process. Additionally, abundant debris associated with timber extraction led to instream debris and sediment accumulations that created potential fish passage barriers (CDFG 1968, CDFG 1976). Several of these debris accumulations were cleared to allow fish passage (Melo 1976, CDFG 1982a). Clearing of instream wood combined with the depletion of new wood recruitment opportunities through flood damage and logging activities likely contributed to the long-term lack of instream cover and large wood in Standley and McCoy creeks (CDFW 2014, Figure 9-3).

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\textsuperscript{10} Formally referred to as large wood debris (LWD) in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.
Figure 9-3. Habitat suitability indices of large wood densities in the Standley Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
Once large wood was removed, there was little channel complexity to slow water velocities or capture and retain gravels, allowing stream energy to rapidly down-cut through the large sediment deposits left by the floods. In many stream reaches, this altered process resulted in severely incised channels which were largely disconnected from their floodplains. The current sediment input-storage imbalance has transformed areas typically used for spawning to exhibit simplified and coarsened substrate or bedrock channels that do not offer a mosaic of sorted sediment deposits necessary for productive salmon spawning (SHaRP unpublished data). The lack of large wood has also reduced hydraulic scouring resulting in shallower pool depths, reduced stream complexity, and vastly diminished connectivity to floodplains (Kaufman 1988) and a lack of critical refugia during winter flows (Bair 2016).

After the 1974 prohibition on logging in riparian zones, the plant communities have been undergoing disturbance succession. In the Pacific Northwest coastal zones, this succession moves relatively quickly from colonizing herbaceous vegetation to a community dominated by hardwoods including maple and alder species and, in the later stages, mature conifers dominate the forest (Naiman et al. 2000). This trend can be seen in the changes in canopy density measured in CDFG stream inventories from 1992 to 2009 (Figure 9-4). In 1992, average canopy cover was 63% and only 34% of the riparian forest was coniferous. By 2009 canopy cover had risen to 94% and conifer represented 56% of the riparian forest. While broad leafed hardwoods trees such as alder species provide canopy cover and other essential ecosystem services within a mature riparian forest, they generally do not grow large enough, nor remain in streams for long (once recruited) relative to large conifers (Naiman et al. 2000). The continued succession from a hardwood dominated riparian to a mature conifer riparian forest that can contribute substantial large wood available to alter channel form will likely take many tens to hundreds of years (Gregory et al. 1991).
Figure 9-4. Habitat suitability indices of canopy density in the Standley Creek sub-watershed derived from CDFW stream habitat inventories completed in the time periods of 1990-1999 and 2000-2010. Surveyed reaches varied per time period based on funding and crew availability.
Despite the history of anthropogenic impacts to the Standley Creek sub-watershed, conditions have remained suitable for salmonids and other anadromous fish. Standley Creek scored relatively high in the SHaRP ranking process: it had the fifth highest overall priority score among sub-watersheds. This high ranking entailed the fifth highest score for Biological Importance, the fourth highest scores in Habitat Conditions and Integrity and Risk, and tied for third in Optimism and Potential. Measured and modeled water temperatures indicate temperatures are optimal for salmonids throughout most of the tributaries in the sub-watershed based on guidelines developed by the Coastal Watershed Planning and Assessment Program (CDFW 2014, Figure 9-5). Pool quality has increased over the last two decades; pools in the middle reaches have deepened, though pool cover is still lacking throughout the sub-watershed (CDFW 2014). Pool tail-outs had a high occurrence of spawning gravels suitable for salmonids and approximately 85% of the upper 1.9 miles of stream had embeddedness values highly suitable to spawning. However, approximately 64% of tailouts in the lower 3 miles of stream had embedded gravels poorly suited to spawning (Figure 9-2). Spawner surveys indicate that most of the surveyed reaches of the Standley Creek sub-watershed are utilized by adult Coho Salmon, Chinook Salmon and steelhead at a relatively low spawning density (Figure 9-6). Steelhead have the broadest distribution of the three salmonid species within the sub-watershed closely followed by Coho Salmon (Figure 9-7).
Figure 9-5. Observed and modeled stream temperatures and associated suitability for Coho Salmon and steelhead rearing in the Standley Creek sub-watershed.
Figure 9-6. Total density of Coho Salmon, Chinook Salmon, and steelhead redds in the Standley Creek sub-watershed, all years combined (2010-2019), based on CDFW spawner surveys (Guczek et al. 2019). The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.
Figure 9-7. Observed distribution of Coho Salmon, Chinook Salmon, and steelhead in the Standley Creek sub-watershed. Source: compiled observations maintained by CDFW.
Currently, most of Standley Creek and the other western tributaries are owned by the Usal Redwood Forest Company. Since acquiring lands surrounding Standley Creek, Usal Redwood Forest Company’s parent organization, Redwood Forest Foundation Inc. have partnered with Trout Unlimited (TU), Pacific Watersheds Associates (PWA), and the Eel River Watershed Improvement Group (ERWIG) and conferred with experts from UC Berkeley, National Oceanic and Atmospheric Administration (NOAA) Fisheries, Humboldt State University, and Cal Fire to develop and implement restoration projects aimed at decommissioning roads and improving instream conditions through the placement of large wood and riparian planting (RFFI 2019). The Usal Redwood Forest Company continues to be an active participant in the SHaRP process. Unlike the other tributaries, McCoy Creek has many private residences along the lower river and several landowners have historically denied access to the stream, thus making surveying and restoration planning difficult.

9.3 Historic and Current Restoration Efforts in Standley Creek

Restoration efforts have occurred in the Standley Creek sub-watershed since the mid-1980s to improve salmon and steelhead populations (Figure 9-8). The desire to improve the streams in this area has permeated landowners, non-profits, agencies, and interested stakeholders, but efforts have been partially hindered by the limited access to remote areas within the watersheds. Standley Creek has long stretches of stream that are confined by moderately steep canyons with little to no road access. Some of the other tributaries in the sub-watershed, such as Bear Pen Creek, also lack an active, developed road network. Despite these obstacles, a variety of restoration work has occurred in this sub-watershed, particularly in Standley Creek and a few of its tributaries.

Early restoration efforts focused on woody debris log jam modifications with intentions to improve fish passage through areas littered with remnants of previous logging activities. Long stretches of streams contained enormous amounts of slash from historic logging operations, which was believed to have prevented or hindered fish passage. In the late 1980s and early 1990s Standley and Piercy creeks had funded log jam modification projects, but additional log jam modifications most likely occurred in other streams in this sub-watershed during this time period.

In the following decades, restoration practiced shifted towards improving stream complexity. In 1992, the California Conservation Corps (CCC) installed 25 instream structures in the lower 8,300 feet of Piercy Creek. McCoy Creek appears to have had limited restoration work; however, one major project occurred in 2001 and 2002. The project involved redirecting a portion of lower McCoy Creek into its natural channel and moving the creek channel away from the toe of a significant slide to decrease the chance of a major slide causing sediment input and blocking the channel.

Beginning in 2007 TU, in partnership with PWA, received FRGP funding to conduct an analysis and subsequent restoration of road networks within the Standley Creek sub-watershed (PWA 2007). With the results of that analysis, TU and PWA collaborated with the Redwood Forest
Foundation Inc. (RFFI), who manages much of the property in the Standley Creek watershed, completed six phases of sediment reduction and habitat improvement projects. By 2018, the projects collectively treated and decommissioned approximately 19.49 miles of road in the Standley Creek sub-watershed (Table 9-1), treated problematic upslope areas (landslides), and planted over one thousand coniferous trees species to reduce/prevent sediment delivery to waterways and improve fish passage at road crossings (Novelli and Leroy 2019). These projects prevented an estimated 101,149 cubic yards of sediment from entering waterways in the sub-watershed (Table 9-1) (Novelli and Leroy 2019). In addition to the road decommissioning, in 2015 phase 5 of the project included constructing 15 large wood structures in Standley Creek to improve instream habitat. CDFW, RFFI, PWA, TU, ERWIG, and the CCC continue to collaborate on developing future restoration projects in the Standley Creek sub-watershed.

Table 9-1. Estimated sediment savings resulting from road treatments in the Standley Creek sub-watershed (Novelli and Leroy 2019).

<table>
<thead>
<tr>
<th>Standley Creek Project Phase</th>
<th>Miles of Road Treated</th>
<th>Cubic Yards Sediment Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>5.68</td>
<td>18,606</td>
</tr>
<tr>
<td>Phase 2</td>
<td>4.34</td>
<td>24,463</td>
</tr>
<tr>
<td>Phase 3</td>
<td>1.45</td>
<td>16,095</td>
</tr>
<tr>
<td>Phase 4</td>
<td>2.20</td>
<td>5,120</td>
</tr>
<tr>
<td>Phase 5</td>
<td>2.00</td>
<td>14,647</td>
</tr>
<tr>
<td>Phase 6</td>
<td>3.82</td>
<td>22,218</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>25.49</strong></td>
<td><strong>101,149</strong></td>
</tr>
</tbody>
</table>
Figure 9-8. Past and current restoration projects intended to improve salmonid habitat in the Standley Creek subwatershed.
9.4 Limiting Factors and Threats Affecting Salmonids and Their Habitat in Standley Creek

The Standley Creek Expert Panelists discussed available data and personal observations of the sub-watershed on March 25, 2019. During this discussion, each participant scored how limiting they thought each limiting factor and threat was to each life stage of each species through an interactive process. The limiting factor tables (Table 9-2 and Table 9-3) describe conditions in two areas: 1) the tributaries (McCoy, Piercy, Bear Pen and Standley Creeks), and 2) the mainstem (the portion of the mainstem of the SFER in the Standley Creek sub-watershed area). When rating threats, Expert Panel considered all of the sub-watershed as a whole and ranked the relative impact of each threat on all life stages and species (Table 9-3). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; thus cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered that limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
Limiting Factors

Table 9-2. Effect of each limiting factor on each life stage of Coho Salmon and steelhead in two areas of the Standley Creek sub-watershed.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Tributaries</th>
<th></th>
<th></th>
<th></th>
<th>Mainstem</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>McCoy, Piercy, Bear Pen, and Standley Creeks</td>
<td>S.F. Eel River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coho Salmon and Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barriers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel complexity, including pool depth</td>
<td>1.7</td>
<td>1.9</td>
<td>2.4</td>
<td>2.1</td>
<td>1.1</td>
<td>1.2</td>
<td>2.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Climate change next 10 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season flow</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>High water temperature</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>1.8</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
<td>1.2</td>
<td>1.3</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>1.8</td>
<td>1.4</td>
<td></td>
<td></td>
<td>1.0</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.2</td>
<td>2.7</td>
<td>2.6</td>
<td></td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet season flow (timing and volume)</td>
<td>3.4</td>
<td>2.6</td>
<td>3.4</td>
<td>3.0</td>
<td>3.6</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 9-3. Effect of each limiting factor on each life stage of Chinook Salmon in two areas of the Standley Creek sub-watershed.

<table>
<thead>
<tr>
<th>Limiting Factor</th>
<th>Tributaries</th>
<th>Mainstem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eggs</td>
<td>Fry</td>
</tr>
<tr>
<td>Barriers</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Channel complexity, including pool depth</td>
<td>1.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Climate change next 10 years</td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>Large wood recruitment, canopy cover</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Sediment (catastrophic road failures and chronic turbidity)</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Wet season flow (timing and volume)</td>
<td>3.8</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Many of the highest impact limiting factors for Coho Salmon, Chinook Salmon, and steelhead in Standley Creek are related to a relative lack of physical habitat complexity (Table 9-2 and Table 9-3). Channel complexity and off-channel habitat rated high or very high impact for all juvenile life stages of all species in all areas of the sub-watershed. The Expert Panel hypothesized that due to sedimentation, lack of instream wood, and channel incision, much of the instream habitat has been simplified and disconnected from adjacent floodplains, resulting in the poor pool depth and cover rating observed. Large wood recruitment and canopy cover were also rated as high or very high impact for juvenile salmonids due primarily to the lack of instream wood and relatively young age of the riparian forest due to the logging activities of the past. Most tributaries in the sub-watershed have excellent riparian shading based on stream inventories conducted in the 2000-2010 surveys; however, canopy cover was a concern in the mainstem SFER because shading of the wide mainstem channel requires taller trees than in the narrower tributary channels.

Other limiting factors related to water quality and quantity were also rated as high or very high impact for one or more species. For all species, life stages, and areas considered, sediment was a
high or very high impact limiting factor. Extensive legacy logging road networks and associated land failures are delivering excess sediment yields to the sub-watershed, embedding gravel, filling pools, and directly impacting juvenile fishes. Though there has been a concerted effort to treat these roads, the Expert Panel indicated that there were many more untreated roads and other land disturbances continuing to contribute sediment to the sub-watershed. For Coho Salmon and steelhead summer parr, high water temperatures were rated close to 1, the highest impact, in the mainstem SFER but were rated as only a moderate impact in tributaries of the sub-watershed due to the drastically different summer water temperatures of those two areas (Figure 9-5). Despite good canopy cover and cool temperatures in the tributaries, dry season flow was rated as a high impact limiting factor for Coho Salmon and steelhead summer parr in both the tributaries and the SFER. It was noted that a few of the tributaries of Standley Creek go dry in the summer, but it was uncertain if this was a result of recent timber harvests in the area or if this was the natural character of the stream. Additionally, the Expert Panel was concerned about residential and agricultural water use in McCoy Creek and the cumulative impacts to dry season flow. The timing and volume of wet season flow was rated as high impact for Coho Salmon and steelhead winter parr in tributaries and eggs in the mainstem SFER, and for Chinook Salmon fry and migrating adults in tributaries and fry in the mainstem SFER. These rating reflect the diversity of challenges faced by different life stages in different parts of the sub-watershed. Additionally, Expert Panel indicated that climate change over the next 10 years could be a high impact migrating adult Coho Salmon and steelhead in tributaries.

**Threats**

Table 9-4. Effect of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in the Standley Creek sub-watershed overall.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Egg</th>
<th>Summer Parr</th>
<th>Winter Parr</th>
<th>Fry</th>
<th>Migrating Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel impingement</td>
<td>3.4</td>
<td>3.0</td>
<td>3.7</td>
<td>3.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Land conversion, development*</td>
<td>4.4</td>
<td>4.7</td>
<td>4.6</td>
<td>4.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Pile driven by humans</td>
<td>3.0</td>
<td>3.5</td>
<td>2.0</td>
<td>4.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Road crossings, debris accumulation, and other barriers</td>
<td>2.3</td>
<td>2.5</td>
<td>1.8</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Rural private roads (chronic)</td>
<td>1.8</td>
<td>2.3</td>
<td>2.8</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Vegetation and fire management</td>
<td>2.2</td>
<td>3.2</td>
<td>2.8</td>
<td>3.2</td>
<td>2.8</td>
</tr>
</tbody>
</table>

* Subdivision of large parcels, rural residential development, land clearing, and increased road network development.
Several aspects of road networks, fish passage barriers, and vegetation and fire management are of broad concern in Standley Creek, affecting multiple life stages of all three species. Barriers, including road crossings and debris accumulations, have a very high impact on Coho Salmon and steelhead summer parr because they prevent these species from distributing during the summer low-flow period when such barriers are the most severe. Barriers were rated as a key threat to all other species and life stages. Chronic impacts from rural private roads, including sediment delivery, increased storm runoff, and routing flows out of watersheds rated very high impact to Coho Salmon and steelhead eggs. Roads have a less severe, though still high impact on Chinook Salmon eggs because Chinook Salmon can successfully spawn in larger tributaries with higher flows. Roads pose a high impact to juveniles of all three species, both in the winter and summer due to chronic sediment delivery and its associated direct and indirect impacts to these sensitive life stages. The Expert Panel rated Vegetation and fire management (i.e., fire suppression) as a large threat to all life stages of all species except for Chinook Salmon eggs and winter parr. Poor forest management practices can threaten the forest recovery process and until mature forest characteristics return, stream habitat processes will be disrupted, broadly impacting all species. While timber harvest practices have greatly improved over the years, taking an active role in shaping the recovery of a diverse riparian forest has generally not occurred and forests are largely managed to maximize harvest, not stand diversity or resilience. Many of the forests in the sub-watershed have a high fire risk as a result of post-logging forest regeneration and several decades of fire suppression. The Piercy Fire Protection District has recently begun conducting fuel reductions in the sub-watershed including prescribed burns, but much more of the sub-watershed remains to be treated and this should become a regular practice.

Invasive Sacramento Pikeminnow were rated as a major threat to Coho Salmon and steelhead summer parr. While this species has broadly invaded the SFER sub-basin, piscivorous-sized adults have not been observed in tributaries and juvenile salmonids likely only encounter these fish as predators during spring smolt emigration or while rearing in the mainstem SFER during the summer. During that time, it is likely that many juvenile salmonids could be consumed. Summer parr may also compete with juvenile Sacramento Pikeminnow while rearing in tributaries. The Expert Panel did not consider Sacramento Pikeminnow to be a threat within the sub-watershed otherwise.

Channel impingement due to streamside roads and land conversion and development was rated a moderate to low threat for all species and life stages in the Standley Creek sub-watershed. This is likely due to existing ownership by a very few number timberland managers as well as the restoration history of the sub-watershed.

9.5 Recovery Strategy

The Action Team reviewed the results of the Expert Panel and discussed restoration actions to address high and very high impact limiting factors and threats. Because limiting factors and threats affecting the mainstem SFER could not be treated by actions in the sub-watershed alone,
treatments were not recommended for this area. Limiting factors and threats affecting the mainstem SFER will be the focus of a subsequent SHaRP effort. The Action Team considered the remaining tributaries as two Action Groups based on their similar characteristics: 1) the Western Tributaries (Piercy Creek and Standley Creek), and 2) the Eastern Tributaries (Bear Pen Creek and McCoy Creek).

The recovery strategy for the Standley Creek sub-watershed is targeted at improving habitat complexity for juvenile fish during the summer and winter, storing and sorting sediments to increase suitable spawning habitat and reduce stream entrenchment, assessing and nullifying upslope erosion hazards, and improving the riparian forests through active riparian management. This strategy identifies reach-scale regions where treatments will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. Where high-resolution data were available and/or members of the Action Team could identify treatment areas, specific project locations were identified for treatments (Figure 9-9, Table 9-5); however, further designs are likely required to appropriately implement the recommendations. As more data becomes available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 9-9. Restoration treatments recommendations identified by Standley Creek Action Team.
Table 9-5. Recommended treatments to improve salmonid habitat in the Standley Creek sub-watershed. Treatment descriptions, targets, stream name(s), and survey reach codes are listed for all treatments identified by the Action Team.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>Large wood for summer rearing (pools, sorting gravel)</td>
<td>Piercy Creek, Standley Creek, “Clark’s Fork” Standley Creek, Tributary to Standley Creek, McCoy Creek</td>
<td>820, 826, 827, 828.1, 829, 830, 830.1, 847, 866, 866.1</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Piercy Creek, Standley Creek</td>
<td>820, 826, 827</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Tributary to Standley Creek, Standley Creek</td>
<td>826.1, 829, 830, 830.1</td>
</tr>
<tr>
<td><strong>Adult Spawning</strong></td>
<td>Large wood for gravel storage</td>
<td>McCoy Creek</td>
<td>847</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Riparian Treatment</td>
<td>“Clark’s Fork” Standley Creek, McCoy Creek</td>
<td>828.1, 847, 848</td>
</tr>
<tr>
<td></td>
<td>Mass wasting assessment</td>
<td>McCoy Creek</td>
<td>846, 848</td>
</tr>
<tr>
<td></td>
<td>Road network</td>
<td>Piercy Creek</td>
<td>820</td>
</tr>
<tr>
<td></td>
<td>Upslope erosion hazard assessment</td>
<td>McCoy Creek, N.F. McCoy Creek</td>
<td>846, 847, 848, 850</td>
</tr>
<tr>
<td></td>
<td>Habitat assessment</td>
<td>Bear Pen Creek</td>
<td>866, 866.1</td>
</tr>
</tbody>
</table>
Treatments to Improve Overwinter Conditions for Winter Parr and Fry

Habitat which provides refuge from winter flows, whether instream or off-channel, is crucial to the survival of juvenile salmonids. Adding instream large wood to increase channel complexity and provide velocity refuge during winter flows is recommended in the lower mainstem Standley Creek, a portion of McCoy Creek, and Piercy Creek (reaches 820, 826 – 827, and 847) (Figure 9-9, Table 9-5). These reaches have low gradients that will likely provide instream habitat for juveniles during winter months; however, they lack enough large wood to create winter velocity refugia and are generally lacking complexity. These reaches are also topographically confined which means fish may have to rely more heavily on instream refugia to avoid being swept downstream. Treatments to improve access to suitable off-channel habitats are recommended in upper Standley Creek, an unnamed tributary at the reach node between reaches 826 and 827 (reaches 826 – 827, 829 – 830) (Figure 9-9, Table 9-5). These reaches have wide valley widths and low gradients suitable for off-channel winter habitat. Additionally, off-channel habitat could be created at the mouth of the unnamed tributary at the end of reach 826 by backing up water with instream structures in the mainstem of Standley Creek. This treatment was identified by the Expert Panel based on field observations but will require a focused survey effort and associated designs. Specific locations for creating or improving access to off-channel habitat at other locations could not be identified based on the available data.

Treatments to Improve Adult Salmonid Spawning Distribution

Large wood can be strategically placed to trap and sort gravels and effectively increase the amount of suitable spawning habitat in a stream. The Expert Panel identified a portion of McCoy Creek which supports spawning salmonids but would benefit from increased gravel storing and sorting to expand spawning opportunities (reach 847) (Figure 9-9, Table 9-5). This reach has low stream complexity, very little instream large wood, and currently has vehicle access making it an ideal location to install large wood structures.

Treatments to Improve Conditions for Summer Parr

Large wood can also create or augment habitat used by salmonids during summer months by scouring pools. The availability of deep pools with complex cover provides juvenile salmonids with thermal refugia, shelter from predators, and a lengthened hydroperiod during hot, dry summers. Treatments using large wood to create summer rearing habitat are recommended in Piercy Creek, most of Standley Creek (including an unnamed tributary in the center of reach 828), and a portion of McCoy Creek (reaches 820, 826 – 828, 829 – 830, and 847) (Figure 9-9, Table 9-5). These reaches are at or near popular spawning areas where salmonids are born and will likely rear and they have suitable water temperatures year-round; however, they lack high quality pool habitat and enough instream large wood to create suitable summer habitat.
Treatments to Improve Watershed Processes

Sediment Sources and Riparian Treatments

Managing upslope habitat to improve soil stability, reduce sediment input and improve riparian forest cover and composition can improve instream conditions by reducing sedimentation, increasing stream shade, and by providing a source of large wood. Two landslides were identified by the Expert Panel as needing treatment to reduce sediment delivery to McCoy Creek (reaches 846 and 848) (Figure 9-9, Table 9-5). Understanding the causes of these slides and the most appropriate treatment will require more investigation. Riparian tree planting and active riparian management is recommended for the upper McCoy Creek, and an unnamed tributary in Standley Creek to stabilize landslides (reach 848) and improve the wood recruitment potential (reach 828, and 848) (Figure 9-9, Table 9-5). While canopy cover and stream temperatures are suitable in most of these streams, the chronic shortage of instream wood is likely due to the deficit of mature riparian conifers. The history of timber harvest and flood disturbances in the sub-watershed decimated much of the riparian forest and forest recovery and succession is likely progressing too slowly to aid in the recovery of salmonids. Riparian planting and active management to increase the rate of forest succession should be applied as appropriate to improve the composition and function of the riparian forest in these reaches. Additionally, the unnamed tributary in the center of reach 828 of Standley Creek has recently been logged and would benefit from riparian tree planting to maintain and improve riparian cover and long-term sources of large wood.

In addition to the acute land disturbances described above, many portions of the sub-watershed have untreated legacy logging disturbances that are likely chronic sources of sediment to the streams. In particular, the Expert Panel identified Piercy Creek and upper North Fork McCoy Creek as having a significant number of problematic roads that have yet to be treated (reaches 820 and 850) (Figure 9-9, Table 9-5). Legacy road networks and associated stream crossing and land disturbances in those areas will need to be assessed to determine the appropriate course of treatment.

Habitat Assessment

The Expert Panel and Action Team noted that little was known about Bear Pen Creek due to its relatively inaccessible nature and because it is seldom surveyed for salmonids, but the presence of anadromous salmonids and relatively high IP values indicate this stream warrants further investigation for restoration potential. Habitat inventories indicate that pool depth, pool shelter, and embeddedness ratings are all poor; however, the appropriate treatment is not apparent. The same habitat inventories suggest that there is an abundance of both large and small wood within the stream, though much of this wood may be stored within large debris accumulations. Additionally, little is known about the condition of the upslope environment and it is likely that legacy logging roads and stream crossing may be contributing sediment to the stream. Riparian forest age and composition are also poorly suited to recruiting large wood in the future and may
require planting or other treatments. Digital elevation models suggest suitable gradients and valley widths exist in the middle and upstream portions of the stream, but it is unknown if these areas provide suitable off-channel habitat or if salmonids can access these areas regularly. Juvenile Coho Salmon and steelhead have been observed in Bear Pen Creek well above many of the aforementioned debris accumulations indicating that it is an important anadromous salmonid stream and adult fish passage within the lower 2 miles of stream may not be limiting access to the habitat. The Action Team recommends further investigation of Bear Pen Creek to determine the most appropriate treatments to improve salmonid habitat in this area.

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
10. Chapter 10: Hollow Tree Creek Action Plan

10.1 Sub-Watershed Overview

The Hollow Tree Creek (HTC) sub-watershed is located at the southwest corner of the South Fork Eel River (SFER) sub-basin in northwestern Mendocino County (Figure 10-1). HTC is a third order stream and has approximately 19.5 miles of blue line stream according to the United States Geologic Survey (USGS) Leggett 7.5 minute quadrangle. HTC drains approximately 42 square miles of land with elevations ranging from about 760 feet at the mouth of the creek to 1,900 feet in the headwater areas. Mixed coniferous and hardwood forests, predominantly composed of Redwood, Douglas fir, and tan oak dominate the forests of HTC sub-watershed. Despite having less coastal fog than the lower SFER sub-basin (Torregrosa et al. 2016), peak summer air temperatures are lower in HTC than other portions of the SFER sub-basin due to the proximity of the Pacific Ocean (PRISM Climate Group 2018). The sub-watershed is primarily privately owned and is managed for timber production.

The Coastal Terrane geology that underlies the sub-watershed creates a sheer landscape that tends to form incised drainages. The steep forested slopes of HTC drain approximately 60 inches of rainfall annually (CDFW 2014) and sustain moderate summer baseflows (Dralle et al. 2018). This hydraulic power has incised channels throughout the sub-watershed on geologic timescales; however, recent anthropogenic disturbances combined with devastating flood events have accelerated the process and likely resulted in floodplain disconnection (see section 4.2). Valley widths are relatively narrow, with nearly all stream channels accessible to anadromous fish being either confined or moderately confined (defined as valley to bankfull channel width ratio of <2 or 2-4, respectively) (MRC 2004). Despite the prevalence of low gradient channels, valley confinement and relatively entrenched channels (SHaRP 2018) leave little room for the formation of off-channel habitats and promotes the conveyance of gravels. Long-term geologic uplift within the SFER sub-basin have also resulted in channel incision which propagates up stream networks reaching erosively-resistant geology that create knickzones (Foster and Kelsey 2012) and cause fish barriers (CDFW 2014) (Figure 10-2). In many of HTC’s tributaries, these knickzones manifest as bedrock waterfalls which are either partial or complete barriers to anadromous fish passage and are often located a short distance upstream of tributary confluences.

The deeply weathered shale and sandstone bedrock also support productive timberlands, primarily redwood and Douglas fir, as well as hardwoods, which have spurred several generations of timber industry in the area (Hahm et al. 2019). Most of the sub-watershed is currently owned by two industrial timber companies, Mendocino Redwood Company (MRC) and Usal Redwood Forest Company. Both organizations manage their lands to maximize long term timber yield. As a result, there are far fewer residents, cannabis farms, and water diversions than most other SFER sub-watersheds. Small, private landholdings are concentrated near Hales Grove on Mule Creek, on
terraces along lower HTC, and scattered in HTC’s eastern headwater tributaries near federal land managed by the Bureau of Land Management.
Figure 10-1. The Hollow Tree Creek sub-watershed’s position in the South Fork Eel River sub-basin.
Figure 10-2. Salmonid distribution and fish passage barriers in the Hollow Tree Creek sub-watershed.
10.2 History of Land Use and Fish Habitat

The exact timing of timber harvest history in HTC is not readily accessible; however, the general pattern for the SFER sub-basin was that late 19th and early 20th century logging was restricted to redwoods in accessible areas around creek mouths, followed by logging of upper watersheds in the decades following World War II (CDFW 2014). During this time, several mills operated within the HTC sub-watershed including a mill in Leggett near the mouth of HTC and a mill in Hales Grove in the middle of the sub-watershed (Usal Redwood Forest Company 2016). In the 1970s, Louisiana-Pacific lands, now MRC, in the HTC sub-watershed were tractor-logged intensively using skid trails in or near low-order streams following standard practices of the era (Stillwater Sciences 1999). These disturbances resulted in high rates of erosion, primarily from roads but also from mass wasting (MRC 2004). In recent decades, sediment production has declined due to greatly improved harvest practices and forestry regulations. For example, delivery of sediment from mass wasting in HTC and adjacent watersheds were nearly 50% lower in the period 1979-2000 than in the period 1969-1979 (274,000 tons versus 500,000 tons) (MRC 2004).

The anthropogenic disturbances to the SFER sub-basin were greatly exacerbated by the devastating floods of 1955 and 1964 and by other natural disasters. Though there is no readily available information specific to HTC regarding the effects these floods, the effects may have been similarly catastrophic as in other parts the SFER sub-basin. When the unrelenting rainfall of 1955 and 1964 hit the recently logged watershed, vast amounts of sediment were deposited in waterways, rapidly aggrading stream beds (Sloan et al. 2001). The floods also swept the riparian corridor of vegetation and woody debris and without coarse structures to moderate stream flow, channels rapidly down-cut through the thick alluvial deposits as flows receded, leaving floodplains perched high above the active channel (Sloan et al. 2001). Other disturbances included the Will Creek Fire near Leggett in 1945, which burned a substantial portion of the HTC sub-watershed, as well as several smaller fires in recent decades (CDFW 2014).

HTC has long been recognized for its salmonid production within the SFER. During a survey of a reach of HTC in late May 1940, Renowned Fisheries Biologist Leo Shapovalov found a 25-inch adult steelhead trout. He noted, “watershed partly logged-off long ago, but with good stand of Douglas fir and redwood. In this section the most beautiful stream I have seen in the Eel R. drainage” (CDFG 1940). Another survey in 1968 noted that the creek was “in excellent shape”, had a “constant good flow of water” and “excellent” spawning and rearing conditions (CDFG 1968a). CDFW conducted stream habitat surveys in HTC sub-watershed in the early 1990s (1990–1992) and again in the early 2000s (2001-2003), finding that overall habitat suitability was low throughout the mainstem and low to high in the tributaries with some reaches improving and some declining over that time period (CDFW 2014). MRC’s 2004 watershed analysis corroborates these findings and notes recent improvements to sediment delivery and stream complexity due in part to restoration projects (MRC 2004). In preparation for the SHaRP Action Team meeting, CDFW conducted field reconnaissance surveys in the fall of 2018 in a subset of reaches to measure
bankfull widths, channel entrenchment, valley widths, large wood\textsuperscript{11} abundance and recruitment potential of downed trees in the nearby riparian forest, and to identify side channels and backwaters. The 2018 CDFW surveys found HTC and its tributaries to be lacking large wood except for remaining constructed instream structures with little potential for recruitment of downed trees from the nearby riparian. The same survey identified multiple split channels and areas of potential backwater inundation in low gradient lower reaches that could be enhanced with large wood additions.

Fisheries biologists have continued to survey HTC to assess the salmonid populations that it supports. CDFW conducted annual electrofishing surveys on three index reaches along HTC from 1986 to 2015 to sample the population of salmonids rearing there (Figure 10-3). The highest densities of juvenile Coho Salmon were observed in the cool, low-gradient reach of the upstream portion of HTC above the confluence with Huckleberry Creek (Figure 10-3). CDFW’s California Monitoring Program (CMP) spawner surveys (2010 to 2016) indicate that Coho Salmon spawn in many streams within the HTC sub-watershed, with particularly high densities in the upstream portion of the sub-watershed near Michael’s Creek (Figure 10-4) (Starks and Renger 2016). Sacramento Pikeminnow were detected in HTC near its confluence with the SFER beginning in 1994 and then subsequently in 2005 and most years thereafter (even years between 2006 and 2012, and 2015) (Scott Harris, unpublished data).

HTC was ranked as the highest overall priority sub-watershed in the SHaRP process with the highest scores for Habitat Conditions and Optimism and Potential, a tie for the highest Biological Importance, and second highest score for Integrity and Risk. In the SFER watershed assessment, HTC was designated as one of few “high quality refugia” streams in the SFER sub-basin (CDFW 2014).

\textsuperscript{11} Formally referred to as large wood debris (LWD) in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.
Figure 10-3. Annual time series of density of juvenile Steelhead Trout (top) and Coho Salmon (bottom) from multi-pass electrofishing surveys on three index reaches along HTC during September or October in the years 1986–2015. LOW = approximately 300-350 feet upstream from confluence with the SFER, MID = approximately 1500 feet downstream of Mule Creek confluence, UPP = upstream of Huckleberry Creek confluence. Map shows reach locations as X symbols on the HTC stream network. Data source: Scott Harris, unpublished data.
Figure 10-4. Observed Coho Salmon redd densities from CDFW's CMP surveys (2010 to 2018).
10.3 Historic and Current Restoration Efforts

There is a long history of efforts to improve salmon and steelhead populations in HTC and its tributaries. These efforts have included a hatchery that operated from 1979 through the early 2000’s. Instream structures supporting the hatchery were removed in 2010 to improve fish passage with the help and coordination of Trout Unlimited (TU) and funding by CDFW Fisheries Restoration Grant Program (FRGP) (CHRPD 2018). With FRGP funds awarded in 1993, TU and Pacific Watershed Associates (PWA) conducted an analysis and subsequent restoration of road networks within the HTC sub-watershed, treating and decommissioning over 30 miles of roads to reduce sediment delivery to waterways and improve fish passage at road crossings (CHRPD 2018). From 1991 to 2006, the California Conservation Corps (CCC) and the Eel River Watershed Improvement Group (ERWIG) installed over 184 large wood structures to improve instream habitat complexity and stabilize banks (Figure 10-5). Working together they also modified 23 large debris accumulations and one rock chute to improve fish passage (CHRPD 2018). CDFW, USFWS, MRC, and TU continue to collaborate on restoration projects in the HTC sub-watershed, including recent road upgrades, road decommissioning, instream structure installation, and post-project monitoring (CDFW 2014).
Figure 10-5. Locations where large wood has been added as part of past restoration projects before and after the year 2000, when the wood loading targets increased. Source: CDFW personal communication, Scott Monday and David Kajtaniak 2018.
10.4 Limiting factors and threats affecting salmonids in Hollow Tree Creek

The HTC Expert Panelists discussed available data and personal knowledge of the sub-watershed on April 24, 2018. Through an interactive process, each participant rated the impact of each limiting factor and threat while completing three worksheets: Coho Salmon and steelhead limiting factors by location and life stage; Chinook Salmon limiting factors by location and life stage; and threats by limiting factor and species. The Expert Panel considered two locations for each limiting factor worksheet; 1) the mainstem of HTC and 2) all of the fish-bearing tributaries of HTC. The effect of each limiting factor on each life stage of Coho Salmon and steelhead in the tributaries and mainstem HTC is shown in Table 10-1, the same information is shown for Chinook Salmon in Table 10-2. The severity of each threat based on its effect on each species across the entire sub-watershed is shown in Table 10-3. All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered that limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
Limiting Factors

Table 10-1. The effect of each limiting factor on each life stage of Coho Salmon and steelhead in the HTC sub-watershed in the mainstem location and the tributaries location. Cells are shaded according to values that indicate the severity of the effects of each limiting factor (1 = most limiting, 5 = least limiting, blank = not applicable).

<table>
<thead>
<tr>
<th>Life Stages and Areas</th>
<th>Hollow Tree Creek Tributaries</th>
<th>Hollow Tree Creek Mainstem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spawners</td>
<td>Eggs/Alevins</td>
</tr>
<tr>
<td>Limiting Factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited in-channel LWD, pool depth</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>LWD recruitment</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Limited off-channel ponds, backwater areas</td>
<td>5.0</td>
<td>3.3</td>
</tr>
<tr>
<td>High Water Temperature</td>
<td>4.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Water Chemistry (DO, pH, toxins)</td>
<td>4.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Dry Season Flow</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Wet Season Flow (includes timing of onset of wet season)</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Barriers (Levees, tidegates, culverts, dams)</td>
<td>3.9</td>
<td>4.1</td>
</tr>
<tr>
<td>Excess sediment delivery</td>
<td>3.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Riparian shading</td>
<td>4.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Predation, competition with non-native aquatic animal species</td>
<td>5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Lack of adequate spawning gravels/Spawnable* substrate*</td>
<td>1.5</td>
<td>3</td>
</tr>
</tbody>
</table>

*Limiting factor was considered by only two participants.
The most important limiting factors for Coho Salmon and steelhead in HTC are related to a relative lack of physical habitat complexity (Table 10-1). In-channel large woody debris (large wood), pool depth, and large wood recruitment were rated a score of 3 or lower for nearly all life-stages of Coho Salmon and steelhead. Similarly, lack of off-channel ponds and backwater areas were also a highly rated limiting factor for winter parr, smolts, and fry in both the mainstem and tributaries. Limited large wood recruitment was a concern despite excellent riparian shading in tributaries of HTC, reflecting the relatively young age of riparian trees. Though most of the riparian forest is too young to recruit naturally, many of the trees may be of useful size for accelerated recruitment restoration treatments. In contrast, the lack of riparian shading was a concern in mainstem HTC for summer parr because shading of the wide mainstem channel requires taller trees than the narrower tributary channels.

For summer parr, high water temperatures were rated a 2.8 out of 5 in the mainstem HTC. Water temperatures in tributaries to HTC were rated a 4 out of 5 reflecting temperatures are generally supportive of summer rearing. Other limiting factors in tributaries rated as three included dry season flow for summer parr, timing of onset of wet season for returning adults, and excess sediment delivery for eggs/alevins. Although still rated as important, dry season flows are much less of a concern in HTC sub-watershed than in other sub-watersheds of the SFER because there are so few water diversions.
Table 10-2. The effect of each limiting factor on each life stage of Chinook Salmon in HTC sub-watershed in the mainstem locations and the tributaries locations. Cells are shaded according to values that indicate the severity of the effects of each limiting factor (1 = most limiting, 5 = least limiting, blank = not applicable).

<table>
<thead>
<tr>
<th>Chinook Salmon</th>
<th>Life Stages and Areas</th>
<th>Hollow Tree Creek Tributaries</th>
<th>Hollow Tree Creek Mainstem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spawners</td>
<td>Eggs/Alevins</td>
</tr>
<tr>
<td>Limited in-channel LWD, pool depth</td>
<td>3.4</td>
<td>3.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Limited LWD recruitment</td>
<td>2.8</td>
<td>3.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Limited off-channel ponds, backwater areas</td>
<td>4.0</td>
<td>3.0</td>
<td>3.1</td>
</tr>
<tr>
<td>High Water Temperature</td>
<td>3.7</td>
<td>3.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Water Chemistry</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Dry Season Flow</td>
<td>4.1</td>
<td>4.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Wet Season Flow</td>
<td>3.2</td>
<td>3.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Barriers (Levees, tidegates, culverts, dams)</td>
<td>4.0</td>
<td>4.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Excess sediment delivery</td>
<td>3.9</td>
<td>3.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Riparian shading</td>
<td>3.8</td>
<td>3.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Predation, competition with non-native aquatic animal species</td>
<td>5.0</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Spawnable Substrate*</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Limiting factor was considered by only two participants.
For Chinook Salmon, the most important limiting factors for fry were in-channel large wood, pool depth, and large wood recruitment (Table 10-2). The timing of onset of wet season flows was the highest rated limiting factor for returning adults. In years with delayed rains, Chinook Salmon may not be able to access SFER tributaries like HTC (e.g., see Ricker et al. 2015). Similarly, wet season flow was also rated at a value of 1 for limiting returning adults and spawners to tributaries because many tributaries have natural barriers caused by knickpoints which limit upstream passage of adults during low flow periods and restrict the spawner distribution in the watershed. Other limiting factors rated as 2.9 or less in the tributaries to HTC include excess sediment delivery for eggs and alevins.

**Threats**

Table 10-3. The impact of current threats on key limiting factors for Coho Salmon and steelhead, and Chinook Salmon in HTC. The lower the number, the higher the impact, thus where red is the worst impact and dark green is the least impact.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Coho &amp; Steelhead</th>
<th>Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altered hillslope hydrology*</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Channelization/Diking</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Culverts, other barriers</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Diversions</td>
<td>2.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Pikeminnow and other introduced aquatic species</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Riparian management</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Rural private roads (chronic effects)</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* Only one person considered and ranked this threat.

The greatest threat for all species in HTC was land use conversion/development, followed by rural private roads, channelization/diking, and culverts and other barriers (Table 10-3). The Expert Panel agreed that land conversion and development has the greatest effect on physical habitat complexity including the availability of off-channel habitat and recruitment of in channel large wood. Land
conversion and development was also associated with the other highest ranking threats such as rural private roads, culverts, and channelization. In the HTC sub-watershed, roads and stream crossings are used primarily for timberland management, the existence of which affects hydrology, sediment delivery, access to off-channel habitat, and instream habitat complexity (large wood and pool depth).

10.5 Recovery Strategy

On November 27, 2018, the HTC Action Team discussed the outcomes of the Expert Panel meeting discussed above and identified restoration actions that would best address the most limiting factors and the highest severity threats. The team collaboratively identified the best locations for these restoration actions by reviewing spatial data on printed maps and computer monitors, and identifying locations known to the experts of the panel. Figure 10-6 shows the treatment types as colored stipes following the stream reaches identified by the team, and subsequently interpreted by the steering team. Table 10-4 references treatment action type by stream name and reach codes.

The recovery strategy for HTC is targeted at improving physical habitat complexity for juvenile fish during summer and winter, increasing the area and distribution of suitable spawning habitat for spawning adults, and improving adult fish passage in key tributaries (Table 10-4, Figure 10-6). This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design.
Figure 10-6. Restoration treatments identified by HTC Action Team.
Table 10-4. Recommended restoration treatments for Hollow Tree Creek sub-watershed.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>LWD for summer rearing (pools, sorting gravel)</td>
<td>Hollow Tree Creek, Bond Creek, Huckleberry Creek, Butler Creek, Little Bear Wallow Creek</td>
<td>943.1, 943.2, 950, 950.1, 950.2, 950.3, 991, 1007, 1008, 1009, 1011, 1012, 1014</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>Hollow Tree Creek, Bond Creek, Bear Wallow Creek, Little Bear Wallow Creek, Butler Creek, Tributary to Butler Creek</td>
<td>941, 941.1, 941.2, 941.3, 941.4, 941.5, 943, 943.1, 943.2, 950, 950.1, 950.2, 950.3, 991, 1008, 1009, 1011, 1012, 1014, 982, 984, 996, 1007, 1008, 1009</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>Hollow Tree Creek, Redwood Creek, S.F. Redwood Creek, Michaels Creek, Huckleberry Creek, Bear Wallow Creek, Little Bear Wallow Creek</td>
<td>941, 941.1, 941.2, 941.3, 941.4, 941.5, 943.1, 943.2, 981, 982, 984, 996, 1007, 1008, 1009</td>
</tr>
<tr>
<td><strong>Adult Spawning</strong></td>
<td>LWD for gravel entrainment</td>
<td>Hollow Tree Creek, Redwood Creek, Bond Creek, Waldron Creek</td>
<td>943, 943.1, 943.2, 950, 950.1, 950.2, 982, 991, 1002</td>
</tr>
<tr>
<td></td>
<td>Natural barrier</td>
<td>Bear Creek, Redwood Creek, Waldron Creek</td>
<td>980, 981, 1002</td>
</tr>
<tr>
<td></td>
<td>Gravel augmentation</td>
<td>Redwood Creek</td>
<td>982</td>
</tr>
</tbody>
</table>
Treatments to Improve Overwinter Conditions for Winter Parr and Fry

To improve habitat for overwintering juvenile salmonids, a key limiting factor identified by the Expert Panel, treatments to increase and enhance instream and off-channel habitat features and increase the frequency of floodplain inundation and off-channel habitats were recommended. Stream reaches which were lacking large wood but maintain low gradients that could support suitable, in-channel refuge were identified as locations to improve in-channel winter habitat. These criteria were also used to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths and/or the observation of existing floodplain habitats that could be inundated more frequently.

While these treatments were identified throughout the sub-basin, most of the instream winter habitat treatments are suggested on the mainstem of HTC. Low gradient reaches of mainstem streams become more important in the winter as juvenile fish emigrate from spawning and summer habitats typically found in the highest reaches and tributaries (Johnson 2016, Wallace et al. 2015, Rebenack et al. 2015). Thus, providing complex winter refugia in mainstem reaches will provide some of the best opportunities for growth and survival of juvenile salmonids during winter months. Winter survival, however, can be high in smaller tributary habitats (Ebersole et al. 2016) and the Action Team noted areas with high potential for winter rearing habitat at the confluence of the South Fork Redwood Creek and Redwood Creek, and areas of Bear Wallow and Michaels Creek. Natural barriers such as the bedrock falls on Redwood Creek and South Fork Redwood Creek temporally limit upstream and downstream movement of juveniles. The Action Team recommend improving adult passage over the bedrock falls and improving spawning conditions in the upstream habitat (see Treatments to Improve Adult Salmonid Spawning Distribution). Coupled with enhancement of winter rearing conditions above temporal-barriers, this strategy would allow adults to seed this habitat more frequently and juveniles would have a greater capacity to rear in this habitat year-round despite the temporal barrier. Installing large wood structures for in-channel winter habitat is recommended for the mainstem of HTC (reaches 941 – 1014), Bond Creek (reach 991), Bear Wallow Creek (reach 1008), Little Bear Wallow Creek (reach 1009), and Butler Creek (reach 1012) (Figure 10-6).

Treatments to improve off-channel winter habitat by creating and re-connecting floodplain habitat and increasing the frequency of floodplain inundation can also increase the overall rearing capacity of a stream. The Action Team recommended these treatments in the mainstem of HTC from its mouth to the confluence with Mule Creek (reaches 941 – 941.5), between Lost Man Creek and Redwood Creek (reaches 943.1 – 943.2), and between Michaels Creek and Huckleberry Creek (reach 950.2). These treatments are also recommended in tributaries including Huckleberry Creek (reach 1007), Bear Wallow Creek (reach 1008), Little Bear Wallow Creek (reach 1009), Michaels Creek (reach 996), Redwood Creek (reaches 981 – 982), and the South Fork of Redwood Creek (reach 984) (Figure 10-6). These reaches were identified with the best available data and observations provided by the Action Team; however, these reaches will require further
investigation and site-specific designs to determine the most appropriate implementation plan. It is important to note that while the downstream portion of mainstem HTC was recommended for treatment, this area has poor road access so projects occurring in these regions will either require hand work, reverse cable yarding, or the use of helicopters. Accelerated recruitment of large wood upstream of these areas may also be effective at distributing wood to these areas.

**Treatments to Improve Adult Salmonid Spawning Distribution**

To increase the amount of suitable spawning habitat, gravel augmentation and treatments to trap and sort gravel with large wood were recommended in portions of the sub-watershed. Highly suitable juvenile rearing habitat and suitable spawning gradients exists in Redwood Creek, Bond Creek, and Waldron Creek (Reaches 982, 991, and 1002), but suitable spawning gravels are limiting the colonization of these areas. The lack of spawning habitat in these reaches is likely due in part to the lack of channel obstructions such as large wood that can trap and sort naturally occurring gravel. The Action Team also recommended exploring the potential for gravel augmentation in Redwood Creek due to observations suggesting the stream lacks sufficient sources of naturally occurring gravel and existing roads facilitate implementation (Figure 10-6). The Action Team recognizes that gravel augmentation may be logistically challenging in most streams (i.e., lack of road access close enough to the channel to deliver adequate volumes of gravel), and it is unknown how long the benefits would last, but also acknowledge there is little risk and financial burden involved in the pilot effort recommended at this location (reach 982). The Action Team recommends using large wood in all the reaches noted above to retain more suitable spawning gravels. Improving spawning conditions in these reaches may lead to the colonization and use of the highly suitable juvenile habitats present in these reaches which will likely improve overall smolt production for HTC. The middle reaches of HTC from Michael’s Creek downstream to Mule Creek (Reaches 943 – 950.1) were also identified as needing large wood to trap and sort gravel (Figure 10-6) due to a relative lack of spawning gravel in suitably low-gradient habitat. The lack of spawning gravels in this region is likely due to the scarcity of existing instream obstructions. Adding large wood here can lead to the deposition and sorting of suitable spawning gravels in reaches which would otherwise convey these materials further downstream.

The distribution of spawning adults in the sub-watershed is influenced by the severity of the natural barriers at tributary confluences. Unfortunately, some of the best potential fish habitats are located upstream of tall bedrock waterfalls for which there are likely no feasible methods of providing passage. Previous attempts to improve passage at natural barriers, such as the use of daisy chain boulder structures in Waldron Creek, appear to have been largely unsuccessful. The Action Team recommended exploring other approaches, such as backwatering tributary confluences by using channel-spanning wood structures in mainstem channels downstream of the confluence. Additionally, the Action Team elected to focus treatments on partial barriers that would be improved by reduced jump heights and improved step pools, thereby increasing the range of passable flows. Sites recommended for further evaluation include the mouths of Bear Creek and
Waldron Creek and the downstream portion of Redwood Creek (reaches 980, 981, and 1002) (Figure 10-6). Improving fish passage along the lower end of Redwood Creek is high priority given that the jump heights are already relatively low, and the upstream portion of Redwood Creek is one the few areas in the sub-watershed with good floodplain connectivity (MRC 2004). No anthropogenic barriers were identified as restoration priorities.

*Treatments to Improve Conditions for Summer Parr*

The Action Team identified several reaches that would likely support juvenile salmonids during the summer months but would greatly benefit from improved pool depth and pool cover. Treatments to add instream structures which create deeper pools under scouring flows and complex cover under summer base-flow conditions were recommended in reaches with cooler water temperatures near frequently used spawning habitat, including portions of Bond Creek (reach 991), Huckleberry Creek (reach 1007), Bear Wallow Creek (reach 1008), Little Bear Wallow Creek (reach 1009), Butler Creek (reach 1012), and mainstem HTC (reaches 943.1–1014) (Figure 10-6).

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
11. Chapter 11: South Fork Eel River Headwaters Action Plan

11.1 Sub-Watershed Overview

The South Fork Eel River (SFER) headwaters sub-watershed, located in northern Mendocino County near the town of Branscomb, includes the SFER and tributaries beginning upstream of the confluence with Tenmile Creek and ending in the headwaters of the SFER (Figure 11-1). The sub-watershed drains over 37,800 acres of land through 17 named tributaries and contains approximately 64.7 miles of anadromous waterways (Christy 2012). Elevations range from approximately 1,200 feet at the downstream end of the sub-watershed to approximately 4,200 feet in the tributary headwaters. The vegetation in the sub-watershed is predominantly mixed hardwood and coniferous forest composed primarily of tan oak, Douglas fir, and redwood with patches of hardwood forest and grassland in the upstream portions of the sub-watershed and coniferous forest in the western tributaries and downstream portion of the sub-watershed (CDFW 2014).

Most of the sub-watershed is privately owned by timber companies, ranchers, and rural private residents, but a large portion of the sub-watershed is protected as a natural reserve. The Angelo Coast Range Reserve is a natural resource reserve and research station in the northeastern portion of the sub-watershed. The Reserve is co-managed by the University of California (UC), Berkeley and the UC Natural Reserve System (http://angelo.berkeley.edu) for university-level teaching, research, and public outreach. Adjacent land to the northwest and east is owned by Bureau of Land Management (BLM) and designated as an Area of Critical Environmental Concern. Together with the BLM land holdings, the reserve protects 7,660 acres of land in the sub-watershed.

The sub-watershed has a long history of human use beginning with Cahto tribal villages and seasonal occupation throughout the sub-watershed and surrounding areas. This was followed by post-European settlement and homesteading beginning in the 1850’s culminating in the logging boom of the 1950’s and continuing into contemporary rural residential and forestry use (Johnson 1979). The area has historically been an abundant source of Coho Salmon, Chinook Salmon, and steelhead. However, poorly regulated historical logging practices and other anthropogenic and natural disturbances (most notably the floods of 1955 and 1964) degraded stream habitat in much of the sub-watershed, leading to the dramatic decline of salmonid populations. Improvements in regulations and restoration actions in more recent years are aiding in the recovery of habitat, but many streams require greater efforts to restore habitat to its former state.

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12 The area referred to as the South Fork Eel River headwaters sub-watershed is equivalent to the 12-digit Elder Creek hydrologic unit as defined by the USGS (unit # 180101060103). The name was changed to avoid confusing the sub-watershed with the Elder Creek tributary.
Figure 11-1. Overview of the South Fork Eel River sub-basin showing the location of the SFER headwaters sub-watershed.
11.2 History of Land Use and Fish Habitat

The geology of the SFER headwaters sub-watershed is predominantly composed of mudstones, sandstones, and shales of the Franciscan Complex Coastal Belt downstream of Little Rock Creek and predominantly Central Belt mélange upstream of Little Rock Creek (CDFW 2014). Coastal Belt terranes usually form steep, crested ridges and deep valleys. The underlying shale and sandstone is porous and deeply fractured, providing a high capacity to store water as “rock moisture” and sustain mixed conifer-evergreen broadleaf forests through the dry summers, even during multi-year droughts (CDFW 2014, Hahm et al. 2019). However, the properties that make Coastal Belt rock ideal for water storage also make the land prone to deep-seated and shallow landslides, especially when driven by river incision, large rainstorms, and other land disturbances (CDFW 2014). The landscape to the south of Little Rock Creek is primarily underlain by mélange bedrock, a diverse medley of pulverized rock. This soft layer is morphed by numerous, large deep-seated landslides, many of which are currently inactive. This earth movement has given rise to the distinctive irregular topography characteristic of mélange geology (CDFW 2014). Central Belt mélange has much lower water storage capacity, leading to more volatile stream flows in winter and stream drying during summer. Mélange landscapes that shed rather than store water support drought tolerant forest such as the deciduous oak and grass savannahs of the upper sub-watershed (Hahm et al. 2019).

Geologic uplift of the SFER sub-watershed has resulted in anomalous landforms in stream channels of the SFER headwaters sub-watershed, including perched tributary mouths and knickpoints (Willenbring 2013). As the landscape of the SFER has risen, the hydraulic power of the river has been incising the channel leaving ancient river terraces and smaller tributaries perched above. Where the stream encounters large portions of un-fractured bedrock, a knickpoint is formed and stream incision stalls in progression upstream (Foster and Kelsey 2012). This process is responsible for producing many of the barriers to anadromy in the SFER (CDFW 2014) and has likely produced many of the natural barriers in the SFER headwaters sub-watershed. Similarly, smaller tributaries such as Elder Creek and Dutch Charlie Creek which lack the hydraulic power to erode stream channels as fast as the SFER are left perched above the main-stem river channel at their confluences.

Prior to the arrival of European settlers to the region, Native Americans including the Cahto tribe used the diversity of natural resources present in the sub-watershed for subsistence. They harvested

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13 Water cycles here (and elsewhere) are mediated through the critical zones—the vertical skin of the Earth where water is received, stored, and released to support surface flows or vegetation. Critical zones extend from the top of vegetation canopies down to the top of unweathered bedrock, where water becomes immobile on ecological time scales (Rempe and Dietrich 2017).
acorns, collected basket materials, and hunted in open meadows and oak forests while the waterways were used to seasonally harvest fish (Baumhoff 1963, reviewed in Johnson 1979). Native Americans likely used fire to manage the landscape to improve these resources and facilitate travel across the ridge tops (Johnston 1979, Sharron Edell pers. com.).

The wide valleys, open meadows, and surrounding forests that Native Americans used also attracted settlers to the region. Beginning in the 1880’s, the first mill opened near present day Branscomb and settlers began to homestead the open valleys of the sub-watershed (Johnston 1979). Settlers of this era felled redwoods for split products, barked tan oaks, grazed livestock, and raised orchards and vegetable gardens. By the early 1900’s, two independent wilderness resorts allowed visitors to enjoy the scenic beauty of the area as well and hunt game and fish the local streams (Johnston 1979). Life in the SFER headwaters sub-watershed continued in this way through the 1930’s.

After the end of World War II, the returning workforce and development of mechanized timber harvest methods ushered in a logging boom to the region. Many new mills were built within the sub-watershed as well as the surrounding valleys to cut board and beam products, facilitating the harvest of pine and fir trees which required milling. By 1950, there were over 90 milling operations throughout the sub-watershed and neighboring Laytonville valley (Baldo and Brown 2008). The logging practices of this era utilized large tractors and dozers to plough roads into the rugged mountains and drag massive logs from the felling sites to staging areas (Baldo and Brown 2000). Standard logging practices of the era included few protection measures for waterways and almost no erosion control or reforestation efforts. Additionally, county ad valorem taxes levied on standing merchantable timber incentivized rapid harvest throughout the region, leading to widespread deforestation and land disturbances (Figure 11-2, Geinger 2017). Portions of the SFER headwaters sub-watershed including the lands surrounding Elder Creek (Figure 11-2), Fox Creek, and the present day Admiral Standley State Recreation Area were spared from industrial logging by early conservationists and continue to be protected areas.
Figure 11-2. Aerial photo of the SFER headwaters sub-watershed circa 1952 (CDF 1952). The effects of logging practices of the era are readily visible along the western portion of the sub-watershed as compared to the eastern portion near Elder Creek which was never commercially logged.

The rapidly constructed and poorly designed road networks left the landscape prone to erosion and catastrophic land failures. Additionally, excessive logging debris formed large wood jams throughout the sub-watershed, which threatened fish passage (CDFG 1938a, CDFG 1969c, CDFG 1969d, CDFG 1979a, CDFG 1979c). When the SFER was struck by a series of devastating floods in 1955 and 1964, massive debris and sediment yields were delivered to the Eel River in quantities approximately three times greater than observed in the geologic record of the basin (Sommerfield et al. 2002). These floods carried away vast amounts of instream wood14, destroyed riparian vegetation, and aggraded channels of SFER tributaries with sediments (Sloan et al. 2001).

Remaining wood jams were often viewed as either a barrier to fish passage or the cause of deleterious sediment deposition in stream channels; many of these jams were removed in efforts to restore fish populations (Godey 1979, CDFG 1979a, CDFG 1982b, CDFG 1984). Despite these

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14 Formally referred to as large wood debris (LWD) in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). LWD may appear in figures and citations made prior to the adoption of the updated terminology, but it is synonymous with large wood.
efforts, the extensive land disturbances caused by legacy logging practices degraded instream habitat with excessive sedimentation and gravel embeddedness only recently beginning to improve (Figure 11-3). Furthermore, complete removal of large wood likely contributed to the demise of salmonid habitat as the benefits of large wood in streams were overlooked for its harmful effects (Maser and Sedell 1994). It is important to note that not all salmonid streams had naturally occurring abundant stream wood. In 1938, stream surveys of Elder Creek indicated that the dominant substrate was boulders and that few pieces of large wood were present (CDFG 1938b). Elder Creek was never industrially logged nor were log jams removed, so these observations are likely of the streams’ natural state. The higher gradients (3-7%) of Elder Creek promote the entrainment of smaller substrates and may also promote the mobilization of large wood, maintaining a boulder-dominated channel.

After flood waters removed riparian vegetation from stream banks and logging activities were restricted from riparian habitat with the enactment of the Forest Practices Act (1973), the plant communities have been recovering. In the Pacific Northwest coastal zones, riparian succession moves relatively quickly from colonization by herbaceous vegetation to a community dominated by alder (Naiman et al. 2000). California Department of Fish and Wildlife15 (CDFW) and Bureau of Land Management (BLM) habitat surveys of streams in the sub-watershed corroborate this process; canopy cover was typically less than 80% over most of the streams and dominated by broadleaf species, such as white alder (Alnus rhombifolia) and big-leaf maple (Acer macrophyllum) (CDFW 1969a, CDFW 1969b, CDFW 1969c, CDFW 1969d, BLM 1975, CDFG 1979b, CDFG 1979c). In recent years, mean canopy cover has increased substantially and conifers are now contributing more to stream shading (CDFG 1991a, CDFG 1992a, CDFG 1992b, CDFW 2014). While alder and other broad-leaved trees are an essential component of a mature riparian forest and contribute substantially to biological and physical stream processes, most broad-leaved trees do not grow very large, nor do they persist once recruited to a stream channel relative to most conifers common to the region (Naiman et al. 2000). The continued succession from an alder-dominated riparian community to a mature conifer riparian forest which can contribute substantial and persistent large wood will likely take many tens to hundreds of years (Gregory et al. 1991), during which time native salmonid populations remain in jeopardy of endangerment and potential extirpation.

Historically abundant salmonid populations greatly decreased due in part to widespread habitat degradation, chronic turbidity, and competition with invasive species. As early as 1938, abundant steelhead and juvenile Coho Salmon were observed throughout the sub-watershed (CDFG 1938, 1969a, 1969b, 1969c, BLM 1975). Chinook Salmon, Coho Salmon, and steelhead are consistently observed spawning throughout the sub-watershed with notable abundance in Dutch Charlie Creek, Jack of Hearts Creek, Redwood Creek, and the upper South Fork Eel River (Figure 11-4). A 1965 proposal to turn the sub-watershed into a reservoir was not approved in part due to the high-quality

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15 Formerly known as the California Department of Fish and Game
fish habitat that would have been lost as a result of the project (DWR 1965). Salmonid populations began a drastic decline in the mid-1940’s and have remained depressed due to the deleterious effects of logging described above, competition with invasive Sacramento Pikeminnow (*Ptychocheilus grandis*), water extraction, and other anthropogenic alterations to habitat of the Eel River Basin (CDFW 2014). Due to improvements in environmental regulation and restoration actions, some habitat in the SFER headwaters sub-watershed is improving. Based on an analysis of habitat surveys conducted by CDFW, pool depth, canopy cover, and gravel embeddedness has improved over-all in the sub-watershed, with several stream reaches exhibiting high quality habitat (CDFW 2014). Additionally, stream temperatures are suitable for salmonids year-round throughout most of the sub-watershed, with only the downstream portion of the SFER becoming too warm by August (Figure 11-5, pers. comm. Philip Georgakakos). Sacramento Pikeminnow distribution in the sub-watershed is also constrained due to low water temperatures, with observations typically occurring only in the warmest portion of the lower mainstem SFER during the summer months. While salmonids have persisted and habitat has improved, further efforts are required to restore habitat to a productive state which supports healthy salmonid populations.
Figure 11-3. Habitat Suitability Indices (HSI) for gravel embeddedness in the SFER headwaters sub-watershed.
Figure 11-4. Total density of Coho Salmon, Chinook Salmon, and steelhead redds in the sub-watershed, all years combined (2010-2018), based on CDFW spawner surveys (Starks and Renger 2016). The redd survey was designed for Coho Salmon, so the duration and extent of the survey do not encompass the full spatial or temporal expression of the Chinook Salmon or steelhead run.
Figure 11-5. Observed mean weekly maximum temperature (MWMT) and modeled August mean temperature (NorWeST) associated with Coho Salmon and steelhead summer rearing in the SFER headwaters sub-watershed.
11.3 Historic and Current Restoration Efforts

Overall restoration efforts in the SFER headwaters sub-watershed began somewhat slowly with a few projects in the 1990s; however, the number of projects and area treated has greatly increased in the last decade as private landowners, non-profit groups, agencies, UC Berkeley, and interested stakeholders have put forth significant efforts in restoring this important area. Restoration work has consisted of the major categories of habitat improvement such as upslope/road improvement, sediment reduction, barrier modifications, and instream habitat improvement. These projects were primarily funded through CDFW’s Fisheries Restoration Grant Program (FRGP) and associated cost-sharing with project partners. A great deal of watershed ecology and salmonid-related research and monitoring have also occurred in the Angelo Coast Reserve and surrounding properties. Previously completed restoration projects are described beginning at the downstream end of the sub-watershed and moving upstream. A map depicting the type and location of these restoration projects is included at the end of this section (Figure 11-6).

Restoration of the downstream portion of the sub-watershed began in 1994 as New Growth Forestry completed an instream habitat improvement project in lower Jack of Hearts Creek. This project increased pool habitat, pool cover and complexity, and modified impediments to improve salmonid access to perennial habitat. From 2001-2002, a sediment reduction project was performed to upgrade and replace culverts at 10 class II (perennial) and III (ephemeral) stream crossings. The project also reshaped 3.5 miles of Jack of Hearts Creek Road, installed 10 rocked rolling dips and removed road berms at selected sites from mile 0 to mile 3.5 (E Center 2004). In 2014, Trout Unlimited (TU) with technical assistance from Pacific Watershed Associates (PWA) performed a road inventory and implemented erosion control measures of over 6 miles of forest roads (predominantly composed of rock/gravel and dirt) in the upper portion of Jack of Hearts Creek on Mendocino Redwood Company, Hawthorne Timber Company, and Walton Woods Trust properties. The goals of the inventory were to identify, quantify, and prioritize sources of future erosion and sediment delivery within the sub-watershed and develop corrective measures to reduce or eliminate future sediment delivery from road networks (PWA 2014). In conjunction with this project, TU received a Project Design FRGP grant intended to plan the removal of Walton Woods Pond dam, an earthen barrier approximately 3 miles up Jack of Hearts Creek and subsequent restoration of the re-opened stream channel. Upon completion of the design grant, TU, Michael Love and Associates (MLA), and PWA collaborated to remove the Walton Woods Pond earthen barrier, improve fish passage through a perennial stream crossing, and treat two road-related sediment sources (PWA 2019). Completed in the summer/fall of 2018, the project restored and enhanced 0.22 miles of stream habitat for salmonids in upper Jack of Hearts Creek.

Moving upstream along the SFER, Deer Creek, Dutch Charlie Creek, Little Charlie Creek, and Redwood Creeks were the next streams to receive restoration treatments. In 2003 the Mendocino County Department of Transportation (MDOT) through FRGP grant funding completed a fish passage improvement project in Deer Creek at the Wilderness Lodge Road crossing. The project
replaced an undersized circular culvert with a National Marine Fisheries Service (NMFS) approved bottomless pipe arch culvert, effectively restoring access to 3,700 feet of stream habitat (MDOT 2004). In 2015 TU completed a watershed action plan encompassing Dutch Charlie, Little Charlie, and Redwood Creeks. The plan included assessments of upslope road-related sediment sources, identification of road-related fish passage barriers, prioritization of barriers for removal, and salmonid habitat inventories. As a result of this plan, TU and PWA are currently engaged in a road decommissioning project that will likely be coupled with large wood enhancement sites in Dutch Charlie and Redwood Creeks (A. Halligan, TU, personal communication 2020).

Within the last decade, Kenny Creek has benefitted from multiple restoration projects. The Eel River Watershed Improvement Group (ERWIG) constructed habitat enhancement structures at 20 sites along 2,000 feet of lower Kenny Creek (ERWIG 2009). Between 2010 and 2011, the Mendocino County Resource Conservation District with technical support from PWA completed upslope restoration prescriptions to reduce road-related sediment from 39 sediment sources along 5.4 miles of Kenny Creek Road. The project occurred in the lower to the middle portion of Kenny Creek and extended into the adjacent Mud Creek watershed (PWA 2012). Mud Creek also had a road decommissioning and upgrading project completed by the BLM in 1999. This project removed sediment sources by decommissioning 2.6 miles of road and upgrading drainage on 3.4 miles of road. Most recently, ERWIG with MLA design plans replaced a culverted fish passage barrier with a single span bridge near the mouth of Kenny Creek allowing for perennial fish passage (ERWIG 2019).

In the upper watershed, the Center for Education and Manpower Resources was responsible for one of the earlier restoration projects (1993) as they modified a log jam barrier to improve fish passage in lower Taylor Creek. The project also enhanced fish habitat through the placement of digger logs and boulder clusters to deepen pools and provide additional cover for salmonids. Mendocino County also completed several fish passage improvement projects in the upper watershed. Completed in 2001, these projects upgraded and installed baffles on culverts inhibiting fish passage in Windem, Bear, and Taylor Creeks. All of these were performed on Branscomb Road stream culverts and were located near tributary confluences within the SFER.

While not necessarily implementing typical restoration practices, the Angelo Coast Range Reserve occupying most of the northeast portion of the sub-watershed has been protected from major anthropogenic disturbance since the 1930s. The reserve is dedicated to university-level research, teaching, and public outreach and provides a crucial window into the workings of natural river, riparian, wetland, forest, meadow, and chaparral ecosystems of California’s North Coast (http://angelo.berkeley.edu/). The Berkeley-based “Eyes on the Eel” was a three-year survey of the state of river and tributary food webs along the Eel River mainstem (SFER focused) and tributaries. Subsequent analysis of these data helps inform future restoration treatments for the recovery of salmonids in the SFER headwaters sub-watershed as well as the entire SFER.
Figure 11-6. Previously completed restoration projects in the SFER headwaters sub-watershed.
11.4 Limiting Factors and Threats

The Elder Creek Expert Panelists discussed available data and personal observations of the sub-watershed on December 17, 2019. During this discussion, each participant ranked the severity of each limiting factor and threat for each life stage species in an interactive process. The limiting factor tables (Table 11-1, Table 11-2) summarize the Expert Panel rankings in four areas: 1) The mainstem South Fork Eel River (South Fork Eel River from Mud Creek to the downstream extent of the sub-watershed), 2) the Western Tributaries (Barnwell Creek, Jack of Hearts Creek, Dutch Charlie Creek, Little Charlie Creek, and Redwood Creek), 3) Eastern Tributaries (Fox Creek, Elder Creek, Dear Creek, Rock Creek and Kenny Creek), and 4) the South Fork Eel River Headwaters (South Fork Eel River and tributaries from Mud Creek to the terminus of the sub-watershed including Mud Creek, Taylor Creek, Bear Creek, Windham Creek, and other named and unnamed tributaries). These areas were chosen to reflect the dominant hydrologic, geologic, and vegetative conditions of each area to facilitate group discussions of processes and limiting factors affecting each area. Threats are characterized across the entire sub-watershed (Table 11-3). All Expert Panel scores for each factor and life stage were averaged and categorically ranked to indicate how much each factor and threat limits the viability of each life stage of each salmonid. The lower the number, the greater the impact; cells scoring less than 2 are red (very high impact), scores between 2 and 2.9 are yellow (high impact), scores between 3 and 3.9 are light green (moderate impact), and scores of 4 and above are dark green (low impact). When reviewing the ratings as a group, the Expert Panel considered that limiting factors and threats scoring high or very high impact likely need restoration treatment, if possible. The data used during this meeting are available on the SHaRP web site at https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern.
Table 11-1. Average scores for the severity of impact of each limiting factor on each life stage of Coho Salmon and steelhead in four areas of the SFER headwaters sub-watershed.

<table>
<thead>
<tr>
<th>Coho Salmon and Steelhead</th>
<th>Mainstem</th>
<th>Western Tribs.</th>
<th>Eastern Tribs.</th>
<th>Headwaters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.F. Eel River Mainstem</td>
<td>Barnwell, Jack of Hearts, Dutch Charlie, and Redwood Creeks</td>
<td>Fox, Elder, Rock, and Kenny Creeks</td>
<td>S.F. Eel River, Mud, Taylor, Bear, and Windham Creeks</td>
</tr>
<tr>
<td>Limiting Factor</td>
<td>Eggs</td>
<td>Summer Parr</td>
<td>Winter Parr</td>
<td>Migrating Adults</td>
</tr>
<tr>
<td>Barriers</td>
<td>5.0</td>
<td>4.5</td>
<td>4.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Canopy cover</td>
<td>4.4</td>
<td>4.6</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>Catastrophic sediment delivery</td>
<td>3.3</td>
<td>3.5</td>
<td>2.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Channel complexity (including pool depth)</td>
<td>3.8</td>
<td>2.3</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Chronic turbidity (fine grain sediment, primary production, feeding opportunities)</td>
<td>1.1</td>
<td>1.3</td>
<td>1.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Dry season flow</td>
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<td></td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Ecological facilitation (interactions, lamprey)</td>
<td>1.8</td>
<td></td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>High water temperature</td>
<td>3.6</td>
<td></td>
<td>4.3</td>
<td></td>
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<td>Invasive predators (bullfrog, pikeminnow)</td>
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<td>4.5</td>
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<tr>
<td>Large wood recruitment</td>
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<td>2.7</td>
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<tr>
<td>Off-channel habitat</td>
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<td>2.0</td>
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<tr>
<td>Sediment (fines affecting egg survival and fry emergence)</td>
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<td></td>
<td>2.3</td>
<td></td>
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<tr>
<td>Wet season flow (timing and volume)</td>
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<td>4.3</td>
<td>3.3</td>
<td>3.6</td>
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</table>
Table 11-2. Average scores for the severity of impact of each limiting factor on each life stage of Chinook Salmon in four areas of SFER headwater sub-watershed.

<table>
<thead>
<tr>
<th>Chinook Salmon</th>
<th>S.F. Eel River Mainstem</th>
<th>Barnwell, Jack of Hearts, Dutch Charlie, and Redwood Creeks</th>
<th>Fox, Elder, Rock, and Kenny Creeks</th>
<th>S.F. Eel River, Mud, Taylor, Bear, and Windham Creeks</th>
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<tr>
<td>Limiting Factor</td>
<td>Eggs</td>
<td>Fry</td>
<td>Migrating Adults</td>
<td>Eggs</td>
</tr>
<tr>
<td>Barriers</td>
<td>4.3</td>
<td>4.7</td>
<td></td>
<td>4.3</td>
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<tr>
<td>Canopy cover</td>
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<tr>
<td>Channel complexity (including pool depth)</td>
<td>3.8</td>
<td>4.0</td>
<td>4.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Chronic turbidity (fine grain sediment, primary production, feeding opportunities)</td>
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<td>1.7</td>
<td>2.7</td>
<td>1.5</td>
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<tr>
<td>Large wood recruitment, canopy cover</td>
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<td>3.5</td>
<td>2.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Off-channel habitat</td>
<td>2.1</td>
<td></td>
<td>3.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Sediment (fines affecting egg survival and fry emergence)</td>
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<td></td>
<td>2.4</td>
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<tr>
<td>Wet season flow (timing and volume)</td>
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<td>4.0</td>
<td>2.4</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Table 11-3. Effect of each threat on each life stage of Coho Salmon, steelhead, and Chinook Salmon in the SFER headwaters sub-watershed.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Egg</th>
<th>Summer Parr</th>
<th>Winter Parr</th>
<th>Fry</th>
<th>Migrating Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coho &amp; Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channelization (roads)</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Culvert, levee, dam</td>
<td>5.0</td>
<td>5.0</td>
<td>4.3</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Diversions</td>
<td>4.0</td>
<td>4.0</td>
<td>2.0</td>
<td>3.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Land conversion, development</td>
<td>2.9</td>
<td>3.6</td>
<td>2.6</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Riparian mgmt.</td>
<td>4.8</td>
<td>4.8</td>
<td>4.3</td>
<td>4.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Rural private roads (chronic)</td>
<td>1.6</td>
<td>1.5</td>
<td>2.5</td>
<td>2.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Chapter 11: South Fork Eel River Headwaters
Limiting Factors

Many of the limiting factors with the highest impacts on Coho Salmon, Chinook Salmon, and steelhead in the SFER headwaters sub-watershed are related to turbidity and fine sediment (Table 11-1, Table 11-2). Chronic turbidity rated high or very high as a key factor limiting all juvenile life stages of all species in the SFER mainstem, western tributaries, and headwaters area of the sub-watershed. Though streams in the sub-watershed generally have clean, clear water in the summer, turbid spring flows can reduce primary productivity, an effect which will cascade up the trophic levels and affect summer parr (pers. comm Gabriel Rossi 2019). This factor received the second lowest score (greatest impact) of all the factors and species considered. Similarly, sediment deposition was also rated as a high or very high limiting factor for egg life stages of all species in the SFER mainstem, western tributaries, and headwaters area of the sub-watershed. Catastrophic sediment delivery was rated as a high impact limiting factor for Coho Salmon and steelhead egg life stages in western tributaries. A recent fire in the northwestern portion of the sub-watershed around Barnwell Creek left exposed soil and erosion issues in its wake.

Several other factors affecting physical habitat for salmonids including channel complexity, large wood recruitment, and off-channel habitat were also rated high or very high limiting factors. Channel complexity including pool depth was rated as a high or very high impact limiting factor for Coho Salmon and steelhead summer parr in all areas of the sub-watershed and for Coho Salmon and steelhead winter parr in the western tributaries. The lack of channel complexity was largely attributed to the legacy effects of land use (e.g. land disturbances from logging, road construction, and large wood recruitment alterations) and geologic processes such as uplift and subsequent incision. Large wood recruitment was rated as having a high impact to Coho Salmon and steelhead winter parr in all areas, high or very high impact for summer parr in the mainstem SFER and the western tributaries, and high impact for migrating adults in the western tributaries and the headwaters area of the sub-watershed. Large wood recruitment was also rated as a high impact limiting factor for Chinook Salmon fry in western tributaries and the headwaters area of the sub-watershed. Off-channel winter habitat was rated as a high or very high impact limiting factor for Coho Salmon and steelhead winter parr in all areas except the headwaters and for Chinook fry in the mainstem SFER. The availability of low velocity winter refugia was generally considered to be a significant limiting factor for juvenile salmonids. The Expert Panel ratings generally reflect the sentiment that low velocity refuge is essential to juvenile salmonids, especially during the winter months. Variance in the ratings can be attributed to necessities of other life stages for stream-specific habitat deficiencies such as large, deep pools for summer rearing in flow-limited streams.

Ecological interactions both positive and negative were also rated as high or very high impact for very different reasons. Ecological facilitation, in this case improved juvenile salmonid foraging success as mediated by spawning lamprey, was rated as a very high limiting factor for Coho Salmon and steelhead summer parr in both the mainstem SFER and the headwaters area. Based on
field observations and unpublished research at the Angelo Coast Range Reserve, lamprey spawning activities greatly increase the foraging success of juvenile steelhead (pers. comm. Philip Georgakakos 2019). However, it is uncertain how significant this facilitation is to juvenile growth and survival. These observations likely apply to the entire SFER but this factor was not considered in other sub-watersheds because this information was previously unknown. The Expert Panel considered the depressed lamprey populations to therefore limit the growth potential of summer-rearing salmonids in the areas described above. Since the focus of this plan is salmonid recovery, specific actions to improve lamprey populations were not recommended; however, restoration actions which improve aquatic habitat for salmonids will likely carry mutual benefits for lamprey as well. In contrast, the growing populations of invasive predators such as Sacramento Pikeminnow and American Bullfrog (*Lithobates catesbeianus*) threaten juvenile salmonids where ranges overlap. The Expert Panel rated invasive predators as a very high limiting factor for Coho Salmon and steelhead summer parr in the mainstem SFER, the only portion of the sub-watershed which reaches suitably warm temperatures for the non-native species. The Expert Panel rated this factor similarly to chronic turbidity due to its potential effects on the entire sub-watershed. Invasive predators in the lower mainstem river can potentially encounter all emigrating juvenile salmonids, placing the entire population at risk of predation.

Fluctuations in stream flow during both summer and winter were also considered high to very high limiting factors. The timing and volume of wet season flow was rated high for all migrating adult salmonids in the western tributaries, the eastern tributaries, and the headwaters area. This factor was also rated high impact for Chinook Salmon migrating adults in the mainstem SFER. Due to the position of the sub-watershed at the origin of the SFER, access to the sub-watershed and tributaries, especially early in the fall and winter, is highly dependent on the timing and intensity of storm events. Furthermore, numerous perched tributary mouths require appropriately timed elevated flows to allow adult immigration (Kelson 2018). The Expert Panel predicted that increased stochasticity in weather patterns due to climate change could greatly impact how often migrating adult salmonids, particularly earlier migrating species such as Chinook and Coho Salmon, have access to the sub-watershed. Dry season flow was rated as a high impact limiting factor for Coho Salmon and steelhead summer parr in the western tributaries and the headwaters area. Tributaries in these areas have a relatively dense population of residents that use water for domestic use and potentially for agriculture including illicit cannabis cultivation. Though the impacts of this water use are not well documented, the Expert Panel suspected that some of these tributaries are being overdrawn, impairing summer flows and ultimately limiting salmonid growth and survival.

Barriers (culverts and natural barriers) and canopy cover rated low or very low limiting factors across species, life stages, and areas. Additionally, catastrophic sediment delivery and channel complexity were rated moderate to low impact for all life stages of Chinook Salmon in all areas.
**Threats**

The highest rated threats to the sub-watershed were related to road networks and, to a lesser extent, land conversion and development. Rural private roads were rated as a very high to high threat to all life stages and species except migrating adults, for which they rated a moderate threat. The threat of these roads stems from their influence on sediment transport and chronic turbidity. Additionally, channel confinement due to roads was rated as a high threat to all life stages and species, due in part to its effects on floodplain connectivity.

Land conversion and development, as well as diversions, were rated from high impact to low impact depending on the life stage (Table 11-3). Generally, land conversion and development threatened most juvenile life stages while diversion primarily threatened summer parr. The high variance in these ratings are likely due to the existing ownership; a mosaic of small private parcels and larger areas held by timber operators, nature reserves, and the BLM. These ownerships offer opportunities for habitat preservation and restoration; however, some of the private land use practices such as illicit cannabis cultivation can threaten salmonid habitat. Furthermore, some larger parcels could be subdivided, thus increasing the human population density and associated impacts. There are relatively few registered diversions in the sub-watershed and most of the tributaries in the sub-watershed do not seem to be greatly impacted by water diversions, thus this was rated as a moderate impact threat. However, the Expert Panel noted that it is not well known exactly how much water is being diverted for registered, unregistered, or illicit use and that investigating this factor may be warranted in some of the more populated tributaries.

**11.5 Recovery Strategy**

On December 17, 2019 and January 29, 2020\(^{16}\) the Elder Creek Action Team discussed the outcomes of the Expert Panel meeting (Table 11-1, Table 11-2, and Table 11-3) and identified restoration actions that would best address the limiting factors and threats with the most impact to salmonid life stages. The team collaboratively identified the best locations for these restoration actions by reviewing spatial information prepared in a GIS as well as considering locations known to the experts of the Action Team. Figure 11-7 and Table 11-4 show the treatment types and stream reaches identified by the team, as recorded during the meeting and later interpreted by the steering team.

The recovery strategy for the SFER headwaters sub-watershed is primarily focused on improving habitat complexity for juvenile fish during summer and winter, improving floodplain connectivity, and assessing and rectifying upslope erosion hazards. To a lesser extent, the strategy also addresses

\(^{16}\) Due to scheduling conflicts, several members of the Action Team could not attend the first meeting. To ensure these members could participate, a second meeting was held. The same process was followed at both meetings and the recommendations produced were combined into this report.
anthropogenic partial barriers, the need for habitat assessments, investigation of flow enhancement opportunities, and the extent of composition of riparian forest restoration. This strategy identifies reach-scale regions of the sub-watershed where treatments will likely have the greatest benefit to salmonids, but specific project locations and the methods of implementation will require further investigation and site-specific design. Where high resolution data were available and/or members of the Expert Panel had precise knowledge of treatment areas, specific project locations were identified for treatments; however, partners may require further designs to appropriately implement the recommendations. The materials used by the SHaRP Action Team may be useful to the restoration community for more detailed project planning. As more data become available based on further assessment and analyses of the sub-watershed, these treatments may be applicable to other reaches in the future.
Figure 11-7. Restoration treatments identified by the Elder Creek Action Team.
Table 11-4. Restoration treatments identified by the Elder Creek Action Team.

<table>
<thead>
<tr>
<th>Target</th>
<th>Treatment Description</th>
<th>Stream Name(s)</th>
<th>Survey Reach Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Juvenile Rearing</strong></td>
<td>Large wood for summer rearing (scour pools and provide shelter)</td>
<td>Jack of Hearts Creek, Kenny Creek, Mud Creek, S.F. Eel River and an unnamed tributary</td>
<td>1290, 1291, 1291.1, 1327, 1350, 1363</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.F. Eel River, Jack of Hearts Creek, Dutch Charlie Creek, Kenny Creek, Mud Creek, S.F Eel River tributary</td>
<td>103, 113, 1290, 1291, 1303, 1305, 1306, 1327, 1350, 1363</td>
</tr>
<tr>
<td><strong>Winter Juvenile Rearing</strong></td>
<td>In-channel winter habitat</td>
<td>S.F. Eel River, Jack of Hearts Creek, Kenny Creek, Mud Creek, S.F Eel River tributary</td>
<td>95, 97, 98, 100, 101, 102, 103, 105, 106, 107, 108, 109, 110, 111, 113, 1291, 1301, 1303, 1305, 1306, 1314, 1316, 1350, 1363</td>
</tr>
<tr>
<td></td>
<td>Off-channel winter habitat</td>
<td>S.F. Eel River, Jack of Hearts Creek, Little Charlie Creek, Dutch Charlie Creek, Redwood Creek, Kenny Creek, Mud Creek, S.F Eel River tributary</td>
<td>95, 97, 98, 100, 101, 102, 103, 105, 106, 107, 108, 109, 110, 111, 113, 1291, 1301, 1303, 1305, 1306, 1314, 1316, 1350, 1363</td>
</tr>
<tr>
<td></td>
<td>Large Wood for gravel storage</td>
<td>Dutch Charlie Creek, Redwood Creek</td>
<td>1303, 1305, 1314, 1316</td>
</tr>
<tr>
<td><strong>Streamflow</strong></td>
<td>Investigate summer flow enhancement opportunities</td>
<td>Kenny Creek</td>
<td>1327, 1329</td>
</tr>
<tr>
<td><strong>Watershed Processes</strong></td>
<td>Riparian Treatment</td>
<td>S.F. Eel River</td>
<td>97, 98</td>
</tr>
<tr>
<td></td>
<td>Road network</td>
<td>S.F. Eel River, Jack of Hearts Creek tributaries, Dear Creek, Kenny Creek, S.F. Eel River tributary</td>
<td>95, 1292, 1293, 1293.1, 1294, 1298, 1327, 1329, 1363</td>
</tr>
<tr>
<td></td>
<td>Sediment reduction</td>
<td>Jack of Hearts Creek tributaries, Little Charlie Creek, Thompson Creek, Eagle Creek</td>
<td>1296, 1297, 1301.1, 1301.2, 1310, 1310.1, 1303-1305, 1307, 1307.1, 1307.2, 1311, 1311.1, 1314, 1314.1, 1314.2, 1318, 1319, 1316, 1316.1, 1320, 1320.1</td>
</tr>
<tr>
<td></td>
<td>Upslope hazard assessment</td>
<td>Barnwell Creek, Rock Creek, Kenny Creek</td>
<td>1274, 1322, 1327, 1329</td>
</tr>
<tr>
<td></td>
<td>Water use management, education, and outreach</td>
<td>Kenny Creek</td>
<td>1327, 1329</td>
</tr>
<tr>
<td><strong>Fish Passage</strong></td>
<td></td>
<td>Dutch Charlie Creek, Taylor Creek, Bear Creek, Windem Creek</td>
<td>1303, 1357, 1359, 1374</td>
</tr>
<tr>
<td><strong>Habitat assessment</strong></td>
<td></td>
<td>Deer Creek, Rock Creek, Muddy Gulch Creek</td>
<td>1298, 1322, 1325</td>
</tr>
</tbody>
</table>
Treatments to Improve Overwinter Conditions for Winter Parr and Fry

Habitat that provides refuge from winter flows, whether instream or off-channel, is crucial to the survival of juvenile salmonids (Gallagher et al. 2012, Bair et al. 2016). Adding instream large wood to increase channel complexity and provide velocity refuge during winter flows is recommended in portions of the South Fork Eel River below Mud Creek and above Middleton Creek, most of the main stem of Jack of Hearts and Dutch Charlie Creeks, the lowest reach of Kenny Creek, a downstream portion of Mud Creek, and an unnamed left bank tributary downstream of Little Rock Creek (reaches 103, 113, 1290-1291.1, 1303 – 1306, 1327, 1350, and 1363) (Figure 11-5, Table 11-4). These reaches are low gradient and thus likely to provide low velocity instream habitat for juveniles during winter months; however, they lack enough large wood to create winter velocity refuge. Since these reaches are topographically confined, they likely feature very little suitable off-channel habitat making the availability of instream habitat even more important. Additionally, these sites are adjacent to or overlap frequently used spawning habitat and thus, likely to support recently emerged fry or overwintering parr (Figure 11-4).

The lack of off-channel habitat, including floodplains, alcoves, and backwaters was also identified as limiting for overwintering juvenile salmonids. Much of the SFER headwaters sub-watershed is naturally confined due to geologic uplift and subsequent stream incision; however, there are some areas which have wide floodplains that may inundate regularly. The Action Team used the same criteria described for in-channel winter habitat to assess suitable locations for off-channel winter habitat with the additional requirement that ideal reaches should have unconfined channels, wide valley widths and/or the observation of existing floodplain habitats that could be enhanced to ensure frequent access to low-velocity habitat during high winter flows. The Action Team also utilized detrended elevation models derived from LiDAR data to determine locations which may be prone to flooding. Treatments to improve floodplain inundation and access to suitable off-channel habitats during winter flows are recommended throughout the mainstem South Fork Eel River, the middle portions of Jack of Hearts and Dutch Charlie Creeks, Little Charlie Creek, most of Redwood Creek, the downstream portion of Mud Creek, and an unnamed left bank tributary downstream of Little Rock Creek (reaches 95, 98, 100-106, 108-111, 113, 1291, 1301, 1303-1306,1314-1316, 1350, and 1363) (Figure 11-5, Table 11-4). Note that only portions of many of these reaches are delineated in Figure 11-5 based on available data to be as specific as possible. To complement off-channel restoration in Dutch Charlie and Redwood Creeks (reaches 1305, 1306, 1314, and 1316), the Action Team recommended using large wood treatments to capture gravels and raise the stream bed in portions of stream to more frequently inundate the floodplain. Wide valleys exist in these locations and detrended elevation models suggest the river terraces are relatively close to the channel elevation, but floodplain connectivity would likely be improved by raising the water surface elevation.
Treatments to Improve Conditions for Summer Parr

Large wood can create or enhance habitat used by salmonids during summer months by scouring pools and providing cover from predators. The availability of deep pools with complex cover increases the rearing capacity of a stream by providing thermal refugia, shelter from predators, and a lengthened hydroperiod. The Action Team recommends treatments using large wood to create summer rearing habitat in portions of most of the main stem of Jack of Hearts Creek, lower Kenny Creek, lower Mud Creek, and an unnamed left bank tributary downstream of Little Rock Creek (reaches 1291, 1291.1, 1327, 1350, 1363) (Figure 11-5, Table 11-4). These reaches are at or near high density spawning areas where salmonids will likely rear and have suitable water temperatures year-round; however, they lack high quality pool habitat.

Treatments to Restore Watershed Processes

Sediment

Sedimentation was rated by the Expert Panel as one of the greatest limiting factors across multiple life stages and species. The Action Team recommends reducing the sources of fine sediments by treating road networks, stream crossings and land disturbances near waterways that were highly connected and prone to erosion. Treatment areas include legacy logging roads and stream crossings which have been identified as moderate to high priority projects in previously completed road assessments (Hughes et al. 2014, Weppner et al. 2015). These locations are near unnamed tributaries in upper Jack of Hearts Creek, upper Little Charlie Creek, a middle reach of Dutch Charlie Creek from Eagle Creek to the right bank tributary downstream of Thompson Creek, unnamed tributaries in the headwaters of Dutch Charlie Creek, Thompson Creek, Eagle Creek, a middle reach of Redwood Creek downstream of the North Fork to the last left bank tributary and including the four downstream unnamed left and right bank tributaries, the headwaters of Redwood Creek, and the North Fork of Redwood Creek (reaches 1296, 1297, 1301.1, 1301.2, 1310, 1310.1, 1303-1305, 1307, 1307.1, 1307.2, 1311, 1311.1, 1314, 1314.1, 1314.2, 1318, 1319, 1316, 1316.1, 1320, and 1320.1) (Figure 11-5, Table 11-4). Specific locations and site-specific treatment recommendations for these areas are detailed in the reports cited above.

The Action Team also recommends investigating sediment sources in other portions of the sub-watershed that have not been inventoried but are likely contributing sediment. Based on the land use history and recent fire-caused disturbances, the Action Team recommends investigating and, if necessary, implementing sediment reduction treatments in areas near the South Fork Eel River between Jack of Hearts Creek and Elder Creek, Barnwell Creek, northern tributaries to Jack of Hearts Creek, Deer Creek, Rock Creek, Kenny Creek, and an unnamed left bank tributary to the South Fork Eel River downstream of Little Rock Creek (reaches 95, 1274-1294, 1298, 1322, 1327, 1329, and 1363). A recent fire in the northern portion of the sub-watershed is causing increased sediment delivery to the South Fork Eel River and Barnwell Creek, thus the Action Team recommends implementing sediment reduction projects in this area. Reach 1363 has known legacy
logging roads throughout the valley bottom and the county road along reach 95 of the South Fork Eel River was noted to be in poor condition with a poorly drained, soft road surface and connected drainages. Furthermore, these roads are frequently used in the winter which promotes sediment contributions. The Action Team recommends an assessment of these roads to determine if actions to mitigate sediment would be necessary. The Action Team noted that while roads along Kenny Creek have been previously treated in 2005, Kenny Creek is still sediment-impaired and roads in along the stream are still contributing sediment. The Action Team recommends reviewing these roads again and re-treating portions where necessary.

**Habitat Assessment**

Several tributaries in the sub-watershed have had little to no habitat assessment conducted in the recent decades, limiting the Action Team’s ability to assess habitat condition and appropriate treatment applicability. Deer Creek, Rock Creek, and Muddy Gulch Creek have had no habitat assessments conducted in the last 30 years but could have many sources of sediment based on the land use history and observations of landslides in Rock Creek. Based on GIS data and modeled stream temperatures, Lower Muddy Gulch Creek (reach 1325) could have suitable winter and summer rearing habitat for juvenile salmonids and should be investigated. It is therefore recommended that these tributaries should be assessed for habitat conditions and potential anthropogenic sediment sources.

**Riparian Forest**

The Expert Panel rated large wood recruitment as a high limiting factor across multiple life stages and locations (Table 11-1, Table 11-2). However, the Action Team recognized that this limitation was primarily due to the size and age of most of the forests of the sub-watershed and thus available treatments were limited in scope. The Action Team did identify one portion of the mainstem South Fork Eel River from Redwood Creek to just upstream of Little Charlie Creek (reach 98) where land conversion drastically altered the forest composition, leaving only a narrow band of riparian vegetation dominated by broadleaf species. It is recommended that riparian planting be conducted in this area to aid in the recolonization and succession of conifer species to improve future riparian conditions and restore large wood recruitment.

**Stream Flow**

The Expert Panel rated water diversion as a high impact threat to the sub-watershed. The Action Team noted that while most tributaries in the sub-watershed seem to have dry season flows capable of growing and sustaining juvenile salmonids, there were several observations that dry season flows may be impair in Kenny Creek, likely due to excessive water withdrawal. It is recommended that the lower half of Kenny Creek (reaches 1327-1329) be investigated to quantify the effects of water diversion on the tributary and conduct outreach to provide education and technical assistance to help landowners to better manage water use.
Fish Passage

Though no complete anthropogenic barriers exist in the sub-watershed, there are several partial barriers that may block juvenile migration into tributaries that provide high quality rearing habitat. Where Branscomb Road crosses Taylor Creek, Bear Creek, and Windham Creek, culverts were updated in 2001 to improve fish passage. However, subsequent assessments conducted in 2005 indicate these crossing are still barriers to juvenile salmonids. In Taylor Creek, a failed log stringer bridge approximately 150 feet upstream from the county road culvert presents a complete barrier to fish passage (CTM 2009). Any gains to fish passage made at the county road crossing will not be fully realized without addressing this additional barrier. Furthermore, there were no salmonids observed above the failed stringer bridge, suggesting that this barrier has been problematic for many years and the presence of other potential barriers upstream suggest that Taylor Creek may have seldom allowed salmonids access on a regular basis (CTM 2009). These factors will have to be carefully considered before pursuing actions to implement additional changes to the existing culvert. There are no known additional barriers above the county road crossing in Bear Creek and salmonids have been observed to approximately 1000 feet upstream of the confluence. The Action Team recommends implementing the measures outlined in the California Fish Passage Assessment Database (Elston 2019) or replacing the culverts with fully spanning crossings to restore natural access to the tributaries.

The Action Team also noted that the mouth of Dutch Charlie Creek could be improved to ensure all life stages have more frequent access to suitable spawning and rearing habitats. Dutch Charlie Creek has a perched tributary mouth that presents steep, boulder-strewn cascades to immigrating adult salmonids or juveniles during redistribution. The Action Team recommends investigating the feasibility of improving fish passage into this tributary using instream structures in the South Fork Eel River. However, it was also noted that the South Fork Eel River is quite large in the vicinity of Dutch Charlie Creek and that structures would need to be both large and likely anchored or engineered to provide a lasting effect. Furthermore, access to this site could be very difficult, complicating the possibility of implementing such a project. The perched tributary mouth is likely due to natural geologic processes and human alterations of that process may be unsuccessful in the long term.

If you have questions or would like to collaborate on implementing the actions in this chapter, please contact Julie Weeder, NMFS recovery coordinator (707-825-5168, julie.weeder@noaa.gov) or Allan Renger, CDFW area supervisor (707-725-7194, Allan.Renger@wildlife.ca.gov).
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Appendix A: Spatial datasets used during the South Fork Eel River SHaRP process

In each stage of the SHaRP process, spatial and tabular data were one of the tools made available to help inform the SHaRP steering team and stakeholders of historic and current habitat conditions for selecting the priority sub-watersheds, evaluating limiting factors and threats to salmonids, and prescribing reach-level restoration treatments. Datasets used in the early stage of selecting priority sub-watersheds as described in Chapter 1 constitute the core datasets used throughout the SHaRP process with additional datasets compiled on a sub-watershed basis.

While efforts were made to provide maps using the best available data, it was inappropriate to rely on geographic information system (GIS) data as the sole input into the decision-making process. The SHaRP process also relied on stakeholder expertise and local knowledge to provide what wasn’t captured in a dataset, such as the current stream and habitat conditions and socioeconomic impacts within the sub-watershed. Stakeholder input also helped to counter or substantiate datasets that were derived from models. There were streams where the combination of local knowledge or data analysis did not provide the information required to make a sound decision about an impact or treatment recommendation. These situations made the steering team aware of data gaps that needed to be researched and streams that required more ‘on-the-ground’ data collection.

In preparation for generating maps, datasets were obtained from various government agencies, non-governmental organizations (NGO), and commercial services. Most datasets were received as GIS shapefiles or file geodatabases (Environmental System Research Institute, Inc. © [ESRI]) which were imported into a file geodatabase projected to the Universal Transverse Mercator (UTM) Zone 10, North American Datum (NAD) 1983 spatial reference system. Data provided as spreadsheets were imported into ESRI’s ArcMap or ArcGIS Pro software, converted to GIS format, and saved to the file geodatabase.

In evaluating a dataset for use on the map, the data was reviewed for:

**Currentness:** Is the dataset the most current version? Some datasets, like flow data from U.S. Geological Survey (USGS) stream gages, can be current to the hour while the most current geology or vegetation dataset may be 10 or 20 years old. If the dataset is old, is it still relevant for the SHaRP process? A dataset may not need to be updated on a yearly basis because conditions experience negligible or no change over time or the updates are time or cost prohibitive.

Data versions released after restoration treatments were prescribed were not updated on the map if the newer data would have yielded different restoration treatments during the Action Team meeting. The amount of collaboration involved with engaging stakeholders in the SHaRP process means that the data and maps in this document are snapshots of biological conditions. Given the
time frame of evaluating each sub-watershed, it was not feasible to reconvene participants every time a dataset version was released. Therefore, it is the practitioner’s responsibility to conduct their own site-specific data analysis, and it is the funder’s responsibility to require it.

**Completeness**: Does the dataset have the necessary information needed for the stated purpose? The reach score in the habitat suitability index (HSI) dataset is calculated based on several stream survey metrics. If one of the metrics is missing then the dataset is not complete for mapping reach score; however, the dataset may be complete for mapping a different HSI score that does not require the missing metric. The survey reach nodes dataset is complete for representing the start and end points of reaches used to conduct fish surveys. However, during the SHaRP process, additional reach nodes were added to some sub-watershed maps to provide a visual reference point for data or restoration actions described in this report. The additional reach nodes are not implemented in the Coastal Monitoring Program’s (CMP) sampling framework.

**Accuracy**: Does a feature’s map location represent its true location on the ground? Does an attribute value represent correct information about a feature? Accuracy was reviewed for the dataset as a whole and not for the thousands of individual data records. Fish barriers located off stream, geographic shift of features by a consistent distance, and gaps in continuous linear features were some of the ways to flag spatial inaccuracies. Incorrect symbology representation, software errors during data processing, and values outside the normal range (e.g. a value of “50” when the acceptable range of values is -1 to 1) were the more obvious flags for attribute inaccuracies. Datasets that underwent a QA/QC process or were evaluated and updated regularly for analysis were afforded a greater level of confidence and less stringent review when received than those with little documentation or received 2nd or 3rd-hand.

Data inaccuracies discovered during the SHaRP process were updated in the maps as soon as possible. On the occasion that inaccuracies were corrected after restoration treatments were prescribed, efforts were made to email corrected maps to the participants and solicit treatment changes. Data corrections that would not have changed the outcome for a stream treatment because other factors mitigated the correction’s influence were updated in the map and included in the final document.

**Spatial extent**: Does the dataset contain the presence or absence of features for the entire sub-watershed? A dataset can have visual gaps if the gaps are due to a valid lack of features on the ground. A road map with no roads in the north part of a sub-watershed because it wasn’t surveyed is different than if the north part was surveyed but no roads existed. An exception is with datasets like the California State Water Resources Control Board’s (SWRCB) electronic water rights information management system (eWRIMS) where water diverters are responsible for submitting water right, diversion, and use information into the central database. While water diverters are required to report their water information to SWRCB, the database will not contain data for illegal diverters which can have a sizeable unreported impact on available water for salmonids. In some sub-watersheds, impacts due to water diversion were significant enough to map diversions despite
the small spatial extent or incompleteness. Stream flow monitoring studies and input from local landowners provided insight to infer potential impacts from unreported water diversions.

**Temporal extent**: What time period does the dataset cover? Will the dataset(s) reflect current or historic conditions? Data collection may occur at regular intervals, like census or streamflow data, or irregular intervals. In the case of stream surveys, data collection in a given year or stream can be influenced by land access, weather conditions, or staff resources resulting in streams being surveyed in different years. In addition to using time as a record of data collection, SHaRP used the temporal component of a dataset to show change over time. HSI data was symbolized by decade to show how reach habitat conditions improved or declined over time, which can indicate a reach’s potential to support existing or future salmonid populations. Changes in a monthly streamflow compared over several years could provide insight into other factors that may impact salmonid populations, such as climate change, water diversions, or land management practices. Whether or not a dataset is symbolized by time on the map, most of the datasets represent data that has been collected over an extended period of months or years with exceptions including census and landowner data.

**Scale**: At what level of detail was the data collected or intended to be use on the map? Using data without regard to scale can result in maps providing too much or too little information. Roads or streams digitized from USGS topographic quadrangle maps at a 1:24,000 scale can overwhelm a map scaled at 1:100,000 and miss capturing local features on a 1:1,000 scale map. Sub-watersheds were mapped at various scales from Redwood Creek sub-watershed at a 1:55,000 scale to South Fork Eel River Headwaters sub-watershed at approximately 1:112,000 scale. While the scale of most datasets was appropriate for map display, some measures were taken to improve data presentation at the various map scales.

To provide data for different species or time frames on the same map, feature offsets were used to present data side-by-side. Offsetting linear features at certain scales resulted in features with the most offset appearing grossly exaggerated. Generalizing the dataset into lines with fewer bends allowed multiple datasets to appear on the map without compromising the map’s meaning.

Data points collected at short distance intervals on a stream were converted to line segments of the point interval length to make it easier to see the data on the map.

Large scaled data derived from high resolution LiDAR (e.g. inundation polygons) could not be seen at the sub-watershed scale, so the data was provided during the SHaRP meetings using real-time display in GIS software, on a wall size map, or as small scale maps focused on specific stream reaches of interest.

Local streams not captured in a dataset were digitized or copied from the USGS National Hydrography Dataset (NHD) at a 1:24,000 scale.
Generalized datasets were created only for map purposes, so the original datasets were retained for analysis purposes.

**Documentation:**

Data documentation or metadata provides information on the who, what, why, when, and where of the data along with other information to help evaluate the dataset’s fitness for analysis or mapping use. Without metadata there is a risk of including inappropriate data or excluding perfectly good data from a project. Ideally metadata should always accompany the dataset; however, sometimes metadata is lost or ignored during file transfers, lost due to software compatibility issues, or not created by the data originator. Datasets used for the SHaRP process were received with varying degrees of metadata detail in the form of the Federal Geographic Data Committee’s (FGDC) Content Standard for Digital Spatial Metadata (CSDGM) standard XML files, text files, or reports. Some data were provided for specific sub-watersheds without written metadata; however, personal communication with the originator and data reference in reports deemed the data appropriate for the SHaRP process. If the data did not come with the standard XML metadata file, then basic metadata was created in ESRI’s ArcGIS Pro software to guide data users to the dataset’s originator or source documentation for more information.

*Table A-1* is a compilation of data description, source, limitation, and year for datasets included in maps created for the SHaRP Expert Panel and Action Team meetings.
<table>
<thead>
<tr>
<th>Data</th>
<th>Data used in sub-watershed</th>
<th>Data originator or provider</th>
<th>Year of data or data received</th>
<th>Notes on data description, limitations, updates, etc.</th>
<th>Originator Link</th>
<th>Data link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humboldt county parcels</td>
<td>Elder</td>
<td>Digital Map Products (LandVision)</td>
<td>2019</td>
<td>Parcels grouped by owner of record in dataset. Family parcels with different owner of record were grouped by owner name and not family name.</td>
<td><a href="https://www.digmap.com/platform/landvision/">https://www.digmap.com/platform/landvision/</a></td>
<td></td>
</tr>
<tr>
<td>Census block</td>
<td>Redwood</td>
<td>U.S. Department of Commerce, U.S. Census Bureau (Census MAFT/TIGER database)</td>
<td>2010</td>
<td>Briceland was not counted in the 2010 census. Calculated acres/person instead of people/acre due to sparse and spread out population. # of acres provides a better visual of land vs population than &quot;0.1 person/acre&quot;. Calculated acres for each census block. Area per person = acres/population Owners grouped by primary owner in parcel data so family parcels listed under different name are not combined.</td>
<td><a href="https://www.census.gov/en.html">https://www.census.gov/en.html</a></td>
<td><a href="https://www2.census.gov/geo/tiger/TIGER2010BLKPOPHU/tabblock2010_06_wshu.zip">https://www2.census.gov/geo/tiger/TIGER2010BLKPOPHU/tabblock2010_06_wshu.zip</a></td>
</tr>
<tr>
<td>Anchor sites</td>
<td>Hollow Tree Sproul Bull</td>
<td>Riverbend Sciences</td>
<td>2016</td>
<td>Anchor sites provide all essential habitat features necessary for Coho to complete the freshwater portion of their life cycle. Anchor sites are identified and scored based on terrace height, channel gradient, valley width, and temperature using the NOAA Coho IP and NorWeST modeled mean August temperatures.</td>
<td><a href="http://www.riverbendsci.com/">http://www.riverbendsci.com/</a></td>
<td></td>
</tr>
<tr>
<td>Level of erosion concern</td>
<td>Riprap</td>
<td>Northern Hydrology and Engineering</td>
<td>received 2019</td>
<td>CA State Parks used several factors to assess stream bank erosion. Areas of high erosion concern may need existing riprap to remain intact for stability; whereas, areas of low erosion concern might have opportunities for riprap removal. Riprap data shows locations where failed riprap resulted in winter rearing habitat for salmonids.</td>
<td><a href="http://www.northernhydrology.com/">http://www.northernhydrology.com/</a></td>
<td></td>
</tr>
<tr>
<td>Bank wood count</td>
<td>Hollow Tree</td>
<td>California Department of Fish and Wildlife (CDFW)</td>
<td>2018</td>
<td>Bank wood is dead and down wood on the bank of a stream outside the bankfull channel which could be pulled into the stream channel for restoration. Data extracted from stream habitat inventory surveys. Wood visible from the channel that is at least one bankfull width long and 20' in diameter are counted.</td>
<td><a href="https://wildlife.ca.gov/Regions/1">https://wildlife.ca.gov/Regions/1</a></td>
<td><a href="https://www.calfish.org/ProgramsData/HabitatandBarriers/CaliforniaFishPassageAssessmentDatabase.aspx">https://www.calfish.org/ProgramsData/HabitatandBarriers/CaliforniaFishPassageAssessmentDatabase.aspx</a></td>
</tr>
<tr>
<td>Bank wood density</td>
<td>Bull</td>
<td>CDFW</td>
<td>2007</td>
<td>Bank wood is dead and down wood on the bank of a stream outside the bankfull channel which could be pulled into the stream channel for restoration. Small wood is 1-2' diameter, 6-20' long, and rootwad 1-2' diameter. Large wood is 1-2' diameter, &gt;20' long, and rootwad 2-3' diameter or 2-3 diameter and &gt;6' long. Extra large wood is anything larger than large wood specification.</td>
<td><a href="https://wildlife.ca.gov/Regions/1">https://wildlife.ca.gov/Regions/1</a></td>
<td></td>
</tr>
<tr>
<td>LWD wood count</td>
<td>Hollow Tree</td>
<td>CDFW</td>
<td>2018</td>
<td>Count of naturally recruited wood. Long wood is &gt;= 1.5 bankfull width. Short wood is 1 to &lt;1.5 bankfull width.</td>
<td><a href="https://wildlife.ca.gov/Regions/1">https://wildlife.ca.gov/Regions/1</a></td>
<td></td>
</tr>
<tr>
<td>Humboldt county parcels</td>
<td>Redwood</td>
<td>Digital Map Products (LandVision)</td>
<td>2019</td>
<td></td>
<td><a href="https://www.digmap.com/platform/landvision/">https://www.digmap.com/platform/landvision/</a></td>
<td></td>
</tr>
<tr>
<td>Salmonid distribution</td>
<td>All</td>
<td>NOAA, Southwest Fisheries Science Center (Chinook) CDFW (Coho, steelhead)</td>
<td>2005 (Chinook) 2016 (Coho) 2012 (steelhead)</td>
<td>Distribution datasets were updated internally for SHaRP in 2019 and 2020 based on current barrier status, survey reports, salmonid observations, etc.</td>
<td><a href="https://www.fisheries.noaa.gov/region/west-coast#southwest-science">https://www.fisheries.noaa.gov/region/west-coast#southwest-science</a></td>
<td></td>
</tr>
<tr>
<td>Fish passage barriers</td>
<td>All</td>
<td>CDFW, Pacific State Marine Fisheries Commission (PSMFC)</td>
<td>2018 (updated internally 2019)</td>
<td>Edits were made to original dataset to reflect barriers that have been resolved or updated barrier attributes based on SHaRP Steering Committee recommendations. Total=barrier to all life stages Partial=barrier to certain life stage or under certain conditions Unknown=unknown if barrier is total, partial, or has been resolved</td>
<td><a href="http://www.psmfc.org/">http://www.psmfc.org/</a> (PSMFC)</td>
<td><a href="https://www.calfish.org/ProgramsData/HabitatandBarriers/CaliforniaFishPassageAssessmentDatabase.aspx">https://www.calfish.org/ProgramsData/HabitatandBarriers/Cali forniaFishPassageAssessmentDatabase.aspx</a></td>
</tr>
<tr>
<td>Geologic hazards</td>
<td>All</td>
<td>CA Geological Survey (CGS)</td>
<td>deep seated slide data provided by the Redwood Forest Foundation, Inc. (RFFI)</td>
<td>data taken from 1999 CGS CD-ROM 99-002 but data is based on 1981 data</td>
<td>Data available for viewing on the CA Department of Conservation, Geologic Map of California web app</td>
<td><a href="https://www.conservation.ca.gov/cgi-bin/gz">https://www.conservation.ca.gov/cgi-bin/gz</a> (CGS)</td>
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<tr>
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</tr>
</tbody>
</table>

| Humboldt county parcels | Redwood | Digital Map Products (LandVision) | 2019 | Parcel dataset is provided to CDFW as a paid subscription. Map is intended to show major blocks of landowners, so contiguous landowner acreage outside the sub-watershed boundary was retained in acreage calculation. | https://www.digmap.com/platform/landvision/ | https://wildlife.ca.gov/Regions/1 |

| Inundation Secondary stream channel | Indian | Pacific Watershed Associates (PWA) | received 2019 | Inundation thresholds inside and outside the stream corridor were modeled from LiDAR-derived detrended DEM (1-meter resolution). The stream corridor centerline was derived from the thalweg equal to or greater than one meter of width's prediction. Secondary channel was GPSed. Hillshade derived from LiDAR-derived detrended DEM (1-meter resolution). Data could not be mapped at the sub-watershed scale so Jones Creek in Standley Creek sub-watershed and Anderson Creek in the Indian Creek sub-watershed were selected to provide large scale maps of inundation. | http://www.pacificwatershed.com/ | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Pool depth | Redwood | Sproul | 2017 | Data was collected based on CDFW standards; however, canopy density was not collected. Data was not incorporated in the CDFW Habitat Suitability Index maps because canopy density is needed to calculate reach score for CDFW. Suitability categories defined in the CWPA 2014 South Fork Eel River Assessment Report, SF Eel River Basin Overview report. | Data was not incorporated in the CDFW Habitat Suitability Index maps because canopy density is needed to calculate reach score for CDFW. Suitability categories defined in the CWPA 2014 South Fork Eel River Assessment Report, SF Eel River Basin Overview report. | https://www.stillwatersci.com/ |

| Reach score | All | CDFW | 2019 | Entrenchment ratio=floodplain width (0)/bankfull width (0). It is an indication of how much floodplain is available for water once it breaches the streambank. Lower values = very incised channel, higher values = wider and flatter channel. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Canopy density | All | CDFW Coastal Watershed Planning and Assessment Program, PSMFC | 2019 | Specific data collection protocols provided in the CA Salmonid Habitat Restoration Manual (Flot Et Al. 2010). Scores were calculated using EMDS-based analysis. Canopy density is the percent of stream influenced by tree canopy. Pool tail embeddedness is a measure of the percent of small cobbles (2.5” to 5” in diameter) buried in fine sediment. The percent by stream reach of adequately deep pools or primary pools is determined according to stream order. The pool quality network is composed of an evaluation of pool depth and pool shelter complexity rating. Reach score is calculated from other indices such as canopy density, embeddedness, etc. The pool shelter rating is a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submerged or overhanging vegetation. Suitability categories and scoring process are defined in the CWPA 2014 South Fork Eel River Assessment Report, SF Eel River Basin Overview report. | Specific data collection protocols provided in the CA Salmonid Habitat Restoration Manual (Flot Et Al. 2010). Scores were calculated using EMDS-based analysis. Canopy density is the percent of stream influenced by tree canopy. Pool tail embeddedness is a measure of the percent of small cobbles (2.5” to 5” in diameter) buried in fine sediment. The percent by stream reach of adequately deep pools or primary pools is determined according to stream order. The pool quality network is composed of an evaluation of pool depth and pool shelter complexity rating. Reach score is calculated from other indices such as canopy density, embeddedness, etc. The pool shelter rating is a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submerged or overhanging vegetation. Suitability categories and scoring process are defined in the CWPA 2014 South Fork Eel River Assessment Report, SF Eel River Basin Overview report. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Embeddedness Pool shelter | Bull | Stillwater Sciences | 2015 | Data was collected based on CDFW standards; however, canopy density was not collected. Data was not incorporated in the CDFW Habitat Suitability Index maps because canopy density is needed to calculate reach score for CDFW. Suitability categories defined in the CWPA 2014 South Fork Eel River Assessment Report, SF Eel River Basin Overview report. Coordination is intended to show major blocks of landowners, so contiguous landowner acreage outside the sub-watershed boundary was retained in acreage calculation. | Data was collected based on CDFW standards; however, canopy density was not collected. Data was not incorporated in the CDFW Habitat Suitability Index maps because canopy density is needed to calculate reach score for CDFW. | https://www.stillwatersci.com/ |

| Embeddedness Pool quality | All | NOAA, Southwest Fisheries Science Center | 2017 | Steelhead and Chinook datasets do not contain reaches where IP=0 upstream of the upper extent of predicted distribution or areas upstream of long-standing natural barriers. Steelhead and Chinook IP scores reflect a 12% gradient threshold. | Steelhead and Chinook datasets do not contain reaches where IP=0 upstream of the upper extent of predicted distribution or areas upstream of long-standing natural barriers. Steelhead IP scores reflect a 12% gradient threshold. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Inundation | Indian | Standley Creek | 2019 | Entrenchment ratio=floodplain width (0)/bankfull width (0). It is an indication of how much floodplain is available for water once it breaches the streambank. Lower values = very incised channel, higher values = wider and flatter channel. | Entrenchment ratio=floodplain width (0)/bankfull width (0). It is an indication of how much floodplain is available for water once it breaches the streambank. Lower values = very incised channel, higher values = wider and flatter channel. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Canopy density | All | NOAA, Southwest Fisheries Science Center | 2011 | Coho IP score with no temperature mask; there was no 2017 Coho data update for SONCC ESU. | Coho IP score with no temperature mask; there was no 2017 Coho data update for SONCC ESU. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Pool quality | All | Standley Creek | 2019 | Canopy density | All | NOAA, Southwest Fisheries Science Center | 2011 | Coho IP score with no temperature mask; there was no 2017 Coho data update for SONCC ESU. | Coho IP score with no temperature mask; there was no 2017 Coho data update for SONCC ESU. | https://www.fisheries.noaa.gov/region/west-coast#southwest-science | https://archive.fisheries.noaa.gov/v/wcr/publications/ys_maps/ys_data/other/noaa_nccc_salmon_id_ip_swfsc_jan2017.gdb.zip |

| Hillshade | All | Redwood | 2019 | Parcel dataset is provided to CDFW as a paid subscription. Map is intended to show major blocks of landowners, so contiguous landowner acreage outside the sub-watershed boundary was retained in acreage calculation. | Parcel dataset is provided to CDFW as a paid subscription. Map is intended to show major blocks of landowners, so contiguous landowner acreage outside the sub-watershed boundary was retained in acreage calculation. | https://www.digmap.com/platform/landvision/ | https://wildlife.ca.gov/Regions/1 |

| Stations Stream flow | Redwood Salmon Restoration Federation (SRF) | 2013-2018 | Stream flow data was collected for a few days each month as part of SRF's Redwood Creek Low-Flow Monitoring project. | https://www.calsalmon.org/ | https://www.calsalmon.org/programs/redwood-creek-low-flow-monitoring |

| LWD Structures | Hollow Tree CDFW | 2018 | Count of man-made LWD structures; not included in Long or Short LWD counts | https://wildlife.ca.gov/Regions/1 |

| Main roads Restoration roads | Indian Standley | Redwood Forest Foundation Inc. | 2015 (received 2019) | Wood volume was collected every 500 ft. as point locations. To make data easier to view on a map, the points were converted to 500 ft. lines for display use only. | http://www.pacificwatershed.com/ |

| Greenhouses Outdoor gardens | Redwood CDFW | 2014 (based on 2011 and 2012 aerials) | Data was digitized from aerial imagery. Additional criteria were used to differentiate grows from traditional agriculture or horticulture crops. | https://wildlife.ca.gov/Regions/1 |

| Gradient percent | All CDFW NOAA Fisheries, Southwest Fisheries Science Center | 2016 (CDFW) 2011 (NOAA) | Percent gradient is suitable for evaluating passage opportunity. CDFW calculated percent gradient on a 10-meter basis using a 10-meter DEM. NOAA gradient are derived from the intrinsic potential model. Gradient reaches are defined by the IP model and can range from 50-200 meters. Values restricted to 0-5% for passage evaluation. | See intrinsic potential link |

| Gradient decimal derived from intrinsic potential model | Hollow Tree Indian Standley Redwood Sproul Elder | NOAA, Southwest Fisheries Science Center | 2011 | Decimal gradient is suitable for evaluation spawning opportunity. Gradient reach is defined by the IP model and can range from 50-200 meters. Values restricted to 0-0.9 for evaluating spawning opportunity. | See intrinsic potential link |

<p>| Restoration projects | All CDFW Fisheries Restoration Grant Program and habitat surveys | 1980s - 2019 | FRGP data represented all projects as points including projects spanning a stream section or containing multiple site locations. Restoration reports and maps were used to update some project point locations with multiple points to reflect projects with multiple sites or lines for projects covering a stream section. Project codes are generalizations of a project's purpose and may include multiple treatments not described on map. | <a href="https://wildlife.ca.gov/Grants/FRGP">https://wildlife.ca.gov/Grants/FRGP</a> |</p>
<table>
<thead>
<tr>
<th>Table heading</th>
<th>Category</th>
<th>Source</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach nodes</td>
<td>All</td>
<td>CDFW</td>
<td>2016</td>
<td>Nodes mark the start and end of a survey reach used for conducting fish surveys, which is different from the survey frame used for habitat typing surveys. During the SHaRP process, data and treatments were associated with stream reaches that were not in the original fish survey reach dataset. In order to reference a restoration treatment reach within the report new survey nodes and labels were created for the map display use only. The added nodes are not associated with any on-the-ground survey efforts.</td>
</tr>
<tr>
<td>Redds</td>
<td>All</td>
<td>CDFW spawner surveys</td>
<td>2010-2017 survey seasons</td>
<td>Chinook and steelhead redd data were collected during surveys targeting the spatial and temporal extent of Coho Salmon spawning, so Chinook and steelhead data will be incomplete. Not all streams were surveyed every year, so density is calculated as the mean for all years a reach was surveyed. The number of years surveyed for each stream ranges from 1-6 years. Data is recorded by survey season which covers the end of one calendar and the start of the next calendar year, so the 2017 season contains data collected in 2018.</td>
</tr>
<tr>
<td>Refugia</td>
<td>All</td>
<td>CDFW, PSMFC</td>
<td>2014</td>
<td>Data used for figures in the CDFW South Fork Eel River Watershed Assessment report; Refugia categorized by professional judgment and criteria developed for North Coast watersheds, such as measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. Refer to the South Fork Eel River Watershed Assessment Report, 2014 for a detailed explanation of refugia.</td>
</tr>
<tr>
<td>Water diversions</td>
<td>Standley Redwood</td>
<td>CA State Water Resources Control Board</td>
<td>2019</td>
<td>Data based on input from water diverters so not a complete picture of all water diversions. Impact from water diversion will depend on amount of water diverted which is not reflected in the map.</td>
</tr>
<tr>
<td>CalFire roads</td>
<td>All</td>
<td>CA Dept. of Forestry and Fire Protection</td>
<td>2015 and 2019</td>
<td>Habitat functionality score for a channel reach is derived from the summation of five riparian corridor attributes ranked 1-4: riparian condition, average pool cover, average stream gradient, average residual pool depth, and dominant channel bed substrate. Surveys were conducted where salmon were present, so stream gradient attributes are biased towards suitable rankings. Residual pool depth = max pool depth - pool tail depth Riparian condition score based on riparian tree diameter and % conifer. Score parameters from Usal Forest Watershed Action Plan for Coho Recovery in the SFER, Mendocino County, California (PWA, 2015)</td>
</tr>
</tbody>
</table>

Appendix A
<table>
<thead>
<tr>
<th>Data Type</th>
<th>Source</th>
<th>Year(s)</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream temperature</td>
<td>Riverbend Sciences and Eel River Recovery Project (ERRP)</td>
<td>2016</td>
<td>Stream temperature is a provisional dataset derived from analysis of multiple data sources. Contact Eli Asarian of Riverbend Sciences to discuss data limitations or data gaps. Temperature is displayed as average of daily maximum temperatures for the hottest week of the year for 1980-2015. Reach temps are averaged from all sites within a reach.</td>
<td><a href="http://www.riverbendsci.com/">http://www.riverbendsci.com/</a></td>
</tr>
<tr>
<td>Stream temperature</td>
<td>U.S. Forest Service; Rocky Mountain Research Station; Air, Water, and Aquatic Environments Program (AWAE)</td>
<td>2017</td>
<td>NorWeST temperature is a prediction of stream temperature based on a model and displayed as August mean temp for 1993-2011.</td>
<td><a href="https://www.fs.fed.us/rm/boise/AWA%D0%95/projects/NorWeST.html">https://www.fs.fed.us/rm/boise/AWAЕ/projects/NorWeST.html</a></td>
</tr>
<tr>
<td>Stream temperature</td>
<td>CalTrout</td>
<td>2015-2017</td>
<td>CalTrout temperature was only provided for Sproul Creek. Data is averaged from 2015-2017 MWMT.</td>
<td><a href="https://caltrout.org/">https://caltrout.org/</a></td>
</tr>
<tr>
<td>Streamflow</td>
<td>CalTrout</td>
<td>2015-2017</td>
<td>Streamflow graphs were provided by CalTrout and set to a log scale of base 10. Data collected as part of CalTrout’s Sproul Creek Instream Flow Study.</td>
<td><a href="https://caltrout.org/">https://caltrout.org/</a></td>
</tr>
<tr>
<td>Valley width</td>
<td>NOAA, Southwest Fisheries Science Center</td>
<td>2011</td>
<td>Valley width = valley width in meters on left side of channel + valley width in meters on right side of channel. Data constrained to 24-75 meters as being the width most likely to accommodate salmonids.</td>
<td>See intrinsic potential link</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Redwood Forest Foundation, Inc.</td>
<td>received</td>
<td>Data only covers area within the Usal Redwood Forest boundary. Map shows the potential wood available for natural wood recruitment in the streams. Wood from conifers provide longer term benefits as LWD in streams because they tend to decay slower and persist in streams longer than hardwoods.</td>
<td><a href="https://www.rffi.org/">https://www.rffi.org/</a></td>
</tr>
<tr>
<td>Wailaki territory</td>
<td>Wailaki tribe</td>
<td>received</td>
<td>Boundary digitized from a map provided by the Wailaki tribe.</td>
<td><a href="https://wailaki-wlc.org/sample-page/maps/">https://wailaki-wlc.org/sample-page/maps/</a></td>
</tr>
<tr>
<td>LWD root wad Key piece density</td>
<td>CDFW</td>
<td>2019</td>
<td>Data collected during stream habitat inventory surveys for reaches with LWD counts. There are no established rankings for root wad categories so they are based on key piece recommendations.</td>
<td><a href="https://wildlife.ca.gov/Regions/1">https://wildlife.ca.gov/Regions/1</a></td>
</tr>
</tbody>
</table>