Mill Creek Watershed Management Plan

Needs Assessment and Action Plan: A Living Document

Sonoma Resource Conservation District
2015

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EXECUTIVE SUMMARY

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ACRONYMS

BMI	Benthic Macroinvertebrates
BMP	Best Management Practice
CCC	Central California Coast
CAL FIRE	California Department of Forestry and Fire Protection
CDFW	California Department of Fish and Wildlife (formerly known as CDFG: CA Department of Fish and Game)
CEMAR	Center for Ecosystem Management and Restoration
CESA	California Endangered Species Act
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CSG	California Sea Grant
DBH	Diameter at breast height
DO	Dissolved Oxygen
DWR	California Department of Water Resources
ESA	Endangered Species Act
EQIP	Environmental Quality Incentives Program
GIS	Geographic information system
LWM	Large wood material
NMFS	National Marines Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
PRISM	Parametric-elevation Regressions on Independent Slopes Model
RCD	Resource Conservation District
RRCSCBP	Russian River Coho Salmon Captive Broodstock Program
SCWA	Sonoma County Water Agency
SIP	Streamflow Improvement Plan
SOD	Sudden Oak Death

SRCD	Sonoma Resource Conservation District (formerly Sotoyome and Southern Sonoma RCDs)
SSC	Species of Special Concern
SWM	Small Woody Material
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TU	Trout Unlimited
UCCE	University of California Cooperative Extension
USACE	United States Army Corps of Engineers (Corps)
USEPA (EPA)	US Environmental Protection Agency
USFS	United States Forest Service
USFWS	U.S. Fish & Wildlife Service
WQO	Water Quality Objectives

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Sonoma Resource Conservation District
Mill Creek Watershed Management Plan

SECTION 1.
INTRODUCTION AND BACKGROUND

CHAPTER 1. INTRODUCTION

PURPOSE OF THE MILL CREEK WATERSHED MANAGEMENT PLAN

The purpose of this Plan is to provide tools, resources and guidance for stakeholders to protect the natural resources of the Mill Creek watershed; restore and enhance altered landscapes, and to steward the land in perpetuity. Special focus within the Plan is given to salmonids, their current status, limiting factors and a prioritized plan of action to remedy those limiting factors.

PROCESS FOR DEVELOPING THE PLAN

The development of this Plan included general scoping of the watershed, gathering existing information, stakeholder engagement, and developing a needs and action assessment. This Plan follows the US EPA's nine elements of an effective watershed plan (see the following section for more information). The purpose of this Plan is to be used as a guidance document for landowners, land managers and resource agencies working in the watershed to improve water reliability, maintaining the viability of agricultural land and healthy forests and enhancing fisheries and wildlife habitat.

STAKEHOLDER GROUPS

Community outreach is an important part of the development and implementation of any watershed management plan. Watershed goals are most effectively identified and accomplished when agencies, watershed groups and landowners coordinate and work together. Below is a (non-exhaustive) list of the of the stakeholder groups (past and present) working on conservation in the Mill Creek Watershed.

Mill Creek Watershed Group

In 1996, a group of landowners formed the Mill Creek Watershed Group to galvanize interest among landowners to voluntarily "solve conservation problems on their land". The group was led by a steering committee made up of four members: Ruth and Eric Stadnik, Clint Folger and John Van der Zee. The Steering Committee was responsible for producing several newsletters between 1996 and 2000 that provided technical information geared towards new landowners on best management practices to improve fish habitat such as weed removal, road maintenance, forest management and fire protection. The group served as a liaison between landowners and regulatory agencies and helped to generate a sense of cooperation among landowners to participate in stewardship activities and to allow access for Department of Fish and Wildlife-sponsored restoration activities.

Sonoma Resource Conservation District (SRCD)

Sonoma RCD works with landowners in the watershed on a voluntary basis, providing technical, educational and financial assistance to protect natural resources and improve the viability of agricultural and rural lands. SRCD has been a stakeholder in the watershed dating back to the 1950s when the RCD worked with landowners on soil erosion and flooding and more recently has been helping landowners complete rural road upgrades, assessing areas for stream enhancement, providing conservation planning assistance on agricultural lands and conducting water quality monitoring. In 2009, the SRCD helped form the Russian River Coho Water Resources Partnership (Partnership) which is funded by the National Fish and Wildlife Foundation, as one of only two Keystone Initiatives in the State of California. The

Partnership was formed by the SRCD and a group of agencies and organizations that includes the Center for Ecosystem Management and Restoration (CEMAR), Gold Ridge Resource Conservation District, Occidental Arts and Ecology Center WATER Institute, Trout Unlimited, UC Cooperative Extension (UCCE) and California Sea Grant (CSG), and the Sonoma County Water Agency. Through the Partnership, the SRCD works with landowners to find water conservation and storage solutions to help restore streamflow during critical times of the year and ensure water reliability for both fish and people.

California Department of Fish and Wildlife (CDFW)

The CDFW conducted stream inventories for Mill, Felta, Palmer, Wallace and Angel Creeks in 1995 to assess habitat conditions for anadromous salmonids. Bob Coey, CDFW Fisheries Biologist at the time, compiled the reports and presented the information to landowners in 1996 when he was quoted as referring to the Mill Creek watershed as “a jewel” for both steelhead and coho salmon habitat. This was followed by several years of habitat enhancement project implementation, funded by CDFW and the Sonoma County Water Agency, to address the limiting factors to threatened and endangered salmonids in the watershed (see Appendix A). CDFW still considers Mill Creek a very high priority watershed for fish habitat enhancement and restoration and is actively involved in several Technical Advisory Committees and in funding restoration efforts. Most recently, they have provided funds for this management plan and other restoration planning and implementation projects as described in Appendix A.

University of California Cooperative Extension/California Sea Grant-Russian River Coho Salmon Captive Broodstock Program (RRCSCBP)

CDFW, National Oceanic & Atmospheric Administration, and the US Army Corps of Engineers (USACE) initiated the RRCSCBP in 2001 with the goal of re-establishing self-sustaining runs of coho salmon in tributary streams within the Russian River basin. Under this program, offspring of wild captive-reared coho salmon are reared at the Don Clausen Fish Hatchery at Warm Springs Dam and released as juveniles into tributaries within their historic range so that they might return to the streams as adults and spawn naturally. Capture of juvenile coho has occurred annually since 2001, and Felta Creek is one of three primary source streams. Mill and Palmer Creeks are two of nineteen tributaries in the Russian River basin where juveniles have been released. Since 2005, the RRCSCBP has monitored stream conditions in Mill and Palmer Creeks. RRCSCBP staff regularly visit the Mill Creek watershed and have worked with landowners to gain access to monitoring locations and stream gauges.

National Oceanic and Atmospheric Administration’s National Marine Fisheries Service’s (NMFS)

This federal agency is responsible for planning the recovery of threatened and endangered salmon in the U.S. The Mill Creek watershed falls within the critical habitat designated for federally endangered Central California Coast (CCC) coho salmon, federally threatened California Coast Chinook and for federally threatened CCC steelhead trout. NMFS has been active participants in the planning and identification of restoration priorities for the recovery of endangered salmonids in the Mill Creek watershed and the greater Russian River. In the NMFS Recovery Plan for Central California Coast coho salmon Evolutionarily Significant Unit (coho Recovery Plan) implementation of water conservation strategies such as off-channel water storage ponds and roof water harvesting systems is listed in the “immediate threat abatement actions” for the Russian River. The salmonid lifestage most impacted and threatened by water diversions is the juvenile rearing stage during spring, summer, and fall, as this corresponds to California’s dry season and period of highest water demands. The coho Recovery Plan designates several tributaries as core, high priority areas for coho protection and restoration work in the Russian River basin. The Mill Creek watershed is one of these core priority areas, in addition to a focused watershed for a 2013 proposed flow recovery program. Representatives from NMFS are members of technical advisory committees for the RRCSCBP and the Coho Water Resources Partnership.

The Sonoma County Forest Conservation Working Group

The Sonoma County Forest Conservation Working Group was created in 2005 to provide information and resources to private forest and woodland owners of small parcels, with the goal of protecting and sustaining healthy forests, woodlands, and watersheds in Sonoma County. Members represent forest landowners, local and regional land trusts, watershed councils, and state and local agencies, including the Sonoma County Agricultural Preservation and Open Space District, Sonoma Land Trust, CAL FIRE, University of California Cooperative Extension, Sonoma and Gold Ridge RCDs.

Sonoma County Water Agency (SCWA)

The Sonoma County Water Agency is responsible for implementing the Russian River Biological Opinion (BO). The BO was approved in 2008 and is a federally mandated 15-year blueprint to help save endangered fish and ensure Sonoma County’s water supply is not compromised. Work under the BO includes the Russian River Instream Flow and Restoration project, which consists of the Russian River Estuary Management project, changes in the flow to the Russian River, Dry Creek flow reduction and habitat improvement, and fisheries monitoring. SCWA helps to fund extensive water quality and quantity monitoring projects within the Russian River and important tributaries, including Mill Creek. SCWA has also been involved in funding the design and implementation of fish barrier removal projects, riparian revegetation projects, instream habitat enhancement projects, and floodplain restoration projects. SCWA has played an active role in Mill Creek restoration.

Natural Resources Conservation Service (NRCS)

The Natural Resources Conservation Service is the federal agency that distributes Farm Bill conservation funding and helps landowners implement conservation projects on agricultural lands. Resource Conservation Districts work with NRCS to help leverage funding and implement projects. Through programs such as the Environmental Quality Incentives program (EQIP), NRCS works to promote agricultural production, forest management, and environmental quality as compatible goals. With funding and technical assistance through EQIP, farmers and ranchers can optimize agricultural production while meeting Federal, State, and local environmental regulations.

California Department of Forestry and Fire Protection (CAL FIRE)

CAL FIRE is dedicated to the fire protection and stewardship of over 31 million acres of California's privately-owned wildlands. In addition, the Department provides varied emergency services in 36 of the State's 58 counties via contracts with local governments. CAL FIRE's mission emphasizes the management and protection of California's natural resources; a goal that is accomplished through ongoing assessment and study of the State's natural resources and an extensive CAL FIRE Resource Management Program. CAL FIRE oversees enforcement of California's forest practice regulations, which guide timber harvesting on private lands.

ORGANIZATION OF THE PLAN

The organization of this Plan is based upon the US Environmental Protection Agency's nine elements of an effective watershed management plan, as described in the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" (2005). This Plan addresses the following descriptions of the USEPA's nine elements.

a) An identification of causes of impairment and pollutant sources.
b) An estimate of load reductions expected from management measures.
c) A description of the nonpoint source management measures that will be implemented to achieve load reductions.
d) An estimate of the amounts of technical and financial assistance needed to implement those management measures.
e) An information and education component used to enhance public understanding of the project and to encourage their early and continued participation in selecting, designing, and implementing nonpoint source management measures.
f) A schedule for implementing nonpoint source management measures identified in the plan.
g) A description of interim measurable milestones for project implementation efforts.
h) A set of criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
i) A monitoring component to evaluate the effectiveness of implementation efforts over time.

WATERSHED GOALS

The Mill Creek Watershed Management Plan provides descriptions of current watershed conditions and identifies needs and assessments that aid in achieving the Plan's goals and objectives. The table below links watershed goals with indicators that demonstrate whether or not the goals are being attained, potential sources of impact that could be altered to attain the goals, and management objectives to help achieve the goals. The Mill Creek Watershed Management Plan, designed as a living document, aims to facilitate and support stakeholder collaboration on the paramount needs for agricultural and natural resource sustainability within the watershed.

Table 1.1 Watershed goals and associated indicators, potential sources of impact, and management objectives for the Mill Creek watershed.

Goal	Indicator	Potential Source of Impact	Management Objective
Improve the viability, health and productivity of agricultural lands	Need for increased pollinator habitat, need for bank stability to protect ranch roads, riparian vegetation management to control Pierces disease	Agricultural run-off, lack of rainwater conservation practices, potential sediment delivery from erosion areas, lack of wildlife habitat and pollinator habitat	Provide technical and financial assistance to interested landowners to implement Best Management Practices and habitat enhancement projects
Improve water conservation and reliability	Low streamflow observations and measurements,	Lack of rain water storage and ground water recharge during critical	Implement a Mill Creek Streamflow Improvement Program in critical stream

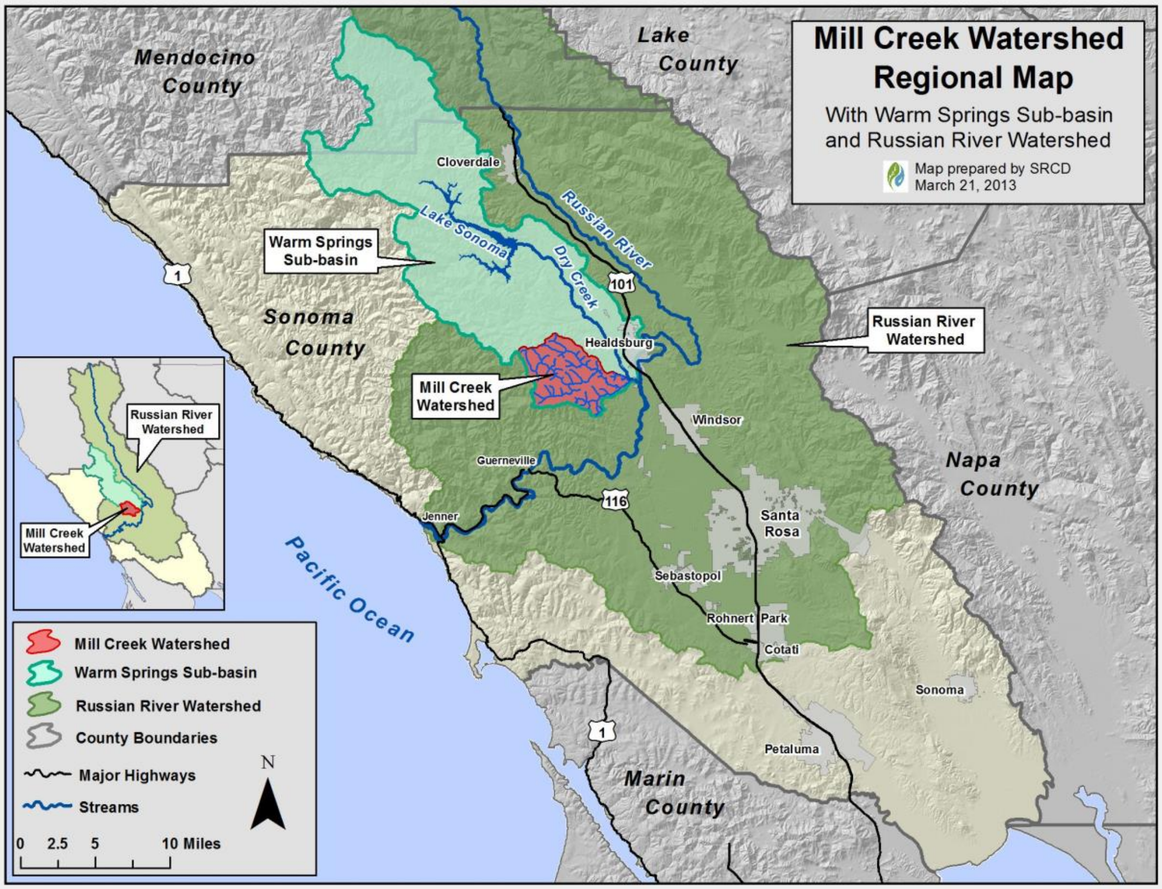
	concerns expressed by landowners about water reliability and storage during critical periods	low flow periods.	reaches; promote Best Management Practices for water conservation and storage
Meet water quality standards for sediment/siltation	Substandard water quality levels for turbidity and total suspended solids	Destabilized streambanks; removal of riparian vegetation; modified drainage pathways; gully erosion; unmaintained rural roads	Stabilize and revegetate stream corridors; mitigate erosion from gullies and rural roads; investigate and treat significant sediment sources
Support aquatic life and restore aquatic habitat	Substandard water quality levels for; temperature and turbidity; sedimentation;; reaches with weak benthic macroinvertebrate communities; riparian vegetation deficiency; lack of instream habitat structure; fish barriers	High turbidity levels and aggradation of stream channels raises water temperature; sediment loads alter streambed composition; removal of riparian vegetation; fish passage barriers	Stabilize and revegetate stream corridors; mitigate erosion from gullies and rural roads; conduct stream habitat typing; remove fish passage barriers; and increase instream habitat structure and complexity.
Assess and enhance riparian habitat and associated flood plains	Extent & condition of wetland plant communities; wetland functional assessments; habitat connectivity; bird species diversity and richness	Streambank and upland erosion	Map and assess wetland functions and conditions; improve agricultural management practices in sensitive areas;
Decrease anthropogenic sediment inputs into Mill Creek	Excessive fine sediment in stream; buried cobbles, filled in pools; bank erosion resulting from stream incision; gullies and landslides developing on hillslopes adjacent to creek.	Development of agricultural lands and rural residential properties, large network of maintained and unmaintained roads, historical dams installed on Mill Creek.	Develop a prioritized outreach plan based on geomorphic surveys in Mill Creek and its primary tributaries and an aerial photo history of landslides and road development, assess high priority areas, produce and implement sediment reduction plans.
Restore and protect forest health upland plant communities	Levels of Sudden Oak Death, forests with even age trees and low diversity, areas with high fuel and forest fire threats, levels of oak woodland regeneration and level of invasive plants	Spread of Sudden Oak Death pathogen; modification of forest structure and composition, erosion, decreased ground water recharge, increased forest fires, Doug-fir encroachment in oak woodland forests	Implement fuel reduction projects, help landowners complete forest management plans, assess areas for Sudden Oak Death and take steps to reduce the spread of the pathogen, encourage oak woodland regeneration and health, reduce levels of invasive plants

CHAPTER 2. HISTORICAL AND CURRENT CONDITIONS

REGIONAL SETTING

The Mill Creek watershed is located in central Sonoma County approximately 60 miles north of San Francisco and just west of the Highway 101 corridor. Healdsburg, the nearest city, is 2 miles east of the watershed (See Map 2.1).

Map 2.1 Regional Context of the Mill Creek Watershed



GEOGRAPHIC DESCRIPTION AND CONTEXT

The Mill Creek watershed is located within the Russian River watershed Hydrologic Unit and the Warm Springs Hydrologic Sub-Basin as classified by Cal-Watershed 2.2a. The Warm Springs sub-basin runs along the western edge of the Russian River basin in Sonoma County and contains the vast expanse of the Dry Creek watershed and Lake Sonoma, which now occupies the majority of the sub-basin watershed. This sub-basin is named after Warm Springs Dam, constructed in 1982, which impounds Lake Sonoma. Primary ownership throughout the sub-basin is private, although USACE owns and manages Lake Sonoma.

Major tributary watersheds within the Dry Creek watershed below the dam include Peña Creek and Mill Creek, as well as numerous perennial and intermittent tributaries. Mill Creek, the second largest tributary system in the Dry Creek watershed, joins Dry Creek just above the confluence of Dry Creek with the Russian River. Major tributaries include Felta, Wallace, Palmer and Angel Creeks along with a smaller tributary Boyd Creek which together drains a basin of approximately 24 square miles. The system has a total of 29 miles of blue line stream and includes both 2nd and 3rd order streams (Table 2.1). Elevations range from about 60 feet at the mouth of Mill Creek proper to 1400 feet in the headwater areas.

Map 2.2 Map of Mill Creek Watershed with Sub-watershed Boundaries

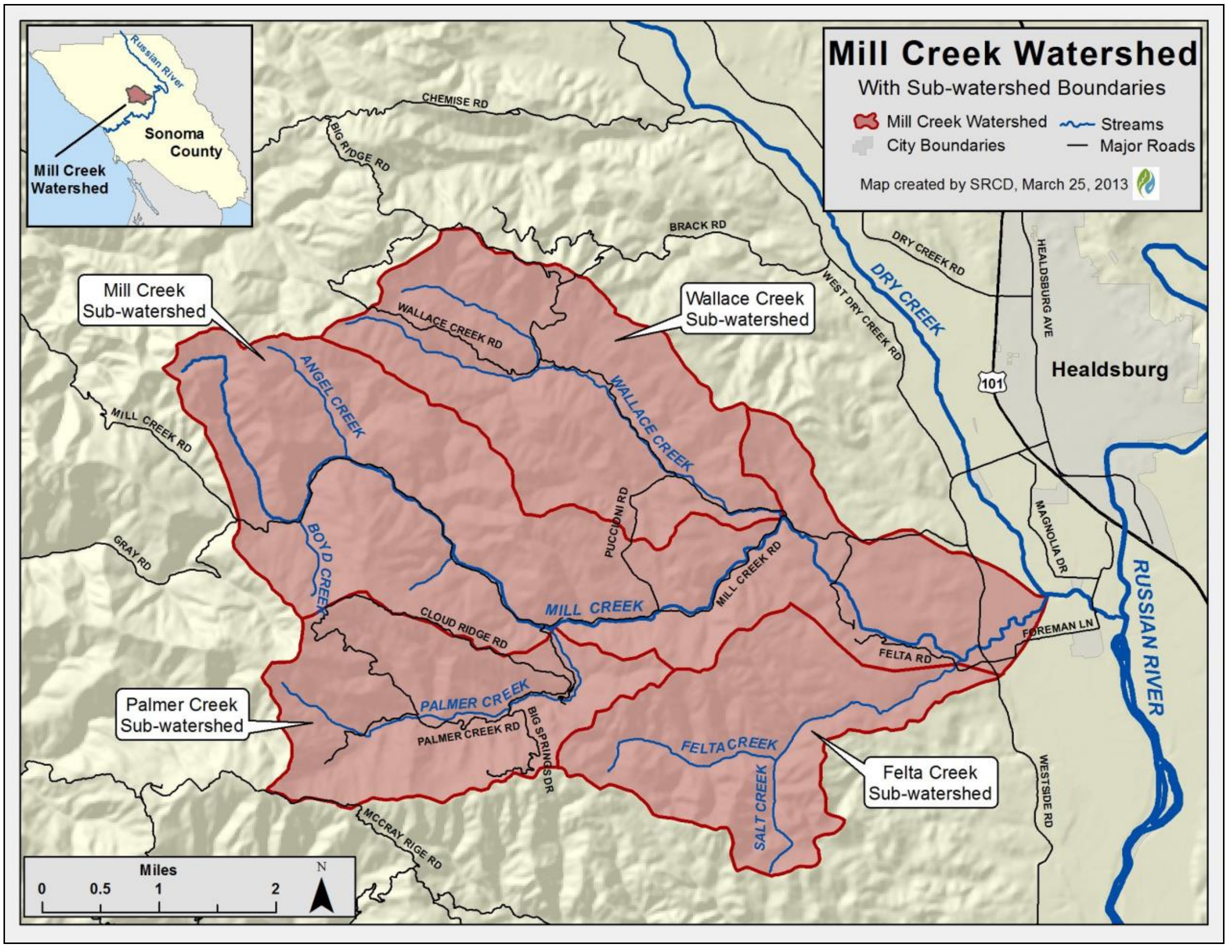


Table 2.1 Creek Characteristics within the Mill Creek Watershed

Creek	Watershed Area (sq. mi.)	Stream length (mi.)	Stream Order	Tributaries	Legal Description
Felta	3.7	5	2nd	Salt Creek	T09N, R09W, S32 (at confluence with Mill Creek)
Mill	24 (including tribs)	12 (29 with tribs)	3rd perennial	Felta, Palmer, Wallace, Boyd	T09N, R09W, S33 (at confluence with Dry Creek)
Palmer	3.4	3.4	2nd		T09,R10W,S34 (at confluence with Mill Creek)
Wallace	5.8	5.7	2nd		T9N,R10W,S25 (at confluence with Mill Creek)
Angel	1.23	1.1	2nd		T9N,R10W,S28 (at confluence with Mill Creek)

Demographics & Economics

The Mill Creek watershed is located within a picturesque, rural setting that is made up of private residences, family-owned wineries, and small-scale agricultural operations. The nearest major city is Healdsburg which is located 2 miles to the east and has a population of approximately 11,656 (U.S. Census Bureau, 2014). Located within the world-class wine growing region of the Dry Creek Valley, land values are high and economic pressures are causing a decrease in small family-operated farms and an increase towards new estate home construction and vineyard development. Increased vineyard and winery development has been accompanied by an increase in winery-related tourism. Timber sales help to support the local economy; however, these are typically small-scale selective harvests that are often used to manage forest health and not for large economic benefit.

Land Uses – Historic and Current

Initial settlements in the watershed consisted of prehistoric villages on the lowland areas along the Dry Creek alluvial plain and along Mill Creek. These early inhabitants were Southern Pomo Indians who cultivated the land in their traditional ways through burning, tilling, sowing and pruning native plants. American and European settlers began arriving in the early 1800s. By 1841, the area was included within the 49,000 acre Mexican land grant deeded to Henry Fitch termed Rancho Sotoyome, named after the local tribe whose chief was referred to as Chief Soto. Rancho activity from 1840 to 1850 introduced livestock grazing, and farming for crops and feed. Fruit crops and grape vines were also introduced at this time. As settlement increased in the area, the need for a saw mill and flour mill was apparent and in 1850 the first sawmill to operate in northern Sonoma County was erected in the Mill Creek watershed. The original site was located near the “Upper Falls” on Mill Creek and later moved to a point just below the second falls and continued operating until 1881. Redwood logs supplied beams for construction and the developing railroad and tanbark was sent to a Santa Rosa tannery.

In the flatter areas of the watershed, the forests were often cleared and converted to prune orchards, vineyards and grassy openings for livestock grazing. In the 1920s, the name Venado was given to identify the settlement in Mill Creek and a post office was erected. A number of the early settlers were former engineers who bought 40-acre plots of land from the original land owner. A crushed stone quarry was mined in the early 1900s for building blocks and cobblestones. (Historical information from www.healdsburgmuseum.org)

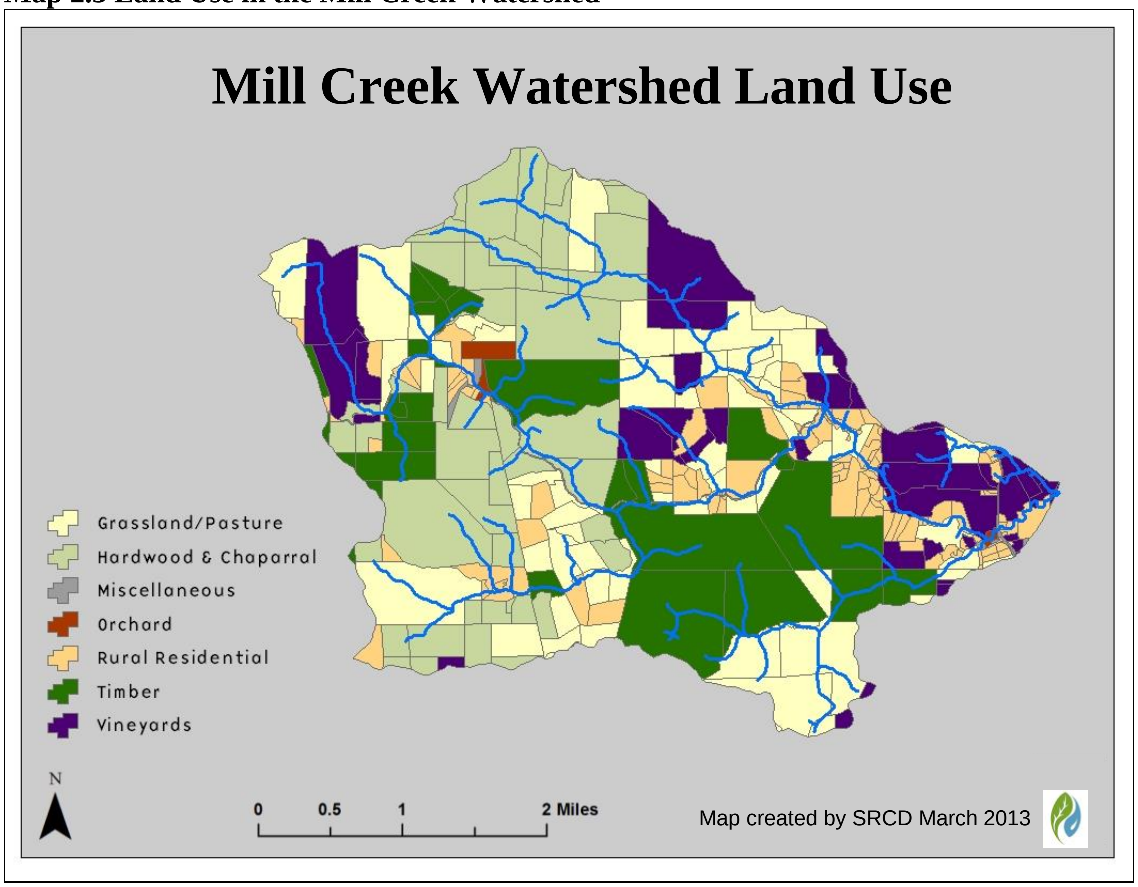
Over time, wine grape growing continued to expand throughout the Dry Creek Valley, and since the time of prohibition in the 1920s, it has emerged as the predominant land use in the area and is recognized as world class grape growing and wine producing region.

The legacy of the early land use activities, particularly logging, can still be seen in the watershed. Improperly drained roads, use of stream channels as skid trails, and the placement of landings in creek beds, have all contributed to the large amounts of sediment found in Mill Creek (Kreck NTMP).

Photo taken in the Mill Creek area circa 1908 (Healdsburg Museum and Historical Society).

Today, the Mill Creek watershed is completely privately owned. Land cover is forest, grassland, vineyards and rural residential areas (Figure 2.1). Coniferous and hardwood forests make up 43% of the land cover (8,825 acres); while grasslands make up 32% of land cover (6,658 acres); vineyards make up 16% (3,271 acres); rural residential 9% (1,858 acres); orchards (70 acres) and other miscellaneous categories include camps, roads and schools making up the remaining 37 acres. Most of the parcels are less than 600 acres in size. In the lower elevations where Mill Creek meets up with Dry Creek, land use is primarily made up of vineyards and wineries. Going up the watershed, the valley narrows and the steep forest-covered hills limit the amount of agriculture that can take place. Many of the landowners pursue a diverse mixture of land uses that includes residential dwellings, wine grape growing, vegetable farming, fruit production, livestock production and in some cases small wineries that are open to the public.

Map 2.3 Land Use in the Mill Creek Watershed



**Data shown is based on information provided by the Sonoma County Permit and Resource Management Division.*

CULTURAL RESOURCES

According to information gathered from the Healdsburg Museum and Historical Society (www.healdsburgmuseum.org), the earliest residents in the Mill Creek watershed were tribes of the Southern Pomo Indians who inhabited the area for thousands of years. The Southern Pomo were divided into tribelets which encompassed a number of small villages. It is estimated that at least 23 village sites were present in the vicinity of the nearby city of Healdsburg. A tribelet named "Amati-o" was located on

Mill Creek. The indigenous pre-contact population is not known, but General Vallejo's accounts in the 1830s would indicate between 5,000 and 10,000 in the area. A local resident claimed that 2,000 Indians were living around the Sotoyome Rancho in 1849.

An extensive 10-year archaeological and cultural resources study took place prior to the construction of the Warm Springs Dam and a report was submitted to the Army Corps of Engineers in 1985 titled, *Before Warm Springs Dam, A History of the Lake Sonoma Area, Sonoma County, California* http://www.sonoma.edu/asc/projects/warmsprings/). This lengthy report provides a detailed picture of the life and activities of the indigenous people in the area surrounding Lake Sonoma and the events which is located less than 5 miles to the north of Mill Creek watershed. This document should be referred to for those interested in more information on cultural resources than what is provided in this management plan.

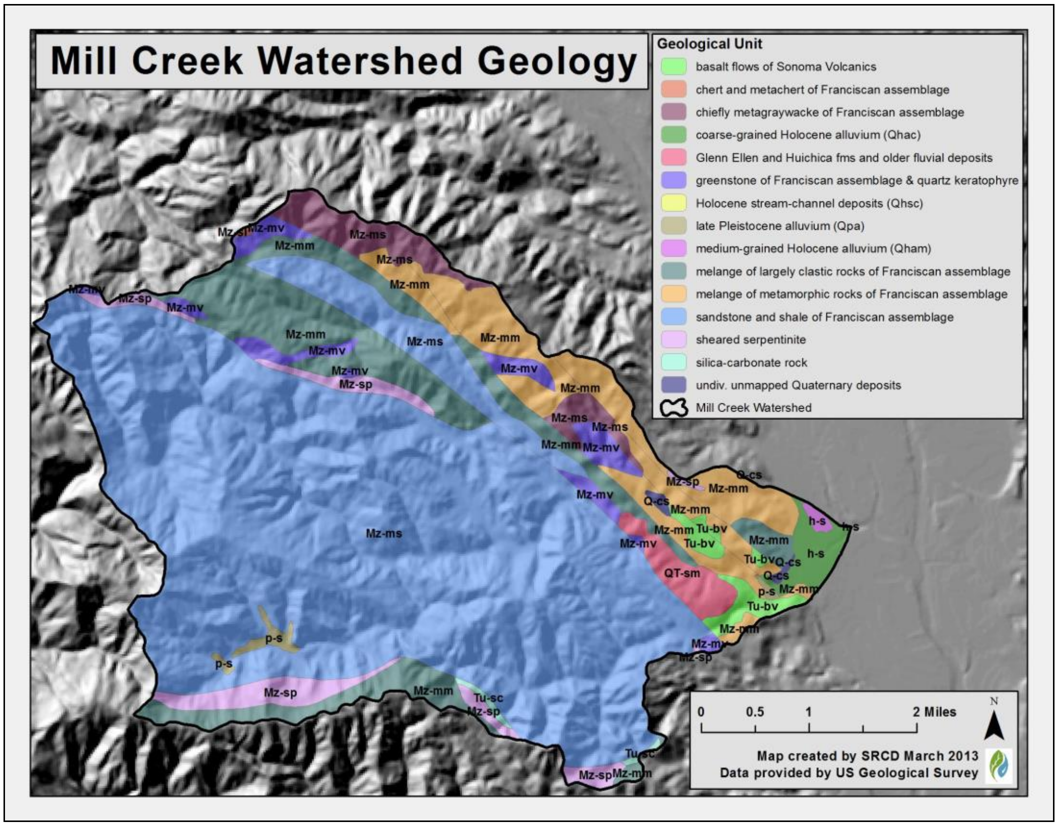
NATURAL ENVIRONMENT

Geology and Soils

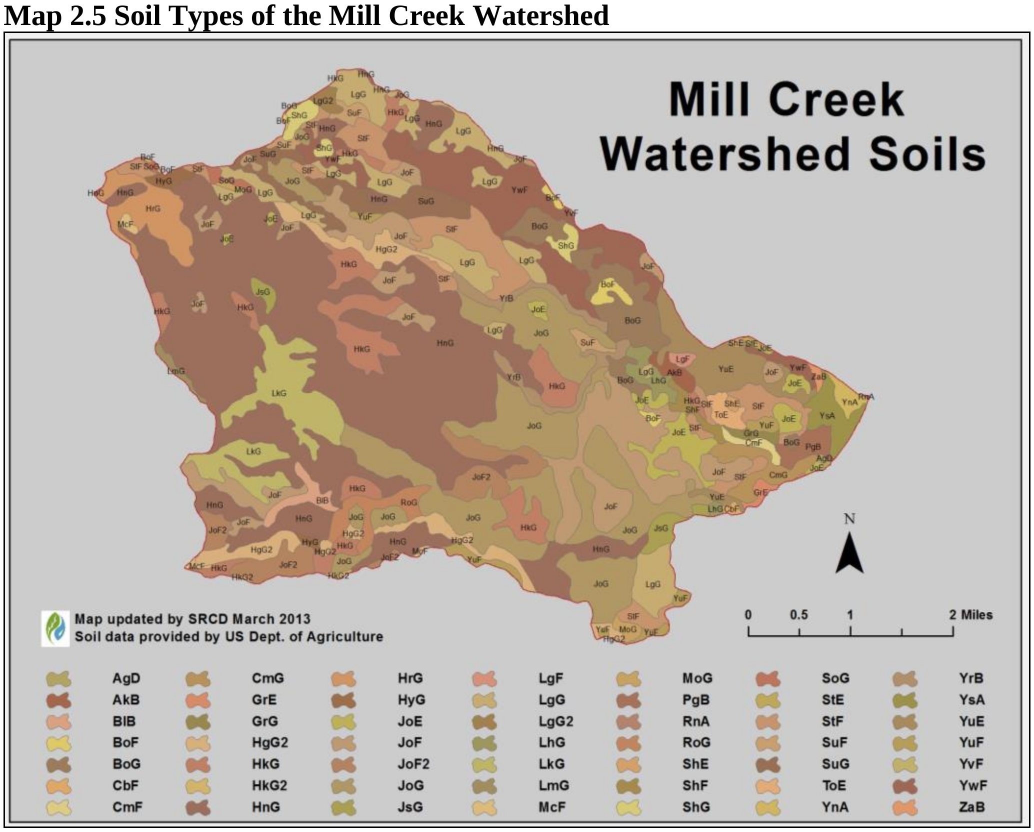
Geologically, Sonoma County is bisected by the San Andreas Fault. To the west, on the tip of Bodega Head, are ancient continental rocks formed far to the south and moved north at least 335 miles by the fault (Map 2.4). To the east of the fault lies the Franciscan Complex; oceanic rocks mixed by faulting as ocean floor slid east under the edge of the continent. Both areas are covered by a thin mantle of more recent rocks formed in shallow seas, beaches, volcanoes and rivers. Recent sharp uplift and ongoing river erosion has sculptured the scenery (Wright 1998). Within the Mill Creek watershed the predominant geologic substrate is derived from Franciscan rocks such as sandstone, greywacke, metagraywacke and mélange. Other deposits not belonging to the Franciscan complex include: alluvial deposits close to the Russian River, landslide deposits, and outcrops of basalt, greenstone, chert and chert blocks (Blake et al. 2002).

The watershed's terrain is characterized by steep topography and soils that are highly erosive and sensitive to disturbance. The predominant soil types within the watershed are within the Hugo-Josephine Complex, 50 to 75 percent slopes (HnG), making up 28 percent of the area (Map 2.5). Josephine loam with 50 to 75 percent slopes (JoG) is the next most common with 13 percent cover, followed by Josephine loam with 30 to 50 percent slopes (JoE), with 8 percent cover, and the Yorkville-Suther complex (YwF), 0 to 50 percent slopes, with 6 percent cover. The Hugo series consists of well-drained very gravelly loams that have gravelly sandy clay loam subsoil. The Josephine series consists of well-drained loams that have clay loam subsoil. These soils occur on mountainous uplands that are typically used for timber production, particularly redwood and Douglas-fir, where runoff is very rapid and the erosion hazard is very high. These lands are also used for grazing, where the soils have been logged and cleared. The Yorkville series is made up of moderately well-drained clay loams that have clay subsoil. Yorkville soils are used for grazing by sheep and cattle. A list of all soil types with relative percent area is located in Appendix B.

Map.2.4 Underlying Geology of the Mill Creek Watershed



Map 2.5 Soil Types of the Mill Creek Watershed



Forestry and Vegetation Resources

Vegetation in the Mill Creek watershed is diverse and is characterized by the typical North Coast Mediterranean vegetation types. Along the ridges and south facing slopes, oak woodlands, grasslands, and chaparral plant communities are dominate and integrate with redwood and Douglas-fir forests within the canyons, where it is wetter and cooler. Trees species including Tan oak, madrone, bay, and live oak are key species within the forest areas along steep slopes and forest edges. These forest types integrate with riparian habitat along the creeks, which are composed primarily of willow, valley oak, live oak, maple, redwood and bay. Forest health and habitat quality are vital factors when assessing a watershed. While the forests of Mill Creek watershed are generally healthy, there are concerns with many of the diseases and blights common to the northern California coastal ranges. Sudden Oak Death (caused by the plant pathogen *Phytophthora ramorum*) is a problem in the watershed that leads to hindered development and death of several species of oak and an increase in fuel loads in the forest. There are also beetles and blights affecting the overall health of the Mill Creek watershed forests that require special assessment and consideration when developing forest management plans and projects. Tree snags, downed wood, and trees with hollows have not been adequately mapped and assessed for their contributions for habitat quality in an area. Mill Creek watershed is home to several species that thrive in these forest features so special consideration is also required for this when forest management decisions are made.

Map 2.6 Vegetation Cover in the Mill Creek Watershed

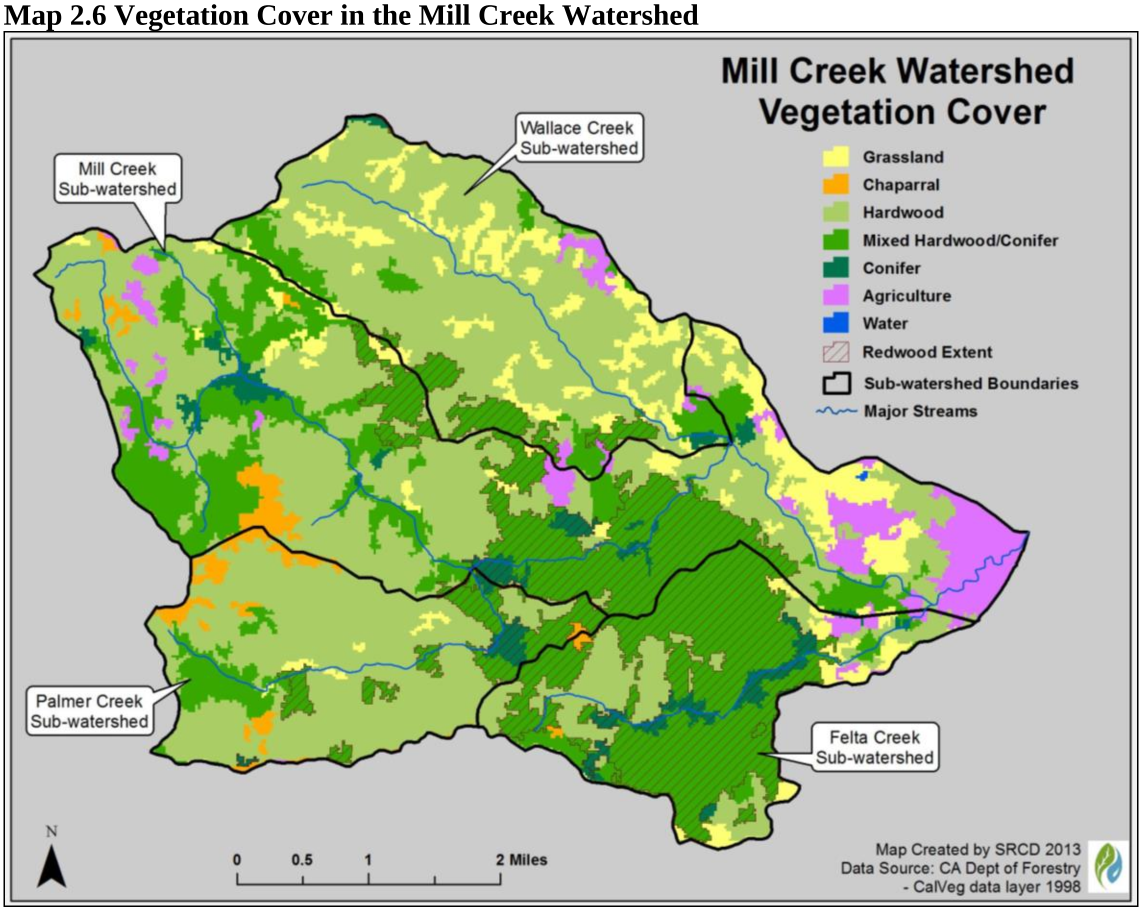


Table 2.2 Vegetation Cover in the Mill Creek Watershed

Vegetation Type	Acreage	% of Total Area
Grassland	1,234	8.3
Chaparral	306	2.1
Hardwood	7,440	50.3
Mixed Hardwood/Conifer	4,604	31.1
Conifer	480	3.2
Agriculture	717	4.8
Water	3	0.2
Total	14,784	100

Water Resources

The climate patterns of the Mill Creek watershed (and Sonoma County in general) are, like most of coastal California, characteristically Mediterranean: summers are warm and dry, and winters are wet and cool. Precipitation occurs almost exclusively as rainfall (i.e., snowfall is very rare), and it occurs mostly during wet winters. The average annual rainfall varies considerably across the county with average ranges from 45 to 50 inches per year (NRCS 1972). Rainfall data over a 50-year period recorded at a NOAA weather station located in the nearest City, Healdsburg (approximately 1 mile from the Mill Creek watershed) reports the average total yearly precipitation during that period was 41 inches with 90 percent of the average annual rainfall occurring between November and April. The average maximum temperature was 74 degrees F and average minimum temperature was 45 degrees F. Regional climate change modeling predicts that precipitation in the area will become less predictable over time, and that the bulk of precipitation will become more concentrated into the mid-winter period, leading to a more extended dry season (Micheli, et al, 2012).

The Mill Creek watershed with its steep forested slopes and higher elevations has on average, lower air temperatures and slightly more precipitation than what was recorded in Healdsburg. The map below illustrates the average annual precipitation distributed across the watershed and shows a recorded high of 63 inches in the higher elevations to the west and a low of 42 inches in the lower elevations to the east near where Felta Creek joins Dry Creek, an area similar in elevation and climate to that of Healdsburg.

Streamflow in nearby streams follow a similar pattern to rainfall. In Pena Creek, an upstream tributary to Dry Creek near Mill Creek, data recorded by the U.S. Geological Survey (USGS) from the 1980s indicates that almost all of the streamflow occurs from November through April (see Figure 2.2).

Figure 2.1 Average monthly precipitation, Healdsburg, CA

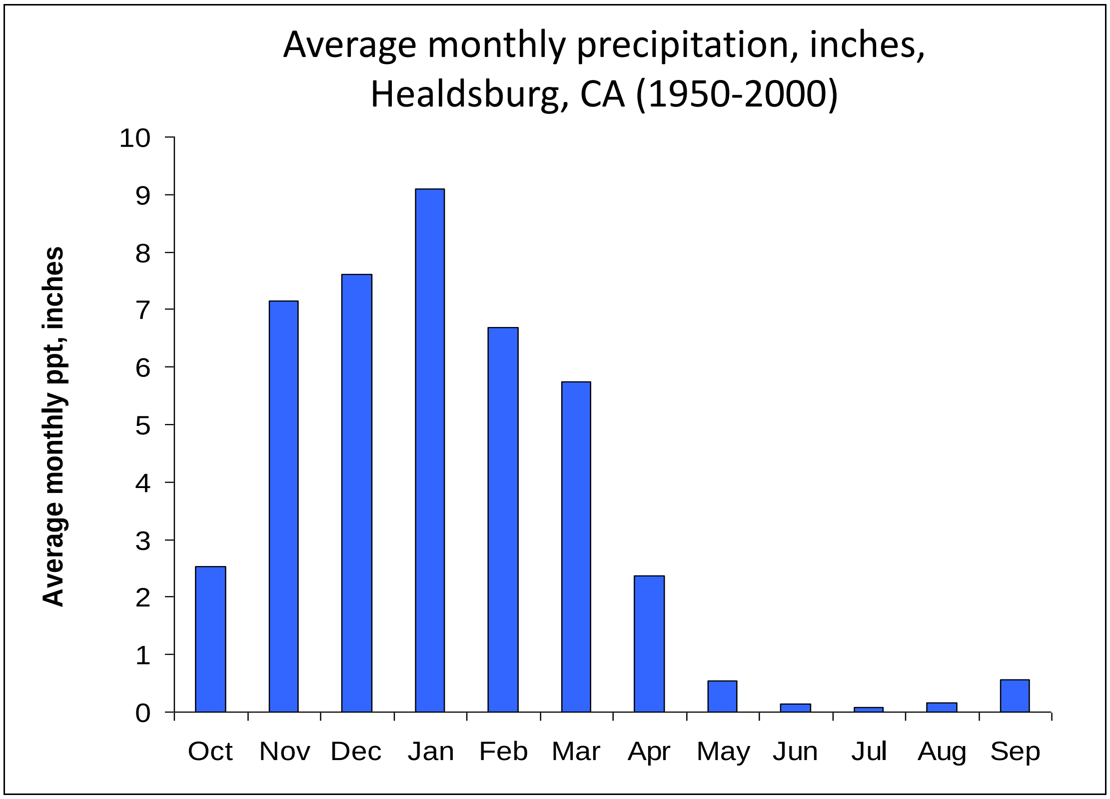
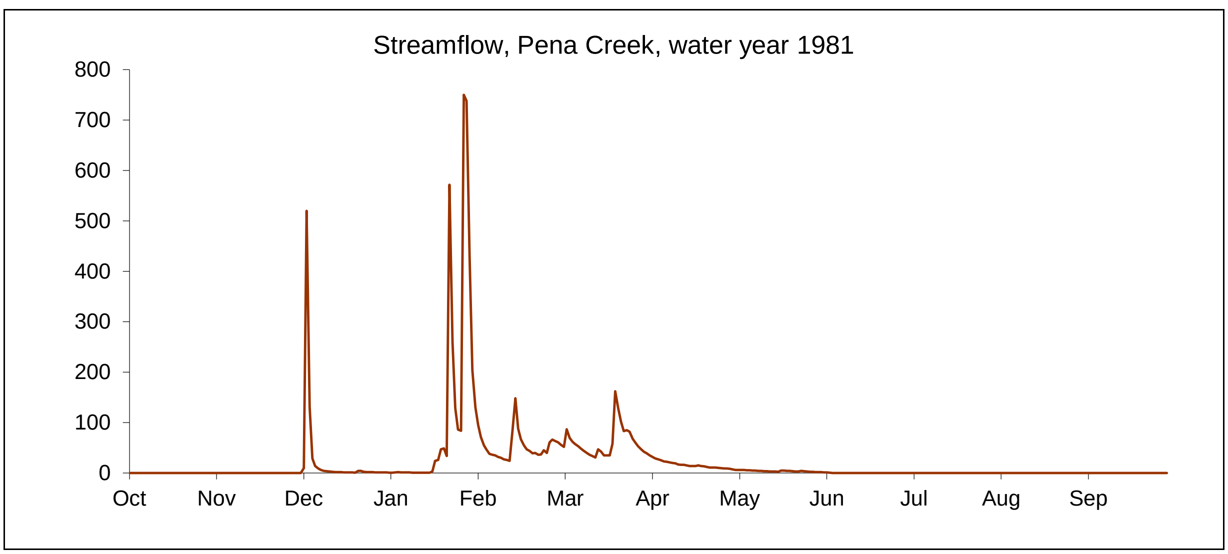
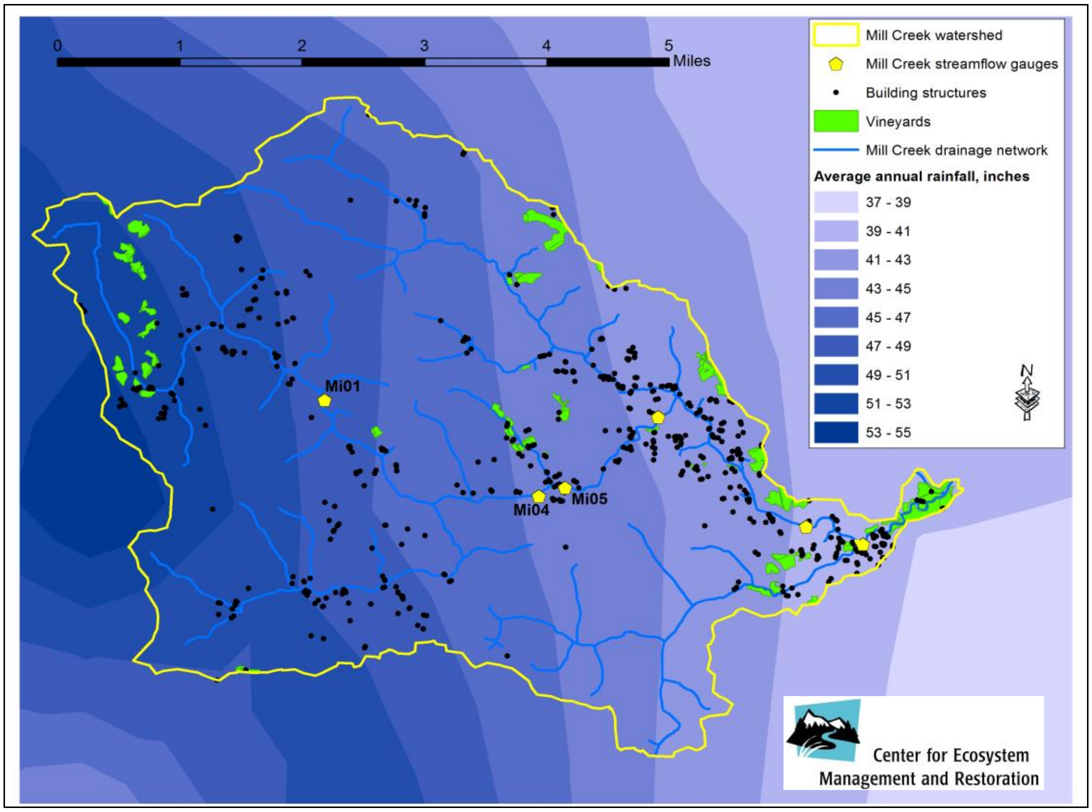


Figure 2.2 Mean daily flow recorded by US Geological Survey, Pena Creek, in a median-type water year based on 10 years of record (1981)



The PRISM spatial data set of rainfall (developed by Oregon State University, widely considered a standard for rainfall analysis in the Western United States) indicates that the Mill Creek watershed receives on average 49 inches of rainfall in an average year, with more occurring at higher elevations in the watershed and less at lower elevations (see Map 2.7). Over the 24 square mile watershed, this amounts to approximately 62,000 acre-feet of water falling on the Mill Creek watershed in an average year.

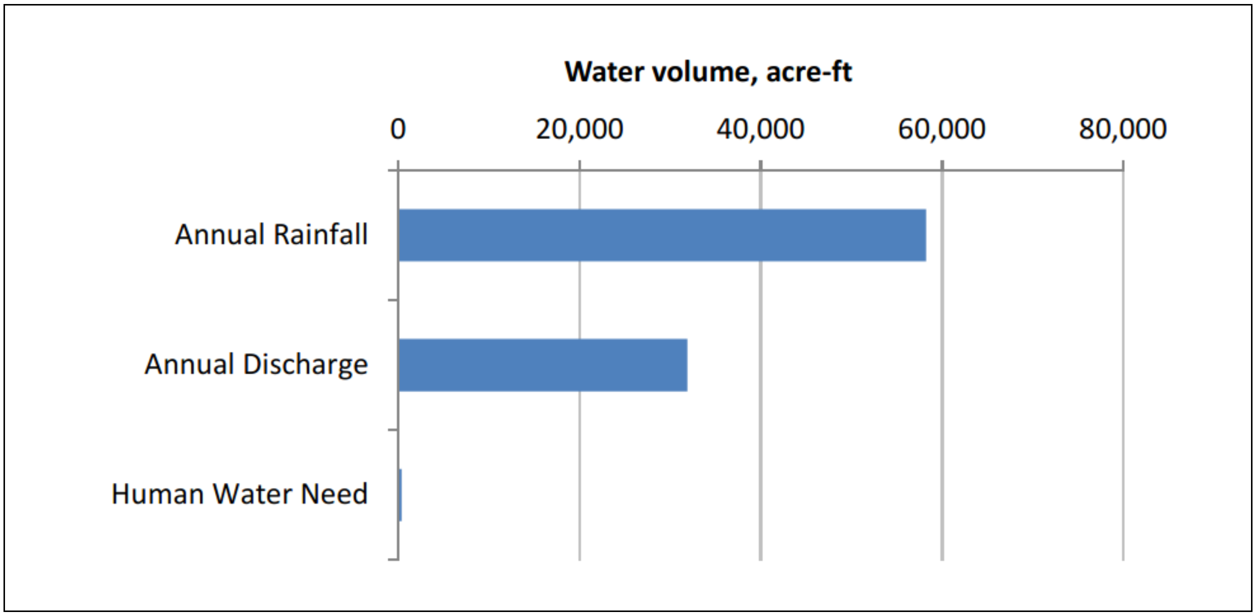
Map 2.7 Isohyetal map of average annual rainfall, Mill Creek Watershed



**Data shown is based on PRISM data.*

Comparatively, estimates can be made to estimate human water need in the Mill Creek watershed. According to the analysis completed as part of the Mill Creek Streamflow Improvement Plan (SIP), completed in 2015, The Mill Creek watershed receives as rainfall approximately 200 times the total amount of water needed for residential and agricultural uses in this watershed, even under dry-type conditions. The average annual discharge is estimated to be approximately 100 times the human water needs (see Figure 2.8 below and Appendix C for details). These results indicate that there is ample water in the Mill Creek watershed on an annual scale to meet human and environmental needs. However, timing of water's availability is the greatest challenge with ecologically sustainable water management.

Map 2.8 Comparison of Average Annual Rainfall, Average Annual Streamflow, and Human Water Need in the Mill Creek Watershed



**Map excerpted from page 21 of SIP (see Appendix C)*

Fish and Wildlife

Habitat for fish and wildlife in the Mill Creek watershed has been impacted by the history of timber harvest and other land use practices in the watershed. Only a small portion of the forest remains as old-growth habitat, and stream habitat for fish has been degraded. The presence of several important species, such as the threatened northern spotted owl (*Strix Occidentalis caurina*) and marbled murrelet (*Brachyramphus marmoratus*), have been documented in the Mill Creek watershed. In addition, three species of anadromous fish are present within Mill Creek watershed. These include the endangered coho salmon (*Oncorhynchus kisutch*), and the threatened steelhead (*Oncorhynchus mykiss*) and Chinook (*Oncorhynchus tshawytscha*). Use of the streams in Mill Creek watershed for spawning, rearing and migration by these species has been observed throughout the watershed and its tributaries. In addition to coho, steelhead, and Chinook, other fish communities using habitat within the watershed include sculpin (*Cottoidea*), California roach (*Lavinia symmetricus*), threespine stickleback (*Gasterosteus aculeatus)*, green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), fathead minnow (*Pimephales promelas*), pacific lamprey (*Lampetra tridentate*), Sacramento sucker (*Catostomidae*), Sacramento pikeminnow (*Ptychocheilus grandis*), and hardhead minnow (UCCE et al, 2013). A variety of amphibian species, including the state and federally listed CA red-legged frog (*Rana draytonii*), depend upon small-pond depressional wetlands and riparian areas in the watershed for breeding and rearing habitat.

With a decline of old growth forest habitat in the watershed due to timber harvesting and/or development, wildlife populations dependent on complex old growth forest conditions have decreased, with some species listed as threatened by federal government, such as northern spotted owl and marbled murrelet. The marbled murrelet is also listed as being threatened and endangered by CDFW. The marbled murrelet, is listed in USFWS's Critical Habitat Database as occurring in the southwestern corner of the Mill Creek watershed. According to anecdotal evidence, the northern spotted owl has been observed in the southern portion of the watershed. Late-successional forest habitat is located throughout the watershed providing an opportunity to decrease habitat fragmentation caused by past forest management activities in the watershed and increase the total amount of habitat for at-risk species. No recent surveys for spotted owls or marbled murrelets have been conducted within the Mill Creek watershed, and no recent documentation of their presence is available.

Because the forest habitat may provide limited structural complexity and species diversity, affecting habitat niches, the number of species present and the number of individuals of most species may be limited. However, if appropriate habitat conditions are present, most wildlife species commonly found in coniferous forest in northwestern Sonoma County could be present in the Mill Creek watershed or in adjacent watersheds. As forests surrounding the wetlands and riparian areas mature and develop late-successional characteristics, the value of watershed areas as migration pathways and foraging sites for fish, wildlife, and amphibians will improve. A list of wildlife that may be expected to be found in or near the Mill Creek watershed, with some based on anecdotal evidence, can be found in Appendix D.

Threatened and Endangered Species

The Federal Endangered Species Act of 1973 (ESA) authorizes the listing of species as threatened or endangered and provides protection for listed species through laws that limit taking of these species and allows acquisition of land and disbursement of funds for conservation of listed species' habitats. Species eligible for listing under the ESA exhibit the following criteria: 1) Habitat is under threat of modification or destruction; 2) Species is over utilized for commercial, recreational, scientific, or educational purposes; 3) Species is subject to extreme disease or predation; 4) Existing regulatory mechanisms are inadequate to protect the species; or 5) The species continued existence is threatened by other natural or manmade factors.

The California Endangered Species Act (CESA) also allows listing of species and protection through limits of takes on those species. Species can be listed under either or both of the ESA and CESA, and can have different status on each list. Additionally, the California Department of Fish and Wildlife (CDFW) has the authority to list Species of Special Concern (SSC). These species are not listed under the ESA or the CESA, but are either declining at a rate that could result in listing, or have historically occurred in low numbers and are known to have current threats to their existence. SSC listing criteria are similar to ESA criteria, and include small, isolated populations, marked population declines, habitat decline, and conversion of land adjacent to limited and specialized habitat. Other criteria include prevalence on historic land, and limited records of recent presence in the state.

The California Native Plant Society (CNPS) maintains lists of plants to categorize degrees of concern for the survival of these species. These lists include but are not limited to plants that are listed under the ESA and CESA. List 1A consists of plants presumed to be extinct in California. List 1B includes plants that are rare, threatened or endangered in California and elsewhere. List 2 consists of plants that are rare, threatened or endangered in California, but more common elsewhere. It is mandatory that species on lists 1A, 1B and 2 be considered during environmental impact analyses prepared in accordance with the California Environmental Quality Act. List 3 is a review list of plants that CNPS wishes to learn more about before categorizing. List 4 is a watch list of plants that have limited distribution which cannot be considered rare, but whose status should be monitored regularly.

The Mill Creek watershed provides habitat for many species that are listed as threatened, endangered, species of special concern, and species listed on CNPS lists. A California Natural Diversity Database (CNDDB) search of the Guerneville, Cazadero, Geyserville, Healdsburg and Camp Meeker USGS 7.5m quadrangles produced the list of endangered animal and plant species provided in Appendix D.

Status of Salmonid Populations and Habitat

Abundance and Distribution within the Mill Creek Watershed

Along the Pacific Coast, populations of salmonids have significantly declined over the last century. In the Russian River watershed, abundance of coho salmon is estimated to be 15% of 1940 levels (Obedzinski et al. 2008) and CCC steelhead is estimated at 15% of its estimated population size of 65,000 in 1970 (NMFS 2005) and the Mill Creek watershed is no exception to this decline.

Documented historic and recent occurrences of salmonids in the Mill Creek watershed come from two main sources: 1. stream surveys conducted by the CDFW in 1995 (CDFW 2006) and 2. Incidental reports taken during monitoring associated with the Russian River Coho Salmon Captive Broodstock Program.

The CDFW habitat and biological inventories were conducted in the summers of 1995 and 1996 in Mill, Felta, Palmer, Wallace and Angel Creeks. The inventories included evaluations of the abundance and distribution of fish and other aquatic species with an emphasis on anadromous salmonids. Surveys indicated that Central California Coast (CCC) steelhead (*Oncorhynchus mykiss*), CCC coho salmon (*O. kisutch*), and California Coastal (CC) Chinook salmon (*O. tshawytscha)* have all occurred within the Mill Creek watershed and its tributaries (Table 2.3). Steelhead were found in Mill, Felta and Palmer Creeks but not in Wallace Creek. Coho juveniles and Chinook spawners were found in Felta and Mill Creeks. In both streams, coho were far less abundant than steelhead.

Table 2.3 Summary of survey data collected by CDFW in the Mill Creek watershed. Data from CDFW stream inventory reports for Felta, Mill, Palmer and Wallace Creeks (CDFG, 2006).

Tributary	Year	Agency	Juvenile	Adult
Felta	1968	CDFW	SH	
	1995/1996		SH, SS	KS
Mill	1957, 1973, 1982	CDFW	SH	
	1995		SH, SS, KS	KS
	1996			KS, SH
Palmer	1995	CDFW	SH	
Wallace	1968	CDFW	SH	No surveys
	1995		SH	No surveys

Key: SH-steelhead, SS-silver salmon or coho salmon and KS-king salmon or Chinook salmon

To supplement declining wild populations of salmonids, hatchery-raised fish have been introduced into the Mill Creek watershed. Hatchery raised steelhead fingerlings were added in 1982-1984 and 1986 and transplanted from Dry Creek into Mill Creek in 1958 (CDFW 2006). Coho have been released into Mill, Felta, and Palmer creeks by the Russian River Coho Salmon Broodstock Program (RRCSCBP) (see Table 2.4).

Under the RRCSCBP, offspring of wild captive-reared coho salmon, reared at the Don Clausen Fish Hatchery at Warm Springs Dam, are released as juveniles into tributaries within their historic range so that they might return to the streams as adults and spawn naturally. Felta Creek is one of three source streams where wild juvenile coho have been captured since 2001. These juveniles have been released into nineteen tributaries in the Russian River basin including Mill, Felta, and Palmer Creeks (SCWA 2012). These sites were selected based on habitat suitability, minimal land use threats, cooperative landowners, and high potential for successful monitoring and evaluation (Obedzinski et al. 2008). RRCSCBP has monitored stream conditions in Mill, Felta, and Palmer creeks since 2005. Specific monitoring objectives include estimating seasonal instream abundance and survival of spring and fall-released coho, estimating adult return rates and juvenile to adult survival rates, measuring coho size and condition, and documenting food availability, baseline flow, and temperature regimes (Obedzinski et al. 2008). Results of monitoring data have been summarized in annual broodstock program reports from 2004-2011 and newsletters intended for a wider audience were released in 2005, 2006, 2010, and 2011. All reports and newsletters can be found at http://groups.ucanr.org/RRCSCBP/.

Table 2.4. Excerpted from Table 1: *Number of coho released into Russian River tributaries by the RRCSCBP in spring and fall of 2004-2013* (Bauer et al. 2013).

Tributary	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Mill	Spring	0	0	5297	8038	6046	825	1648	1014	1032	N/A
	Fall	3433	4399	6302	25154	28568	27992	28654	25014	16040	N/A
	Smolt	0	0	0	0	2996	5411	5952	5905	N/A	N/A
Felta	Spring	0	0	0	0	0	0	0	0	0	0
	Fall	0	0	0	0	0	0	0	0	0	0
Wallace	Spring	0	0	0	0	0	0	0	0	0	0
	Fall	0	0	0	0	0	0	0	0	0	0
Palmer	Spring	0	2466	2102	3967	4023	821	824	7059	7045	N/A
	Fall	0	1920	3021	3880	4000	4141	6092	0	0	N/A
	Smolt	0	0	0	0	999	2131	0	0	N/A	N/A

Salmonid Habitat

The sustainability of salmonid populations in the Russian River watershed depends upon a variety of factors, including habitat conditions. During each life stage, an individual salmonid requires a specific set of environmental conditions to succeed. Essential habitat requirements are known as "limiting factors." Limiting factors are defined as environmental conditions that, if at sub-optimal levels, will prevent an organism from reaching its full biotic potential. Anadromous steelhead and coho salmon have specific habitat requirements for each of their lifestages (i.e. clean, well-aerated gravels for spawning and hatching; deep, well-shaded pools for rearing and resting; and unimpeded channels for migration). Other requirements include adequate supplies of cool, clean, oxygenated water and food. Degradation of one or more of the salmonid habitat factors can lead to population stress and eventual localized extinction.

Information on habitat conditions in the Mill Creek watershed comes primarily from CDFW stream inventories conducted in the summer of 1995. These inventories were completed following the methodology presented in the “California Salmonid Stream Habitat Restoration Manual” (Flosi et al. 2004).

California Department of Fish and Wildlife Stream Survey Reports

Along with fish population surveys, CDFW staff conducted habitat inventories in Mill, Felta, Palmer, Wallace and Angel Creeks. The objective of the habitat inventories was to document the amount and condition of available habitat to fish and other aquatic species with an emphasis on anadromous salmonids. Inventories concluded that, in general, Mill Creek and its tributaries were considered to have good salmonid habitat excluding Wallace Creek which was considered “marginal.” It was recommended that all be managed as anadromous natural production streams. Specific limiting factors and enhancement opportunities were identified in the CDFW reports and are summarized in Chapter 5. Complete stream inventory reports are included in Appendix E.

Sonoma Resource Conservation District

Mill Creek Watershed Management Plan

SECTION 2.

MANAGEMENT AND RECOMMENDATIONS

CHAPTER 3. AGRICULTURAL AND RURAL SUSTAINABILITY

Land use cover and associated activities have been described in, *Section 1, Chapter 2. Historical and Current Conditions.* Chapter 3 presents a background, resource concerns and recommended actions associated with the two large land uses in the Mill Creek watershed – agriculture and rural residential.

AGRICULTURAL SUSTAINABILITY

Approximately 40% of the Mill Creek watershed is in agricultural land use (see *Map 2.3, Land Uses-Historic and Current*) (CDFFP and USDA Forest Service 2002). Rangeland grazing and vineyards are the primary agricultural pursuits in this watershed. These activities generally occur at lower elevations. Throughout the county, smaller farms on parcels from two to 10 acres are increasingly important economically. Grape production is one of a few crops that provide enough revenue to support small-scale farming operations (Sonoma County PRMD 2008).

Sonoma County ranks 6th in the state and 34th in the nation in agricultural productivity; the county recognizes that agriculture is an important economic, social, and historic resource and has taken measures to protect it (Sonoma County PRMD 2008). The Sonoma County General Plan 2020 (Sonoma County PRMD 2008) contains an Agricultural Resources Element (Element) that provides "policies, programs and measures that promote and protect the current and future needs of the agricultural industry." These provide guidelines for land use and other decisions in agricultural areas to protect existing agricultural practices. It also provides policies to assist in marketing and promotion of agricultural products and provide fair conditions for farm laborers.

The concept of sustainability is based upon the principle that management activities should meet the needs of the present without compromising future generations' ability to meet their needs. Agricultural sustainability incorporates three main goals: preservation of environmental systems and processes, economic profitability, and social and economic equity. Stewardship of both natural and human resources is important. Stewardship of natural resources includes preservation and rehabilitation of ecological processes such as groundwater recharge, pollutant sequestration, pollination services, and nutrient sequestration. Stewardship of human resources includes social concerns such as health and housing conditions for laborers, the needs of rural communities, and long-term consumer health and safety. Many agricultural enterprises throughout the county practice stewardship of natural and human resources. Such activities include unpaved roads maintenance and repair, riparian revegetation, and provision of agricultural employee housing. Conservation easements are a means toward sustainability involving natural and human resources – they preserve ecological processes while supporting the area's agricultural heritage. Private conservation easements are identified in the Sonoma County General Plan 2020 as a mechanism for natural resource and agricultural lands preservation and enhancement in several General Plan policies (Sonoma County PRMD 2008). Conservation easements can be acquired through Williamson Act[1] contracts or through purchase. Williamson Act contracts involve the landowner agreeing to maintain land in agricultural or open space condition in exchange for reductions in tax obligations. About 300,000 acres of agricultural land are under Williamson Act contracts with almost 300,000 acres in fee title easements (Sonoma County PRMD 2008). Efforts to increase economic sustainability include local farmers' markets and development of specialty and niche products, such as organic crops and processed products. Organic farming increased in Sonoma County from 2012 to 2014; commodities produced included fruits, vegetables, wine-grapes, meats, grain, and eggs (Sonoma County Department of Agriculture 2015). Sustainability practices such as organic growing can provide financial gain. Not only do sustainable agricultural practices reap long-term local benefit, they also contribute toward implementation of statewide goals and programs. Implementation of sediment-control, water conservation, and other BMPs contributes toward attainment of Total Maximum Daily Load (TMDLs) allocations for sedimentation, temperature, and nutrients. Sustainable agricultural practices also contribute toward achievement of goals in the North Coast Regional Water Quality Control Board Watershed Management Initiative Chapter, the California Water Plan, the California Department of Fish and Game Coho Recovery Plan, the North Coast Integrated Regional Water Management Plan, and the Sonoma County Climate Action Plan.

Agricultural Best Management Practices

All Agricultural BMPs support one or more aspect of agricultural sustainability. BMPs for vineyard and ranching operations such as those in the Mill Creek watershed include irrigation water management, spring frost protection, development and implementation of nutrient management plans, cover cropping, prescribed grazing, riparian fencing, riparian re-vegetation (see *recommendation in Chapter 6*), and erosion control and road related sediment source assessment and sediment reduction projects (see *recommendation is Chapter 7*).

RECOMMENDED ACTIONS

Recommendation ARS1 – Implement agricultural and rural best management practices to prevent soil erosion and enhance soil quality.

Recommendation ARS2 – Improve water use efficiency of irrigation and frost protection systems. Explore alternative water sources for these uses.

Recommendation ARS3 – Manage grazing to protect and enhance soil quality, plant communities and water quality.

The table below describes several sources for BMPs that have widespread acceptance and local applicability. Many of these management activities are supported through funding assistance from agencies such as the NCRS, CDFW, SWRCB, DWR and the Sonoma County Energy Independence Program.

[1] The California Land Conservation Act of 1965--commonly referred to as the Williamson Act--enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. In return, landowners receive property tax assessments which are much lower than normal because they are based upon farming and open space uses as opposed to full market value. Local governments receive an annual subvention of forgone property tax revenues from the state via the Open Space Subvention Act of 1971.

Table 3.1. Resources for Agricultural Management Measures.

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. Section III contains information on Conservation Management Systems, which establish standards for sustained use. Detailed information about conservation practices is available in Section IV.	All aspects of agricultural operations – extensive list of irrigation water management measures.	http://efotg.nrcs.usda.gov
LandSmart	This regional conservation program helps land managers and land owners meet their natural resource goals while supporting productive lands and thriving streams through LandSmart plans and on-the-ground beneficial management practice implementation.	All aspects of agricultural operations.	www.LandSmart.org
Groundwork – A Handbook For Small Scale Erosion Control in Coastal California, 2nd Edition	A comprehensive resource detailing erosion control methods for rural and agricultural lands.	Erosion control	http://www.conservation.ca.gov/dlrp/RCD/Documents/Erosion%20Control/Groundwork_4-18.pdf
Handbook for Forest and Ranch Roads: A Guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads.	A comprehensive resource for planning, designing, constructing, reconstructing, maintaining and closing wildland roads.	Roads	http://mcrcd.org/wp-content/uploads/Handbook_for_Forest_Ranch&Rural_Roads.pdf
US EPA National Management Measures to Control Nonpoint Source Pollution from Agriculture	This technical guidance document contains information on the best available, economically achievable means of reducing agricultural sources of pollution to surface and ground water.	All aspects of agricultural operations – nutrient, pesticide, grazing, and irrigation water management, erosion and sediment control, and animal feeding operations.	http://water.epa.gov/polwaste/nps/agriculture/agmm_index.cfm
US Forest Service Pacific Southwest Region Water Quality Management for National Forest System Lands in California	This technical guidance document provides BMPs for timber management, road and building construction, mining, recreation, vegetation, fuels management, watershed management, and range management. Written from an agency perspective.	BMPs that address all aspects of USFS activities in California.	http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5362512.pdf

Resource	Description	Focus	URL
California State Water Resources Control Board Nonpoint Source (NPS) Pollution Control Program	Multi-tool website that contains a Management Practices Miner Tool, a Management Measures Encyclopedia, and NPS Guidance in Specific Interest Areas. The Miner Tool is a compendium of documented NPS pollution management practices collected from scientific texts, journals, web sites, grant projects, and presentations. The encyclopedia is a free online reference guide designed to facilitate understanding of NPS pollution control and provide quick access to resources available on the internet.	All aspects of agricultural operations including erosion and sediment control, animal waste, nutrient management, pest and weed management, grazing management, irrigation water management, groundwater protection, and education and outreach. Also contains management practices for Riparian Areas.	http://www.waterboards.ca.gov/water_issues/programs/nps/ http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/6_wtld_vts.shtml
Sonoma County University of California Cooperative Extension Farm & Ranch Stewardship Web Page	This web page contains several UC Agriculture and Natural Resources publications to reduce Nonpoint source pollution from agricultural operations.	Water quality management – NPS reduction, vegetative buffer strips, pesticide choice, greenhouse and nursery management.	http://cesonoma.ucanr.edu/Watershed_Management923/General_Watershed_Management_Information/Farm_-_Ranch_Stewardship/
Sonoma County Agricultural Division New Best Management Practices for Agricultural Erosion and Sediment Control Handbook Est. January 2010	BMPs presented in this document are specific to Sonoma County agricultural practices, soil types and weather conditions.	Control of water quality impacts from accelerated erosion from agricultural sources.	http://www.sonoma-county.org/agcomm/vesco.htm

RURAL RESIDENTIAL

Rural residential is a minor land use in the Mill Creek watershed with approximately 9% coverage. Rural residential development is associated with potential watershed impacts including sedimentation, nutrient and pesticide runoff, spread of invasive species, and water supply issues. However, management practices specific to the category "rural residential land use" have not been developed for Sonoma County. In lower reaches of Mill Creek, rural residential development is likely contributing to reductions in summer water supply and increased sedimentation (see *Chapter 2, Water resources, and Chapter 4, Water Conservation*). Many of the issues resulting from rural residential development are experienced in a more concentrated manner by urban areas – runoff, flood control, groundskeeping/chemical control, and onsite wastewater treatment systems. Therefore, much of the information about management measures to ameliorate conditions resulting from urbanization is applicable to rural residential land use, including water conservation measures.

An aspect of rural residential development not commonly found in urban areas is the construction, use, and maintenance of unpaved access roads. Roads are widely recognized as a significant source of sedimentation (see *Chapter 7, Sediment Sources and Impacts*). Management practices to reduce sedimentation from roads are available from many sources. The table below lists several sources for BMPs that have widespread acceptance and relevance to local rural residential issues.

Table 3.2. Resources for Rural Residential Management Measures.

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. The information is mostly intended for large landowners.	Natural resources conservation. Road and trail closure, habitat restoration.	http://efotg.nrcs.usda.gov
Slow it. Spread it. Sink it. Store it!	This document offers straightforward best management practices that can help to protect and replenish surface water and groundwater resources, offset groundwater use, reduce erosion and pollution, while providing many other benefits.	Beneficial stormwater management and water conservation.	http://www.sonomarcd.org/htm/rainwater.htm
USEPA National Management Measures to Control Nonpoint Source Pollution from Urban Areas	This document provides guidance regarding management measures to reduce nonpoint source pollution from urban activities.	This document provides implementation actions at the municipal scale.	http://water.epa.gov/polwaste/nps/urban/
USEPA Protecting Water Quality from Urban Runoff	This web page gives an overview of how individual dwellings impact a watershed and provides actions individuals can take to reduce NPS pollution.	Reducing NPS pollution through individual, municipal, and planning implementation activities.	http://water.epa.gov/polwaste/nps/urban_facts.cfm
California State Water Resources Control Board Nonpoint Source (NPS) Pollution Control Program	Multi-tool website that contains a Management Practices Miner Tool, a Management Measures Encyclopedia, and NPS Guidance in Specific Interest Areas. The Miner Tool is a compendium of documented NPS pollution management practices collected from scientific texts, journals, web sites, grant projects, and presentations. The encyclopedia is a free online reference guide designed to facilitate understanding of NPS pollution control and provide quick access to resources available on the internet.	*Urban areas* – most information is agency level, however individual homeowners will find useful information for landscaping and water management. *Forestry* – homeowners may find useful information regarding road construction, reconstruction, and management. *Education and Outreach* –describes specific practices on the individual household scale.	http://www.waterboards.ca.gov/water_issues/programs/nps/ http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/2_forest.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/3_3_edu.shtml

Resource	Description	Focus	URL
FishNet 4C Roads Manual	This document provides guidelines for county road maintenance to protect aquatic habitat and fisheries.	County road maintenance, some information applicable to homeowners.	http://www.marinwatersheds.org /documents/RoadsManual.pdf
Energy Independence A Sonoma County Program	This website provides suggestions for residential and commercial improvements to conserve water and energy.	Financial incentives for individual homeowners to implement water and energy saving measures.	http://www.sonomacountyenergy.org/
Marin County Stormwater Pollution Prevention Program Resources About Pesticides and Alternatives Web Page	This web page contains several publications that provide homeowner – level information about less-toxic pesticides, gardening, and water quality.	Reducing toxins in the environment, providing least-toxic pest management to homeowners and schools.	http://www.mcstoppp.org/pesticides .htm
House and Garden Audit: Protecting Your Family's Health and Improving the Environment, A Guidebook to Reducing Your Impacts on the Environment	"The House and Garden Audit is for all people interested in learning how to protect their health while improving the environment."	Reducing toxins in the environment through individual homeowner effort.	Book – Available through bookstores and online vendors
Less-Toxic Pest Management: Pesticides and Water Pollution.	This is an informative brochure about homeowner contributions to water quality impairments.	Provides tips for homeowner reduction of pesticide use.	http://ourwaterourworld.org/Portals/ 0/documents/pdf/PesticidesWQ.pdf

CHAPTER 4. WATER CONSERVATION

OVERVIEW OF WATER QUANTITY

Flow and hydrology conditions have been studied in Mill Creek for the last five years with the installation of seven streamflow gauges. These efforts have been made possible through the Russian River Coho Water Resources Partnership (Partnership) formed in 2009 and one of only two Keystone Initiatives in the State of California (refer to Appendix F, Map F-1). The goal of the Partnership is to develop a systematic approach to improve streamflow and water supply reliability for both fish and people. Mill Creek is one of five focus watersheds within the Russian River where the Partnership is working to implement innovative water conservation strategies in coordination with interested landowners within critical reaches of the watershed.

The Partnership's primary goals include:

Changing water management practices. Currently, many farmers and homeowners divert water from streams or from wells next to streams throughout spring, summer, and fall, when streams naturally recede to low levels. To protect coho, the Partnership works to find and implement water management solutions that include storing water when it is plentiful, in the winter rainy season, for use when water is scarce, in the summer.

Implementing habitat restoration and conservation projects. Physical activities can be undertaken to re-structure stream channels and riparian areas where alterations have had negative impacts on habitat value.

Population augmentation and monitoring. Because of the low number of coho currently in the Russian River watershed, the Partnership monitors critical broodstock populations to evaluate the success of stocking efforts to identify potential causes of mortality or survival.

Continued flow monitoring has provided critical data about understanding both the natural and anthropogenic influences of flow conditions. This flow monitoring has been coupled with monitoring salmonids within treatment and reference reaches[1] to better understand flow thresholds and how habitat, gradient and other factors affect flow conditions. Based on this understanding, the Partnership can identify actions to increase flow to levels that will improve conditions for salmonids and other aquatic species, while increasing water reliability for humans in the watershed as well.

It is the goal of the Partnership to identify solutions and methods for water conservation and water management that benefit landowners and work in the long term to improve flow to acceptable levels. In the Mill Creek watershed, improving low flow conditions is one of the most critical limiting factors to supporting sustainable populations of coho. This is especially true for the reach of Mill Creek from the confluence of Wallace Creek to Westside Road where much work has been completed to address fish passage and migration barriers and where there are evident water quantity and water quality concerns.

[1] The Partnership has selected treatment reaches—thought likely to be influenced by streamflow improvement projects—and reference reaches—thought unlikely to be influenced by projects—to conduct coho survival monitoring.

Through the Partnership, a Streamflow Improvement Plan (SIP) was completed in 2015 for the Mill Creek watershed, in order to analyze current surface hydrology conditions and regimes in the watershed. Six stream gauges deployed by the Partnership and an additional gauge installed by the State Water Resources Control Board have collected streamflow data in the past five years. Stage data was collected by pressure transducers at 15-minute intervals, and streamflow was measured at approximately monthly intervals beginning in water year 2010. Using measured streamflow values, rating curves were developed to correlate streamflow with stage data from each site. Stream gauge locations are shown in Figure 4 of the SIP, included in Appendix C.

Monitoring data collected in Mill Creek watershed have shown that flow during winter is punctuated by rainfall-driven high flow events, and that flow recedes through spring and summer eventually becoming intermittent. Streamflow decreases to below 0.5 ft^3/s (225 gallons per minute), even during a wet year, which indicates that winter peak flows are typically more than one thousand times higher than those of summer base flow.

The data suggests that many small diversions from the Mill Creek drainage network and adjacent shallow aquifers can cumulatively reduce streamflow. These effects may be most ecologically significant in the summer, when small diversions can cause flow reductions of as much as 50% and when cumulative effects of many small (i.e. residential) diversions may cause substantial reductions in flow. This data suggests that offsetting pumping for rural residential water use with rainwater catchment and off-stream storage, especially in areas with concentrated residential development, could significantly improve summer streamflows. Streamflow enhancement projects are based on the concept that modifying the timing of diversions from summer to winter, or reducing those diversions through the use of stored rainwater, can lead to increased summer base flows while also maintaining environmental flows in winter and providing water security for human needs.

Streamflow data also have provided a better understanding of where water conservation actions can be implemented to make needed changes in flow to improve key habitat areas. The precise benefit of restored streamflow in cubic feet per second for water storage projects is difficult to calculate without knowing the magnitude of diversion associated with current water management practices. However, we can generalize about how much water might be restored if water users are taking 10 gallons per minute (a typical pump rate) simultaneously from a stream reach. Ten houses pumping ten gallons per minute correspond to 1.67 gallons per second or 0.22 ft^3/s. This benefit in flow is approximately the same order of magnitude as measured streamflow in Mill Creek late in the dry season, suggesting that ten water storage projects could have a significant benefit on streamflow through the latter portion of the dry season.

The drought conditions experienced in 2012 – 2015 represent one of the three periods where below-average rainfall has been recorded for four or more consecutive years. The effect of drought is evident in streamflow data collected in the Mill Creek watershed, which show a substantial difference in discharge among wet years and dry years: wet years (2010, 2011) had greater base flow and sustained discharge through the year, while dry years often did not. With each sequential dry year, the data showed a noticeable decline in base flow and earlier onset of intermittence, with flow becoming intermittent in August of 2013 and 2014. Given the changes in rainfall patterns that are predicted in the coming decades (see SIP in Appendix C for details), off-stream storage projects will be critical for maintaining reliable water supplies for human water needs and for maintaining ecological processes in the Mill Creek watershed.

The Partnership will continue to collect streamflow data in Mill Creek to provide information on how fluctuations in streamflow may affect different parts of the watershed based on where they occur and other factors including geology, and the associated riparian habitat that can affect low flow conditions. Also, there is a growing need to understand the link between forest management and forest conditions with upland groundwater resources. Groundwater recharge in uplands areas is a critical component affecting flows during the dry season.

Along Mill Creek from Westside Road to the confluence of Dry Creek, the land is predominantly in agricultural production. Within this reach, there is a lack of understanding of the natural and anthropogenic causes that contribute to low flow conditions and major discontinuous pools during the dry season. The SIP recommends that a focused hydrological study be done in this lower reach of Mill Creek to better understand what habitat enhancement and resource conservation work can be done to make the needed improvements towards flow recovery.

Current data generated through the Partnership can be accessed and viewed through the following links:

- stream hydrology science, http://cohopartnership.org/hydrology.html
- streamflow data, http://cohopartnership.org/streamflow-data.html
- coho salmon monitoring data, http://cohopartnership.org/coho-monitoring.html

RECOMMENDED ACTIONS

Recommendation WC1 - Implement the recommendations of the Mill Creek Streamflow Improvement Plan

Recommendation WC2 - Develop and complete a hydrology study for the lower reach of Mill Creek (from Westside Road to Confluence of Dry Creek) to determine what habitat enhancement and conservation actions should be implemented to improve summer flows in that reach.

Recommendation WC3 - Outreach to landowners where multiple small diversions are impacting stream flows on a larger scale.

Recommendation WC4 - Develop and implement a rural residential roof water catchment program and demonstration project.

Recommendation WC5 – Provide resources to landowners on the benefits of restoring groundwater and methods for increasing groundwater recharge in uplands areas through small landowners meetings.

Recommendation WC6 - Outreach to landowners to determine if there are opportunities to increase water use efficiency or identify an alternative water source for these uses.

Recommendation WC7 - Outreach and work with foresters and landowners with forest land to help improve forest health and to better understand how upland forest conditions affect ground water recharge and flow regimes. Connect landowners with NRCS and CalFire with available educational and technical resources and cost share programs to implement beneficial practices.

CHAPTER 5. WATER QUALITY

OVERVIEW OF WATER QUALITY

Water quality refers to the physical, chemical and biological characteristics of water. Water quality information can be used to assess the safety of surface water for a variety of beneficial uses ranging from drinking water, contact recreation, and aquatic wildlife habitat requirements. Water quality is often framed in context of measureable concentrations of contaminants.

Water quality is determined and affected by a complex web of chemical, physical and biological processes. A wide range of human activities can affect water quality in ways that aren't always obviously related. The impacts to water quality from human activities in the surrounding watershed depend on the type of activity, its timing, location, duration and intensity. Each type of activity affects the watershed and may contribute pollutants to the stream system. The concentration of pollutants varies by season, by day, and sometimes from hour to hour. This can make it difficult to measure water quality and critical to build a data record over time to assess how different conditions affect water quality.

Temperature, for example, affects water chemistry and the functions of aquatic organisms. It has influences on the amount of oxygen that can be dissolved in water, the rate of photosynthesis by algae and other aquatic plants, the metabolic rates of organisms, and the sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction, migration, and aestivation of aquatic organisms.

Temperature is an important environmental factor for aquatic habitat and at times is the determining factor for species assemblages; as waterways that were historically cool become warmer, cold water fish can be replaced by species better suited to warmer conditions. Protection and restoration of the Cold Freshwater Habitat beneficial use is imperative to restoring coho and steelhead fisheries in the Mill Creek watershed, and the greater Russian River watershed. Salmonids are poikilothermic – (cold blooded) – animals, which mean that their body temperature is regulated by their environment. Temperature is an important factor in activity level and physiological processes at all stages of the salmonid life cycle; temperature requirements vary depending upon species and developmental stage. Timing of upstream migration is dependent upon flows and temperature; coho salmon enter the Russian River between November and January, with most spawning occurring in December. Steelhead enter the river between December and April, with most spawning occurring from January through March (Coey et al. 2002). Summer water temperatures are critical for the survival and health of all salmonid species that occur in the Mill Creek watershed. Additionally, temperature affects other aquatic organisms as well as influencing other characteristics of water, including dissolved oxygen (DO), and other physical and chemical characteristics.

Table 5.1. Water Temperature (°C) Criteria for Different Life Stages of Steelhead and Coho (Thompson and Larsen 2004, Coey et al. 2002, McEwan and Jackson 1996, KRIS Web 2011)

Adults				Juvenile Rearing		
Species	**Migration**	**Spawning**	**Incubation**	**Preferred**	**Optimum**	**Lethal**
Coho	4.44 – 9.44	4.39 – 9.39	4.39 – 13.28	11.78 – 14.61	9 – 15.6	26
Steelhead	7.78 – 11.11	3.89 – 9.39	8.89 – 11.11	7.28 – 15.56	10	24.11

Dissolved oxygen (DO) is the amount of oxygen gas present in water and available to aquatic organisms; it provides a good measure of general aquatic health. It is added to water through diffusion from air, turbulence, and photosynthesis of aquatic plants, and removed through respiration of aquatic organisms, decomposition of organic material, and other chemical reactions that use oxygen. Additionally, DO passes from the water to the air in response to changes in atmospheric pressure, temperature, or salinity; more oxygen can dissolve in cold water, under greater pressure, and at lower salinity. DO levels are extremely variable; they can change with time of day, weather, and temperature. Continuous dissolved oxygen monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, should be considered for future monitoring efforts, particularly during the summer and fall when temperature tends to be high and streamflow is low. Dissolved oxygen levels can range from 0–18 milligrams per liter (mg/l), but most aquatic ecosystems require at least 5–6 mg/L to support a diverse biological assemblage. When the concentration of DO is greatly reduced, the ability of gills to acquire oxygen for respiration is impaired, potentially leading to chronic effects such as reduced growth, increased susceptibility to disease, or reduced reproductive success.

Macroinvertebrate species sensitive to decreasing DO levels include mayfly nymphs, stonefly nymphs, caddisfly and beetle larvae, all which are a food source for salmonids. As DO levels decrease, these pollution-intolerant organisms are replaced by pollution-tolerant worms and fly larvae; a decrease in DO is usually an indication of an influx of organic pollutant (GRRCD, 2010). If DO concentrations fall below 3 to 4 mg/L, fish species such as salmon can experience physiological stress; however, many aquatic organisms can recover from short periods of low DO availability. The optimal DO level for salmonids is 9 mg/l with a level of 7-8 mg/l acceptable and 3.5-6 mg/l considered poor. DO levels below 3.5 mg/l are likely to be fatal to salmonids; levels below 3 mg/l are stressful to most vertebrates and other forms of aquatic life.

Water Quality Objectives from the North Coast Regional Water Quality Control Plan set minimum dissolved oxygen levels at 7.0 mg/l for the Russian River HU with 7.5 monthly mean (90% Lower Limit) and 10.0 monthly mean (50% Lower Limit) (NCRWQCB 2007). DO objectives were developed to protect the 5 beneficial uses related to the preservation and enhancement of fish: marine habitat (MAR), inland saline water habitat (SAL), warm freshwater habitat (WARM), cold freshwater habitat (COLD), and spawning, reproduction, and/or early development (SPWN).

Most water quality monitoring is conducted via grab sample and subsequent chemical analysis. Grab sampling takes a snapshot of the water quality conditions occurring at that particular spot at that particular time. Water quality sampling can be designed to take a number of instantaneous samples over time to examine trends in water quality, decline or improvement, and potentially catch a pollution event when it occurs. Water quality is only one piece of the puzzle of evaluating stream health. Many things can influence the health of a creek and its ability to sustain sensitive species.

Table 5.2.Partial list of habitat characteristics and their function in maintaining sensitive aquatic species, such as the highlighted anadromous salmonids. Adapted from NMFS, 2007.

Habitat	Characteristic	Function
Water quality	Temperature, dissolved oxygen, conductivity, chemical pollution	• Mortality • Growth • Toxicity/sub-lethal effects
Water quantity	Low flow, high velocity	• Mortality • Competition • Predation • Interactions with water quality (i.e. dilution)
Substrate quality	Sedimentation, substrate size	• Spawning • Incubation • Macroinvertebrate production
Geomorphology (i.e. pools and riffles)	Cover material (e.g. large woody debris, boulders), depth, gradient	• Flow refugia • Shelter from predators • Sediment traps and substrate sorting • Nutrient reservoirs • Macroinvertebrate production • Spawning • Oxygenation
Riparian corridor, extent and health	Canopy, vegetation type, vegetation amount	• Water temperature (shade) • Nutrient sources (invertebrate production • Source of large woody debris • Physical buffer and filter for sediment and chemical pollution from surrounding uplands

It is important to note that water quality analysis only provides information about the constituents analyzed for; it can only answer the questions that are asked. Due to the procedural difficulty (transport, holding times, etc.) and the expense of many analytical procedures, most water quality monitoring programs analyze for a few common chemical and physical parameters such as Temperature, pH, Dissolved Oxygen, Conductivity and concentrations of common pollutants of concern such as nutrients, pesticides, metals, oil and grease, etc.

Beneficial Uses for Surface Water

Beneficial uses describe existing and potential uses of water within a waterbody. The State and Regional water boards are responsible for designating and protecting these beneficial uses in all waters of the state. The Water Quality Control Plan for the North Coast Region (NCRWQCB 2007) designates the following existing beneficial uses for the Warm Springs Hydrologic Sub-area where Mill Creek watershed occurs.

Municipal and Domestic Supply (MUN) Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Agricultural Supply (AGR) Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Industrial Service Supply (IND) Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.

Groundwater Recharge (GWR) Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Freshwater Replenishment (FRSH) Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Navigation (NAV) Uses of water for shipping, travel, or other transportation by private, military or commercial vessels.

Hydropower Generation (POW) Uses of water for hydropower generation.

Water Contact Recreation (REC-1) Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white-water activities, fishing, or use of natural hot springs.

Non-Contact Water Recreation (REC-2) Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Commercial and Sport Fishing (COMM) Uses of water for commercial, recreational (sport) collection of fish, shellfish, or other aquatic organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Warm Freshwater Habitat (WARM) Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold Freshwater Habitat (COLD) Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Wildlife Habitat (WILD) Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Rare, Threatened, or Endangered Species (RARE) Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.

Migration of Aquatic Organisms (MIGR) Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

Spawning, Reproduction, and/or Early Development (SPWN) Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Aquaculture (AQUA) Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Potential beneficial uses may be designated for a number of reasons, including if that beneficial use existed prior to 1975 but does not currently exist, if there are plans to develop such a use, if existing water quality conditions do not support that use but could reasonably be improved to attain that use, or if there is insufficient information to show that the uses exists, but there is potential for the use to exist. The Basin Plan also designates the following potential beneficial uses for the Warm Springs Hydrologic Subarea:

Industrial Process Supply (PRO) Uses of water for industrial activities that depend primarily on water quality.

The Federal Clean water Act (CWA), Section 303(d), recognizes two types of water pollution: pollution discharged by *point sources* and pollution discharged by *nonpoint sources*. Point sources include water treatment plants, factories, and other "discernible confined discrete conveyances." Nonpoint source (NPS) pollution is dispersed throughout a watershed and includes pathogens, bacteria, metals, nutrients or pesticides delivered to water bodies in stormwater runoff. NPS pollution also includes sediment discharged to water bodies from roads, streambanks, gullies, and sheet and rill erosion. The insidious nature of nonpoint source pollution is that the individual pollutant contributions may be small, but their combined effects can significantly impact aquatic health. Identifying that a pollutant is present in a stream is the first step to identifying the source of the pollutant and the potential for stemming its input. The main mechanism for pollutants entering Mill Creek and its tributaries is through NPS inputs. NPS inputs are pollutants that arise from a number of places throughout a watershed. The insidious nature of nonpoint pollution is that the individual pollutant contributions may be small, but their combined effects can be significant. Despite the widespread concern over toxic substances in our streams, the leading pollution concerns in the Mill Creek watershed are sediment and increasing water temperatures. The cumulative effects of excessive amounts of these naturally occurring substances/conditions are exacerbated by the reduction in stream flows.

Table 5.3 Potential Sources of Sedimentation and Increased Water Temperature (NCRWQCB 2007)

Pollutant/Stressor	Potential Nonpoint Sources
Sediment/Siltation	Agriculture Irrigated Crop Production Specialty Crop Production Agriculture-storm runoff Agriculture-grazing Silviculture Construction/Land Development Highway/Road/Bridge Construction Land Development Hydromodification Channelization Dam Construction Upstream Impoundment Flow Regulation/Modification Habitat Modification Removal of Riparian Vegetation Streambank Modification/Destabilization Drainage/Filling of Wetlands Channel Erosion
Water Temperature	Hydromodification Upstream Impoundment Flow Regulation/Modification Habitat Modification Removal of Riparian Vegetation Streambank Modification/Destabilization Nonpoint Source

WATER QUALITY CONCERNS

Suitable water quality conditions are critical for the development, growth, and survival of all salmonid life stages. Steelhead and salmon need cool water temperatures, high dissolved oxygen, and low quantities of fine sediment for successful juvenile rearing and adult migration and spawning. The main source of water quality data availability in the Mill Creek watershed is collected during stream surveys and monitoring conducted by UCCE staff. In 2004, the UCCE and agency partners implemented a monitoring program to evaluate the effectiveness of the RRCSCBP stocking efforts to recover endangered salmonids that utilize the Mill Creek watershed for spawning. Mill Creek is one of five priority watersheds where the Partnership focused initial stocking and monitoring efforts. The work was designed to provide baseline data for evaluating the effects of coho survival, and to implement and/or expand monitoring efforts to include estimates of over-summer growth, movement, and survival of salmonids in priority streams in relation to environmental conditions such as flow and temperature. Estimates of monthly survival during the dry season were compared with measurements of flow, temperature, wetted volume, and dissolved oxygen. This chapter is a summary of the 2005-2014 temperature data (and dissolved oxygen in 2010) collected, under the Partnership's program, on coho program streams in order to document and compare patterns in temperature among stocking streams that sustain wild coho populations.

Summary of Water Quality Conditions Based on Measured Data

This section summarizes temperature data collected from existing water quality conditions in Mill Creek and its tributaries based on recent available data. Assessments of water quality conditions were recently conducted as part of the Partnership's study efforts. Factors influencing water temperature in the watershed include heat loading from direct sunlight due to lack of riparian vegetation, high turbidity levels due to high rates of sedimentation, and hydrologic disconnection with cold water inputs such as spring flows and seeps. Sediment deposition can cause pool infilling and channel aggradation, which results in shallower water with warmer temperatures as well as other habitat impacts. Human activities associated with sedimentation are discussed in the next section. The optimum summer temperature range for juvenile coho is 10° to 15°C (McMahon 1983). At water temperatures greater than 20° C, significant decreases in swimming speed and increases in mortality due to disease have been noted to occur (McMahon 1983). 25.8°C is the upper lethal limit for coho at all life stages (Raleigh et al 1984).

Since 2004, Onset Hobo Temp or Optic StowAway loggers have been deployed at various sites in Mill, Palmer, Felta, and Wallace. During the summer, temperature loggers were deployed in multiple reaches on each stream (between two and five loggers per stream) with the exception of Wallace and Felta which had one logger per stream. Temperature was recorded hourly at each station. This distribution of loggers enabled within-stream temperature comparisons during the summer survival period. Temperature loggers were deployed in the spring (April-June) and removed in the fall (October-November). Stream audits were performed three times over the summer season to download data and check that the instrumentation was functioning properly. At the downstream temperature (and flow) recording station on Mill Creek, temperature loggers were left in the streams year-round to record hourly temperature during all seasons. Continuous stream monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, of other water characteristics should be considered for future monitoring

In 2005, during the study period, running weekly average temperatures at lower reaches never fell below 10°C or above 19.7°C, and running weekly maximum temperatures never fell below 10.9°C or above 20.9°C. All creeks showed a similar pattern of increasing temperature from winter to late spring. Running weekly average temperatures were consistently high on Mill. Trends in running weekly maximum temperatures were similar to running weekly averages.

In 2006, stream temperatures were consistently warmer across monitored streams in 2006 than in 2005. Temperature in the monitored streams rises and falls according to an annual cycle. In the winter months temperatures are cool, approximately 10°C or cooler and warm in the summer to temperatures above 14°C. Winter temperatures, were generally similar. In contrast, there can be a wide range in summer stream temperatures between streams. This difference can be as great as 10°C for single temperature measurements. Documenting these differences in stream temperatures between streams and the duration of potential exposure of stocked coho to stress-related temperatures will increase the program's understanding of the variation in survival rates of spring stocked coho into these streams.

In general, average stream temperatures in 2007 between June 15 and October 15 were higher than 2005 averages and lower than 2006 averages with some variability among streams. At stream sites where data was collected in consecutive years from 2005 to 2007, maximum weekly average and maximum weekly maximum temperatures between June 15 and October 15 in 2007 were similar to values in 2005 and lower than values in 2006. In addition to annual variability, stream temperatures generally warm up in the downstream direction. However this was not consistent in Mill Creek, that may suggest that that there is influence of cooler tributaries and ground water that enters at various locations along the stream course.

In order to compare over-summer temperature among spring-release streams, a temperature monitoring site within the stocking reach was chosen for each stream. These sites were also chosen based on continuity of data collection since 2005 but are not necessarily consistent with respect to location in the stocking reach (e.g. Palmer site was high in the stocking reach). Despite these potential biases, consistently cooler running weekly average temperatures and running weekly maximum temperatures were observed each year in Palmer Creek, whereas temperatures were often highest at specific sites in Mill.

Temperatures in all reaches of Mill and Palmer Creeks remained relatively cool throughout the study period in 2010, with the warmest peaks in late June, late July, and late August**.** In all streams, average and maximum daily water temperatures observed in treatment reaches were higher than those observed in reference reaches. *Average* daily water temperatures in study reaches were below 20° C during the study period. Maximum daily temperatures reached the following highs in the reaches: 19.6° C in the Mill Creek treatment reach, 18.4° C in the Mill Creek reference reach, 18.0° C in the Palmer Creek reference reach.

DO measurements were also collected and recorded during the 2010 monitoring period. DO values were summarized at the reach scale. The average DO concentrations observed were above the Water Quality Objectives (WQOs) in the Mill reference reach, Palmer reference reach, and Mill treatment reach (refer to Appendix F, Table F-2).

Continuous temperature loggers were also deployed across the Mill Creek watershed by the Partnership between 2011 and 2014. Average temperatures observed in the watershed sampling locations were above the preferred range for coho salmon, but within the tolerance range, and within the suitable range for steelhead (see additional details in SIP, Appendix C). DO data collected between 2011 and 2014 indicated that average DO concentrations in the watershed reaches sampled met or exceeded the water quality objective of 7.0 mg/L (as a year-round daily minimum) defined by the North Coast Regional Water Quality Control Board for DO in the Mill Creek watershed. However, DO concentrations fell below the objective in August and October of 2013 and in August of 2014, when stream flows were extremely low.

Need for Water Quality Monitoring in Mill Creek watershed

Continued and enhanced monitoring will provide a more thorough understanding of current water quality conditions and establish additional reference data for comparison. Limited water quality monitoring has been conducted in the watershed since 2004, primarily by the UCCE. This historical data has been valuable when providing targets for management activities and projects.

Results from past monitoring in the Mill Creek watershed suggest that the water quality parameters measured, temperature and dissolved oxygen, meets WQO's for salmonid survival at different life stages.

However, summer months pose the greatest challenge for water quality, likely due to the low flow regime during that time. Low flow conditions result in less water volume available to dilute the concentration of pollutants or attenuate the high summer temperatures, both of which drastically affect the quality and availability of aquatic habitat. Temperature increases, low levels of DO, and an absence of habitat may limit survival of juvenile salmonids in the watershed. Because these factors are so closely related, efforts to increase summer flow are likely to have a beneficial effect on water temperature and DO concentrations.

Water Quality Goals

Promote and protect the Beneficial Uses of the watershed
Reduce nonpoint source sedimentation
Reduce summer water temperature and provide increased summer flows through a combination of off-stream storage and conservation practices

Chapter 7 discusses sedimentation in more detail. BMPs that support sustainable agriculture, improve road development and maintenance, and reduce the impact of rural residential development are discussed in detail in Chapter 3.

RECOMMENDED ACTIONS

The following are recommended components to continue ambient water quality monitoring with enhanced equipment at an increased number of sites:

Recommendation WQ1 - Measure parameters to include continuous stream discharge, temperature, DO, pH, Conductivity, TSS, and nutrients. Install temperature loggers in select sites through the summer months.

Recommendation WQ2 - Obtain instrumentation/lab facilities/funding to measure total suspended solids (TSS) during periods of high turbidity to determine duration of high turbidity. These measurements can be useful to calculate total quantities of material within or entering a stream system and are not possible with NTU measurements, as well as provide more information about potential impacts to aquatic wildlife.

Recommendation WQ3 - Conduct bioassessments as an indicator of aquatic habitat quality. Use benthic macroinvertebrate assemblages. Use algal communities in stream reaches where algae are consistently present, as an indicator of nutrient impacts to aquatic habitat quality.

Recommendation WQ4 - Implement Management Actions to decrease sediment loads. See Chapters 3 and 7.

Recommendation WQ5 - Implement Management Actions to decrease summer water temperatures, increase flow, and improve dissolved oxygen. See Chapters 4 and 6.

CHAPTER 6. INSTREAM AND RIPARIAN HABITAT

This chapter provides a description of the instream and riparian habitat conditions within the Mill Creek watershed. Characterization of habitat conditions was based primarily on recent reach-by-reach field observations (UCCE, DFW, SRCD), surveys (UCCE, DFW), and the 2012-2013 large woody material assessment (SRCD and Bey). The full assessment can be found in Appendix G. Maps providing locations of reaches and surveyed sites can be found in Appendix H.

Since the mid-1990s several phases of projects involving the placement of large wood structures for habitat enhancement have been completed in the Mill Creek watershed. In conversations with Mill Creek landowners over the course of the Plan development, multiple landowners expressed interest in better understanding the past placement of large wood in the creeks for habitat enhancement. As part of this Plan, the SRCD and Ryan Bey completed an assessment that included the status of past installations of these large wood structures. In this assessment of the past installations, care was taken to map existing structures, assess the effectiveness and stability of them, as well as note occurrence of mobility and displacement by flow.

The data and information collected in the CDFW Stream Inventory Reports of Mill Creek and its tributaries were utilized, among other resources, in the development of the instream and riparian habitat concerns and recommendations included in this chapter. Full reports of CDFW's stream inventories of each stream can be found in Appendix E. Maps providing locations of reaches referenced in the CDFW's stream inventories can be found in Appendix H.

The chapter discusses the management actions for instream and riparian habitat in general terms and prioritizes these actions based on the opportunities and constraints to implement them. In some instances, it was beyond the scope of this plan to develop site- or reach-specific projects or actions. The potential improvements and management activities are coordinated with the management activities for water conservation and sediment improvements in Chapters 3, 4, and 6, respectively.

FOCAL SPECIES AND HABITAT

Fish and other wildlife are key ecosystem components. Restoration of a fully functioning ecosystem with all its component elements is consistent with the Plan's goals for the Mill Creek watershed. Several listed species are found within the Mill Creek watershed. Among the endangered species is the *Oncorhynchus kisutch,* coho salmon. Threatened species that have been documented in the watershed include the *Rana draytonii,* CA red-legged frog, and the *Oncorhynchus mykiss,* the steelhead trout.

Instream and riparian habitat quality for each of these species vary throughout the Mill Creek watershed. Instream conditions such as food availability and temperature affect growth rates of salmonid within a stream and also between different streams (USFWS, 1983). High winter flows increase salmonid emigration and may effect smolt production (Giannico & Healy, 1998). Quantity of woody material and density of habitats are strongly linked to salmonid overwintering survival (Quinn & Peterson, 1996). Large wood material (LWM) directly improves fish habitat. It is especially effective in pools; a pool with significant amounts of large wood is preferred by salmonids over a pool without it. Submerged large wood with a rootwad attached provides especially good cover for fish. The presence of large wood in fast water areas such as riffles and rapids creates a physical barrier around which water must flow, thus reducing water velocity. Decomposition of large wood in the stream serves as an energy source for the growth of microorganisms, which in turn are fed upon by macroinvertebrates, the main food source for salmonid fry. Many macroinvertebrate species spend part of their life cycles on large wood substrate. Large accumulations of large wood can trap gravel and create new channels, especially during periods of high flow. This increases the diversity and complexity of fish habitat.

Riparian habitats are essential for healthy stream systems for aquatic species and to help maintain the viability of surrounding communities. Riparian habitats are the plant communities growing along a stream, river or other body of water and interface with land and water. Riparian habitats also interface with upland plant communities that play an important role in the health of the stream system and associated riparian habitat. Riparian corridors are made up of the riparian habitat and associated stream, river, creek and floodplain. In this Plan riparian corridors are used to describe the specific management area to implement practices to maintain and improve riparian functions and health (USDA 2011).

Healthy riparian corridors help reduce the adverse effects of flooding by allowing for increased changes in flow, reducing erosion, and improving stream bank protection. In addition riparian corridors improve water quality by reducing temperatures and filtering out excess nutrients from agricultural and urban runoff from entering the stream. Healthy riparian corridors, which provide key habitat to many different types of terrestrial plant and animal species, also provide a long term source of large wood material which is critical for salmonids and other aquatic species. Lastly, riparian corridors provide essential habitat linkages for wildlife movement.

RECOMMENDED ACTION

> **Recommendation FS1 —** Conduct surveys for species of concern, including but not limited to pond-breeding and stream-breeding amphibians throughout the watershed; and support on-going RRCSCBP monitoring and survey efforts of salmonid populations.

FISH PASSAGE

Habitat quality is influenced not only by the physical habitat available in a given reach of stream, but also the accessibility of that habitat to the aquatic species that use it. Natural stream features such as log jams, as well as man-made structures: dams, weirs, and culverts, are all instream barriers that potentially prevent or inhibit the natural movement of aquatic species. Maintaining conditions within the stream that provide hydrologic and structural barriers to fish habitat are limiting their recovery. Enhancing habitat will not benefit these species without free access.

Reach-by-reach field surveys and observations have identified that access upstream by anadromous salmonids has been significantly limited due to a flashboard dam located in the lower mainstem of Mill Creek. Adult coho and steelhead would have better access to the upper Mill Creek system, which includes excellent spawning and rearing habitat and is less susceptible to drying out in drought years, if the flashboard dam barrier was made passable. This alteration is important to the long term reestablishment of a self-sustaining coho salmon population in the Mill Creek watershed. There are a few other locations that become barriers during low flow conditions in the mainstem of Mill Creek due to high gradient and drop offs, i.e, a natural falls just below the dam, a high gradient section upstream of the waterfall, and log jams further upstream. Additionally, there is potential for fish passage issues at the Mill Creek Road bridge over Wallace Creek in lower flows, however, adult salmonids would have little trouble passing in normal winter flows. (Bauer et al, 2013). It is recommended that a fish passage study be completed throughout the Mill Creek watershed. The evaluation of potential impediments to fish passage should be based on features such as length, water velocity, slope, depth, jump height and pool depth for culverts, and features such as downstream pool depth and waterfall length for dams and weirs.

Recommended Action

Recommendation FP1 — Remove major barriers to fish migration in the watershed.

Instream Habitat Conditions and Concerns

Large Wood Assessment, 2012-2013

In 2012- 2013, a large wood assessment was conducted over five study reaches (Map 4). The study reaches were Mill Creek to Puccioni Road Bridge (hereafter known as Mill Creek reach), Palmer Creek to the confluence with Mill Creek (Palmer Creek reach), and Felta Creek: F1a, F1b, and F2. The total length of all five study reaches was approximately 4.4 kilometers (2.7 miles). Assessment reaches were selected by landowner accessibility. All contained naturally occurring wood, and previously installed LWM by the CDFW and SCWA. Wherever present within each reach, data on wood, pools and recruitment were gathered. A hand-held Trimble was used to geo-reference each location where data was collected which then was entered into the mapping program ArcGIS for analysis. Data gathering commenced at a pre-determined downstream location and terminated at a pre-determined up-stream location.

The assessment focused on salmonid habitat in the low-flow dry period, the season prior to consistent winter rains typical of Northern California climate. Naturally occurring pieces of wood touching low-flow creek water were measured and counted. Pieces suspended above low-flow creek water were not assessed, with the exception of all previously installed LWM. Assessment of the CDFW/SCWA-installed LWM, involved recording current functioning status, and length and diameter measurements of each piece. All previously installed LWM structures were assessed within the selected reaches regardless of placement and/or designed as low-flow or high-flow structures. Large wood installed by CDFW/SCWA was identified by the use of attachment cables and bolts (Figure 1 in Appendix G) and by metal identification tags secured to living trees on either bank.

At each potential LWM site, the assessment consisted of several steps. Large wood was immediately classified as either naturally occurring, intentionally installed or a combination of both, typically at a debris jam. The diameter and length of pieces meeting or exceeding the 30.5 cm (12”) diameter and 1.8 m (6’) length criteria established by Flosi *et al*., (1998) were recorded. A diameter at breast height (DBH) tape and measuring tape were used to measure diameter and length, respectively. Diameter measurement was taken at the midpoint of the piece. The total number of qualifying pieces was recorded. Each LWM occurrence was geo-referenced using a hand-held Trimble. Large wood pieces were identified and classified as either conifer or hardwood. The presence of small woody material (SWM) was also noted if present. SWM were not measured or counted. To assess current functioning status of CDFW/SCWA-installed LWM functioning criteria was considered i.e. if the piece was still properly attached, if it had moved or was currently mobile, if the piece was broken and/or decaying, if a pool attributable to the

LWM was present, and if the piece still met the accepted LWM length and diameter criteria established by Flosi *et al*. (1998). These criteria were recorded for analysis.

Within the four reaches, any pool with a residual pool depth equal-to or greater-than 30.5cm (1 foot) were measured, recorded and geo-referenced using a hand-held Trimble. Residual pool depth reflects the low-flow conditions of the stream and is independent of stream discharge (Lisle, 1987). It is calculated by subtracting the pool tail crest from the maximum pool depth of the entire pool system. Pools and pool tail crests were measured using a stadia rod. Wherever possible, the structure or agent resulting in pool formation was/were determined and recorded. Structures included LWM, boulders, or a combination. The type of pool was also recorded, wherever possible. Types of pool include boulder-, root wad-, bedrock- and log-enhanced lateral scour pool. Creek bed materials were also noted and classified as either bedrock, very large, double-head or single head-size boulders, large, medium, small or fine gravel or silt.

A visual assessment of left and right banks was conducted. This served to identify causes of LWM recruitment not only at that particular site, but also to establish an overall assessment of the dominant recruitment method(s) in the watershed, a particular creek or a designated reach. Recruitment methods included bank slides, bank undercut, intentional placement, other causes or a combination of the aforementioned. In an effort to better understand LWM recruitment outside and beyond creek banks, any other factors affecting LWM recruitment were also recorded. Examples include roads, bridges, buildings, railroads, and predominant land use.

Surrounding predominant land-use was noted and classified as agriculture, livestock, dairy, forestry, agriculture, other, or a combination. Land ownership was also reported and classified as private, public or other. Any easements attached to the land were also noted (Bey, 2013).

Results of 2012-2013 Mill Creek watershed Large Wood Assessment

The total length of all creeks surveyed was approximately 4.4 km (2.7 miles). Mill Creek reach sampling commenced at the confluence of Palmer Creek, terminated at the Puccioni Road Bridge, and was approximately 2 km (1.25 miles) in length. Palmer Creek reach sampling terminated at its confluence with Mill Creek and was 914 m (3,000 feet) in length. Felta Creek (F1a & F1b) sample reach consisted of two sub-reaches, totaling approximately 335 m (1,100 ft). Felta Creek F1a commenced and terminated on a single land-owners property. F1b ran through multiple properties and terminated at the Felta Road bridge. Felta F2 sample reach was entirely in a single landowner’s property and was approximately 1,103 m (3,620 ft). See LWM Assessment maps in Appendix H.

The predominant land uses throughout the survey are were small-scale timber production and agriculture, predominantly grape growing. The dominant cover throughout is a mixture of conifer and hardwood, including Douglas fir (*Pseudotsuga menziesii*), Coast redwoods (*Sequoia sempervirens*), California bay laurel (*Umbellularia californica*) and alders (*Alnus spp*.).

Large wood was sampled at 57 sites. These sites comprised 38 natural LWM sites, 16 CDFW/SCWA-installed sites and three combination natural and CDFW/SCWA -installed sites, together consisting of 125 pieces of wood. Rootwads were present at 23 sites. The mean diameter of all measured wood was 41 cm (16 in), ± 17.5 cm (7 in) and the mean length was 7 m (23 feet), ± 4.1 m (13.6 ft).

The overall functioning effectiveness of CDFW/SCWA installed LWM is mixed. Mill, Palmer and Felta (F1a & b) reaches contained CDFW/SCWA -installed pieces of LWM that no longer qualified as LWM. The diameter of these pieces was less than the minimum requirement of 30.5 cm (12 in). In Palmer Creek, a piece of LWM suspended over low-flow water (not measured for statistical analysis) had snapped into two pieces due to decay. In Felta (F1a & b) a structure consisting of four pieces of LWM cabled and bolted together, and anchored to the bank, had separated completely with pieces now lying on either side of the creek. At a different site in the same reach, a piece of LWM lay disconnected, 12 m (40 ft) away from the original structure. However, the effectiveness of installed LWM creating pools reveals different results.

Eighty-nine pools in all five reaches were sampled. The mean depth was 61 cm (2 ft) and the standard deviation was 24cm (9.5 in). The deepest pool measured was 111 cm (3 ft 8 in). Forty-nine pools (55.1%) had a residual depth greater-than or equal-to 30.5 cm (1 ft) but less than 61 cm (2 ft), 27 pools (30.3%) had a residual depth of greater-than or equal-to 61 cm (2 ft) but less than 91.5 cm (3 ft) and 13 pools had a residual depth greater-than or equal to 91.5 cm (3 ft).

A comparison of the mean RPD of pools associated with CDFW/SCWA LWM (single and multiple pieces and attached to boulders) and naturally occurring LWM in all reaches indicates that installed LWM is functioning like naturally occurring LWM. The mean RPD of all types of installed LWM (single and multiple pieces, combinations of installed and natural pieces and structures containing CDFW/SCWA wood and boulders) is 67 cm (2 ft 2in). The mean residual depth of all sampled pools associated with naturally occurring LWM is (2 ft 1in) and the mean residual depth of pools containing rootwads is 65 cm (2 ft 2 in). These data suggest that CDFW/SCWA LWM, whether installed with just CDFW/SCWA wood, a combination of CDFW/SCWA and naturally occurring wood, or using a combination of wood attached to boulders, is functioning as well as naturally occurring LWM and rootwads. However, over time CDFW/SCWA -installed pieces are decaying. It is unclear if they will continue to function by replicating natural structures as they continue to decay.

Throughout the sampled sections, the creek bed material ranges from silt and sand to gravel of assorted sizes. All creeks contain boulders of varying sizes, but Palmer Creek contains some noticeably large boulders constricting creek flow. Felta (F1a and b) contains several boulder weirs, unlike the other sampled reaches. Scour pools are the predominant pool type throughout the watershed. The majority of pools are log-, rootwad-, boulder- and bedrock-enhanced scour pools.

Large wood recruitment opportunities throughout the sampled reaches are mixed. A significant inhibitor of large wood in Mill Creek is the presence of Mill Creek Road. Used primarily by homeowners in the watershed, this paved road serves as the major access artery in and out of the valley. The importance of this road limits the potential for LWM recruitment as falling wood would quickly be cut and cleared, ensuring the road remains open to traffic. Felta Creek Road, although smaller, acts similarly and appears to be impacting LWM recruitment. Palmer and Felta (F2) do not suffer the same recruitment limitations as Mill and Felta (F1a and b). Other factors influencing recruitment are selective timber harvesting adjacent to Mill, Palmer and Felta (F2) Creeks, and grape growing within the sampled reaches is predominantly adjacent to Felta (F1a and b) Creek. Clearing of stands to make way for agriculture continues to impact LWM recruitment, especially where natural buffers between areas under cultivation and creeks are narrow. Land-ownership throughout the watershed is private, potentially reducing protection of future LWM sources.

Summary of CDFW Stream Reports and Current Observations for Instream Habitat

Mill Creek

In general, Reach 1 (See map in Appendix E) has good spawning habitat however, rearing habitat is limited and much of the reach dries up in most years. More deep pools with adequate shelter and cooler summer temperatures are needed. The unstable banks and effects of channelization downstream of the Westside Rd bridge limits instream habitat improvement alternatives, although some opportunity exists upstream. In reach 2, rearing habitat is much better, although few riffle habitat exists for spawning due to the boulder section, and what does exist is unsuitable for spawning due to high gravel embeddedness. Reach 3 has only fair rearing and spawning habitat. Upstream of the Wallace Creek confluence, conditions are better. In reaches 4 and 5, spawning and rearing habitat exists, canopy shading is higher, although instream shelter is still lacking and stream bank erosion is prevalent due to poor road maintenance, the lack of large woody debris, and high stream velocities. However, many opportunities and alternatives exist for habitat improvement due to the stable channel types. Upslope land use practices such as logging and vineyards on steep slopes have impacted spawning gravels and decreased pool volume in the upper reaches. Additionally, these upstream effects seriously impact spawning resources downstream in lower gradient reaches (4 and 5). Channel incision in Reach 8 has occurred due to the dams cutting off gravel supply. Structures to offset channel downcutting and recruit gravel for spawning, are recommended.

Boyd Creek, Angel Creek and Coldwater Gulch are smaller tributaries of Mill Creek. Boyd Creek was surveyed by CDFG in 1996 and is included in the Mill Creek Stream Inventory Report.

Limiting Factors:

Gravel/Cobble embeddedness in fine sediment
Loss of instream structure and shelter
Loss of pools and pool habitat

Instream Habitat Enhancement Opportunities:

Monitor fish passage at lower falls
Increase woody cover in the pool and flatwater habitats along the entire length of the stream. This must be done where banks are stable as in reaches 2-7 or in conjunction with stream bank armor to prevent erosion reaches 1, 8 and 3.
Reach 7 would benefit from bank-placed boulders single and opposing wing-deflectors.
Reaches 3 and 7 are excellent for many types of low and medium stage instream enhancement structures. Many site specific projects can designed to increase pool frequency, volume and shelter.

Overall results of the survey in Boyd Creek showed salmonid habitat was impacted due to elevated stream temperatures and embeddedness ratings in pool tailouts, and low shelter ratings. It was recommended to install structures to offset channel downcutting and to recruit gravel.

Felta Creek

Overall, habitat conditions for both steelhead and coho throughout the Russian River basin have declined over time. However, of the Russian River tributaries surveyed so far since 1994, Felta Creek is in the best condition for salmonid habitat. In general, reaches 2-4 of Felta Creek (See map in Appendix E) are fair for salmon and steelhead habitat. The many scour pools may be used as rearing habitat, however, shelter is lacking and stream temperatures are moderately high. Riffle habitat exists for spawning, but some reaches have high gravel embeddedness. The intermittent flow of reach 1 and boulder section of reach 2 limits instream habitat improvement alternatives, although some opportunity exists. Any work considered in reaches 1 and 2 will require careful design, placement, and construction that must include protection for the adjacent road and high stream velocities. Log cover structures could be used to increase instream shelter.

Upstream of the Boring's bridge, conditions are better. In reaches 3 and 4, spawning and rearing habitat exists and canopy shading is high overall, although some areas have no canopy at all. However, instream shelter is still low, stream temperatures are higher and stream bank erosion is prevalent due to past logging roads. Opportunities for improvement with Reach 3 are minimal due to unstable banks. Reach 4 is excellent for many types of low and medium stage instream enhancement structures and many opportunities and alternatives exist for habitat improvement due to the more stable channel type. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and shelter.

The best spawning habitat in the watershed exists within reaches 3 and 4, and within Salt Creek. Down-stream in Reach 1 and 2 spawning and rearing habitat quality diminishes due to the effects of eroding stream banks and high energy of the boulder section 16 respectively. Sediment transported downstream from stored sediments in reach 4 during high winter flows impact the spawning habitat in lower gradient reaches below. Erosion control riparian planting is recommended.

Limiting Factors:

- Elevated stream temperatures
- Gravel/Cobble embeddedness in fine sediment
- Loss of pool habitat
- Loss of instream structure and shelter

Instream Habitat Enhancement Opportunities:

- Where feasible, design and engineer pool enhancement structures to increase the number of pools. This must be done to where banks are stable (reaches 1, 3, and 4) or in conjunction with stream bank armor to prevent erosion.
- Where feasible increase woody cover in the pool and flatwater habitats along the entire stream. Add high quality complexity with larger woody cover. Cover/scour structures constructed with boulders and woody debris would be effective in flatwater and pool locations. This should be done where banks are stable (Reach 4) or in conjunction with stream bank armor to prevent erosion.
- Fish passage should be monitored in Reach 2 where access for migrating salmon has been identified as a concern.

Structures to recruit spawning gravel should be installed to trap, sort and expand red distribution in the stream especially in reach 3 below Folger's bridge and in reach 4 above the Salt Creek confluence.

Salt Creek, a small tributary to Felta Creek, was also surveyed in 1995. Results of the survey indicated loss of pool habitat, low shelter ratings over riffles and elevated cobble embeddedness. It was recommended to enhance log and root wad cover.

Palmer Creek

In general, Palmer Creek is good for steelhead habitat. There are abundant pools with adequate depth but little shelter. Although 12 riffle habitat exists, some of it is impacted from sediment, which increases in an upstream direction. The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water that is able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence. Shade canopy and riparian vegetation are good in Palmer Creek. If the riparian zone is undisturbed, eventually steelhead habitat will improve due to new recruitment of large woody debris into the stream. Since this process may take many decades, and salmonid populations are dwindling quickly, it is advisable to improve conditions with instream structures.

Limiting Factors:

Elevated stream temperatures

Gravel/Cobble embeddedness in fine sediment

Instream Habitat Enhancement Opportunities:

Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream.

Adding high quality complexity with larger woody cover is desirable.

Where feasible, design and engineer pool enhancement structures to increase the number of pools in all reaches.

Wallace Creek

In general, Wallace Creek is marginal for salmonid habitat. Although the existing pools are relatively deep, more pools and better pool shelter is needed. Even though canopy levels are fair, water temperatures are close to the threshold stress level for salmonids. Although there is an adequate amount of gravel in the riffle habitats, this gravel is highly embedded, making it poor for spawning salmonids.

Limiting Factors:

Loss of pools

Loss of pool shelter

Elevated stream temperatures

Gravel/Cobble embeddedness in fine sediment

Instream Habitat Enhancement Opportunities:

Where feasible, increase woody cover in the pool and flatwater habitats along the entire system.

Where feasible design and engineer pool enhancement structures to increase the number of pools.

Angel Creek

In general, Angel Creek is fair for steelhead habitat. There are relatively few pools with adequate depth and shelter. Although riffle habitat exists, much of it is impacted from sediment, making it marginal for spawning. Shade canopy is good on Angel Creek, although it mostly consists of younger trees.

Summary of Streamflow Improvement Plan Observations for Instream Habitat and Conditions

Habitat quality and conditions were evaluated as part of the Streamflow Improvement Plan (see Appendix C). A key finding of the study was that juvenile coho were able to persist at extremely low surface flows in Mill Creek (see Figures 32 – 37 in SIP). The data collected indicate that pool connectivity is a key factor in survival of juvenile coho during the summer season with coho surviving at flows below 0.5 ft^3/s, as long as pools remained connected. These findings suggest that stream flow improvement plans designed to benefit salmonid populations should support efforts that will, at a minimum, keep pools connected.

Since survival of salmonids to the adult stage is positively correlated with smolt size, increased growth in the stream environment can increase chances of fish returning as adults to spawn. Flow has been positively correlated with production of benthic macroinvertebrates (BMI), which are a primary food source for rearing juvenile salmon. Based on the findings in the SIP and prior research, the data suggests that increasing summer velocities beyond minimum persistence flows would likely promote higher growth of juvenile salmon and, in turn, more adults returning to spawn.

RECOMMENDED ACTIONS

Recommendation IH1 – Continue assessing all large wood previously installed through the CDFW/SCWA projects as well as naturally occurring pieces, and complete a more extensive watershed-wide large wood survey.

Recommendation IH2 — Provide resources to landowners about large wood in streams, and develop and implement instream enhancement projects in areas of Mill, Felta, Palmer and Wallace creeks with less than adequate cover and scour for anadromous species.

Recommendation IH3 — Assess presence and quality of decaying, or soon-to-decay, wood, snags, and downed wood to protect streambank features and to potentially increase their abundance and functionality.

Recommendation IH4 — Work with landowners to maintain existing large wood in the stream and repair failures of installed large wood structures watershed-wide.

RIPARIAN HABITAT CONDITIONS AND CONCERNS

In the Mill Creek watershed, the riparian habitat is characterized by the following trees and shrubs: California Bay, (*Umbellularia californica),* big leaf maple (*Acer macrophyllum),* white alder (*Alnus rhombifolia),* willow (*Salix* spp*.),* coast redwood (*Sequoia sempervirens),* Douglas-fir (*Pseudotsuga menzieii),* spicebush (*Calycanthus occidentalis),* wild and cultivated grape (*Vitis sp.),* Oregon ash (*Fraxinus latifolia)* and live oak (*Quercus agrifolia).* Also, there are a variety of grasses, herbs, sedges and rushes that make up the herbaceous layer of the riparian corridor. These plant assemblages integrate with upland plant comminutes that may include: mixed conifer forests, oak woodlands and grasslands.

For most salmonid stream bearing systems, canopy coverage of 80% or greater is considered sufficient to provide enough shade and coverage. Based on past CDFW stream surveys, approximately one third of the watershed is lacking sufficient canopy and shade along the creek. In addition to canopy coverage, the function of the riparian corridor should also be assessed based on the width and degree of adjacent floodplains, degree of regeneration and the health of the trees and understory vegetation.

A major issue in the Mill Creek watershed is the majority of the stream segments that are confined by either main roads or rural residential and agricultural development. This causes channelization of the stream which increases channel incision and leads to many habitat problems such as bank erosion and loss of riparian habitat (CDFW 2006).

Within the lower part of the watershed and along some sections of Wallace Creek, there are more open areas with direct sun exposure along the creek. Within the upper part of the watershed Mill Creek and parts of Felta and Palmer flow within steeper gulches that are naturally shaded. Also, the long legacy of logging and vegetation management in Mill Creek has impacted the riparian corridor by limiting the establishment of larger trees along portions of the creek and within adjacent uplands areas which can contribute to erosion and the removal of riparian habitat.

In general, the majority of the watershed has a thin corridor and where possible, should be expanded. Also, there are areas of low natural recruitment and sections where there are many dead and dying trees. Also, there are sections of the creek heavily inundated with invasive plants including Himalayan blackberry and vinca which both suppress natural regeneration of native riparian plans and are carriers for Pierces disease. These areas are more abundant along Mill Creek Road and parts of Wallace creek and less so along Felta and Palmer creeks.

It is critical to provide resources to landowners on the multi-benefits of healthy riparian corridors both for habitat values and for the long term protection of adjacent agricultural and residential properties. Helping landowners understand these benefits and specific management actions that can be implemented is needed for long term habitat improvement in the watershed. The involvement of landowners is key to implementing the needed actions recommended in this plan.

The following includes a discussion of recommendations for riparian enhancement throughout the Mill Creek watershed. Additional sources of agency enhancement recommendations are provided in Appendix I. East of Westside Road, Mill Creek and the associated riparian corridor is restricted by agricultural development on both sides of the creek. There are some areas within this reach that are lacking regeneration and there are semi bare areas along the stream. More assessment and outreach is needed to determine specific zones and treatments within this reach. This needs to be done in conjunction with determining the habitat enhancement value of this work based hydrology conditions in that reach. Upstream of Westside Road to the confluence of Wallace Creek is a high priority area for stream enhancement. Increased riparian cover is needed within specific reaches where the creek is exposed. In addition, the riparian corridor is thin primarily on the left bank. More assessment and outreach should be conducted within this reach to determine the highest priority zones and specific treatments. Between the confluence of Wallace Creek and approximately a ¼ mile before Puccioni Road, there are sections where there is low regeneration and complexity. Although most of the channel is shaded, the riparian corridor should be expanded where it is not restricted by Mill Creek Road or other development. More assessment and outreach should be conducted within this reach to determine the highest priority zones and specific treatment. Between Puccioni Road and Palmer Creek, there are reaches with dead and dying alder trees and a dense establishment of Himalayan Blackberry that is suppressing natural recruitment. Landowners have already been identified who are interested in Himalayan blackberry control and riparian enhancement in this area.

To improve the riparian corridor in Felta Creek, more assessments should be done to determine the priority and need for increasing canopy and extending the riparian corridor. In Wallace Creek, approximately 2000 feet upstream from Mill Creek for approximately 800 feet, there are open areas lacking in cover and regeneration. Within this area, there are evident erosion sites and bare banks. Near-stream plantings should be installed and the riparian corridor should be expanded where possible within this reach. Further assessment and outreach needs to be completed to determine priority level and specific treatments within the upper two thirds of Wallace Creek, as there is an overall lack of understanding of stream conditions in this area and landowner participation thus far has been low.

Due to current riparian conditions along Palmer Creek, increasing shade may be less of a priority however, where possible the corridor should be expanded. Further assessment should be done to determine specific treatment zones and determine landowner interest. Outreach should be done to landowners with forest lands to develop forest management plans and help landowners apply for cost share funding for those that qualify. Where needed, provide resources to landowners on invasive plant identification, the methods of invasive plant removal and connect landowners with technical and funding assistance.

RECOMMENDED ACTIONS

Recommendation RH1 - Conduct targeted outreach and coordinate with other agencies to assess high priority reaches and areas lacking habitat information and develop site specific treatments. This should be done in tandem with outreach and development of instream or other conservation projects. Where instream projects or other conservation projects are implemented, the stream corridor should be assessed to determine the need for increased riparian canopy and coverage.

Recommendation RH2 - Hold small landowner meetings with neighbors along Wallace Creek and other tributaries in the watershed. Where instream projects or other conservation projects are implemented, the stream corridor should be assessed to determine the need for increased riparian canopy throughout the watershed

Recommendation RH3 - Prioritize and implement the highest priority riparian enhancement projects for multi-purpose restoration treatments.

Recommendation RH4 – Secure funding to implement the highest priority, multi-purpose riparian enhancement projects and help landowners apply for cost share programs.

CHAPTER 7. SEDIMENT SOURCES AND IMPACTS

EROSION PROCESSES AND CONCERNS

Background

Since the early 1800s, human activities have altered the natural erosion and hydrologic regimes of the Mill Creek watershed. Through the development of a thriving logging industry, construction of an extensive road network, and more recent residential development, the rate and volume of erosion and the surface hydrology of the watershed have been significantly altered. In addition, the further development of residential primary access roads into the watershed directly alongside Mill Creek and its major tributaries has acted to further channelize the waterways. The combination of these factors has caused dramatic changes in the types and rates of erosion in the watershed with consequences for both stream channel form and aquatic habitat quality.

The processes and rates of erosion occurring in a watershed combined with the mechanisms by which the eroded material is transported dictate the volume and rate the eroded sediments will be delivered to a stream network. Gravel and sediment recruitment is a natural function of a stream system but land management practices can have a great effect on erosion rates and the mechanisms that lead to the sediment delivery to a stream. Historically, it is likely that Mill Creek delivered sediment derived from its steep upper reaches to the low-gradient Dry Creek alluvial plain at a slow but steady rate. The sediment transport rate of the Mill Creek tributary network would have been at a relative balance with the sediment inputs. This consistent process would be accentuated by the occasional large erosion event such as a landslide or debris flow resulting from a large but infrequent storm event. These large erosion events were likely the primary catalysts to significant alterations in the morphology of the Mill Creek stream network.

In the last 150 years, human activity has made significant changes to the Mill Creek landscape in the form of land cover and stream channels. High intensity logging has taken place over the majority of the watershed area, increasing storm runoff and sedimentation. Formerly undeveloped native timberlands and scrub have been converted for a variety of uses including vineyards, orchards, cattle grazing, and residential development. This alteration to the landscape has created a significant increase in bare compacted soils and impervious surfaces, such as roads and rooftops, significantly increasing runoff volumes and rates as well as erosion and transport of fine sediments. The increased runoff leads to increased peak discharge of Mill Creek and its tributaries and has altered sedimentation rates and overall geomorphology of the stream networks.

Erosion Types in Mill Creek and Related Concerns

Limited scientific assessment of erosion and sediment delivery to streams has occurred in the Mill Creek watershed. From these assessments, as well as other studies, recent field observations and anecdotal evidence, channel incision and road-related erosion appear to be the most significant management-induced sources of sediment in the watershed.

A CDFG stream inventory conducted in 2000 attributed extensive channel incision in Mill Creek to the incision of the Russian River causing headcutting through Dry Creek and into the lower reaches of Mill

Creek. Historically, dams in the headwaters of Mill Creek cut off replenishing gravel supplies which contributed to increased stream incision (CDFW 1995). This incised condition can lead to several different factors that affect the morphology of a stream channel.

Roads can have a significant impact on a watershed by disrupting drainage patterns and adding compacted impervious surfaces that lead to increased runoff patterns. By diverting water from its natural course down a hillside or ephemeral stream there is an increased risk of the water gaining erosive force and leading to gully development and landsliding. Anywhere a road crosses a stream channel is a constant potential for erosion that requires consistent observation and maintenance to prevent failure. While necessary for our access needs, roads are prominent sources of fine sediment in Mill Creek.

Rainsplash, sheet and rill erosion on agricultural lands and other disturbed lands where cover conversion has occurred may be a considerable source of fine sediment in the watershed, but no systematic survey has been performed. From a review of current satellite imagery of the watershed, mass movements do not appear to be a frequent occurrence in Mill Creek. Although mass movement sites are active contributors to the sedimentation of Mill Creek, especially in the steep headwater streams, they are not prominent features on the landscape.

Excessive fine sediment in a stream system can have significant impacts. Besides the unappealing aesthetic of a very turbid stream, there are very serious affects to aquatic habitat quality, particularly for salmonids. The quality of the water salmonids reside in heavily influences their success to propagate and sustain their populations for future generations. Fine sediment pollution has been shown to negatively affect salmonids on multiple levels. It has been demonstrated that fine sediments severely impact incubation success of salmonid embryos (Reiser and White 1988). Female salmonids create a nest in the substrate of stream by using their tails to winnow away fine sediments from an area while leaving larger gravels in place to lay their eggs among. However, fine sediment eventually finds its way back into the redd by the "pulling" of water downward through the redd. Redds are constructed in such a way to create down-welling through it to bring oxygen rich water into contact with incubating eggs and to remove metabolic wastes (Kondolf 2000). This down-welling also brings with it fine sediments that are drawn into the redd even at times when high water velocities would prevent deposition on the gravel surface. Therefore, suspended sediments that would normally get carried out to the bay or get deposited in fringe, low velocity areas work their way down through the redd. These sediments often form a seal above the egg pocket (the actual location of egg deposition) thus sealing off the eggs for effective metabolism (Chapman 1988). Increased fine sediments may also have the effect of decreasing the production of macroinvertebrates that are an important food source for fry, juveniles, and smolts which can lead to reduced growth rates. It may also result in gill abrasion, impaired water quality, and overall reduced feeding success (McDonald 1991).

Channel incision

Steam channel incision defined as the lowering of the stream bed over a period of time. A "stable" stream is in a dynamic equilibrium when, over a decadal time scale, sedimentation processes are balanced so that the channel, while changing locally, maintains the same average morphological character. The morphology of a stream depends on two independent variables; runoff and sediment yield. These act in concert to determine channel depth, cross section, and grade. Boundary conditions include the valley slope, geology, resistance, soil type, and vegetation and may also include man-made controls such as dams, bridges, and water take from the creek for agriculture or other uses. Changes in sediment load, flow regime, and boundary conditions can disrupt the balance resulting in a creek that undergoes rapid morphological changes. When long-term stream erosion exceeds sedimentation, channel incision occurs. Channel modification, including confinement and straightening of the channel, often leads to incision. Other causes for channel incision include reduced sediment transport due to upstream dams, increased peak flows caused by residential development, cover alterations in a watershed, and the removal of wood from a stream channel.

In the Mill Creek watershed most of the mentioned altering variables are in effect. The development of impervious surfaces from residences and compacted roads with installed drainage culverts has hardened the watershed, which has increased the rate of storm run-off. The dams in the Mill Creek headwaters have cut off gravel supplies to the upper watershed and below to a lesser extent, since many of the tributaries supply gravel to Mill Creek. Channel narrowing, channelization and straightening of the creek associated with Mill Creek Road, and seasonal dams have caused an increase in stream velocity, excessive debris transport, and an overall channel incision in the upper portion of the stream. This has led to many habitat problems in the stream including: loss of gravel used for spawning, bank erosion and loss of riparian habitat, loss of instream structure (i.e. woody debris) and thus pool habitat. Anecdotal information from landowners indicates increased urbanization and summer dams have decreased summertime flow for domestic use since the 1970's, particularly in between the Palmer and Felta Creek confluences with Mill Creek. In general this has also resulted in an overall loss of pools, and loss of instream shelter for juvenile salmonids. Downcutting in the upper watershed has caused a migration barrier in Boyd Creek at the confluence with Mill Creek (CDFW 1995).

Surface Erosion

Surface erosion processes area relatively small scale erosion processes that can be broken down into rainsplash, sheet and rill erosion. These are processes that can take place over broad areas where there are bare soils or overall lack of cover. Rain drops which fall directly upon bare soils will have a splash effect; this is called rainsplash and is defined as the impact of rain drops on the soil surface. Rainsplash only occurs if rain falls with sufficient intensity. If it does, then as the raindrops hit bare soil their kinetic energy is able to detach and move soil particles a short distance. In many cases, particles may only be moved a few centimeters, however, if rain fall begins to concentrate, these particles are easily transported by sheet erosion. Sheet erosion is the transport of materials overland in broad extremely shallow flows rather than in defined channels or rills. A more or less uniform layer of fine particles is removed from the entire surface of an area, often times from a disturbed area such as plowed fields or unsurfaced roads, where there is a lack of vegetative cover. As sheet flow coalesces it will form into rills which are small channels generally categorized as measuring less than 1 ft x 1 ft in cross-sectional area (Flosi et al. 2006). Rill erosion has the ability to transport large volumes of material delivered to them from the previous processes and can also expand as contributing flow increases thus increasing the total amount of material in transport.

No systematic assessment or modeling of surface erosion has been conducted for the Mill Creek watershed, but it is likely that the process of converting native woodlands to other land uses (residential, agricultural) has increased surface erosion over historical levels. Aside from increased erosion rates, residential and agricultural properties are often designed to drain water rapidly which leads to increased rates of storm runoff and higher peak storm flows in the creeks. This results in increased delivery of surface erosion to the creeks and can lead to increased scour and incision of the stream channels.

Gullies

A gully is created when the process of rilling grows to larger features measuring larger than 1 ft x 1ft in cross sectional dimension (Flosi et al. 2006). Gullies can become very large features that transport significant amounts of sediment from erosive hillslopes to a stream network. They can form from the coalescing of rills or be caused by concentrated drainage exiting a roadbed or culvert. This concentrated flow creates a new linear erosion feature where there was no drainage feature before. These features have the ability to stabilize on their own or can continue to erode and become significant features on a hillslope contributing large volumes of material to a stream depending on soils, slope gradient, and water input. They act to contribute sediments to the waterway by transporting materials already in solution at the head of the gully and by expanding in size contributing its eroded materials.

Gullying does not currently appear to be a major source of sediment in the Mill Creek watershed. Field observations indicate, however, that gully formation is becoming more common on floodplain surfaces adjacent to incised stream channels throughout the watershed.

Roads

In the Draft Russian River Basin Fisheries Restoration Plan (Basin Plan) prepared by the CDFG, it is stated that, “In terms of accelerated erosion, road building is the most detrimental human activity.” Sediment delivery to stream channels from roads and road networks has been extensively documented, and is recognized as a significant impediment to the health of salmonid habitat (Harr and Nichols, 1993; Flosi et al., 1998). Reasons given for the detrimental effects of roads include the fact that the slopes at which many roads are built tend to inhibit the natural dispersal of water thereby concentrating runoff and creating gullies and landslides. In addition, road networks have created drastic changes in the natural drainage patterns of the watershed through increasing the amount of impervious surfaces and diverting water to follow roads rather than natural patterns.

Roads are a major source of erosion and sedimentation on most managed forest and ranch lands. Compacted road surfaces increase the rate of runoff, and road cuts intercept and bring groundwater to the surface. Ditches concentrate storm runoff and can transport sediment to nearby stream channels. Culverted stream crossings can plug, causing fill wash outs or gullies where the diverted streamflow runs down nearby roads and hillslopes. Roads built on steep or unstable slopes may trigger landsliding which deposits sediment in stream channels. Filling and sidecasting (the act of placing material on the hillslope to increase road width) increases slope weight, road cuts remove slope support, and construction can alter groundwater pressures, all of which may trigger landsliding. Unstable road or landing sidecast materials can fail, often many years after they were put on steep hillslopes. Lack of inspection and maintenance of drainage structures and unstable road fills along old, abandoned roads can also result in soil movement and sediment delivery to stream channels (Weaver and Hagans 1994).

The compacted impervious surfaces road beds create across a watershed actively capture and transport hillslope drainage down their lengths due to road insloping or the existence of inboard ditches that transfer flow. These conduits transport fine sediments derived from the road surface, the exposed cutbank of the road, and the inboard ditch itself, and deliver it to stream channels. This is referred to as "chronic erosion" because it is a steady and on-going process.

Stream crossings on road networks require careful design and maintenance to ensure longevity. Classically, stream crossings, particularly culverted crossings, have been under-designed and poorly constructed. Culverts are regularly too small to handle peak flows of the streams they are installed to convey, they are installed too shallow making them subject to plugging, and the crossings are designed in a way that, in the case of the culvert being overwhelmed, the stream will flow down the roadbed rather than staying within its natural channel. This diversion of a stream can lead to extreme erosion in the form of gullying or landsliding where the flow exits the road and finds its way back into the channel. This erosion is referred to as "episodic erosion" (Weaver and Hagans 1994) and can lead to significant pulses of sediment being delivered to a stream system.

Road assessments and Implementation techniques

Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of rural, ranch, and forest road systems has an immediate benefit to the streams and aquatic habitat of a watershed. It helps ensure that the biological productivity of the watershed's streams is minimally impacted by future road-related erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas (Weaver and Hagans, 1994).

It is unknown how many miles of road exist in the Mill Creek watershed. Gaining access to properties in Mill Creek to assess the road networks is a significant first step in understanding what processes are occurring in the watershed. The purpose of a road-related sediment source assessment is to identify and quantify road-related erosion and sediment delivery to streams, and present a prioritized plan-of-action for cost-effective erosion prevention and erosion control for the road system.

Depending on the future land use needs a landowner or property manager may have, different techniques of drainage improvements may be utilized: upgrading or decommissioning. Upgraded roads are kept open, and are inspected and maintained. Their drainage structures are designed to accommodate the 100-year peak storm flow. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as "hydrologically invisible" as possible, that is, to reduce or prevent future sediment delivery from the road to the local stream system (Weaver and Hagans 1994).

Completed road assessments and implementation

Steps towards decreasing the inputs of road derive fine sediments have been completed in Mill Creek and its tributaries. In 1997 Pacific Watershed Associates (PWA) completed an assessment of Palmer Creek Road which is the primary access to a rural residential subdivision in the Palmer Creek watershed. This assessment of over 2 miles of road was funded by CDFG with help from Sonoma RCD (at that time called Sotoyome RCD). Overall, the assessed road was deemed insufficiently constructed with regard to preventing or controlling erosion, with poorly constructed stream crossings and inadequate road drainage. In the assessment PWA identified erosion sites that were actively eroding or had potential to contribute fine sediment to Palmer Creek and also identify lengths of road that were contributing drainage to the erosion sites. The result of this assessment was a prioritized plan of action to treat the erosion concerns along Palmer Creek. In 2000 work began to implement the drainage improvement recommendations with funding from Sonoma County Water Agency and Department of Fish and Game. Along Palmer Creek Road, drainage improvement work was implemented at 26 sites in 2.16 miles of road. The implementation of this project is estimated to have prevented 2,187 yd^3 of fine sediment from entering Palmer Creek from the 26 erosion sites only. Sediment savings from this process increases when we factor in the fine sediment being produced by road surface and ditch erosion. By disconnecting approximately 90% of the 2.16 miles of Palmer Creek Road from Palmer Creek, it is estimated that another 1,500 yd^3 was prevented from entering the stream network over a course of a decade.

In 2010 work began on the *Felta Creek Sediment Reduction Implementation Project*. Based on a project plan utilizing guidelines established by the *Handbook for Forest and Ranch Roads* (Weaver and Hagans 1994) a sediment reduction project on 20.4 miles of unpaved road was developed that would have a direct effect on roads contributing fine sediment to Mill Creek, Felta Creek, and Salt Creek. Funded by CDFG with match funding from SRCD and the landowner, 192 erosion sites were improved and drainage enhancements were made along 19.2 miles of hydrologically connected road. Completed in 2011, it is estimated that over 7,000 yd^3 of road derived fine sediment was prevented from entering Mill Creek and its tributaries.

Summary of CDFW Stream Reports and Current Observations for Sediment Source and Impacts

Mill Creek

Limiting Factors:

Gravel/Cobble embeddedness in fine sediment

Erosion Management Opportunities:

Map and treat active and potential sediment sources related to the County Road System- particularly in Reach 8.

For sources of upslope and in-channel erosion utilize biotechnical approaches.

Felta Creek

Limiting Factors:

Elevated stream temperatures

Gravel/Cobble embeddedness in fine sediment

Erosion Management Opportunities:

In reach 3 and reach 4, active and potential sediment sources related to the past skid road system need to be mapped and treated according to their potential for sediment yield to the stream and its tributaries.

Alternatives to control erosion in Reach 3.

Palmer Creek

Limiting Factors:

Elevated stream temperatures

Gravel/Cobble embeddedness in fine sediment

Erosion Management Opportunities:

For sources of upslope and in-channel erosion utilize biotechnical approaches.

Map sources of erosion on secondary roads and prioritize them according to present and potential sediment yield. (*This was completed in 1997; roads were upgraded in 2001.)*

Wallace Creek

Limiting Factors:

Elevated stream temperatures

Gravel/Cobble embeddedness in fine sediment

Erosion Management Opportunities:

Active and potential sediment sources related to the past skid road system need to be mapped and treated according to their potential for sediment yield to the stream and its tributaries.

Map sources of upslope and in-channel erosion, and prioritize them according to present and potential sediment yield. Identified sites should then be treated to reduce the amount of fine sediments entering the stream.

RECOMMENDED ACTIONS

Recommendation SSI1 - Assess watershed and reach-scale geomorphic processes to better understand the geomorphic condition of Mill Creek and impacts of erosion in the watershed. Conduct in-depth hydrologic and geomorphic assessment of the Mill Creek and its major tributaries. This assessment should include:

- Hydrologic modeling to identify critical factors affecting groundwater and summer baseflow conditions. Modeling may also prove useful in evaluating bank stability conditions related to flow confinement and water table position.
- Identify the extent, causes and impacts of channel incision, and recommending a strategy for arresting or reversing it, and mitigating its effects.

Recommendation SSI2 - Conduct a road development history study utilizing historic aerial photos for every available photo series going back to the 1960's (roughly 1 photo series per decade). Utilize this study to find historic concentrations of road in order to prioritize outreach into the watershed for road sediment source assessment development.

Recommendation SSI3 - Conduct outreach to high priority landowners in the Mill Creek watershed based on the road history study findings.

Recommendation SSI4 - Conduct a multi-phased series of road sediment source assessments on high priority road networks in order to developed prioritized sediment reduction plans for the watershed.

Recommendation SSI5 - Implement road sediment reduction plans resulting from the road related sediment source assessments. Conduct these in a prioritized multi phased series based on funding availability.

Recommendation SSI6 - Conduct a landslide/mass wasting history study utilizing historic aerial photos for every available photo series going back to the 1960's (roughly 1 photo series per decade). Utilize this study to map, measure, and analyze historic landslides within the Mill Creek watershed. Use this survey to determine if the erosion features are naturally occurring or if they have been induced by management practices in the watershed. In tandem, conduct field visits to 20% of the mapped features to determine accuracy of air photo survey.

Recommendation SSI7 - Make land management improvement suggestions to property managers that have current management induced mass-wasting occurring. Utilize bioengineering techniques, where feasible, to stabilize landslides and bank erosion.

CHAPTER 8. FOREST LANDS

BACKGROUND

Forestland vegetation in the Mill Creek watershed is typical of the North Coast Mediterranean vegetation types. Where temperatures are relatively high and precipitation and soils are shallow, oak woodlands and chaparral-associated plants predominate. In the cooler and wetter areas, soils are deeper, and mixed evergreen forest and oak woodland communities occur. Redwood and Douglas fir dominate in cooler, moister areas, whereas hardwood evergreens, such as tan oak, madrone, live oak, and bay occur on well-drained slopes. On southern exposures and the edges of the mixed forest can be seen the northern oak woodland type. Oregon and black oak and Manzanita dominate here, while coniferous trees are scarce. Much of the grassland in the watershed has developed on land cleared of hardwoods and conifers for grazing.

CONDITIONS AND CONCERNS

Current concerns in the Mill Creek watershed in relation to forest health are increased wildfire threat, decrease of health, vigor and productivity in timber species, and the spreading of Sudden Oak Death (SOD). The majority of Mill Creek is identified as 'High Fire Hazard Severity' by Cal Fire. The lack of forest management in much of the watershed has created overstocked forests resulting in a dense understory that provides the potential for stand replacing wildfire through the abundance of fuel load and ladder fuels. Overstocked forests also inhibit regeneration and growth of seedlings as well as degradation of wildlife habitat, particularly for raptor species that thrive in open spaces for hunting. Invasive species are a growing concern in Mill Creek watershed. Field observations during the development of this plan indicate that French broom is one of the abundant invasive species, and an increasing concern for forest landowners. Various forest diseases are present in the watershed, and SOD is a disease of increasing interest.

Forest stand improvement practices such as thinning, pruning, forest slash treatment, and fuel breaks are beneficial to decrease over all wildfire hazard. These practices decrease fuel load and ladder fuels, improve wildlife habitat, and release desirable species for optimal growth potential. Timber harvest and pre-commercial thinning can also be beneficial for the previous stated reasons. Addressing invasive species and competing vegetation by hand, mechanically, or with chemical treatment are beneficial forest management practices. Tree planting is often conducted to improve stand composition of timber species, increase tree species diversity, improve riparian canopy cover, and revegetate areas with tree loss from SOD.

Mortality and Snags

Management of the forest in the Mill Creek watershed could include the allowing snags to develop or snag creation in groups, maintenance of dense stands, and continued development of significant downed woody debris. While this will improve over time, important wildlife and soil elements for habitat may be increasing by thinning and snag creation over time. Timber inventories in the watershed also recorded standing dead trees, or snags, and downed woody debris. Inventories note very large numbers of snags, predominantly Douglas fir, madrone, laurel, and tanoak. Conifer diameters tended to be much higher than hardwoods, and their condition generally much less decayed (Max 2007).

Fire

Fires are a part of the natural ecosystem in the Mill Creek and surrounding watersheds. Fires act to clean out the brushy understory of a forest as well as take out dead and dying trees. This decreases competition for healthy thriving trees to promote continued growth. A large fire swept through the Mill Creek watershed in the early 1950's that burned large areas in Palmer Creek, Mill Creek mainstem, and Wallace Creek. The area was then heavily logged during the late 1950s (Walker, R. 2013) and 1960s to collect the salvageable timber. Since this large-scale logging occurred, the majority of the stands in the Mill Creek watershed have been allowed to grow uninterrupted - with a few exceptions. Much of the forests are dense with trees aged 60 years or less. Fires that would have naturally burned through the area every 20 years or so and thinned out the forest have not occurred due to fire suppression to protect residential development in the watershed. This fire suppression has created a more dense and brushy condition than would naturally development in the region. For example, ridgetops were typically habitat for oaks with Douglas firs being controlled by fire. Without recent fires, the Douglas firs are now overtopping, shading, and killing many of the oaks (black oaks in particular share this habitat) (Loganbill, B. Anecdotal Evidence. 2013).

Insects

In Sonoma County forests, insect attacks generally occur in scattered small areas. For Douglas fir, build-up of insect populations to the point where damage is significant is generally associated with trees that have blown down, logging slash and fire damage, all of which provide a favorable habitat for insects. Bark beetles cause major damage to California forests, boring tunnels into inner bark and cambium to lay eggs; hatching larvae bore additional galleries as they mature, and the process repeats, sometimes several generations in a single year.

Generally beetles are specific to one particular species of tree, though some may infest several types, and severe infestations weaken and often kill the tree or whole stands of trees. Two bark beetles that attack Douglas fir are the Douglas fir beetle (*Dendroctonis pseudotsugae)*, and the Douglas fir engraver (*Solutes unispinosus)*. Older, stressed Douglas fir are more successfully attacked by bark beetles. Bark beetle attack symptoms generally include the upper parts beetle-infested trees fading first from the deep green to light green, then yellow, and finally to red. The top alone may be killed or the entire tree may be affected. Other less noticeable initial signs of bark beetle attack can include boring dust from entry holes through the bark or pitch tubes exuding from entrance holes. Infested trees with living bark beetles should be cut down and removed, burned or debarked. Maintaining the vigor and health of a stand of forest, and good management and sanitation practices is the best defense (Max 2007).

Douglas Fir Diseases

Diseases which may affect the stem of Douglas fir in this area include white pocket rot, *Phellinus pini,* or *Fomes pini,* also called red ring rot, a heart rot which is a leading cause of decay. It infects trees through roots and open wounds, fire and lightening scars. Red brown rot *(Phaelus schweinitzii)* similarly attacks usually just the butt of the tree. Black stain root disease *(Verticiclaiella wagnenerii)* has been found on Douglas fir in Sonoma County, infecting the roots of trees of all ages where it spreads throughout the sapwood of the root system, root crown, and lower bole, causing a visible decline in the tree crown, reducing terminal growth, needle production and eventually death. Occurrences of conks are common with *Phellinus* and appear occasionally with other fungi. Annosus root disease (*Heterobasidion annosum)* can be found in Douglas fir, coast redwood, madrone, and manzanita. This fungus enters on cut surfaces or through root contact making thin stands especially vulnerable. Trees weakened by fungus diseases are more susceptible to beetle attack. Common points of infection for these fungi that cause the wood to rot are branch stubs, wounds, and fire scars (Max 2007).

Redwood Diseases and Insects

Some insects that attack redwood are the flat-headed borer *(Anthraxia aeneogaster)* and the round headed borers *(Callidium sempirvirens, C. pallidum, Leptura obliterate, Preonius Californicus)*, the redwood bark beetle *(Phloesinus sequoia)* attacks weakened redwood trees. Redwood pocket rot *(Poria sequoia)* is a large brown pocket rot of the butt and trunks, commonly on old trees.

Sudden Oak Death

Sudden Oak Death (SOD) is a problem in the Mill Creek watershed. The disease is caused by a previously unknown species of *Phytophthora (P. ramorum)*. The death rate of tanoak, coast live oak and black oak trees has accelerated alarmingly in the affected areas reaching epidemic proportions and exacerbating fire danger. The infection was first detected in tanoak trees in 1995 (USDA 2013). Tanoak trees are extremely resilient, which makes their susceptibility even more unusual. An inconsistent symptom of the pathogen is an oozing liquid, usually on the trunk of the tree. *Phytophthora ramorum* enters through bark and limbs, and thrives in cool, wet conditions. At least two insects and two additional fungus diseases are associated with this oak decline- the western oak bark beetle and the oak ambrosia beetle and *Armillaria* root disease and *Hypoxylon thourarsiarum*. These pathogens may be contributing stress factors leading to mortality or they may also be causative.

Signals to watch for are the sudden decline and death of oaks, usually in isolated individual trees, and a brown or black resiny exudation on the lower trunk. Tanoak stands in the Mill Creek watershed, generally very crowded from resprouting after logging and fire, are already stressed and may be more susceptible than more open, less dense or more mature stands. Following forest thinning activities, increased moisture in the trees may create excellent conditions for the transmission of this disease, and it is anticipated that trees will continue to become infected. Infected trees will spread the disease less if felled and lopped in place.

Madrone Die Back

Madrone is subject to leaf and twig diseases, notably Blister Blight *(Exobasidium vaccinii)* and madrone canker *(Nattrassia mangiferae* and/or *Botryosphaeria dothide).* While it is not uncommon to see trees with dead leaves in the fall season, the trees generally come back the following year. Madrone mortality is generally due to overcrowding in the forest.

Forest Health

Sanitation is important in maintaining good forest health. Lopping of slash and quick decomposition of dead trees in logging operations and in thinning practices will reduce disease and insect vectors. Most diseases spread through wounds, fire scars or cut surfaces, and infected trees are much more prone to insect attack in a weakened or otherwise stressed condition.

RECOMMENDED ACTIONS

Recommendation FV1—Assess forest habitat elements, such as snags and downed wood, in order to protect these features and to potentially increase their abundance. Retain large hardwoods, especially those with rotten cavities for denning, nesting, and foraging sites.

Recommendation FV2—Conduct surveys for species of concern to assess current populations and develop restoration plans. Surveys for the following species of concern are recommended, as they may be informative:

> Marbled murrelet—although there has been no documentation of murrelet use of habitat within the Mill Creek watershed, and suitable habitat is minimal at best, murrelets are likely using old-growth forest to the west for nesting. Radar surveys are an effective method to detect murrelet presence and are recommended to be conducted early in plan implementation. If murrelets are flying over en route to nesting sites, they should be detectable using radar. Knowing if murrelets are present in the Mill Creek watershed would be essential to implementing appropriate disturbance minimizations and in designing restoration strategies to benefit this species.
>
> Northern spotted owl—there does not appear to be sufficient late-successional habitat within the Mill Creek watershed to support a spotted owl pair; however, according to anecdotal evidence, this species has recently been observed in the watershed.

Recommendation FV3—If located, nest sites of the spotted owl, the marbled murrelet, and other listed or sensitive species should be protected by implementation of noise and disturbance minimization within minimum distances of nest sites or occupied stands, depending on the species. For northern spotted owl and marbled murrelet, disturbance should be minimized within a minimum 0.25-mile radius of nest sites (owl) or occupied stands (murrelet) during nesting and rearing. Protection for other species of concern should also be developed and implemented wherever and whenever appropriate, as such circumstances are identified.

Recommendation FV4—Complete an entomology and pathology study of large forested properties within the Mill Creek watershed to help assess, diagnose, and plan treatment practices for suspected pest and/or disease problems.

Recommendation FV5—Outreach to landowners to develop Forest Management Plans on forested properties in the watershed that will promote management actions to decrease the potential for wildfire. These would include specifications for several aspects of forest management including stocking rates, fuel load management, shaded fuel breaks and maintenance thereof, and fire crew access into the property.

Sonoma Resource Conservation District

Mill Creek Watershed Management Plan

SECTION 3.
IMPLEMENTATION

CHAPTER 9. PLAN IMPLEMENTATION

The management plan is intended to be implemented over a 10-year timeframe and will be reviewed and updated as needed during that time. A complete review and update of the Plan should commence at the end of the 10-year period. The vision, goals, objectives, and policies of the Plan are well established, though the recommended actions are designed to be revised and updated as appropriate, thus providing some flexibility over the course of plan implementation. This chapter provides a framework for implementing the recommended actions defined in the previous chapters.

Table 9.1 summarizes the management actions, the timing of planned implementation, and the chapter of this plan in which the actions are described in detail. The information provided in the table can be used in conjunction with the more detailed management actions described in the previous chapters and associated appendices. Each recommended action will be included in one or more of the following:

• 5-Year Actions—First five years of plan implementation includes many of the water conservation actions as well as instream and riparian restoration actions and sediment source actions pertaining to watershed health and water quality.

• 10-Year Actions—Years 5-10 of implementation are follow-up on tasks or monitoring related to actions initiated in the 5-Year period. These actions are integral to achieving other watershed management goals.

• As-Needed Actions—As-Needed actions are essential to meeting the watershed goals identified in this Plan. They will be carried out as-needed in order to facilitate the effective implementation of the other management actions in the Plan.

IMPLEMENTATION OF THE MILL CREEK WATERSHED MANAGEMENT PLAN

Table 9.1. Identification of the status of each management action as: Ongoing, Initiated, or Needed.

Management Action[1]	Description	Chapter	Date	Status	Potential Partners
As-Needed Actions					
Outreach and education – As discussed throughout this Plan, the Mill Creek Watershed is 100% privately owned and landowner participation and involvement is critical for the successful implementation of the recommended actions. The RCD has been building relationships and outreaching to landowners within this watershed since the early 1990's and understands the importance of trust between landowners and the agencies working in the watershed. Close coordination is important so that the community understands how the various agencies work together. RCD's mission is to help provide resources to landowners as well as provide technical and funding assistance when needed and requested.			2013-2023	Ongoing	
5-Year Actions					
WC1	Implement the recommendations of the Mill Creek Streamflow Improvement Plan	4	2016-2018	Initiated	TU; NFWF; CEMAR
FV1	Assess forest habitat elements, such as snags and downed wood, in order to protect and enhance these features.	8	2016-2018	Initiated	NRCS, CalFire
FV2	Conduct surveys for species of concern to assess current populations and develop restoration plans.	8	2016-2018	Needed	
IH1	Continue to assess and survey watershed-wide all large wood material (LWM) – current existing structures and natural occurring pieces	6	2016-2018	Initiated	NOAA; Landowners
IH3	Assess presence and quantity of decayed, snags and downed wood to protect streambank features and to potentially increase their abundance/functionality	6	2016-2018	Ongoing	NOAA
IH2	Provide resources to landowners about large wood in streams, and develop and implement instream enhancement projects in areas with less than adequate cover and scour for anadromous species	6	2016-2019	Initiated	NOAA, DFW, SCC

5-Year Actions (continued)					
WC2	Develop and complete hydrology study for lower reach of mainstem of Mill Creek	4	2016-2019	Needed	NFWF, TU, CEMAR
RH1	Conduct targeted outreach and coordinate with other agencies to assess high priority reaches and areas lacking habitat information and develop site specific treatments. This should be done in tandem with outreach and development of instream or other conservation projects	6	2016-2021	Ongoing	NOAA, DFW, SCC
RH2	Hold small landowner meetings with neighbors along Wallace Creek and other tributaries in the watershed.	6	2016-2021	Ongoing	NOAA, DFW, SCC
SSI2	Air photo road-history study of watershed to create prioritized outreach plan	7	2017-2018	Needed	SCC, NOAA
FV3	Establish noise disturbance minimizations around spotted owl and murrelet nests in surveyed areas	8	2017-2018	Needed	
FV4	Conduct entomology and pathology studies on forested properties to assess, diagnose, and plan treatment practices for suspected pest and/or disease problems.	8	2017-2018	Needed	NRCS, CalFire
SSI6	Conduct a landslide/mass wasting history study utilizing historic aerial photos to map, measure, and analyze historic landslides in Mill Creek watershed.	8	2017-2018	Needed	DFW, SCC, NOAA
WC5	Provide resources to landowners on the benefits of restoring groundwater and methods for increasing groundwater recharge in uplands areas through small landowners meetings	4	2017-2019	Needed	

5-Year Actions (continued)					
WQ1	Install temperature loggers in select sites through the summer months and conduct ambient water quality monitoring of continuous stream discharge, temperature, DO, pH, conductivity, TSS, and nutrients	5	2017-2019	Ongoing	UCCE, NFWF
WQ2	Obtain instrumentation/lab facilities/funding to measure total suspended solids (TSS)	5	2017-2019	Needed	NCRWQCB
WQ5	Implement Management Actions to decrease summer water temperatures, increase flow, and improve DO (see Ch. 4 and 6)	5	2017-2019	Needed	NCRWQCB
WC6	Outreach to landowners to determine if there are opportunities to increase water use efficiency or identify alternative water source for these uses	4	2017-2020	Needed	
SSI1	Conduct in-depth hydrologic and geomorphic assessment of the Mill Creek and its major tributaries to evaluate impacts of erosion in the watershed	7	2017-2020	Needed	DFW, SCC, NOAA
WC7	Outreach and work with foresters and landowners with forest land to help improve forest health and to better understand how upland forest conditions affect ground water recharge and flow regimes.	4	2017-2020	Needed	Landowners, NRCS, CalFire
WQ3	Conduct watershed-wide bioassessments (BMI/algal) as an indicator of aquatic habitat quality	5	2017-2021	Needed	
SSI7	Create land management improvement recommendations based on mass wasting study	8	2018-2019	Needed	DFW, SCC, NOAA
SSI3	Conduct outreach to high priority landowners, based on road study	7	2018-2019	Ongoing	SCC, NOAA
SSI4	Perform road related sediment source assessments on high priority road networks	7	2019-2021	Initiated	DFW, SCC, NOAA
WQ4	Implement Management Actions to decrease sediment loads (see Ch. 3 and 7)	5	2019-2021	Needed	

10-Year Actions					
WC3	Outreach to Mill Creek landowners where multiple small diversions are impacting flows on a larger scale	4	2016-2026	Initiated	
ARS1	Implement agricultural and rural best management practices to prevent soil erosion and enhance soil quality	3	2016-2026	Needed	
ARS2	Improve water use efficiency of irrigation and frost protection systems. Explore alternative water sources for these uses	3	2016-2026	Needed	
ARS3	Manage grazing to protect and enhance soil quality, plant communities and water quality	3	2016-2026	Needed	
WC4	Develop and implement a rural residential roof water catchment program and demonstration project	4	2016-2026	Needed	
IH4	Work with landowners to maintain existing LWM and repair failures of installed large wood structures watershed-wide	6	2016-2026	Ongoing	
RH4	Secure funding to implement the highest priority, multi-purpose riparian enhancement projects and help landowners apply for cost share programs	6	2016-2026	Ongoing	NOAA, DFW, SCC, TU
FV5	Outreach to landowners to develop Forest Management Plans; create management plans for forested properties that act to decrease the potential for wildfire	8	2017-2022	Initiated	NRCS, CalFire
FP1	Remove major barriers to fish migration in the watershed	6	2017-2023	Needed	Private landowner
IH5	Install LWM and instream structures in the mainstem of Mill Creek, and Felta, Palmer, and Wallace creeks	6	2017-2023	Needed	DFW, TU
FS1	Conduct surveys of fish and wildlife species of concern	6	2017-2026	Needed	
RH3	Prioritize and implement the highest priority riparian enhancement projects for multi-purpose restoration treatments	6	2017-2027	Ongoing	NOAA, DFW, SCC
SSI5	Implement sediment reduction plans on assessed roads	7	2020-2024	Initiated	DFW, SCC, NOAA

[1] Actions defined in Section 2 Chapters 3-8; codes correspond to listed recommended actions.
ARS= Agricultural and Rural Sustainability; WC = Water Conservation; WQ= Water Quality;
IH = Instream Habitat; RH=Riparian Habitat; SSI = Sediment Sources and Impacts;
FV = Forest and Vegetation

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APPENDIX A

Known Fish Habitat Projects in Mill Creek Watershed

Known fish habitat enhancement projects that have taken place within the Mill Creek watershed. This list is a draft and is by no means exhaustive. Some information excerpted from Appendix F (CDFW 2002).

Creek	Project	Project Manager	Year	Purpose	Project Type	Cost and funder
Felta	Stream Enhancement Project #1	CDFW	1997	Install 10 boulder weir structures to create pools and add cover to pools	Instream work	$13,120/CDFW
Felta	Stream Enhancement Project #2	CDFW	1998	Improve 3,620 feet of juvenile coho and steelhead habitat	Instream work	$9,227/CDFW
Felta	Sonoma County Stream Enhancement Projects	CDFW	1985-1986	Remove boulders from a jump pool to improve fish passage	Instream work	$35,000 (one of several projects)/CDFW
Felta	Road Improvements	SRCD	2009-2011	Improve 20.4 miles of roads	Road Work	$431,317/CDFW
Felta	Dam Modification-Designs	SRCD	2009-2010	Improve Fish Passage	Instream work	CDFW
Mill	Stream Enhancement Project #1	CDFW	1997	Install 11 complex and 6 simple log cover structures in pool habitats.	Instream work	$23,460/CDFW
Mill	Stream Enhancement	CDFW	1997-1999	Enhance coho and steelhead habitat by constructing 8 log cover/scour structures and 3 boulder weirs and planting 3100 trees.	Instream work	$15,880/CDFW
Palmer	Palmer Creek Sedimentation Reduction Project	SRCD	1999-2002	Decrease amount of sediment in stream gravel and riffle habitat with the objective of increasing production of juvenile steelhead. Funds used to implement the erosion control and storm proofing treatment measures at 26 sites along 2.16 miles of road.	Road work	$117,200/CDFW
Palmer	Stream Enhancement Project #1		1997-1999	Enhance 3000 feet of coho and steelhead habitat by installing 7 cover/scour structures and planting 1500 native alder trees.	Instream work	$8,496/CDFW

APPENDIX B

Soils of the Mill Creek Watershed

Symbol	Name	Total Area	Relative Percent
AgD	Arbuckle gravelly loam, 5 to 15 percent slopes	23428.86	0.039189
AkB	Arbuckle gravelly sandy loam, 0 to 5 percent slopes	181920.9	0.304297
BlB	Blucher clay loam, 2 to 5 percent slopes	285495.5	0.477545
BoF	Boomer loam, 30 to 50 percent slopes	265861.2	0.444703
BoG	Boomer loam, 50 to 75 percent slopes	1620269	2.710205
CbF	Cibo clay, 15 to 20 percent slopes	39350.27	0.065821
CmF	Cohasset gravelly loam, 30 to 50 percent slopes	134053.5	0.22423
CmG	Cohasset gravelly loam, 50 to 75 percent slopes	545140.2	0.91185
GrE	Guenoc gravelly silt loam, 5 to 30 percent slopes	94518.33	0.1581
GrG	Guenoc gravelly silt loam, 30 to 75 percent slopes	111553.2	0.186594
HgG2	Henneke gravelly loam, 30 to 75 percent slopes, eroded	1549421	2.591698
HkG	Hugo very gravelly loam 50 to 75 percent slopes	2887833	4.830445
HkG2	Hugo very gravelly loam 50 to 75 percent slopes, eroded	35292.35	0.059033
HnG	Hugo-Josephine complex, 50 to 75 percent slopes	16502443	27.60345
HrG	Hugo-Los Gatos complex, 50 to 75 percent slopes	1018441	1.703535
HyG	Huse stony clay loam, 30 to 75 percent slopes	199956.8	0.334465
JoE	Josephine loam, 9 to 30 percent slopes	1066288	1.783568
JoF	Josephine loam, 30 to 50 percent slopes	4686415	7.838913
JoF2	Josephine loam, 30 to 50 percent slopes	1535523	2.568452
JoG	Josephine loam, 50 to 75 percent slopes	7649993	12.79606
JsG	Josephine-Sites loams, 30 to 50 percent slopes	383154.6	0.640898
LgF	Laughlin loam, 30 to 50 percent slopes	75434.75	0.126179
LgG	Laughlin loam, 50 to 75 percent slopes	3163304	5.291222
LgG2	Laughlin loam, 50 to 75 percent slopes, eroded	125391.2	0.20974
LhG	Laughlin-Yorkville Complex, 30 to 75 percent slopes	339491.7	0.567864
LkG	Los Gatos loam, 30 to 75 percent slopes	2228840	3.728154
LmG	Los Gatos gravelly loam, 30 to 75 percent slopes	109171.6	0.18261
McF	Maymen gravelly sandy loam, 30 to 50 percent slopes	98897	0.165424
MoG	Mantara cobbly clay loam, 30 to 75 percent slopes	133512.1	0.223324
PgB	Pleasanton gravelly loam, 2 to 5 percent slopes	318571.2	0.53287
RnA	Riverwash	2773.258	0.004639
RoG	Rock land	531780.3	0.889503
ShE	Sobrante loam, 15 to 30 percent slopes	58072	0.097136
ShF	Sobrante loam, 30 to 50 percent slopes	199077.8	0.332995
ShG	Sobrante loam, 50 to 75 percent slopes	389942.5	0.652252
SoG	Stonyford gravelly loam, 50 to 75 percent slopes	121164.7	0.202671
StE	Suther loam, 15 to 30 percent slopes	31200.26	0.052188
StF	Suther loam, 30 to 50 percent slopes	2662777	4.453996
SuF	Suther-laughlin loams, 15 to 30 percent slopes	318032.7	0.53197
SuG	Suther-laughlin loams, 50 to 75 percent slopes	1207183	2.01924
ToE	Toames rocky loam, 2 to 30 percent slopes	205742.5	0.344143
YnA	Yolo loams, 0 to 2 percent slopes	173990.6	0.291032

Symbol	Name	Total Area	Relative Percent
YrB	Yolo gravelly loams, 0 to 5 percent slopes	747263.1	1.249938
YsA	Yolo silt loam, 0 to 2 percent slopes	498575.2	0.833961
YuE	Yorkville clay loam, 5 to 30 percent slopes	1338564	2.239
YuF	Yorkville clay loam, 30 to 50 percent slopes	446703.7	0.747196
YvF	Yorkville-Laughlin Complex, 30 to 50 percent slopes	2682.991	0.004488
YwF	Yorkville-Suther complex, 0 to 50 percent slopes	3390449	5.671165
ZaB	Zamara silty clay loam, 2 to 5 percent slopes	49056.05	0.082055

APPENDIX C

Mill Creek Streamflow Improvement Plan

Mill Creek
Streamflow Improvement Plan





Prepared by:

The Russian River Coho Water Resources Partnership

With support from:

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Acronyms

AF	Acre-Feet or Acre-Foot
AWEP	Agricultural Water Enhancement Program
BACI	Before-After Control-Impact
BMI	Benthic Macroinvertebrate
CCC	Central California Coast
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife (formerly CDFG)
CEMAR	Center for Ecosystem Management and Restoration
CI	Confidence Interval
CSG	California Sea Grant
DO	Dissolved Oxygen
DPS	Distinct Population Segment
EDSU	Emergency Small Domestic Use Registration
ESU	Evolutionarily Significant Unit
eWRIMS	Electronic Water Right Information Management System
FRGP	Fisheries Restoration Grant Program
GIS	Geographic Information System
GRRCD	Gold Ridge Resource Conservation District
KIBP	Keystone Initiative Business Plan
MWAT	Maximum Weekly Average Temperature
MWMT	Maximum Weekly Maximum Temperature
NCRWQCB	North Coast Regional Water Quality Control Board
NFHAP	National Fish Habitat Action Plan
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NOAA	National Oceanic and Atmospheric Administration
NOAA-RC	National Oceanic and Atmospheric Administration Restoration Center
OAEC	Occidental Arts and Ecology Center
PAD	Passage Assessment Database
PIT	Passive Integrated Transponder
POD	Point of Diversion
PPT	Precipitation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RM	River Mile
SD	Standard Deviation
SDU	Small Domestic Use (Registration)
SCC	State Coastal Conservancy
SCWA	Sonoma County Water Agency

SIP	Streamflow Improvement Plan
SRCD	Sonoma Resource Conservation District
SWRCB	State Water Resource Control Board
TU	Trout Unlimited
UC	University of California Cooperative Extension and California Sea Grant's Russian River Coho Monitoring Program
UCCE	University of California Cooperative Extension
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDMP	Water Demand Management Program
YOY	Young-of-the-Year (age 0+ fish)

Executive Summary

The Russian River Coho Water Resources Partnership prepared this Streamflow Improvement Plan (SIP) as part of the Russian River Coho Keystone Initiative. The Keystone is an effort led by the Partnership with support from the National Fish and Wildlife Foundation. Since its establishment in 2009, it has grown to include many other funding and conservation partners.

The purpose of the Keystone is to restore a viable self-sustaining population of coho salmon in the Russian River watershed. The Partnership selected five focal watersheds, all sub-basins within the Russian River watershed, in which it aims to (1) restore a more natural flow regime, (2) increase the viability of juvenile coho and numbers of returning adult coho, and (3) increase water supply reliability for water users.

The Partnership applies a systematic, watershed-scale approach that brings together landowner interests, streamflow and fish monitoring, technical, planning and financial assistance, and water rights and permitting expertise to modify water use and management to improve instream flow.

This Streamflow Improvement Plan is a roadmap for prioritizing and implementing streamflow improvement projects with multiple public benefits and a diversity of approaches in the Mill Creek watershed. Mill Creek is the second of five watersheds for which we are developing Streamflow Improvement Plans. The others are Grape Creek, Dutch Bill Creek, Green Valley Creek, and Mark West Creek (though completion is depending upon available funding).

Mill Creek Streamflow Improvement Plan

The purpose of the Mill Creek Streamflow Improvement Plan (SIP) is to identify specific measures that moderate the impact of dry season water demand and improve instream flow for coho salmon and ecosystem function. Our goal is to manage water demand through conservation, storage and modified diversion practices in order to maintain a flow regime that is protective of the various life history stages of salmon.

Section 1 provides an overview of the Russian River Coho Water Resources Partnership, describes our rationale for selecting Mill Creek as a focal watershed under the Keystone Initiative, and describes the purpose of the SIP and its nexus with other watershed planning efforts.

Section 2 describes rainfall and streamflow patterns in the Mill Creek watershed.

Section 3 analyzes human water needs relative to available water supply and streamflow at different temporal scales. Sufficient water is available in Mill Creek to meet human needs on an annual scale. By reducing the disparity between discharge in the rainy versus dry seasons and use in the dry versus rainy season, we can meet human and fisheries needs.

Section 4 summarizes the presence and status of coho salmon in Mill Creek and their relationship to flow and habitat.

Section 5 uses the information in Sections 3 and 4 to provide recommendations and describe permitting considerations. It also provides a preliminary calculation of water availability for permitting purposes (based on the criteria provided by the State Water Board). This Section provides a roadmap for achieving both the physical/infrastructure and social/management changes necessary to ensure streamflow improvement.

Section 6 describes monitoring efforts, long-term threats to the water savings recommended in this SIP, and strategies to ensure durable results.

1 Introduction

1.1 The Russian River Coho Water Resources Partnership

1.1.1 Mission and Partners

The Russian River Coho Water Resources Partnership (Coho Partnership) was established in 2009 to implement the National Fish and Wildlife Foundation (NFWF) Keystone Initiative Business Plan (KIBP) for coho salmon in the Russian River. The Partnership includes the Center for Ecosystem Management and Restoration (CEMAR), Gold Ridge Resource Conservation District (GRRCD), Sonoma Resource Conservation District (SRCD), Occidental Arts and Ecology Center's WATER Institute (OAEC), Trout Unlimited (TU), and University of California Cooperative Extension and California Sea Grant (UC), in partnership with the Sonoma County Water Agency (SCWA). The multi-year KIBP aims to restore a viable self-sustaining population of coho salmon in the Russian River watershed.

The population of coho salmon native to the Russian River approached extinction during the last decade. With the inception of a population augmentation program in 2004, habitat improvements, and changes in ocean conditions, the number of returning adults has increased annually, with estimated returns approaching 500 during the winter of 2012-13. However, the coho recovery program is still far from reaching state and federal targets of self-sustaining runs of over 10,000 adult coho returning to the watershed each year.

Providing streamflow for juvenile coho during the dry season is a critical but often overlooked component of coho recovery in the Russian River. The Partnership was established to fill that gap and to improve instream flow and water reliability for water users in the Russian River watershed. Drawing from state and federal fisheries recovery plans, the KIBP identified five key sub-watersheds in the Russian River basin where near-term changes in water management are critical to restoring coho salmon: Dutch Bill, Green Valley, Mill, Mark West, and Grape Creeks.

The Partnership's goals are to (1) restore a more natural flow regime in five priority watersheds, especially in spring, summer, and fall; (2) increase the viability of juvenile coho and numbers of returning adult coho in the region; and (3) increase water supply reliability for water users in each focal watershed. The Partnership's approach integrates targeted outreach and community support; project development, implementation, and evaluation; support for strategic changes in water rights and policy; and streamflow and fisheries monitoring.

The combination of efforts in the Russian River to restore habitat, augment coho populations with hatchery releases, and conduct coho life cycle monitoring is unique, and the Coho Partnership builds on these efforts to address the survival bottleneck caused by low streamflow in Russian River tributaries. These efforts address the highest priority actions identified in the National Marine Fisheries Service's (NMFS) Central California Coast (CCC) Coho Recovery Plan. Since NFWF established the Keystone Initiative in 2009, the Russian River has become a focus area for complementary efforts: the National Oceanic and Atmospheric Administration (NOAA) selected the Russian River as its first Habitat Blueprint

Area, the Natural Resources Conservation Service (NRCS) included the Russian in its California Salmon Habitat Improvement Partnership, Grape Creek (another priority tributary) was selected as one of the ten national Waters to Watch by the National Fish Habitat Action Board, and NOAA recently named the CCC Coho population as a "Species in the Spotlight."

1.1.2 Rationale for Selecting Mill Creek

Mill Creek was chosen as a focal watershed because it provided the critical intersection of feasibility of salmon restoration, degree of impairment of stream by diminished flows, landowner interest in collaboration, importance to coho salmon, range of land and water uses with the potential to demonstrate a variety of solutions, and federal and state recovery plan prioritization. NMFS's CCC Coho Recovery Plan identifies Mill Creek as a Core Area for protection and restoration (See Figure 1).

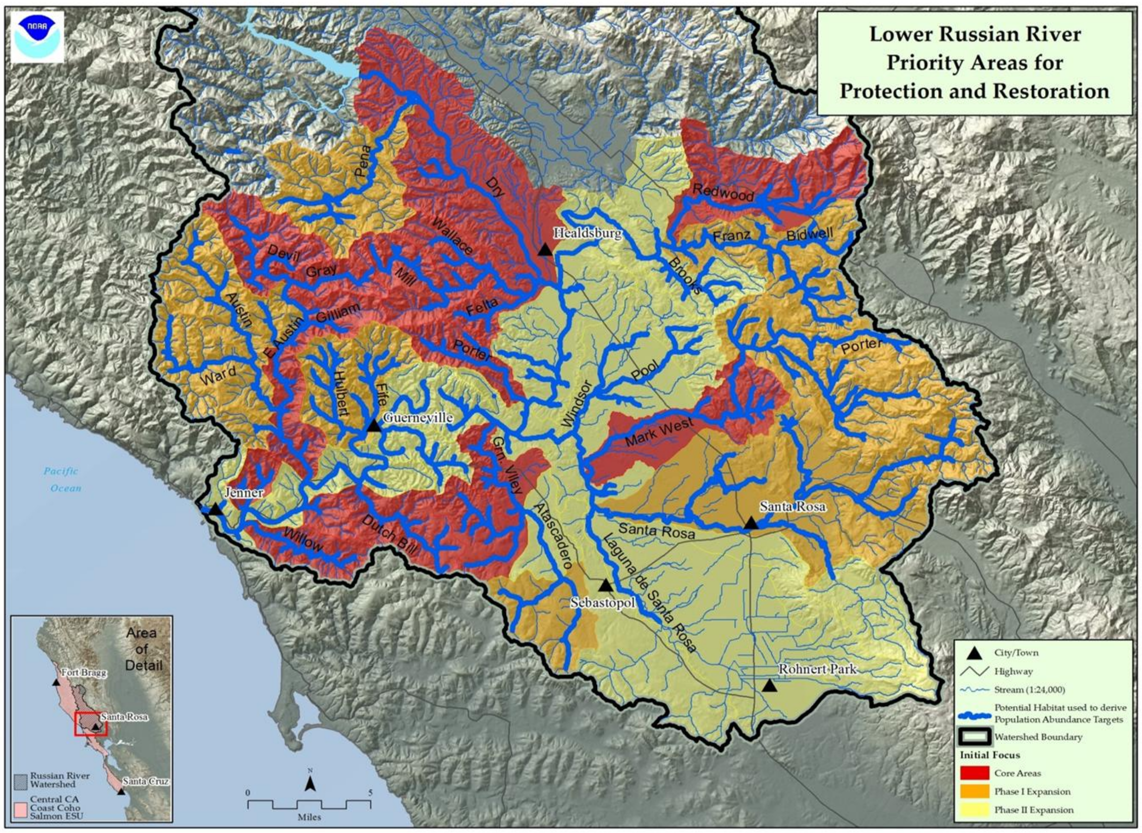

Figure 1. Core Area Identified in the NMFS CCC Coho Recovery Plan (NMFS 2012).

In spring 2015, the California Department of Fish and Wildlife (CDFW) and NMFS identified Mill Creek as one of four Russian River tributaries (and one of nine streams in the state) for a voluntary drought initiative and asked water users along Mill Creek to reduce their reliance on water from Mill Creek and its adjacent shallow aquifer in order to protect native coho and steelhead. In summer 2015, the State Water Board adopted an emergency conservation regulation for Mill Creek and three other Russian River tributary streams.

1.2 Purpose of the Mill Creek SIP

The purpose of this SIP is to provide a foundation and rationale for actions to improve streamflow conditions for salmon and steelhead and water supply reliability for water users in the watershed. The SIP integrates information gathered through the Partnership's activities and recommends future actions in the watershed.

1.2.1 Nexus with the Mill Creek Watershed Management Plan

In 2013, SRCD drafted Phase I of the Mill Creek Watershed Management Plan. The Plan provides information on watershed background, management recommendations, agricultural and rural sustainability, water conservation, water quality, instream and riparian habitat, sediment sources and impacts, and forest lands. One of the Plan's recommendations is to complete this SIP. Because SRCD has already compiled information concerning habitat quality and non-water quantity-related threats and recommendations, the Partnership intends that this SIP be used in conjunction with the Management Plan. The SIP will focus on providing watershed-specific streamflow monitoring information and recommendations based on the (hydrologic and fisheries) data collected by the Partnership. Both are intended to be living documents.

2 Rainfall and Discharge

2.1 Rainfall

The climate patterns of the Mill Creek watershed are, like most of coastal California, characteristically Mediterranean: summers are warm and dry, and winters are wet and cool. Precipitation occurs almost exclusively as rainfall (i.e., snowfall is very rare), and it occurs mostly during winter. Rainfall data over a 50-year period recorded at the nearest city, Healdsburg, CA (approximately 1 mile from the Mill Creek watershed), show that 90 percent of the average annual rainfall occurs during the wet half of the year November through April; less than 2 percent of the average annual rainfall occurs from June through August (Figure 2). While the total amount of rainfall may be variable from one year to the next, the seasonality of precipitation is consistent among all years.

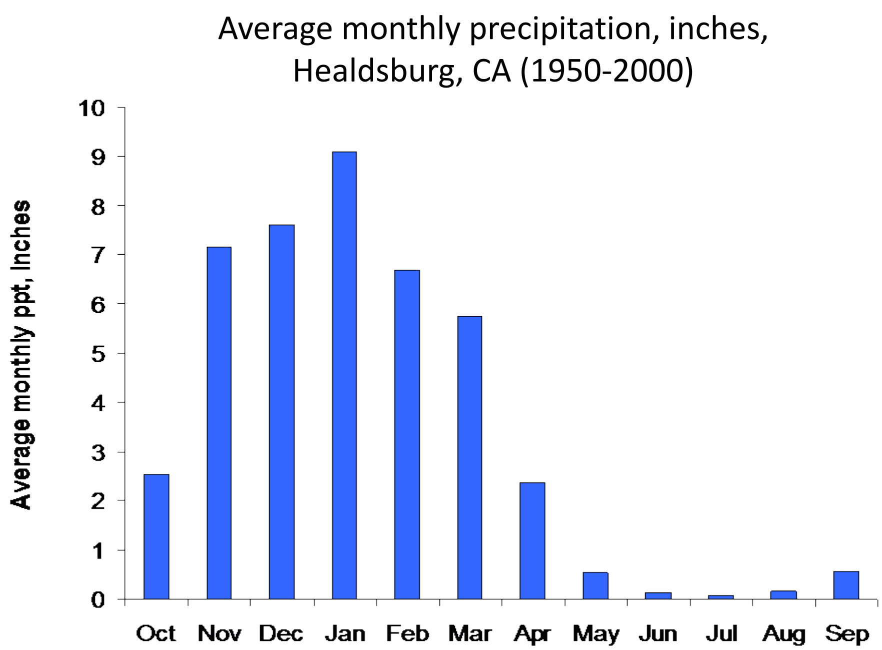

Figure 2. Average monthly rainfall recorded at Healdsburg, CA.

Computer models indicate that the Mill Creek watershed receives 49 inches of rainfall in an average year, with up to 54 inches occurring at higher elevations in the watershed and 40 inches occurring in the lower elevations (Figure 3).[1]

[1] This was estimated using a spatially distributed dataset developed through the Parameter-elevation Regressions on Independent Slopes Model (PRISM), a precipitation model developed by researchers at Oregon State University

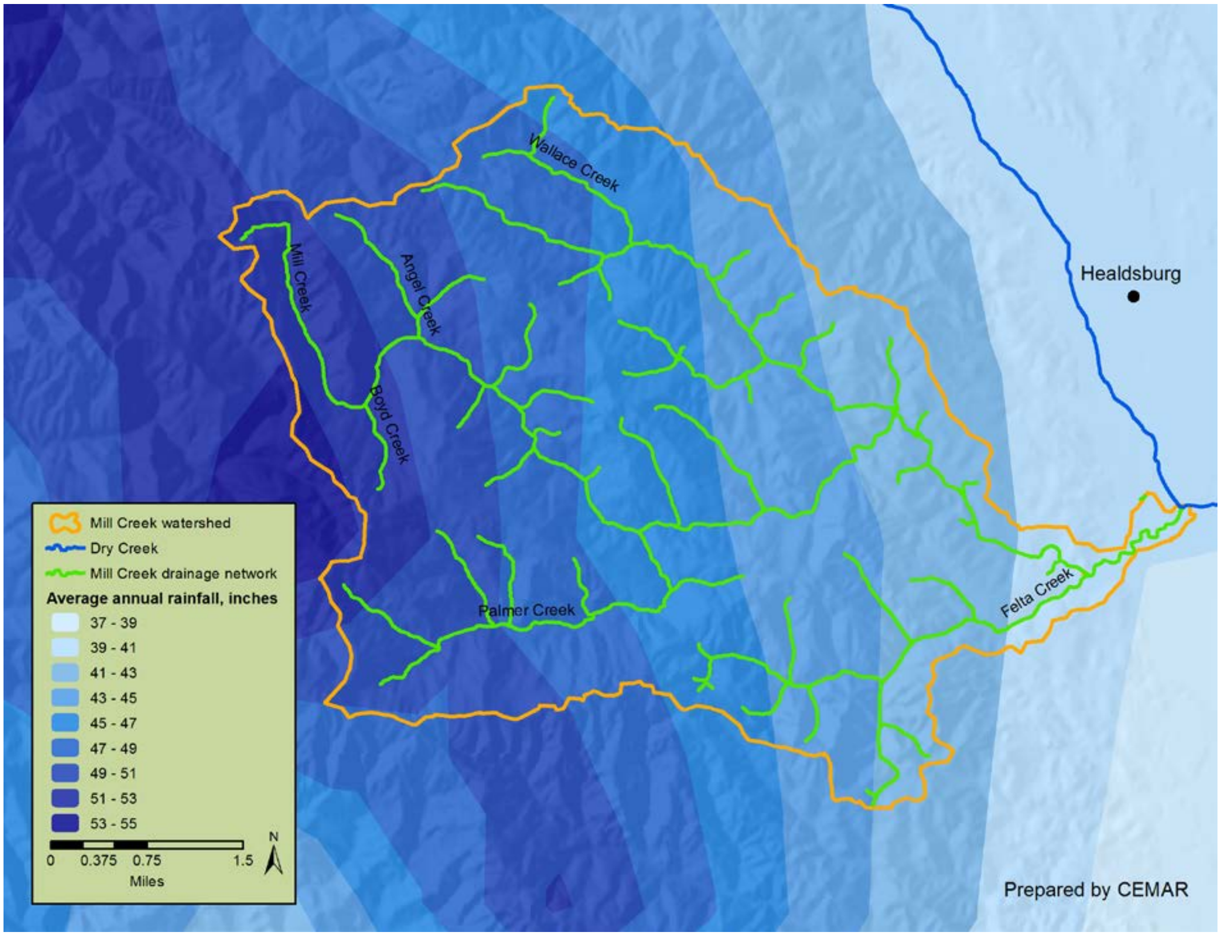

Figure 3. Average annual rainfall over the Mill Creek watershed.

Long-term records from nearby Healdsburg, CA indicate that rainfall can be variable from one year to the next. Over the 65-year period 1951 to 2015, annual rainfall has varied from as low as 16 inches to as much as 83 inches, with extended periods of low and of high rainfall throughout the historical record (Figure 3A). Most notably, the drought of 2012-2015 represents one of three periods of below-average rainfall for four or more consecutive years: the others were 1959-1962 (four years) and 1987-1992 (six years).

(considered state-of-the-art in precipitation modeling in the western United States) and publicly available over the internet. The rainfall dataset was converted into a shape file and used in a Geographic Information System (GIS) to depict the rainfall patterns in the watershed and to perform needed calculations.

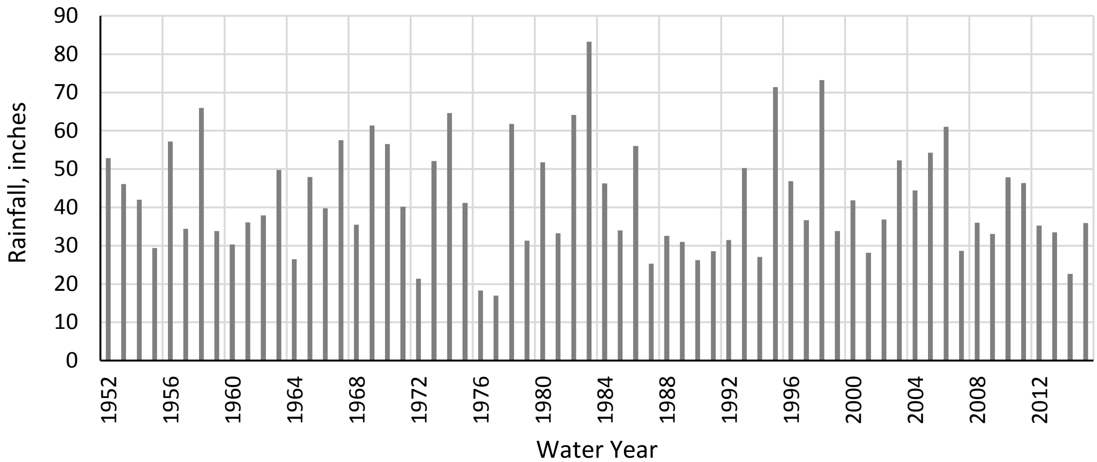

Figure 3A. Annual rainfall recorded at Healdsburg, CA, 1952-2015.

During the dry period 2012 to 2015, rainfall at Healdsburg was not evenly distributed through the winter; rather, it was focused either early in winter or late in winter, and occurred in a few large rainfall events (Figure 3B). For example, in water year 2012 (October 2011 to September 2012), 75% of the rainfall occurred in four storms, all after January 15. In water year 2013, 75% of the rainfall occurred before January 1. In water year 2014, 95% of the rainfall occurred after February 1; and in 2015, 80% of the rainfall occurred in a December storm and a February storm.

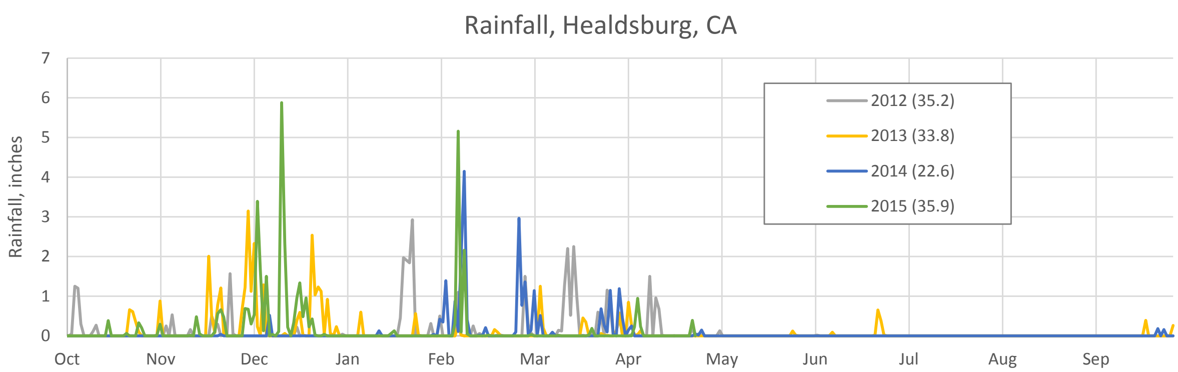

Figure 3B. Rainfall recorded at Healdsburg, CA, water years 2012-2015.

Future climate change scenarios for the Northern San Francisco Bay Area (Micheli et al. 2012) suggest that precipitation in the area will become more variable, with unprecedented annual extremes. Both "wetter" and "drier" climate change scenarios predict a potentially extended dry season, with reduced early and late wet-season precipitation. Rainfall patterns in these recent drought years offer a window into what can be expected more often in the future.

2.2 Streamflow

Streamflow is an essential component for understanding the interaction between humans and the surrounding ecosystem in the Mill Creek watershed. Streamflow data provide the foundation for many applications, such as quantifying the magnitude of the impairment that water use may cause on streamflow and helping to identify reaches that will benefit most from winter water storage. The data also are important for determining the means by which water can be obtained and stored in winter to minimize the impacts to environmental resources such as salmonid habitat. Streamflow data can also provide a baseline condition for flow prior to implementation of streamflow improvement projects and can be used to illustrate benefits of the projects once they have been completed.

We installed six pressure transducers in the Mill Creek watershed to serve as streamflow gauges during the course of the project (Mi01-Mi06 in Figure 4, note the Mi02 gauge on Palmer Creek only operated From June 2010 to October 2011); an additional gauge was installed by the State Water Resources Control Board farther downstream (Mi09 in Figure 4). We also measured streamflow at approximately monthly intervals beginning in water year 2010, following protocols adapted from the CDFW Standard Operating Procedures for Discharge Measurements in Wadeable Streams (CDFW 2013).[2] Using the measured streamflow values, we developed rating curves to correlate streamflow with discharge for each site. In addition, we installed staff plates to account for pressure transducer drift and other factors that may cause phase shifts (i.e., changes in the relationship between stage and streamflow) over the course of the project.

[2] Rather than using Marsh-MacBirney current meters as described in CDFW (2013), we used a Price mini and Price AA current meters because our experience has suggested the Price mini current meter provides more accurate low-velocity measurements.

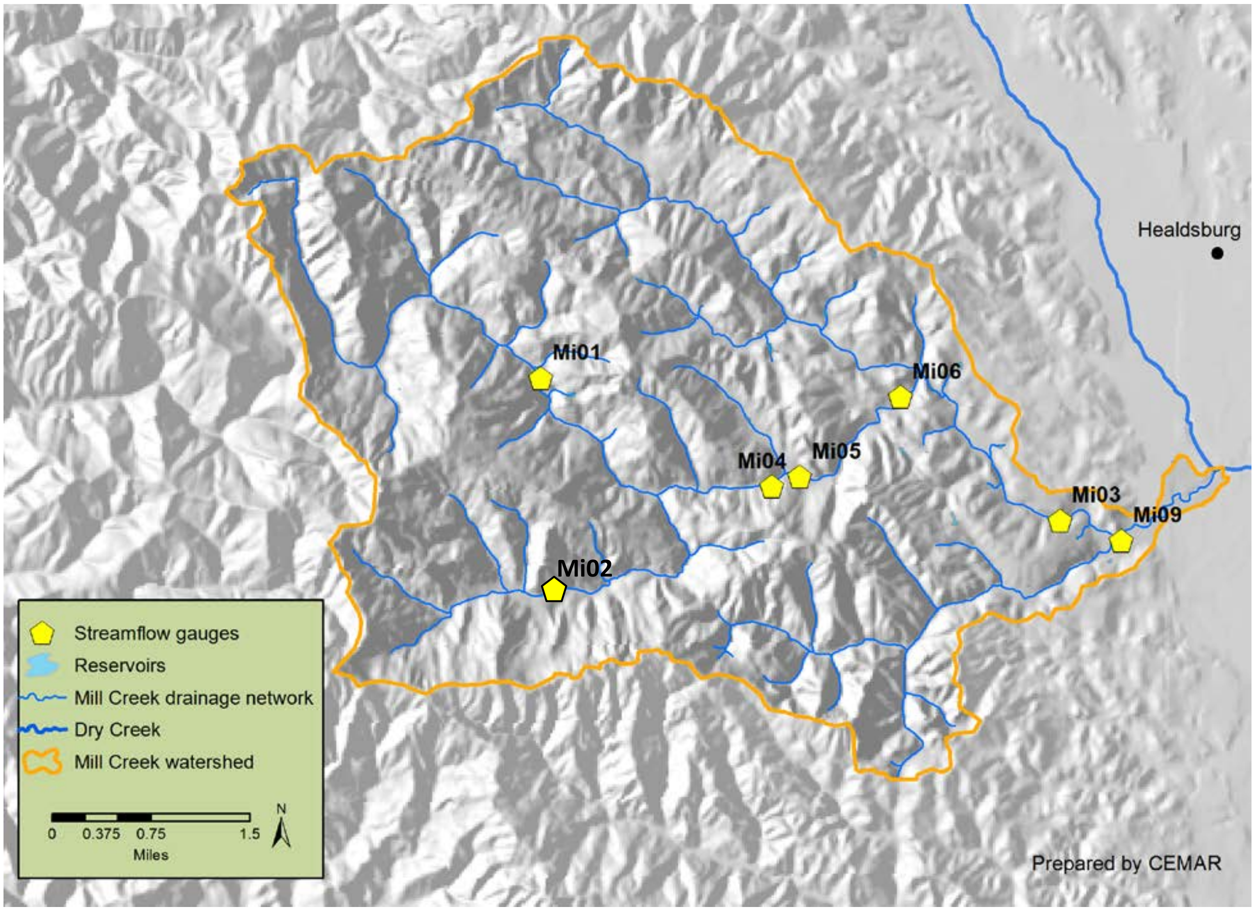

Figure 4. Streamflow gauge locations in the Mill Creek watershed.

2.2.1 Seasonal trends

Streamflow in Mill Creek shows seasonal trends that are characteristic of Mediterranean-climate streams. Like rainfall, the majority of discharge occurs during the winter months; during the period of gauge operation, as much as 95% of discharge occurred between November and April (Figure 5). Similar to rainfall, there may be substantial variability from one year to the next: Figure 5 shows how most discharge may occur in two months as in 2013, or may be spread through the winter as in 2011. However, the seasonality is consistent among years.

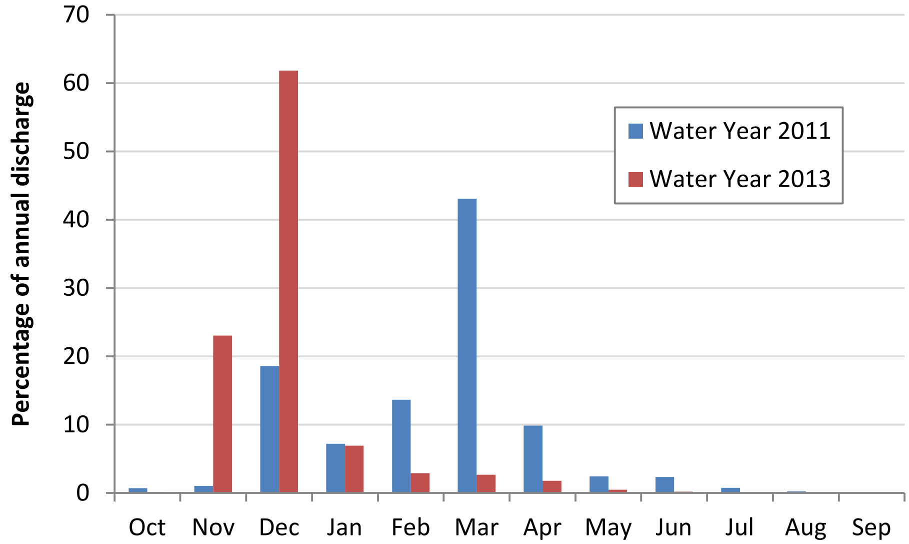

Figure 5. Monthly discharge as a percentage of annual discharge in Mill Creek, 2011.

Within the winter rainy season, streamflow typically occurs as a series of high-flow events during and immediately following rainfall events, and prolonged periods of declining base flow (Figure 6). Streamflow recedes following rainfall events at the onset of the dry season toward (and often reaching) intermittence in summer.

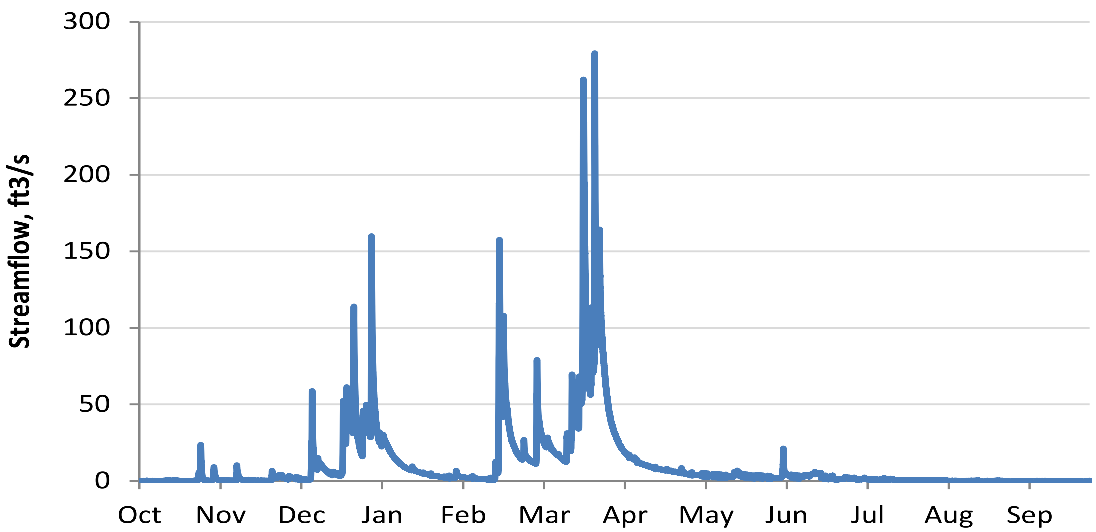

Figure 6. Streamflow recorded in Mill Creek at Bear Flat (Mi01), water year 2011.

This climatic regime poses several significant challenges to people living and working in the region, as well as aquatic organisms that use the Mill Creek drainage network for their life cycles. During the prolonged summer dry season, streams can be an unreliable source of water. Some people turn to springs, wells, and water gathered during the rainy winter for use in summer. Winter water storage may be especially important in dry years, because other water sources like springs and wells may go dry in summer. Additionally, the *variation* in winter discharge also is challenging for water users: if the majority of rainfall and discharge in a year occurs in December, then storage infrastructure must be ready to store water early in the year and maintain it until needed in summer. Aquatic organisms such as steelhead and coho salmon also face challenges; they are exposed to the high-flow conditions that occur periodically through winter, and then must persist in freshwater streams through the summer dry season until the rainy season brings water to streams once again.

Though rainfall occasionally occurs in spring or even summer (e.g., 2011), all streams in coastal California without regulated flow (i.e., dam releases) recede toward intermittence through summer. Gauges at Mill Creek show this trend toward intermittence, with some sites ceasing to flow by September in 2011 and August in 2013 (Figures 7, 8).

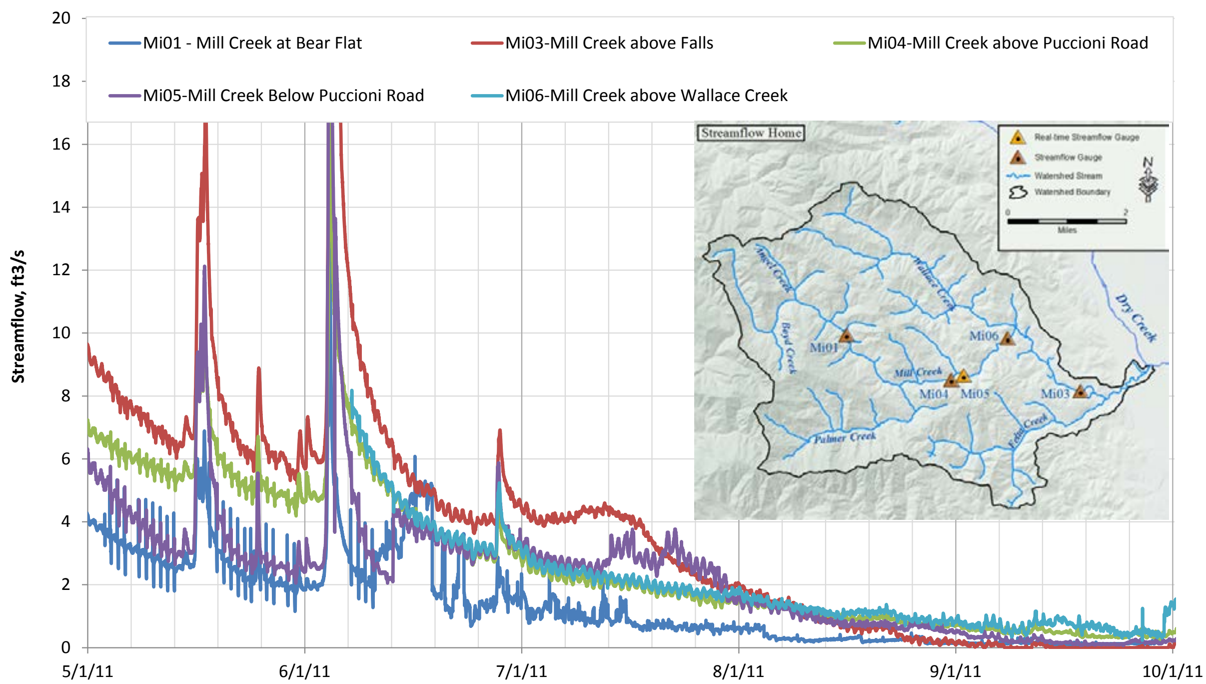

Figure 7. Streamflow at five locations in Mill Creek, May – October 2011.

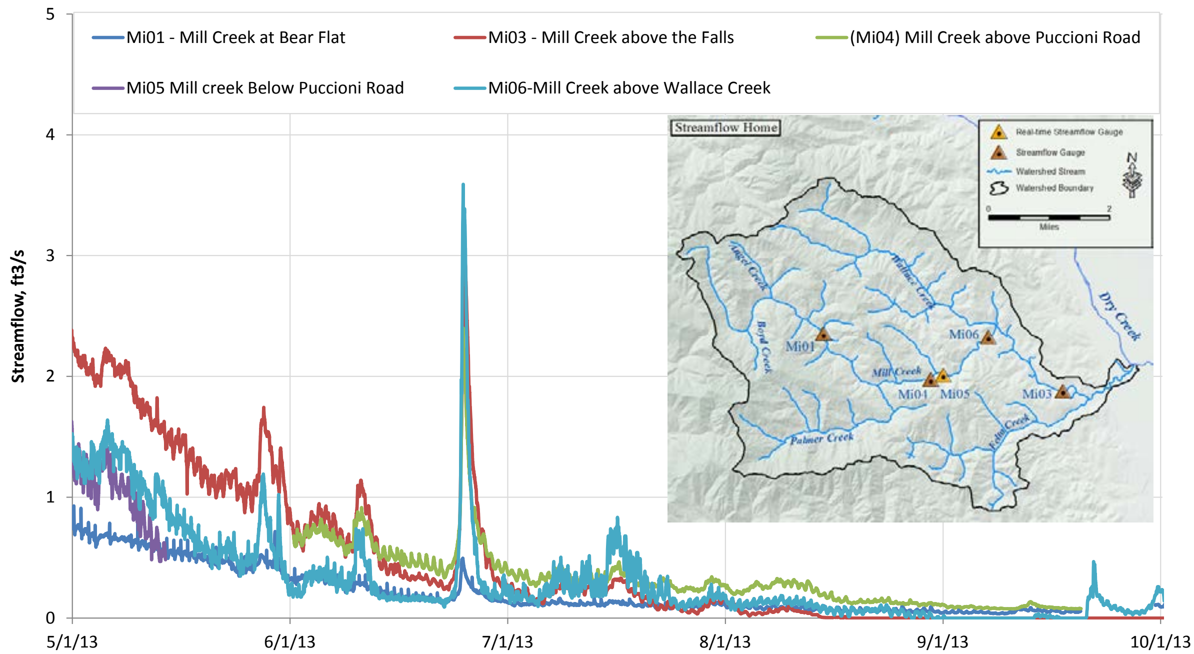

Figure 8. Streamflow at five locations in Mill Creek, May – October 2013.

2.2.2 Dry-season flows and human influence

Streamflow data collected in Mill Creek show the influence of water management practices on streamflow during the dry season. If Palmer Creek in 2011 represents typical flow conditions for an unimpaired stream (showing the consistent pattern of diurnal fluctuations in water level due to evapotranspiration; Figure 9), deviations from that flow pattern illustrate how water management practices along Mill Creek affect streamflow during summer. The Mi05 and Mi06 gauges, located in stretches of several rural residences along Mill Creek, show sudden drops in flow on the order of 0.1 to 0.3 ft^3/s through summer 2011. The sudden flow recessions are not as evident in the most downstream site (Mi03), but flow is lower than at upstream sites, suggesting that the cumulative effects of several small diversions could be causing an overall reduction in streamflow in Mill Creek. Similar patterns of reduced streamflow with distance downstream through the middle of Mill Creek, from Mi04 to Mi06 to Mi03, were measured in summer 2012 and 2013 (e.g., 2013 in Figure 10). In 2013, flow at Mi03 (farthest downstream) became intermittent in mid-August, while sites upstream maintained flow through the month (Mi04 continued to flow through summer and Mi06 became intermittent in early September).

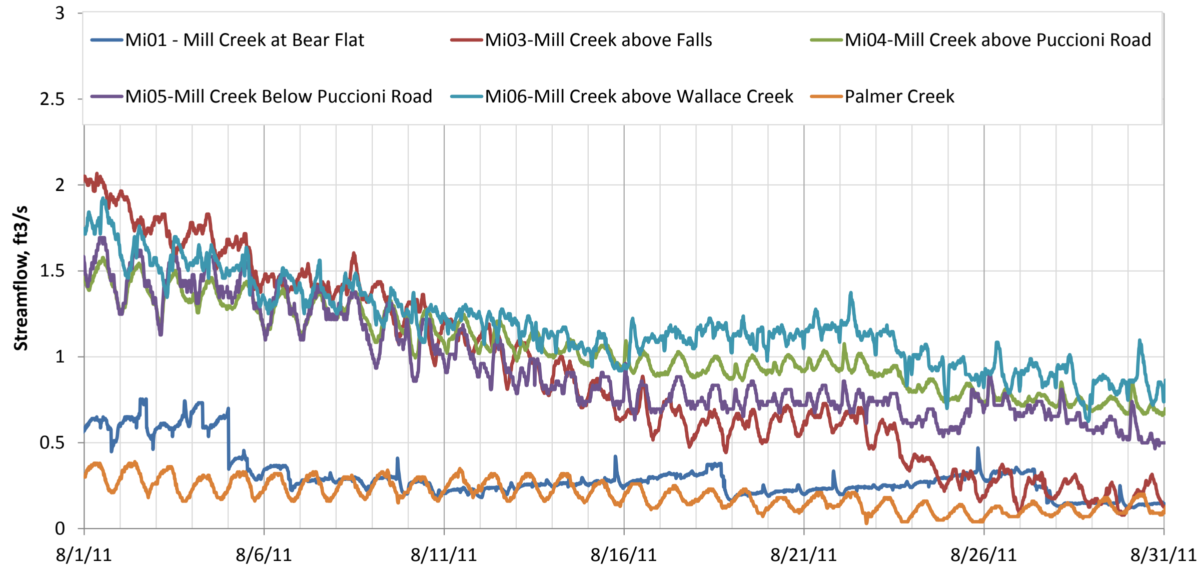

Figure 9. Streamflow at five locations in Mill Creek, August 2011.

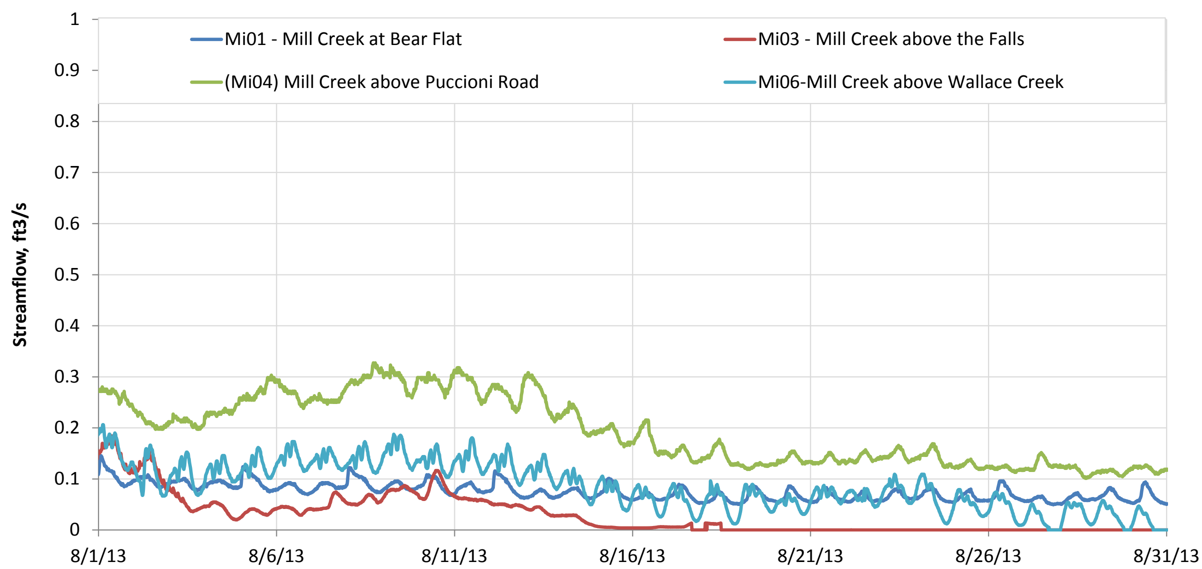

Figure 10. Streamflow at four locations in Mill Creek, August 2013.

Streamflow data during spring also show the influence of water management on streamflow in Mill Creek. Streamflow in May 2011 increased and decreased in unexpected ways beginning at the most upstream site Mi01; this pattern of rising and falling during the day was recorded at three additional sites farther downstream (Figure 11). Similar changes in flow during May were recorded in 2012 and 2013 (though the changes in flow were not as great as in 2011).

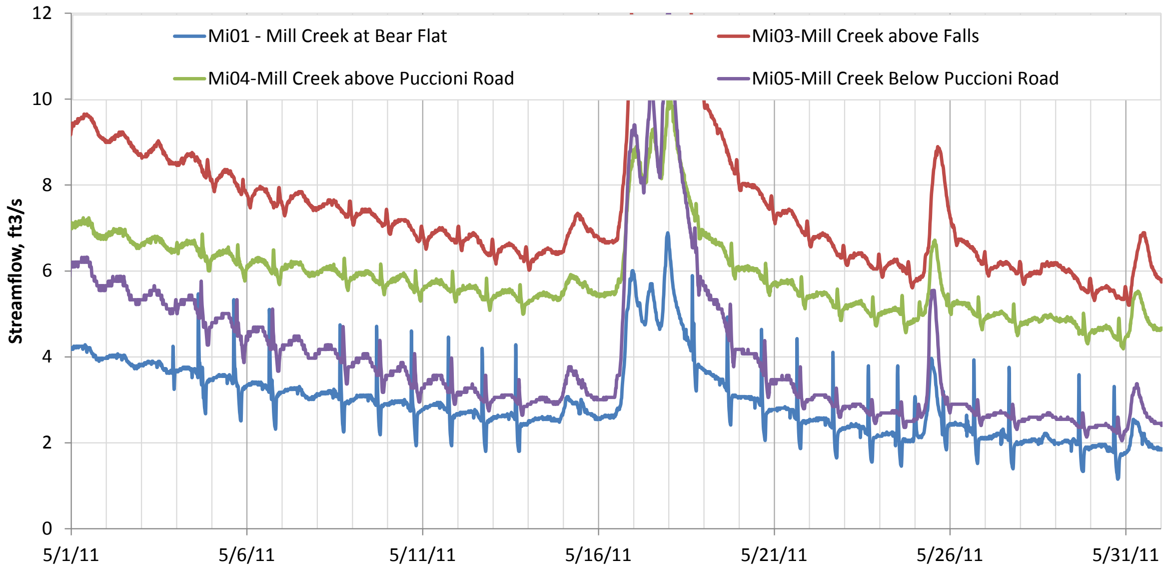

Figure 11. Streamflow in Mill Creek, May 2011.

2.2.3 Influence of 2012-2015 drought

Streamflow data gathered from the Mill Creek drainage network show the effect of the drought over the past few years, and provide valuable insights for potential future conditions. The data show a substantial difference in discharge among wet years and dry years: wet years (2010, 2011) have greater base flow and sustain discharge through the year, whereas dry years often do not. The flow records also show a consistent pattern of less base flow and earlier intermittence in each sequential dry year in Mill Creek. Whereas Mill Creek sustained flow through 2010, 2011 and 2012, it became intermittent in August of 2013 and July of 2014 (the latter resulting in at least three months of zero flow).

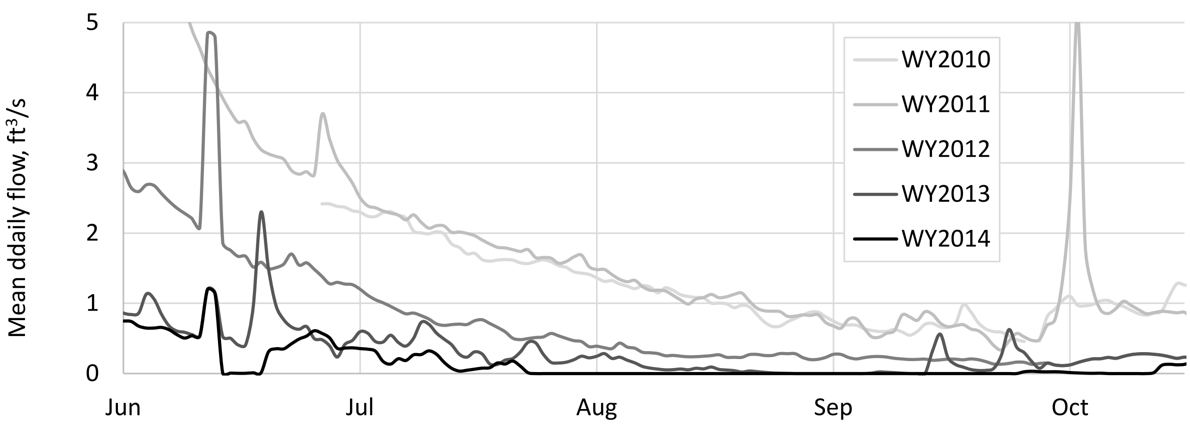

Figure 12. Mill Creek mean daily flow, June-October, 2010 to 2014.

2.3 Summary

The data collected over the past five years in Mill Creek show the typical characteristics of streamflow in Mediterranean-climate regions: flow during winter is punctuated by rainfall-driven high flow events, and flow recedes through spring and summer toward intermittence. Streamflow recedes to less than 0.5 ft^3/s (225 gallons per minute) even in a wet year, meaning that winter peak flows are typically more than one thousand times the magnitude of summer base flow.

Data also indicate that instream diversions can have measurable effects on streamflow throughout the drainage network. These effects may be most ecologically significant in summer, when small diversions can cause flow to drop by as much as 50%. Further, the cumulative effects of many small (i.e., residential) diversions may cause substantial reductions in flow throughout the dry season.

In dry years, many parts of Mill Creek become intermittent. Among our streamflow monitoring sites, those sites that become intermittent earliest tend to be located downstream of clusters of residences, which are common along the middle and lower reaches of Mill Creek. The multi-annual drought of 2012 to 2015 has caused summer flows to consecutively decrease with each subsequent drought year, resulting in streams becoming intermittent earlier with each dry year.

3 Human Needs

3.1 Comparing human water needs to water in Mill Creek

As described above, streamflow data suggest that human water management practices can adversely affect streamflow through spring and summer. A preliminary hydrologic evaluation can help to determine whether there indeed is sufficient water available on an annual scale to meet human water needs with minimal ecological impacts by initiating projects to restore streamflow.

This preliminary hydrologic evaluation compares rainfall, discharge, and human water need on an annual scale. Rainfall and discharge define water availability in a watershed: rainfall provides the overall input of water into a watershed, and discharge describes the portion that reaches streams. Rainfall is typically evaluated as average (or "normal") annual rainfall, which depicts conditions that occur most typically (our interest in long-term project resilience means that we often consider rainfall for "dry" type water years in subsequent evaluations). Rainfall can be captured off rooftops or collected directly in ponds, and it provides recharge of groundwater during winter. Discharge is the cumulative amount of streamflow from the watershed. Watershed discharge at an annual scale is an important component in this framework because it characterizes the amount of water available for stream ecosystem processes and is the source of water for people who divert directly from streams. Discharge integrates several watershed processes such as evapotranspiration and groundwater recharge that affect the fraction of rainfall that becomes converted to streamflow through the year.

3.2 Rainfall and discharge

As described above, the Mill Creek watershed receives considerable rainfall in an average year: we estimate that the annual average rainfall in the watershed is 49 inches, with a range of 54 inches in the headwaters to 40 inches in Dry Creek Valley. Over the 14,260 acre watershed, this results in a total of 58,200 acre-feet of water falling onto the Mill Creek watershed in an average year.

To estimate average discharge in Mill Creek, we modeled discharge using a simple drainage basin area-ratio transfer based on historical streamflow records measured at two nearby streamflow gauges. Data from the USGS gauge on Pena Creek near Geyserville, CA, and the USGS gauge on Austin Creek near Cazadero, CA, guided the discharge estimates used for Mill Creek.

The scaling method entails multiplying discharge recorded at the historical USGS streamflow gauge according to a ratio of catchment area and then by a ratio of average annual rainfall (based on PRISM data) in the Mill Creek watershed to average annual rainfall above the USGS streamflow gauges:

$$Q_{project\ wshd} = Q_{gauged\ wshd}\left(\frac{Area_{project\ wshd}}{Area_{gauged\ wshd}}\right)\left(\frac{Annual\ ppt_{project\ wshd}}{Annual\ ppt_{gauged\ wshd}}\right) \qquad (1)$$

In Equation 1, the terms $Q_{project\ wshd}$, $Area_{project\ wshd}$, and Annual $ppt_{project\ wshd}$ refer to discharge, upstream watershed area, and average annual precipitation of the study basin; the terms $Q_{gauged\ wshd}$, $Area_{gauged\ wshd}$, and Annual $ppt_{gauged\ wshd}$ refer to discharge, upstream watershed area, and average annual precipitation upstream of a historically gauged watersheds (i.e., Pena Creek and Austin Creek).[3] This equation appears in Appendix B of the State Water Board's North Coast Instream Flow Policy (SWRCB 2014).

This method for modeling streamflow was chosen because of its clarity and simplicity to calculate using GIS, as well as for its regulatory application: the State Water Board advises water right applicants in this region to scale streamflow using this approach to determine if sufficient flow exists to allow a new water right (SWRCB 2014). Further, an evaluation by the USGS (Mann et al. 2004) found that the basin area ratio transfer method of estimating streamflow generally performed better in this region than methods based solely on rainfall. We calculated two discharge values for Mill Creek – one modeled from Pena Creek and one from Austin Creek – and used the average of the two values for this report. The resulting streamflow information is summarized in Table 1.

Table 1. Basin hydrology characteristics, Pena Creek, Austin Creek and Mill Creek.

Stream	Wshd area, acres	Average annual rainfall, inches	Average annual rainfall volume, AF	Average annual discharge volume, AF
Pena	14,300	56	67,200	29,890 (measured, 1979-1990)
Austin	40,400	54	181,700	118,007 (measured, 1960-2013)
Mill	14,300	49	58,200	31,859 (estimated)

3.3 Human Need

Human water need describes the amount of water required for human uses over a period of time such as a year and characterizes the amount of water people can expect to need in the future (Deitch et al. 2009). In the Mill Creek watershed, irrigated agriculture and rural residences are the two most evident forms of water use. In addition, wineries and other commercial industries within the region contribute to the human water need. Irrigated agriculture can have varying water needs depending on the type of crop grown. Wine grapes are the most prevalent crop in watershed, and can require water for both irrigation and frost protection. Domestic water needs typically include requirements for landscaping and household use. Wineries require water for barrel and equipment cleaning, and for dish washing in tasting rooms. Water needs at locations such as schools can include restrooms and landscaping irrigation.

[3] The method used here for extrapolating discharge from USGS gauges does not incorporate other differences in watershed characteristics such as land cover or underlying geological formations, though these features also likely affect discharge.

This study focused on potential streamflow enhancement related to agricultural, industrial and rural residential water use. We identified features such as winery locations, agricultural fields, and building structure locations in the Mill Creek watershed using aerial imagery in ArcMap to construct a model of the human development footprint in the watershed (Figure 13). Of those structures identified as buildings, we distinguished between those that are houses and those that are other types (such as barns and garages) based on proximity to green lawns, driveways, and other residence-associated features, on size, and roof features (such as shingle color and roof lines).

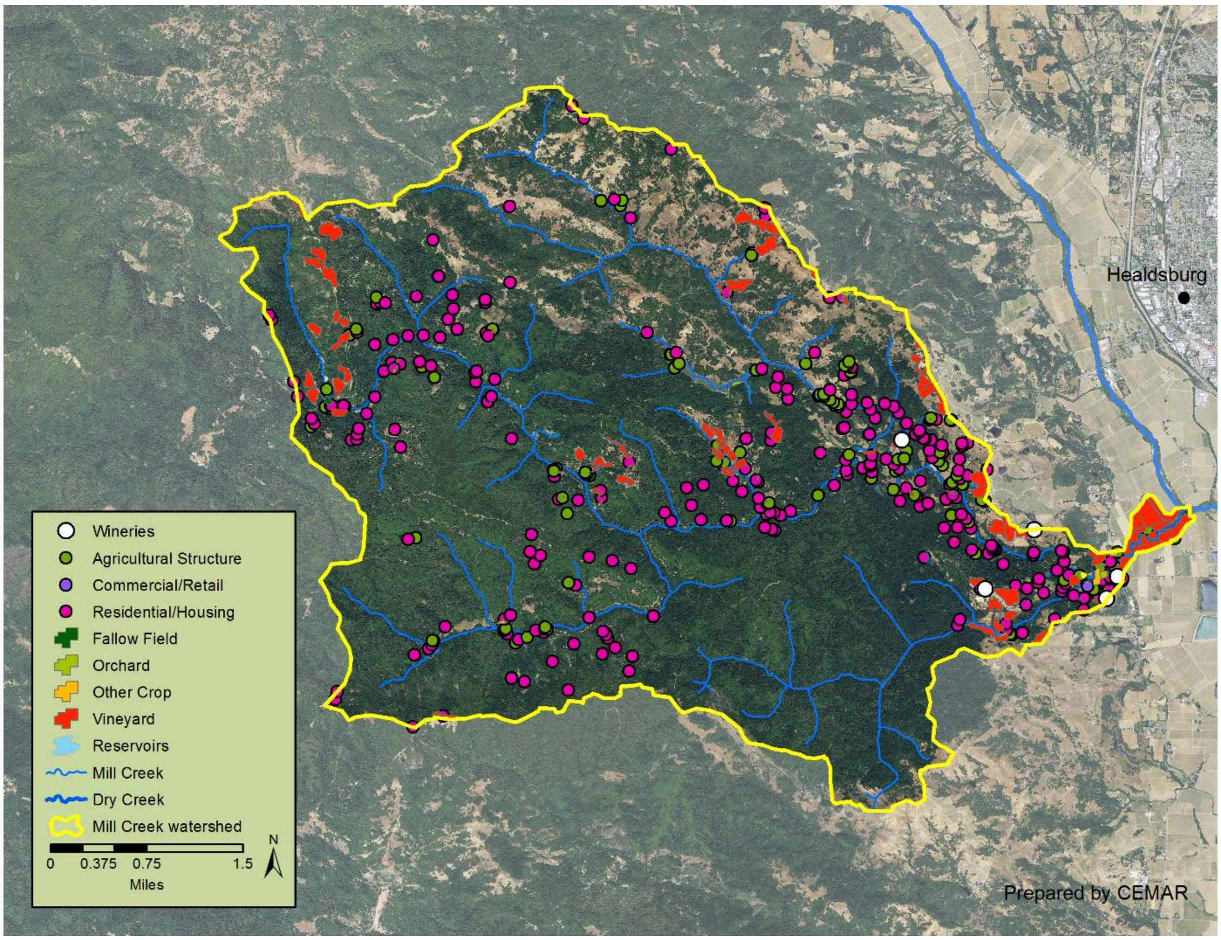

Figure 13. Human footprint in Mill Creek watershed, used to estimate water need.

The information gathered, along with standardized water use estimates, guided our assessment of human water needs in the study area:

Agricultural. We used digitized agricultural coverage to estimate the total acreage of land as vineyards in the watershed, and then calculated total agricultural water need based on regional per-area estimates of water use. For example, vineyard irrigation in coastal Northern California may require up to 0.6 acre-feet of water per acre of grapes annually (Smith et al. 2004). Since our approach is based on average use rates, and many vineyards producing premium wines typically use water at lower rates (especially for fully established vines), our estimates should be considered conservative. For olive orchards, we used per area water use rates derived by researchers at the University of California Davis (i.e., 2 acre-ft. of water per acre).[4]

Industrial (wineries). We used existing data sets to create an estimate of wine production water use in terms of gallons of water per acre of grapes. Winery water needs were only calculated for those vineyards that appeared to be affiliated (based on proximity) with wineries in the watershed. Our approach assumes that wine production is limited to only those grapes grown near the winery, and may underestimate total winery water use. However, our estimates of wine production correspond well with figures provided by the wineries themselves (on their web sites). We relied on various sources to estimate that wineries require approximately 2,750 gallons of water to make wine from an acre of grapes (i.e., 0.008 acre-feet of water per acre of vineyards).

Residential. Residential water use is variable in coastal California. Based on our review of residential water use data in coastal northern California (CEMAR 2014), we estimated rural residential water use at 300 gallons of water per day. This rate was applied to the number of households within each watershed to estimate the annual water need for residences, and thus includes consideration of greater water needs in summer for landscaping purposes.

School. We estimated the annual water use for the West Side Elementary School based on our previous work in a subregion of coastal northern California, as well as USGS determined school water-use rates. We used 4.5 gallons of water per day per person rate for toilet use, hand-washing and drinking; and estimated outdoor irrigation at a 2.5 acre-feet/year per irrigated acre rate based on our work in a nearby watershed. Our approach assumes that the school is only in operation 183 days/year (the California standard).

We estimated the amount of human water need for the Mill Creek watershed based on the water use rate factors described above. Mill Creek has approximately 348 acres of vineyards, requiring 206 acre-feet of water annually for irrigation (Table 2). Five wineries are located within the watershed, with varying amounts of production. Based on individual winery production estimates, the total annual water used by Mill Creek watershed wineries is 0.4 acre-feet. We estimate that the school in Mill Creek has 1.5 acres of irrigated area and 200 people onsite. We count 254 rural residences in the Mill Creek watershed. The total amount of water needed for these residences is approximately 82 acre-feet per year.

[4] Based on deficit irrigation estimates described by Goldhamer (1999).

Table 2. Water need calculation factors and water needs in Mill Creek watershed.

Mill Creek	Residences	Wineries	Schools	Vineyards (acres)	Orchards (acres)	Other Crops (acres)	Total human water need (acre-feet/yr)
Number	254	5	1	348	7	8	
Water need, acre-ft/yr	82	0.4	4.25	206	14	16	322

3.3.1 Annual Scale

Comparing the human water needs in Mill Creek watershed to the average rainfall and discharge provides an initial assessment for whether human water needs can be met through the water resources available on-site on an annual scale. Our analysis indicates that total water needs in the Mill Creek watershed comprise a small fraction of the total water available – 0.5% of the average annual rainfall and 1% of the average annual discharge (Figure 14).

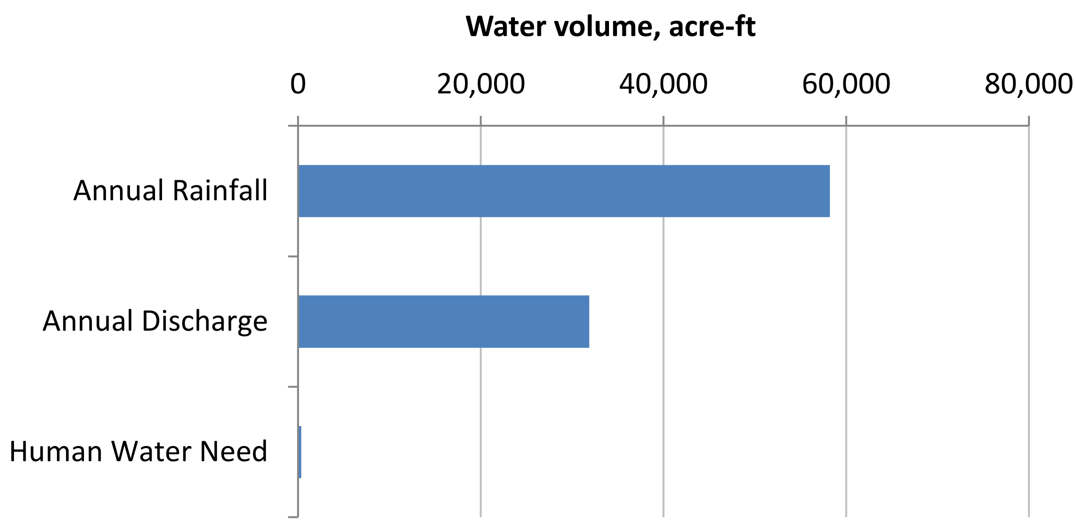

Figure 14. Comparison of average annual rainfall, average annual streamflow and human water need in the Mill Creek watershed.

In a dry year, annual rainfall may be as little as half of the average (data from Healdsburg indicate that annual rainfall was less than half of average twice during the 65-year period 1951-2015, so a year with half the average annual rainfall is atypically dry but not the driest on record). If total water needs are the same in a dry year as a normal-type year, then water needs would comprise 1% of the annual dry-year rainfall. Data from nearby historical streamflow gauges show that discharge in dry-type years is approximately half the rainfall (i.e., annual rainfall is 50% of discharge, regardless of wet year or dry year conditions, possibly because so much of the rainfall occurs in winter and in large events), so total water need would comprise 2% of dry-year discharge.

3.3.2 Summary

The above data provide important insights into the complexities of water management in the Mill Creek watershed. The Mill Creek watershed receives as rainfall approximately 200 times the total amount of water that we estimate people need for residential and agricultural uses in the watershed, even under dry-type conditions. We estimate that average annual discharge is approximately 100 times human water needs. In a dry year (e.g., a year with rainfall that is exceeded by 90% of all years), rainfall is approximately half of the average; rainfall would still greatly exceed the amount of water needed for various human uses in the Mill Creek watershed. All these results indicate that there is ample water in the Mill Creek watershed *on an annual scale* to meet human and environmental needs, even in a dry-type year.

Despite this abundance of water, the timing of its availability is the greatest challenge associated with ecologically sustainable water management. Our streamflow data corroborate this idea: many small diversions from the Mill Creek drainage network and adjacent shallow aquifers can cumulatively reduce streamflow during the dry season. Streamflow enhancement projects are based on the concept that modifying the timing of diversions from summer to winter can lead to increased summer base flow while also maintaining environmental flows in winter and providing water security for human use. By diverting water in winter and storing it for use in the dry season, people would no longer be diverting water from the stream when flow is low in summer. Given changes in rainfall patterns predicted in coming decades (described above), such storage projects will be critical for maintaining reliable water supplies for human water needs and for maintaining ecological processes in the Mill Creek watershed.

3.4 Water Rights in the Mill Creek Watershed

Water rights records provide one view into scale and type of human water needs across the Mill Creek watershed.

3.4.1 Water Rights Overview

There are two basic types of surface water rights in California, riparian and appropriative rights.

A riparian right entitles a landowner with land immediately adjacent to a stream (or other body of water) to a reasonable amount of the natural flow for use on that land. The right is inherent to ownership of the land and cannot be lost through non-use. When water is scarce, riparian owners share the available supply. The use of riparian rights does not require approval from the State Water Board, but users are required to submit Statements of Water Diversion and Use annually. Riparian rights are senior to appropriative rights, but also have significant limitations: water cannot be used on land that is not associated with a riparian parcel and no seasonal storage (generally more than 30 days) is allowed.

Appropriative rights are created by putting a specific quantity of water at a specific location for beneficial use. Unlike riparian rights, appropriative rights allow water to be stored and to be used on non-riparian land. They are junior to riparian rights, and priority among appropriative users is established by date (“first in time, first in right”). Appropriative rights can be lost if they are not used. There are two types of appropriative rights, pre-1914 and post-1914 rights.

Before 1914, a water user could establish an appropriative right by posting a notice, constructing diversion facilities, and putting the water to use. California enacted the Water Commission Act in 1914, which established a comprehensive permit system for appropriative rights. Since then, all new appropriative rights are created by application to what is now the State Water Board. Post-1914 appropriative rights can be approved only after a public process in which the applicant is required to demonstrate the availability of unappropriated water and the ability to place that water to beneficial use. The quantity of the water right is described in a permit, license, or registration. Pre-1914 users are required to file Statements of Water Diversion and Use annually; post-1914 users are required to file permittee or licensee reports annually; registration holders are required to report every five years.

3.4.2 Water Rights in Mill Creek

The Electronic Water Rights Information Management System (eWRIMS) database lists water rights on file with the State Water Board throughout the state of California. For the Mill Creek watershed, eWRIMS lists 27 appropriative rights (21 licensed, 2 permitted, and 4 pending), 1 stockpond registration, 3 domestic use registrations, 15 riparian claims, 2 pre-1914 claims and 1 other claim (Figure 15). Nineteen of the rights allow for storage.

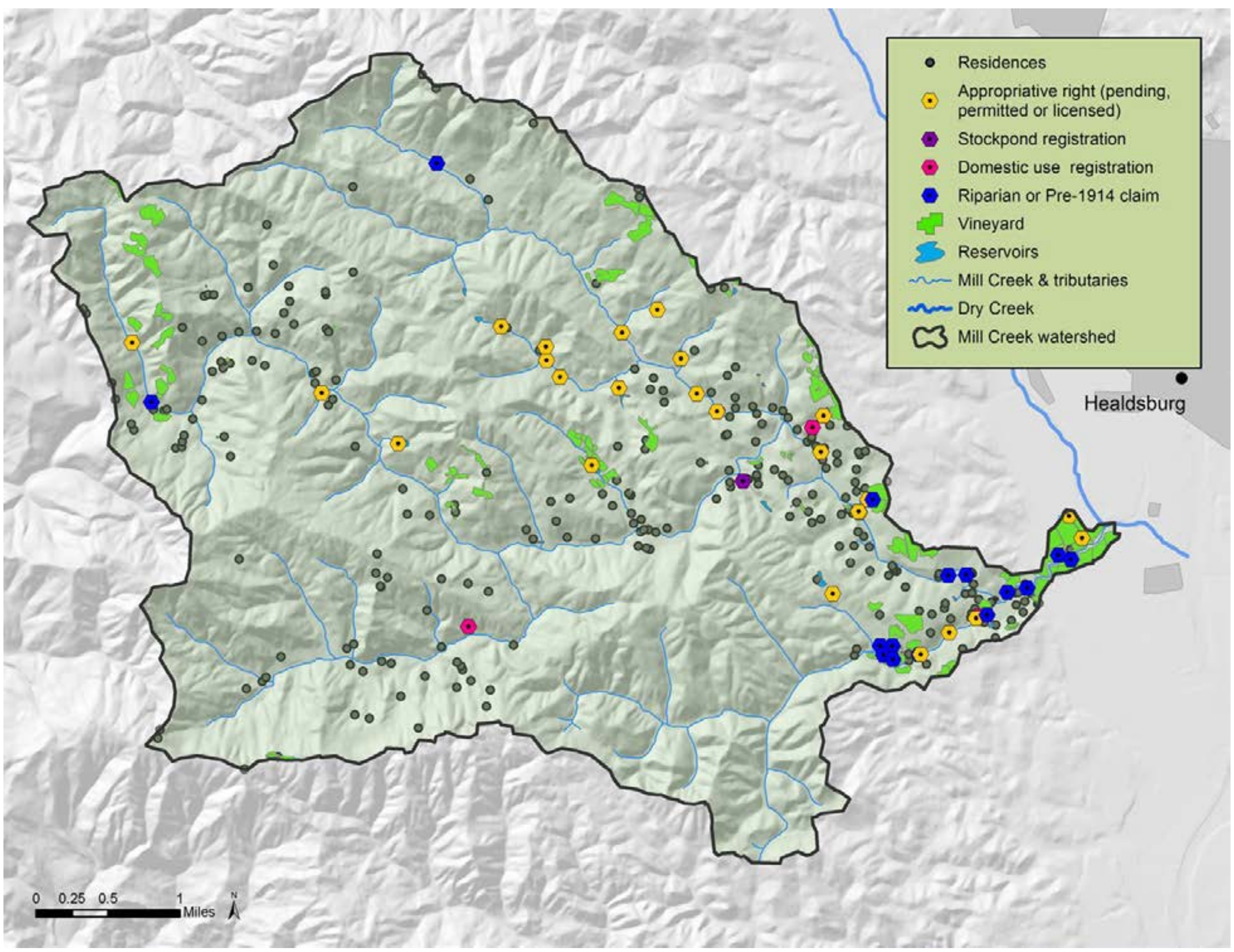

Figure 15. Locations of water rights in the Mill Creek watershed in eWRIMS as of August 2015.

Water rights may not be the most accurate way to estimate water need in the Mill Creek watershed as they under-represent the number of diversions. The eWRIMS database does not capture riparian or pre-1914 water rights if the water user has not submitted a Statement of Water Diversion and Use, uses for which a permit or license is not required (e.g., diversions from springs that meet certain criteria or pumping from percolating groundwater), or illegal water use. In addition, the State Water Board may be processing Statements of Water Diversion and Use that have not yet posted to eWRIMS.

4 Fish and Habitat

4.1 Historic presence

The Russian River watershed once supported native runs of anadromous coho (*Onchorhynchus kisutch*) and pink salmon (*O. gorbuscha*), as well as steelhead trout (*O. mykiss*) (Steiner 1996). Due to a lack of historic survey records, it is unknown whether Chinook salmon (*O. tshawutscha*) were present in the Russian River prior to the first release of hatchery fish in 1881 (Chase et al. 2007), however, a self-sustaining population of Chinook currently exists today.[5] Russian River coho salmon were historically prevalent enough to support a commercial fishery and Russian River steelhead formed the basis of a highly prized game fishery that attracted anglers from around the world until the 1950s (Steiner 1996). Pink salmon are now extirpated from the system and Chinook and steelhead are listed as threatened under the Federal Endangered Species Act. The Central California Coast Evolutionarily Significant Unit (CCC ESU) of coho salmon (including those found in the Russian River), which are estimated to have numbered in the tens of thousands as recently as the early 20th century (Steiner 1996), are on the brink of extinction. The decline of CCC coho has been especially rapid in recent decades, resulting in their listing as endangered under both the State of California and federal Endangered Species Acts.
Coho salmon, steelhead and Chinook salmon are currently present within the Mill Creek watershed. Early documentation of salmonid presence in the Mill Creek watershed is limited, but historic coho salmon presence was confirmed in Mill, Felta and Wallace Creeks (Spence et al. 2005) (Table 3), and steelhead were likely present in all of the major tributaries within the system. Dry Creek had an estimated population of 300 coho before Warm Springs Dam was built and returns of adult coho salmon to the Warm Springs Hatchery were documented every year except for one between 1981/82 and 1999/2000, though in increasingly lower numbers over time (Coey et al. 2002). Chinook have been observed in the lower reaches of Mill and, occasionally, in Felta Creeks (Obedzinski et al. 2009).

Table 3. Summary of coho presence recorded during historic CDFW surveys of Mill Creek and tributaries as noted in Spence et al. (2005) and CDFW's Stream Inventory Reports for Mill, Felta, Wallace and Palmer Creeks.[6]

Stream	Years with documented historic coho presence
Mill	1951, 1952, 1960, 1966, 1995
Felta	1966, 1995
Wallace	1952, 1966
Palmer	not surveyed

[5] http://www.scwa.ca.gov/chinook/
[6] No coho were observed during other survey years.

Over the past century, coho salmon populations in the Russian River watershed have experienced steep declines, along with other populations across the Pacific Coast. Historically, the Russian River had the largest coho population in the CCC ESU but the number of coho salmon smolts migrating to the ocean is estimated to have declined 85 percent between 1975 and 1991 (NMFS 2012). Extensive surveys by CDFW in the early 2000s found coho salmon to be present in only four of 39 historic coho streams within the basin, and only one stream had three consecutive year classes (Conrad 2005, Spence et al. 2005). By the time coho became the focus of local resource agencies in the mid-1990s, coho salmon numbers had dwindled to the point of near collapse throughout the Russian River. After the 1995 documentation of juvenile coho salmon in Mill and Felta Creeks, wild coho were not observed in the Mill Creek watershed again until the spring of 2005, when a small number of young-of-year coho, believed to have originated in Felta Creek, were captured in a smolt trap on Mill Creek (Conrad et al. 2006).

4.2 Russian River Coho Salmon Captive Broodstock Program

Private landowners, organizations and agencies responded to this decline by conserving and restoring critical salmonid habitat within the Russian River Watershed, but that effort in itself was not enough. In 2001, with Russian River coho salmon populations on the brink of extinction, a collaborative effort was formed to restore self-sustaining runs of native coho salmon to streams within the watershed that historically supported them. The Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) represents a broad partnership involving the CDWF, NMFS, U.S. Army Corps of Engineers (USACE), SCWA, UC, and hundreds of private landowners. This multi-year program was built on the use of native coho juveniles as broodstock for the production of juvenile salmon for release into historic coho streams. Broodstock program partners carefully capture wild juvenile coho, rear them to adulthood at the Don Claussen Warm Springs Hatchery, spawn them, release the juvenile offspring into selected tributary streams and monitor their growth and survival until the fish move downstream, into the ocean. This cycle is repeated annually, along with monitoring of adult coho that return to spawn in those same streams two to three years after their release as juveniles.

Broodstock Program partners captured the first coho broodstock from Green Valley and Dutch Bill Creeks (tributaries to the Russian) each summer from 2001 through 2003 and began releasing their offspring as juveniles into designated streams in October of 2004 (Conrad 2005). Mill Creek was one of the first streams stocked in 2004 and has been stocked each year since. Palmer Creek has received annual plantings of juvenile program coho since 2005. A total of 318,850 juvenile coho from the Broodstock Program were planted into Mill Creek and its tributaries from fall 2004 through fall 2014 (Table 4). Releases into the Mill Creek watershed since 2004 have averaged approximately 35% of all releases into Russian River tributaries each year, ranging from 15% to 58% (Ben White, USACE, unpublished data).

Table 4. Total numbers of Broodstock Program juvenile coho salmon stocked into Mill Creek and its tributaries (Ben White, USACE, unpublished data).

Stream	Brood year	Release year	Total release
Mill Creek	2003	2004	3,433
	2004	2005	4,399
	2005	2006	11,599
	2006	2007	33,192
	2007	2008-09	37,610
	2008	2009-10	34,228
	2009	2010-11	36,254
	2010	2011-12	31,933
	2011	2012-13	17,072
	2012	2013	19,168
	2013	2014	19,182
Palmer Creek	2004	2005	4,386
	2005	2006	5,123
	2006	2007	7,847
	2007	2008-09	9,022
	2008	2009-10	7,093
	2009	2010	6,916
	2010	2011	7,059
	2011	2012	7,045
	2012	2013	7,027
	2013	2014	7,204
Angel Creek	2010	2011	2,058
TOTAL			**318,850**

4.3 Coho Broodstock Program monitoring

UC's Russian River Coho Salmon Monitoring Program conducts ongoing monitoring of salmonid populations in tributaries to the lower Russian River in order to evaluate the efficacy of the Broodstock Program, and to apply advances in scientific knowledge to its management. Working in this capacity, they are documenting the abundance, survival, and distribution of wild and program coho salmon throughout the southern portion of the Russian River basin over time. Both wild and hatchery stocks of Mill Creek coho have been the subject of year-round monitoring since the first Broodstock Program planting in 2004, with incidental documentation of steelhead and Chinook. Due to the endangered status of coho salmon and the objective of coho recovery guiding UC and Coho Partnership monitoring efforts, coho salmon will remain the salmonid species of focus for the purposes of this report.

UC biologists maintain Passive Integrated Transponder (PIT) tag antennas on Mill, Felta, and Palmer Creeks to track the movement of PIT-tagged program coho at all life stages (Figure 16). A downstream migrant smolt trap has been operated by UC on the lower reach of Mill Creek each spring since 2005 (Figure 16). Additional fish monitoring activities on Mill, Felta, Palmer and, as of 2013, Wallace Creeks include spawner surveys throughout the winter months to document adult returns and snorkel surveys in the summer to document the presence and abundance of juveniles.

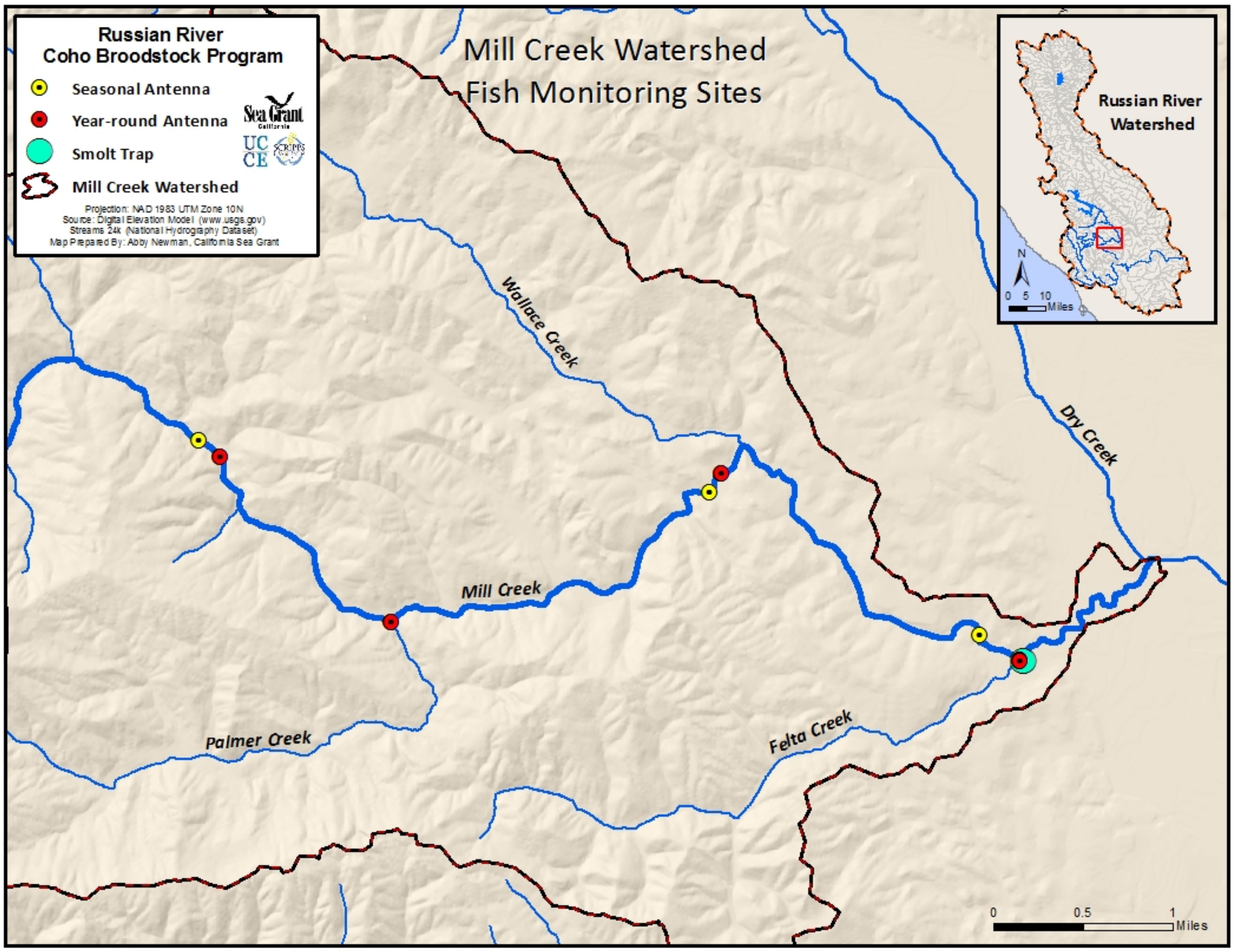

Figure 16. Fish monitoring stations in the Mill Creek watershed, including PIT tag antenna locations and downstream migrant smolt trap site.

4.3.1 Smolt abundance and juvenile survival

Each spring, UC operates a smolt trap and PIT tag antenna array near the mouth of Mill Creek (Figure 16) to estimate the number of smolts migrating to the ocean, estimate juvenile survival and growth of hatchery releases, and document smolt migration timing. Figure 17 shows the estimated number of hatchery and wild coho smolts leaving the Mill system each year, paired with the total number of juveniles released upstream of the traps since the previous spring . Survival of fall-released juveniles to the smolt stage averaged 0.26 (range 0.12 to 0.56) over the last nine years (Figure 18) and falls within rates observed in neighboring wild populations in Marin (Reichmuth et al. 2006, Carlisle et al. 2008). On average, the majority of PIT-tagged juveniles emigrating from Mill Creek are detected between March and June, however, a portion of the fish are detected leaving Mill during the previous fall or winter season (prior to March 1) (Figure 19).

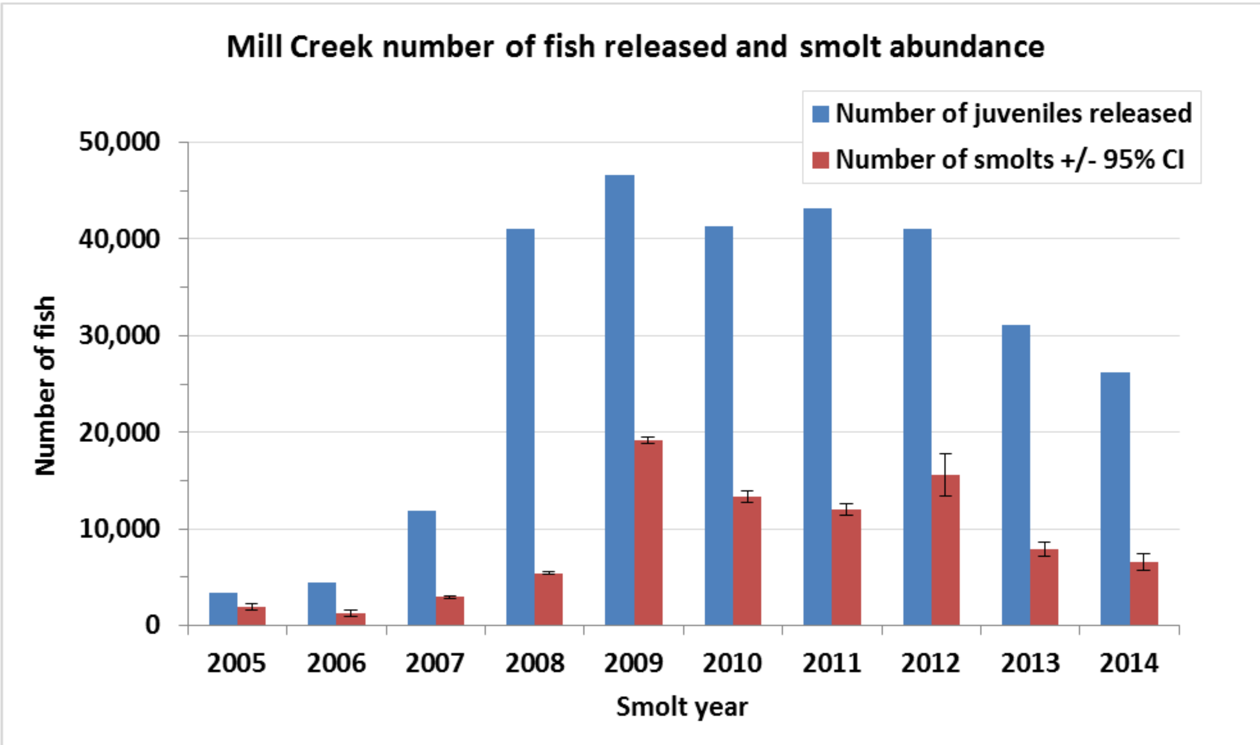

Figure 17. Estimated number of coho smolts leaving Mill Creek each year, along with corresponding number of juvenile coho planted since the previous spring.

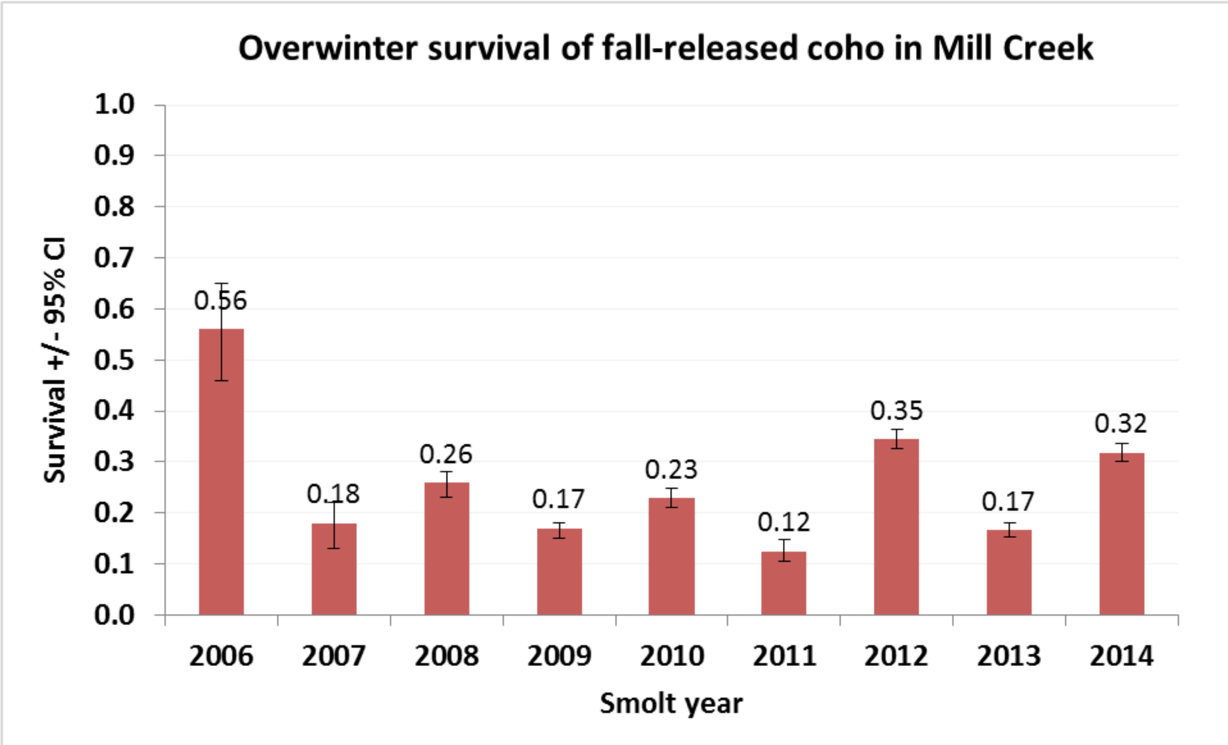

Figure 18. Estimated overwinter survival of juvenile coho released into Mill Creek during the fall season and emigrating as smolts the following spring.

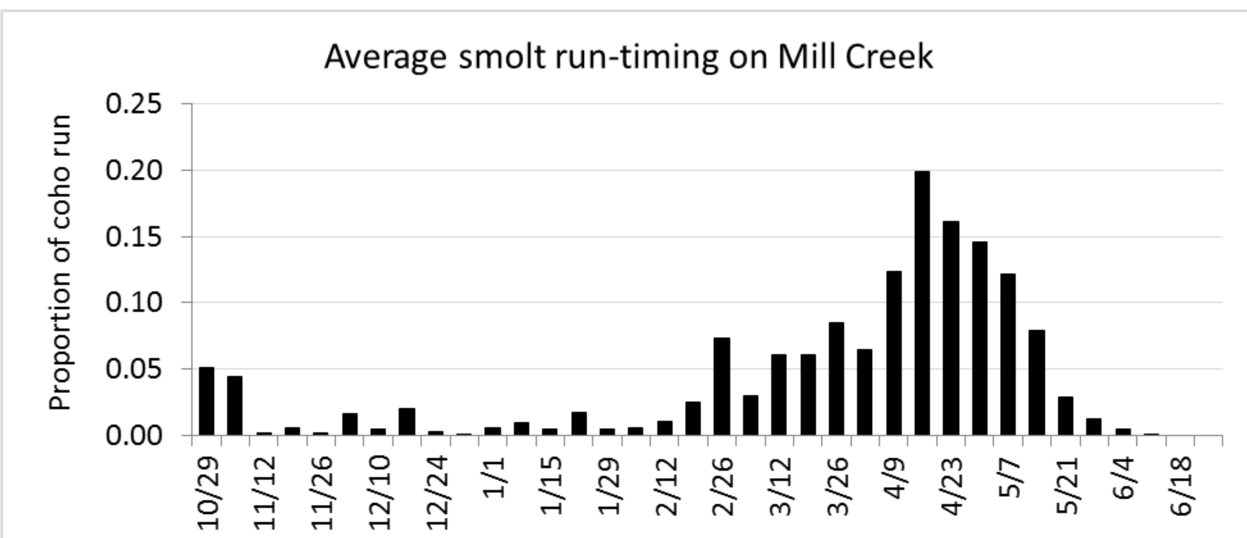

Figure 19. Average proportion of smolts detected emigrating each week from the time of fall release through the end of the smolt migration period. Dataset includes all fall releases between 2007 and 2013.

4.3.2 Adult returns

A combination of spawner surveys (2006-2014), adult trapping (2007-2011) and operation of PIT tag antenna arrays (2007-2014) have been used to estimate the number of adult coho returning to Mill Creek each year, beginning in the winter of 2006-2007 (Figure 20). Comparing the estimated number of smolts leaving each year with the estimated number of adults returning approximately one and a half years later, “marine” survival (survival from the mouth of Mill as smolts, through the river, to the ocean, and back to Mill as adults) averaged 0.3% for the last eight cohorts, ranging from 0 to 0.8%. Figure 21 displays the distribution of redds observed during annual winter spawner surveys conducted from 2006 and 2015. Although spawning has been observed throughout the watershed, the majority of known coho redds were observed in the lower reaches of Mill Creek (Figure 21). While it is possible that some of the unknown salmonid redds were coho redds, it is likely that the majority of them were steelhead redds based on the fact that, in subsequent juvenile surveys, greater numbers of juvenile steelhead than juvenile coho were observed in those locations.

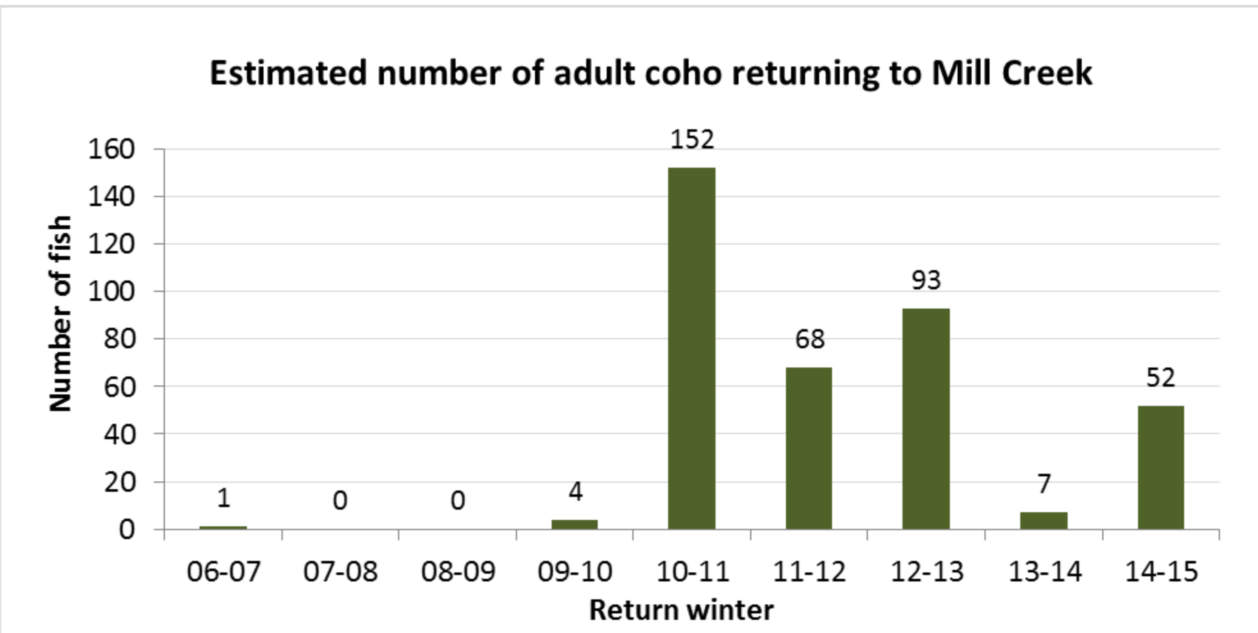

Figure 20. Estimated number of adult coho returning to Mill Creek each winter.

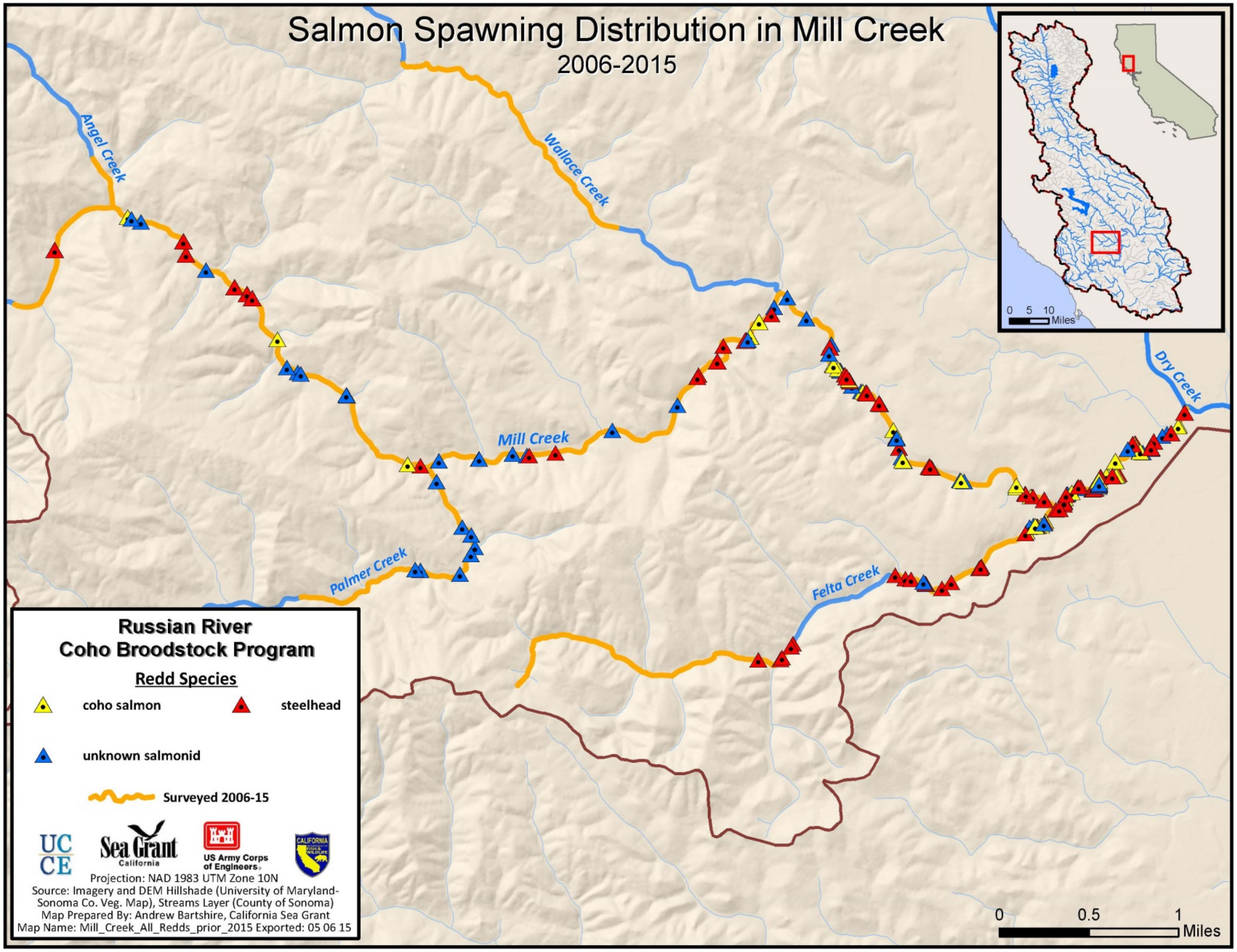

Figure 21. Map showing salmonid redds observed in Mill Creek between 2006 and 2015.

4.3.3 Natural production

Each summer (June-August), UC conducts snorkeling surveys in the Mill Creek watershed to document the presence of wild juvenile coho salmon, which provides evidence that successful spawning of adults occurred the previous winter. Since the inception of the Broodstock Program, the number of wild juveniles observed each year has generally increased, with the exception of 2014 in which no wild juvenile coho were observed (Table 5). The absence of wild juvenile coho in 2014 is likely explained by poorer ocean conditions than in previous years, as well as drought conditions during the winter of 2013-2014 that prevented adult coho from accessing Mill Creek until early February, after the peak spawning months of December and January.

Table 5. Total minimum count of wild coho young-of-the-year observed during UC presence/absence dive surveys, abundance surveys, and in downstream migrant smolt trapping operations in the Mill Creek watershed.

Year	Mill	Felta	Wallace	Palmer	Total
2005	23 [1]	33	n/a	0	56
2006	3 [1]	50	n/a	0	53
2007	2	0	n/a	0	2
2008	35 [1]	366	n/a	0	401
2009	0	n/a	n/a	0	0
2010	394	n/a	n/a	147 [2]	541
2011	1,585	310 [3]	n/a	3	1,898
2012	590	211	n/a	0	801
2013	3,259 (6,518) [4]	78	0	27	3,364 (6,623)
2014	0	0	0	0	0

[1] *These fish were thought to have originated in Felta Creek.*

[2] *Wild offspring of adult coho released into Palmer the previous winter.*

[3] *Limited access to conduct survey.*

[4] *Every other pool snorkeled. Expanded count is double the observed count.*

4.4 Flow-related bottlenecks to survival

Coho salmon need sufficient stream flow in order to complete their life cycle. During the summer season, juveniles need cool, connected pools in which to survive and grow. As one-year-old smolts, they need sufficient flows to migrate out of Mill Creek between March and June, through Dry Creek and the Russian River on their way to the ocean. One and a half years later, they need sufficient flows to migrate back upstream as adults and into Mill Creek to spawn in December through February. In Mill Creek, flow limitations have been documented for juvenile rearing, as well as for smolt and adult migration.

4.4.1 Flow limitations to juvenile rearing

As part of an effort to identify flow-impaired reaches in Mill Creek, in 2012 UC began conducting annual low flow surveys to document the lowest flow conditions fish might experience within a year. Each September, the stream is walked and flow conditions are categorized as dry, intermittent (wet pools but no surface flow), or wet (wet pools connected by surface flow) (Figure 22). The lowest reaches of Mill Creek have gone dry in all survey years and, with progressively drier years, the amount of dry habitat has been extending further and further upstream over time (Figure 22).

In order to understand the impact of these flow conditions on juvenile coho that are rearing in the stream during the summer months, the low flow survey data was overlaid with juvenile snorkeling count data collected earlier each summer to estimate the proportion of juveniles that were observed in reaches that later dried out. For example, Figure 23 shows the 2013 densities and distribution of juvenile coho salmon observed during June and July snorkeling surveys in relation to the low flow conditions that the fish experienced in September. Of approximately 3,819 wild juvenile coho observed in the Mill Creek watershed during the summer of 2013, 2,766 (72%) were found in reaches that became dry in September (Figure 23).

The high proportion of wild juveniles observed in the lower reaches of Mill during the summer is related to the fact that the majority of coho spawning occurs in the lower reaches of Mill Creek (Figure 21). One likely reason for the observed spawning distribution was the presence of two partial passage barriers low in the watershed that were likely preventing adults from accessing the upper watershed in some winters. The lower of the two partial barriers was removed in 2012. Following that removal, a significant increase in the number of redds was observed upstream of that barrier (Figure 24, Figure 25). The second barrier is a high priority for removal to increase access of adults to the upper reaches of Mill Creek that remain wet throughout the summer dry season.

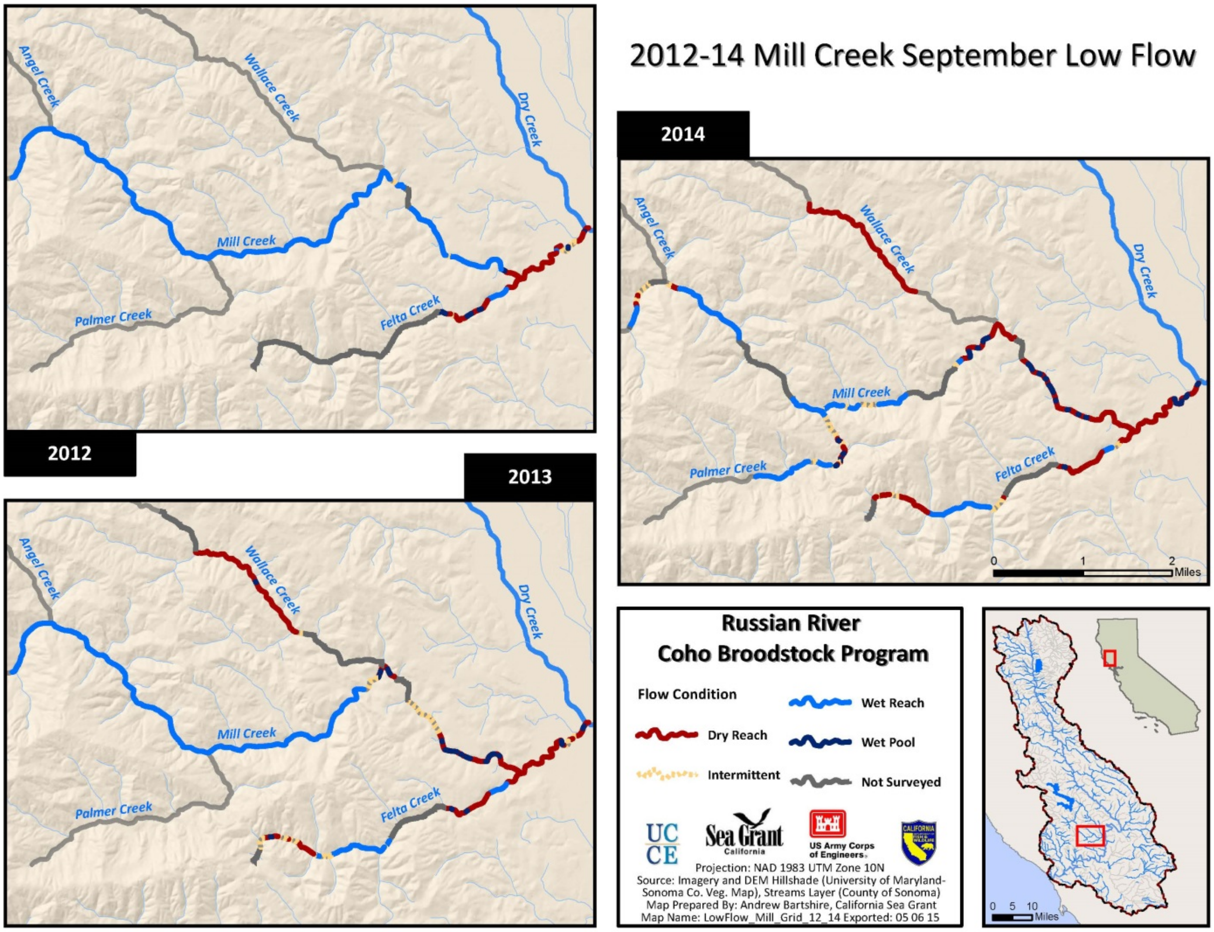

Figure 22. Low flow conditions in Mill Creek each September from 2012 through 2014.

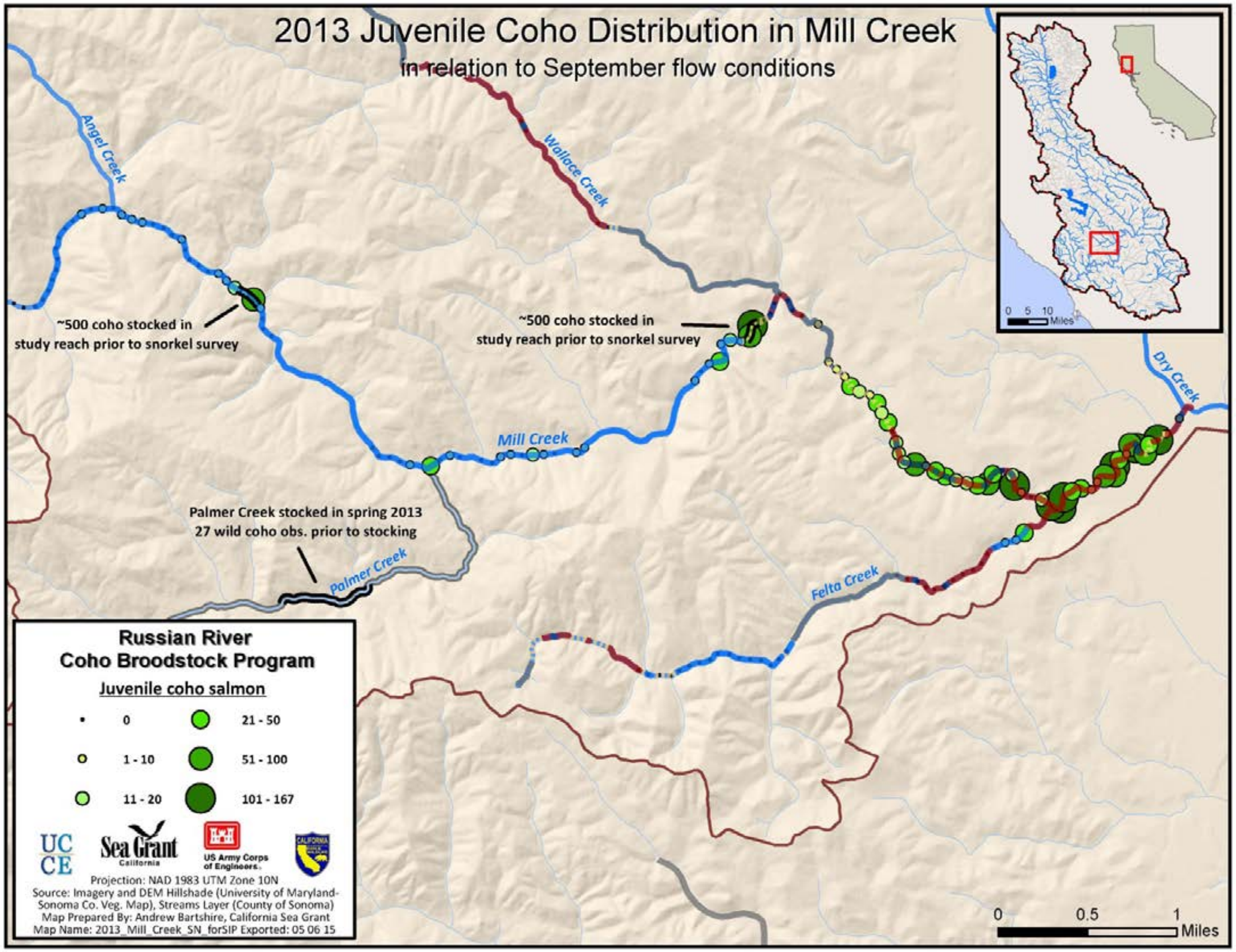

Figure 23. Distribution of juvenile coho observed during the summer of 2013, in relation to low flow conditions in September 2013.

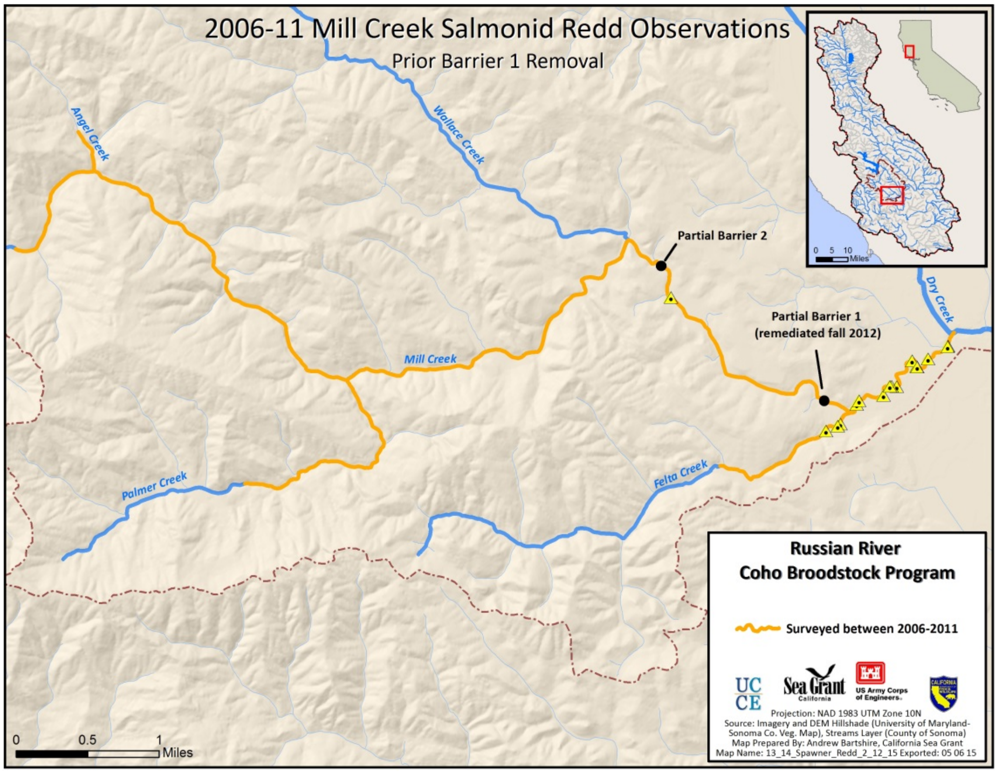

Figure 24. Coho salmon redd observations before partial passage barrier removal in Fall 2012.

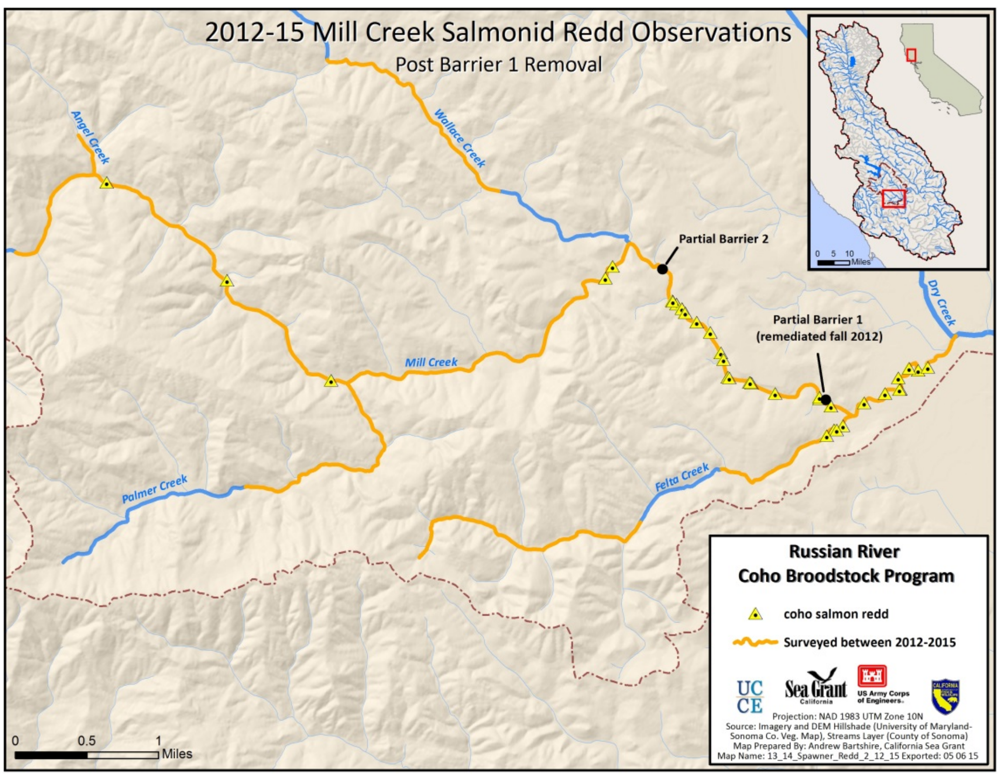

Figure 25. Coho salmon redd observations following partial passage barrier removal in Fall 2012.

4.4.2 Low flow impacts on migration of smolts and adults

In some years, lack of surface flow has cut off the migration corridor for smolts attempting to leave Mill Creek in the spring, as well as adults attempting to migrate upstream during the winter. For example, during the spring of 2008, Mill Creek became disconnected from Dry Creek on May 14, prior to completion of the smolt run (Figure 26). In this year, 1,261 coho smolts (23% of all smolts captured) were unable to migrate to the ocean due insufficient surface flow. Since 2005, such disruptions to smolt migration have occurred in 2008, 2009 and 2014, and are likely to occur in 2015.

During the winter of 2013-2014, coho salmon adults were documented entering the Russian River during October- December 2013 but, due to lack of flow, were not able to access spawning habitat in Mill Creek until February 6, 2014, after the first significant rain event that reconnected Mill Creek to Dry Creek and the mainstem of the Russian River. Although this extreme winter drought event was unique over the last 10 years of monitoring, the flashier nature of winter stream conditions in recent years appears to be influencing access to streams during the winter, as well as exposing redds between storm events.

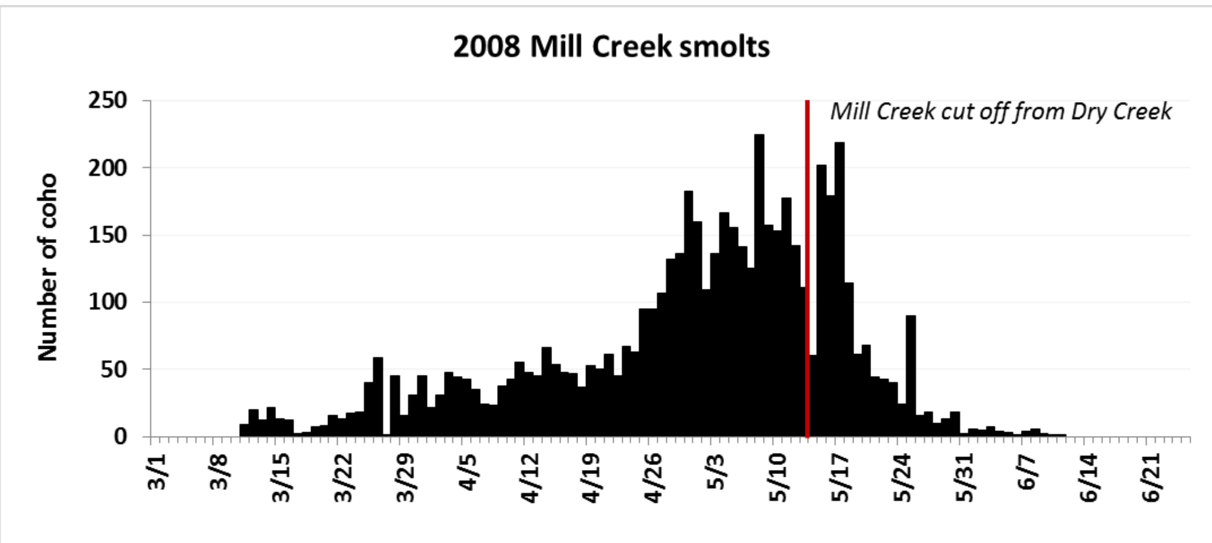

Figure 26. Migration timing of Mill Creek coho smolts in relation to when Mill Creek became disconnected from Dry Creek due to lack of surface flow in 2008.

4.5 Survival and flow monitoring

4.5.1 Overview

Through its work with the Coho Partnership, UC has been conducting an ongoing study of over-summer survival of juvenile coho in relation to flow and other environmental variables in Mill Creek, as well as three other Russian River tributaries (Dutch Bill, Green Valley and Grape Creeks), since 2010. The goal of this study is to describe the relationship between juvenile coho oversummer survival and environmental metrics, and to evaluate the effectiveness of flow enhancement projects at increasing survival of juvenile coho salmon.

The overall study design follows the BACI (Before-After, Control-Impact) framework, which examines conditions *Before* and *After* project implementation, as well as comparing a *Control* site (reference reach) with an *Impact* site (treatment reach). Having a control, or reference, reach allows the effects of restoration actions to be discerned from natural variability, stochastic events, and underlying trends. UC biologists selected treatment reaches—which were likely to be influenced by streamflow improvement projects—and reference reaches—which were unlikely to be influenced by projects—and compared survival at pre-determined intervals during the dry season with environmental variables most likely to impact survival (flow, temperature, wetted volume and dissolved oxygen). Each site has been surveyed over regular intervals (e.g., monthly) through each of the past five summers; at each survey session, juvenile coho salmon were counted, and streamflow, physical channel characteristics (e.g., pool depth, wetted area, total wetted volume) and other environmental metrics (e.g., water temperature, dissolved oxygen) were measured. More detailed descriptions of methods are described below.

The Mill Creek reference reach, in the upper watershed, maintains relatively steady flow through the summer and is located upstream of any prospective future flow enhancement project sites. It begins at river kilometer 12.39 and extends upstream for 240 meters (Figure 27). This reach has been surveyed, as part of this study, from 2010-2014 and ongoing sampling is expected. The Mill Creek treatment reach was originally established at river kilometer 8.65, upstream of the Puccioni Road crossing, and extended for 300 meters upstream (Figure 27). After the first year of sampling, it was determined that this reach was not well-suited as a treatment reach, since it was not notably flow-impaired and was unlikely to be a target location for flow improvement work. In 2011, a more suitable treatment reach was established at river kilometer 6.10, upstream of the confluence with Wallace Creek (Figure 27). This treatment reach,[7] which extends upstream for 210 meters, is located in an area of marginal surface flow. In most years, Mill Creek becomes disconnected, or dries entirely, downstream of this reach, while it remains mostly wet upstream. The reach itself generally has sufficient surface flow but becomes flow-impaired in the driest years, or possibly as a result of withdrawals. Sampling occurred in this reach from 2011-2014 and is expected to continue.

[7] From this point forward, the Mill treatment reach discussed in this document refers solely to the reach established in 2011 at river kilometer 6.10, unless otherwise specified.

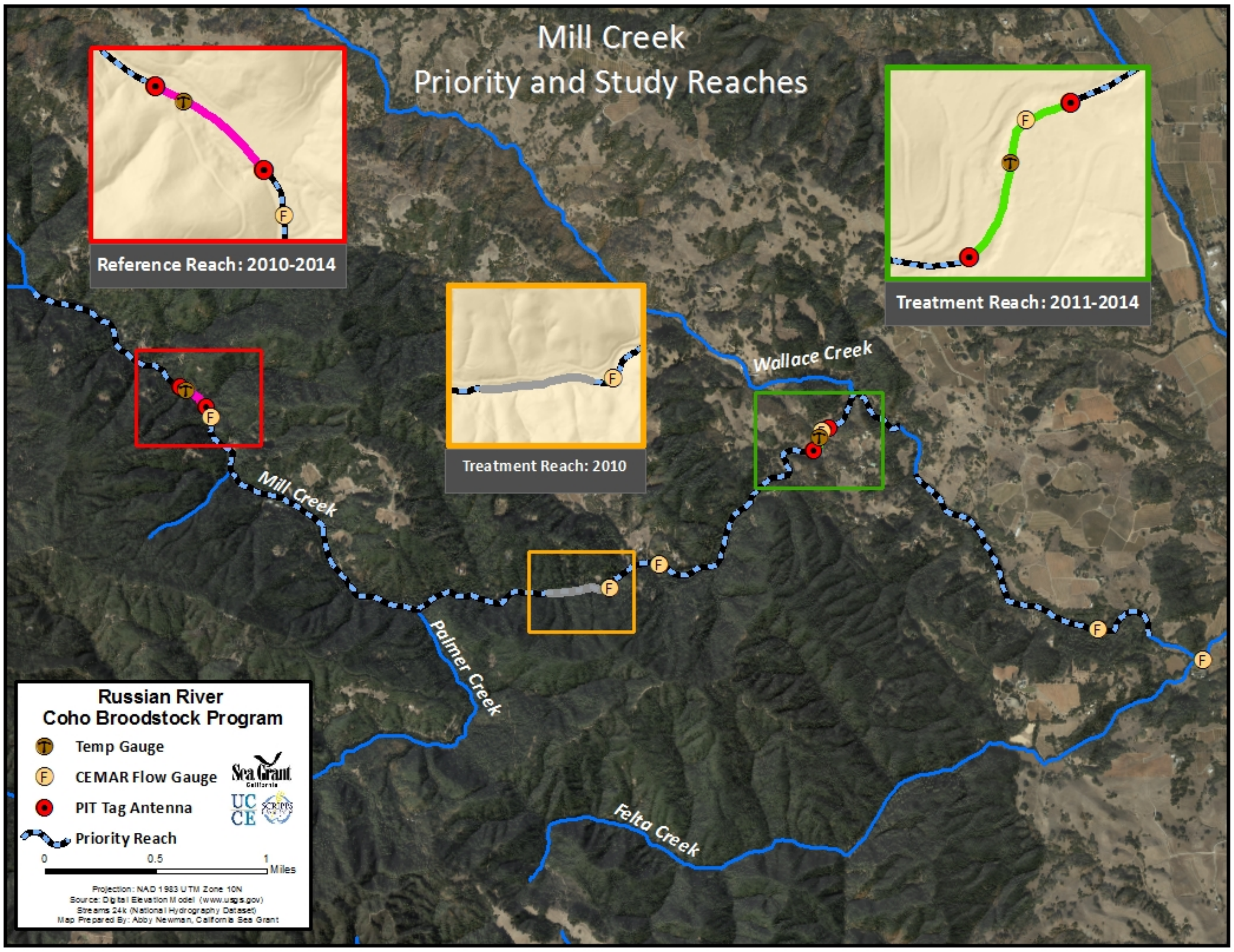

Figure 27. Map of the priority focus reach, reference and treatment reaches in Mill Creek.

4.5.2 Methods

Each year, UC biologists worked with the Russian River Coho Salmon Captive Broodstock Program to implant PIT tags in approximately 1,000 young-of-the-year (yoy) coho produced at the Don Clausen Warm Springs Hatchery and released 500 into each of the Mill Creek study reaches in June. Prior to the release, UC constructed and installed PIT tag antennas at the downstream boundary of the study reaches to document emigration throughout the summer survival interval. An additional antenna was installed at the upstream boundary of the Mill treatment reach in 2013 and at the upstream end of the Mill reference reach in 2014 to account for upstream movements as well.

Habitat surveys and dissolved oxygen sampling were conducted in each reach at pre-established intervals of approximately 4-8 weeks between June and October. In 2012, only June and September surveys were conducted, due to funding limitations. Hourly water temperature data was collected throughout the study period by deploying a continuously recording temperature logger in a representative pool within each reach.

UC biologists conducted paired "wanding" survey at the same intervals as the habitat surveys, using a portable PIT tag detection system, in order to estimate survival of coho over each interval. Approximately one month after planting, an additional wanding survey was conducted above reaches that had no upstream boundary antennas in order to account for fish that had moved out of the study reach. UC biologists relied on streamflow data from the CEMAR gauges in the watershed to correlate fish survival with streamflow. A multiple-day electrofishing survey was conducted on each reach in late September or early October to measure coho in order to estimate oversummer growth.

4.5.3 Results

4.5.3.1 Habitat

Channel type, average over-channel canopy cover, average oversummer shelter rating and pool depth were used to describe basic morphological and habitat characteristics within each of the study reaches (Table 6).

Both the Mill Creek treatment and reference reaches were classified by CDFW as F4 channel types (CDFW 2000). F4 channels are defined as entrenched, meandering, riffle-pool channels on low gradients with a high width-to-depth ratio and gravel substrate (Flosi et al. 1998).

Canopy was assessed each June in order to quantify the amount of vegetation providing shade cover over the stream channel, an important factor in maintaining cool water temperatures and reducing evaporation during the hot summer months. Average percent coniferous cover was also assessed in order to characterize dominant riparian forest composition. Between 2011 and 2014, the Mill Creek treatment reach had an average canopy cover of 90%, with virtually no coniferous cover, while the reference reach had an average canopy of 83%, with 45% of that cover comprised of coniferous trees (Table 6). Average canopy cover in both Mill Creek reaches exceeded CDFW's habitat benchmark of ≥80% (Flosi et al. 1998).

Shelter was assessed for all pool and flatwater units in order to quantify the amount of instream cover available to fish. For each unit, a shelter rating was derived through an assessment of shelter composition, quality and percent total cover within the stream channel. The shelter rating values listed in Table 6 were averaged for all pool and flatwater units over the survey period of June to October from 2011 to 2014. The average instream shelter rating was 16.5 in the Mill treatment reach and 31.6 in the reference reach (Table 6). CDFW established a shelter value criterion of ≥80 for suitable salmonid habitat (Flosi et al. 1998). Shelter values in both Mill Creek reaches were well below this criterion (Table 6).

Maximum depth was measured in every pool during each habitat survey. When June depths were averaged over all years, 38% of pools in the reference reach and 71% of pools in the treatment reach had maximum depths of >3.0 (Table 6). CDFW has stated that ≥ 40% of pools in a reach (by length) should be ≥ 3.0 feet deep in order to meet the habitat needs of salmonids for third order streams (Flosi et al. 1998). In June, the reference reach nearly met this benchmark and the treatment reach exceeded it substantially (Table 6).

Dominant substrate was recorded for all riffles. When averaged over a two-year period, 87% of riffles in the study reaches were dominated by gravel or small cobble substrate; substrates designated as desirable for salmonid spawning (Flosi et al. 1998).

Table 6. Mill Creek study reach characteristics, averaged from 2011 to 2014. Note that the percentage of pools >3.0' deep reflects measurements of maximum depth, not residual depth, taken during the June survey.

Reach	Channel type[1]	Avg canopy (%) +/- 1 SD	Avg coniferous cover (%) +/- 1SD	Avg shelter rating +/- 1 SD	Avg % pools >3.0'D by length +/- 1 SD
Mill treatment	F4	90.2 +/- 8.9	0.1 +/- 0.4	16.5 +/- 14.0	0.71 +/- 0.04
Mill reference	F4	82.8 +/- 10.8	45.5 +/- 24.9	31.6 +/- 15.9	0.38 +/- 0.12

[1]*Rosgen stream channel classification from CDFW stream reports*

Though habitat characteristics were not quantified for the entire stream, the habitat in our defined study reaches was averaged over all study years and qualified in relation to CDFW's established benchmarks (Flosi et al. 1998). Average canopy cover in both Mill reaches exceeded CDFW's habitat benchmark. The Mill treatment reach exceeded CDFW's benchmark for the proportion of primary pools ≥ 3.0 feet by reach length, while the reference reach was just 5% short of it. The vast majority of riffles in the study reaches met CDFW's criteria for suitable spawning substrate.

By contrast, shelter values were well below CDFW's desired value of ≥80 for salmonids (Flosi et al. 1998). Shelter ratings of ≥80 have not been recorded in any study reaches on Russian River tributaries, where the greatest shelter value documented was 62, in a highly-enhanced reach. In the context of the four streams included in this study, shelter ratings in both the Mill treatment reach (16.5) and the Mill reference reach (31.8) were very close to the average values exhibited across all treatment and reference study reaches for all years (16.5 and 30.8, respectively).

The results of this study, combined with a decade of year-round observations of stream conditions and fish distribution, led UC biologists to characterize the physical habitat in both Mill Creek study reaches, along with the majority of Mill Creek upstream of the Westside Road crossing, as relatively high quality. The available habitat appears sufficient to meet the needs of salmonids occupying those reaches, in the presence of ample surface flow.

4.5.3.2 Temperature

Continuous temperature loggers were deployed in each study reach throughout the oversummer season. Daily water temperature in the Mill treatment reach from June 15 to October 15 of 2011 to 2014 averaged 16.1° C (+/- 0.6° C SD), with an average maximum weekly average temperature (MWAT) of 18.5° C (+/- 1.4° C SD), and an average maximum weekly maximum temperature (MWMT) of 19.8° C (+/- 1.9° C SD). Oversummer daily temperatures in the Mill reference reach from

June 15 to October 15 of 2010 to 2014 averaged 15.2° C (+/- 0.4° C SD), with an average MWAT of 17.2° C (+/- 0.7° SD) and an average MWMT of 18.0° C (+/- 0.9° C SD).

Optimal instream temperatures for coho salmon are between 10° and 15° C (McMahon 1983). Welsh et al. (2001) found that coho salmon were absent from otherwise suitable rearing habitat in the Mattole watershed when MWAT exceeded 16.7° C, and MWMT exceeded 18° C. At 20-20.3° C and above, coho experience significant decreases in swimming speed, increased mortality from disease and cease to grow (McMahon 1983). Temperatures exceeding 25-26°C are lethal to coho salmon (NMFS 2012). CDFW established a benchmark of ≤15.5° C for coho and ≤18.3° C for steelhead (Flosi et al. 1998). This criterion was established for the entire North Coast region, but there is evidence that Russian River salmonids can survive at higher temperatures over the summer months (Obedzinski et. al 2008).

Average water temperatures observed in the Mill treatment reach over the summers of 2011 to 2014 are above the preferred range for coho salmon, but within the tolerance range, and within the suitable range for steelhead. The following graph, however, illustrates that average daily temperatures in this reach exceeded the optimal threshold for coho for the majority of the study period and exceeded the impairment threshold of 20° C in the hottest period during July, 2013 (Figure 28). Average MWAT in the treatment reach was above the avoidance threshold for coho but below the impairment threshold, while average MWMT was above the avoidance threshold and nearly reached the impairment threshold.

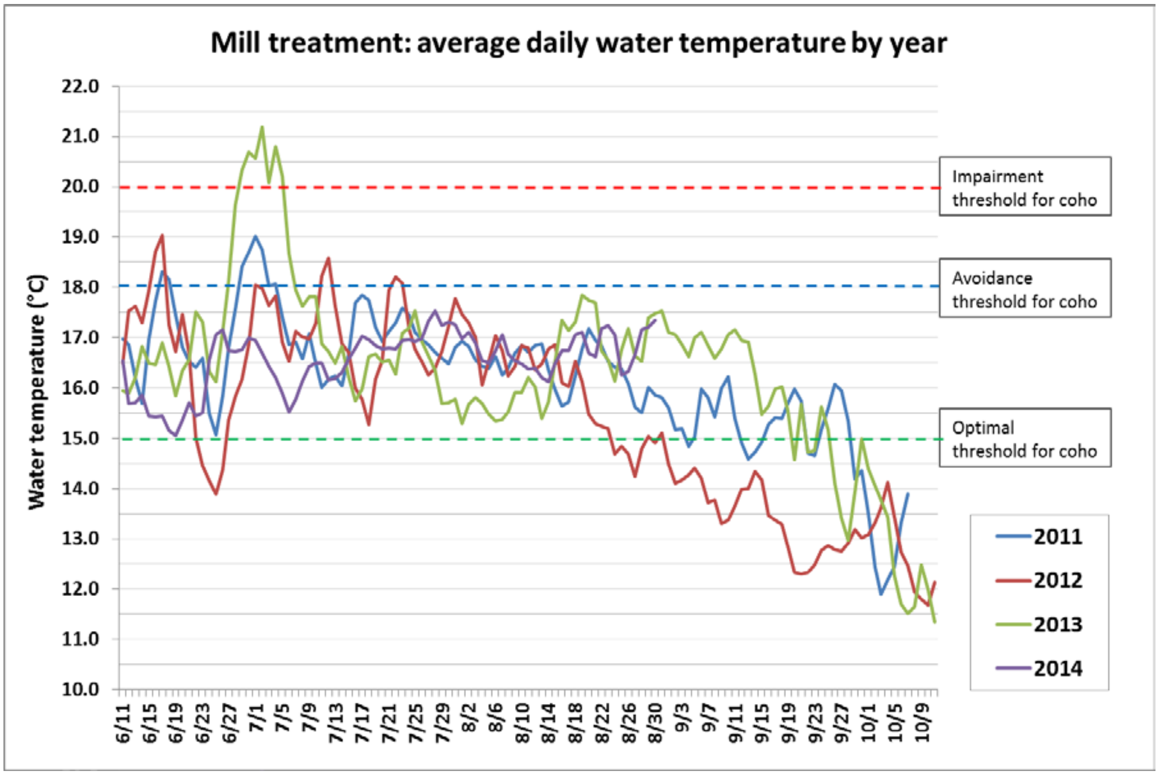

Figure 28. Average daily water temperatures in the Mill Creek treatment reach over the summers of 2011-2014 in relation to thresholds described in McMahon (1983).

Average daily water temperatures in the Mill reference reach over the summers of 2011 to 2014 were at the high end of the optimal temperature range for coho but well within the suitable range for steelhead. A closer look at the entire season by year shows that average daily temperatures in this reach exceeded the optimal threshold for coho for the majority of the study period and exceeded the avoidance threshold of 18° C in the hottest period during July, 2013 (Figure 29). Average daily water temperatures never exceeded the impairment threshold for coho in the reference reach (Figure 29). Average MWAT over all study years in the reference was above the preferred range for coho, but below the avoidance threshold, while average MWMT was right at the threshold level for avoidance, but within the tolerance level.

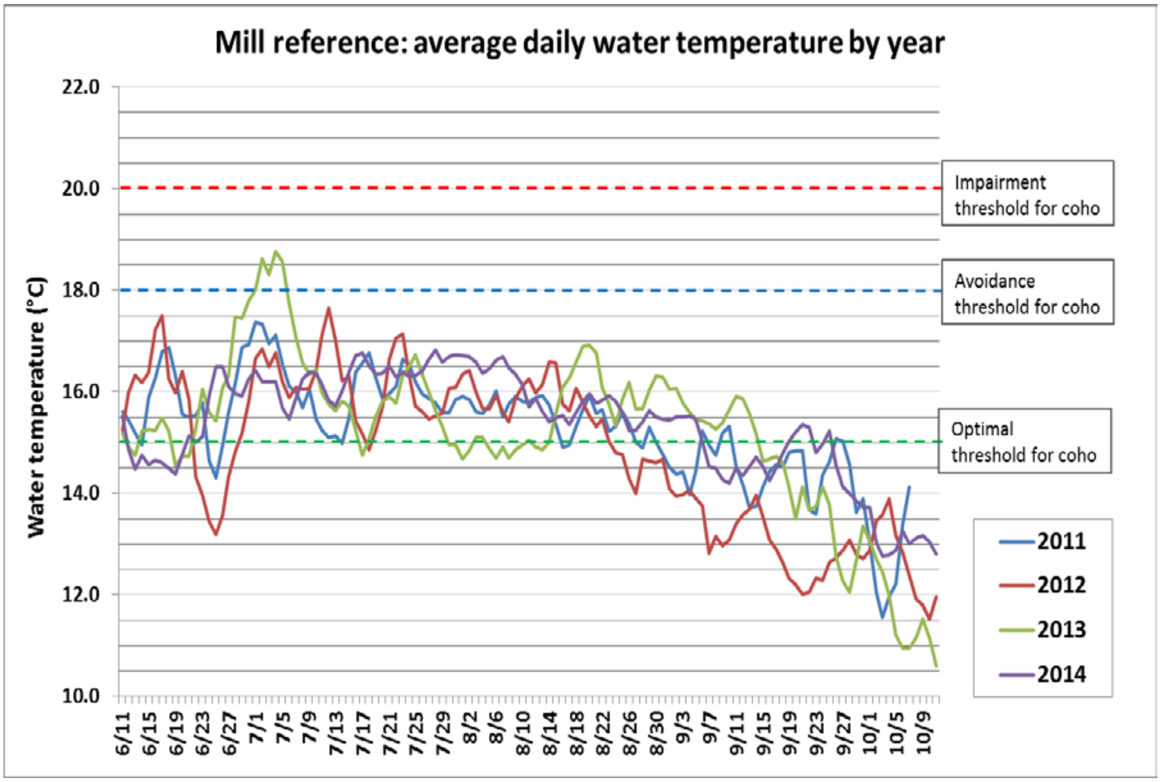

Figure 29. Average daily water temperatures in the Mill Creek reference reach over the summers of 2011-2014 in relation to thresholds described in McMahon (1983).

4.5.3.3 Dissolved oxygen

Dissolved oxygen (DO) data was collected at survival sample intervals in each study reach over the summers of 2011 to 2014, using a YSI 55D and YSI Pro20 handheld DO sensor (model varied by year). All sampling was conducted at the same location and depth (0.9') in every pool within a reach for each study year. DO data was collected within a window of about an hour in late morning (9:00-10:00 a.m.). DO in the Mill treatment reach over all years averaged 7.7 mg/L (+/- 2.0 mg/L SD), while DO in the Mill reference reach over the same period averaged 8.8 mg/L (+/- 0.9 mg/L SD).

The North Coast Regional Water Quality Control Board (NCRWQCB) listed an objective of 7.0 mg/L as a year-round daily minimum DO objective for the Russian River Hydrologic Unit (NCRWQCB 2007). Moderate production impairment is known to occur below 5.0 mg/L (NCRWQCB 2007). Food conversion decreases below 4.5 mg/L, inhibiting growth in juvenile salmonids, who have been documented avoiding waters with DO concentrations this low (McMahon 1983). The lower limit to avoid acute mortality in salmonids is 3.0 mg/L (NCRWQCB 2007).

Average DO concentrations in both Mill Creek reaches over the summers of 2011-2012 met or exceeded NCRWQCB's water quality objective. DO concentrations in the treatment reach fell below this threshold in August and October of 2013, and dropped well below mortality levels in August of 2014 when surface flows were 0.00 ft^3/s (Figure 30). Average DO in the reference reach only fell below 7.0 mg/L in August of 2014 and remained above production impairment levels on every date sampled (Figure 31).

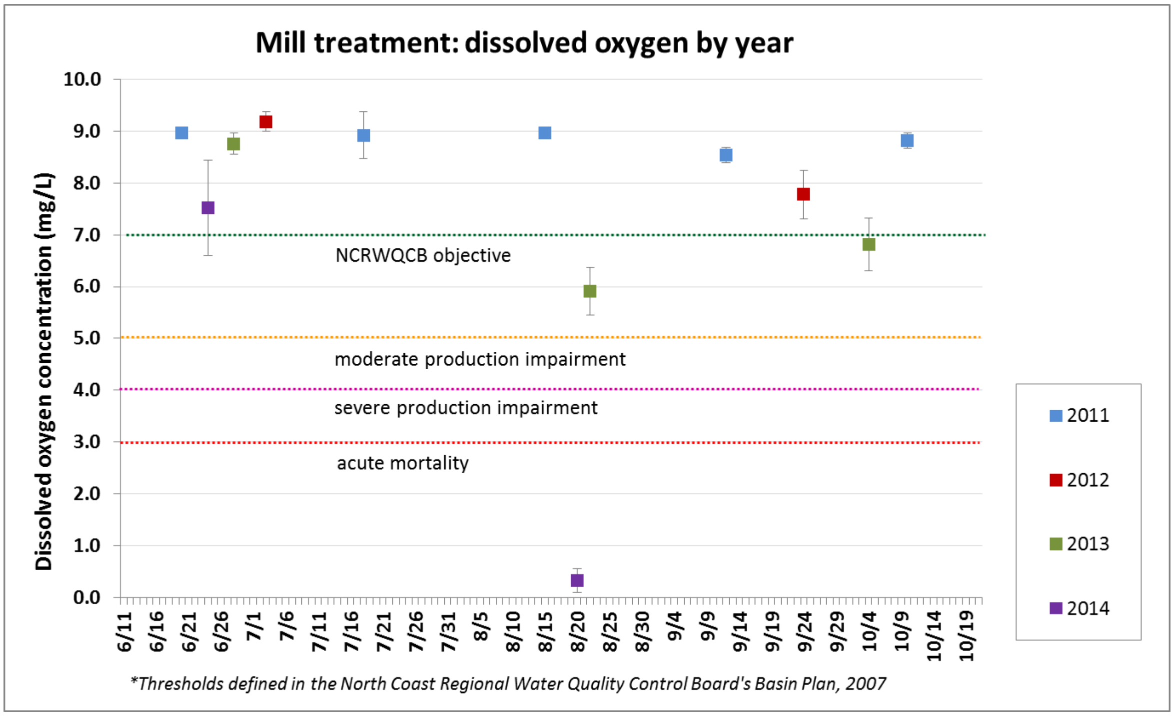

Figure 30. Reach average dissolved oxygen concentration in the Mill Creek treatment reach for all sample intervals, 2011-2014.

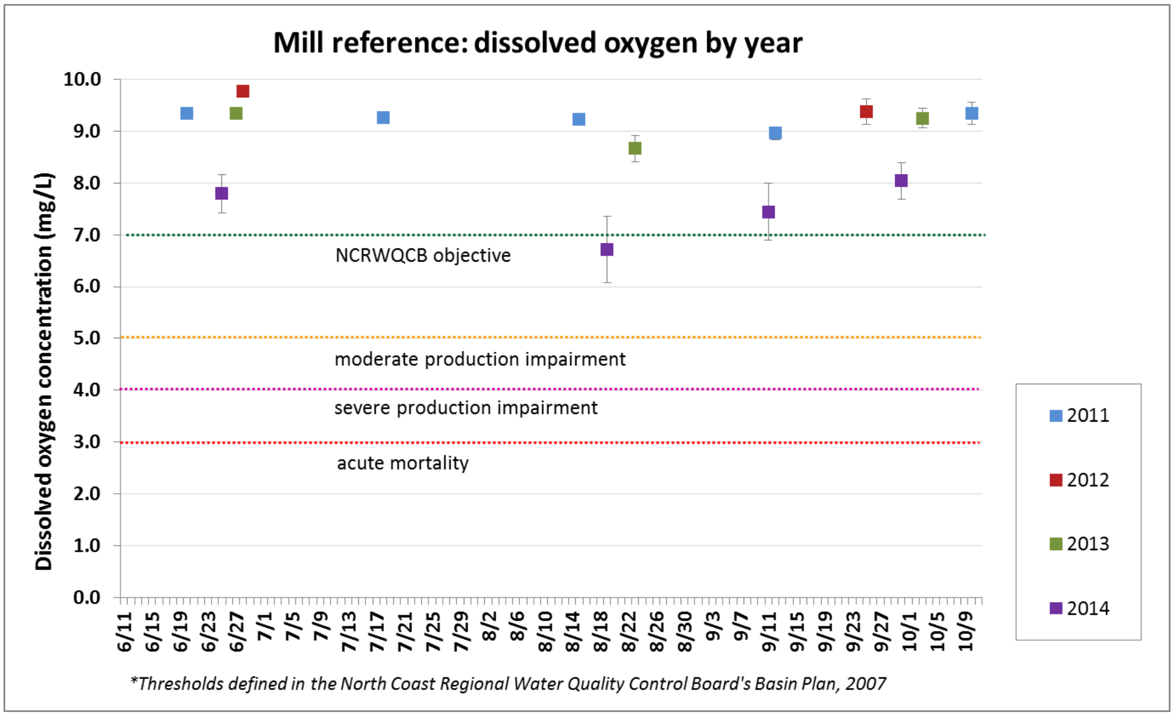

Figure 31. Reach average dissolved oxygen concentration in the Mill Creek reference reach for all sample intervals, 2011-2014.

4.5.3.4 Survival and surface flow

Patterns in oversummer survival between the treatment and reference reach differed during the study period of 2011 through 2014 (Figure 32). In the treatment reach, survival decreased from 0.81 in 2011 to 0.00 in 2014 (Figure 32). In contrast, we observed little variation in survival in the reference reach over the same time period (range 0.62 to 0.81)(Figure 32). In both reaches, we observed a decline in survival from 2011 through 2013, however, the overall decrease in the treatment reach (0.37) was greater than in the reference reach (0.13). In 2014, there was an extreme difference in survival between the two reaches; in the treatment reach no fish survived while, in the reference reach, we observed higher survival than in any other year (Figure 32). In comparison with other study streams, average oversummer survival between 2011 and 2014 in the Mill treatment reach (0.36) and the Mill reference reach (0.64) were higher than average survival in all treatment and reference reaches collectively over the 2011 to 2014 study period (0.27 and 0.51, respectively).

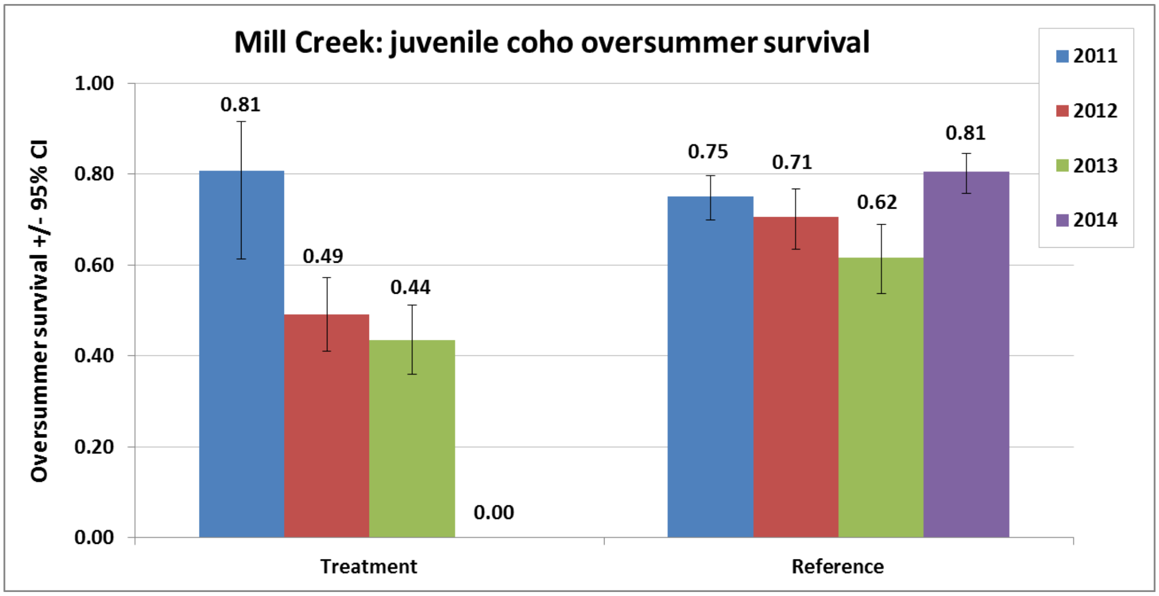

Figure 32.Survival in the Mill Creek treatment and reference reaches from 2011-2014, scaled to the period of June 25-October 15.

Flow patterns from 2011 through 2014 also differed between the two reaches (Figure 33, Figure 34). In general, flows were lower but more consistent in the reference reach compared to the treatment reach (Figure 33, Figure 34). The generally lower stream flows observed in the reference reach can be explained partly by the fact that it is located more than six kilometers upstream of the treatment reach, above the confluence with a substantial tributary, and has a smaller cross-sectional area. While stream discharge in June and July was typically higher each year in the treatment reach, more variation was observed from late July through October in this reach, with levels dropping to 0.00 ft^3/s for extended periods in both 2013 and 2014 (Figure 33). In the reference reach, discharge nearly always remained below 0.5 ft^3/s, with the exception of 2011, but only dropped to 0.00 ft^3/s for one day in 2014 (Figure 34, Figure 35).

Relationships between flow and survival in Mill Creek are complex. Despite generally lower surface flows in the Mill reference reach (Figure 33, Figure 34), survival was almost always higher in this reach (Figure 32). In part, this may be attributed to the fact that flow is not the only factor influencing survival. Differences in shelter (Table 6), temperature (Figure 28, Figure 29) or factors that we did not account for, such as predation or density, may also explain the overall differences in survival between the two reaches. Geophysical differences such as substrate and connection to the aquifer may also influence the relationship between flow and survival in these reaches.

Within the treatment reach, we observed a decrease in survival that corresponded to increasingly lower surface flows between 2011 and 2014, but we did not observe this pattern in the reference reach (Figure 36, Figure 37). The 100% mortality observed in the Mill treatment reach in 2014, after three years of high to average oversummer survival, can be attributed to an extreme drop in surface flow conditions that year. In late July, average daily discharge dropped from 0.18 ft^3/s to 0.0 ft^3/s in just three days and minimum daily discharge over that period fell from 0.10 ft^3/s to 0.00 ft^3/s (Figure 35). Zero surface flow persisted, leaving pools disconnected and/or dry for 65 days (Figure 35).

By contrast, survival was high in the reference reach in 2014 and the hydrograph sustained a natural pattern of minimal and gradual reduction through late September (Figure 35). There was only one day during the study period with an average discharge of 0.0 ft^3/s, so there was no persistent disconnectivity in that reach (Figure 35).

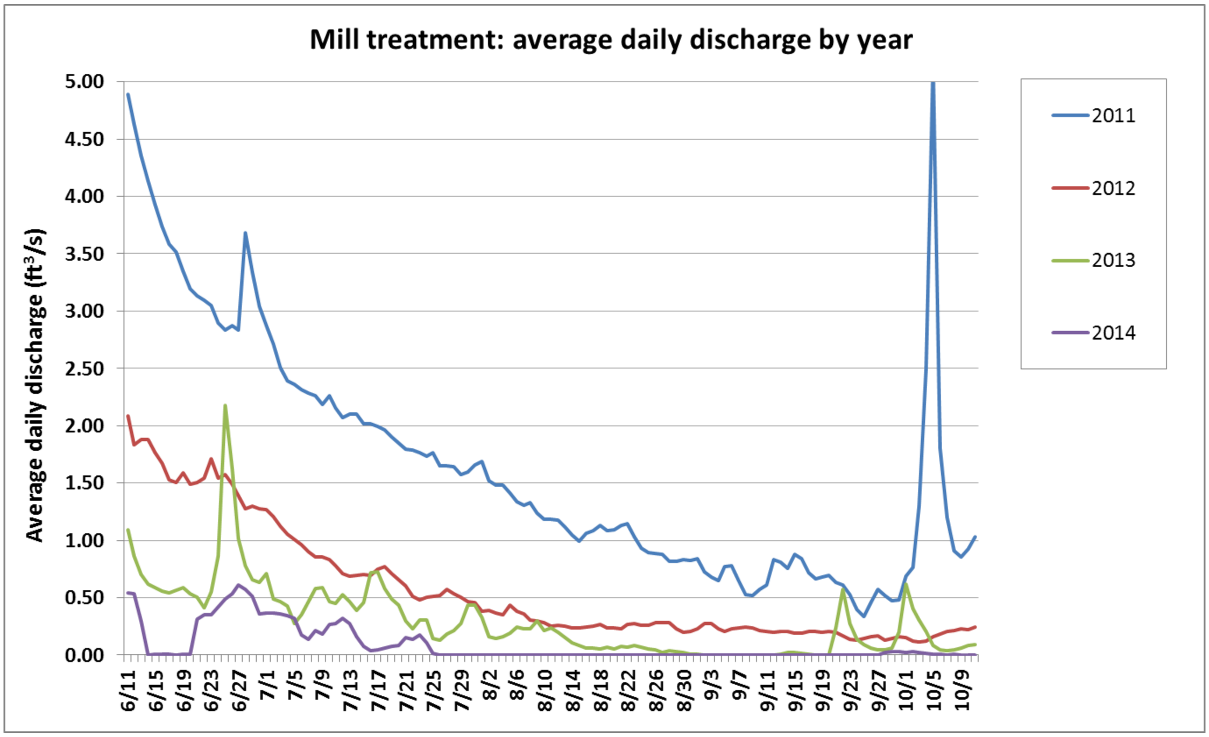

Figure 33. Average daily discharge in the Mill Creek treatment reach over the summers of 2011-2014.

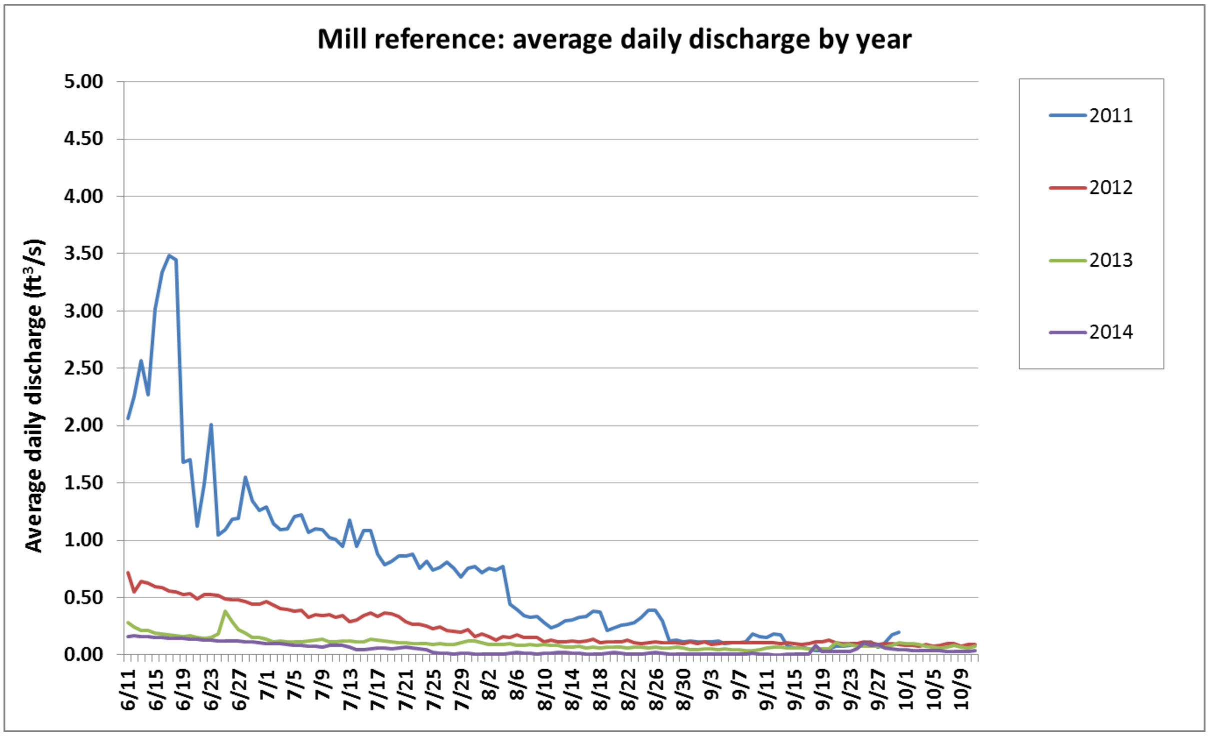

Figure 34. Average daily discharge in the Mill Creek reference reach over the summers of 2011-2014.

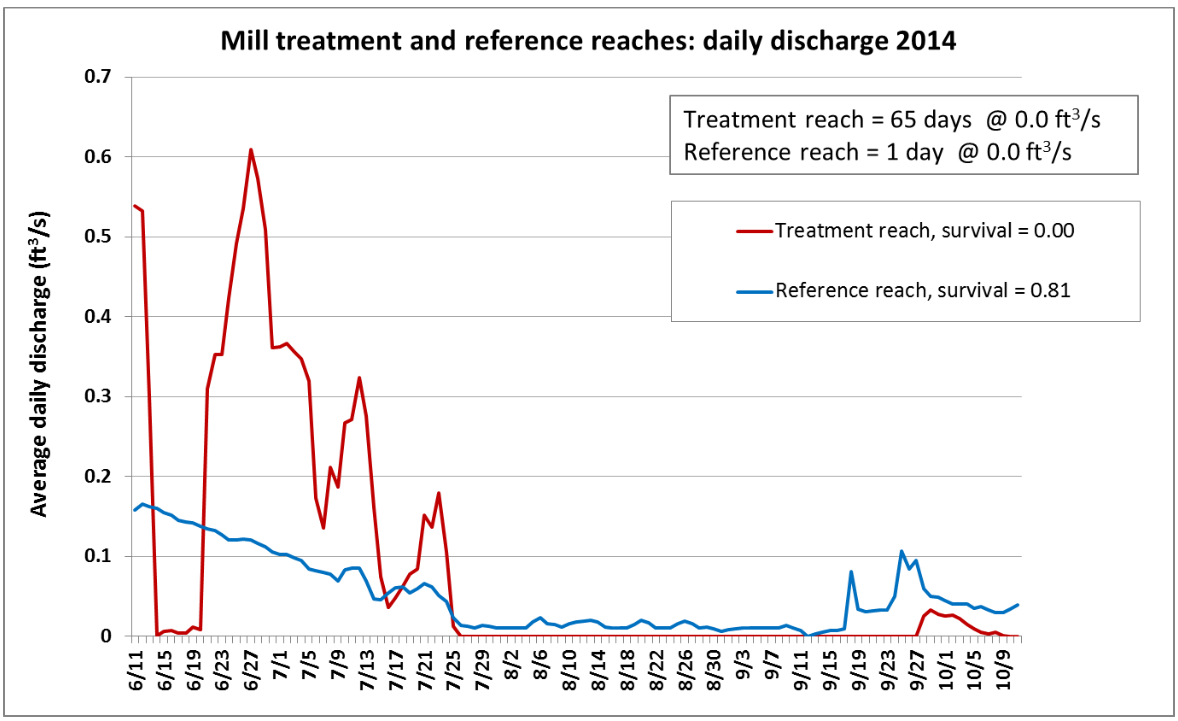

Figure 35. Average daily discharge in the Mill Creek treatment and reference reaches over the summer of 2014. Table shows total number of days over the study period that average discharge was at 0.00 ft3/s—the value at which pools were disconnected.

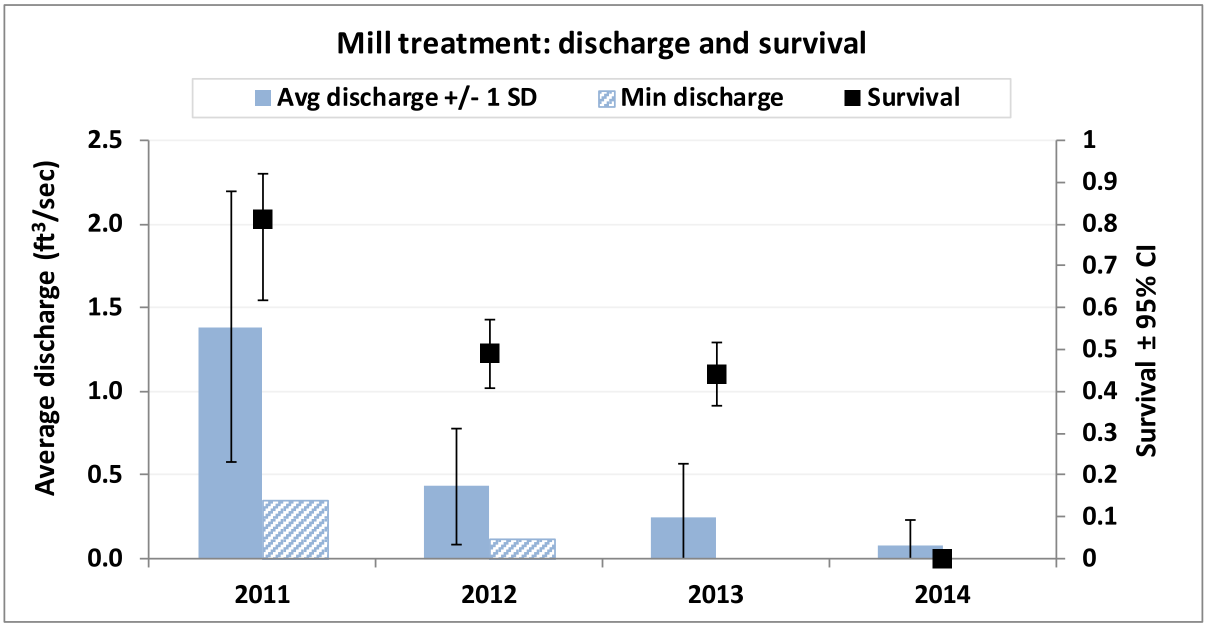

Figure 36. Stream discharge and survival in Mill Creek treatment reach between 2011 and 2014.

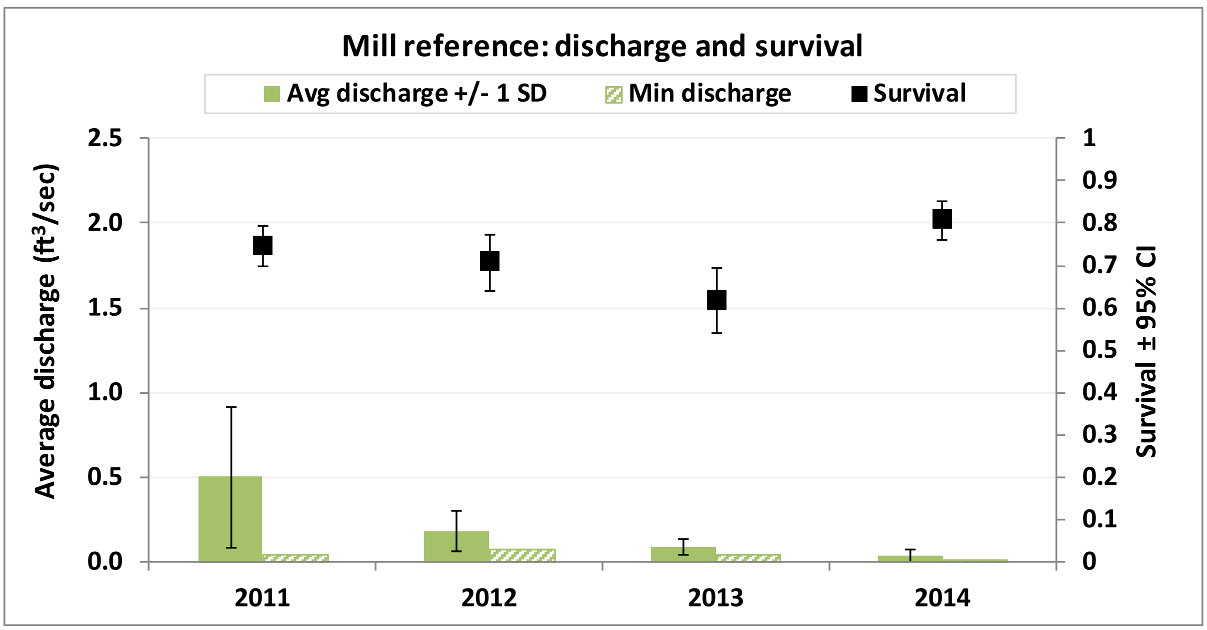

Figure 37. Stream discharge and survival in Mill Creek reference reaches between 2011 and 2014.

4.5.3.5 Survival and other environmental conditions

Comparison of survival with wetted volume, dissolved oxygen levels and stream temperature provides insight into the differing survival patterns observed in the two reaches. In general, while streamflow was lower in the reference reach, wetted volume remained more consistent, dissolved oxygen levels were higher and temperatures were lower.

The change in reach-scale total wetted volume over each summer was evaluated for the Mill treatment reach in relation to survival (Figure 38). The highest wetted volume each year in Figure 38 is the amount of water available in cubic meters during the June sample and the lowest is the amount remaining at the driest point of the season (generally in September). Surface flow in the Mill treatment reach dropped to 0.0 ft^3 in late July, 2014 and the reach was essentially dry during our August habitat survey, with a total wetted volume of only 16.6 m^3. Compared to our June measurement of 355.1 m^3, this equaled a reduction in wetted pool volume of 97% (Figure 38). The reach remained dry through our final sample in late September. Desiccation of nearly all of the pools corresponded to zero survival (Figure 38).

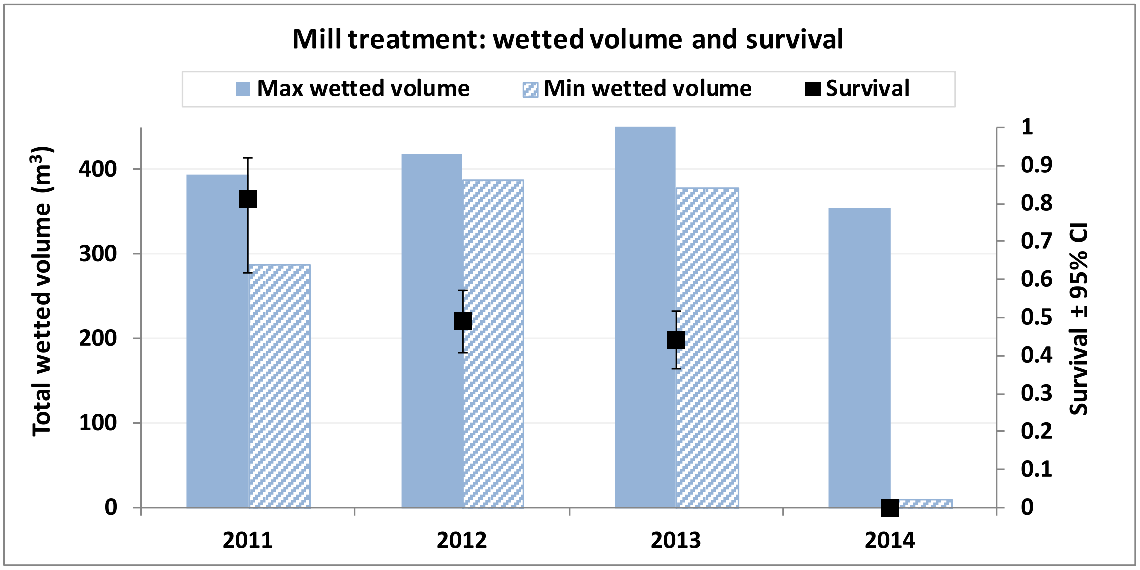

Figure 38. Total wetted volume at the wettest (June) and driest points in the season and oversummer survival in the Mill treatment reach.

During that same year, wetted volume in the Mill reference reach dropped by only 10%, from 203.2 m^3 to 182.5 m^3 (Figure 39). Due to location within the watershed, the reference reach started the 2014 season with less than 60% of the wetted volume of the treatment reach but, remarkably, there was very little decrease in wetted volume over the summer in this reach, despite drought conditions. The stability of streamflow and wetted volume at the Mill Creek reference reach indicates that the springs, groundwater inflow, and other sources of water were capable of sustaining summer base flow through the third consecutive drought year; and upstream human water uses were not large enough to deplete these sources before reaching the reference reach. This likely contributed to the higher survival rates observed.

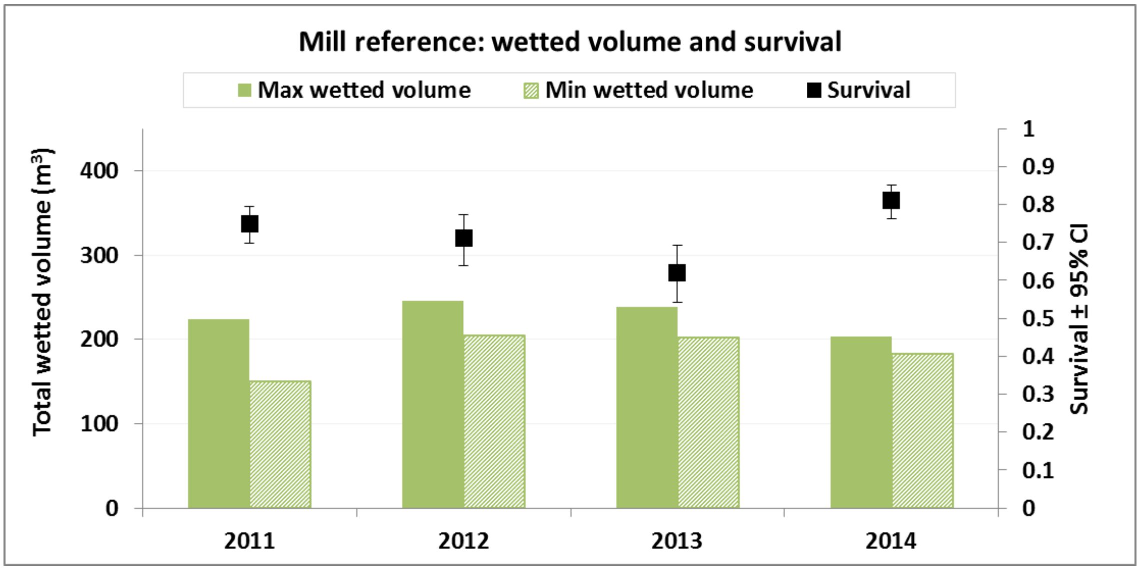

Figure 39. Total wetted volume in the Mill reference reach by year at the wettest (June) and driest points in the season.

Changes in average DO over the study period followed similar patterns as changes in wetted volume (Figure 38 - Figure 41). In the Mill treatment reach, DO concentrations were above impairment levels for salmonids at the lowest points of the 2011 to 2013 seasons. DO dropped to lethal levels in 2014, however, when—or shortly after—flow reached 0.00 ft^3/s and pools became disconnected (Figure 40).

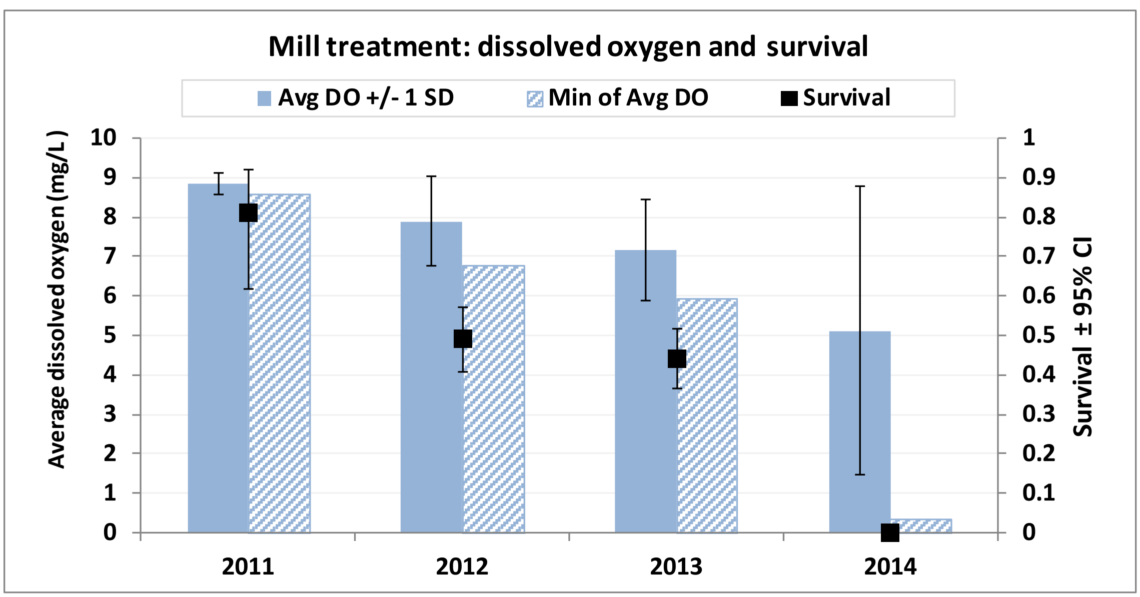

Figure 40. Average dissolved oxygen concentrations in the Mill treatment reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

In the Mill reference reach, average DO concentrations over the summers of 2011 to 2013 remained significantly higher than NCRWQCB's recommended objective of 7.0 mg/L, even at the lowest points (Figure 41). In 2014, the lowest average DO observed, 6.72 mg/L, was below this objective but well above impairment levels to salmonids (Figure 41). The high DO concentrations observed in this reach can likely be explained by the consistent inflow of aerated water into pools due to riffle connectivity.

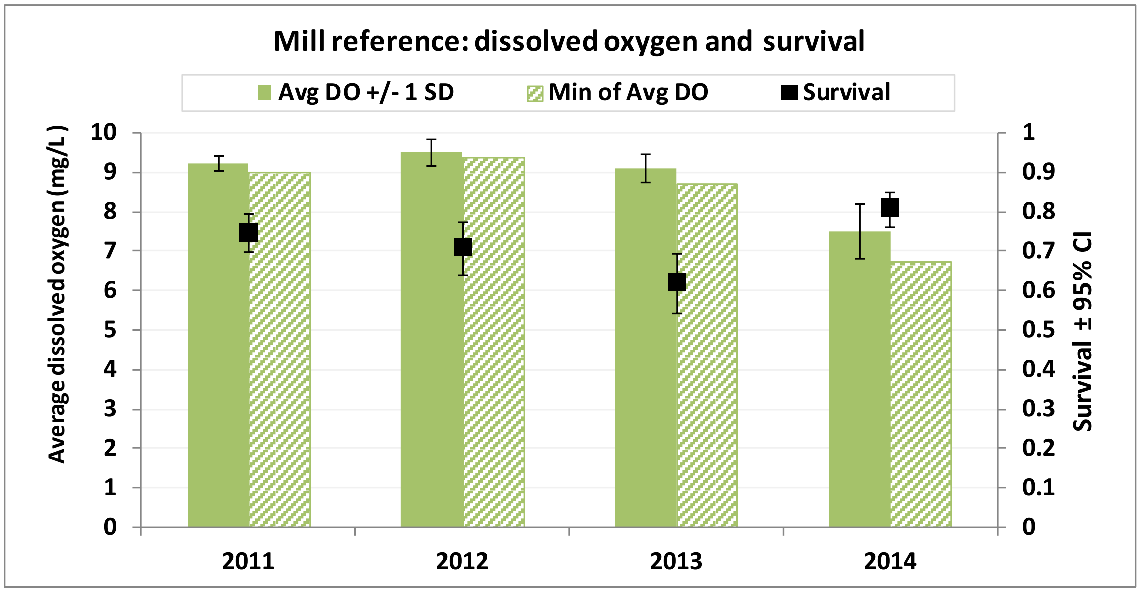

Figure 41. Average dissolved oxygen concentrations in the Mill reference reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

Although we did not observe a strong correlation between temperature and survival, it may help explain some of the finer scale differences observed between and within reaches (Figure 42, Figure 43). For example, in 2013—the year with the highest water temperatures—survival was slightly lower in both reaches compared with the previous year, despite relatively similar wetted volume and DO values. The lower temperatures observed in the reference reach may also help explain the generally higher survival rates in years when surface flows remained connected in both reaches. Temperatures above the tolerance threshold for salmonids may cause other stressors (e.g., disease, limited food supply) to have a greater detrimental impact than they would under optimal temperature conditions.

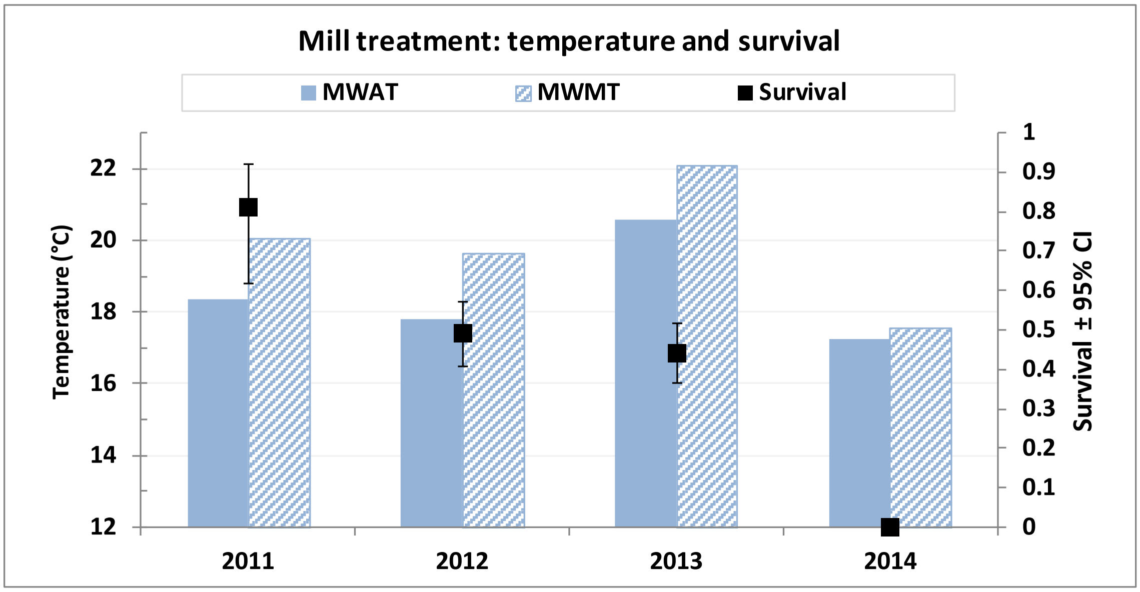

Figure 42. MWAT, MWMT, and oversummer survival of juvenile coho in the Mill treatment reach each year from 2011 through 2014.

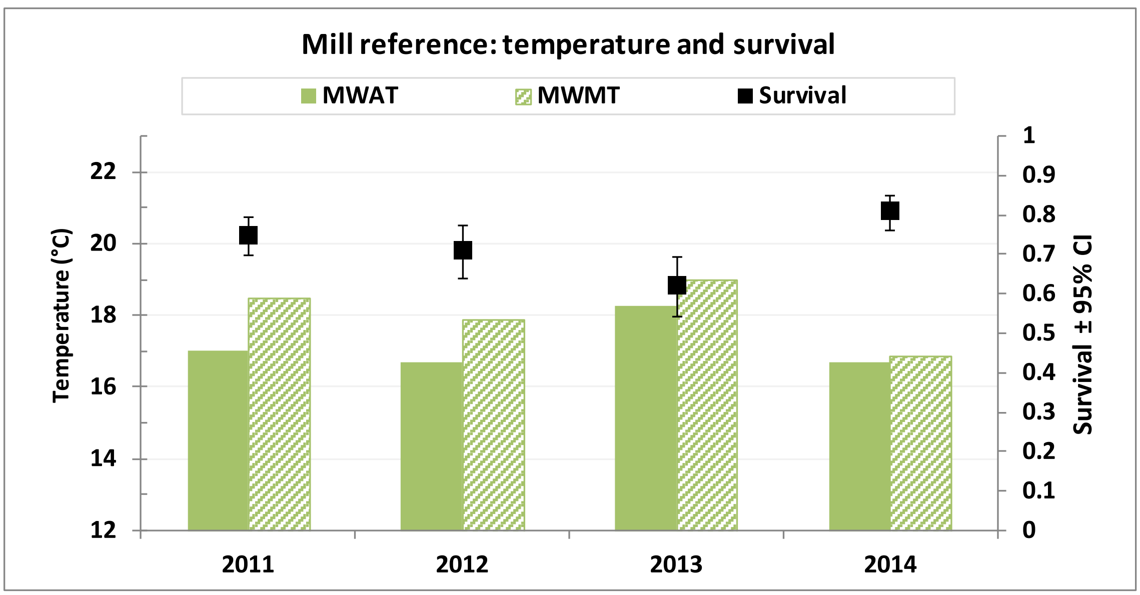

Figure 43. MWAT, MWMT, and oversummer survival of juvenile coho in the Mill reference reach each year from 2011 through 2014.

4.5.3.6 Oversummer growth

Fish length and weight was measured during PIT tagging prior to the June release and, again, at recapture during electrofishing surveys in September and October. Over the summers of 2011 to 2013, juvenile coho in the Mill treatment reach experienced an average daily growth rate, in fork length, of 0.09 mm/day, while fish in the Mill reference reach grew an average of 0.06 mm/day. Growth rates in both of the Mill reaches reflected the precise average growth for treatment and reference reaches in all four study streams for that period; 0.09 and 0.06 mm/day, respectively.

Growth was higher in treatment reaches than in reference reaches (Figure 44), which could be explained by the fact that treatment reaches, which are lower in the stream systems, tend to have higher flow, greater wetted volume, and deeper pools and, in turn, lower fish densities than reference reaches in the upper watershed.

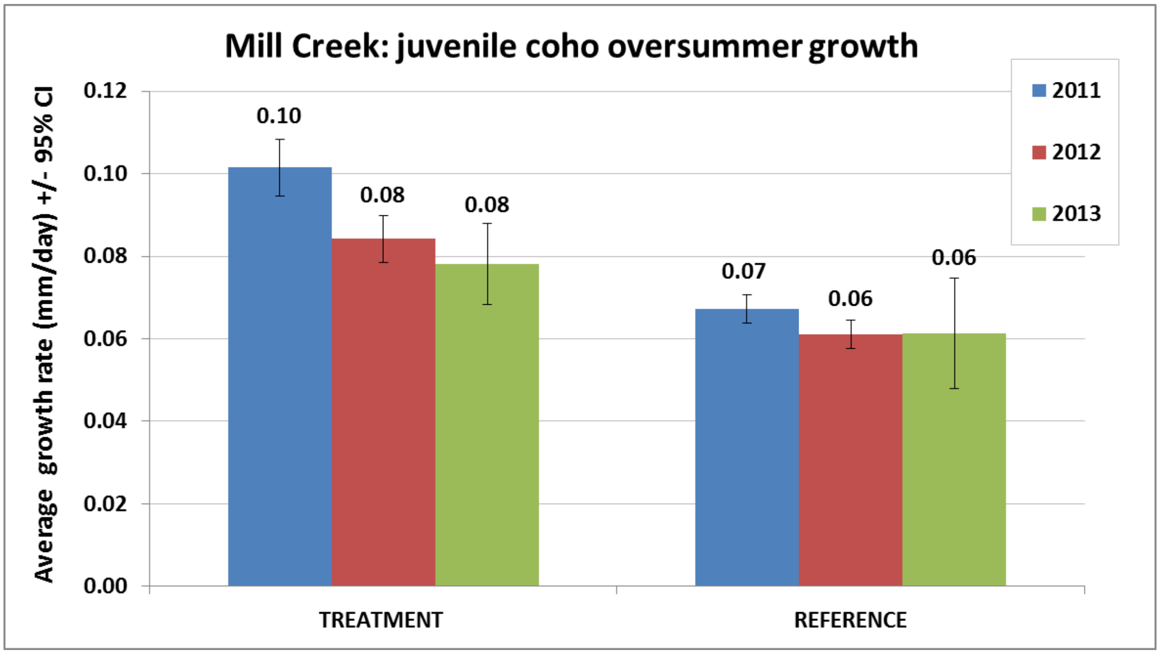

Figure 44. Average daily oversummer growth rate, in fork length, by year in the Mill Creek study reaches.

4.5.4 Evaluation of streamflow improvement projects

To date, all of the monitoring data that has been collected is considered “before” or pre-project data in our BACI design. Following implementation of stream flow improvement projects, continued monitoring in the treatment and reference reaches will allow us to evaluate the effects of projects on flow and survival.

4.6 Discussion

A key finding of this study is that juvenile coho were able to persist at extremely low surface flows in Mill Creek (Figure 32- Figure 37). In almost all years, flow levels dropped below 0.5 ft^3/s for at least a portion of the season and, with the exception of the treatment reach in 2014, survival from June 25 to October 15 ranged from 0.44 to 0.81 (average 0.66) (Figure 32). Between 2011 and 2014, the only extreme acute mortality event occurred in the treatment reach in 2014 when surface flow dropped to zero for an extended period, DO levels declined below impairment levels and pools dried out, causing all of the fish to die. Similar findings in other Russian River tributaries indicate that pool connectivity is a key factor in survival of juvenile coho during the summer season. In Green Valley and Grape Creeks, we have observed that when surface flow drops to zero, pools become disconnected, DO levels and wetted volume decline and survival, in turn, decreases. The rate at which this decline occurs varies by reach. In lower, more alluvial reaches (e.g. lower Green Valley and Grape treatment reaches), pool desiccation can occur within a matter of days following disconnectivity, whereas in other reaches (e.g. upper Green Valley and Grape reference reaches), the decline may occur over several weeks. Although geology of reaches was not characterized in this study, reaches that continue to hold water following disconnectivity appear to contain more clay substrate than the ones that rapidly dry out following pool disconnection. Cold water temperatures in the reaches that tend to hold water for a longer period after disconnection suggest that they are closely connected to an aquifer.

Given these findings, an important goal in stream flow improvement plans designed to benefit salmonid populations is to support efforts that will, at a minimum, keep pools connected. In reaches that appear to be closely connected to an aquifer, such as the upper reference reaches of Mill, Green Valley and Grape Creeks, stream flow improvement projects that increase stream flow by as little as 0.1 ft^3/s could improve survival of juvenile coho throughout the summer season. In more alluvial reaches, where connection to the aquifer is less certain (e.g., lower Mill Creek), surface flow levels that support connectivity will have to be determined in order to set minimum targets.

Achievement of recovery goals for coho populations in the Russian River will require more than minimum connectivity of pools. Growth, fish condition and habitat availability in relation to flow are all important factors to consider when determining what flow levels will support the long-term viability of coho populations. Although fish may be able to persist at extremely low flows in Mill Creek, if they are in poor condition at the end of the summer (small size, disease, parasites, etc.), survival may be compromised at later life stages. Additionally, low flow may reduce the amount of habitat available to fish and, in turn, the number of fish that can be produced—a further limitation to population viability and recovery.

Survival of salmonids to the adult stage is positively correlated with smolt size (Bennett et. al. 2015, Hayes et. al. 2008), therefore, increased growth in the stream environment can increase the chances of fish returning as adults to spawn. Flow has been positively correlated with benthic macroinvertebrate (BMI) production (Gore et al. 2001), which are the primary prey for rearing juvenile salmon. The greatest diversity and abundance of BMI species have been documented in riffles with velocities of 1.5 to 2.5 ft/s, while significantly fewer species are present at velocities of less than 0.5 ft/s (Gore et al. 2001). Through controlled flow manipulations in a small California stream, Harvey et al. (2006) found that with increased stream flow, invertebrate drift and juvenile rainbow trout growth increased while survival remained similar. Similarly, Nislow et al. (2004) found increased growth in juvenile Atlantic salmon rearing in a stream in years with higher stream flow.

Based on these findings, we can expect that increasing summer velocities beyond minimum persistence flows would likely promote higher growth in juvenile salmon and, in turn, more adults returning to spawn. Growth was minimal during the summer season in both reaches of Mill Creek, however, in the treatment reach, which generally had higher flow, we observed higher growth rates than in the reference reach (Figure 44).

The amount of foraging habitat available to fish in a stream is a function of stream flow (Nislow et al. 2004). If more habitat is available, there is an opportunity for production of greater numbers of fish and/or larger fish, further improving chances for recovery.

In this study, we observed juvenile coho surviving at flows that dropped below 0.5 ft^3/s, as long as pools remained connected. These low surface flows that sustain connectivity should be considered minimum persistence flows for the upper Mill Creek watershed, and not levels that support high growth or sufficient production. Identifying such flows is beyond the scope of this study, however other approaches have been used to estimate these values in the Mattole Headwaters Sub-basin, a similar sized watershed as Mill Creek (McBain and Trush, Inc. 2012). In an instream flow needs study, McBain and Trush, Inc. recommended summer low flow juvenile rearing thresholds ranging from 1.5 to 5 ft^3/s (depending on location in the watershed) to avoid poor to negative growth, high risk of disease and predation, shrinking habitat availability and heightened competition for food. A similar study in Russian River tributaries to determine such thresholds would greatly help in setting stream flow targets relative to specific goals (e.g., minimum persistence, population stability, population growth).

UC will continue its monitoring effort in the Mill Creek watershed to evaluate the effects of project implementation and water management changes on oversummer survival and to provide further insight into the complex relationship between flow, survival and environmental factors. We recommend further studies to help generalize results and to identify flow thresholds appropriate to maximize survival, growth, condition and abundance.

5 Diversion Management Recommendations

Drawing on the streamflow, water need, and fish monitoring data provided above, this section recommends actions to maintain pool connectivity and reduce drops in flow within the Mill Creek watershed. It then provides an overview of permitting considerations for projects that may result from those actions.

5.1 Project and Management Recommendations

5.1.1 Residential Water User Tank Program

Because the data suggest that summer flow is adversely affected by the cumulative effect of residential diversions, we recommend pursuing a tank program for residential users, especially along the stream reaches between Puccioni Road and West Side Elementary School.

The program would provide technical and financial assistance to landowners whose residential water use may be impacting streamflow. A typical project would include water storage tanks and an agreement with the landowner to forbear use of their diversion during critical low-flow periods. The tanks would be filled with water from sources most suitable for each parcel (e.g., roofwater, surface water, springs, or wells). This program could be combined with other strategies to reduce water use and reduce the instantaneous draw-down of streamflow, such as encouraging use of water-efficient appliances and irrigation systems, coordinating timing of diversions, reducing diversion rates/pump size, and/or using pumps with variable pumping rates.

Examples of successful residential demonstration projects can be found in other watersheds. Sanctuary Forest has a surface water tank storage and forbearance program in the Mattole River Headwaters. Gold Ridge RCD and OAEC piloted a successful roofwater harvesting storage and forbearance program in Salmon Creek (south of the Russian River watershed). Clusters of projects will likely need to be implemented before streamflow is appreciably improved, but there may be ample opportunity for implementing water storage projects, given the number of houses along Mill Creek that likely obtain water from the stream or adjacent shallow aquifer.

5.1.1.1 Roofwater harvesting Analysis

Several factors make roofwater harvesting a viable and ecologically compatible means of meeting water needs in the Mill Creek watershed. First, impacts to streamflow caused by roofwater harvesting systems are low. This is mainly because the amount of surface area (typically rooftops) comprises a small fraction of the total watershed area. Roofwater harvesting systems effectively eliminate the production of runoff from the collection surface, but the proportion of watershed area comprised by collection surfaces makes this impact negligible. For example, if 40 roofwater harvesting systems are implemented in the Wallace Creek subcatchment of the Mill Creek watershed, and the average collection surface is 2,000 square feet, then a total of 80,000 square feet (1.8 acres) would no longer produce runoff. The total area of the Wallace Creek subcatchment is approximately 5.3 square miles, or 3,400 acres; in this scenario, the amount of area that would no longer generate runoff is 0.05% of the total Wallace Creek subcatchment. Similarly, if 400 roofwater harvesting systems are implemented in the Mill Creek watershed (total watershed area 14,300 acres, or 22.3 square miles) and the average collection area is 2,000 square feet (totaling 800,000 square feet, or 18.4 acres), the 400 projects would reduce the total area producing runoff in the Mill Creek watershed by 0.1%. (If the average collection area is doubled to 4,000 square feet, the total loss of runoff would be 0.2%) Roofwater harvesting also is low-impact compared to other methods of obtaining water because it only collects water when rainfall is occurring, and does not collect water during periods of lower flow between rainfall events.

Roofwater harvesting may not always be adequate to meet all water needs. Most notably, the rooftop area may limit the amount of water that can be captured and stored. For example, a surface area of 1,000 square feet in an area that receives 3.5 feet (42 inches) of rainfall will produce 26,000 gallons of water—not enough to meet needs usually associated with residential uses through a four- or five-month dry season (typically 40,000 to 50,000 gallons). For larger agricultural uses, water needs are typically described in acre-feet: if an area receives 3.5 feet of rain, then the amount of rooftop needed to store an acre-foot of water (approximately 326,000 gallons) is approximately 12,500 square ft. This is feasible for a large operation with a lot of rooftop area, but for smaller developments, this may not be realistic. The amount of water available to harvest also depends on annual variation in rainfall: less water will be stored in a dry year than in a wet year. For example, in 2014, Healdsburg only received 1.9 feet (22.6 inches) of rainfall. Under these conditions, a storage facility designed around the average annual rainfall of 3.5 feet would be little more than one-half full at the end of the rainy season. In order for roofwater harvesting to be resilient to climate variability (and thus resilient to climate variations expected in the coming decades), projects would need to significantly overbuild for normal-year conditions or have additional water sources to meet needs in dry years; or develop a contingency plan for how to prioritize water uses if only a fraction of the desired amount of water is available.

Another common limiting factor to roofwater harvesting is the amount of space that can be dedicated to storage. A 50,000 gallon tank standing 8 feet tall would have a diameter of 35 feet. One option is to place tanks underground. For example, elsewhere in Sonoma County, a 270,000 gallon cistern system was buried under a dairy to allow the surface area to be continuously used for other purposes (Ag Innovations Network 2013). In a watershed as mountainous as Mill Creek, finding space to dedicate to a large water tank may be the most limiting condition to the implementation of a roofwater harvesting system.

5.1.2 Agricultural Water User Program (frost, reducing rates of diversion, releases, roofwater storage)

Agricultural irrigation and frost protection represent a significant portion of the water used in the Mill Creek watershed in both the wet and dry seasons. Before recent frost protection regulations took effect, the quick withdrawal of large amounts of water for frost protection threatened coho and steelhead by stranding them as streamflow dropped. We recommend continued compliance with recent frost regulations, researching the viability of other methods of frost protection such as frost fans, or development and use of alternative water sources like off-stream ponds.

Additionally, we recommend that agricultural water users outside of Lower Mill Creek (Dry Creek to Felta Creek), employ irrigation auditing and efficiency measures, and consider installing off-stream storage to offset dry season diversion and/or allow for a reduction in pump rates. For water users that have excess stored water, we recommend that users work with CDFW during the driest periods to explore reservoir releases to benefit coho and steelhead.

The program would initially target water conservation and water storage projects with a goal of reducing instantaneous demand for frost protection water and reducing the quantity or rate of water used for irrigation.

5.1.2.1 Hydrologic Assessment of Lower Mill Creek

In lower Mill Creek, we recommend completing a ground-surface water assessment prior to developing streamflow improvement projects with agricultural and other water users. In Lower Mill Creek, there are 90.5 acres of vineyards – using approximately 45 acre-feet of water annually - and 1.8 acres of orchards – using approximately 3.9 acre-feet of water annually. There are no reservoirs in the area, and water is diverted directly from the creek or from groundwater wells adjacent the creek to meet most of these agricultural water needs.

As described above, lower Mill Creek has been a main focus for coho spawning; but juvenile monitoring has indicated that much of this reach may become dry under normal conditions. This drying may be a result of nearby water use, but it also may be a result of geological conditions frequently found in alluvial fans similar to lower Mill Creek.

We recommend conducting additional research in lower Mill Creek to evaluate the extent of pools and surface flow in lower Mill Creek, as well as the water level in the aquifer adjacent to Mill Creek through the dry season. The study would help determine whether habitat restoration activities in Mill Creek will be beneficial or would be undermined by the lack of water in the shallow groundwater table. Most spawning in recent years has occurred in the lower portion of the watershed, but habitat is poor and pools may not be persistent. Such a study could include the following:

- Mapping the presence of pools and water table levels along Mill Creek below the Falls during the spring-summer dry season.
- Correlating the level of the stream bed with the level of Dry Creek and the Russian River using LiDAR data sets available through the Sonoma County Vegetation Mapping and LiDAR Program.
- Conducting visual surveys of pools through the lower reaches by walking from West Side Elementary School to the confluence with Dry Creek weekly from June through October, and recording and tracking pool depths and note the extent of surface flow through lower Mill Creek.
- Measuring the depth to groundwater in at least four existing test wells during each visit (access dependent).
- Evaluating whether Mill Creek is gaining or losing to the aquifer at each visit.

- Determining how closely the level of Dry Creek is related to Mill Creek and its adjacent shallow aquifer.
- Installing a minimum of two pressure transducers in lower Mill Creek and set recording intervals to 15 minutes, to determine whether additional, otherwise unobserved, flow dynamics make lower Mill Creek unsuitable for supporting juvenile salmonids (e.g., channel going dry at night, or just for a few days during the summer).

If the results of the study suggest that changes in water management will lead to an increase in streamflow, we recommend exploring options with landowners in this reach.

5.1.3 Community Awareness, Education, and Demonstration

We recommend additional outreach to the Mill Creek watershed community. This could include:

- Larger landowner meetings to solicit public input on short- and long-term opportunities and challenges in the watershed;
- Small-group and individual meetings with landowners or neighborhoods to scope out project opportunities;
- Trainings and other technical assistance in developing and troubleshooting projects and monitoring and changing water use practices;
- Signage to remind water users to conserve during the low flow season and store during the rainy season.

In addition, we recommend using other projects to demonstrate water management alternatives. The Coho Partnership is working currently with West Side Elementary School to implement a roofwater harvesting project that will offset dry season diversion for garden irrigation with rainwater. The project has a significant educational component, and we recommend using the project and the opportunity to showcase roofwater harvesting within the watershed. West Side Elementary School has been a long-standing partner in fisheries restoration in the Mill Creek watershed; its students have participated in coho Broodstock monitoring and the school has partnered with many organizations to integrate the natural environmental into both its facilities and curriculum.[8] A similar project was completed in 2014 in the Mattole River watershed with Whitethorn School and the Southern Humboldt Unified School District and it has been a valuable example for students and their families.

5.1.4 Explore Collective Options

We recommend that the Mill Creek water user community explore collective options such as constructing shared storage (particularly in cases where one landowner may have locations for off-stream storage and others have site constraints), rotations among neighbors to reduce diversion

[8] http://www.westsideusd.org/main/about/history.html

rates (e.g., diverting every other day or at different hours), and releases (e.g., neighbors agree to allow water released from a reservoir to reach the intended reach to benefit fish populations).

5.1.5 Mill Creek Recharge Potential

We recommend exploring opportunities for recharge in Mill Creek in areas with the greatest recharge potential. Over the past century, land use changes in Russian River tributary watersheds have resulted in drastically reduced infiltration of rainfall, leading to lower base flow in the dry season. Mechanisms for this loss of infiltration include reducing the amount of soil to absorb rainfall, increasing the headwater drainage network, and installing subsurface drainage tiles beneath agricultural fields, all leading to more storm runoff. While these processes have often been altered over the entire watershed, it may be possible to implement projects to increase infiltration in key strategic locations where the potential for influencing recharge is greatest. We evaluate locations within the Mill Creek watershed with the greatest potential for recharge below.

In its recent Sonoma Creek Watershed study, SCWA outlined a process for evaluating the potential for groundwater recharge based on four main factors: geology, soil type, vegetation cover, and slope. Spatially explicit data characterizing each of these broad categories is widely available for input into a GIS. The potential for recharge was calculated throughout the watershed based on these four factors, though the weight of each factor was not equivalent. Underlying geology was given the heaviest weight, at 50%; soil was weighted 25%; slope was weighted 15%; and vegetation cover was weighted 10%. We applied this process for evaluating recharge potential to the Mill Creek watershed to identify those locations where projects aimed at augmenting groundwater recharge could have beneficial effects to base flow in Mill Creek.

Most of the underlying geology of the Mill Creek watershed is composed of the Franciscan assemblage, referring to a combination of mélange and pressurized sedimentary rock (Graymer et al. 2007), often resulting in minerals like quartz, feldspar, and other minerals formed within the pressurized sedimentary matrix, formed originally as ocean floor during the Jurassic and Cretaceous Period (to an age of 60 to 200 million years) and pressurized through tectonic uplift. Franciscan bedrock is characteristically poor for storing and transmitting water (Kleinfelder Inc. 2003, Su et al. 2007). However, the uplift that created the coastal ranges in California resulted in many fractures in the bedrock; these fractures allow water to move much more easily through Franciscan formations than it can through the bedrock itself. Local geohydrologists attribute these fractures, which have greater porosity, permeability, and hydraulic conductivity, as the reason why springs are common and wells can provide adequate yield for domestic and some agricultural uses in Franciscan geology (e.g., Phillips 2012). Because these fractured bedrock aquifers are irregular features in the landscape, they are seldom mapped at a watershed scale and their influence to supporting summer base flow is highly variable and poorly known.

A few other locations in the Mill Creek watershed are categorized as having soft sedimentary geology—Huichica or Glen Ellen formation. These formations have high clay content and are often described as poor for aquifers, but not as poor as Franciscan bedrock. We characterized geology as ranked from 1 (poor) to 3.5 (high) potential for recharge, where Franciscan bedrock had a ranking of either 1 or 1.5; the sedimentary bedrock was ranked at 2, and alluvium ranked as 3 or 3.5, depending on when it was believed to be deposited (Pleistocene or Holocene; Figure 45A). We did not attempt to incorporate fractured Franciscan bedrock into this analysis, but it may be useful to consider at a later stage of the project.

Soil types were generally categorized following the same rankings as were outlined by the SCWA study, based on clay content of the soil. Those soils with high clay content were ranked low, whereas those with low clay content were ranked high (Figure 45B). Vegetation was ranked based on its capacity for interception: forest land was ranked low, whereas grassland was ranked high (Figure 45C). Based on these features, the Mill Creek watershed has variable but overall low potential for recharge through most of the watershed (Figure 45D); with the greatest potential for recharge in the lower reaches near the confluence with Dry Creek and the lowest potential for recharge in the mountainous headwaters.

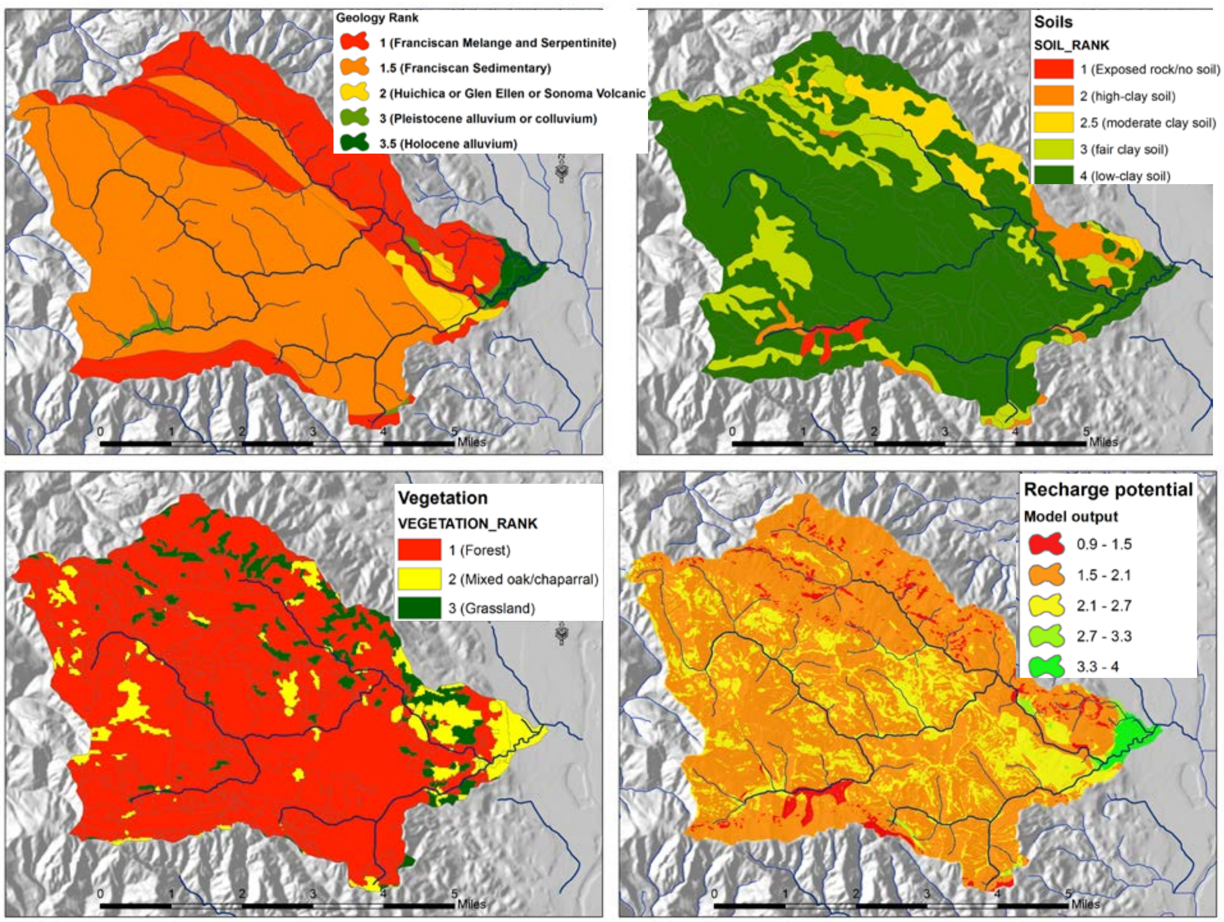

Figure 45A-D. Recharge potential in the Mill Creek watershed.

5.1.6 Fish Passage and Habitat Projects

We recommend continuing to implement habitat and fish passage projects that improve conditions for coho and steelhead, particularly barrier removal projects that allow salmonids to access the wetter reaches of Mill Creek and instream habitat improvements (e.g., large wood) that increase pool depth. We recommend that project proponents consider and integrate flow information and instream flow project locations in their project selection and design.

5.2 Permitting Considerations

Some of the projects recommended above will require water rights permitting or water rights changes. For example, projects that divert and store water may require an appropriative water right from the State Water Board if water is seasonally stored (e.g., diverted in winter for summer use) and if the source is a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 5.2.4). Water users may also be required to notify CDFW of the diversion as part of the Lake and Streambed Alteration program (Fish and Game Code Section 1600). Below we provide an overview of likely water rights permitting pathways, if applicable, for various project types.

5.2.1 Roofwater harvesting

As described above, projects that include rainwater harvesting have the dual benefit of reducing diversions from the creek during the dry season (by offsetting summer need) and reducing runoff from impervious surfaces (roofs) during the winter. The State Water Board has clarified that a water right permit is not required for roofwater capture and storage.[9] For any project that reduces the quantity of water that users need to divert in the dry season, landowners, project partners, and funders should ensure that reductions in water use under any existing water rights are protected instream (e.g., through an instream dedication and/or forbearance agreement) (See Section 6.1).

This approach has been implemented successfully in Salmon Creek (Sonoma County)[10] where Gold Ridge Resource Conservation District, Occidental Arts and Ecology Center, Prunuske Chatham Inc., and NOAA Restoration Center piloted an approach to offset dry season use through winter roofwater harvesting[11] and in Chorro Creek where Morro Bay National Estuary Program and NOAA-RC installed roof rainwater tanks with Cal Poly San Luis Obispo. In both cases, landowners ceased summer use under a forbearance agreement.

5.2.2 Residential tank storage

Where residential users switch the timing of their diversions from the creek from summer to winter and add storage tanks to satisfy year-round use, the projects will likely require a new water right. (A riparian right does not allow for seasonal storage.) It is likely that many diversions will be small

[9] http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml
[10] http://salmoncreekwater.org/cs/Roofwater_Harvesting.pdf
[11] http://salmoncreekwater.org/bodega-pilot-program.html

enough to qualify for a Small Domestic Use Registration (SDU) or Emergency Small Domestic Use Registration (ESDU).

The ESDU streamlines the process for obtaining a SDU registration while the drought is in effect. As CDFW states, the agencies have "essentially 'pre-approved' the installation of storage tanks that meet general criteria. The State Water Board has agreed to incorporate these criteria as conditions of approval, and to expedite the issuance of the registrations."[12]

This residential tank storage approach has been implemented successfully in the Mattole River watershed through Sanctuary Forest's Water Storage and Forbearance Program, and more information is available in Legal Options for Streamflow Protection (Sanctuary Forest 2008). Sanctuary Forest's approach has included installing tank storage to provide sufficient potable water for the dry season, restrictions on diversion during the dry season (while the water user relies on the stored water), and rotation schedules among multiple users when flow falls below certain thresholds. These terms and conditions are implemented through a combination of a forbearance agreement (a covenant that runs with the land restricting riparian water use), a Small Domestic Use registration issued by the State Water Board, and a Streambed Alteration Agreement issued by CDFW.

5.2.3 Agricultural water storage

Projects with agricultural water users that rely on diversion from the stream and store water for seasonal use will require an appropriative water right. For diversions to storage that do not exceed 20 acre-feet per year for irrigation, frost protection, or heat control of currently cultivated lands, water users may be able to file a small irrigation registration, a type of appropriative right.[13] For projects that relay on streamside wells and seek to reduce dry season impacts by pumping through the rainy season and storing water for year-round use, water rights permitting requirements will depend on the method of diversion and the nature of the water source (see Section 5.2.4).

A summary of the registration options is provided in Table 7.

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[12] http://cdfgnews.wordpress.com/2014/03/13/state-streamlines-domestic-water-tank-storage-process-in-response-to-drought/

[13] http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/

Table 7. Summary of Water Rights Registrations

	Small Domestic Use Registration (SDU)	Emergency Small Domestic Use Registration (ESDU)	Small Irrigation Use Registration (SIU)
Max Quantity	4,500 gallons per day or diversion to storage of 10 acre-feet per year	4,500 gallons per day or diversion to storage of 10 acre-feet per year	42,000 gallons per day or 20 acre-feet per year
Permitted Uses	Domestic uses* or aesthetic, fire protection, recreational, or fish and wildlife purposes associated with a dwelling or other facility for human occupation	Domestic uses* or aesthetic, fire protection, recreational, or fish and wildlife purposes associated with a dwelling or other facility for human occupation	Irrigation, heat control, or frost protection, including impoundment for incidental aesthetic, fire protection, recreational, or fish and wildlife purposes
Other restrictions	Diversions from stream segments (1) that have established minimum streamflow requirements, (2) are fully appropriated, (3) are on designated Wild and Scenic Rivers	Restrictions on SDUs apply plus: (1) Only eligible during a drought emergency, (2) must have an existing water right for domestic use, (3) rigid tanks only (no bladders), (4) at least 60 days of storage + forbearance	Only for (1) offstream reservoirs existing or proposed on cultivated lands or (2) onstream reservoirs on Class III streams
Geography	No restriction	Coastal streams within CDFW Region 1 or 3	Currently limited to North Coast Instream Flow Policy Area***
Expedited? **	No	Yes - no CDFW site inspection and no individually tailored conditions required	No
Fee	$250	$250	$250
Flow chart	Small Domestic Use Flow Chart		Small Irrigation Use Flow Chart
Lake and Streambed Alteration Agreement req?	Yes	No	Yes
Renewal	Every 5 years	Every 5 years	Every 5 years
Renewal Fee	$100	$100	$100

More information: http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/

* Domestic use means the use of water in homes, resorts, motels, organization camps, camp grounds, etc., including the incidental watering of domestic stock for family sustenance or enjoyment and the irrigation of not to exceed one-half acre in lawn, ornamental shrubbery, or gardens at any single establishments (California Code of Regulations §660 - Domestic Uses).

** The Division of Water Rights prioritizes applications that meet certain conditions.

*** Coastal streams from the Mattole River to San Francisco and coastal streams entering northern San Pablo Bay.

5.2.4 Groundwater Use

Where a landowner pumps from a groundwater well in the winter and stores that water for dry season use, an appropriative water right may or may not be required. Permitting requirements depend on the categorical nature of the groundwater pumped. Where the well lies within a subterranean stream and water use is in accordance with riparianism, the water user may assert a riparian right to the water. However, since the objective of most streamflow projects includes storage of water across seasons and because riparian rights do not allow for seasonal water storage, a groundwater user pumping water from a subterranean stream may be required to obtain an appropriative water right for storage and use. For reference, a draft subterranean stream map covering the Mill Creek watershed is included as Figure 46. If the well lies outside of a subterranean stream, the water diverted from the well may be considered percolating groundwater, and not submit to the permitting jurisdiction of the State Water Board.[14]

[14] See also: State Water Board, FAQs, "How do I know if I need a water right permit?" at http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml

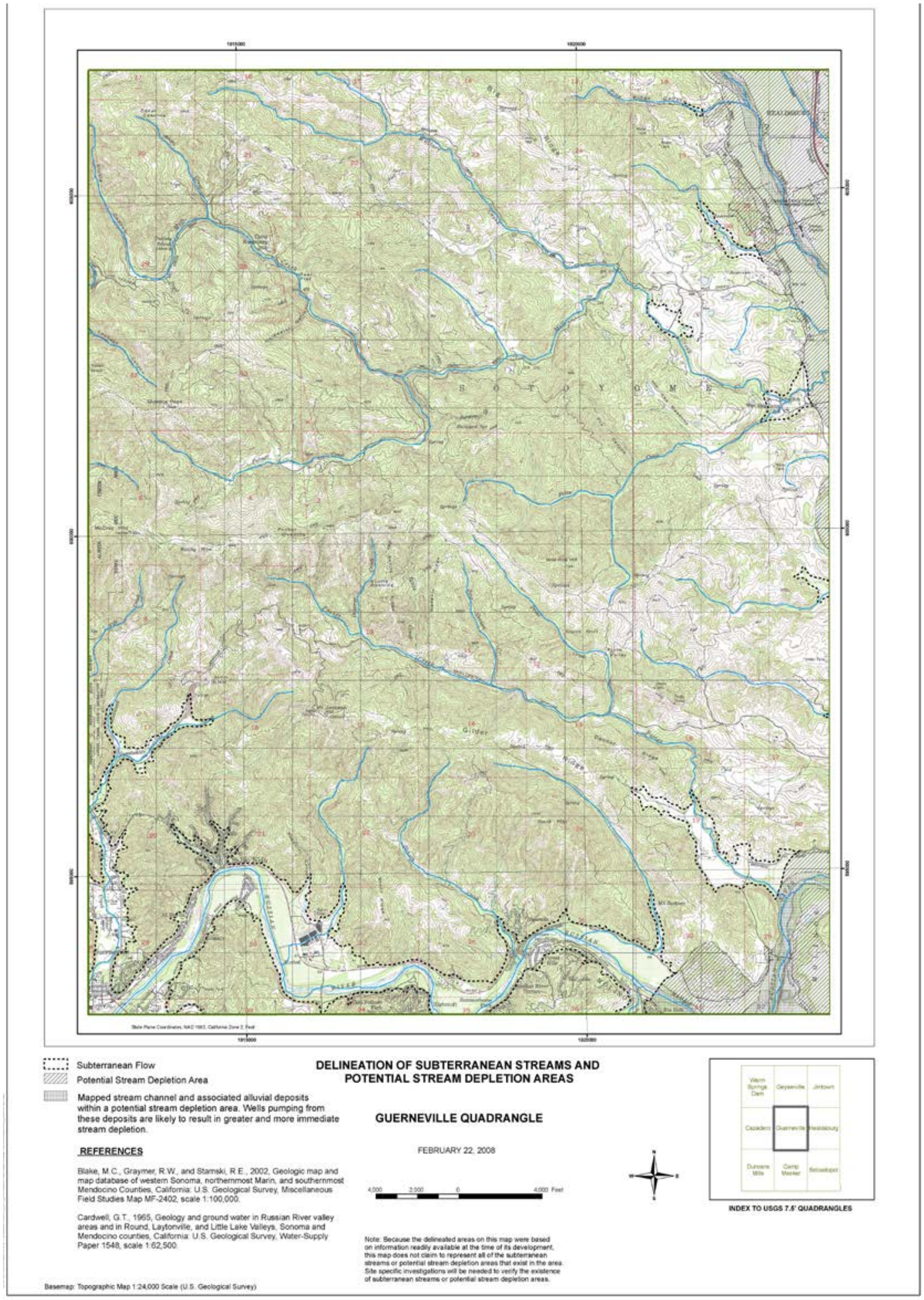

Figure 46. Excerpt from draft subterranean stream map (Stetson Engineers 2008).

5.2.5 Water Availability Analysis

If an appropriative water right is required for a project, the State Water Board will likely require a thorough evaluation of how additional water appropriation will affect new water right holders, as well as how the rate of diversion used to obtain water will affect streamflow and environmental resources (such as habitat for anadromous salmonids). In order to evaluate the feasibility of obtaining a new appropriative water right in the Mill Creek watershed, we performed a preliminary set of calculations required for a Water Availability Analysis.

This calculation represents the first step in evaluating whether additional water can be appropriated: any new diversion needs to be considered in combination with all existing water rights to ensure that downstream water right holders will be minimally affected by a new diversion. The calculation is a comparison of estimated "unimpaired" discharge at a particular location based on historical streamflow data[15] to the amount of water requested by existing documented water rights holders (including appropriative and riparian rights). The resulting statistic of this analysis is a percentage of water that remains, given existing upstream diversions, at the particular location. Generally, if the amount of water accounted for in existing diversions is less than 5 percent of unappropriated discharge, then it is possible that more water could be appropriated.

We calculated Water Supply Tables (Tables 8-10) for the water rights in the Mill Creek watershed (similar to that which would be required for submission to the State Board in an appropriative water right application). All of the water rights in the watershed need to be considered when determining unappropriated water volume. Each table includes the following fields:

- Each water right is given an ID number (POD_ID); this POD_ID provides a label for each water right in the accompanying map.
- For each water right, we begin by calculating the upstream watershed area and average annual precipitation in the upstream watershed (which we have done using the PRISM data set). We use these data to scale historical streamflow measured at the historical Pena Creek USGS streamflow gauge to each water right location: historical streamflow is scaled to all water rights by a ratio of upstream watershed area and mean annual precipitation, as described in the State Water Board's Policy for Maintaining Instream Flows in Northern California Coastal Streams.
- From these data, we calculate the "Seasonal Unimpaired Flow Volume", which is an estimate of unimpaired discharge over the period of interest (for example, the diversion season December 15 through March 31) based on streamflow from the historical USGS streamflow gauge scaled by Ratio1.
- The "Water Right Volume" over the defined period reflects the amount of water that each water right has a right to use during the period of interest.

[15] Using an average of discharge from a USGS streamflow gauge such as the nearby Pena Creek near Geyserville gauge, number 11465150, which was operated from 1978 to 1990.

- The “Senior Upstream Water Right Volume” represents the sum of volume for all water rights upstream of each diversion point.
- The “Remaining Impaired Discharge” quantifies how much of the unimpaired flow remains, given what upstream water right holders have a right to take. This can also be expressed as a percentage, as seen in the final column.
- We calculated the Remaining Impaired Discharge for all Mill Creek watershed water rights over the following periods: the winter season December 15 through March 31 (which the State Water Board identifies as the “diversion season” for north coast streams; Table 3, below), as well as the months of April and May for additional comparison for water availability from a regulatory perspective (Tables 4 and 5). The tables below show the Water Supply Tables for the 49 points of diversion in the watershed.

Table 8. Winter season (December 15 through March 31) Draft Water Supply Table for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	21,054	0.00	173.44	20,881	99.18
A024688A	14,191	47.1	21,079	0.00	173.44	20,905	99.18
S023680	14,168	47.3	21,149	0.00	173.44	20,976	99.18
S019972	14,162	47.4	21,196	2.35	173.44	21,022	99.18
S023682	14,140	47.5	21,219	0.00	171.09	21,048	99.19
S013760	14,123	47.7	21,246	0.00	171.09	21,075	99.19
S016032	11,784	49.1	18,273	0.29	125.09	18,148	99.32
S022582	11,740	49.3	18,275	0.00	124.79	18,150	99.32
A011327	11,497	49.5	17,963	3.78	124.79	17,839	99.31
S009039	11,094	50.2	17,565	0.00	110.01	17,455	99.37
S009045	11,094	50.2	17,565	0.00	110.01	17,455	99.37
S009040	11,094	50.2	17,565	0.00	110.01	17,455	99.37
A004612	11,094	50.2	17,565	0.00	110.01	17,455	99.37
A023077	3,243	49.4	5,061	0.00	61.81	4,999	98.78
A023077	3,200	49.6	5,011	0.00	61.81	4,949	98.77
A031521	2,282	50.3	3,623	15.14	37.08	3,586	98.98
S013709	2,248	44.7	3,173	2.78	46.01	3,127	98.55
D029507R	2,232	44.9	3,166	0.18	43.22	3,123	98.63
A018127	2,230	45.2	3,184	0.00	43.05	3,141	98.65
A025125	2,221	58.3	4,087	0.00	8.37	4,079	99.80
A017833	2,193	45.5	3,149	1.63	43.05	3,106	98.63
A020005	2,123	45.7	3,060	1.55	41.42	3,018	98.65
S015862	2,121	45.9	3,073	0.00	39.87	3,033	98.70
S009168	2,064	46.1	3,006	18.41	39.87	2,966	98.67
S013563	2,034	46.2	2,966	0.00	21.46	2,944	99.28
S015916	565	59.3	1,057	0.00	8.37	1,049	99.21
S022703	452	53.8	768	6.80	6.80	761	99.11
A021052	433	59.8	817	8.37	8.37	808	98.98
A015299	356	50.5	568	0.00	1.49	566	99.74
A019554	332	50.6	530	0.00	1.49	529	99.72
A021191	177	49.2	275	2.21	2.21	273	99.20
A031521	126	49.2	195	15.14	15.14	180	92.25
A020951	116	48.1	177	9.54	9.54	167	94.60
A019554	76	48.9	117	13.69	13.69	103	88.28
C003981	72	47.1	107	5.17	5.17	102	95.17
D030758R	42	45.6	61	2.34	22.34	39	63.39
A017479	39	53.8	67	9.86	9.86	57	85.31
A030933	38	45.6	55	20.00	20.00	35	63.59
A019554	32	50.4	51	0.95	0.95	50	98.11
A031256	26	43.0	36	24.00	24.00	12	32.40
S019409	26	43.0	36	24.00	24.00	12	32.40
A029986	18	46.6	26	12.41	21.46	4	17.17
A020728	17	46.6	24	9.04	9.04	15	62.96
A019554	13	51.6	21	0.54	0.54	21	97.47
S013814	8.8	46.0	13	0.00	0.00	13	100.00
S013813	3.2	46.0	5	0.00	0.00	5	100.00
D031569R	0.74	54.3	1	0.26	0.26	1	79.70
A031256	0.22	43.0	0	24.00	24.00	0	0

Table 9. Draft Water Supply Table, month of April, for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	2,028.5	0.73	62.70	1,965.8	96.91
A024688A	14,191	47.1	2,030.9	0.00	61.98	1,968.9	96.95
S023680	14,168	47.3	2,037.7	0.00	61.98	1,975.7	96.96
S019972	14,162	47.4	2,042.1	0.66	61.98	1,980.2	96.97
S023682	14,140	47.5	2,044.4	0.00	61.32	1,983.1	97.00
S013760	14,123	47.7	2,047.0	0.00	61.32	1,985.7	97.00
S016032	11,784	49.1	1,760.6	0.08	35.39	1,725.2	97.99
S022582	11,740	49.3	1,760.7	0.00	35.30	1,725.4	97.99
A011327	11,497	49.5	1,730.7	1.06	35.30	1,695.4	97.96
S009039	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
S009045	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
S009040	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
A004612	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
A023077	3,243	49.4	487.6	4.51	26.35	461.3	94.60
A023077	3,200	49.6	482.8	4.51	21.84	461.0	95.48
A031521	2,282	50.3	349.1	4.25	10.40	338.7	97.02
S013709	2,248	44.7	305.7	0.78	25.93	279.7	91.52
D029507R	2,232	44.9	305.1	0.05	25.15	279.9	91.76
A018127	2,230	45.2	306.8	0.00	25.10	281.7	91.82
A025125	2,221	58.3	393.8	0.00	2.35	391.4	99.40
A017833	2,193	45.5	303.4	0.24	25.10	278.3	91.73
A020005	2,123	45.7	294.8	0.44	24.86	270.0	91.57
S015862	2,121	45.9	296.0	0.00	24.42	271.6	91.75
S009168	2,064	46.1	289.6	18.41	24.42	265.2	91.57
S013563	2,034	46.2	285.8	0.00	6.02	279.7	97.89
S015916	565	59.3	101.8	0.00	2.35	99.5	97.70
S022703	452	53.8	73.9	1.91	1.91	72.0	97.42
A021052	433	59.8	78.7	2.35	2.35	76.3	97.02
A015299	356	50.5	54.7	0.00	0.42	54.3	99.23
A019554	332	50.6	51.1	0.00	0.42	50.7	99.18
A021191	177	49.2	26.5	0.62	0.62	25.8	97.66
A031521	126	49.2	18.8	4.25	4.25	14.6	77.44
A020951	116	48.1	17.0	2.68	2.68	14.3	84.27
A019554	76	48.9	11.3	3.84	3.84	7.4	65.89
C003981	72	47.1	10.3	1.45	1.45	8.9	85.95
D030758R	42	45.6	5.9	0.35	0.54	5.3	90.87
A017479	39	53.8	6.5	2.76	2.76	3.7	57.25
A030933	38	45.6	5.3	0.19	0.19	5.1	96.47
A019554	32	50.4	4.9	0.27	0.27	4.6	94.51
A031256	26	43.0	3.4	0.22	0.22	3.2	93.44
S019409	26	43.0	3.4	0.22	0.22	3.2	93.44
A029986	18	46.6	2.5	3.48	6.02	0	0
A020728	17	46.6	2.4	2.54	2.54	0	0
A019554	13	51.6	2.1	0.15	0.15	1.9	92.65
S013814	8.8	46.0	1.2	0.00	0.00	1.2	100.00
S013813	3.2	46.0	0.4	0.00	0.00	0.4	100.00
D031569R	0.74	54.3	0.1	0.07	0.07	0.1	40.92
A031256	0.22	43.0	0.0	0.22	0.22	0	0

Table 10. Draft Water Supply Table, month of May for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	517.54	0.78	49.41	468.14	90.45
A024688A	14,191	47.1	518.15	1.27	48.63	469.51	90.61
S023680	14,168	47.3	519.87	0.00	47.36	472.51	90.89
S019972	14,162	47.4	521.02	0.68	47.36	473.65	90.91
S023682	14,140	47.5	521.60	0.00	46.68	474.92	91.05
S013760	14,123	47.7	522.26	0.00	46.68	475.57	91.06
S016032	11,784	49.1	449.18	0.08	26.07	423.11	94.20
S022582	11,740	49.3	449.22	0.00	25.98	423.24	94.22
A011327	11,497	49.5	441.57	0.04	25.98	415.58	94.12
S009039	11,094	50.2	431.77	6.09	25.95	405.82	93.99
S009045	11,094	50.2	431.77	6.09	25.95	405.82	93.99
S009040	11,094	50.2	431.77	6.09	25.95	405.82	93.99
A004612	11,094	50.2	431.77	6.09	25.95	405.82	93.99
A023077	3,243	49.4	124.40	4.82	16.47	107.93	86.76
A023077	3,200	49.6	123.18	4.82	11.65	111.52	90.54
A031521	2,282	50.3	89.06	0.14	2.25	86.81	97.47
S013709	2,248	44.7	77.99	0.81	20.61	57.37	73.57
D029507R	2,232	44.9	77.83	0.05	19.81	58.02	74.55
A018127	2,230	45.2	78.27	0.00	19.76	58.51	74.76
A025125	2,221	58.3	100.47	0.00	2.42	98.04	97.59
A017833	2,193	45.5	77.40	0.00	19.76	57.64	74.47
A020005	2,123	45.7	75.22	0.45	19.76	55.46	73.73
S015862	2,121	45.9	75.53	0.00	19.31	56.22	74.44
S009168	2,064	46.1	73.89	19.02	19.31	54.58	73.87
S013563	2,034	46.2	72.91	0.00	0.29	72.62	99.61
S015916	565	59.3	25.98	0.00	2.42	23.56	90.67
S022703	452	53.8	18.87	1.97	1.97	16.90	89.56
A021052	433	59.8	20.07	2.42	2.42	17.65	87.92
A015299	356	50.5	13.95	0.00	0.43	13.52	96.90
A019554	332	50.6	13.03	0.00	0.43	12.60	96.68
A021191	177	49.2	6.75	0.64	0.64	6.11	90.52
A031521	126	49.2	4.80	0.14	0.14	4.66	97.05
A020951	116	48.1	4.34	0.18	0.18	4.16	95.89
A019554	76	48.9	2.87	3.97	3.97	0	0
C003981	72	47.1	2.63	0.10	0.10	2.54	96.33
D030758R	42	45.6	1.50	0.00	0.00	1.50	100.00
A017479	39	53.8	1.65	0.18	0.18	1.47	88.83
A030933	38	45.6	1.35	0.00	0.00	1.35	100.00
A019554	32	50.4	1.24	0.28	0.28	0.97	77.78
A031256	26	43.0	0.87	0.00	0.00	0.87	100.00
S019409	26	43.0	0.87	0.00	0.00	0.87	100.00
A029986	18	46.6	0.64	0.12	0.29	0.35	55.24
A020728	17	46.6	0.60	0.17	0.17	0.43	71.84
A019554	13	51.6	0.52	0.16	0.16	0.37	70.22
S013814	8.8	46.0	0.32	0.00	0.00	0.32	100.00
S013813	3.2	46.0	0.11	0.00	0.00	0.11	100.00
D031569R	0.74	54.3	0.03	0.04	0.04	0	0
A031256	0.22	43.0	0.01	0.00	0.00	0.01	0

Our analysis indicates that there is additional water for appropriation in the winter diversion season December 15 through March 31, and possibly in April as well: the percentage of remaining unappropriated water remains above 95 percent at all existing diversion points along Mill Creek and its major tributaries. The data presented in the first table indicate that additional appropriations from Mill Creek may be possible during this winter diversion season. However, in May, this value is below 95 percent for all of these diversion points, suggesting that water may not be available for appropriation during this period.

Along with the analysis of human water needs described in Section 3.3, these data indicate that there is substantial opportunity to store water in winter for use in summer in the Mill Creek watershed while maintaining water needed for environmental processes. Such projects are likely to have benefits to summer streamflow as well.

6 Ensuring Durable Results

As noted above, water users, project managers, and funders should ensure that any summer water use offset through winter storage remains in and is protected instream. Such tools can also benefit landowners and water users.

6.1 Mechanisms for Protecting Saved Water

6.1.1 Forbearance Agreements

Forbearance agreements are one of the tools for protecting instream flow gains achieved through storage and other water conservation projects. It is a covenant that runs with the land and is recorded with the county property records. Forbearance agreements have been used in the Mattole River Headwaters, Salmon Creek (Sonoma County), Grape Creek (Sonoma County), and Green Valley Creek (Sonoma County). In general, a forbearance agreement sets forth the responsibilities as between the project proponent and the landowner and/or water user. It specifies the terms under which diversions and other water management practices can be initiated and must be ceased.

6.1.2 Instream Dedications (Water Code Section 1707)

In addition to entering into forbearance agreements, water users may file a change petition to dedicate their water right – or a portion of a water right – to instream uses during the dry season under California Water Code Section 1707.

The main benefits of an instream water right dedication are that it offers a layer of protection and durability for the instream water restored through projects that is unachievable with a forbearance agreement alone. Specifically, it offers protection as to other water diversions and provides legal recognition of the instream water in the eyes of the state, and it allows funders, project proponents, and the landowner to ensure that water rights no longer used are not lost to the next junior appropriator or to new appropriators. Water users can also elect to add instream uses as a purpose of use without eliminating existing uses, like irrigation.

If a water user is operating under an appropriative water right and ceases diversion during the dry season, the right could be lost through non-use. In this case, ensuring that the water is protected instream – through a water rights change petition – is important. If the landowner is operating under a riparian right, the landowner would not normally lose the water right as a result of non-use (through abandonment or forfeiture[16]), so some type of forbearance agreement should be sufficient to ensure that the water right is not lost through non-use. The main drawback to pursuing a forbearance agreement alone – without a dedication – is that the water is not protected for instream uses from other diverters. A forbearance agreement would be recorded with the county and run with the land (so it binds future landowners) but it would not be known to other water diverters or prevent them from simply taking the water left instream.

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[16] Note however that dormant (unexercised) riparian rights can sometimes be subordinated in priority in an adjudication.

A water rights dedication for the water no longer consumptively used can be an important part of the strategy for ensuring durable results. This could be all or a portion of a water right (e.g., in Pine Gulch Creek, the landowners dedicated the portion of their riparian water right used for irrigation during a portion of the year and maintained the non-irrigation portion of that riparian water right). This is especially important where projects involve the initiation of a new water right (e.g., winter diversion and storage) and involve an existing appropriative right, as the right can be lost to non-use. There may be cases where an instream water rights dedication is not appropriate. For example, where the landowner has a documented riparian water right (i.e., not lost through non-use), does not seek to initiate a new water right, and where the water no longer diverted is geographically protected from diversion by others (now and in the future). In addition, cost may be a factor for small projects (where the transactions costs of the dedication could be high relative to the overall project cost – e.g., projects like small roofwater harvesting).

6.2 Monitoring and Evaluation

In this SIP, we recommend actions that will produce additional streamflow in summer and fall while also maintaining sufficient water levels in winter and spring, and we predict that these actions will benefit salmonids. These predictions are based on our best models to evaluate improvement, but they are not actual depictions of the benefits from the projects that will be implemented. We recommend continued streamflow and habitat monitoring to evaluate the actual benefit of these projects on streamflow in the drainage network and to determine whether the projects have the benefits we expect (or the conditions under which the benefits are reached, such as in normal-type years or dry years). Such monitoring protocols will help us and others seeking to restore streamflow in coastal California watersheds to understand the benefits of these types of practices, as well as to understand the limitations of these practices given the range of variability across many years. Continued monitoring will also provide resources necessary for landowners to operate diversions appropriately and to ensure compliance with the terms and conditions stipulated in new diversion operations.

Additionally, continued monitoring of streamflow and expanded examination of habitat conditions will help us to gauge the benefit of these projects on fisheries. If data indicate that streamflow is greater and more stable through summer, and rearing habitat quality and juvenile summer survival do not increase, other factors may need to be considered to achieve the goal of creating a healthy fishery in Mill Creek. We note that streamflow is not the only factor limiting the persistence of a healthy fishery in Mill Creek, and work to increase streamflow in summer and continued fisheries resource monitoring will help us to understand the most significant additional challenges facing anadromous salmonids in the watershed.

6.3 Potential Threats

A significant amount of work has been completed to improve instream flow for fish populations in Mill Creek. We are evaluating the risk that future events will compromise the gains made today and are preparing a series of actions to guard against that possibility. Potential threats include:

- Land use changes. Land use change is a threat to streamflow gains in the Mill Creek watershed. The human footprint remains limited and development pressures are less here than in most places, but we must ensure that any streamflow improvements can withstand land use and ownership changes in the long-term.

- Non-participants. The success of the program depends on our ability to continue to recruit new landowners. This is necessary not only to reach the objectives, but also because having a high concentration of participants also helps ensure that water savings by landowners are not captured by other landowners rather than the stream. In addition, high participation creates a cultural climate conducive to water conservation and discourages water waste. Success breeds success.

- Lack of funding for water storage. All progress is subject to funding. Moreover, no one expects public funds to pay for all restoration, even though the public benefits from the projects. Though the funding available through Proposition 1 is promising, we anticipate that funding will be one of the limiting factors for how quickly streamflow improvement projects can progress.

- Lack of funding for monitoring. As mentioned above, long-term monitoring is important for ensuring compliance with water management conditions, for identifying changes in streamflow associated with water management practices, and for evaluating whether our proposed projects when implemented have the benefit we predict. Without additional resources for monitoring, we will not learn whether the projects implemented in Mill Creek are sufficient to restore streamflow beyond our identified thresholds and whether the results are long-lasting. Funding for any type of monitoring is generally major challenge of these types of projects, and we anticipate that monitoring after projects are implemented (while critical to understanding their success) will be even less attractive.

- Climate change. Although future effects of climate change cannot be quantified or predicted precisely, we consider it a significant risk factor for the future.

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Appendix A. Recovery Plan Actions Implemented by the Coho Partnership

The Coho Partnership is addressing and implementing recommendations and actions identified in the following public planning documents:

Central California Coast Coho Recovery Plan

The Central California Coast Coho Recovery Plan identified Mill Creek as Core Priority Area for CCC coho, and deemed the threat to summer rearing juvenile fish from water diversion and impoundments in the Russian River watershed to be "very high" (i.e., the highest threat level) (NMFS 2012). The Coho Partnership's efforts are consistent with and represent progress toward the following recovery plan objectives and recovery actions listed for the Russian River:

RR-CCC-4.1.1.2	Promote, via technical assistance and/or regulatory action, the reduction of water use affecting the natural hydrograph, development of alternative water sources, and implementation of diversion regimes protective of the natural hydrograph.
RR-CCC-4.1.1.3	Avoid and/or minimize the adverse effects of water diversion on coho salmon by establishing: a more natural hydrograph, by-pass flows, season of diversion and off-stream storage.
RR-CCC-4.1.2.1	Reduce the rate of frost protection and domestic drawdown in the spring.
RR-CCC-4.1.2.2	Assess and map water diversions.
RR-CCC-4.2.1.1	Develop cooperative projects with private landowners to conserve summer flows based on the results of the NFWF efforts.
RR-CCC-4.2.2.1	Work with SWRCB and landowners to improve over-summer survival of juveniles by re-establishing summer baseflows (from July 1 to October 1) in rearing reaches that are currently impacted by water use.
RR-CCC-4.2.2.2	Work with SWRCB and landowners to improve flow regimes for adult migration to spawning habitats and smolt outmigration.
RR-CCC-4.2.2.3	Promote alternative frost protection strategies.
RR-CCC-25.1.1	Prevent impairment to stream hydrology (impaired water flow).
RR-CCC-25.1.1.2	Promote water conservation by the public, water agencies, agriculture, private industry, and the citizenry.
RR-CCC-25.1.1.3	Promote off-channel storage to reduce the impacts of water diversion (e.g., storage tanks for rural residential users).

RR-CCC-25.1.1.4 Provide incentives to water rights holders willing to convert some or all of their water right to instream use via petition [for] change of use and [Section] 1707.

RR-CCC-25.1.1.5 Improve coordination between agencies and others to address season of diversion, off-stream reservoirs, bypass flows protective of coho salmon and their habitats, and avoidance of adverse impacts caused by water diversion.

RRR-CCC-25.1.1.8 Promote water conservation best practices such as drip irrigation for vineyards.

Recovery Strategy for California Coho Salmon

The Coho Partnership's efforts are consistent with DFG's Coho Recovery Strategy (CDFW 2004). They address the following recommendations for the Russian River Hydrologic Unit: the identification of water diverters, State Water Board review and/or modification of water use based on the needs of coho salmon and authorized diverters (RR-HU-03) (p. 8.39), and development of "county, city, and other local programs to protect and increase instream flow for coho salmon." The Partnership also implements the following range-wide recommendations:

RW-I-D-01: Encourage elimination of unnecessary and wasteful use of water from coho salmon habitat…Encourage water conservation for existing uses.

RW-I-D-02: Where feasible, use programmatic, cost-efficient approaches and incentives to working with landowners to permit off-channel storage ponds.

RW-I-D-08: Support a comprehensive streamflow evaluation program to determine instream flow needs for coho salmon in priority watersheds.

RW-II-B-01: Pursue opportunities to acquire or lease water, or acquire water rights from willing sellers for coho salmon recovery purposes. Develop incentives for water right holders to dedicate instream flows for the protection of coho salmon (California Water Code § 1707).

California Wildlife Action Plan

The Partnership addresses recommended actions in the California Wildlife Action Plan for the North Coast (CDFW 2007, p.261):

> "For regional river systems where insufficient or altered flow regimes limit populations of salmon, steelhead, and other sensitive aquatic species, federal and state agencies and other stakeholders should work to increase instream flows and to replicate natural seasonal flow regimes. Priorities specific to this region include:
>
> - Agencies and partners should develop water-use and supply plans that meet minimum flow and seasonal flow-regime requirements for sensitive aquatic species [CDFW 2004].

In determining flow regimes, the suitable range of variability in flow, rate of change, and peak- and low-flow events should be considered (Richter et al. 1997).

- Water trusts or other forums that provide a structured process for willing participants to donate, sell, or lease water dedicated to instream use should be pursued [CDFW 2004].
- Innovative ways to manage small-scale water diversions should be developed, such as agreements to alternate diversion schedules (so that all water users do not withdraw water at once) and the use of off-stream reservoirs to store winter water and limit diversion during the dry season. Incentives should be established for water users to participate in these efforts [CDFW 2004].
- Agencies and partners should encourage water conservation practices and use of technologies that reduce water consumption by residential and agricultural water users through incentives and education [CDFW 2004]."

State Water Resources Control Board

The Partnership furthers the California Water Boards' Strategic Plan Update (California Water Boards 2008). The Plan states:

> "The State Water Board strives to use a collaborative watershed management approach to satisfy competing environmental, land use, and water use interests by taking advantage of opportunities within a watershed, such as joint development of local solutions to watershed-specific problems, cost sharing, and coordination of diversions. For example, instead of the State Water Board and other regulatory agencies establishing and enforcing stream flow objectives through regulation of individual diversions, water users could agree to collectively manage their diversion schedules so that needed stream flows are maintained at particular points in a stream. They could also share costs associated with developing data and monitoring programs, and work together on projects to improve habitat at the most significant locations in the watershed. Extensive use of such approaches using coordination and collaboration, however, is currently beyond the Water Boards' resources."

Furthermore, the State Water Board identified the Russian River as one of its first priority rivers and streams in its prioritized schedule of instream flow studies for the protection of public trust resources (California Water Boards 2010).

APPENDIX D

Mill Creek Watershed Species List

Animal species listed as threatened, endangered, and species of special concern in the Mill Creek area. (CDFW 2009) Codes-SSC-Species of Special Concern, FP-Fully Protected, WL-Watch List.

Scientific Name	**Common Name**	**Federal Status**	**California Status**	**DFG Status**	**CNDDB rank**
Ambystoma californiense	California tiger salamander	Threatened	Threatened	SSC	G2G3 S2S3
Andrena blennospermatis	Blennosperma vernal pool andrenid bee	None	None	SSC	G2 S2
Antrozous pallidus	pallid bat	None	None	SSC	
Arborimus pomo	Sonoma tree vole	None	None	SSC	
Ardea herodias	great blue heron	None	None		
Athene cunicularia	burrowing owl	None	None	SSC	
Brachyramphus marmoratus	marbled murrelet	Threatened	Endangered		
Cerorhinca monocerata	rhinoceros auklet	None	None	WL	G5 S3
Danaus plexippus	monarch butterfly	None	None		G5 S3
Dubiraphia giulianii	Giuliani's dubiraphian riffle beetle	None	None		G1G3 S1S3
Elanus leucurus	white-tailed kite	None	None	FP	
Emys marmorata (formerly Actinemys marmorata)	western pond turtle	None	None	SSC	G3G4 S3
Hysterocarpus traski pomo	Russian River tule perch	None	None	SSC	
Lasiurus cinereus	hoary bat	None	None		G5S4?
Lavinia symmetricus navarroensis	Navarro roach	None	None	SSC	
Lavinia symmetricus parvipinnis	Gualala roach	None	None	SSC	
Linderiella occidentalis	California linderiella (fairy shrimp)	None	None		
Mylopharodon conocephalus	Hardhead (fish)	None	None	SSC	
Northern Hardpan Vernal Pool	Northern Hardpan Vernal Pool	None	None		
Oncorhynchus kisutch	coho salmon - central California coast ESU	Endangered	Endangered		
Oncorhynchus mykiss irideus	steelhead - central California coast DPS	Threatened	None		G5T2Q S2
Oncorhynchus tshawytscha	chinook salmon - central Valley spring-run ESU	Threatened	Threatened		
Pandion haliaetus	osprey	None	None	WL	

Rana boylii	foothill yellow-legged frog	None	None	SSC	
Rana draytonii	California red-legged frog	Threatened	None	SSC	
Riparia riparia	bank swallow	None	Threatened		G5 S2S3
Speyeria zerene myrtleae	Myrtle's silverspot	Endangered	None		G5T1 S1
Spirinchus thaleichthys	longfin smelt	None	Threatened		
*Strix occidentalis caurina**	Northern spotted owl*	Threatened	None		
Syncaris pacifica	California freshwater shrimp	Endangered	Endangered		
Taxidea taxus	American Badger	None	None	G5 S4	SSC
Usnea longissima	long-beard lichen	None	None		G4/S4.2

*Anecdotal evidence that species was observed

Plant species listed as threatened or endangered, or included in the CNPS Inventory of Rare and Endangered Plants (2001). Codes: 1A -Plants presumed extinct in California, 1B -Plants rare, threatened, or endangered in California and elsewhere, 2-Plants rare, threatened, or endangered in California, but more common elsewhere, 3-Plants about which we need more information.

Scientific Name	**Common Name**	**Federal Status**	**California Status**	**CNPS Status**
Agrostis blasdalei	Blasdale's bent grass	None	None	1B.2
Alopecurus aequalis var. sonomensis	Sonoma alopecurus	Endangered	None	1B.1
Amorpha californica var. napensis	Napa false indigo	None	None	1B.2
Arctostaphylos bakeri ssp. bakeri	Baker's manzanita	None	Rare	1B.1
Arctostaphylos bakeri ssp. sublaevis	The Cedars manzanita	None	Rare	1B.2
Arctostaphylos densiflora	Vine Hill manzanita	None	Endangered	1B.1
Arctostaphylos stanfordiana ssp. decumbens	Rincon Ridge manzanita	None	None	1B.1
Blennosperma bakeri	Sonoma sunshine	Endangered	Endangered	1B.1
Brodiaea californica var. leptandra	narrow-anthered California brodiaea	None	None	1B.2
Calamagrostis crassiglumis	Thurber's reed grass	None	None	2.1
Calochortus raichei	The Cedars fairy-lantern	None	None	1B.2
Calystegia collina ssp. oxyphylla	Mt. Saint Helena morning-glory	None	None	4.2
Calystegia purpurata ssp. saxicola	coastal bluff morning-glory	None	None	1B.2
Campanula californica	swamp harebell	None	None	1B.2
Carex albida	white sedge	Endangered	Endangered	1A
Carex comosa	bristly sedge	None	None	2.1

Castilleja uliginosa	Pitkin Marsh paintbrush	None	Endangered	1A
Ceanothus confusus	Rincon Ridge ceanothus	None	None	1B.1
Ceanothus foliosus var. vineatus	Vine Hill ceanothus	None	None	1B.1
Ceanothus purpureus	holly-leaved ceanothus	None	None	1B.2
Centromadia parryi ssp. parryi	pappose tarplant	None	None	1B.2
Chlorogalum pomeridianum var. minus	dwarf soaproot	None	None	1B.2
Chorizanthe valida	Sonoma spineflower	Endangered	Endangered	1B.1
Clarkia imbricata	Vine Hill clarkia	Endangered	Endangered	1B.1
Cordylanthus tenuis ssp. capillaris	Pennell's bird's-beak	Endangered	Rare	1B.2
Cryptantha clevelandii var. dissita	serpentine cryptantha	None	None	1B.1
Cuscuta obtusiflora var. glandulosa	Peruvian dodder	None	None	2.2
Delphinium bakeri	Baker's larkspur	Endangered	Endangered	1B.1
Delphinium luteum	golden larkspur	Endangered	Rare	1B.1
Downingia pusilla	dwarf downingia	None	None	2.2
Erigeron greenei	Greene's narrow-leaved daisy	None	None	1B.2
Erigeron serpentinus	serpentine daisy	None	None	1B.3
Eriogonum cedrorum	The Cedars buckwheat	None	None	1B.3
Erysimum concinnum	bluff wallflower	None	None	1B.2
Fritillaria liliacea	fragrant fritillary	None	None	1B.2
Hemizonia congesta ssp. congesta	seaside tarplant	None	None	1B.2
Hesperevax sparsiflora var. brevifolia	short-leaved evax	None	None	1B.2
Horkelia tenuiloba	thin-lobed horkelia	None	None	1B.2
Lasthenia burkei	Burke's goldfields	Endangered	Endangered	1B.1
Lasthenia californica ssp. bakeri	Baker's goldfields	None	None	1B.2
Lasthenia californica ssp. macrantha	perennial goldfields	None	None	1B.2
Leptosiphon jepsonii	Jepson's leptosiphon	None	None	1B.2
Lessingia arachnoidea	Crystal Springs lessingia	None	None	1B.2
Limnanthes vinculans	Sebastopol meadowfoam	Endangered	Endangered	1B.1
Lupinus tidestromii	Tidestrom's lupine	Endangered	Endangered	1B.1
Microseris paludosa	marsh microseris	None	None	1B.2
Monardella villosa ssp. globosa	robust monardella	None	None	1B.2
Navarretia leucocephala ssp. bakeri	Baker's navarretia	None	None	1B.1
Navarretia leucocephala ssp. plieantha	many-flowered navarretia	Endangered	Endangered	1B.2

Piperia candida	white-flowered rein orchid	None	None	1B.2
Pleuropogon hooverianus	North Coast semaphore grass	None	Threatened	1B.1
Rhynchospora alba	white beaked-rush	None	None	2.2
Rhynchospora californica	California beaked-rush	None	None	1B.1
Rhynchospora capitellata	brownish beaked-rush	None	None	2.2
Rhynchospora globularis	round-headed beaked-rush	None	None	2.1
Sidalcea calycosa ssp. rhizomata	Point Reyes checkerbloom	None	None	1B.2
Sidalcea malviflora ssp. purpurea	purple-stemmed checkerbloom	None	None	1B.2
Streptanthus brachiatus ssp. hoffmanii	Freed's jewel-flower	None	None	1B.2
Streptanthus glandulosus var. hoffmanii	Hoffman's bristly jewel-flower	None	None	1B.3
Streptanthus morrisonii	Morrison's jewel-flower	None	None	
Trifolium amoenum	showy rancheria clover	Endangered	None	1B.1
Trifolium buckwestiorum	Santa Cruz clover	None	None	1B.1
Trifolium hydrophilum	saline clover	None	None	1B.2
Viburnum ellipticum	oval-leaved viburnum	None	None	2.3

APPENDIX E

California Department of Fish and Wildlife Stream Inventory Reports

CALIFORNIA DEPARTMENT OF FISH AND GAME
STREAM INVENTORY REPORT
Mill Creek
Report Revised April 14, 2006
Report Completed 2000
Assessment Completed 1995

INTRODUCTION

A stream inventory was conducted during the summer of 1995 on Mill Creek to assess habitat conditions for anadromous salmonids. The inventory was conducted in two parts: habitat inventory and biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids in Mill Creek. The objective of the biological inventory was to document the salmonid and other aquatic species present and their distribution. After analysis of historical information and data gathered recently, stream restoration and enhancement recommendations are presented.

WATERSHED OVERVIEW

Mill Creek is tributary to Dry Creek which is a tributary to the Russian River, located in Sonoma County, California (see Mill Creek Watershed map, page 2). The legal description at the confluence with the Russian River is T09N,R09W,S33. Its location is 38°35'20" N. latitude and 122°52'08" W. longitude. Year round vehicle access to the watershed exists via Mill Creek Road or Felta Road, from Westside Road in Healdsburg. Mill Creek is a perennial third order stream and has approximately 12 miles of blue line stream, according to the USGS Guerneville, and Healdsburg 7.5 minute quadrangles. Major tributaries include Felta, Wallace, Palmer and Angel Creeks. These creeks will each have separate reports from Mill Creek. Boyd Creek, a smaller tributary is included in this report. Mill Creek and its tributaries drain a basin of approximately 24 square miles, and the system has a total of 29.0 miles of blue line stream. Elevations range from about 60 feet at the mouth of the creek to 1400 feet in the headwater areas. Features include a lowland valley area, a short steep boulder section, and a steep U-shaped canyon upstream. A series of earthen dams exist in the upper watershed at about 11 miles. Tan oak, alder, bay and redwood trees forest the drainage area.

The Northern Spotted Owl *(Strix occidentalis caurina)* was listed in DFG's Natural Diversity Database as occurring in Mill Creek watershed. No sensitive plants were listed.

Stream Surveys:

Three DFG surveys were conducted previously and are summarized:

A survey of Mill Creek was conducted in the summer of 1957 (from Felta road bridge to 8.6 miles upstream). A partial survey was done from the Dry Creek confluence upstream to Palmer Creek in the spring of 1973. In the summer of 1982 a survey was conducted from the mouth of Dry Creek to 2 miles downstream of the headwaters (8.5 miles).

The 1957 fall survey generally characterized pool development above Felta Creek as "very good" with "fair sized" pools and "adequate" shelter common throughout the entire system. Flows were described as adequate for rearing fish. **The 1973 spring survey** described the section below Felta Creek to the mouth as having mostly narrow undercut banks. Pools were again found to be fair sized and scattered along the entire creek. However, it also noted that "retaining wall fence pole bases had eroded pools up to 4 feet" deep. Upstream 3 miles there were "abundant holding pools made from falling log jams" or "natural pools under small cascades". From the Wallace Creek confluence to downstream 3 miles, a ratio of 5-10 pools/mile was estimated and described as 3-6 feet deep. Upstream of Wallace Creek 2.5 miles, pools were also estimated to be 3-6 feet deep. Summer flows were reported as diminished due to summer dams. **The fall survey of 1982** indicated very few pools due to low flows, with "fair" shelter consisting of mostly boulders. Few undercut banks were noted and logs and other debris were notably absent with the exception of four log jams. Flows were described as very low due to numerous pumps, dams and wells.

METHODS

The habitat inventory conducted in Mill Creek follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1991). The Americorps members that conducted the inventory were trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG) under the supervision of DFG's Russian River Basin Planner, Robert Coey in May 1995. This inventory was conducted by a two person team.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Mill Creek to record measurements and observations. There are nine components to the inventory form.

1. Flow:

Flow is measured in cubic feet per second (cfs) at the bottom of the stream survey reach using standard flow measuring equipment, if available. In some cases flows are estimated. Flows were also measured or estimated at major tributary confluences.

2. Channel Type:

Channel typing is conducted according to the classification system developed by David Rosgen (1985). This methodology is described in the California Salmonid Stream Habitat Restoration Manual. Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are four measured parameters used to determine channel type: 1) water slope gradient, 2) channel confinement, 3) width/depth ratio, 4) substrate composition.

3. Temperatures:

Water and air temperatures, and time taken, are measured by crew members with handheld thermometers and recorded at each tenth unit typed. Temperatures are measured in Fahrenheit at the middle of the habitat unit and within one foot of the water surface. Temperatures are also recorded using Ryan Tempmentors which log temperature every two hours, 24 hours/day.

4. Habitat Type:

Habitat typing uses the 24 habitat classification types defined by McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "dry". Mill Creek habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. Channel dimensions were measured using hip chains, range finders, tape measures, and stadia rods. Unit measurements included mean length, mean width, mean depth, and maximum depth. Pool tail crest depth at each pool unit was measured in the thalweg. All measurements were taken in feet to the nearest tenth.

5. Embeddedness:

The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. In Mill Creek, embeddedness was visually estimated. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value 4).

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent cover. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All cover is then classified according to a list of nine cover types. In Mill Creek, a standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) was assigned according to the complexity of the cover. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes. Mechanical substrate sampling was also conducted to quantify the percentage of fine sediment within spawning gravels.

Four substrate samples were taken in potential spawning riffles in Mill Creek on November 30 and December 1, 1995. Sample 1 was taken in reach 1, sample 2 was in reach 2, sample 3 was in reach 3 and sample 4 was in reach 8. Each sample consisted of one 12" McNeil sample to characterize each reach.

The samples were placed through a series of sieves with diameters of .85mm, 2.37mm, 4.7mm, 12.5mm, 25.4mm, 50.8mm, 76.2mm and 150mm. Displacement volumes were measured for particles in each size classification. Finally, the remaining sample less than 0.85mm was placed in Imhoff cones for 1 hour with the volume of fines settled out measured.

8. Canopy:

Stream canopy is estimated using handheld spherical densiometers and is a measure of the water surface shaded during periods of high sun. In Mill Creek, an estimate of the percentage of the habitat unit covered by canopy was made from the center of each unit. The area of canopy was further analyzed to estimate its percentages of coniferous or deciduous trees, and the results recorded.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In Mill Creek, the dominant composition type in both the right and left banks was selected from a list of eight options on the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

BIOLOGICAL INVENTORY

Biological sampling during stream inventory is used to determine fish species and their distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. These sampling techniques are discussed in the California Salmonid Stream Habitat Restoration Manual.

DATA ANALYSIS

Data from the habitat inventory form are entered into Habitat Runtime, a dBASE 4.1 data entry program developed by the California Department of Fish and Game (DFG). This program also processes and summarizes the data.

The Habitat Runtime program produces the following tables:

- Riffle, flatwater, and pool habitat types
- Habitat types and measured parameters
- Pool types
- Maximum pool depths by habitat types
- Dominant substrates by habitat types
- Mean percent shelter by habitat types

Graphics are produced from the tables using Lotus 1,2,3. Graphics developed for Mill Creek include:

- Riffle, flatwater, pool habitats by percent occurrence
- Total habitat types by percent occurrence (bar graph)
- Pool types by percent occurrence

HABITAT INVENTORY RESULTS

* ALL TABLES AND GRAPHS ARE LOCATED AT THE END OF THE REPORT *

The habitat inventory of July 24 - August 22, 1995 was conducted by John Fort and Ken Mogan (Americorps members with Watershed Stewards Project). The survey began at the confluence with Dry Creek and extended up Mill Creek to the end of survey at an impassable dam. The total length of the stream surveyed was 81,523 feet. A flow of 2.8 cfs was measured on July 29 just before the Wallace Creek confluence, and a flow of 12.4 cfs was measured on July 28 at Mill

Creek Road below Wallace Creek, with a Marsh-McBirney Model 2000 flowmeter.

This section of Mill Creek has eight channel types: from the mouth to 18,111 an F4; next 3,220 feet a B2; next 34,413 feet an F4; next 1,845 feet an F2; next 13,725 feet a F4; next 4,255 feet an F3; next 1,164 an F2 and the upper 3,916 feet a G4 (Mill Creek Watershed map and Appendix B). F2 types are entrenched, meandering riffle/pool channels on low gradients (<2%) with a high width/depth ratio and a boulder substrate. F3 and F4 types are similar with cobble and gravel substrates. B2 channels are moderate gradient (2-4%), moderately entrenched, large cobble/boulder channels. G4 types are entrenched "gully" step-pool channels with a low width/depth ratio on a moderate gradient and gravel substrate.

During the habitat inventory period, water temperatures ranged from 53 to 74°F. Air temperatures ranged from 57 to 95°F. Summer temperatures were also measured using Ryan Tempmentors placed in pools (see Tempmentor Summary graphs at end of report). A Tempmentor placed in reach one upstream of Westside Road Bridge recorded every two hours from June 30 until August 25, 1995 . The highest temperature recorded was 71.1°F in July and the lowest was 57.9°F in August. The mean of the daily highs was 67.7°F for the month of July and 65.2°F for August. These temperatures are slightly above the threshold stress level of 65°F for salmonids. A second Tempmentor was placed in reach six just upstream of a bridge and recorded every 2 hours from June 30 - October 17, 1995. The high temperature recorded was 64.9°F and the low was 50.9°F. The mean of the daily highs was 62.7°F for July, 62.4°F for August, 59.6°F for September and 55.3°F for October.

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. All pools and 15% of riffle and flatwater types were completely surveyed. By percent **occurrence**, riffles made up 24%, flatwater types 40%, pools 35%, and dry units 1% (Graph 1). Flatwater habitat types made up 57% of the total survey **length**, riffles 23%, pools 20%, and dry 1%.

Twenty Four Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent **occurrence** were low gradient riffles, 22%; runs, 22%; glides, 17%; and lateral scour rootwads 12%; (Graph 2). By percent total **length**, runs made up 33%, glides 21%, low gradient riffles 21% and lateral scour rootwads made up 7%.

Three hundred and sixty two pools were identified (Table 3). Scour pools were most often encountered at 70% (Graph 3), and comprised 67% of the total length of pools.

Table 4 is a summary of maximum pool depths by pool habitat types.

Depth is an indicator of pool quality. One hundred and ten of the 351 pools with maximum depth measured (31%) had a depth of three feet or greater (Graph 4).

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Riffle and pool types both had a mean shelter rating of 53, while flatwater types had a rating of 34. (Table 1). Of the pool types, the scour pools had the highest mean shelter rating at 54, main channel pools rated 51, and backwater pools rated 49 (Table 3).

One hundred seventy-eight of the 352 (51%) pool tail-outs measured had embeddedness ratings of either 3 or 4. One hundred six had a rating of 1 (30%) and sixty-eight had a rating of 2 (19%).

Table 5 summarizes mean percent cover by habitat type. Table 10 summarizes cover areas by habitat type. Boulders are the dominant cover type for pools in Mill Creek and are extensive. Undercut banks, large woody debris and root mass are the next most common cover types (Graphs 6 and 10). Nearly 27% of Mill Creek lacked shade canopy. Of the 73% of the stream that was covered with canopy, 46% was composed of deciduous trees, and 54% was coniferous (Graph 8). Shade canopy was also analyzed by reach with reaches 1,2 and 8 having the lowest percent shade canopy (Appendix B and Graph 11)

For the stream reach surveyed, the mean percent right bank vegetated was 68% and the mean percent left bank vegetated was also 68%. The dominant elements composing the structure of the stream banks consisted of 11% bedrock, 11% boulder, 54% cobble/gravel, 25% silt/clay, 3% bare soil, 2% grass and 10% brush. Additionally, 39% of the banks were covered with deciduous trees, and 46% with coniferous trees, including downed trees, logs, and root wads (Appendix C and Graph 9).

SUBSTRATE SAMPLING

In the 1957 survey, composition of the stream bed was visually estimated as dominated by gravel and small rubble.

In 1973, it was noted that silt and sand were prevalent from erosion of side walls.

In 1982, the survey stated the upper reaches consisted of 50% rubble, 20% gravel, 15% cobble, 10% sand and 5% boulders. The middle section increased in gravel with 50% gravel, 20% cobble, 20% rubble, 9% sand and 1% boulder. Towards the mouth, the bottom consisted of 40% sand and silt, 30% boulders, 15% cobble and 15% gravel.

For the 1995 inventory, Table 6 summarizes the dominant substrate by habitat type. Gravel was the dominant substrate observed in 70% of low gradient riffles measured for substrate composition. Small cobble was the next most frequently observed dominant substrate type, and occurred in 21% of the low gradient riffles measured (Graph 7).

The depth of cobble embeddedness was estimated at pool tail-outs. In Reach 1, 52% of the units measured had a value of 1 and 26% a value of 4. In Reach 2, 6% had a value of 1 and 78% had a value of 4. Reach 3 is evenly split, 35% had a 1, and 35% had a 4. In Reach 4, 14% had a value of either 1 and 43% had a value of 4. Reach 5 is about evenly divided between each value. In reach 6, 8% had either a 1 and 47% had a value of 4. In Reach 7, 21% had a 1 and 57% had a 4. In Reach 8, 32% had a value of 1 and 24% had a value of 4. (Appendix B and Graph 5). Reaches 2,4,7 and 8 are boulder sections with some bedrock, therefore the embeddedness values would be expected to be higher.

Gravel samples were taken in the field by Mogan and Gregory (Americorps). Laboratory analysis was done by Fort, Huber, Nossaman, Sanchez (Americorps), Wilson and Hards (Interns) in May of 1996. The data was then summarized and analyzed with a computer program written by Dwain Goforth (National Park Service).

The analysis showed sample 1 (Reach 1) to be 8.1% fines (<0.85 mm), sample 2 (Reach 2) 7.0% fines, sample 3 (Reach 3) 5.4% fines and sample 4 (Reach 8) to be 10.9% fines. The combined summary of all four samples averaged 7.8% fines. The combined summary showed 75% of the substrate to be less than 44mm, 50% to be less than 16mm and 25% to be less than 4mm (see Grain Size Distribution Plot). Reach 4 had a considerably higher percentage of fines than the other reaches.

HABITAT INVENTORY RESULTS FOR BOYD CREEK

The habitat inventory on August 24, 1995 of Boyd Creek (tributary to Mill Creek) was conducted by John Fort and Ken Mogan. The survey began at the mouth and extended to 131 feet past the end of survey. The total length surveyed was 1,233 feet.

Boyd Creek was determined to be a G4 channel type. This type is described as an entrenched "gully" step-pool with low width/depth ratio, moderate gradient and gravel substrate.

Water temperatures ranged from 59°F to 61°F. Air temperatures ranged from 63°F to 70°F.

By percent ***occurrence****, riffles made up 50%, pools 40%, and flatwater 10%. Riffles made up 65% of the total survey* ***length****,* *pools 27%, and flatwater 9%. The most frequent habitat types by percent* ***occurrence*** *were low gradient riffles, 35%; plunge pools, 18%; high gradient riffles, 13%; and runs, 8%.*

Sixteen pools were identified. Scour pools were most often encountered at 69%, and comprised 49% of the total length of pools. None of the pools had a maximum depth greater than 2 feet.

Riffle types had the highest shelter rating at 37. Flatwater had the lowest rating with 5. Of the pool types, the main pools had the highest mean shelter rating at 35, scour pools rated 29, and backwater pools 10. Boulders are the dominant cover type in Boyd Creek. Undercut banks, large woody debris and root masses also contribute considerably to the cover.

Gravel was the dominant substrate observed and sand was the next most frequently observed. Of the 16 pool tail-outs measured, 6% had a value of 1, 25% had a value of 2, 13% had a value of 3 and 56% had a value of 4. On this scale, a value of one is best for fisheries.

Of the 95% of the stream that was covered with canopy, 4% was composed of deciduous trees, and 96% was composed of coniferous trees. The mean percent right bank vegetated was 66% and the mean percent left bank vegetated was 56%. the dominant vegetation types for the stream banks were: 86% coniferous trees, 7% deciduous trees and 7% bare soil. The dominant substrate for the stream banks were: 61% cobble/gravel, 14% bedrock, 14% boulder and 11% silt/clay/sand.

BIOLOGICAL INVENTORY

JUVENILE SURVEYS:

Steelhead young of year were stated as "abundant throughout the stream" section checked in the 1957 survey. The survey also described their "success and natural propagation to be good". The 1973 surveys indicate that Venus Roach and some SH juvenile and adult fish were observed. The surveys from 1982 indicate steelhead and roach were present although in low numbers (15 fish/100 ft.) No other fish species were noted in any of the past surveys.

A biological inventory was conducted on September 12, 13 and 20 of 1995 on Mill Creek to document the fish species composition and distribution within each reach. Each site was single pass electrofished using one Smith Root Model 12 electrofisher. Fish from each site were counted by species, aged, and returned to the stream. The air temperature ranged from 57-81°F and the water temperature ranged from 58-63°F. The observers were Mogan, Gregory and Coey.

The inventory of reach one was conducted one hundred feet above Westside Road in habitat units 101-114. In pool, glide and run habitat types 123 0+, ten 1+ and two 2+ steelhead were observed along with 78 sculpin, 5 roach, 7 sucker, 3 squaw fish and 1 Pacific giant salamander.

The inventory of reach two was conducted starting at habitat unit 136. In pool, glide and riffle habitat types 180 0+, twenty 1+ and ten 2+ steelhead were observed along with 25 sculpin, 22 squawfish, 5 sucker, 7 bass, 1 sunfish and 2 crayfish. The squawfish were 6-7" long.

The inventory of reach three was near bridge #4 (Mill Creek Lane) in habitat units 229-240. In pool glide and riffle habitat types 23 coho and 71 0+, six 1+ and four 2+ steelhead were observed along with 59 roach, 4 sculpin and 1 sunfish.

The reach four inventory was conducted in habitat units 554-566. In pool, backwater pool, glide, run, low gradient and high gradient riffle habitat types 159 0+, twenty 1+ and one 2+ steelhead were observed along with 88 sculpin and 4 crayfish.

The reach five inventory was 600 feet downstream from bridge #17 in habitat units 689-708. In pool, riffle, glide and run habitat types 29 coho and 85 0+, five 1+ and two 2+ steelhead were observed along with 71 sculpin, 2 crayfish and 1 frog.

The reach six inventory was conducted in habitat units 853-865. In pool and low-gradient riffle habitat types 3 juvenile coho and 56 0+, 10 1+ and 1 2+ steelhead were observed along with 54 sculpin, 7 crayfish and 1 frog. The inventory of reach six was continued 1/8 mile downstream from bridge #23 in habitat units 871-879. In pool, riffle, glide and run habitat types 1 coho, 96 0+, eight 1+ and five 2+ steelhead were observed along with 45 sculpin and 7 crayfish.

The reach seven inventory was started directly under bridge #23 in habitat units 908-929. In pool, riffle and run habitat types 17 juvenile coho and 113 0+, nine 1+ and five 2+ steelhead were observed along with 29 sculpin and 9 crayfish.

The reach eight inventory was near bridge #24 in habitat units 950-1024. In pool, run, glide and low-gradient riffle habitat types 4 juvenile coho and 226 0+, six 1+ and three 2+ steelhead were observed along with 1 crayfish, 3 frogs and 1 salamander.

Notably, both coho and steelhead were found above the falls in reach 3 indicating it is not a migration barrier, at least at high flows. A summary of historical and recent data collected appears in the table below.

Summary of Salmonids found in Juvenile Surveys			
YEAR	SPECIES	SOURCE	SIZE
1957	SH	DFG	Juvenile
1973	SH	DFG	Juvenile
1982	SH	DFG	Juvenile
1995	SH,SS	DFG	Juvenile
1995	KS	DFG	Adult Spawners

SH=Steelhead
SS=Coho (Silver) Salmon
KS=Chinook (King) Salmon

Historical records reflect that hatchery raised steelhead fingerlings were planted in Mill Creek in 1982, 1983, 1984, and 1986. Steelhead fingerlings were transferred to Mill Creek from Dry Creek in 1958 (Table 1). Steelhead fingerlings were rescued/transferred from Mill Creek in 1956, 1960 and 1964 (Table 2).

Table 1. Summary of fish plants/transfers into Mill Creek				
YEAR	**SOURCE**	**SPECIES**	**#**	**SIZE**
1958	Dry Creek	SH	545	FING
1982	Warm Springs	SH	46,684	FING
1982	Warm Springs	SH	17,640	FING
1982	Warm Springs	SH	14,560	FING
1982	Warm Springs	SH	14,484	FING
1983	Warm Springs	SH	29,760	FING

Table 1. Summary of fish plants/transfers into Mill Creek				
YEAR	**SOURCE**	**SPECIES**	**#**	**SIZE**
1983	Warm Springs	SH	15,360	FING
1983	Warm Springs	SH	14,400	FING
1984	Warm Springs	SH	16,250	FING
1986	Warm Springs	SH	13,500	FING

FING = fingerling
SH = Steelhead
Warm Springs = Warm Springs Hatchery (Geyserville)

Table 2. Summary of fish rescues/transfers from Mill Creek				
YEAR	**RELEASE LOCATION**	**SPECIES**	**#**	**SIZE**
1956	Russian River	SH	1,666	FING
1960	Little Sulphur Creek	SH	1,598	FING
1964	Russian River	SH	6,496	FING

Warm Springs = Warm Springs Hatchery (Geyserville)
SH = Steelhead
FING = fingerling

ADULT SURVEYS:

The 1957 survey visually described spawning habitat as "excellent on the entire length of the stream", except that logging near the headwaters had blocked the stream with "logs, dirt and slash". No other barriers were observed.

The 1973 survey description was more specific. From the mouth to the Westside Road Bridge spawning habitat was noted as "poor". From the Westside road bridge upstream to the confluence with Wallace Creek spawning habitat was stated as "fair to good". From Wallace Creek upstream 2.5 miles, spawning habitat was described as "excellent". Three man-made obstructions two to three miles upstream of the Westside Road Bridge; a boulder-concrete dam 4-5' high, the foundation of a summer dam, and a bridge under construction were observed.

The 1982 survey described spawning habitat as "good in the middle section with large amounts of gravel", but indicated four log jams with two being complete barriers to fish passage. It was recommended that the four log jams be removed although it is not known if work was initiated. An 8 foot drop-off from the culvert at the Boyd Creek confluence and a 1.5 foot drop-off at the Angel Creek confluence were also noted.

Recent spawning surveys were conducted on Mill Creek. On December 27, 1995, beginning at the mouth and extending just upstream of Felta Creek, a female Chinook was observed and a possible redd downstream from the Westside Road bridge, in good gravel quality .

Another survey was conducted on January 11, 1996 beginning at Felta Creek and extending to the falls. A large school of yearling salmonids, possibly hatchery smolt, were observed in a pool below the falls. A possible redd was observed in good gravel quality. A female Chinook salmon, two possible redds, and a male Chinook salmon carcass were found upstream.

Another survey was conducted on March 20, 1996, beginning at the Mill Creek Lane bridge and extended upstream to Wallace Creek. A jack salmonid of unknown species and a possible redd in fair gravel quality were observed. The survey was continued on March 25, beginning at Wallace Creek and extending upstream to the bridge at Puccioni Road. A 16" steelhead of unknown sex, and a possible redd were observed upstream of the flashboard dam.

DISCUSSION

Mill Creek has five channel types in eight reaches: F4, B2, F2, F3, and G4. Reaches one, three and five have a total of 66,249 feet of F4 channel type. F4 types are good for bank-placed boulders. They are fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover. Reach 2 has 3,220 feet of B2 channel type along with available LOD either in or nearby the stream. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and pool cover. Specifically, B2 channels are excellent for low and medium-stage plunge weirs, single and opposing wing deflectors and bank cover.

Reaches 4 and 7 have a total of 3,009 feet of F2 channel type. F2 types are fair for low-stage weirs, single and opposing wing-deflectors and log cover.

Reach 6 has 4,255 feet of F3 channel type. F3 types are good for bank-placed boulders and single and opposing wing-deflectors. They are fair for low-stage weirs, boulder clusters, channel constrictors and log cover.

The upper 3,916 feet of Mill Creek is a G4 channel type. This type is good for bank-placed boulders and fair for low-stage weirs, opposing wing-deflectors and log cover.

The water temperatures recorded on the survey days July 24 to August 22 1995 ranged from 53-74°F. Air temperatures ranged from 57-95°F. The warmer water and air temperatures were recorded in Reach 3. These warmer temperatures, if sustained, are above the threshold stress level for salmonids. Information from landowners also indicate temperatures are commonly high. Summer temperatures were measured using Ryan Tempmentors which record temperatures every two hours 24 hrs/day. A Tempmentor was placed in Reach one and the mean of the daily highs was 67.7° F for the month of July and 65.2°F for August. The high temperatures for this pool were slightly above the threshold stress level of 65°F for salmonids. This reach had a low canopy density of 52%, which is most likely contributing to the higher water temperatures. A second Tempmentor was placed in reach six and the mean of the daily highs was 62.7°F for July, 62.4°F for August, 59.6°F for September and 55.3°F for October. The high temperatures for this pool were slightly below the threshold stress level for salmonids. The mean canopy density for this reach was 91%.

From historical information it is clear that pool development decreased as "log jams" and other LOD were cleared from the stream for flood protection and firewood. More recently, flatwater habitat types comprised 57% of the total **length** of this survey, riffles 23%, and pools 20%. The pools are relatively shallow with only 110 of the 351 pools having a maximum depth greater than 3 feet (31%). However, in coastal coho and steelhead streams, DFG considers it desirable to have primary pools comprise approximately 50% of total habitat. In third and fourth order streams a primary pool is defined to have a maximum depth of at least three feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. Therefore, installing structures that will increase pool habitat is recommended for locations where their installation will not jeopardize the unstable stream banks, or subject the structures to high stream energy.

The mean shelter rating for flatwater was low with a rating of 34.

The shelter rating of pool and riffle habitats were both at 53. However, a pool shelter rating of approximately 100 is desirable. The relatively small amount of cover that now exists is being provided primarily by boulders, with root mass, large woody debris and undercut banks contributing a smaller amount. Log and rootwad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat. Log cover structure provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

Seventy percent of low gradient riffles had gravel and 21% had small cobble as the dominant substrate. This is generally considered good for spawning salmonids. However, fifty-one percent of the pool tail-outs measured had embeddedness ratings of either 3 or 4. Thirty percent had a rating of 1 and 19% had a rating of 2. Cobble embeddedness measured to be 25% or less, a rating of 1, is considered best for the needs of salmon and steelhead.

Gravel sampling is conducted to determine the percentage of fine sediment present in probable fish spawning areas. These areas are generally found in low gradient riffles at the tail-outs of pools. The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence.

The gravel program analyzed the substrate sample data for egg to emergence survival rates for steelhead and coho. The survival rates are based on a 95% confidence interval and used the FredleIndex. Based on this index and the data on Mill Creek, the mean egg to emergence survival rate would be 66% for steelhead and 48% for coho.

In Mill Creek, particularly in Reach 8 and in the headwaters, sediment sources related to the road system and upslope problems should be mapped and rated according to their potential sediment yields, and control measures taken. Reaches 1, 3 and 5 appear to hold the best spawning habitat.

The mean percent canopy for the survey reach was 73%. This is a fair percentage of canopy, since 80 percent is generally considered desirable. Elevated water temperatures could be reduced in localized areas (Reach 3 and below Westside Road bridge) by increasing stream canopy. The large trees required to contribute shade to the channel would also eventually provide a long term source of large woody debris needed for instream structures.

Channel incision in the Russian River has headcut upstream throughout Dry Creek to Lower Mill Creek. Many culverts and road development has hardened the watershed, which has increased the rate of storm run-off. The dams in the headwaters have cut off gravel supplies to Reaches 7 and 8 and below to a lesser extent, since many of the tributaries supply gravel to Mill Creek. Channel narrowing, channelization associated with Mill Creek Road, and seasonal dams have caused an increase in stream velocity, excessive debris transport, and an overall channel incision in the upper portion of the stream. This has led to many habitat problems in the stream including: loss of gravel used for spawning, bank erosion and loss of riparian habitat, loss of instream structure (ie. woody debris) and thus pool habitat. Recent information from many landowners indicates increased urbanization and summer dams has decreased summertime flow for domestic use since the 1970's, particularly in Reach 3. In general this has also resulted in an overall loss of pools, and loss of instream shelter for juvenile salmonids. Downcutting in Reach 8 has caused a migration barrier in Boyd Creek at the confluence with Mill Creek.

DISCUSSION FOR BOYD CREEK

Boyd Creek has a G4 channel type. This type is good for bank-placed boulders and fair for low-stage weirs, opposing wing deflectors and log cover.

The water temperatures recorded during the survey are close to the threshold stress level for salmonids. To make any further conclusions, temperatures need to be monitored for a longer period of time through the critical summer months, and more extensive biological sampling conducted.

The shelter rating in the pool habitats was 29. The relatively small amount of pool cover that now exists is being provided primarily by boulders, undercut banks and root masses. Log and root wad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat.

All of the low gradient riffles measured had gravel as a dominant substrate. This is generally considered good for spawning salmonids. However, eleven of the 16 pool tail-outs measured had embeddedness ratings of either 3 or 4. Cobble embeddedness measured to be 25% or less, a rating of 1, is considered best for the needs of salmon and steelhead.

The mean percent canopy for the survey reach was 95%. This is an excellent percentage, since 80 percent is generally considered desirable.

SUMMARY

Biological surveys were conducted to document fish distribution and are not necessarily representative of population information.

Steelhead were documented consistently during each past survey year and coho juveniles (Reaches 3 and 5-8) and Chinook spawners (Reach 1) only recently. Coho juveniles may have been present in previous years and not noticed in the visual surveys done. The 1995 spring surveys documented many 0+ steelhead indicating very successful spawning. However, fewer yearling fish were found indicating poor holding over conditions the year before, or poor holding over conditions in general.

In general, Reach 1 has good spawning habitat however, rearing habitat is limited and much of the reach dries up in most years. More deep pools with adequate shelter and cooler summer temperatures are needed. The unstable banks and effects of channelization downstream of Westside Rd bridge limits instream habitat improvement alternatives, although some opportunity exists upstream. In reach 2, rearing habitat is much better, although few riffle habitat exists for spawning due to the boulder section, and what does exist is unsuitable for spawning due to high gravel embeddedness. Reach 3 has only fair rearing and spawning habitat.

Upstream of the Wallace Creek confluence, conditions are better. In reaches 4 and 5, spawning and rearing habitat exists, canopy shading is higher, although instream shelter is still lacking and stream bank erosion is prevalent due to poor road maintenance, the lack of large woody debris, and high stream velocities. However, many opportunities and alternatives exist for habitat improvement due to the stable channel types.

Uplope land use practices such as logging and vineyards on steep slopes have impacted spawning gravels and decreased pool volume in the upper reaches. Additionally, these upstream effects seriously impact spawning resources downstream in lower gradient reaches (4 and 5). Channel incision in Reach 8 has occurred due to the dams cutting off gravel supply. Structures to offset channel downcutting and recruit gravel for spawning, are recommended.

GENERAL RECOMMENDATIONS

Mill Creek should be managed as an anadromous, natural production stream.

Recent winter storms brought down many large trees and other woody debris into the stream, which increased the number and quality of pools since the drought years. This woody debris, if left undisturbed, will provide fish shelter and rearing habitat, and offset channel incision. Efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be sensitive about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

SPECIFIC FISHERY ENHANCEMENT RECOMMENDATIONS

1) On Mill Creek, active and potential sediment sources related to the county road system need to be mapped, and treated according to their potential for sediment yield to the stream and its tributaries. Many plugged, undersized, and misaligned culverts exist along with overgrown in-board ditches which have along with heavy rains, contributed to severe erosion along the road face for much of the stream.(pending county action)

2) For sources of upslope and in-channel erosion, utilize biotechnical approaches. Near-stream riparian planting along reach 1 of the stream should be encouraged to provide bank stability and a buffering against agricultural and urban runoff.

3) Increase the canopy on Mill Creek by planting willow, alder, redwood, and Douglas fir along the stream where shade canopy is not at acceptable levels (portions of reaches 1 and 3). The reach above the survey section should be assessed for planting and treated as well, since water temperatures throughout are effected from upstream. In many cases, planting will need to be coordinated to follow bank stabilization or upslope erosion control projects.

4) Monitor fish passage at the lower falls.

5) Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream. Most of the existing cover is from boulders and undercut banks. Adding high quality complexity with larger woody cover is desirable. Combination cover/scour structures constructed with boulders and woody debris would be effective in many flatwater and pool locations in the upper reaches. This must be done where the banks are stable (reaches 2-7) or in conjunction with stream bank armor to prevent erosion (reaches 1 and 8 3). In many areas the material is at hand. Reach 7 would benefit from bank-placed boulders and single and opposing wing-deflectors. They are fair for low-stage (low profile) weirs, boulder clusters and channel constrictors. Log cover structures can be used to increase instream shelter. Reaches 3 and 7 are excellent for many types of low and medium stage instream enhancement structures. Many site specific projects can be designed within these channel types, especially to increase pool frequency, volume and shelter.

6) Near-stream riparian planting along reach 3 of the stream should be encouraged to provide bank stability and a buffering against agricultural and urban runoff.

PROBLEM SITES AND LANDMARKS - MILL CREEK SURVEY COMMENTS

STREAM LENGTH (FT)	COMMENTS	(**** HABITAT UNIT #)
712	LARGE FENCE 18' X 120' USED FOR BANK STABILIZATION. MID CHANNEL	
2652	GOOD ELECTROFISHING SITE	
2721	BEDROCK BANK, LEFT BANK	
3357	GOOD ELECTROFISHING SITE; LEFT BANK RIP RAP 100'	
3574	2+ FISH SPOTTED	
9606	BANK STABILIZATION WITH 5 OR MORE OLD VEHICLES, RIGHT BANK	
11805	90'L X 12'H STABILIZATION FENCE	
12006	BRIDGE #1 WESTSIDE ROAD 55'L X 55'W X 30'H	**** UNIT 98
14525	GOOD ELECTROFISHING SITE	
15628	4" CRAYFISH	
15750	MANY FISH	
15854	WITH FELTA CREEK, 67°F. AT FELTA CREEK	**** UNIT 114
16213	BLOWOUT LEFT BANK 40'L X 40'W X 6'	
16363	DAM POOLS CREATED BY BOULDERS/ROCKS STACKED UP	
16432	SUNFISH; 600' OF MANMADE ROCK BANK STABILIZATION, RIGHT & LEFT BANKS	
16973	BRIDGE #2 12'L X 25'H X 100'W	**** UNIT 129
18144	5' 5" WATERFALL	
18701	NICE POOL, NEEDS COVER	
19055	2+ SALMONIDS	
19624	BLOWOUT RIGHT BANK	
19889	2+ FISH	
19971	2+ FISH; OLD BROKEN CONCRETE DAM NOT INTACT/USEABLE 18"W X 35'L	
20142	BRIDGE #3	**** UNIT 165.1
20765	OLD BROKEN ROCK WALL & DAM	
20793	4" CRAYFISH	
21331	OLD CONCRETE DAM SLAB 7'L X 30'W X 2'H HOLDING GRAVEL	
21593	SEVERAL 1+,2+ FISH	
21645	TRIB. RIGHT BANK 62°F.	
21905	MANY 1+ & 2+ FISH; LARGE MOUTH BASS 2-4"; SUNFISH; 8 CRAYFISH	
23367	DRY TRIB. WITH CULVERT 25" DIAM.	
24453	SUNFISH;	

24558 TRIB. RIGHT BANK 63°F.
24820 RIP RAP RIGHT BANK
25301 TURTLE WITH 6 SEGMENTS UNDER BODY SHELL
25457 BRIDGE #4 **** UNIT 226
25569 BLOWOUT RIGHT BANK 172'L X 161'H
28874 2+ FISH SPOTTED
29460 BRIDGE #5 17'H X 9'W X 45' **** UNIT 257
29840 2+ FISH
30141 SUMMER (FLASH DAM) 58'W X 17'L X 6'H HOLDING GRAVEL
32198 2+ FISH
32323 TRIB LEFT BANK DRY
32429 W/ WALLACE CREEK 62°F.
33751 CRAYFISH; ROCK & CONCRETE RETAINING WALL LEFT BANK 10'H X 140'L
34388 CULVERT 24" DIAM. 110' LONG; RIGHT BANK SPRING 60°F.
34969 BRIDGE #6 (MILL CREEK ROAD.) 35'L X 55'W X 12'H NOT HOLDING GRAVEL, NO SILL **** UNIT 322
35407 BRIDGE #7 15'L X 14'H X 35'W; DRY TRIB. LEFT BANK
35785 RIP RAP STABILIZATION RIGHT BANK 105'L X 10'H
35931 57°F. TRIB. RIGHT BANK
36352 DAM 7'H X 7.5'L X 47'W RETAINING GRAVEL
36978 BLOWOUT LEFT BANK
37902 SPRING RIGHT BANK 61°F.
38669 BRIDGE #7 (3" SUMP) COVERED BRIDGE **** UNIT 376
39300 BRIDGE #8
40498 RIGHT BANK LARGE CONCRETE SLABS; LARGE WING DEFLECTOR 3 REDWOOD LOGS
41985 BRIDGE #9 **** UNIT 402
42721 DRY TRIB LEFT BANK
43134 2+ FISH
43224 BRIDGE #10 MILL CREEK ROAD **** UNIT 421
43811 CRAYFISH
43866 SPRING RIGHT BANK
44064 LARGE BLOWOUT; POTENTIAL JAM
44121 LOG JAM
44221 2+ FISH
45951 SPRING RIGHT BANK 59°F.
46536 BRIDGE #11 8'H X 14'L X 40'L **** UNIT 469
46637 BANK STABILIZATION EFFORT USING LARGE BOULDERS
46947 2+ FISH
47716 TRIB LEFT BANK WITH CULVERT 61°F.
47874 2+ FISH
51031 1+ FISH
52048 WITH PALMER CREEK 66°F.
52566 BRIDGE #12 PALMER CREEK ROAD **** UNIT 517
52706 CULVERT RIGHT BANK
53129 BLOWOUT LEFT BANK
53663 2+ FISH SPOTTED

53766 SPRING 59°F. RIGHT BANK
54017 ROAD CULVERT ON LEFT BANK
54115 LEFT BANK CULVERT; TRIB. ON RIGHT BANK 58°F.
54214 GOOD ELECTROFISHING SITE; BLOWOUT RIGHT BANK
55464 CULVERT RIGHT BANK; 24" DOWNCUT MILL CREEK ROAD
55882 SPRING RIGHT BANK
56115 SPRING LEFT BANK
56380 POTENTIAL RESTORATION LOGS; BLOWOUT
56730 SPRING LEFT BANK 58°F.
57649 MASSIVE GULLY WASHOUT LEFT BANK 45W X 50L X 20D
58485 BLOWOUT/LANDSLIDE LEFT BANK 35'W X 25'L X 3'D; 2+ FISH
58551 DRY TRIB LEFT BANK
59389 LOG JAM SOURCE FOR RESTORATION
59966 2+ FISH; GOOD ELECTROFISHING SITE
60126 TRIB RIGHT BANK 57°F.
60810 BRIDGE #14 **** UNIT 633
60838 DRY TRIB LEFT BANK
61035 GOOD ELECTROFISHING SITE
61563 SPRING RIGHT BANK 60°F.
61631 BRIDGE #15 **** UNIT 651
62738 GOOD ELECTROFISHING SITE
62842 DRY TRIB LEFT BANK
62956 BRIDGE #16 **** UNIT 683
63087 1+ FISH
63456 BRIDGE #17 **** UNIT 683
63613 GOOD ELECTROFISHING SITE
63716 SPRING RIGHT BANK; BLOWOUT RIGHT BANK
63847 SPRING RIGHT BANK 57°F.
64233 BLOWOUT LEFT BANK 30'L X 10'H X 3'D; LOG JAM
64342 SPRING RIGHT BANK 59°F.
64435 BLOWOUT LEFT BANK INTO MILL CREEK ROAD 60'L X 11'H X 3'D
64495 2+ AND 1+ FISH
64632 BRIDGE #18 **** UNIT 706
64680 BOX CULVERT LEFT BANK WITH TRIB 59°F.
65154 SPRING RIGHT BANK 59°F.
65216 BLOWOUT RIGHT BANK 55'L X 45'W X 12'D DEBRIS INFLUENCE (HIGH FLOWS); SPRING RIGHT BANK
65330 BRIDGE #19 **** UNIT 718
66381 BLOWOUT RIGHT BANK 20' X 20' X 4'D
66504 FOOT BRIDGE 9'H X 6'L X 25'W
66618 BRIDGE #20 8'H X 10'L X 18'W **** UNIT 726
66953 FLASH DAM 24'W X 6'L X 2'H NOT HOLDING GRAVEL
67000 SPRING RIGHT BANK 57°F; FOOT BRIDGE
67174 BRIDGE #21 14'L X 40'W X 16'H **** UNIT 736
67224 CULVERT LEFT BANK 12" DIAM. X 48'L
67506 BLOWOUT RIGHT BANK 60'L X 45'W X 9D

67663 200 FT OF DEAD FALL TREES AND SMALL SLIDES
HOLDING BACK SOME GRAVEL.
GOOD ELECTROFISHING SITE!
67933 BRIDGE #22 20'L X 80'W X 50'H **** UNIT 752
68121 BLOWOUT LEFT BANK 18'L X 20'W X 4'D
68151 LOG JAM 11'H X 26'W X 15'L HOLDING GRAVEL.

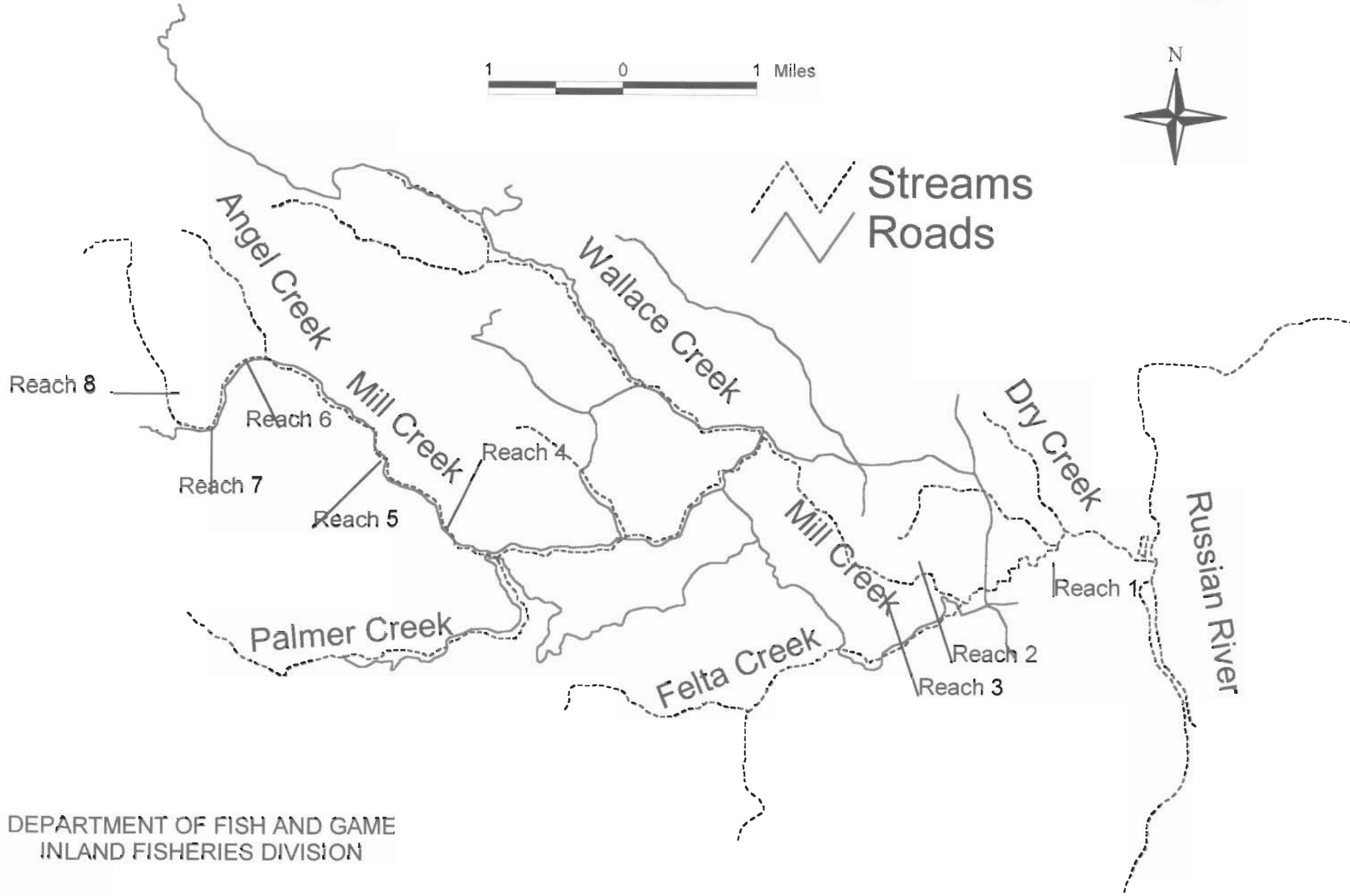
68174 BLOWOUT RIGHT BANK 70'L X 50'W X 3'D
69671 SPRING RIGHT BANK 58°F.
70086 LOGS AND BOULDERS HOLDING BACK GRAVEL
70261 SPRING RIGHT BANK 57°F.
71185 BRIDGE #23 **** UNIT 792
71209 WITH ANGEL; ANGEL CREEK 59°F.
71419 OLD SKID ROAD RIGHT BANK; 2+ FISH
72825 SPRING RIGHT BANK 57°F.
72972 SPRING RIGHT BANK 60°F.
73111 CHANNEL TYPING DONE
73370 DRY TRIB LEFT BANK
73445 SPRING RIGHT BANK
73584 DRY TRIB LEFT BANK
73681 LOG JAM
74016 SPRING LEFT BANK 57°F.
74173 CRAY FISH
74240 GOOD ELECTROFISHING SITE
74394 CULVERT RIGHT BANK; DRY TRIB
74641 DRY TRIB RIGHT BANK; CULVERT RIGHT BANK
75639 CHANNEL TYPE DONE
75815 BOYD CREEK RIGHT BANK 59°F.
76310 BRIDGE #24 **** UNIT 917
76408 CHANNEL TYPE DONE HERE
76427 DRY TRIB RIGHT BANK
76927 SPRING LEFT BANK
77427 FLASH DAM 11'H X 16'W X 1.5'L; 4 FT. FROM CREEK TO
SILL; 2-4"
77463 DRY TRIB RIGHT BANK
77595 SPRING LEFT BANK 60°F.
77643 LEFT BANK SMALL BLOWOUT
78418 SPRING LEFT BANK 59°F.
78509 SPRING RIGHT BANK 57°F.
78548 SPRING RIGHT BANK 61°F.
78596 OLD FLASH DAM 18" CONCRETE SILL
78652 BRIDGE #25 **** UNIT 964
78712 SPRING LEFT BANK 62°F.
79041 GOOD ELECTROFISHING SITE
79102 2+ FISH
79258 CHANNEL TYPING DONE
79646 DAM 9'H X 14'W X 8'L DOWNCUTTING 3' TO DAM SILL
79722 1+ AND 2+ FISH IN DAM POOL
CASING

80074 ROCK GABION LEFT BANK
80423 DIRT ROAD BUILT THROUGH CREEK; NO CULVERT; 49'L X 8'H DIRT AND ROCK
80511 GULLY LEFT BANK; DRY TRIB LEFT BANK
80788 END OF SURVEY
80929 SPILLWAY (CONCRETE); EARTHEN DAM.

PROBLEM SITES AND LANDMARKS - BOYD CREEK SURVEY COMMENTS

STREAM LENGTH (FT)	*COMMENTS*
124	*6' JUMP INTO CULVERT CAUSED BY DOWNCUTTING*
154	*SALAMANDER (PACIFIC)*
316	*2' JUMP TO SILL CAUSED BY DOWNCUT*
373	*INSTREAM CULVERT DOWNCUTTING*
433	*CRAYFISH*
577	*LOG ACCUMULATIOn*
733	*INSTREAM CULVERT 5.5W NO DOWNCUTTING*
987	*LOG JAM*
1001	*DRY TRIB LF BK*
1105	
1197	*TRIB LF BK END OF SURVEY*

MILL CREEK WATERSHED



DEPARTMENT OF FISH AND GAME
INLAND FISHERIES DIVISION

Mill Creek

Drainage: Dry Creek

Table 1 - SUMMARY OF RIFFLE, FLATWATER, AND POOL HABITAT TYPES

Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	ESTIMATED TOTAL AREA (sq.ft.)	MEAN VOLUME (cu.ft.)	ESTIMATED TOTAL VOLUME (cu.ft.)	MEAN RESIDUAL POOL VOL (cu.ft.)	MEAN SHELTER RATING
249	36	RIFFLE	24	74	18378	22	11.6	0.5	500	124408	327	81440	480	53
413	61	FLATWATER	40	112	46389	57	13.4	0.7	842	347759	579	239286	702	34
362	110	POOL	35	45	16182	20	15.5	1.4	800	289424	1433	518655	1194	53
11	0	DRY	1	75	825	1	11.0	0.0	1045	11495	0	0	0	0

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq. ft.)	TOTAL VOL. (cu. ft.)
1035	207	81774	773086	839381

Mill Creek — Drainage: Dry Creek

Table 2 - SUMMARY OF HABITAT TYPES AND MEASURED PARAMETERS — Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

HABITAT UNITS #	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT OCCURRENCE %	MEAN LENGTH ft.	TOTAL LENGTH ft.	TOTAL LENGTH %	MEAN WIDTH ft.	MEAN DEPTH ft.	MAXIMUM DEPTH ft.	MEAN AREA sq.ft.	TOTAL AREA EST. sq.ft.	MEAN VOLUME cu.ft.	TOTAL VOLUME EST. cu.ft.	MEAN RESIDUAL POOL VOL cu.ft.	MEAN SHELTER RATING	MEAN CANOPY %
230	27	LGR	22	76	17404	21	10	0.4	7.0	503	115773	245	56253	392	29	76
16	6	HGR	2	54	857	1	17	0.8	3.6	562	8994	725	11603	634	108	68
1	1	CAS	0	49	49	0	22	1.1	2.7	431	431	474	474	1186	100	75
2	2	BRS	0	34	67	0	6	0.4	0.8	296	592	173	345	0	0	78
172	25	GLD	17	101	17439	21	17	0.6	2.6	1020	175406	686	117978	735	17	70
230	31	RUN	22	119	27440	34	11	0.7	2.4	688	158313	471	108442	545	42	73
11	5	SRN	1	137	1510	2	12	0.7	1.6	984	10824	760	8356	1453	57	82
64	18	MCP	6	36	2279	3	19	1.3	5.0	994	63644	1920	122853	1550	45	76
5	4	CCP	0	41	204	0	16	1.2	4.3	710	3548	1014	5071	890	38	68
5	4	STP	0	59	293	0	21	1.2	5.1	888	4438	1401	7004	943	117	75
3	3	CRP	0	40	121	0	13	1.3	4.8	632	1896	974	2923	800	73	83
26	11	LSL	3	45	1158	1	17	1.5	5.0	736	19146	1207	31376	1019	92	69
127	25	LSR	12	42	5328	7	14	1.4	5.3	655	83223	1040	132087	840	56	77
51	12	LSBk	5	50	2564	3	14	1.5	7.5	802	40898	1601	81654	1373	30	80
28	4	LSBo	3	43	1210	1	14	1.3	4.4	651	18235	1027	28757	820	39	63
18	10	PLP	2	30	541	1	16	1.4	4.3	452	8129	715	12866	584	57	80
10	4	SCP	1	39	389	0	7	0.9	3.1	293	2927	310	3102	197	63	47
3	3	BPB	0	37	110	0	15	1.5	4.0	547	1640	884	2653	492	40	77
3	1	BPR	0	8	25	0	6	0.5	1.1	45	136	23	68	16	85	73
5	4	BPL	0	20	102	0	9	1.1	3.6	212	1061	303	1514	227	55	63
14	7	DPL	1	133	1858	2	21	1.7	7.0	2856	39978	6149	86086	5690	28	69
11	0	DRY	1	75	825	1	11	0.0	0.0	1045	11495	0	0	0	0	38

TOTAL UNITS	TOTAL UNITS	LENGTH (ft.)	AREA (sq.ft)	TOTAL VOL. (cu.ft)
1035	207	81774	770727	821465

Mill Creek

Drainage: Dry Creek

Table 3 - SUMMARY OF POOL TYPES

Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	TOTAL AREA EST. (sq.ft.)	MEAN VOLUME (cu.ft.)	TOTAL VOLUME EST. (cu.ft.)	MEAN RESIDUAL POOL VOL. (cu.ft.)	MEAN SHELTER RATING
74	26	MAIN	20	38	2777	17	19.1	1.3	967	71575	1821	134730	1462	51
253	65	SCOUR	70	43	10922	67	14.7	1.4	677	171342	1141	288650	940	54
35	19	BACKWATER	10	71	2484	15	13.5	1.2	1307	45742	2669	93423	2408	49

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq.ft.)	TOTAL VOL. (cu.ft.)
362	110	16182	288659	516804

Mill Creek Drainage: Dry Creek

Table 4 - SUMMARY OF MAXIMUM POOL DEPTHS BY POOL HABITAT TYPES Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

UNITS MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	<1 FOOT MAXIMUM DEPTH	<1 FOOT PERCENT OCCURRENCE	1-<2 FT. MAXIMUM DEPTH	1-<2 FOOT PERCENT OCCURRENCE	2-<3 FT. MAXIMUM DEPTH	2-<3 FOOT PERCENT OCCURRENCE	3-<4 FT. MAXIMUM DEPTH	3-<4 FOOT PERCENT OCCURRENCE	>=4 FEET MAXIMUM DEPTH	>=4 FEET PERCENT OCCURRENCE
64	MCP	18	2	3	26	41	23	36	8	13	5	8
5	CCP	1	0	0	1	20	3	60	0	0	1	20
5	STP	1	0	0	1	20	3	60	0	0	1	20
3	CRP	1	0	0	1	33	1	33	0	0	1	33
26	LSL	7	0	0	4	15	10	38	10	38	2	8
127	LSR	35	4	3	28	22	61	48	22	17	12	9
51	LSBk	14	1	2	11	22	16	31	19	37	4	8
28	LSBo	8	0	0	7	25	14	50	5	18	2	7
18	PLP	5	0	0	6	33	4	22	7	39	1	6
10	SCP	3	4	40	2	20	2	20	2	20	0	0
3	BPB	1	0	0	1	33	0	0	1	33	1	33
3	BPR	1	2	67	1	33	0	0	0	0	0	0
5	BPL	1	0	0	3	60	1	20	1	20	0	0
14	DPL	4	0	0	4	29	4	29	2	14	4	29

TOTAL
UNITS
362

Mill Creek

Drainage: Dry Creek

Table 5 - SUMMARY OF MEAN PERCENT COVER BY HABITAT TYPE

Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	MEAN % UNDERCUT BANKS	MEAN % SWD	MEAN % LWD	MEAN % ROOT MASS	MEAN % TERR. VEGETATION	MEAN % AQUATIC VEGETATION	MEAN % WHITE WATER	MEAN % BOULDERS	MEAN % BEDROCK LEDGES
230	27	LGR	2	4	25	8	8	4	1	48	0
16	6	HGR	0	0	0	0	0	0	30	70	0
1	1	CAS	0	0	0	0	0	0	40	30	30
2	2	BRS	0	0	0	0	0	0	0	0	0
172	25	GLD	26	0	5	2	19	2	0	41	0
230	31	RUN	8	5	8	10	18	0	3	43	4
11	5	SRN	15	0	0	25	0	0	3	57	0
64	18	MCP	15	5	11	12	5	5	4	36	7
5	4	CCP	43	3	3	17	0	0	0	33	0
5	4	STP	0	4	3	0	0	0	21	40	32
3	3	CRP	33	15	0	5	7	0	0	17	0
26	11	LSL	13	18	41	14	6	0	2	5	1
127	25	LSR	25	9	17	29	11	2	0	6	1
51	12	LSBk	28	5	2	11	5	1	2	17	30
28	4	LSBo	5	3	9	7	4	2	1	68	1
18	10	PLP	6	3	29	9	1	0	24	19	9
10	4	SCP	6	7	11	19	46	3	0	9	0
3	3	BPB	0	3	0	7	0	0	0	33	57
3	1	BPR	0	0	0	100	0	0	0	0	0
5	4	BPL	30	7	36	13	14	0	0	0	0
14	7	DPL	26	1	14	14	4	7	0	31	4
11	0	DRY	0	0	0	0	0	0	0	0	0

Table 6 - SUMMARY OF DOMINANT SUBSTRATES BY HABITAT TYPE Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

TOTAL HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	% TOTAL SILT/CLAY DOMINANT	% TOTAL SAND DOMINANT	% TOTAL GRAVEL DOMINANT	% TOTAL SM COBBLE DOMINANT	% TOTAL LG COBBLE DOMINANT	% TOTAL BOULDER DOMINANT	% TOTAL BEDROCK DOMINANT
230	27	LGR	0	6	70	21	0	3	0
16	6	HGR	0	0	0	0	33	67	0
1	1	CAS	0	0	0	0	0	0	100
2	2	BRS	0	0	0	0	0	0	100
172	25	GLD	0	8	81	12	0	0	0
230	31	RUN	0	20	63	11	0	0	6
11	5	SRN	0	0	17	50	0	17	17
64	18	MCP	0	50	45	5	0	0	0
5	4	CCP	0	75	25	0	0	0	0
5	4	STP	0	25	50	0	0	0	25
3	3	CRP	0	100	0	0	0	0	0
26	11	LSL	0	82	18	0	0	0	0
127	25	LSR	0	58	30	6	0	0	3
51	12	LSBk	0	36	50	0	0	0	7
28	4	LSBo	0	75	25	0	0	0	0
18	10	PLP	0	55	36	9	0	0	0
10	4	SCP	0	25	50	25	0	0	0
3	3	BPB	0	100	0	0	0	0	0
3	1	BPR	50	50	0	0	0	0	0
5	4	BPL	20	40	40	0	0	0	0
14	7	DPL	0	25	75	0	0	0	0
11	0	DRY	0	0	50	50	0	0	0

Mill Creek

Drainage: Dry Creek

Table 10 - Summary of Shelter Type Areas by Habitat Type

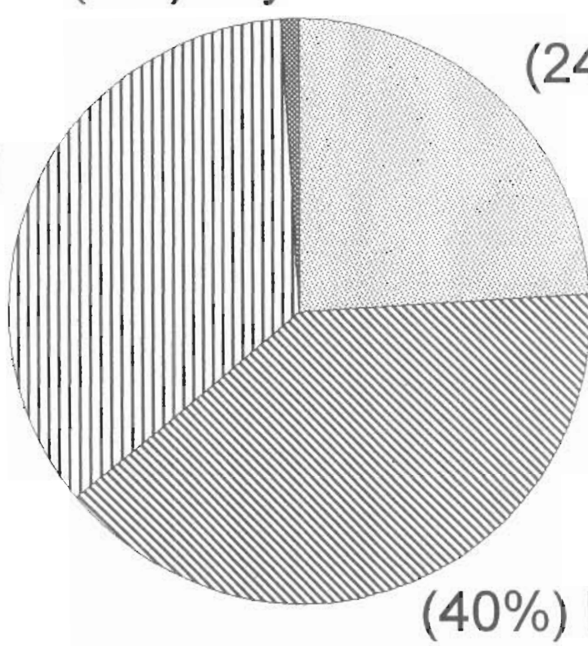
Survey Dates: 07/24/95 to 08/22/95

Confluence Location: QUAD: HEALD/GUER LEGAL DESCRIPTION: T09NR09WS33 LATITUDE: 38°35'20" LONGITUDE: 122°52'8"

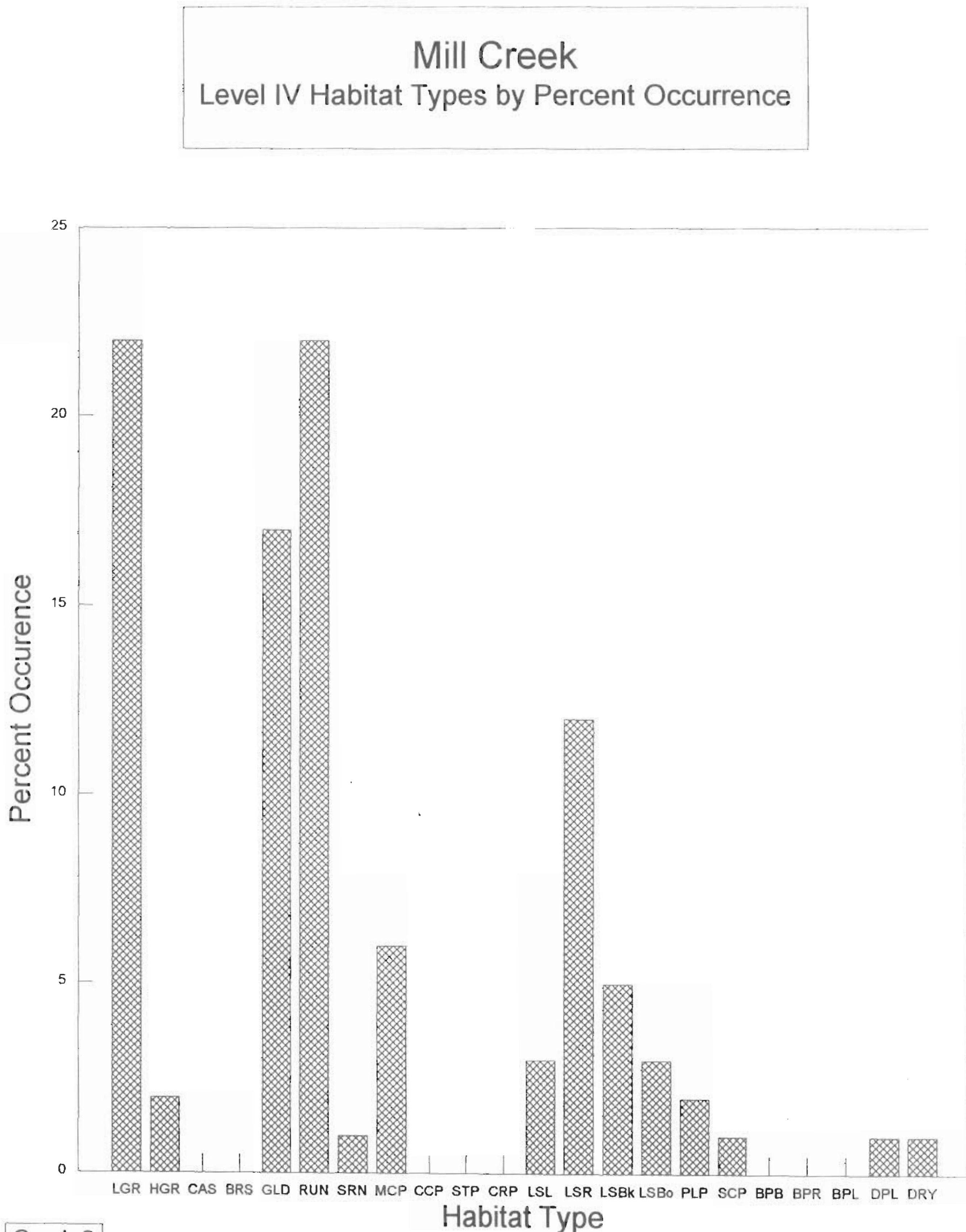
UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	SQ. FT. UNDERCUT BANKS	SQ. FT. SWD	SQ. FT. LWD	SQ. FT. ROOT MASS	SQ. FT. TERR. VEGETATION	SQ. FT. AQUATIC VEGETATION	SQ. FT. WHITE WATER	SQ. FT. BOULDERS	SQ. FT. BEDROCK LEDGES
230	27	LGR	18	31	0	45	461	750	65	1314	0
16	6	HGR	0	0	0	0	0	0	1334	2791	0
1	1	CAS	0	0	0	0	0	0	216	162	162
2	2	BRS	0	0	0	0	0	0	0	0	0
172	25	GLD	249	0	50	70	641	55	0	1173	0
230	31	RUN	125	380	380	393	763	11	175	2037	271
11	5	SRN	16	0	0	372	0	0	216	1653	0
64	18	MCP	343	476	1031	688	705	211	341	1845	749
5	4	CCP	84	14	14	68	0	0	0	304	0
5	4	STP	0	137	75	0	0	0	499	830	835
3	3	CRP	102	80	0	54	72	0	0	179	0
26	11	LSL	407	1347	2330	708	292	0	24	321	46
127	25	LSR	3127	2194	4092	5172	2156	454	23	1640	251
51	12	LSBk	1356	202	164	704	267	16	433	1193	2105
28	4	LSBo	77	94	241	296	239	89	14	2691	15
18	10	PLP	135	59	418	177	174	0	452	622	316
10	4	SCP	33	48	82	113	375	11	0	97	0
3	3	BPB	0	12	0	25	0	0	0	90	239
3	1	BPR	0	0	0	26	0	0	0	0	0
5	4	BPL	17	58	226	58	1	0	0	0	0
14	7	DPL	1526	16	714	309	1077	4224	0	384	813
11	0	DRY	0	0	0	0	0	0	0	0	0
TOTAL 1035	207		7615	5148	9817	9278	7223	5821	3792	19326	5802

Mill Creek

Level II Habitat Types by % Occurrence



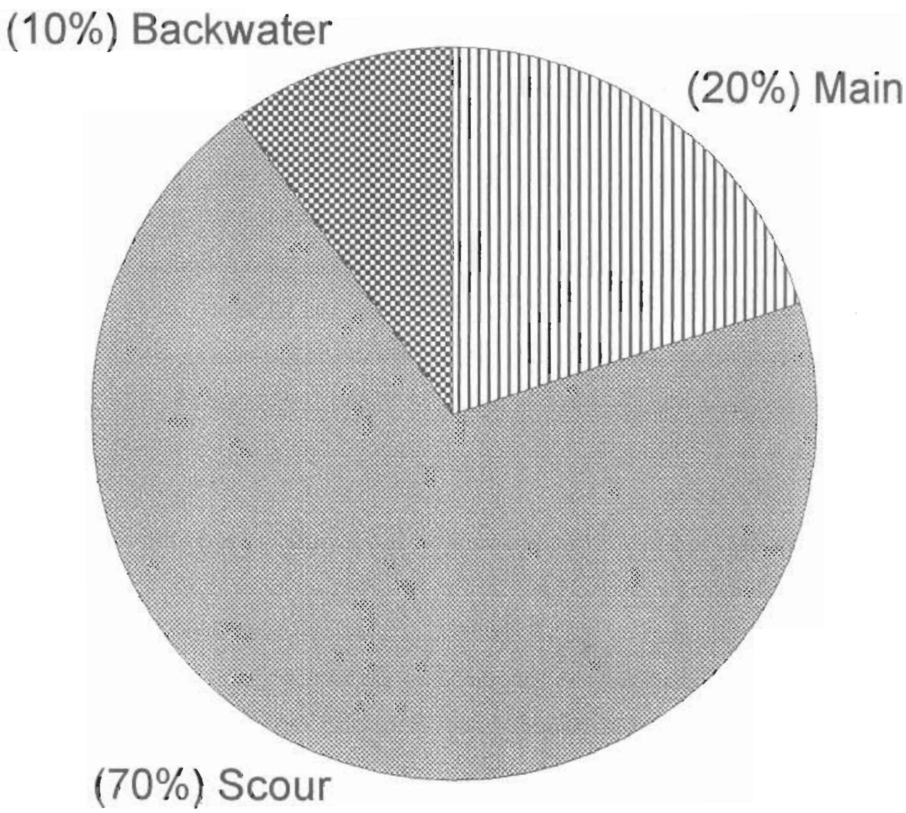
Graph 1


Mill Creek
Level IV Habitat Types by Percent Occurrence
25
20
15
10
5
0
Percent Occurence
LGR HGR CAS BRS GLD RUN SRN MCP CCP STP CRP LSL LSR LSBk LSBo PLP SCP BPB BPR BPL DPL DRY
Habitat Type

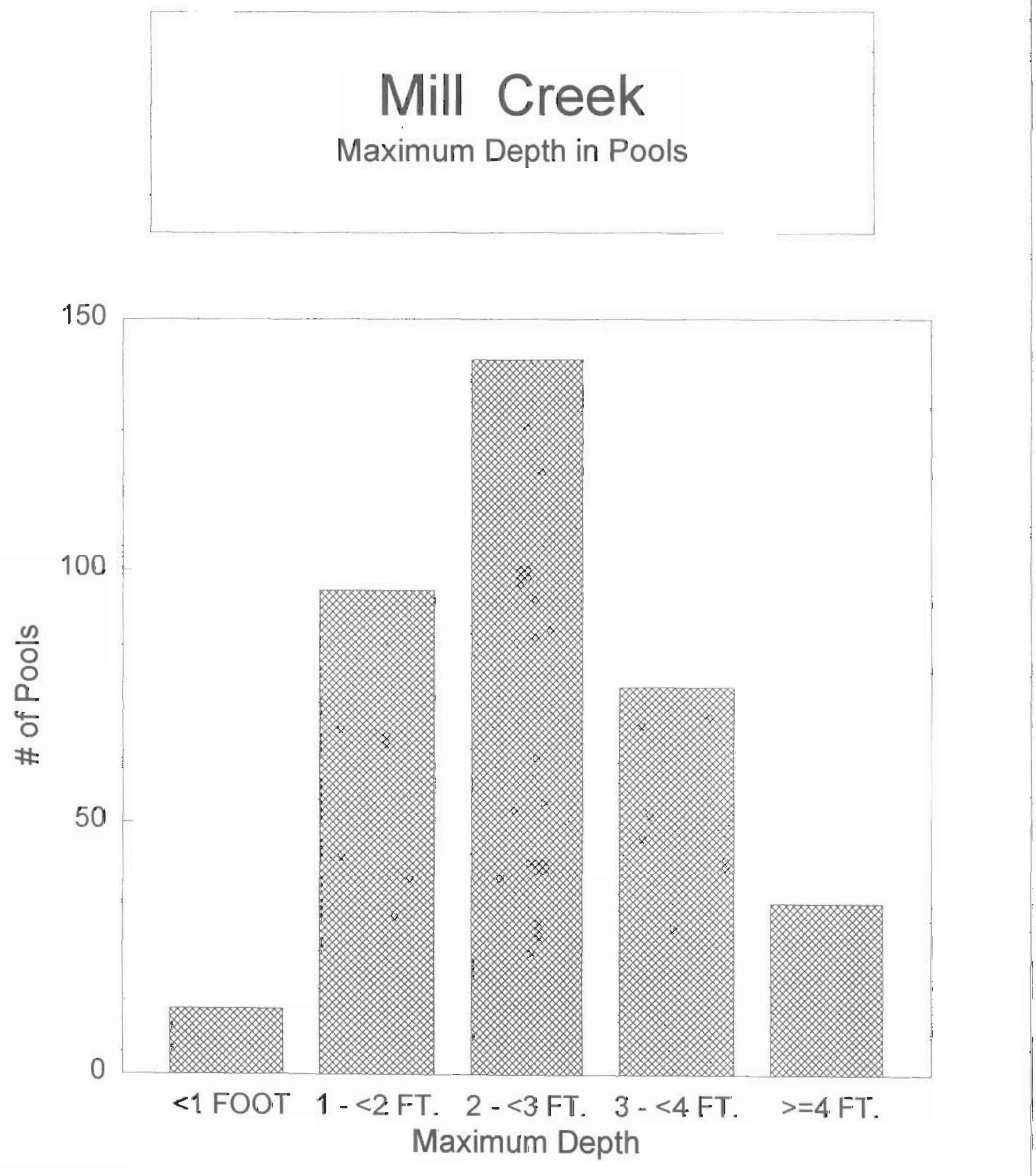
Graph 2

Mill Creek

Pool Habitat Types by % Occurrence



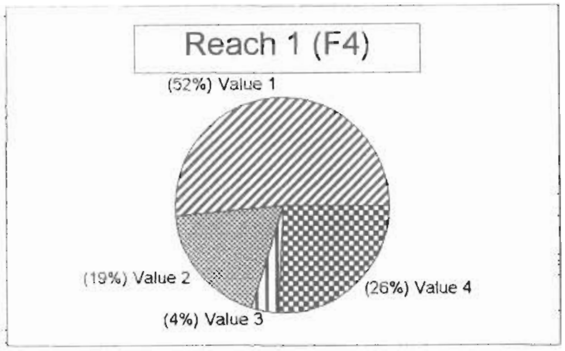
Graph 3

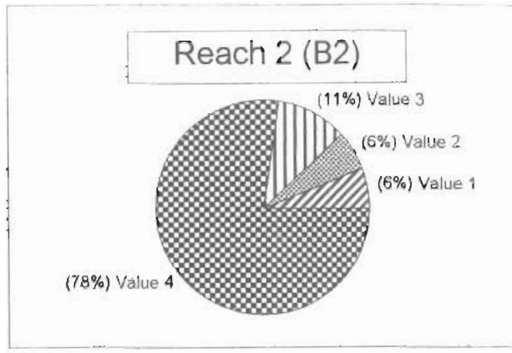

Mill Creek
Maximum Depth in Pools
150
100
50
0
# of Pools
<1 FOOT
1 - <2 FT.
2 - <3 FT.
3 - <4 FT.
>=4 FT.
Maximum Depth

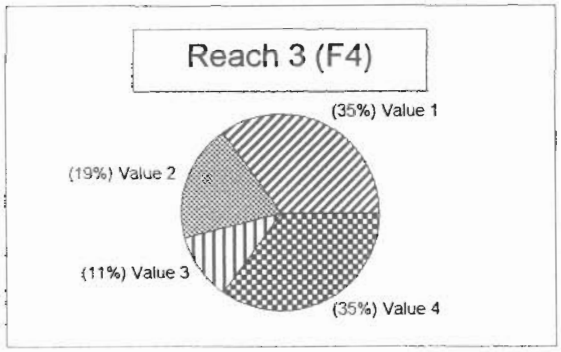
Graph 4

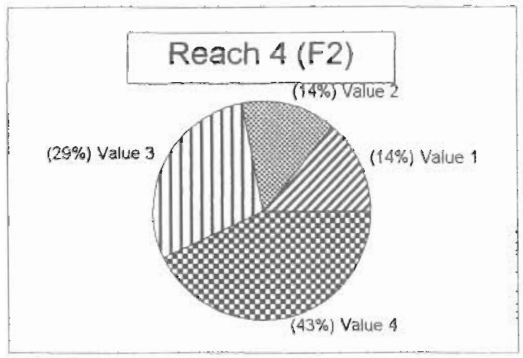
Mill Creek

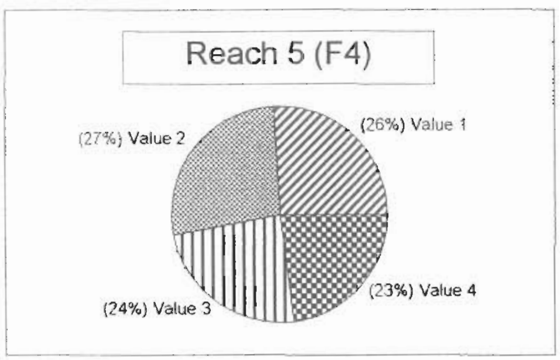
Percent Embeddedness by Reach

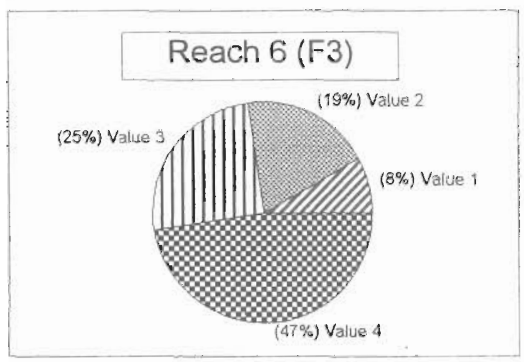


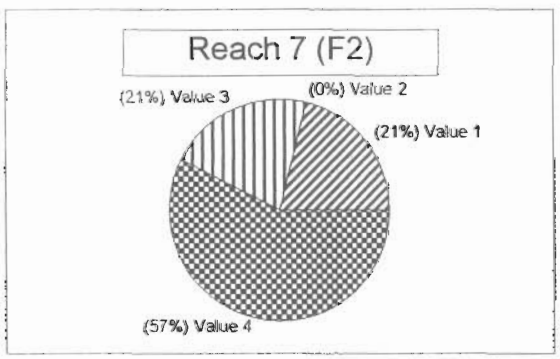


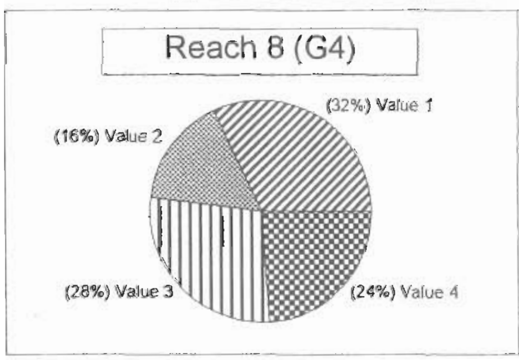










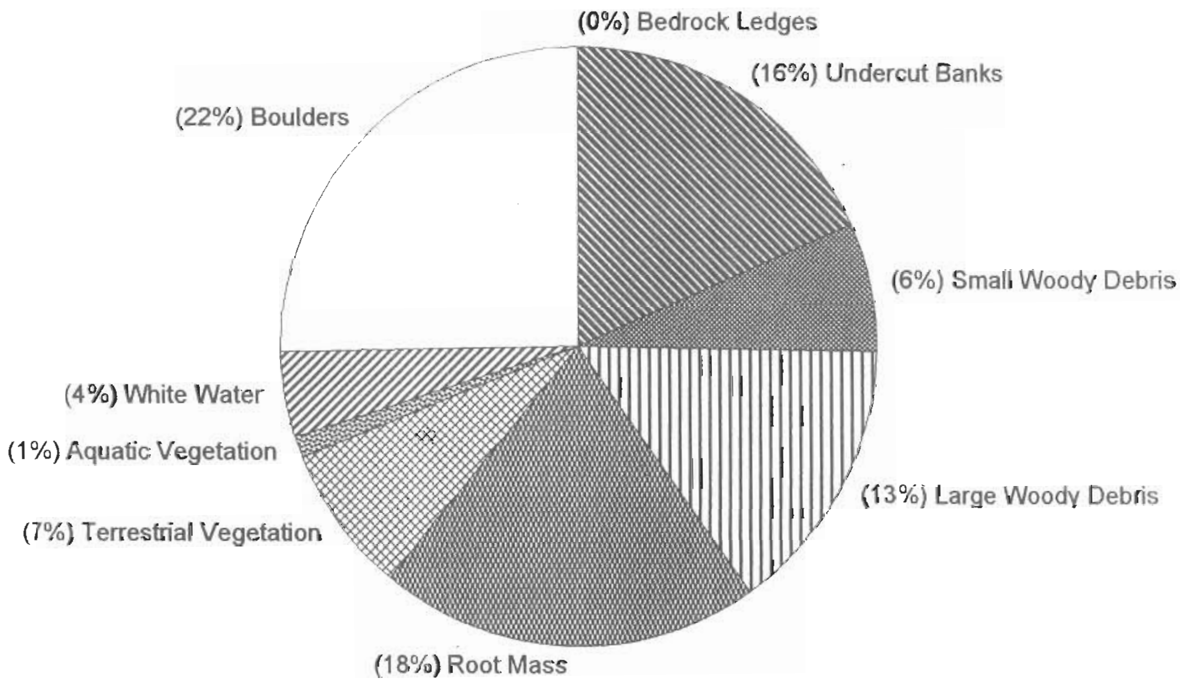


Value 1 = <25% Value 2 = 25-50% Value 3 = 51-75% Value 4 = >76%

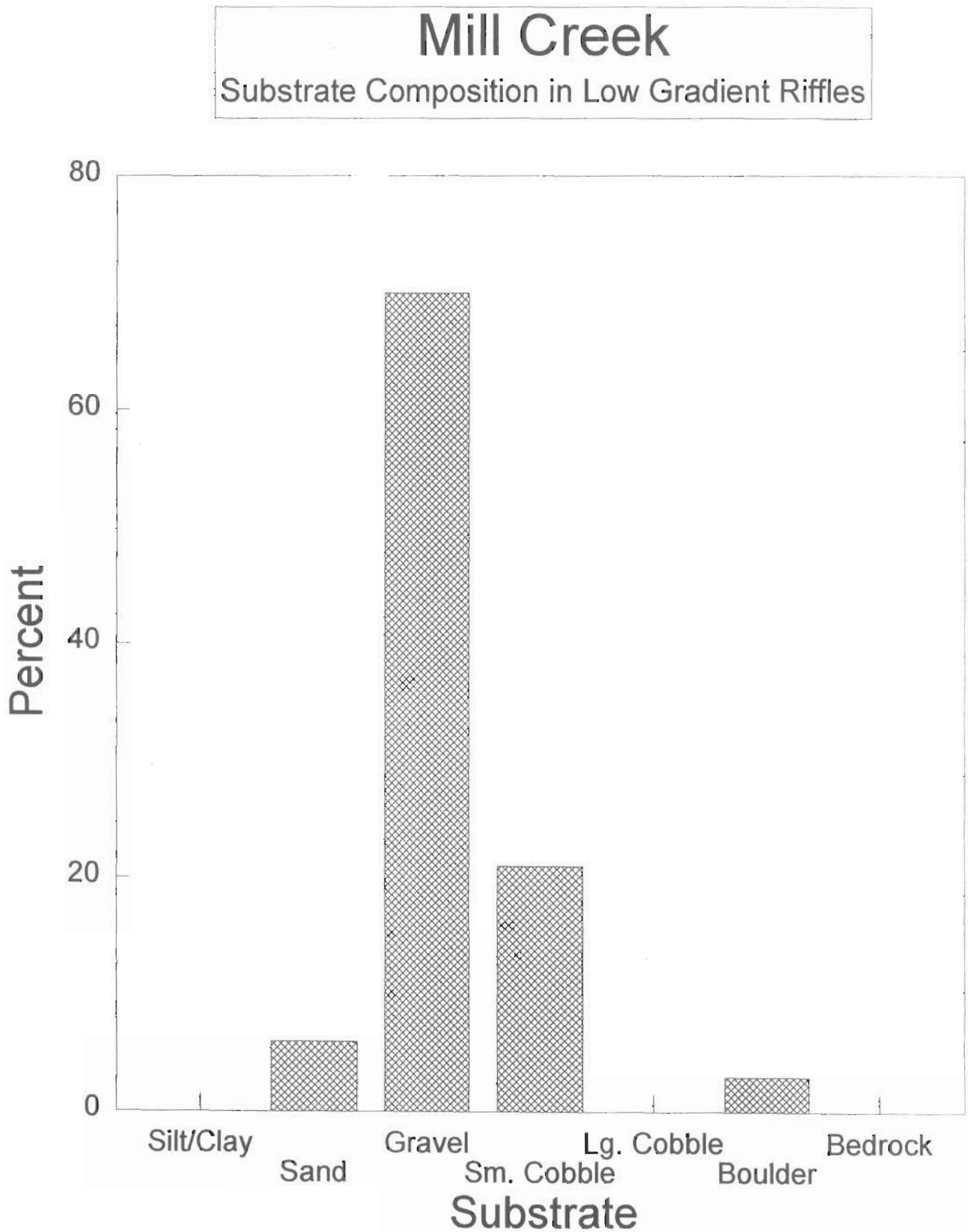
Graph 5

Mill Creek

Mean Percent Cover Types In Pools



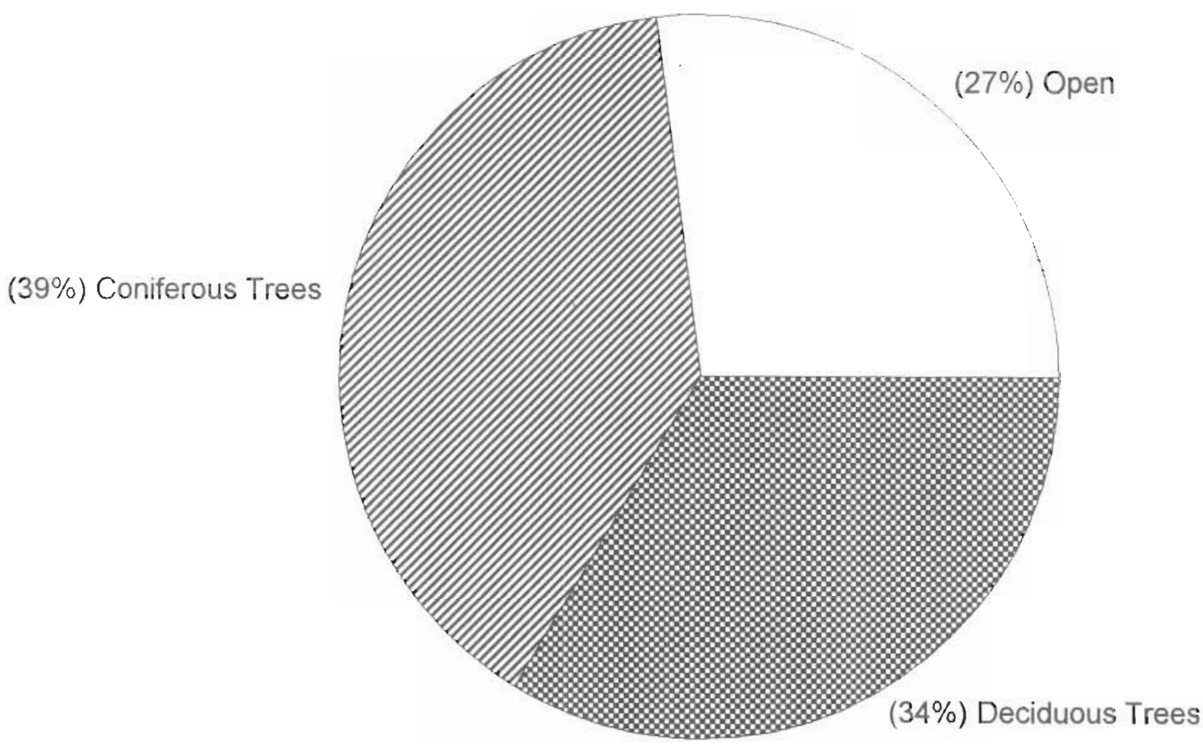
Graph 6


Mill Creek
Substrate Composition in Low Gradient Riffles
80
60
40
20
0
Percent
Silt/Clay
Sand
Gravel
Sm. Cobble
Lg. Cobble
Boulder
Bedrock
Substrate

Graph 7

Mill Creek

Percent Canopy

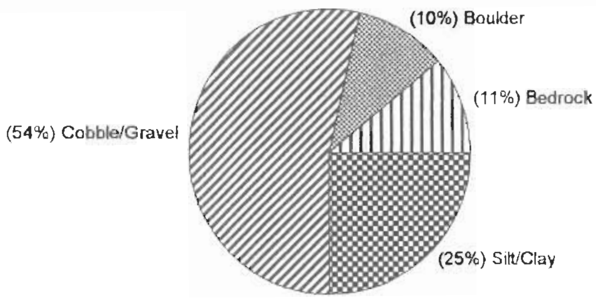


Graph 8

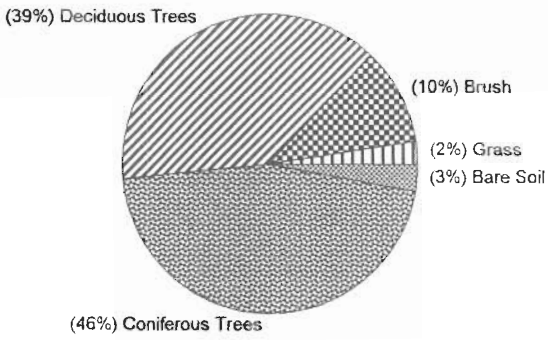
Mill Creek

Percent Bank Composition

Dominant Bank Substrate



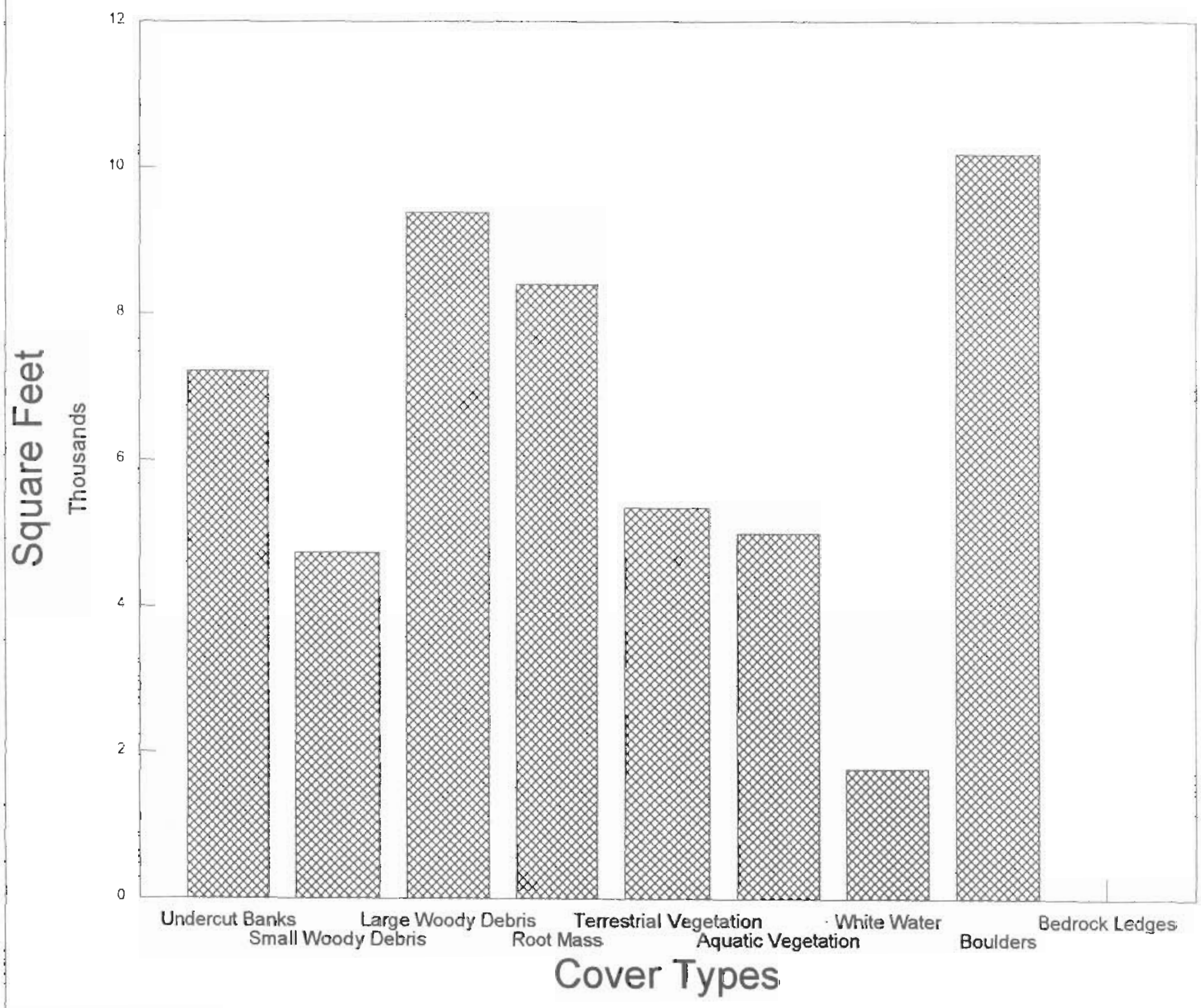
Dominant Bank Vegetation



Graph 9

Mill Creek

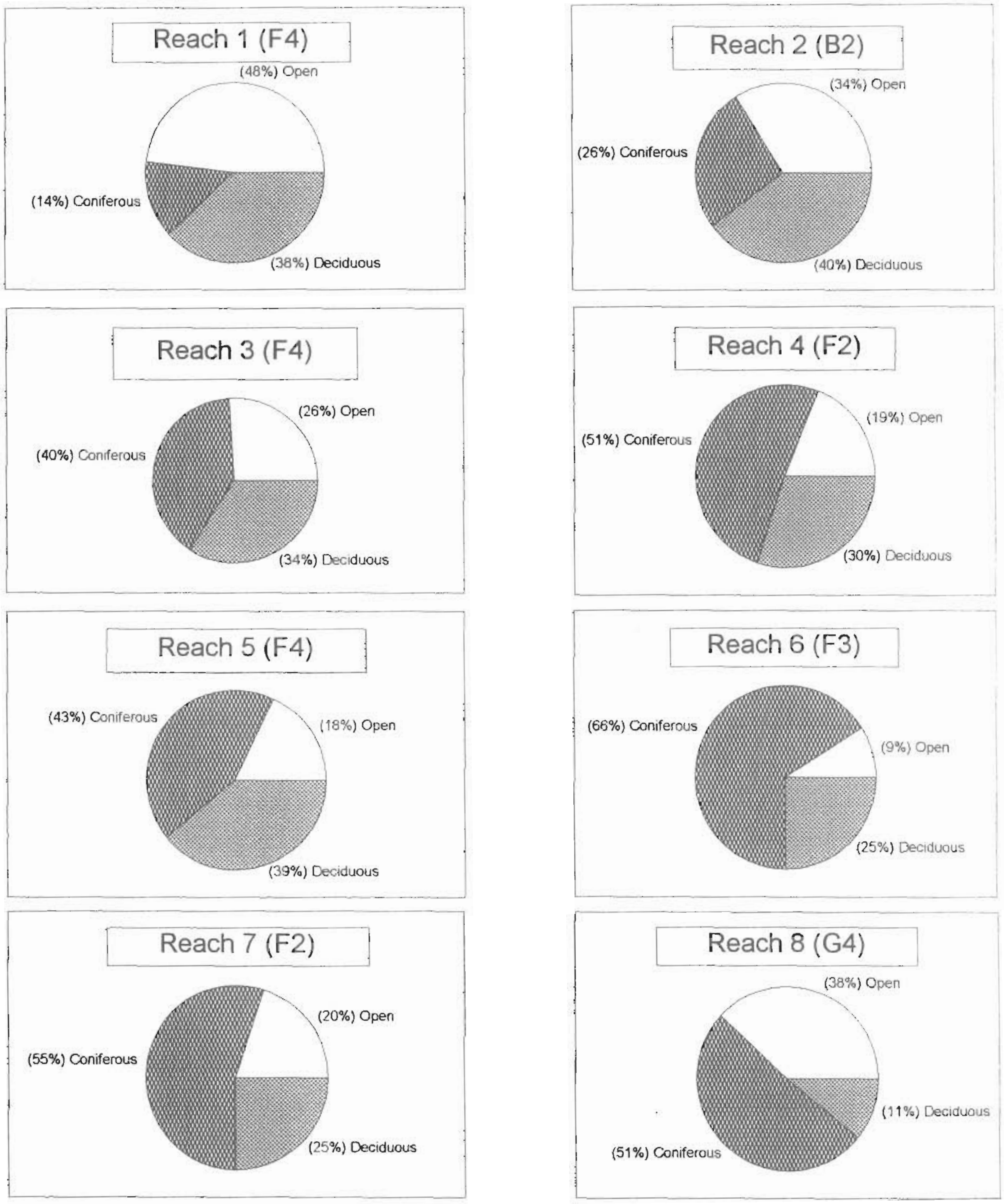
Cover Type Areas in Pools



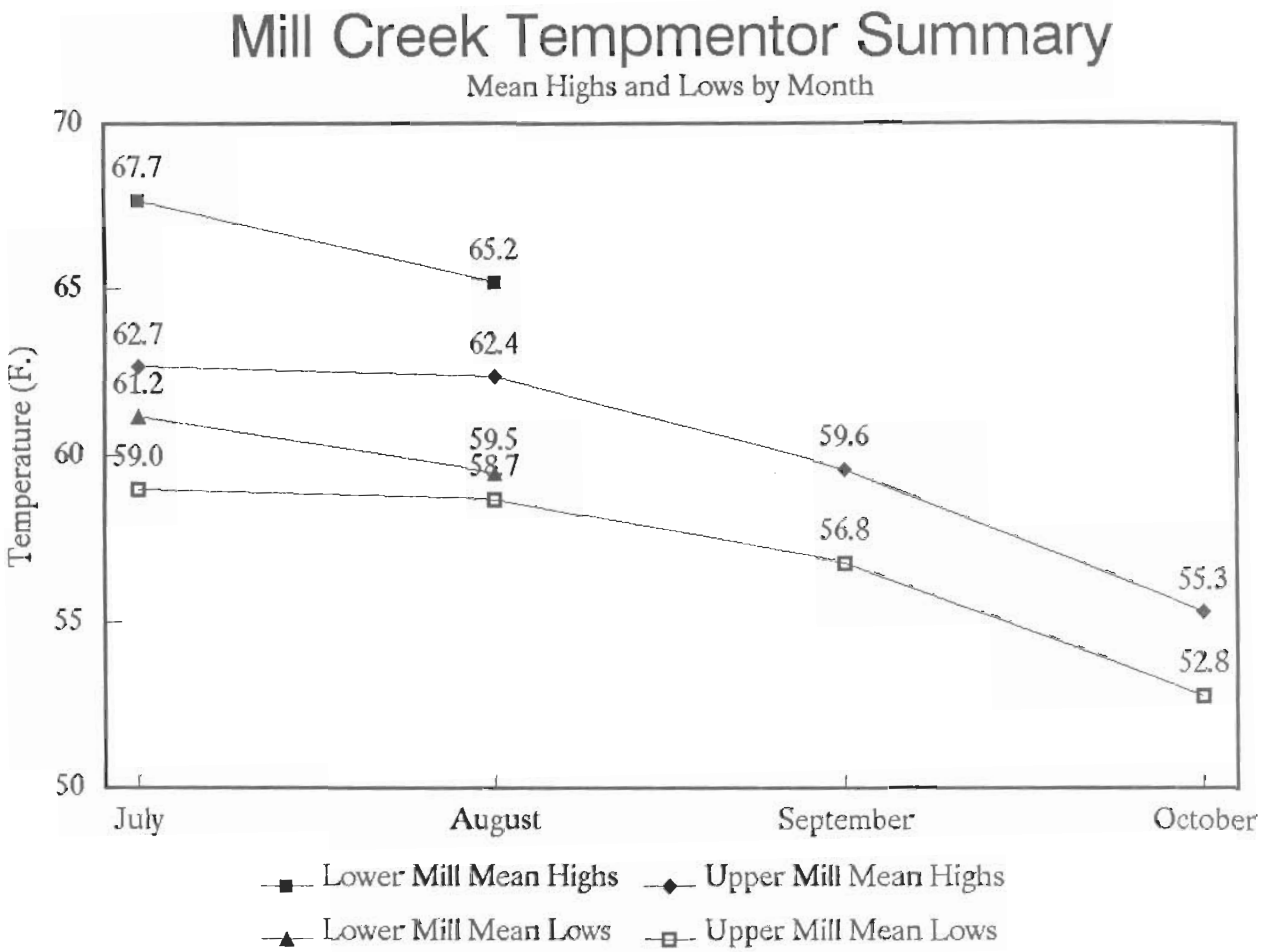
Graph 10

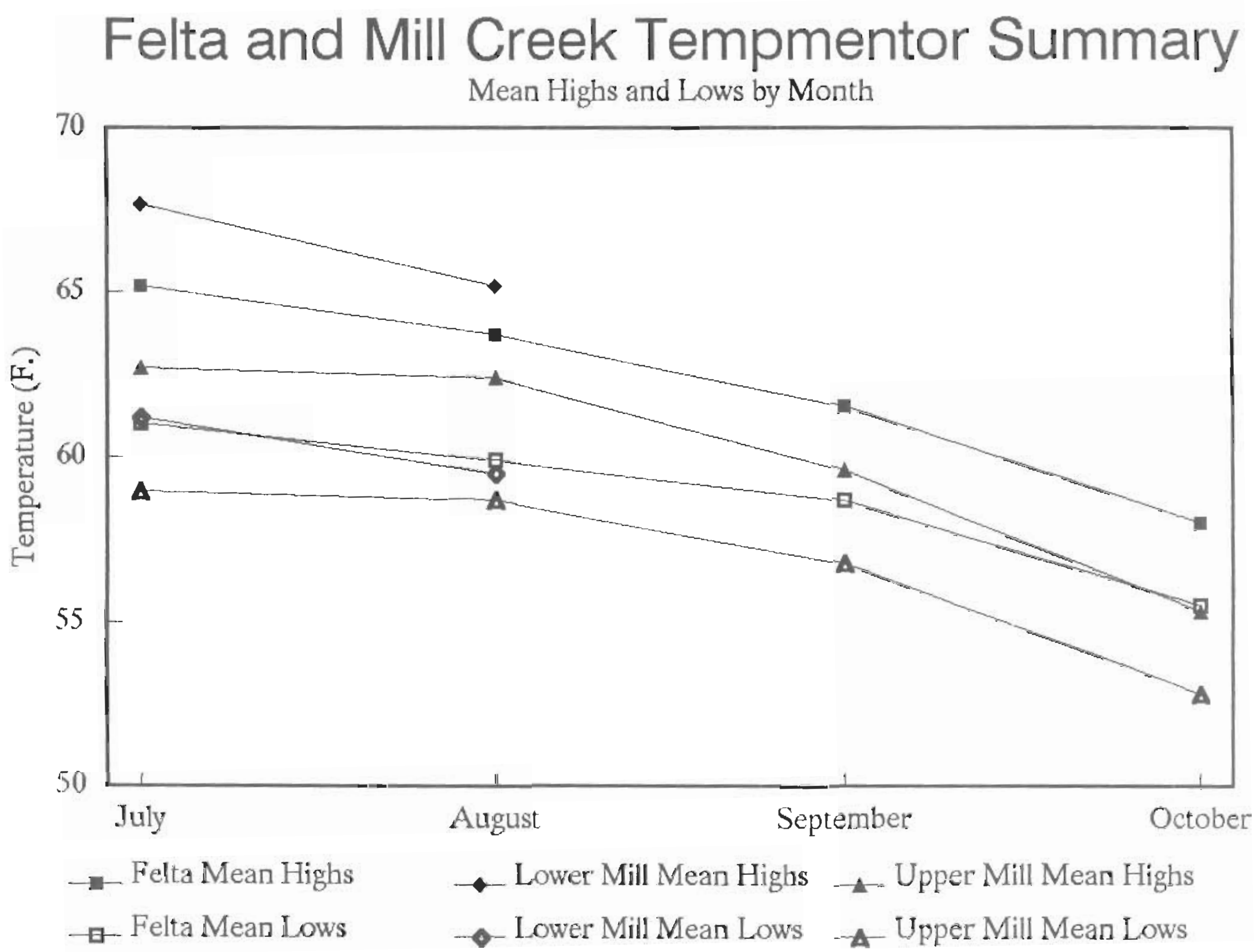
Mill Creek

Percent Canopy by Reach



Graph 11


Mill Creek Tempmentor Summary
Mean Highs and Lows by Month
70
65
60
55
50
Temperature (F.)
67.7
65.2
62.7
62.4
61.2
59.5
58.7
59.0
59.6
56.8
55.3
52.8
July
August
September
October
Lower Mill Mean Highs
Upper Mill Mean Highs
Lower Mill Mean Lows
Upper Mill Mean Lows



Felta and Mill Creek Tempmentor Summary
Mean Highs and Lows by Month
70
65
60
55
50
Temperature (F.)
July
August
September
October
Felta Mean Highs
Lower Mill Mean Highs
Upper Mill Mean Highs
Felta Mean Lows
Lower Mill Mean Lows
Upper Mill Mean Lows

Sample Number 1 of 4 total samples from Sample Site: MILL
NOTES: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

CLASS RANGE	SAMPLE WEIGHT	FRACTION % WT.	CUM. % WEIGHT
0.000 - 0.850 mm	1618.00 gms	8.138%	8.138%
0.850 - 2.370 mm	3610.00 gms	18.156%	26.294%
2.370 - 4.700 mm	1370.00 gms	6.890%	33.184%
4.700 - 12.500 mm	3880.00 gms	19.514%	52.698%
12.500 - 25.400 mm	3925.00 gms	19.740%	72.439%
25.400 - 50.800 mm	3510.00 gms	17.653%	90.092%
50.800 - 76.200 mm	660.00 gms	3.319%	93.411%
76.200 - 150.000 mm	0.00 gms	0.000%	93.411%
150.000 - 160.000 mm	1310.00 gms	6.589%	100.000%

TOTAL SAMPLE WEIGHT .... 19883.00 GRAMS
GEOMETRIC MEAN WHOLE SAMPLE .... 7.44 mm
PERCENT FINES (LESS THAN 0.85 mm).. 8.14 %

Percentile Diameters
D 25 = 2.24mm
D 33 = 4.64mm
D 50 = 10.96mm
D 66 = 20.18mm
D 75 = 27.51mm

Sample Number 2 of 4 total samples from Sample Site: MILL
NOTES: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

CLASS RANGE	SAMPLE WEIGHT	FRACTION % WT.	CUM. % WEIGHT
0.000 - 0.850 mm	1155.00 gms	7.023%	7.023%
0.850 - 2.370 mm	1120.00 gms	6.811%	13.834%
2.370 - 4.700 mm	1000.00 gms	6.081%	19.915%
4.700 - 12.500 mm	2630.00 gms	15.993%	35.908%
12.500 - 25.400 mm	1860.00 gms	11.310%	47.218%
25.400 - 50.800 mm	2570.00 gms	15.628%	62.846%
50.800 - 76.200 mm	1060.00 gms	6.446%	69.292%
76.200 - 150.000 mm	0.00 gms	0.000%	69.292%
150.000 - 160.000 mm	5050.00 gms	30.708%	100.000%

TOTAL SAMPLE WEIGHT .... 16445.00 GRAMS
GEOMETRIC MEAN WHOLE SAMPLE .... 21.44 mm
PERCENT FINES (LESS THAN 0.85 mm).. 7.02 %

Percentile Diameters
D 25 = 6.63mm
D 33 = 10.67mm
D 50 = 28.79mm
D 66 = 64.02mm
D 75 = 150.53mm

Sample Number 3 of 4 total samples from Sample Site: MILL
NOTES: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

CLASS RANGE	SAMPLE WEIGHT	FRACTION % WT.	CUM. % WEIGHT
0.000 - 0.850 mm	990.00 gms	5.432%	5.432%
0.850 - 2.370 mm	2185.00 gms	11.989%	17.421%
2.370 - 4.700 mm	2235.00 gms	12.263%	29.684%
4.700 - 12.500 mm	2850.00 gms	15.638%	45.322%
12.500 - 25.400 mm	2100.00 gms	11.523%	56.845%
25.400 - 50.800 mm	3250.00 gms	17.833%	74.678%
50.800 - 76.200 mm	3120.00 gms	17.119%	91.797%
76.200 - 150.000 mm	700.00 gms	3.841%	95.638%
150.000 - 160.000 mm	795.00 gms	4.362%	100.000%

TOTAL SAMPLE WEIGHT .... 18225.00 GRAMS
GEOMETRIC MEAN WHOLE SAMPLE .... 11.52 mm
PERCENT FINES (LESS THAN 0.85 mm).. 5.43 %

Percentile Diameters
D 25 = 3.70mm
D 33 = 5.78mm
D 50 = 16.66mm
D 66 = 36.28mm
D 75 = 51.10mm

Sample Number 4 of 4 total samples from Sample Site: MILL
NOTES: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

CLASS RANGE	SAMPLE WEIGHT	FRACTION % WT.	CUM. % WEIGHT
0.000 - 0.850 mm	1823.00 gms	10.869%	10.869%
0.850 - 2.370 mm	1280.00 gms	7.631%	18.500%
2.370 - 4.700 mm	1200.00 gms	7.154%	25.654%
4.700 - 12.500 mm	3035.00 gms	18.095%	43.749%
12.500 - 25.400 mm	2655.00 gms	15.829%	59.578%
25.400 - 50.800 mm	3950.00 gms	23.550%	83.128%
50.800 - 76.200 mm	2050.00 gms	12.222%	95.350%
76.200 - 150.000 mm	780.00 gms	4.650%	100.000%

TOTAL SAMPLE WEIGHT .... 16773.00 GRAMS
GEOMETRIC MEAN WHOLE SAMPLE .... 9.59 mm
PERCENT FINES (LESS THAN 0.85 mm).. 10.87 %

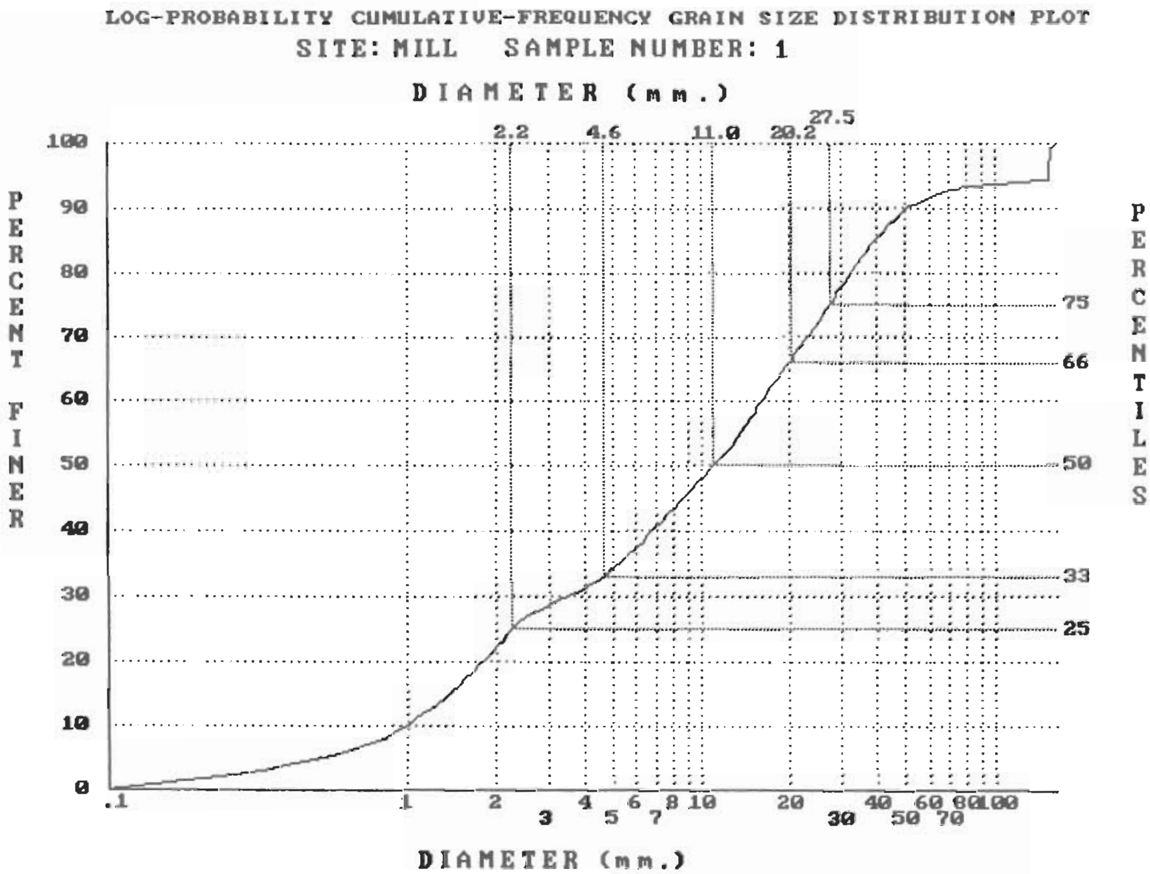
Percentile Diameters
D 25 = 4.42mm
D 33 = 7.08mm
D 50 = 16.50mm
D 66 = 30.31mm
D 75 = 38.56mm

Summary of All 4 COMBINED SAMPLES for Sampling Site: MILL
NOTES: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

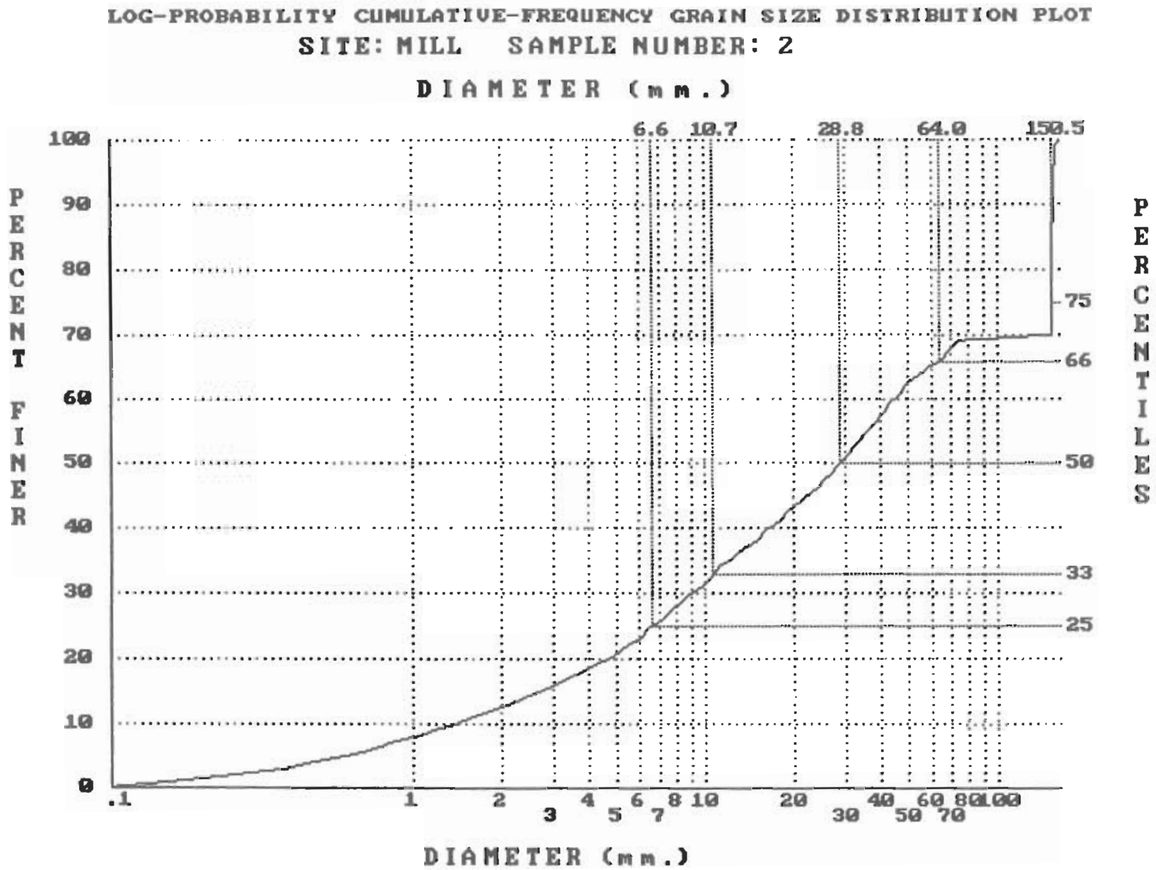
CLASS RANGE	SAMPLE WEIGHT	FRACTION % WT.	CUM. % WEIGHT
0.000 - 0.850 mm	5586.00 gms	7.832%	7.832%
0.850 - 2.370 mm	8195.00 gms	11.489%	19.321%
2.370 - 4.700 mm	5805.00 gms	8.139%	27.460%
4.700 - 12.500 mm	12395.00 gms	17.378%	44.838%
12.500 - 25.400 mm	10540.00 gms	14.777%	59.615%
25.400 - 50.800 mm	13280.00 gms	18.619%	78.234%
50.800 - 76.200 mm	6890.00 gms	9.660%	87.894%
76.200 - 150.000 mm	1480.00 gms	2.075%	89.969%
150.000 - 160.000 mm	7155.00 gms	10.031%	100.000%

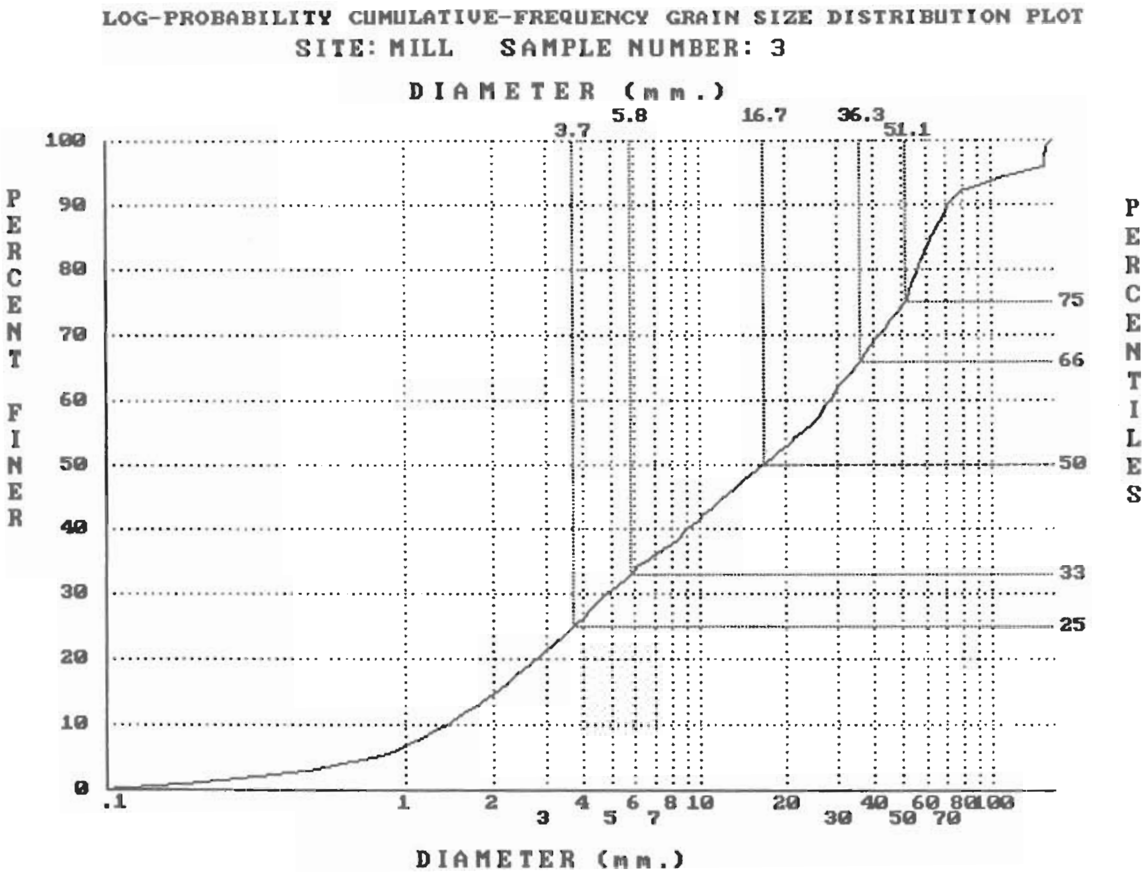
TOTAL SAMPLE WEIGHT .... 71326.00 GRAMS
GEOMETRIC MEAN WHOLE SAMPLE .... 10.87 mm
PERCENT FINES (LESS THAN 0.85 mm).. 7.83 %

Percentile Diameters
D 25 = 3.86mm
D 33 = 6.48mm
D 50 = 15.99mm
D 66 = 32.16mm
D 75 = 44.43mm



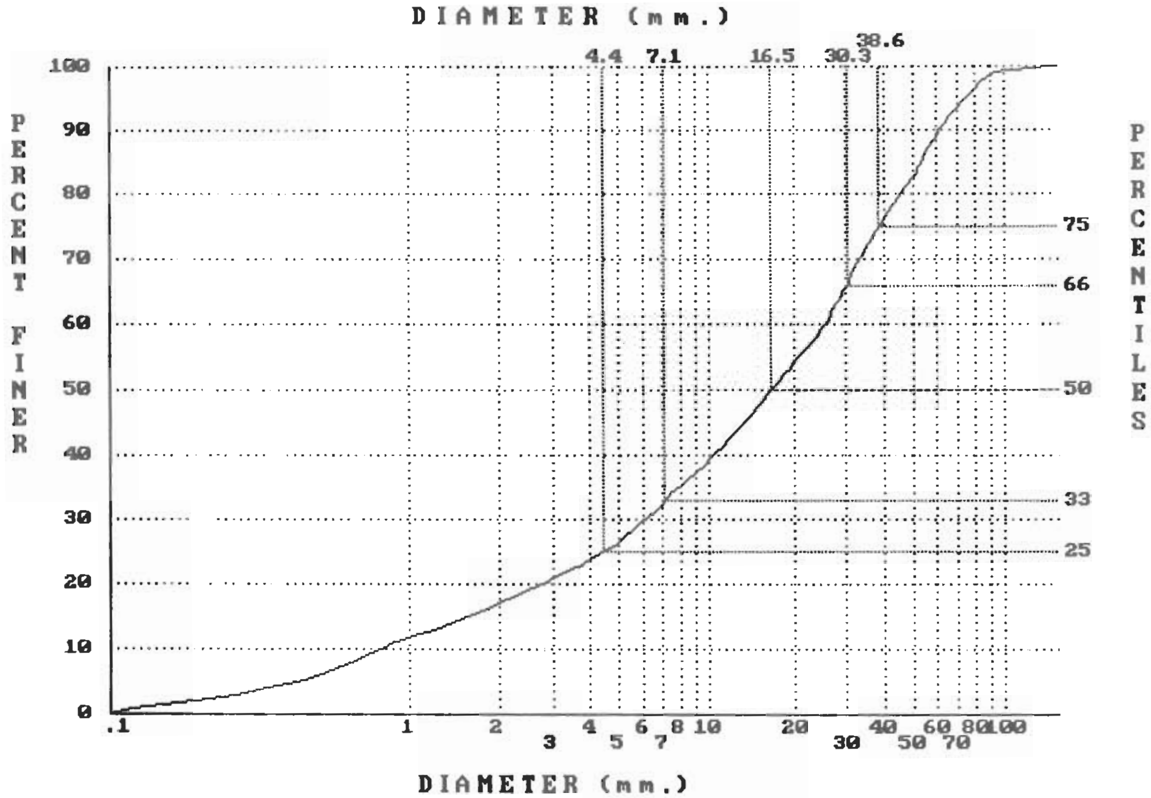
LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: MILL SAMPLE NUMBER: 1
DIAMETER (mm.)
2.2
4.6
11.0
20.2
27.5
PERCENT FINER
PERCENTILES
75
66
50
33
25
100
90
80
70
60
50
40
30
20
10
0
.1
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
DIAMETER (mm.)

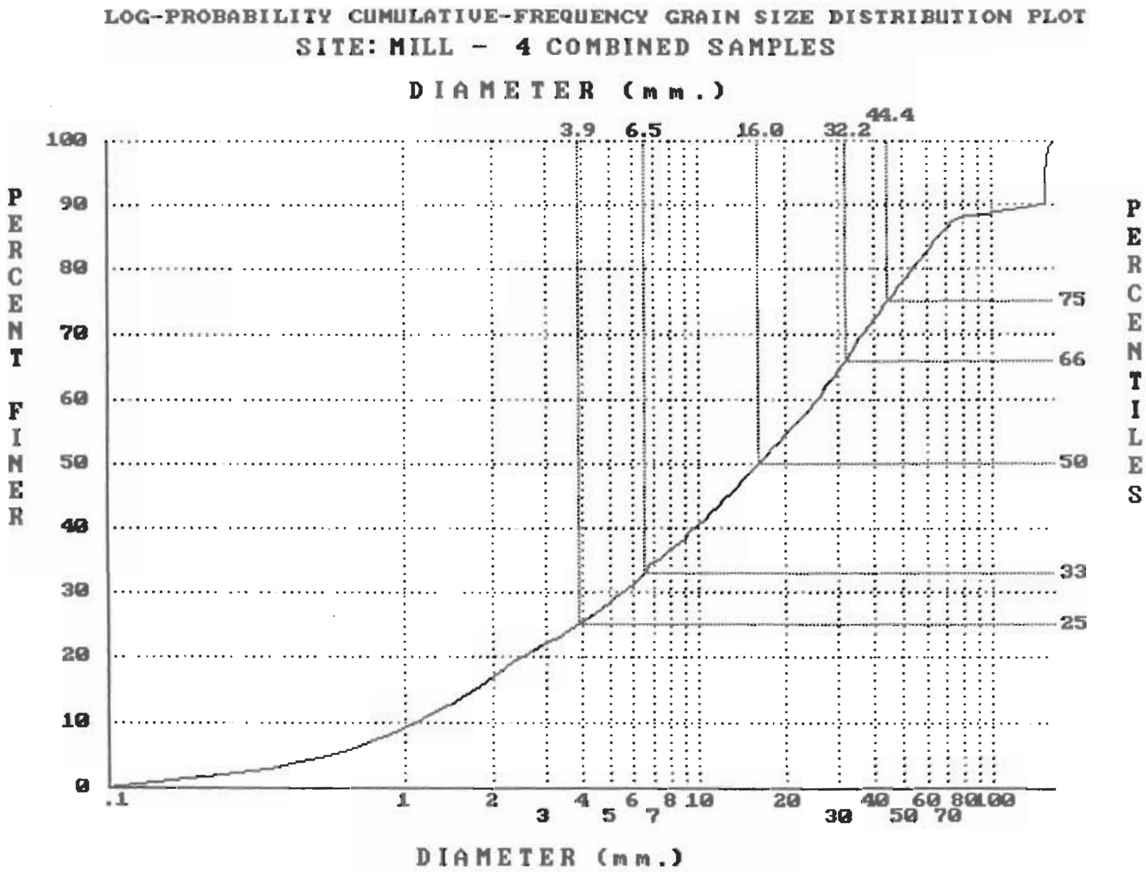

LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: MILL SAMPLE NUMBER: 2
DIAMETER (mm.)
6.6 10.7 28.8 64.0 150.5
PERCENT FINER
PERCENTILES
75
66
50
33
25
100 90 80 70 60 50 40 30 20 10 0
.1 1 2 3 4 5 6 7 8 10 20 30 40 50 60 70 80 100
DIAMETER (mm.)


LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: MILL SAMPLE NUMBER: 3
DIAMETER (mm.)
3.7
5.8
16.7
36.3
51.1
PERCENT FINER
PERCENTILES
75
66
50
33
25
100
90
80
70
60
50
40
30
20
10
0
.1
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
DIAMETER (mm.)

LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT

SITE: MILL SAMPLE NUMBER: 4




LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: MILL - 4 COMBINED SAMPLES
DIAMETER (mm.)
3.9
6.5
16.0
32.2
44.4
PERCENT FINER
PERCENTILES
75
66
50
33
25
DIAMETER (mm.)

RESULTS FOR MILL Sample Date: 11/30/95, 12/01/95

SAMPLE	GEO. MEAN	SORT. COEF.	FREDLE INDEX	STD. DEV.	SKEWNESS	KURTOSIS
1	7.44	3.504	2.123	5.099	-0.2375	0.7293
2	21.44	4.765	4.500	7.067	-0.1509	0.4105
3	11.52	3.716	3.099	5.300	-0.2213	0.5235
4	9.59	2.953	3.247	5.401	-0.3218	0.5357
MEAN	12.50	3.735	3.242	5.717	-0.2329	0.5498
COMBINED	10.87	3.392	3.206	5.840	-0.2183	0.5878

INDEX	SAMPLE n	MEAN	STANDARD DEV	95.0% CONFIDENCE INTERVAL
GeoMean	4	12.497	6.189	2.656 - 22.338
SortCoef.	4	3.735	0.758	2.529 - 4.940
FredleIndex	4	3.242	0.975	1.692 - 4.793

RESULTS FOR MILL Sample Date: 11/30/95, 12/01/95
Notes: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

EGG TO EMERGENCE SURVIVAL RATES FOR STEELHEAD, COHO AND SHINOOK SALMON
Based on 95 percent confidence intervals for GeoMean & FredleIndex

	Confidence Interval Ranges Lower		Higher	Mean Survival
STEELHEAD	40.30 %	to	80.87 %	66.22 %
COHO	19.33 %	to	64.56 %	47.59 %
CHINOOK	1.63 %	to	82.54 %	36.90 %

NOTE: Steelhead and Coho survival rates are based on FredleIndex.
Chinook survival rates are based on (GeoMean/Egg diameter) relationship.

RESULTS FOR MILL   Sample Date: 11/30/95, 12/01/95
Notes: Sample 1=Rch 1; Sample 2=Rch 2; Sample 3=Rch 3 Sample 4= Rch 8

GEOMETRIC MEANS, STANDARD DEVIATIONS AND PERCENTILES

SAMPLE	GeoMean	StdDev	D5	D16	D25	D50	D75	D84	D95
1	7.44	5.10	0.54	1.46	2.24	10.96	27.51	37.94	150.56
2	21.44	7.07	0.62	3.03	6.63	28.79	150.53	151.51	153.49
3	11.52	5.30	0.79	2.17	3.70	16.66	51.10	61.05	127.30
4	9.59	5.40	0.42	1.78	4.42	16.50	38.56	51.80	74.41
MEAN	12.50	5.72	1.84	2.11	4.25	18.23	66.92	75.57	126.44
COMBINED	10.87	5.84	0.56	1.86	3.86	15.99	44.43	63.51	151.44

CALIFORNIA DEPARTMENT OF FISH AND GAME
STREAM INVENTORY REPORT
Felta Creek
Report Revised April 14, 2006
Report Completed 2000
Assessment Completed 1995

INTRODUCTION

A stream inventory was conducted during the summer of 1995 on Felta Creek to assess habitat conditions for anadromous salmonids. The inventory was conducted in two parts: habitat inventory and biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids in Felta Creek. The objective of the biological inventory was to document the salmonid and other aquatic species present and their distribution. After analysis of historical information and data gathered recently, stream restoration and enhancement recommendations are presented.

WATERSHED OVERVIEW

Felta Creek is a tributary to Mill Creek, which is a tributary to Dry Creek which empties into the Russian River, located in Sonoma County, California (see Felta Creek Watershed map, page 2). The legal description at the confluence with Mill Creek is T09N, R09W, S32. It's location is 38°34'52" N. latitude and 122°52'56" W. longitude. Year round vehicle access exists from Felta Lane in Healdsburg, via Westside Road.

Felta Creek is a second order stream and has approximately 5 miles of blue line stream, according to the USGS Guerneville 7.5 minute quadrangle. A first order un-named tributary (Salt Creek) is the only major tributary and is included in this report. Felta Creek and its tributaries drain a basin of approximately 3.7 square miles, and the system has a total of 5 miles of blue line stream. Summer base flow was measured at approximately 1.8 cfs at Felta Road in July, 1985. Elevations range from about 100 feet at the mouth of the creek to 800 feet in the headwaters. Felta Creek flows in an easterly direction and is all privately owned. Tan-oak, live oak, valley oak, alder, bay and redwood trees forest the drainage. Land use is characterized by rural residential, timber production and agriculture.

The Northern Spotted Owl (Strix occidentalis caurina) is listed in DFG's Natural Diversity Database for Felta Creek watershed. No sensitive plants were listed.

Stream Surveys:

CDFG stream surveys were conducted on Felta Creek in October 1968 and July 1985 to assess and improve habitat conditions for anadromous salmonids. Site visits in the fall of 1958 and 1968 were also conducted.

A site visit in October 1958, .3 miles west on Felta Road, found Felta Creek to be dry.

The August 1963 survey found the creek to be completely dry from the mouth to Felta School.

The 1963 survey was conducted to determine the presence of juvenile salmonids in tributaries to the Russian River. Steelhead and roach were present.

The July 1985 survey was conducted to determine the need for instream enhancement work. This survey was initiated in response to a landowner's reports of a potential problem with steelhead passage approximately 1 mile from the confluence with Mill Creek. An abandoned summer dam had accumulated several large boulders at its base. This eliminated the jump pool needed for the steelhead to clear the summer dam obstruction. The boulders were removed, using a grip hoist and silent explosives. Removal of the boulders made approximately two miles of spawning habitat upstream from the dam accessible.

References:

C.D.F.& G. Stream Flow Measurement; August 1963; G.K.B.

C.D.F.& G. Stream Surveys - Russian River, Sonoma County; October 1968; Holman, Gerald, Asst. Fisheries Biologist Region 3.

Stream Enhancement Contract #C - 1245; November 1986; Circuit Rider Productions, Windsor, CA.

METHODS

The habitat inventory conducted in Felta Creek follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1991). The Americorps members that conducted the inventory were trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG) under the supervision of DFG's Russian River Basin

Planner, Robert Coey in May 1995. This inventory was conducted by a two person team.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Felta Creek to record measurements and observations. There are nine components to the inventory form.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Mill Creek to record measurements and observations. There are nine components to the inventory form.

1. Flow:

Flow is measured in cubic feet per second (cfs) at the bottom of the stream survey reach using standard flow measuring equipment, if available. In some cases flows are estimated. Flows were also measured or estimated at major tributary confluences.

2. Channel Type:

Channel typing is conducted according to the classification system developed by David Rosgen (1985). This methodology is described in the California Salmonid Stream Habitat Restoration Manual. Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are four measured parameters used to determine channel type: 1) water slope gradient, 2) channel confinement, 3) width/depth ratio, 4) substrate composition.

3. Temperatures:

Water and air temperatures, and time taken, are measured by crew members with handheld thermometers and recorded at each tenth unit typed. Temperatures are measured in Fahrenheit at the middle of the habitat unit and within one foot of the water surface. Temperatures are also recorded using Ryan Tempmentors which log temperature every two hours, 24 hours/day.

4. Habitat Type:

Habitat typing uses the 24 habitat classification types defined by McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "dry". Felta Creek habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. Channel dimensions were measured using hip chains, range finders, tape measures, and stadia rods. Unit measurements included mean length, mean width, mean depth, and maximum depth. Pool tail crest depth at each pool unit was measured in the thalweg. All measurements were taken in feet to the nearest tenth.

5. Embeddedness:

The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. In Felta Creek, embeddedness was visually estimated. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value 4).

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent cover. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All cover is then classified according to a list of nine cover types. In Felta Creek, a standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) was assigned according to the complexity of the cover. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes. Mechanical substrate sampling was also conducted to quantify the percentage of fine sediment within spawning gravels.

8. Canopy:

Stream canopy is estimated using handheld spherical densiometers and is a measure of the water surface shaded during periods of high sun. In Felta Creek, an estimate of the percentage of the habitat unit covered by canopy was made from the center of each unit. The area of canopy was further analyzed to estimate its percentages of coniferous or deciduous trees, and the results recorded.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In Felta Creek, the dominant composition type in both the right and left banks was selected from a list of eight options on the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

SUBSTRATE SAMPLING

Gravel sampling is conducted to determine the percentage of fine sediment present in probable fish spawning areas. These areas are generally found in low gradient riffles at the tail-outs of pools. Three substrate samples were taken in potential spawning riffles in Felta Creek on December 4, 1995. One sample was taken for each of the first three reaches. Each sample consisted of one 12" McNeil sample to characterize each reach.

The samples were placed through a series of sieves with diameters of .85mm, 2.37mm, 4.7mm, 12.5mm, 25.4mm, 50.8mm, 76.2mm and 150mm. Displacement volumes were measured for particles in each size classification. Finally, the remaining sample <0.85mm was placed in Imhoff cones for 1 hour with the volume of fines settled out and measured.

BIOLOGICAL INVENTORY

Biological sampling during stream inventory is used to determine fish species and their distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. These sampling techniques are discussed in the California Salmonid Stream Habitat Restoration Manual.

DATA ANALYSIS

Data from the habitat inventory form are entered into the Habitat Program, a dBASE 4.1 data entry program developed by the California Department of Fish and Game (DFG). This program also processes and summarizes the data.

The Habitat Runtime program produces the following tables:

- Riffle, flatwater, and pool habitat types
- Habitat types and measured parameters
- Pool types
- Maximum pool depths by habitat types
- Dominant substrates by habitat types
- Mean percent shelter by habitat types

Graphics are produced from the tables using Lotus 1,2,3. Graphics developed for Felta Creek include:

- Riffle, flatwater, pool habitats by percent occurrence
- Total habitat types by percent occurrence
- Pool types by percent occurrence

HABITAT INVENTORY RESULTS

* ALL TABLES AND GRAPHS ARE LOCATED AT THE END OF THE REPORT *

The habitat inventory of June 6 through July 19, 1995 was conducted by Ken Mogan and John Fort (Americorps). The survey began at the confluence with Mill Creek and extended up Felta Creek to the end of survey. The total length of the stream surveyed was 22,866 feet, with an additional 36 feet of side channel.

A flow of 1.8 cfs was measured on July 28, 1995 at Felta Creek Road with a Marsh-McBirney Model 2000 flowmeter.

This section of Felta Creek has four channel types, with one type occurring in two separate reaches: from the mouth to 1,863 feet (to Pearl's flash board dam) an F4; the next 2,246 feet (to the end of the boulder section) a G2; the next 10,056 feet (to the confluence of Salt Creek) an F4; the next 5,897 feet a B4 and the upper 2,841 feet an A2 (Felta Creek Watershed map and Appendix B).

F4 streams have confined, meandering riffle/pool gravel channels on low gradients (less than 2%).

G2 channels are entrenched "gully" step-pools on a moderate (2-4%) gradient, with boulders as the dominant substrate.

B4 channels are moderately entrenched, moderate gradient, riffle dominated channels with infrequently spaced pools. They are predominantly gravel channels with stable banks.

A2 streams are steep, narrow, cascading, step-pool streams with boulder substrate and high energy/debris transport associated with depositional soils.

Water temperatures ranged from 60°F to 70°F. Air temperatures ranged from 56°F to 86°F. A Ryan tempmentor was placed in a pool and recorded temperatures from June 30 - October 17, 1995 (see Tempmentor Summary graph at end of report). The highest temperature recorded was 69°F and the lowest was 54°F. The mean of the daily highs for the month of July was 65°F, August, 64°F, September, 62°F and October, 58°F.

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. By percent **occurrence**, pools made up 41%, flatwater 32%, and riffles 25% (Graph 1). Flatwater habitat types made up 35% of the total survey **length**, pools 34%, and riffles 25% .

Twenty-two Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent **occurrence** were low gradient riffles 24%, glides 17%, runs 14% and root wad scours 13% (Graph 2). By percent total **length**, low gradient riffles made up 23%, glides 16%, runs 17%, and root wad scours 11%.

Two hundred eighty-six pools were identified (Table 3). Scour pools were most often encountered at 72%, and comprised 70% of the total length of pools (Graph 3).

Table 4 is a summary of maximum pool depths by pool habitat types. Depth is an indicator of pool quality. The pools are relatively shallow with only 87 of the 286 pools (30%) having a maximum depth greater than 2 feet (Graph 4).

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Flatwater types had the lowest shelter rating at 18 (Table 1). Pool types had the highest shelter rating at 43. Of the pool types, the main channel pools had the highest mean shelter rating at 45. Scour pools rated 43 and backwater pools rated 40 (Table 3). Pool shelter ratings were highest in reach 2 and lowest in reach 1. (Appendix B).

Table 5 summarizes mean percent cover by habitat type. Table 10 summarizes cover areas by habitat type. Undercut banks are the dominant cover type for pools in Felta Creek. Root masses and large woody debris are the next most common pool cover types (Graphs 5 and 10).

Nearly 17% of Felta Creek lacked shade canopy. Of the 83% of the stream that was covered with canopy, 27% was composed of deciduous trees, and 73% was composed of coniferous trees (Graph 8). Shade canopy was also analyzed by reach (Appendix B and Graph 11)

Table 2 summarizes the mean percentage of the right and left stream banks covered with vegetation by habitat type. For the stream reach surveyed, the mean percent right bank vegetated was 72% and percent left bank vegetated was 73%. The dominant vegetation types for the stream banks were: 60% coniferous trees, 17% deciduous trees, 16% brush, 6% grass and 2% bare soil. The dominant substrate for the stream banks were: 80% silt/clay/sand, 9% cobble/gravel, 8% bedrock and 3% boulders (Appendix C and Graph 9).

SUBSTRATE SAMPLING

Table 6 summarizes the dominant substrate by habitat type. Gravel was the dominant substrate observed in 163 of the 165 (99%) low gradient riffles (Graph 7).

The depth of cobble embeddedness was estimated at pool tail-outs in Felta Creek. Of the 287 pool tail-outs measured, 78 had a value of one (27%); 107 had a value of two (37%); 56 had a value of three (20%); and 46 had a value of four (16%). On this scale, a value of one is best for fisheries. On a reach by reach comparison, reach 1 had the poorest embeddedness values with 64% of the pools having a value of either 3 or 4. Reach 3 had the best values with 74% having either a 1 or 2. Reach 2 had 34%, reach 4 42% and reach 5 53% with a value of 3 or 4 (Appendix B and Graph 5).

Gravel samples were taken in the field by Mogan, Fort, Huber and Gregory (Americorps). Laboratory analysis was done by Fort, Huber, Nossaman, Sanchez (Americorps), Wilson and Hards (Interns) in May of 1996. The data was then summarized and analyzed with a computer program written by Dwain Goforth (National Park Service).

The analysis showed sample 1 (Reach 1) to be 23.8% fines (<0.85 mm). Sample 2 (Reach 2) was 8.2% fines and sample 3 (Reach 3) was 10.1% fines. The combined summary of all three samples averaged 12.8% fines. The combined summary showed 75% of the substrate to be less than 23mm, 50% to be less than 9mm and 25% to be less than 3mm (see Grain Size Distribution Plot). Reach 1 had a significantly higher percentage of fines than reaches 2 or 3.

HABITAT INVENTORY RESULTS FOR SALT CREEK

The habitat inventory of July 12-13, 1995 was conducted by John Fort and Ken Mogan (Americorps). The survey began at the confluence with Felta Creek and extended up Salt Creek to the end of survey. The total length of the stream surveyed was 2,681 feet.

Salt Creek was determined to be a G4 channel type: This type is described as an entrenched "gully" step-pool with a low width/depth ratio, moderate gradient (2-4%) and a gravel substrate.

Water temperatures ranged from 60°F to 62°F. Air temperatures ranged from 63°F to 68°F.

*By percent **occurrence**, riffles made up 42%, pool types 35%, and flatwater 20%. Eleven Level IV habitat types were identified. The most frequent habitat types by percent **occurrence** were low gradient riffles, 40%; glides, 16%; bedrock scours, 16%. Thirty-six pools were identified, with Scour pools most often encountered at 83%. Table 4 is a summary of maximum pool depths by pool habitat types. Three of the 36 pools (8%) had a maximum depth greater than 2 feet.*

Flatwater types had the highest shelter rating at 65. Riffles had the lowest rating with 8. Of the pool types, the main channel pools had the highest shelter rating at 90, scour pools rated 51.

The depth of cobble embeddedness was estimated at pool tail-outs. Of the 36 pool tail-outs measured, 5 percent had a value of 1, 54 percent had value of 2, 35 percent had a value of 3 and 5 percent had a value of 4.

Large woody debris and root masses are the two most common cover types for Salt Creek. Small woody debris and terrestrial vegetation are the next most common types. Gravel was the dominant substrate observed in ninety-five percent of the low gradient riffles measured.

Nearly 17% of Salt Creek lacked shade canopy. Of the 83% of the stream that was covered with canopy, 35% was composed of deciduous trees, and 65% was composed of coniferous trees.

For the stream reach surveyed, the mean percent right bank vegetated was 64% and the mean percent left bank vegetated was 68%. The dominant vegetation types for the stream banks were: 42%

brush, 25% coniferous tree, 24% grass. The dominant substrate for the stream banks were: 55% silt/clay/sand, 45% bedrock.

BIOLOGICAL INVENTORY

JUVENILE SURVEYS:

A biological inventory was taken on July 18, 20, and 26 of 1995 to document the fish species composition and distribution at several locations in Felta Creek. Each site was single pass electrofished using one Smith Root Model 12 electrofisher. Fish from each site were counted by species and returned to the stream. The range in air temperature was 64-81°F and the water temperatures ranged from 62-64°F. The observers were Ken Mogan, John Fort, Joyce Ambrosius, Bob Coey, and Bill Cox.

The inventory of reach one was conducted 200 feet upstream from the Felta School in habitat units 20-50. This reach was dry from the mouth to unit 20 and intermittent from there to the first flashboard dam. In pool, riffle, and run habitat types, 5 coho, 236 0+ steelhead, three 2+ steelhead, 2 sculpin, and 3 crayfish were observed.

The inventory of reach two was conducted from the beginning of the reach in habitat units 50-60. This reach was not intermittent. In pool and riffle habitat types 31 0+ and two 2+ steelhead were observed along with 29 sculpin.

An inventory of reach three was conducted 100' downstream from the Folger's bridge starting at habitat units 120. In pool, riffle, glide and run habitat types 89 0+, ten 1+ and three 2+ steelhead were observed. The inventory was continued 150 yds. downstream from Boring's bridge starting at habitat unit 200. In pool, riffle, run and glide habitat types 130 0+, two 1+ and one 2+ steelhead were observed along with 1 Yellow-legged Frog and 1 salamander. The inventory continued 20 yds from Boring's bridge starting at habitat unit 218. In pool, run, glide and riffle habitat types 129 0+, 5 1+ and 3 2+ steelhead were observed along with 5 newts and 1 salamander.

The inventory of reach four was conducted 1/8 mile downstream from the confluence with Salt Creek in habitat units 375-399. In pool, run and riffle habitat types 207 0+, four 1+ and one 2+ steelhead were observed along with 6 Yellow-legged Frog, some salamanders and newts.

The inventory of reach five was conducted 100' downstream from the confluence with Salt Creek in habitat units 437-474. In pool, riffle and run habitat types 75 0+, ten 1+ and two 2+ steelhead were observed along with 2 frogs, 26 salamanders and 2 newts. Resident 1+ fish (7-8") were seen visually from above in 3' deep pools.

The inventory of Salt Creek was conducted on July 18, 1995. The air temperature was 68°F and the water temperature was 61°F. The inventory started at the confluence to Felta Creek in habitat units 1-51. In pool, run and riffle habitat types 87 0+ and 3 1+ steelhead were observed along with 6 Pacific Giant Salamanders and 2 frogs.

A summary of historical and recent biological data collected appears in the table below.

Summary of Salmonids found in Juvenile Surveys

YEAR	**SPECIES**	**SOURCE**
1968	SH	DFG
1995	SH,SS	DFG

SH= Steelhead SS= Coho (Silver) Salmon

No known hatchery releases or fish rescues have occurred in this watershed.

ADULT SURVEYS:

A spawning/carcass survey was conducted on December 22, 1995 on Felta Creek, beginning at the mouth and extending upstream to Folger's Dam. Near habitat unit 30, 2 possible redds were observed in gravel of fair quality. A live female chinook salmon on a redd was also seen at habitat unit 42 in good gravel. A possible redd was observed downstream of Folger's dam, with good gravel quality.

Another spawning/carcass survey was conducted on Felta Creek on February 7, 1996, beginning at the Felta School bridge and extending upstream to habitat unit 90. No live salmonids, redds or carcasses were observed on this survey.

Another spawning/carcass survey was conducted on February 9, 1996, beginning at the first Felta Creek bridge and extended upstream 1/4 mile past habitat unit 280. Several fish (6-12") were seen attempting to jump the falls above the summer dam at habitat unit 90. It appeared that they were unable to navigate past the falls due to high flows. Two adult steelhead of undetermined sex were observed at habitat unit 110. One adult steelhead of undetermined sex was observed at habitat unit 280.

DISCUSSION

Felta Creek has four channel types: F4, G2, B4 and A2. F4 channel types are generally suitable for certain instream enhancement structures such as; bank placed boulders; low stage weirs; opposing wing-deflector; channel constrictors and cover logs.

The G2 channel type is generally unsuitable for instream enhancement structures, but log cover may be appropriate with careful design and placement.

The B4 channel type is excellent for many types of low and medium stage instream enhancement structures. There are 5,897 feet of this type of channel in Felta Creek, along with a plenitude of LOD either in or nearby the stream. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and cover. Specifically, low-stage plunge weirs; boulder clusters and bank placed boulders; single and opposing wing-deflectors; and log cover.

The high energy and steep gradient of the A2 channel type makes it generally unsuitable for instream enhancement structures.

The water temperatures recorded between June 6, 1995 and July 19, 1995 ranged from 60° F to 70° F. Air temperatures ranged from 56° F to 86° F. The warmer water temperatures were recorded in all reaches except reach 1. These warm water temperatures, if sustained, are above the threshold stress level for salmonids. A Ryan tempmentor was placed in a pool in reach two and recorded temperatures from June 30 - October 17, 1995 (Figure 2). The highest temperature recorded was 69°F in July and the lowest was 54°F in October. The mean of the daily highs for the month of July was 65°F, August, 64°F, September, 62°F and October, 58°F. The July and August high temperatures for this pool were at the threshold stress level for Salmonids. Restoration measures should be taken in the upper watershed to decrease temperatures.

Flatwater habitat types comprised 35% of the total **length** of this survey, pools comprised 34%, and riffles 25%. The pools are relatively shallow with only 98 of the 286 pools having a maximum depth greater than 2 feet (34%). In coastal coho and steelhead streams, it is generally desirable to have primary pools comprise approximately 50% of total habitat. In second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. Therefore, installing structures that will increase pool habitat is recommended for Reaches 1, 3 and 4 where their installation will not jeopardize unstable stream banks, or subject the structures to high stream energy.

The mean shelter rating for flatwater was the lowest with a rating of 18. The mean shelter rating in the riffle habitats was 26 and the shelter rating for pools rated highest at 46. However, a pool shelter rating of approximately 80 is desirable. The relatively small amount of pool cover that now exists is being provided primarily by undercut banks. Additionally, root masses and large woody debris contribute a small amount. Log and root wad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat. Log cover structure provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

Ninety-nine percent of the low gradient riffles had either gravel or small cobble as the dominant substrate. This is considered very good for spawning salmonids. However, 36% of the 286 pool tail-outs measured had embeddedness ratings of either three or four. Reaches 2 and 3 had the lowest embeddedness ratings with reach 1 being the highest. Cobble embeddedness measured to be 25% or less, a rating of one, is considered best for the needs of salmon and steelhead. The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence.

The Gravel program analyzed the substrate sample data for egg to emergence survival rates for steelhead and coho. The survival rates are based on a 95% confidence interval and used the FredleIndex. Based on this index and the data on Felta Creek, the mean egg to emergence survival rate would be 54% for steelhead and 34% for coho. In Felta Creek, sediment sources should be mapped and rated according to their potential sediment yields, and control measures taken.

The mean percent canopy for the survey reach was 83%. This is an adequate percentage of canopy, since 80 percent is generally considered desirable.

Biological surveys were conducted to document fish distribution and are not necessarily representative of population information. The inventory on July 18-26, 1995 found young of the year (0+) steelhead to be especially common, indicating successful spawning conditions. Fewer coho were found and only in reach 1 in this inventory. This is likely because physiological and environmental requirements for coho are more stringent than for steelhead, and coho may be unable to negotiate the boulder section of reach two. Within this reach, a small coffer dam exists which may inhibit adult migration during low flows. Overall, very few fish more than one year old were observed, indicating poor rearing conditions the year before or poor holding-over conditions in general.

DISCUSSION FOR SALT CREEK

Salt Creek is a G4 channel type, which is considered good for bank-placed boulders and fair for low-stage weirs, opposing wing-deflectors and log cover.

The water temperatures recorded on the survey days July 12-17, 1995 ranged from 60° F to 62° F. Air temperatures ranged from 63° F to 68° F. These warmer temperatures, if sustained, are just above the threshold stress level for salmonids. To make any further conclusions, temperatures need to be monitored for a longer period of time through the critical summer months, and more extensive biological sampling conducted.

Riffle habitat types comprised 40% of the total ***length*** *of this survey, pools 25%, and flatwater 18%, however, the pools are relatively shallow with zero pools having a maximum depth greater than 2 feet. Therefore, installing structures that will increase pool habitat is recommended for locations where their installation will not jeopardize unstable stream banks, or subject the structures to high stream energy.*

The mean shelter rating of pools was 60, flatwater 55 and riffles had a rating of 23. The relatively small amount of cover that now exists is being provided primarily by large woody debris and root masses. Additionally, small woody debris and terr. vegetation contribute a small amount. Enhancing the log and root wad cover structures in the pool and flatwater habitats is needed to improve both summer and winter salmonid habitat.

All of the low gradient riffles measured had either gravel or small cobble as a dominant substrate. This is considered excellent for spawning salmonids. However, 40% of the pool tail-outs measured *had embeddedness ratings of either 3 or 4. Cobble embeddedness measured to be 25% or less, a rating of 1, is considered best for the needs of salmon and steelhead.*

The mean percent canopy for the survey reach was 83%. This is a good percentage, since 80 percent is generally considered desirable.

SUMMARY

Biological surveys were conducted to document fish distribution and are not representative of population information. Steelhead were documented consistently during each past survey year, and coho and chinook only recently. Landowners have stated that steelhead are present every year and coho less frequently. Overall, habitat conditions for both steelhead and coho have declined over time. However, of the Russian River tributaries surveyed so far since 1994, Felta Creek is in the best condition for Salmonid habitat.

In general, Reaches 2-4 of Felta Creek are fair for salmon and steelhead habitat. The many scour pools may be used as rearing habitat, however, shelter is lacking and stream temperatures are moderately high. Riffle habitat exists for spawning, but some reaches have high gravel embeddedness. The intermittent flow of reach 1 and boulder section of reach 2 limits instream habitat improvement alternatives, although some opportunity exists. Any work considered in reaches 1 and 2 will require careful design, placement, and construction that must include protection for the adjacent road and high stream velocities. Log cover structures could be used to increase instream shelter.

Upstream of the Boring's bridge conditions are better. In reaches 3 and 4, spawning and rearing habitat exists and canopy shading is high overall, although some areas have no canopy at all. However, instream shelter is still low, stream temperatures are higher and stream bank erosion is prevalent due to past logging roads. Opportunities for improvement with Reach 3 are minimal due to unstable banks. Reach 4 is excellent for many types of low and medium stage instream enhancement structures and many opportunities and alternatives exist for habitat improvement due to the more stable channel type. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and shelter.

The best spawning habitat in the watershed exists within reaches 3 and 4, and within Salt Creek. Down-stream in Reach 1 and 2 spawning and rearing habitat quality diminishes due to the effects of eroding stream banks and high energy of the boulder section respectively. Sediment transported downstream from stored sediments in reach 4 during high winter flows impact the spawning habitat in lower gradient reaches below. Erosion control riparian planting is recommended.

GENERAL RECOMMENDATIONS

Felta Creek should be managed as an anadromous, natural production stream.

Recent winter storms brought down many large trees and other woody debris into the stream, which increased the number and quality of pools since the drought years. This woody debris, if left undisturbed, will provide fish shelter and rearing habitat, and offset channel incision. Efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be sensitive about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

SPECIFIC FISHERY ENHANCEMENT RECOMMENDATIONS

1) In reach 3, active and potential sediment sources related to the past skid road system need to be mapped, and treated according to their potential for sediment yield to the stream and its tributaries. Alternatives to control erosion and increase canopy, in reach 3 should be explored with the landowner, and developed if possible.

2) Near-stream riparian planting along any portion of the stream should be encouraged to provide bank stability and a buffering against agricultural, grazing and urban runoff. Upslope intermittent tributaries should be assessed for planting and erosion control treatment, since water temperatures and spawning habitat throughout are effected from upstream. In many cases, planting will need to be coordinated to follow bank stabilization or biotechnical erosion control projects.

3) Where feasible, design and engineer pool enhancement structures to increase the number of pools. This must be done where the banks are stable (reach 4) or in conjunction with stream bank armor to prevent erosion.

4) Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream. Most of the existing cover is from undercut banks. Adding high quality complexity

with larger woody cover is desirable. Combination cover/scour structures constructed with boulders and woody debris would be effective in many flatwater and pool locations. This must be done where the banks are stable (reach 4) or in conjunction with stream bank armor to prevent erosion. In some areas the material is at hand.

RESTORATION IMPLEMENTED

1) The winter 1995 and 1996 storms brought down many large trees and other woody debris into the stream. This woody debris, if left undisturbed, will provide fish cover and rearing habitat, and offset channel incision in reaches 1 and 3. Many signs of historic tree and log removal were evident in the active channel during our survey. Past efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be educated about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

2) Access for migrating salmonids has been voiced by landowners as an ongoing potential problem in Reach 2, therefore, fish passage should be monitored, and improved where possible. The jump pool above the first summer dam should possibly be modified.

3) Spawning gravels on Felta Creek are limited to relatively few reaches (only reaches 3 and 4 are suitable for spawning). Structures to recruit spawning gravel should be installed to trap, sort and expand redd distribution in the stream (particularly in reach 3 below Folger's bridge and in reach 4 above the Salt Creek confluence).

4) Where feasible, design and engineer pool enhancement structures to increase the number of pools. This must be done where the banks are stable (reaches 1 and 3) or in conjunction with stream bank armor to prevent erosion.

5) Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream. Most of the existing cover is from undercut banks. Adding high quality complexity with larger woody cover is desirable. Combination cover/scour structures constructed with boulders and woody debris would be effective in many flatwater and pool locations. This must be done where the banks are stable (reaches 1 and 3) or in conjunction with stream bank armor to prevent erosion. In some

areas the material is at hand.

6) In reach 4, active and potential sediment sources related to the past skid road system need to be mapped, and treated according to their potential for sediment yield to the stream and its tributaries. Alternatives to control erosion and increase canopy, in reach 3 should be explored with the landowner, and developed if possible.

7) Near-stream riparian planting along any portion of the stream should be encouraged to provide bank stability and a buffering against agricultural, grazing and urban runoff (conifer planting in reaches 2 and 3).

PROBLEM SITES AND LANDMARKS - FELTA CREEK SURVEY COMMENTS

STREAM LENGTH (FT)	COMMENTS	HABITAT UNIT #
319	BLOW OUT ON RT. BANK	
460	FELTA RD. BRIDGE 43'L X 22'W X 11'H	
623	FIRST BUG SAMPLE TAKEN HERE, 6/9/95	UNIT 18
726	2ND BUG SAMPLE TAKEN HERE, 6/9/95	UNIT 21
762	POSSIBLE CHANNEL CHANGE	UNIT 24
831	3RD BUG SAMPLE TAKEN HERE, 6/9/95	
856	POSSIBLE ELECTROFISHING SPOT	
1022	RT. BANK DUMP SITE	
1197	POSSIBLE ELECTROFISHING SPOT	
1867	CHANNEL TYPE CHANGE	UNIT 45
2061	POSSIBLE ELECTROFISHING SPOT	
2189	BRIDGE #2 19'W X 17'L X 8'H	
2579	POSSIBLE ELECTROFISHING SPOT	
3117	9.4'H X 9.5'W X 40'L CONCRETE DAM	
3142	BRIDGE #3 16'W X 11'H X 17'L	UNIT 65
3470	HUMAN-MADE ROCK DAM 25'L X 5'H X 2'W	
3502	DRY TRIBUTARY. RT. BANK	
3774	POSSIBLE ELECTROFISHING SPOT; FLOATING FENCE PARTIALLY OVER CREEK	
3802	3' CASCADE DROP	
4090	LOG JAM HOLDING GRAVEL (4'H X 15'L)	UNIT 106
4141	ROAD CROSSING THROUGH CREEK	
4601	POSSIBLE ELECTROFISHING SPOT	
4927	CHANNEL TYPING DONE	
5003	POSSIBLE ELECTROFISHING SPOT	
5147	BRIDGE #4 28'W X 8'H X 12'L	UNIT 129
5478	LARGE LOG JAM 10'H X 25'W X 32'L	
5681	FLASH DAM 4'H X 12'W X 10'L	UNIT 149
5868	POSSIBLE ELECTROFISHING SPOT	

5954	RT. BANK SPRING	
6139	TEMPERATURE METER PLACED HERE	
6446	BLOW OUT LF. BANK	
6730	SPRING ON LF. BANK, 60°F	UNIT 188
7019	BRIDGE #5 9'H X 11'W X 13'L	
7695	LOG JAM 5'H X 15'W X 11'L	
7925	POSSIBLE ELECTROFISHING SPOT	
8080	POSSIBLE ELECTROFISHING SPOT, 1+ FISH	
8704	LG. GRAVEL BARS BUILT UP	
9056	GRAVEL ROAD THROUGH STREAM - EROSION PROBLEM	UNIT 275
9554	RT. BANK FAILURE	
9622	BLOW OUT RT. BANK	
9927	TRIBUTARY. ON LF. BANK 58°F	UNIT 333
11486	PLUNGE POOL AT HIGHER FLOWS	
11557	LG. REDWOOD LOGS, 3 AT 14'L X 32"D	
11573	SPRING (TRIBUTARY?) LF. BANK, 60°F	
12244	CORNER BLOWOUT RT. BANK	
13131	POSSIBLE ELECTROFISHING SPOT	
13206	BLOWOUT RT. BANK 12.5'H X 180'L	
13419	BLOWOUT LF. BANK 18'W X 7'D X 25'H	UNIT 407
13633	LOG JAM 7'H X 23'W X 10'L	
14334	CONFLUENCE OF UNNAMED TRIBUTARY. (SALT CREEK)	
14438	CORNER BLOWOUT 11'H X 30'L	
14498	BRIDGE #6 OLD FLATCAR 7'H X 35'W X 11'L	UNIT 446
14552	BLOWOUT RT. BANK 12'H X 40'L	
14637	SPRING LF. BANK	
14749	GULLY RT. BANK 3'D X 15'W X 20'H; SKID ROAD RT. BANK	
14895	24" X 8' LOG RT. BANK	
15187	1+ STEELHEAD	UNIT 473
15420	RT. BANK BLOWOUT 15'H X 30'L; OLD SKID RD. ABOVE	
15570	OSPREY NEST W/ YOUNG RT. BANK	
16080	1+ FISH 7-8"	UNIT 534
16657	TRIBUTARY. LF. BANK 59°F.	
16726	1+ FISH 4-6"	
16768	OLD SKID ROAD CROSSING	
17429	ROAD ERODING ABOVE	
17845	RT. BANK BLOWN OUT 7' X 50'	
18085	OLD CROSSING BLOWN OUT	
18155	LF. BANK BLOW OUT 15' X 35'	
18227	18" CULVERT RT. BANK	
18386	BRIDGE #7, 8'H X 35'W X 14'L	
19287	TRIBUTARY. RT. BANK 60°F.	UNIT 628
19370	LOG HOLDING BACK GRAVEL 5'H X 12'W.	
20063	FLOW DISAPPEARS AT THIS POINT FOR 750'	
20073	DRY TRIBUTARY. LF. BANK	
21045	DRY TRIBUTARY. LF. BANK	

22437 UNIT 689

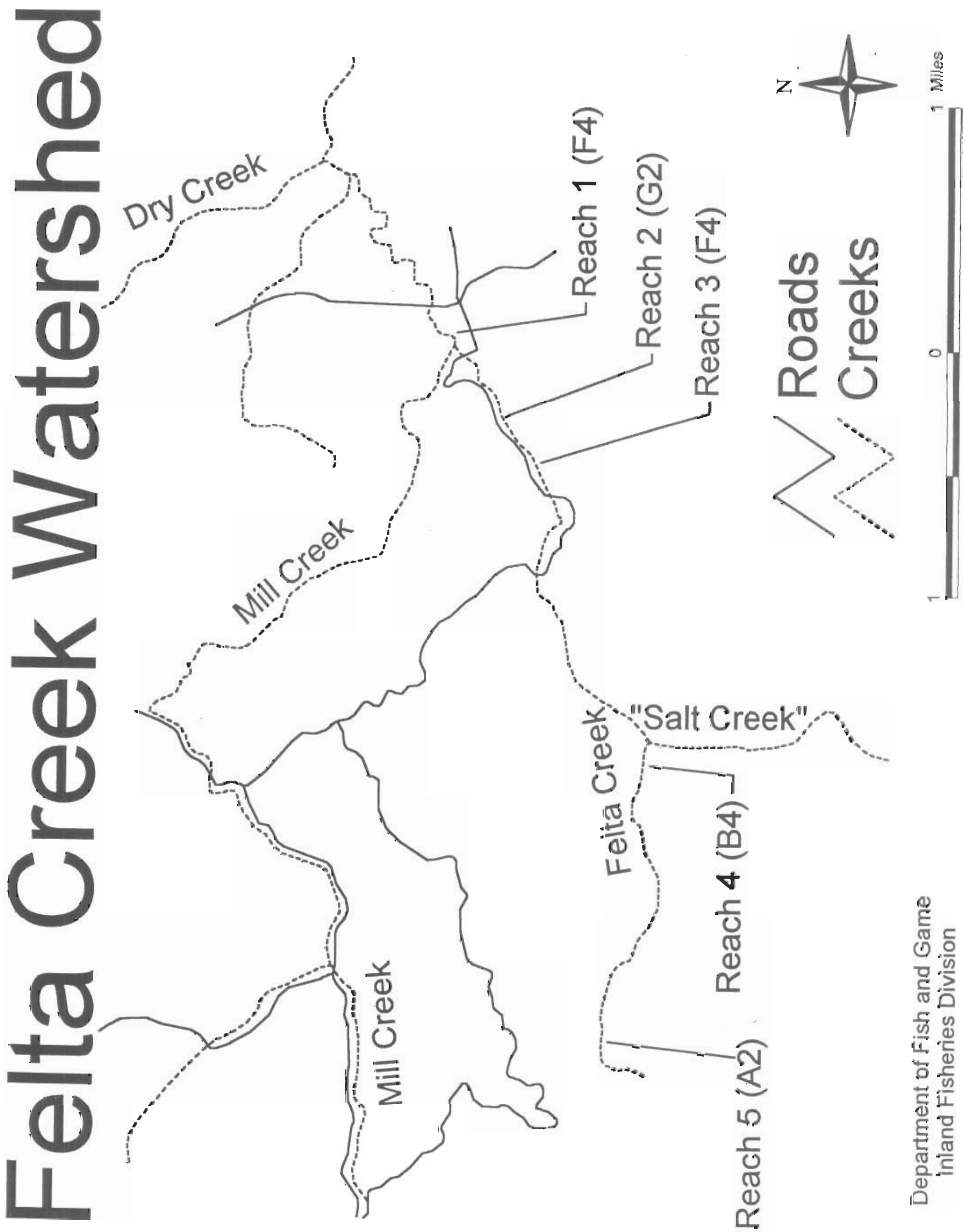
A VISUAL SURVEY WAS DONE UP TO THE CONFLUENCE OF NORTH/SOUTH FORKS. FISH WERE SEEN 60 YDS. BELOW CONFLUENCE, PROBABLY DUE TO HIGH WATER IN RECENT PAST. BOTH FORKS 59°F.

22883 DRY TRIBUTARY. LF. BANK

22914 FISH PRESENT; EITHER STEELHEAD OR ROACH

PROBLEM SITES AND LANDMARKS - SALT CREEK SURVEY COMMENTS

STREAM LENGTH (FT)	COMMENTS	HABITAT UNIT #
89	LOG JAM (LG WOOD) 5'H X 12'W X 10'L HOLDING GRAVEL AND CAUSING SCOUR; 4" FISH	
111	3 OLD CEMENT CULVERTS IN CREEK BED, 6' DIAMETER, 9' LONG HOLDING BACK GRAVEL.	UNIT# 6
220	OLD SKID ROAD PARALLELS CREEK ON BOTH BANKS	
512	ROAD (OLD SKID) PARALLELS CREEK ON BOTH BANKS	
559	SPRING LEFT BANK 59°F	
598	3" FISH	
644	INTERMITTENT AT THIS POINT UPSTREAM; FISH STILL PRESENT	UNIT# 30
652	SKID ROADS RUN PARALLEL TO CREEK ON BOTH BANKS	
676	WATER RUNS SUBALLUVIAL	
942	DRY FOR 100' OF THE 145' LONG UNIT	
1296	DRY TRIBUTARY RIGHT BANK	
1589	OLD SKID ROAD PARALLELS BOTH BANKS	
1992	TRIBUTARY RIGHT BANK 60°F.	
2070	OLD ROAD CROSSING, LARGE WOODY DEBRIS	UNIT# 87
2406	FISH STILL FOUND	
2507	TRIBUTARY LEFT BANK 60°F.	
2689	LOG JAM HOLDING GRAVEL 5'H X 15'W X 10'L	


Felta Creek Watershed
Dry Creek
Mill Creek
Mill Creek
Felta Creek
"Salt Creek"
Reach 1 (F4)
Reach 2 (G2)
Reach 3 (F4)
Reach 4 (B4)
Reach 5 (A2)
Roads
Creeks
N
1
0
1 Miles
Department of Fish and Game
Inland Fisheries Division

FISH HABITAT INVENTORY DATA SUMMARY

STREAM NAME: Felta Creek
SAMPLE DATES: 06/06/95 to 07/19/95
STREAM LENGTH: 22834 ft.
LOCATION OF STREAM MOUTH:

USGS Quad Map: HEALD&GUER	Latitude: 38°34'52"
Legal Description: T09NR09WS32	Longitude: 122°52'56"

SUMMARY OF FISH HABITAT ELEMENTS BY STREAM REACH

STREAM REACH 1

Channel Type: F4	Canopy Density: 82%
Channel Length: 1863 ft.	Coniferous Component: 73%
Flowing Water Mean Width: 8 ft.	Deciduous Component: 27%
Flowing Water Mean Depth: 0.4 ft.	Pools by Stream Length: 37%
Base Flow: 0.0 cfs	Pools >=3 ft.deep: 16%
Water: 55 - 57 °F Air: 61 - 69 °F	Mean Pool Shelter Rtn: 21
Dom. Bank Veg.: Coniferous Trees	Dom. Shelter: Root masses
Vegetative Cover: 63%	Occurrence of LOD: 48%
Dom. Bank Substrate: Silt/Clay/Sand	Dry Channel: 0 ft.

Embeddness Value: 1. 32% 2. 5% 3. 53% 4. 11%

STREAM REACH 2

Channel Type: G2	Canopy Density: 93%
Channel Length: 2246 ft.	Coniferous Component: 78%
Flowing Water Mean Width: 10 ft.	Deciduous Component: 22%
Flowing Water Mean Depth: 0.6 ft.	Pools by Stream Length: 36%
Base Flow: 0.0 cfs	Pools >=3 ft.deep: 8%
Water: 56 - 66 °F Air: 61 - 77 °F	Mean Pool Shelter Rtn: 43
Dom. Bank Veg.: Coniferous Trees	Dom. Shelter: Boulders
Vegetative Cover: 62%	Occurrence of LOD: 30%
Dom. Bank Substrate: Silt/Clay/Sand	Dry Channel: 0 ft.

Embeddness Value: 1. 42% 2. 25% 3. 13% 4. 21%

STREAM REACH 3

Channel Type: F4	Canopy Density: 81%
Channel Length: 10020 ft.	Coniferous Component: 71%
Flowing Water Mean Width: 8 ft.	Deciduous Component: 29%
Flowing Water Mean Depth: 0.3 ft.	Pools by Stream Length: 40%
Base Flow: 0.0 cfs	Pools >=3 ft.deep: 12%
Water: 59 - 70 °F Air: 56 - 85 °F	Mean Pool Shelter Rtn: 45
Dom. Bank Veg.: Coniferous Trees	Dom. Shelter: Undercut Banks
Vegetative Cover: 76%	Occurrence of LOD: 43%
Dom. Bank Substrate: Silt/Clay/Sand	Dry Channel: 0 ft.

Embeddness Value: 1. 22% 2. 51% 3. 19% 4. 7%

STREAM REACH 4

Channel Type: B4	Canopy Density: 82%
Channel Length: 5897 ft.	Coniferous Component: 74%
Flowing Water Mean Width: 6 ft.	Deciduous Component: 26%
Flowing Water Mean Depth: 0.4 ft.	Pools by Stream Length: 33%
Base Flow: 0.0 cfs	Pools >=3 ft.deep: 7%
Water: 60- 70 °F Air: 62 - 86 °F	Mean Pool Shelter Rtn: 55
Dom. Bank Veg.: Coniferous Trees	Dom. Shelter: Undercut Banks
Vegetative Cover: 74%	Occurrence of LOD: 46%
Dom. Bank Substrate: Silt/Clay/Sand	Dry Channel: 111 ft.

Embeddness Value: 1. 29% 2. 28% 3. 17% 4. 25%

STREAM REACH 5

Channel Type: A2
Channel Length: 2810 ft.
Flowing Water Mean Width: 4 ft.
Flowing Water Mean Depth: 0.3 ft.
Base Flow: 0.0 cfs
Water: 62 - 65 °F Air: 68 - 79 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 65%
Dom. Bank Substrate: Silt/Clay/Sand
Embeddness Value: 1. 19% 2. 25% 3. 19% 4. 38%

Canopy Density: 89%
Coniferous Component: 89%
Deciduous Component: 11%
Pools by Stream Length: 12%
Pools >=3 ft.deep: 6%
Mean Pool Shelter Rtn: 40
Dom. Shelter: Boulders
Occurrence of LOD: 40%
Dry Channel: 1247 ft.

Summary of Mean Percent Vegetative Cover for Entire Stream

Mean Percent Canopy	Mean Percent Conifer	Mean Percent Decidous	Mean Right bank % Cover	Mean Left Bank % Cover
83.19	73.43	26.57	72.29	73.45

Mean Percentage of Dominant Substrate

Dominant Class of Substrate	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Bedrock	45	67	8
Boulder	22	22	3.14
Cobble/Gravel	68	59	9.07
Silt/clay	565	552	79.79

Mean Percentage of Dominant Vegetation

Dominant Class of Vegetation	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Grass	44	35	5.64
Brush	92	127	15.64
Decid. Trees	122	112	16.71
Conif. Trees	427	413	60
No Vegetation	15	13	2

Felta Creek Drainage: Mill Creek

Table 1 - SUMMARY OF RIFFLE, FLATWATER, AND POOL HABITAT TYPES Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	ESTIMATED TOTAL AREA (sq.ft.)	MEAN VOLUME (cu.ft.)	ESTIMATED TOTAL VOLUME (cu.ft.)	MEAN RESIDUAL POOL VOL (cu.ft.)	MEAN SHELTER RATING
178	176	RIFFLE	25	32	5645	25	7.9	0.3	206	36616	75	13406	18	26
225	224	FLATWATER	32	36	8058	35	7.2	0.4	235	52828	108	24188	148	18
286	285	POOL	41	27	7810	34	9.4	1.1	270	77243	357	102159	301	46
11	0	DRY	2	123	1358	6	0.0	0.0	0	0	0	0	0	0

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq. ft.)	TOTAL VOL. (cu. ft.)
700	685	22870	166688	139753

Felta Creek Drainage: Mill Creek

Table 2 - SUMMARY OF HABITAT TYPES AND MEASURED PARAMETERS Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

HABITAT UNITS #	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT OCCURRENCE %	MEAN LENGTH ft.	TOTAL LENGTH ft.	TOTAL LENGTH %	MEAN WIDTH ft.	MEAN DEPTH ft.	MAXIMUM DEPTH ft.	MEAN AREA sq.ft.	TOTAL AREA EST. sq.ft.	MEAN VOLUME cu.ft.	TOTAL VOLUME EST. cu.ft.	MEAN RESIDUAL POOL VOL cu.ft.	MEAN SHELTER RATING	MEAN CANOPY %
166	164	LGR	24	31	5208	23	8	0.3	2.5	203	33643	69	11445	18	15	82
10	10	HGR	1	39	387	2	10	0.6	1.3	279	2791	184	1842	0	54	93
2	2	CAS	0	25	49	0	15	0.6	1.2	90	180	56	113	0	170	93
3	3	POW	0	60	179	1	13	0.7	1.6	555	1664	383	1149	0	47	93
116	116	GLD	17	31	3615	16	8	0.4	1.6	245	28466	109	12693	0	12	85
98	97	RUN	14	39	3818	17	6	0.4	1.5	207	20288	89	8752	0	22	81
8	8	SRN	1	56	447	2	8	0.6	1.5	298	2383	197	1576	148	43	94
49	49	MCP	7	22	1087	5	10	1.0	3.8	226	11091	228	11164	188	43	80
2	2	CCP	0	23	46	0	9	1.0	2.4	205	409	202	404	161	30	85
10	10	STP	1	53	533	2	9	0.8	4.1	258	2582	212	2119	113	70	96
6	6	CRP	1	31	184	1	8	1.0	3.4	249	1493	269	1613	223	23	68
27	27	LSL	4	22	607	3	8	1.2	9.0	191	5145	220	5932	178	62	81
92	92	LSR	13	28	2566	11	9	1.0	4.2	254	23385	281	25863	232	52	86
56	56	LSBk	8	28	1566	7	11	1.2	16.0	295	16539	378	21187	324	24	80
15	15	LSBo	2	24	360	2	8	0.9	2.2	195	2931	199	2992	152	23	88
11	11	PLP	2	15	166	1	14	1.4	5.3	233	2563	432	4750	354	60	91
9	9	SCP	1	18	165	1	4	0.8	2.5	69	622	65	589	53	64	83
2	2	BPB	0	13	25	0	5	0.7	1.1	70	139	43	86	21	0	93
2	2	BPR	0	17	33	0	6	0.9	2.5	98	197	99	198	86	0	83
3	2	BPL	0	15	46	0	5	0.7	2.8	78	234	59	177	43	15	68
2	2	DPL	0	213	425	2	23	2.5	4.8	4854	9707	12356	24711	11216	45	65
11	0	DRY	2	123	1358	6	0	0.0	0.0	0	0	0	0	0	0	91

TOTAL UNITS	TOTAL UNITS	LENGTH (ft.)	AREA (sq.ft)	TOTAL VOL. (cu.ft)
700	685	22870	166449	139354

Felta Creek

Drainage: Mill Creek

Table 3 · SUMMARY OF POOL TYPES

Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	TOTAL AREA EST. (sq.ft.)	MEAN VOLUME (cu.ft.)	TOTAL VOLUME EST. (cu.ft.)	MEAN RESIDUAL POOL VOL. (cu.ft.)	MEAN SHELTER RATING
61	61	MAIN	21	27	1666	21	9.8	0.9	231	14082	224	13686	175	49
207	207	SCOUR	72	26	5450	70	9.6	1.1	251	52052	301	62358	250	45
18	17	BACKWATER	6	39	694	9	6.4	1.0	637	11457	1512	27214	1365	41

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq.ft.)	TOTAL VOL. (cu.ft.)
286	285	7810	77591	103258

Felta Creek

Drainage: Mill Creek

Table 4 - SUMMARY OF MAXIMUM POOL DEPTHS BY POOL HABITAT TYPES

Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

UNITS MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	<1 FOOT MAXIMUM DEPTH	<1 FOOT PERCENT OCCURRENCE	1-<2 FT. MAXIMUM DEPTH	1-<2 FOOT PERCENT OCCURRENCE	2-<3 FT. MAXIMUM DEPTH	2-<3 FOOT PERCENT OCCURRENCE	3-<4 FT. MAXIMUM DEPTH	3-<4 FOOT PERCENT OCCURRENCE	>=4 FEET MAXIMUM DEPTH	>=4 FEET PERCENT OCCURRENCE
49	MCP	17	5	10	31	63	9	18	4	8	0	0
2	CCP	1	1	50	0	0	1	50	0	0	0	0
10	STP	3	0	0	6	60	3	30	0	0	1	10
6	CRP	2	0	0	4	67	1	17	1	17	0	0
27	LSL	9	5	19	14	52	6	22	1	4	1	4
92	LSR	32	5	5	54	59	23	25	8	9	2	2
56	LSBk	20	5	9	30	54	15	27	5	9	1	2
15	LSBo	5	0	0	12	80	3	20	0	0	0	0
11	PLP	4	1	9	3	27	4	36	1	9	2	18
9	SCP	3	2	22	5	56	2	22	0	0	0	0
2	BPB	1	0	0	2	100	0	0	0	0	0	0
2	BPR	1	0	0	1	50	1	50	0	0	0	0
3	BPL	1	1	33	1	33	1	33	0	0	0	0
2	DPL	1	0	0	0	0	0	0	0	0	2	100

TOTAL UNITS
286

Felta Creek Drainage: Mill Creek

Table 5 - SUMMARY OF MEAN PERCENT COVER BY HABITAT TYPE Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	MEAN % UNDERCUT BANKS	MEAN % SWD	MEAN % LWD	MEAN % ROOT MASS	MEAN % TERR. VEGETATION	MEAN % AQUATIC VEGETATION	MEAN % WHITE WATER	MEAN % BOULDERS	MEAN % BEDROCK LEDGES
166	164	LGR	39	4	6	8	6	2	1	30	5
10	10	HGR	0	0	1	0	0	0	33	66	0
2	2	CAS	0	5	5	0	0	0	49	42	0
3	3	POW	7	0	0	0	0	0	0	93	0
116	116	GLD	60	4	7	8	11	1	0	7	0
98	97	RUN	37	10	13	14	10	5	1	10	0
8	8	SRN	1	7	0	1	0	0	31	50	11
49	49	MCP	30	10	11	6	6	8	5	13	11
2	2	CCP	10	20	40	20	0	0	0	10	0
10	10	STP	2	4	7	5	0	1	26	55	1
6	6	CRP	69	8	0	5	6	12	0	0	0
27	27	LSL	18	22	44	10	2	0	0	4	0
92	92	LSR	34	11	14	31	6	3	0	0	0
56	56	LSBk	39	7	9	6	6	8	2	11	12
15	15	LSBo	25	10	0	3	0	0	0	55	8
11	11	PLP	32	5	31	7	0	0	7	16	3
9	9	SCP	38	13	8	14	12	6	0	3	6
2	2	BPB	0	0	0	0	0	0	0	0	0
2	2	BPR	0	0	0	0	0	0	0	0	0
3	2	BPL	65	0	35	0	0	0	0	0	0
2	2	DPL	8	5	0	43	45	0	0	0	0
11	2	DRY	0	0	0	0	0	0	0	0	0

Felta Creek Drainage: Mill Creek

Table 6 - SUMMARY OF DOMINANT SUBSTRATES BY HABITAT TYPE Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

TOTAL HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	% TOTAL SILT/CLAY DOMINANT	% TOTAL SAND DOMINANT	% TOTAL GRAVEL DOMINANT	% TOTAL SM COBBLE DOMINANT	% TOTAL LG COBBLE DOMINANT	% TOTAL BOULDER DOMINANT	% TOTAL BEDROCK DOMINANT
166	164	LGR	0	1	93	3	1	1	2
10	10	HGR	0	0	20	0	10	50	20
2	2	CAS	0	0	0	0	0	0	100
3	3	POW	0	33	67	0	0	0	0
116	116	GLD	0	20	73	3	1	0	3
98	97	RUN	0	12	82	1	1	0	4
8	8	SRN	0	0	50	13	0	25	13
49	49	MCP	2	49	35	0	0	2	12
2	2	CCP	0	50	50	0	0	0	0
10	10	STP	0	20	20	0	10	50	0
6	6	CRP	0	67	33	0	0	0	0
27	27	LSL	0	52	48	0	0	0	0
92	92	LSR	0	53	42	3	0	0	1
56	56	LSBk	0	57	30	2	2	4	7
15	15	LSBo	0	33	53	7	0	0	7
11	11	PLP	0	91	9	0	0	0	0
9	9	SCP	0	44	22	0	0	0	33
2	2	BPB	0	50	0	0	0	0	50
2	2	BPR	0	0	50	0	0	0	50
3	2	BPL	0	67	0	0	0	0	33
2	2	DPL	0	0	100	0	0	0	0
11	2	DRY	0	0	100	0	0	0	0

Felta Creek Drainage: Mill Creek

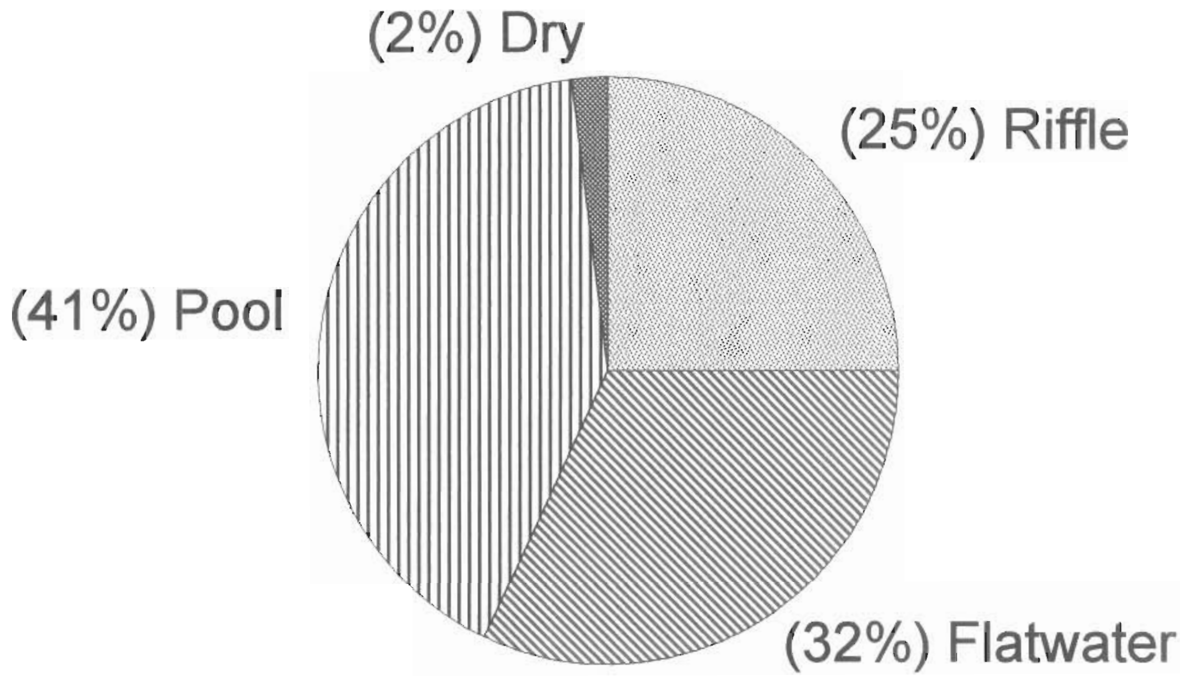
Table 10 - Summary of Shelter Type Areas by Habitat Type Survey Dates: 06/06/95 to 07/19/95

Confluence Location: QUAD: HEALD&GUER LEGAL DESCRIPTION: T09NR09WS32 LATITUDE: 38°34'52" LONGITUDE: 122°52'56"

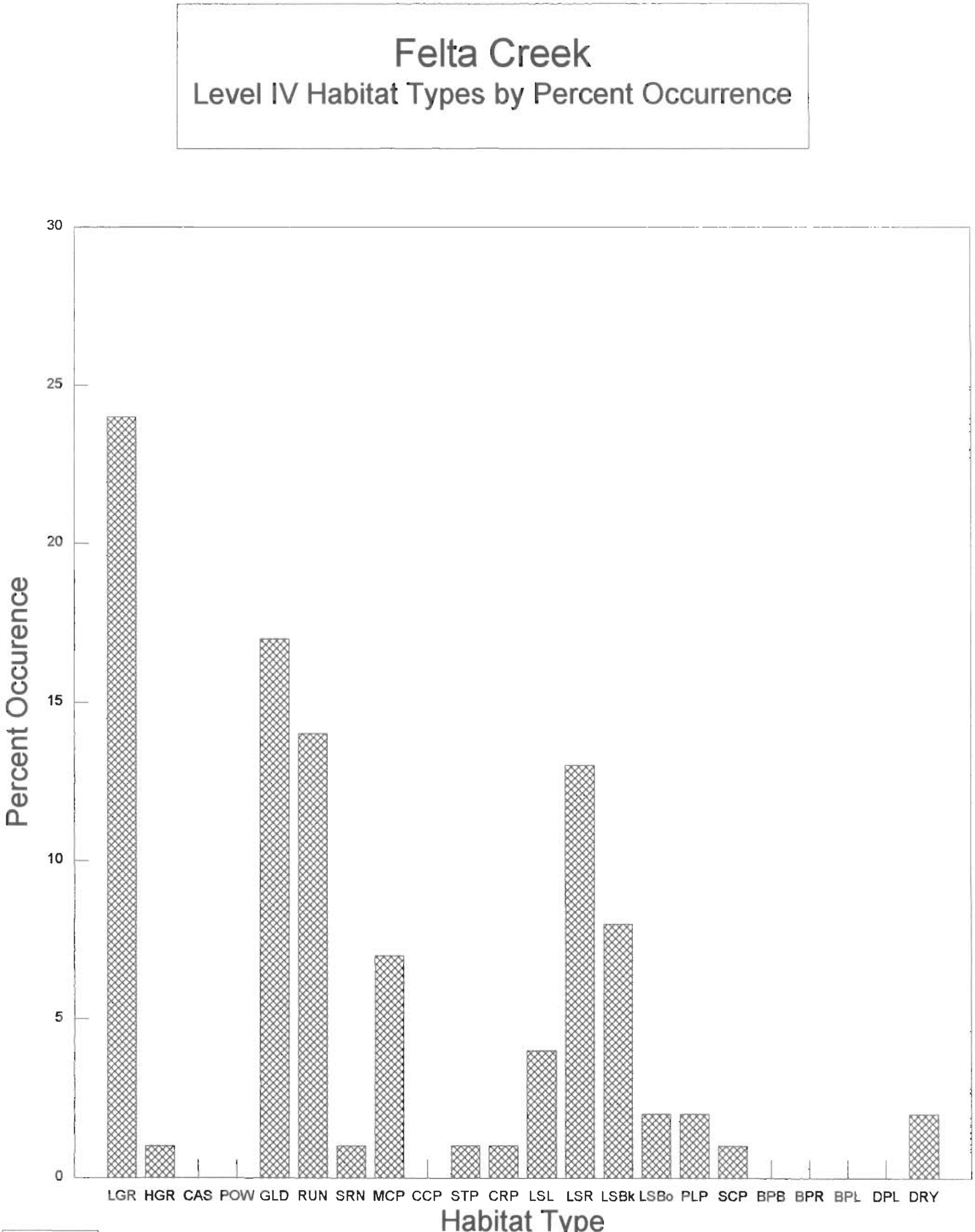
UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	SQ. FT. UNDERCUT BANKS	SQ. FT. SWD	SQ. FT. LWD	SQ. FT. ROOT MASS	SQ. FT. TERR. VEGETATION	SQ. FT. AQUATIC VEGETATION	SQ. FT. WHITE WATER	SQ. FT. BOULDERS	SQ. FT. BEDROCK LEDGES
166	164	LGR	296	68	114	59	73	21	35	898	76
10	10	HGR	0	0	10	0	0	0	347	799	0
2	2	CAS	0	27	27	0	0	0	222	219	0
3	3	POW	19	0	0	0	0	0	0	526	0
116	116	GLD	812	118	89	150	345	7	0	117	2
98	97	RUN	610	150	177	201	89	18	17	165	0
8	8	SRN	15	31	0	15	0	0	197	514	122
49	49	MCP	385	173	202	99	128	116	58	84	127
2	2	CCP	4	8	16	8	0	0	0	4	0
10	10	STP	76	29	47	97	0	8	494	1139	3
6	6	CRP	124	18	0	11	12	27	0	0	0
27	27	LSL	195	320	659	169	48	0	0	16	0
92	92	LSR	1742	661	1118	1760	213	126	13	0	19
56	56	LSBk	1159	138	105	119	82	135	14	80	142
15	15	LSBo	44	40	0	15	0	0	0	212	103
11	11	PLP	120	33	141	21	0	0	27	27	12
9	9	SCP	71	37	38	15	30	13	0	0	4
2	2	BPB	0	0	0	0	0	0	0	0	0
2	2	BPR	0	0	0	0	0	0	0	0	0
3	2	BPL	13	0	7	0	0	0	0	0	0
2	2	DPL	42	165	0	238	1481	0	0	0	0
11	0	DRY	0	0	0	0	0	0	0	0	0
TOTAL 700	685		5727	2016	2750	2977	2501	471	1424	4800	610

Felta Creek

Level II Habitat Types by % Occurrence



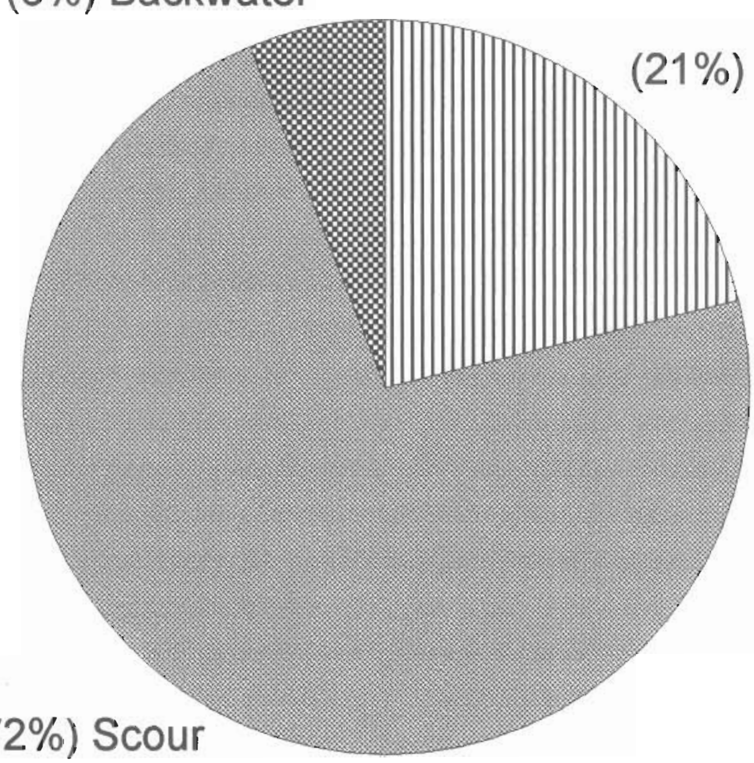
Graph 1


Felta Creek
Level IV Habitat Types by Percent Occurrence
30
25
20
15
10
5
0
Percent Occurence
LGR
HGR
CAS
POW
GLD
RUN
SRN
MCP
CCP
STP
CRP
LSL
LSR
LSBk
LSBo
PLP
SCP
BPB
BPR
BPL
DPL
DRY
Habitat Type

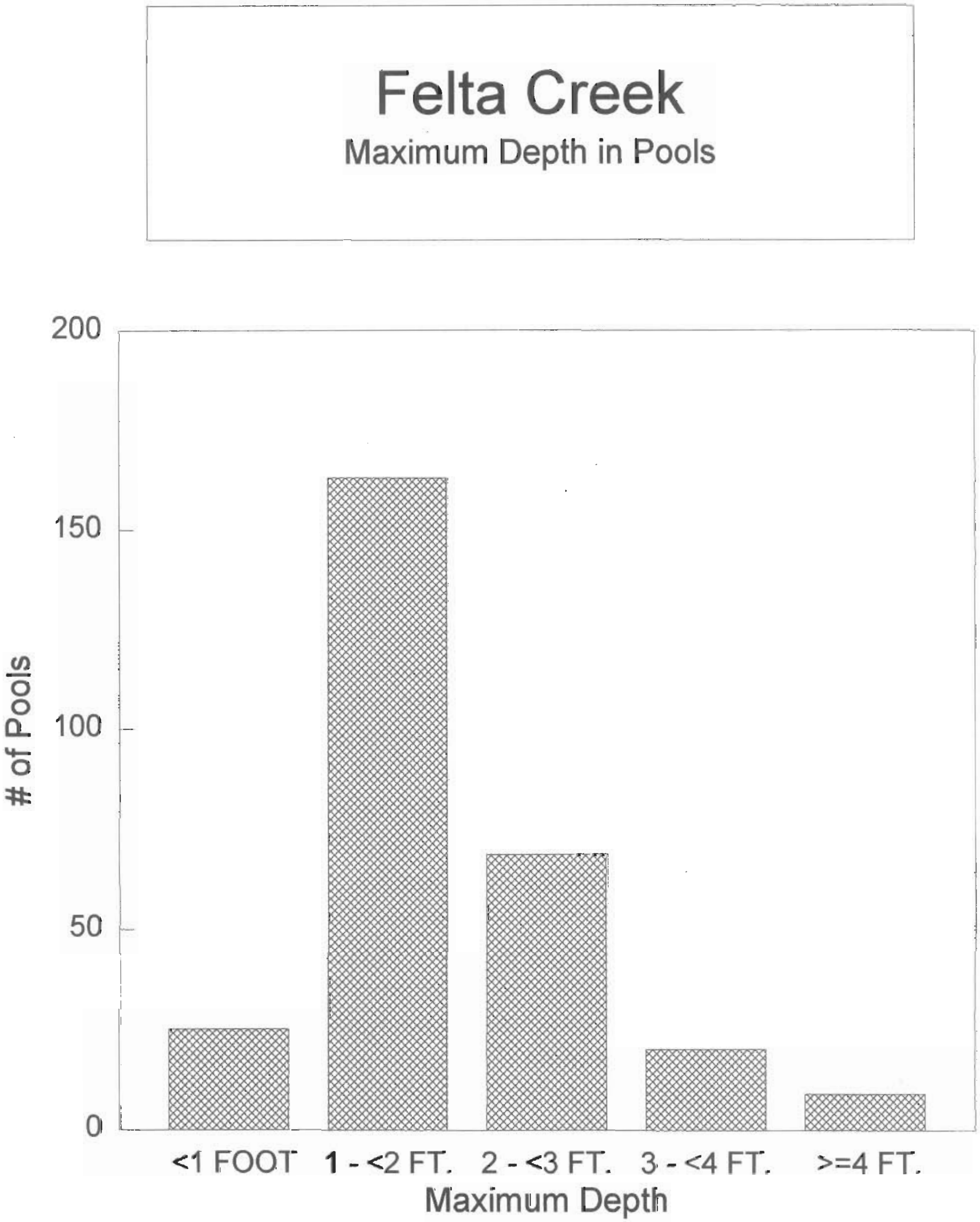
Graph 2

Felta Creek

Pool Habitat Types by % Occurrence



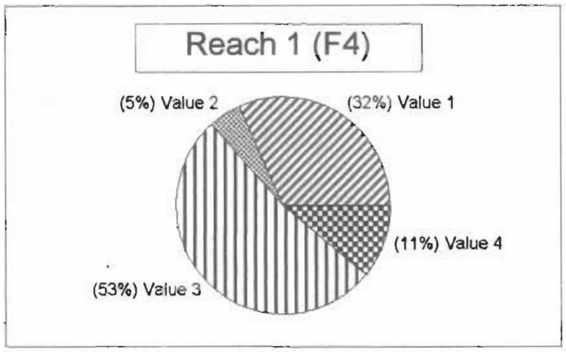
Graph 3

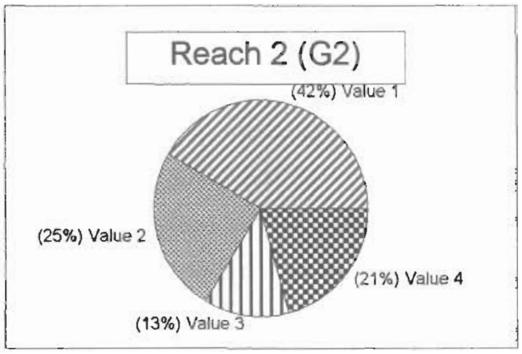

Felta Creek
Maximum Depth in Pools
200
150
100
50
0
# of Pools
<1 FOOT
1 - <2 FT.
2 - <3 FT.
3 - <4 FT.
>=4 FT.
Maximum Depth

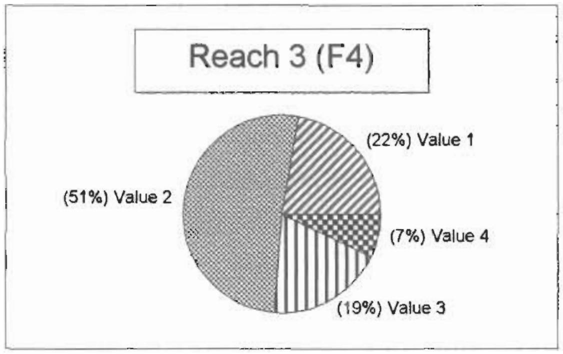
Graph 4

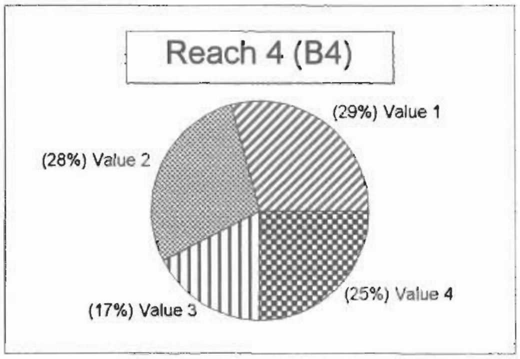
Felta Creek

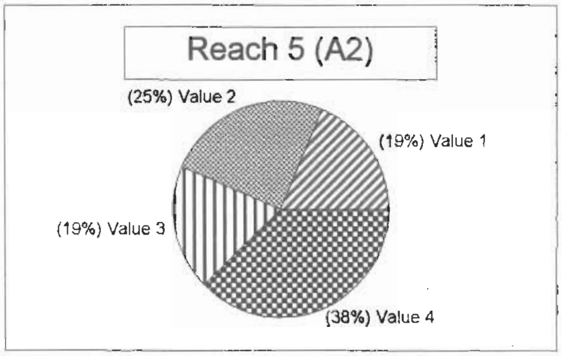
Percent Embeddedness by Reach









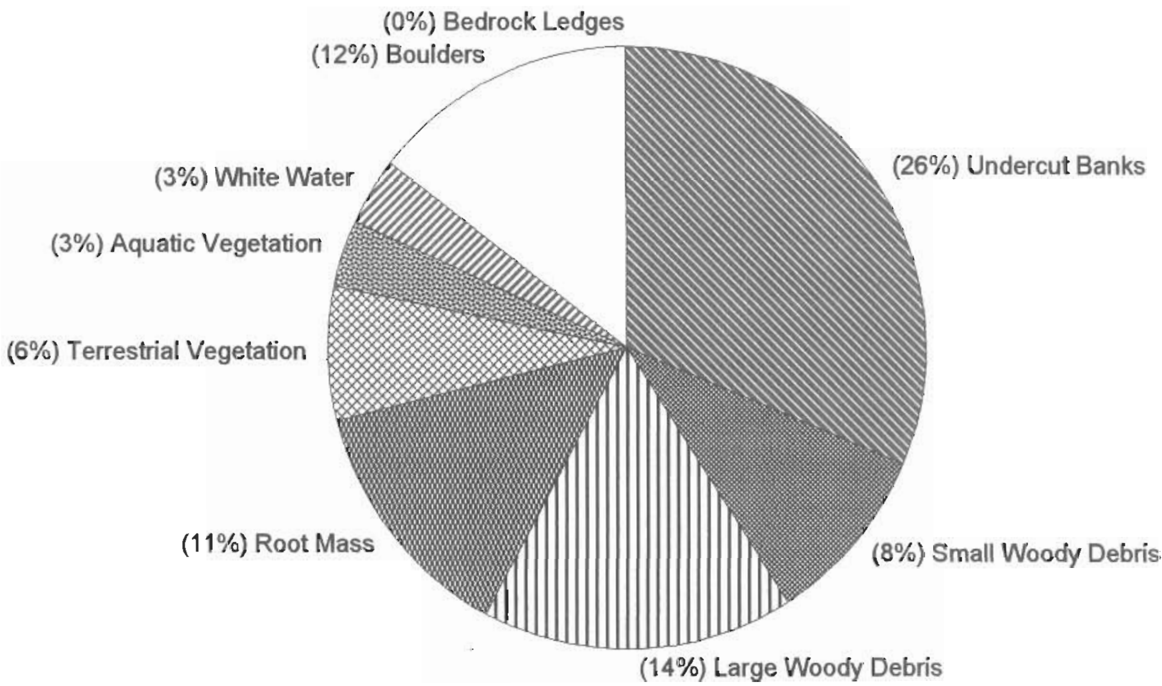


Value 1 = <25% Value 2 = 25-50% Value 3 = 51-75% Value 4 = >76%

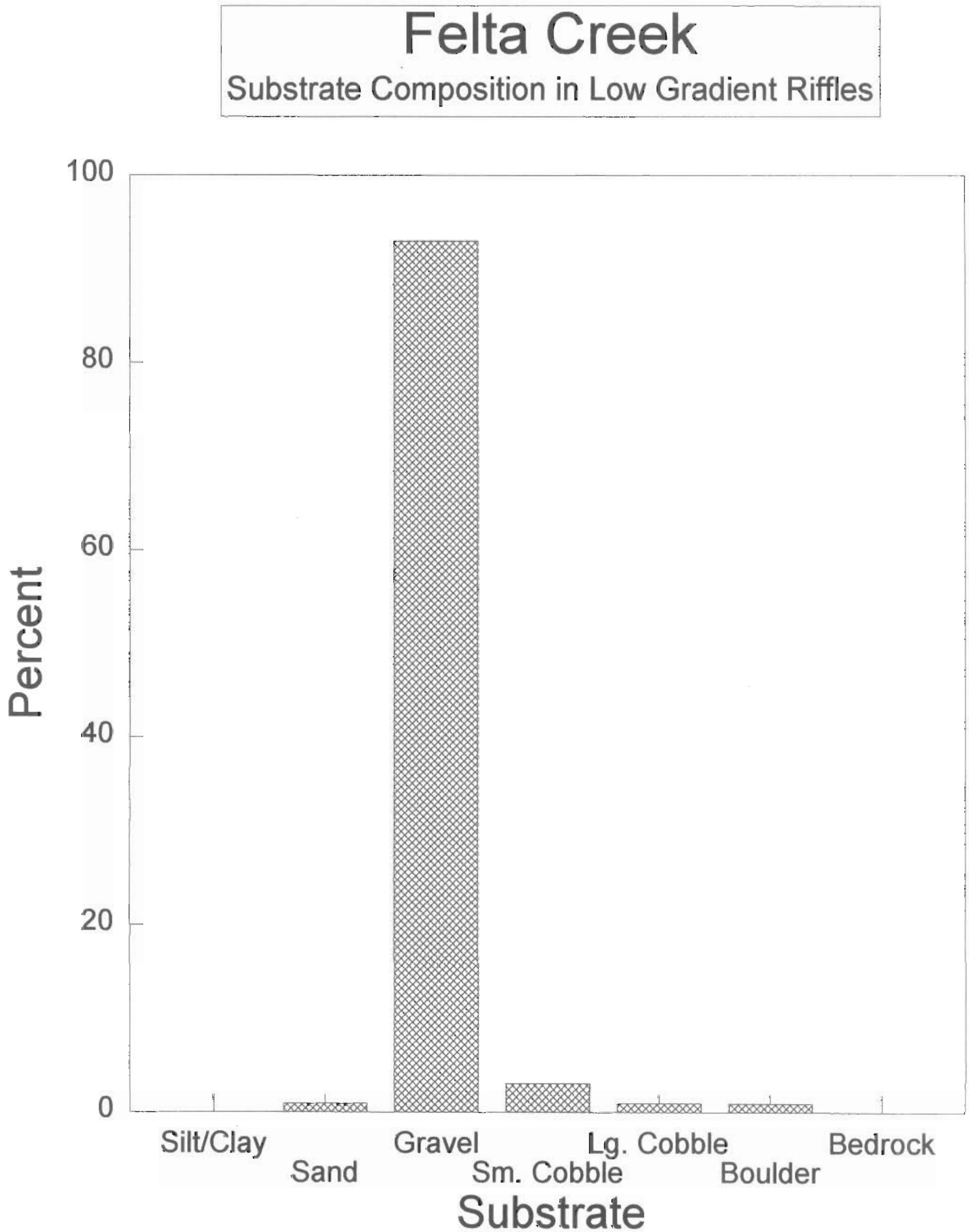
Graph 5

Felta Creek

Mean Percent Cover Types In Pools



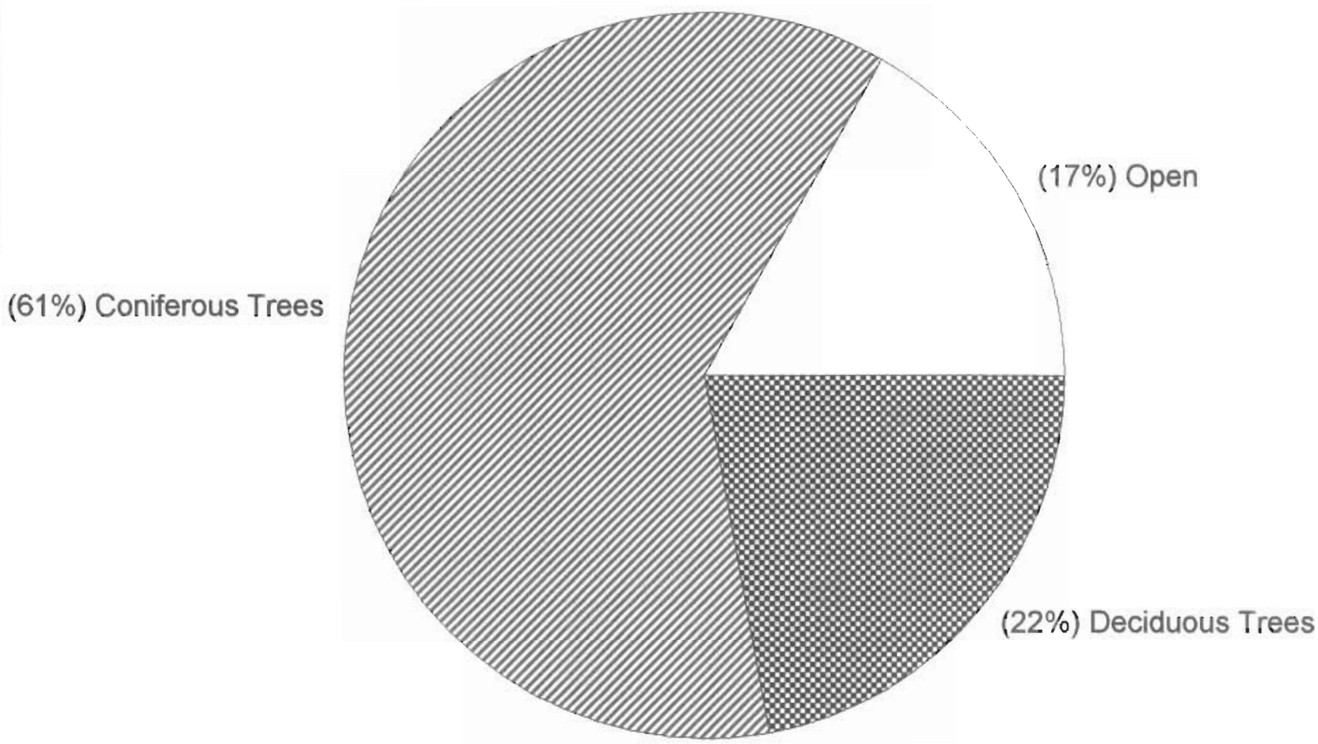
Graph 6


Felta Creek
Substrate Composition in Low Gradient Riffles
100
80
60
40
20
0
Percent
Silt/Clay
Sand
Gravel
Sm. Cobble
Lg. Cobble
Boulder
Bedrock
Substrate

Graph 7

Felta Creek

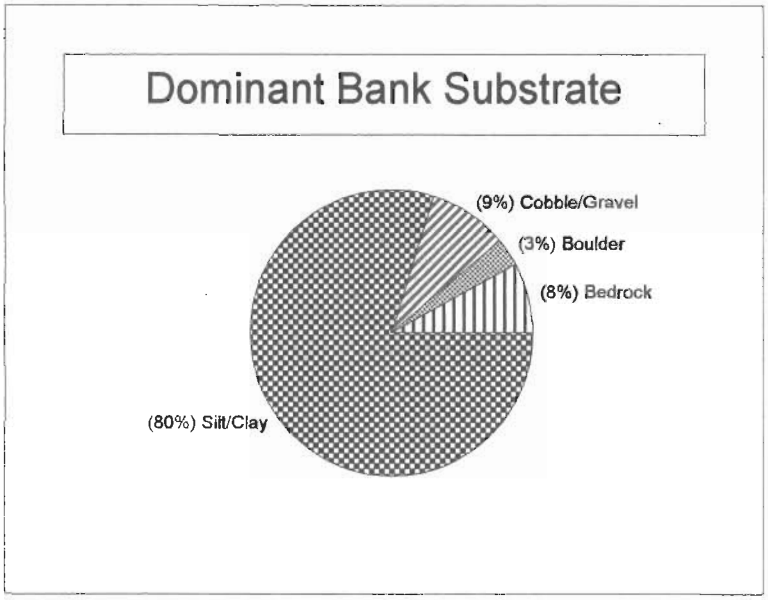
Percent Canopy

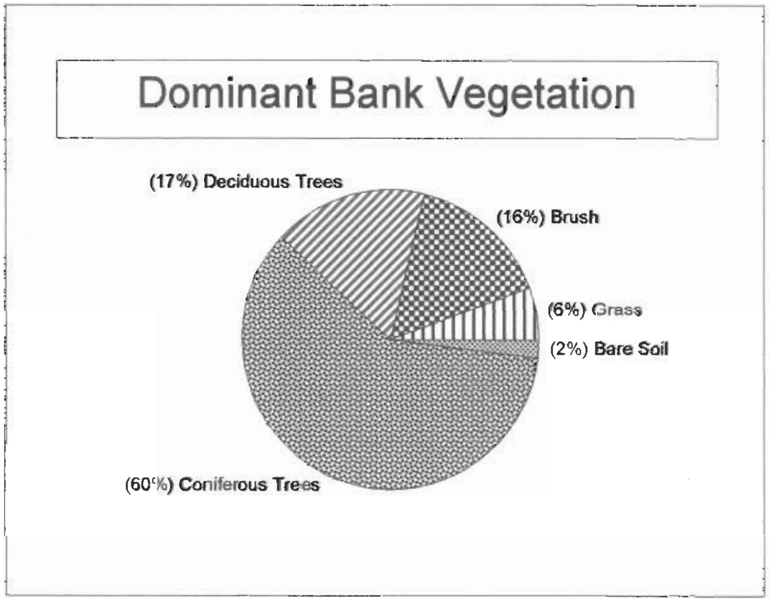


Graph 8

Felta Creek

Percent Bank Composition

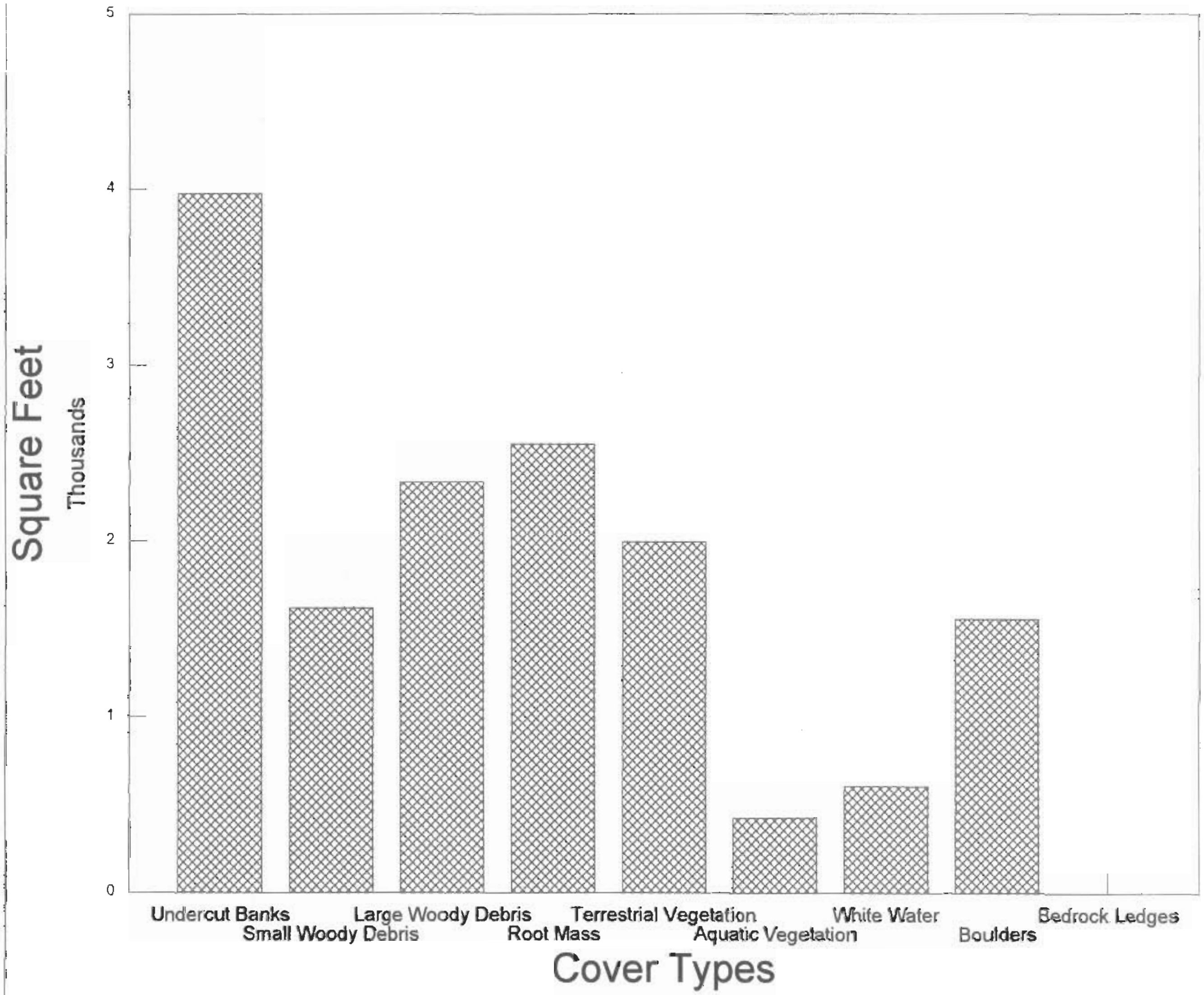




Graph 9

Felta Creek

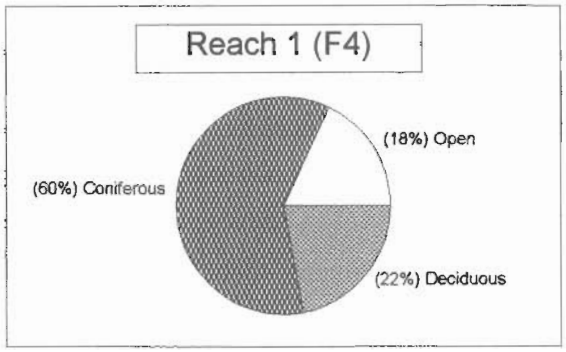
Cover Type Areas in Pools

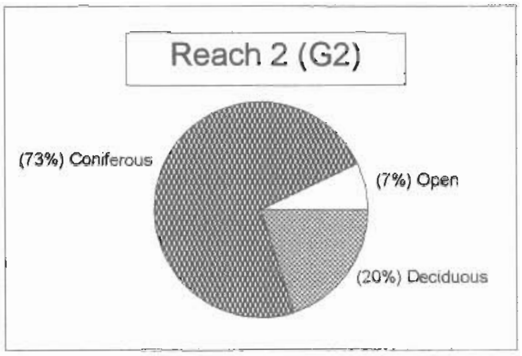


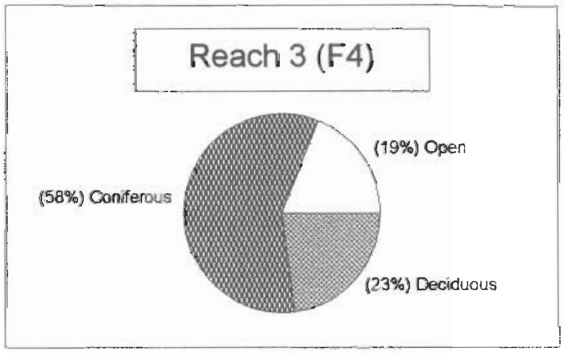
Graph 10

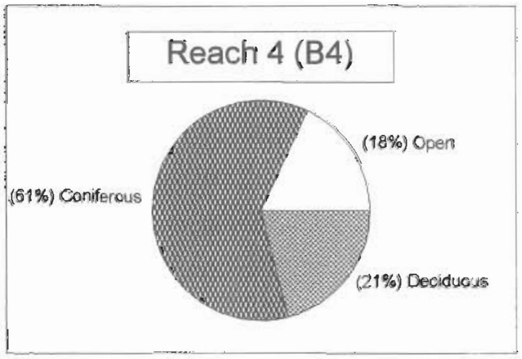
Felta Creek

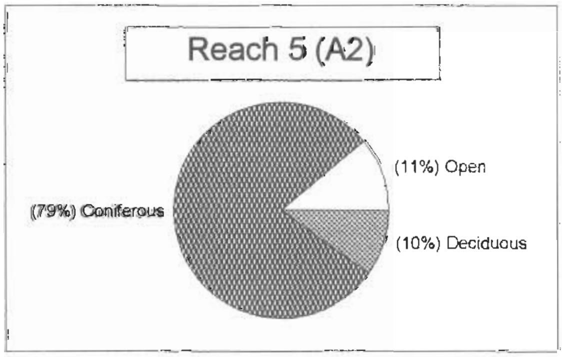
Percent Canopy by Reach



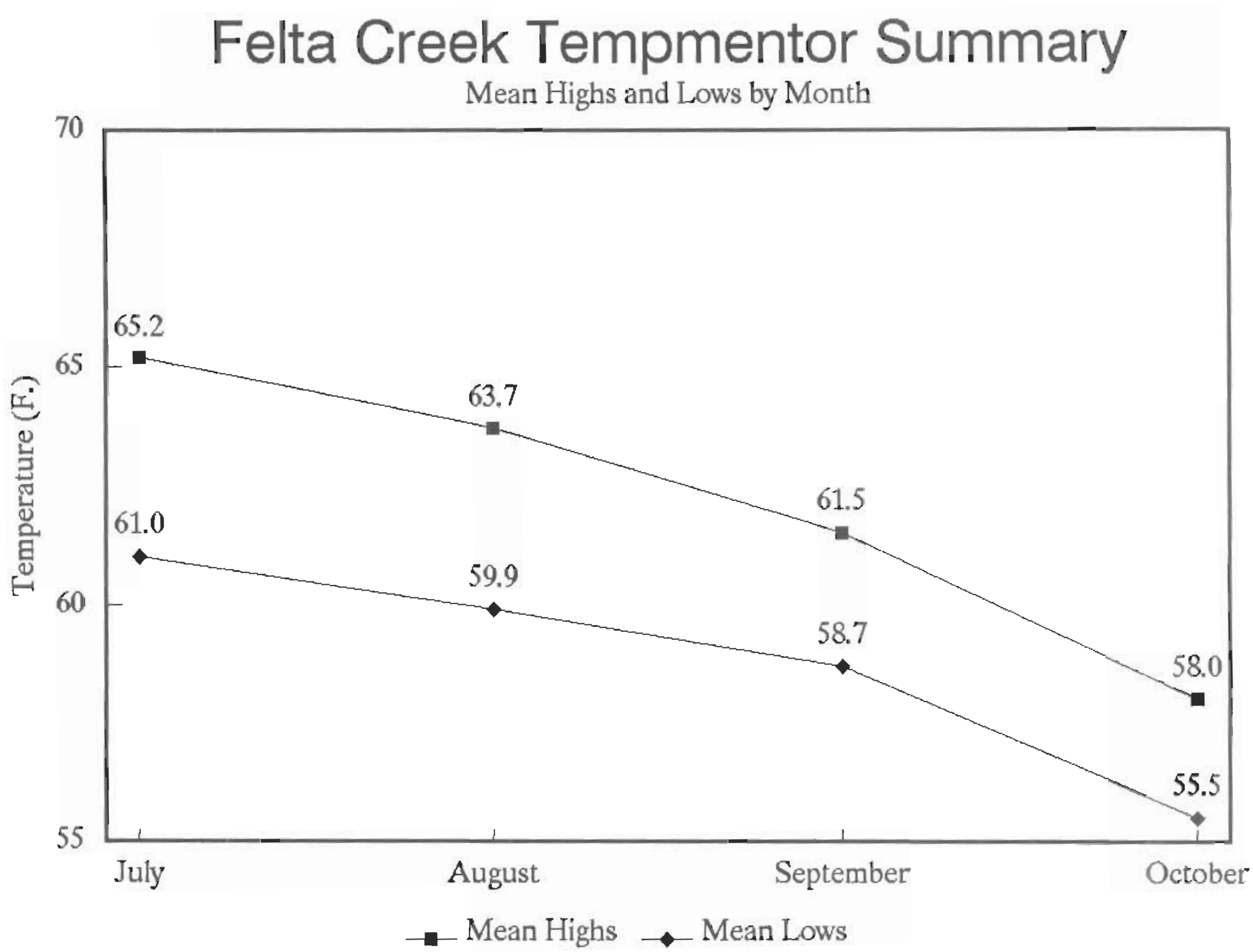




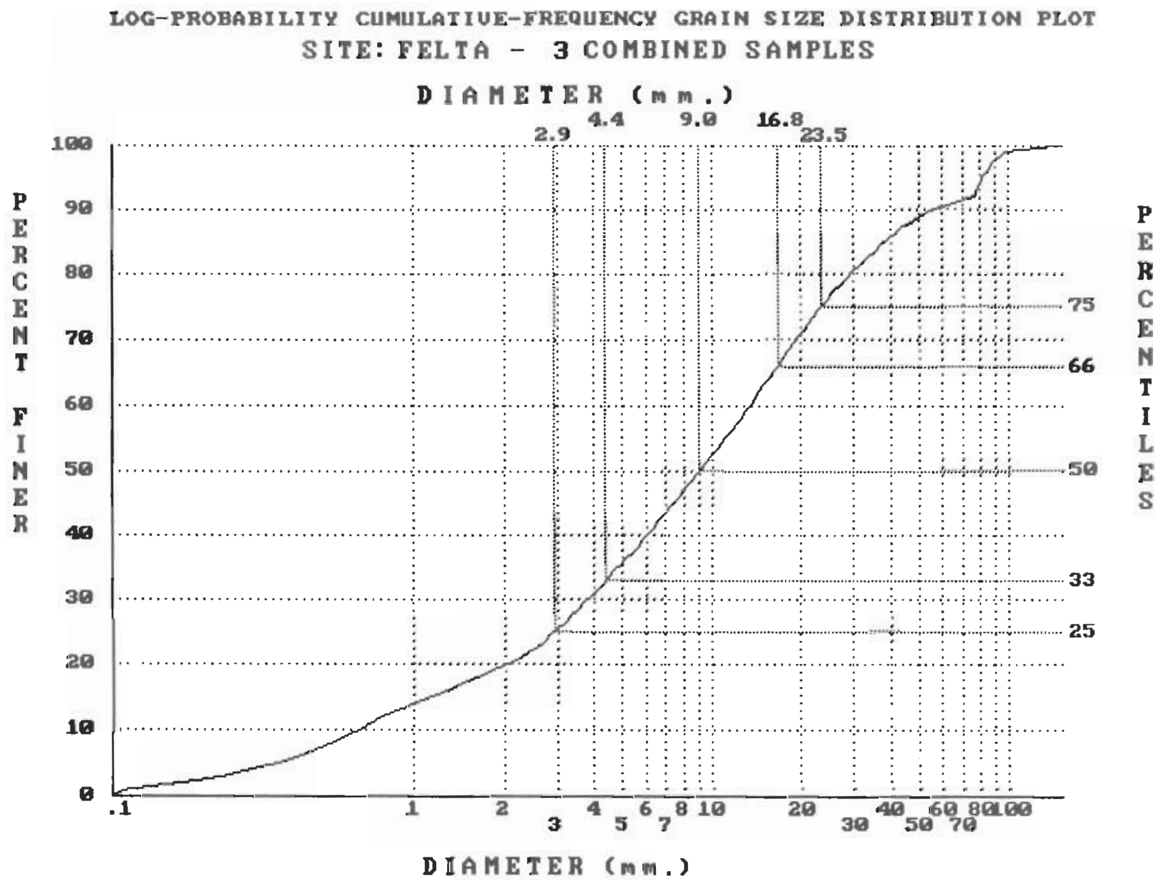




Graph 11



Felta Creek Tempmentor Summary
Mean Highs and Lows by Month
70
65
60
55
Temperature (F.)
65.2
63.7
61.5
58.0
61.0
59.9
58.7
55.5
July
August
September
October
Mean Highs
Mean Lows


LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: FELTA - 3 COMBINED SAMPLES
DIAMETER (mm.)
2.9
4.4
9.0
16.8
23.5
PERCENT FINER
100
90
80
70
60
50
40
30
20
10
0
PERCENTILES
75
66
50
33
25
.1
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
DIAMETER (mm.)

CALIFORNIA DEPARTMENT OF FISH AND GAME
STREAM INVENTORY REPORT

Wallace Creek

Report Revised April 14, 2006

Report Completed 2000

Assessment Completed 1995

INTRODUCTION

A stream inventory was conducted during the summer of 1995 on Wallace Creek to assess habitat conditions for anadromous salmonids. The inventory was conducted in two parts: habitat inventory and biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids in Wallace Creek. The objective of the biological inventory was to document the salmonid and other aquatic species present and their distribution. After analysis of historical information and data gathered recently, stream restoration and enhancement recommendations are presented.

WATERSHED OVERVIEW:

Wallace Creek is a tributary to Mill Creek, located in Sonoma County, California (see watershed map, page 2). Wallace Creek's legal description at the confluence with Mill Creek is T9N,R10W,S25. Its location is 38° 35' 55" N. latitude and 122° 54' 38" W. longitude. Wallace Creek is a second order stream and has approximately 5.8 miles of blue line stream, according to the USGS Geyserville and Guerneville 7.5 minute quadrangles. Wallace Creek drains a watershed of approximately 5.7 square miles in the form of a U shaped canyon. Elevations range from 280 feet at the mouth to 1000 feet at the headwaters. Douglas-fir, redwood, alder, willow, and oak dominate the watershed. Major land uses in the Wallace Creek watershed include paved and unpaved roads, livestock grazing, and timber harvest. All of the property along Wallace Creek is privately owned. Vehicle access exists from Wallace Creek Rd. via Mill Creek Rd., which is approximately 1 mile west on West Side Rd. from US Hwy 101, near Healdsburg.

The Northern Spotted owl *(Strix occidentalis caurina)* is listed in DFG's Natural Diversity Database as occurring within Mill Creek watershed. No sensitive plants were listed.

STREAM SURVEYS

The Department of Fish and Game conducted a brief survey of the entire stream on July 16, 1945. The stream was described as clear with low flows and a water temperature at 69°F. Pool and shelter conditions were described as good. It was noted that the stream was dry at the mouth with only isolated pools. This was also noted in August of 1946.

In 1961, a Fish and Game biologist noted that the upper 2/3 of Wallace Creek rarely receives a steelhead during spawning season. About 1/2 mile downstream from the extreme limits of the headwaters there was a dam. Upstream of the dam, no fish were observed and only two pools large enough to support fish were noted. The section below the dam contained only rainbow trout stocked by the owners of the dam and only occasionally had a steelhead migration when water conditions were at the optimum. On the day of the investigation, the stream for all purposes was dry from the dam downstream for a good 3 miles.

METHODS

The habitat inventory conducted in Wallace Creek follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1991). The Americorps members that conducted the inventory were trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG) under the supervision of DFG's Russian River Basin Planner, Robert Coey in September of 1995. This inventory was conducted by a two person team.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Wallace Creek to record measurements and observations. There are nine components to the inventory form.

1. Flow:

Flow is measured in cubic feet per second (cfs) at the bottom of the stream survey reach using standard flow measuring equipment, if available. In some cases flows are estimated. Flows were also measured or estimated at major tributary confluences.

2. Channel Type:

Channel typing is conducted according to the classification system developed and revised by David Rosgen (1985 rev. 1994). This methodology is described in the California Salmonid Stream Habitat Restoration Manual. Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are five measured parameters used to determine channel type: 1) water slope gradient, 2) entrenchment, 3) width/depth ratio, 4) substrate composition, and 5) sinuosity.

3. Temperatures:

Water and air temperatures, and time, are measured by crew members with hand held thermometers and recorded at each tenth unit typed. Temperatures are measured in Fahrenheit at the middle of the habitat unit and within one foot of the water surface.

4. Habitat Type:

Habitat typing uses the 24 habitat classification types defined by McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "DRY". Wallace Creek habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. All unit lengths were measured, additionally, the first occurrence of each unit type and a randomly selected 10% subset of all units were completely sampled (length, mean width, mean depth, maximum depth and pool tail crest depth). All measurements were in feet to the nearest tenth.

5. Embeddedness:

The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. In Wallace Creek, embeddedness was visually estimated. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value 4) or "not suitable" (value 5) was assigned to tail-outs deemed unsuited for spawning due to inappropriate substrate particle size, having a bedrock tail-out, or other considerations.

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All shelter is then classified according to a list of nine shelter types. In Wallace Creek, a standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) was assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all fully measured habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes.

8. Canopy:

Stream canopy density was estimated using modified handheld spherical densiometers as described in the California Salmonid Stream Habitat Restoration Manual, 1998. Canopy density relates to the amount of stream shaded from the sun. In Wallace Creek, an estimate of the percentage of the habitat unit covered by canopy was made from the center of approximately every third unit in addition to every fully-described unit, giving an approximate 30% sub-sample. In addition, the area of canopy was estimated visually into percentages of evergreen or deciduous trees.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In Wallace Creek, the dominant composition type and the dominant vegetation type of both the right and left banks for each fully measured unit were selected from the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

SUBSTRATE SAMPLING

Gravel sampling is generally conducted to determine the percentage of fine sediment present in low gradient riffles at the tail-outs of pools. The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence.

A substrate sample was taken in a potential spawning riffle in reach 1 of Wallace Creek on December 1, 1995. The sample was placed through a series of sieves with diameters of .85mm, 2.37mm, 4.7mm, 12.5mm, 25.4mm, 50.8mm, 76.2mm and 150mm. Displacement volumes were measured for particles in each size classification. Finally, the remaining sample less than 0.85mm was placed in Imhoff cones for 1 hour with the volume of fines settled out measured.

BIOLOGICAL INVENTORY

Biological sampling during stream inventory is used to determine fish species and their distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. These sampling techniques are discussed in the California Salmonid Stream Habitat Restoration Manual.

DATA ANALYSIS

Data from the habitat inventory form are entered into the Habitat Program, a DBASE 4.1 data entry program developed by the California Department of Fish and Game (DFG). This program also processes and summarizes the data.

The Habitat Runtime program produces the following tables:

- Riffle, flatwater, and pool habitat types
- Habitat types and measured parameters
- Pool types
- Maximum pool depths by habitat types
- Dominant substrates by habitat types
- Shelter type areas by habitat types

Graphics are produced from the tables using Lotus 1,2,3. Graphics developed for Wallace Creek include:

- Level II Habitat Types by % Occurrence
- Level IV Habitat Types by % Occurrence
- Pool Habitat Types by % Occurrence
- Maximum Depth in Pools
- Percent Embeddedness
- Percent Cover Types in Pools
- Substrate Composition in Low Gradient Riffles
- Mean Percent Canopy
- Percent Bank Composition

HABITAT INVENTORY RESULTS

* ALL TABLES AND GRAPHS ARE LOCATED AT THE END OF THE REPORT*

The habitat inventory of September 25-26, 1995 was conducted by Ken Mogan and Kurt Gregory. The survey began at the confluence with Mill Creek and continued up Wallace Creek to the end of survey. The total length of the stream surveyed was 7513 feet.

A flow of 0.046 cfs was taken on July 29, 1995 below the Mill Creek crossing with a Marsh-McBirney Model 2000 flowmeter.

This section of Wallace Creek has one channel type, an F4. F4 types are meandering, well confined, gentle gradient (< 2%) gravel channels.

Water temperatures ranged from 57°F to 67°F. Air temperatures ranged from 59°F to 73°F.

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. By percent occurrence, pools made up 38%, flatwater types 29%, and riffles 25% (Graph 1). Pool habitat types made up 35% of the total survey **length**, flatwater 32% and riffles 26%.

Eleven Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent **occurrence** were low gradient riffles, 25%; glides, 16%; runs, 13%; and root wad scours, 12% (Graph 2). By percent total **length**, low gradient riffles made up 26%, glides 18%, runs 14%, and root wad scours 10%.

Forty-Nine pools were identified (Table 3). Scour pools were most often encountered at 82%, and comprised 84% of the total length of pools (Graph 3).

Table 4 is a summary of maximum pool depths by pool habitat types. Depth is an indicator of pool quality. Twenty-seven of the 49 pools (55%) had a depth of two feet or greater (Graph 4).

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Pool types had the highest mean shelter rating at 31. Riffles had the lowest rating with 13 and flatwater types rated 15 (Table 1). Of the pool types, the Scour pools had the highest mean shelter rating at 33, Main channel pools rated 26, and Backwater pools 15 (Table 3).

Table 10 summarizes cover by habitat type. Boulders are the dominant cover type for all habitat types. Boulders are also the dominant cover type for pools. Undercut banks and terrestrial vegetation are the next most common cover types for pools. Graph 6 describes the pool cover in Wallace Creek.

Nearly 28% of Wallace Creek lacked shade canopy. Of the 72% of the stream that was covered with canopy, 49% was composed of deciduous trees, and 51% was composed of coniferous trees. Graphs 8 and 11 describe the canopy in Wallace Creek.

Table 2 summarizes the mean percentage of the right and left stream banks covered with vegetation by habitat type. For the stream reach surveyed, the mean percent right bank vegetated was 59% and the mean percent left bank vegetated was 78%. For the habitat units measured, the dominant vegetation types for the stream banks were: 46% coniferous trees, 35% deciduous trees, 8% brush, 6% grass and 4% bare soil. The dominant substrate for the stream banks were: 44% cobble/gravel, 27% silt/clay/sand, 25% bedrock, 4% boulder (Graph 9).

SUBSTRATE SAMPLING

Table 6 and Graph 7 summarize the dominant substrate by habitat type. Gravel was the dominant substrate observed in 4 of the 6 low gradient riffles measured (67%).

The depth of cobble embeddedness was estimated at pool tail-outs. Of the 49 pool tail-outs measured, none had a value of 1; 8 had a value of 2 (16%); 9 had a value of 3 (18%); and 32 had a value of 4 (65%). On this scale, a value of one is best for fisheries (Graph 5).

Substrate sampling was conducted in the field by Morgan and Gregory (Americorps). Laboratory analysis was done by Fort, Huber, Nossaman, Sanchez (Americorps), Wilson and Hards (Interns) in May of 1996. The data was then summarized and analyzed with a computer program written by Dwain Goforth (National Park Service).

The analysis showed the sample to be 17.4% fines (<0.85 mm). The summary showed 75% of the substrate to be less than 14mm, 50% to be less than 5mm and 25% to be less than 1.43mm (see Grain Size Distribution Plot).

BIOLOGICAL INVENTORY

JUVENILE SURVEYS:

The only historical juvenile survey conducted by DFG on Wallace Creek was in 1968 when 19 tributaries of the Russian River were checked for juvenile coho salmon. Although no coho were found, steelhead, roach and sucker were noted.

A Biological inventory was taken on September 27 of 1995 on Wallace Creek. Each site was single pass electrofished using one Smith Root Model 12 electrofisher. Fish from each site were counted by species, and returned to the stream. Observers were Ken Mogan and Kurt Gregory.

The inventory of reach one was conducted near the second bridge in pool, run and riffle habitat types. Forty-eight 0+, 5 1+ and 3 2+ steelhead were found along with 95 roach, 10 sunfish, 2 crayfish and 1 sculpin.

According to DFG files no hatchery stocking, transfers or rescues have been conducted on Wallace Creek.

ADULT SURVEYS:

According to DFG files, no historical adult surveys have been conducted on Wallace Creek.

Due to shortage of staffing, no adult surveys were conducted in 1995.

DISCUSSION

The section of Wallace Creek surveyed was determined to be an F4 channel type. This channel type has a suitable gradient (<2%) and stable stream banks necessary for the installation of instream structures designed to increase pool habitat, trap spawning gravels, and provide protective cover for fish. F4 types are considered good for bank-placed boulders and fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover. They are poor for medium-stage weirs and boulder clusters. Well placed and engineered structures that constrict the channel to form pool habitat or cover structures are usually appropriate and have a good chance of success in this channel type.

The water temperatures recorded on the survey days September 25-26, 1995 ranged from 57°F to 67°F. Air temperatures ranged from 59°F to 73°F. The warmer temperatures, if sustained, are just above the threshold stress level for salmonids. To make any further conclusions, temperatures need to be monitored for a longer period of time through the critical summer months, and more extensive biological sampling conducted.

Pool habitat types comprised 35% of the total length of this survey. In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. The pools are relatively deep with 27 of the 49 pools having a maximum depth greater than 2 feet (55%). However, these pools comprised only 22% of the length of total stream habitat. In coastal coho and steelhead streams, it is generally desirable to have primary pools comprise approximately 50% of total habitat. Installing structures that will increase pool quantity, depth and shelter is recommended for locations where their installation will not jeopardize any unstable stream banks, or subject the structures to high stream energy.

The mean shelter rating for riffles was low with a rating of 13. The shelter rating in the flatwater habitats was better at 15. Pools rated highest at 31. However, a pool shelter rating of approximately 100 is desirable. The relatively small amount of pool cover that now exists is being provided primarily by boulders. Undercut banks and terrestrial vegetation are the next most common cover types for pools. Log and root wad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat. Log cover structure provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

The mean percent canopy for the survey reach was 72%. This is a fair percentage of canopy, since 80 percent is generally considered desirable. Elevated water temperatures could be reduced by increasing stream canopy. Cooler water temperatures are desirable in Wallace Creek. The large trees required to contribute shade would also eventually provide a long term source of large woody debris needed for instream structure and streambank stability.

Four of the six low gradient riffles measured (67%) had gravel as the dominant substrate. This is generally considered good for spawning salmonids.

Pool tail embeddedness, a measure of the suitability of spawning gravel was estimated. Forty-one of the 49 pool tail-outs measured (84%) had embeddedness ratings of 3 or 4. None had a 1 rating. Cobble embeddedness measured to be 25% or less, a rating of 1, is considered best for the needs of salmon and steelhead.

Substrate sampling is conducted to determine the percentage of fine sediment present in probable fish spawning areas. These areas are generally found in low gradient riffles at the tail-outs of pools.

The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence.

The gravel program analyzed the substrate sample data for egg to emergence survival rates for steelhead and coho. The survival rates are based on a 95% confidence interval and used the FredleIndex. Based on this index and the data on Wallace Creek, the mean egg to emergence survival rate would be 29% for steelhead and 7% for coho.

In Wallace Creek, sediment sources should be mapped and rated according to their potential sediment yields, and control measures taken.

SUMMARY

In general, Wallace Creek is marginal for salmonid habitat. Although the existing pools are relatively deep, more pools and better pool shelter is needed. Even though canopy levels are fair, water temperatures are close to the threshold stress level for salmonids. Although there is an adequate amount of gravel in the riffle habitats, this gravel is highly embedded, making it poor for spawning salmonids.

Biological surveys were conducted to document fish distribution and are not necessarily representative of population information. The 1995 spring survey documented 0+ fish indicating successful spawning in Wallace Creek. However, few 1+ fish were observed indicating poor rearing conditions the year before or poor holding-over conditions in general. Predatory green sunfish were found in the basin, likely spilled from upper farm ponds.

The F4 channel type of this stream is good for bank-placed boulders and fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover. Many site specific projects can be designed to increase pool frequency and shelter.

GENERAL RECOMMENDATIONS

Wallace Creek should be managed as an anadromous, natural production stream.

The winter 1995 and 1996 storms brought down many large trees and other woody debris into the stream, which increased the

number and quality of pools since the date of this survey. This woody debris, if left undisturbed, will provide fish cover and rearing habitat, and offset channel incision. Many signs of recent and historic tree and log removal were evident in the active channel during our survey. Misguided efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be educated about the natural and positive role woody debris plays in the system, and encouraged
not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

SPECIFIC FISHERY ENHANCEMENT RECOMMENDATIONS

1) In Wallace Creek, active and potential sediment sources related to the road system need to be mapped, and treated according to their potential for sediment yield to the stream and its tributaries.

2) Map sources of upslope and in-channel erosion, and prioritize them according to present and potential sediment yield. Identified sites should then be treated to reduce the amount of fine sediments entering the stream. Near-stream riparian planting along any portion of the stream should be encouraged to provide bank stability and a buffering against agricultural, grazing and urban runoff.

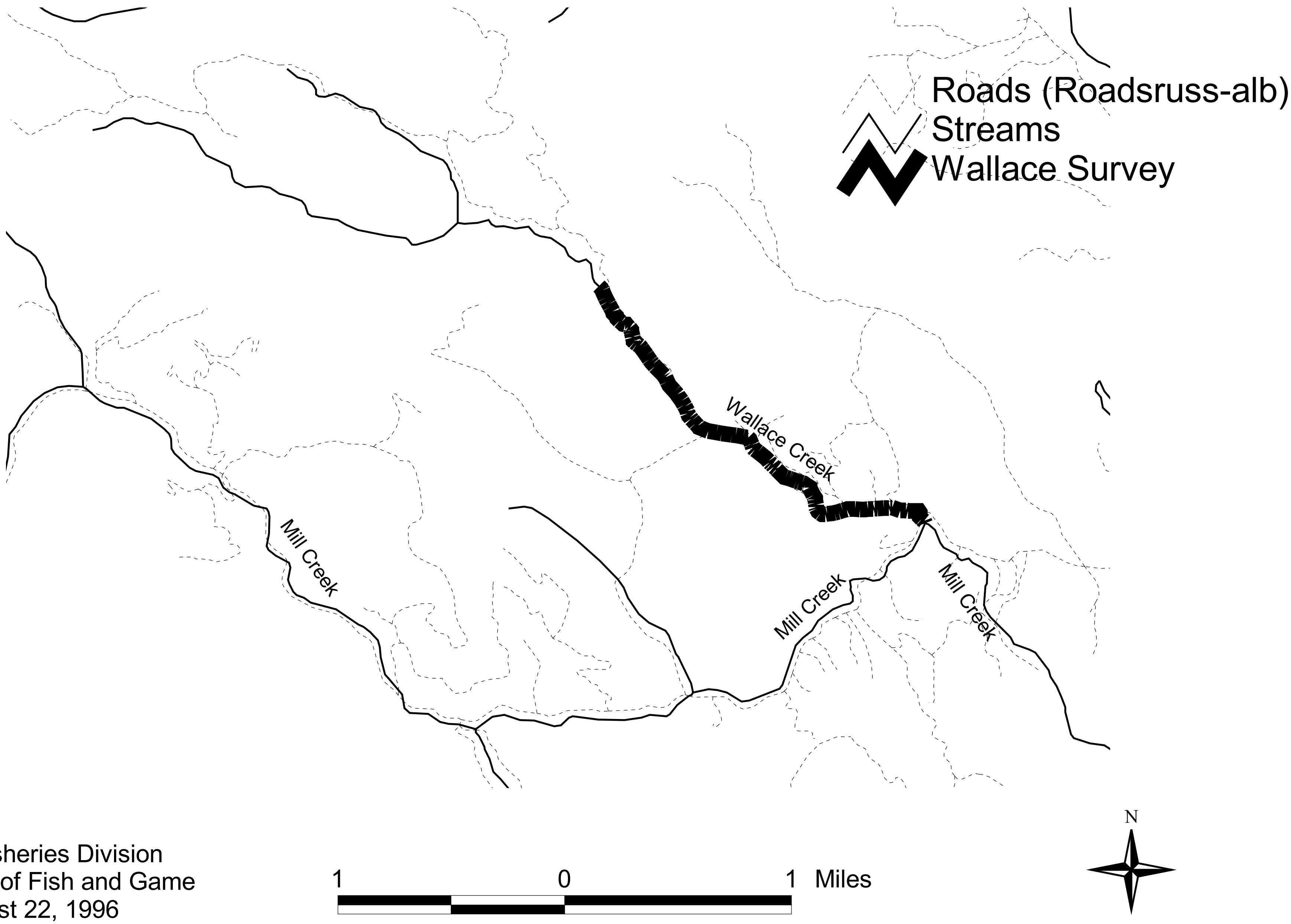
3) Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream. Most of the existing cover is from boulders and undercut banks. Adding high quality complexity with larger woody cover is desirable. Combination cover/scour structures constructed with woody debris would be effective in many flatwater and pool locations. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion. In some areas the material is at hand.

4) Where feasible, design and engineer pool enhancement structures to increase the number of pools. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion.

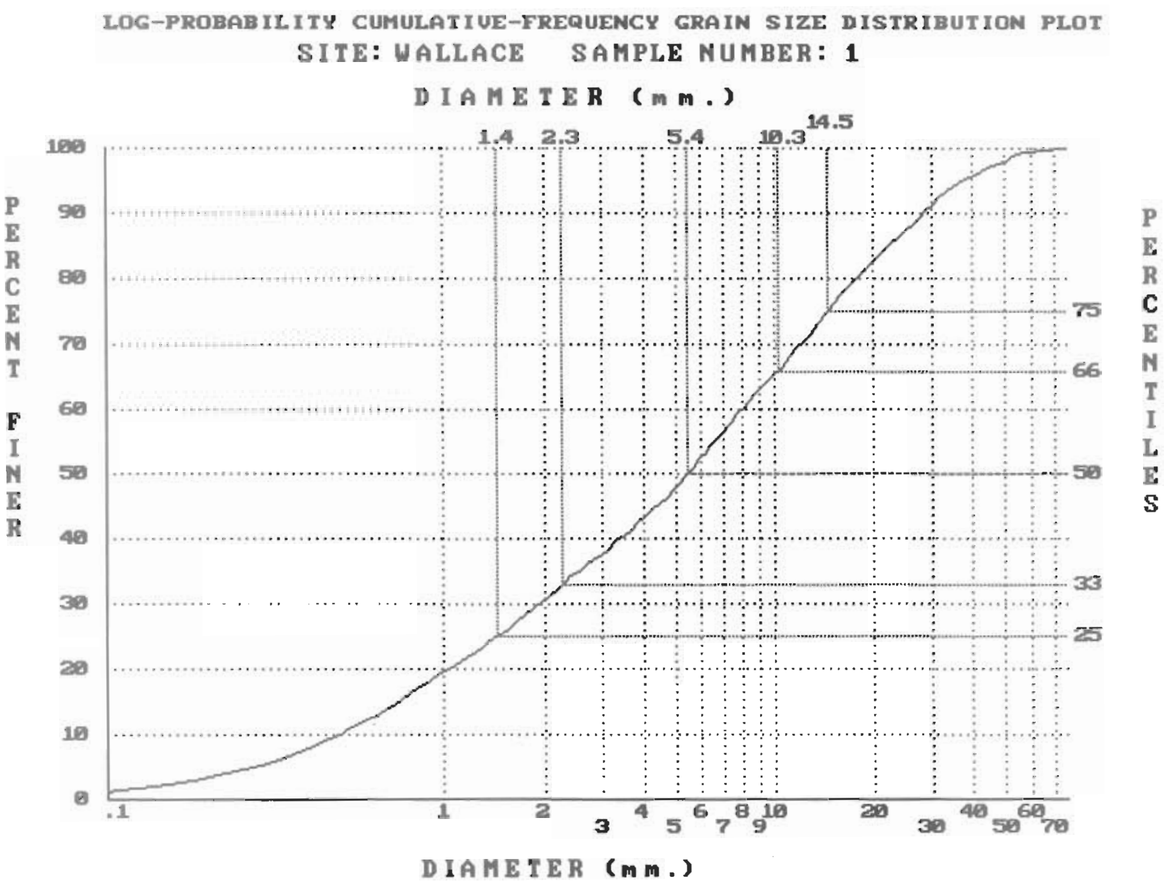
PROBLEM SITES AND LANDMARKS - WALLACE CREEK SURVEY COMMENTS

HABITAT UNIT #	STREAM LEN (FT)	COMMENTS
1.00	44	BRIDGE #1
9.00	405	DAM 2'H X 2'L X 19'W
34.00	1597	BRIDGE #2
35.00	1657	FOOT BRIDGE #1
42.00	2077	OLD ABANDONED LOG CROSSING
51.00	2458	GOOD ELECTROFISHING SITE; DEAD SCULPIN IN WATER
59. 00	2954	BRIDGE #4
73.00	3729	BRIDGE #5 10'H X 18'L X 40'W; NO SILL, WALLACE CREEK RD.
75.00	3819	OLD CONCRETE DAM #3, SILL 20'W X 10'L X 2'H
95.00	5509	DIRT ROAD THROUGH CREEK, SUMMER CROSSING
96.00	5584	BRIDGE #6 10'H X 11'L X 25'W, NO SILL
103.00	5946	DRY TRIB LF BK
108.00	6258	GOOD ELECTROFISHING SITE
109.00	6317	2+ FISH
111.00	6403	CULVERT RT BK
119.00	6798	BRIDGE #7
120.00	6839	MARSH AREA
128.00	7284	THREE 2+ STEELHEAD
129.00	7424	TRIB. RT BK 59°F

Wallace Creek



Inland Fisheries Division
Department of Fish and Game
August 22, 1996


LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: WALLACE SAMPLE NUMBER: 1
DIAMETER (mm.)
1.4
2.3
5.4
10.3
14.5
PERCENT FINER
PERCENTILES
75
66
50
33
25
DIAMETER (mm.)

Wallace Creek — Drainage: Mill Creek

Table 1 - SUMMARY OF RIFFLE, FLATWATER, AND POOL HABITAT TYPES — Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	ESTIMATED TOTAL AREA (sq.ft.)	MEAN VOLUME (cu.ft.)	ESTIMATED TOTAL VOLUME (cu.ft.)	MEAN RESIDUAL POOL VOL (cu.ft.)	MEAN SHELTER RATING
33	6	RIFFLE	25	60	1983	26	8.9	0.2	195	6423	46	1514	0	13
38	5	FLATWATER	29	64	2438	32	10.0	0.5	619	23527	413	15708	0	15
49	10	POOL	38	54	2652	35	10.7	1.2	596	29180	799	39143	708	31
10	0	DRY	8	44	440	6	0.0	0.0	0	0	0	0	0	0

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq. ft.)	TOTAL VOL. (cu. ft.)
130	21	7513	59129	56364

Wallace Creek — Drainage: Mill Creek

Table 2 - SUMMARY OF HABITAT TYPES AND MEASURED PARAMETERS — Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

HABITAT UNITS #	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT OCCURRENCE %	MEAN LENGTH ft.	TOTAL LENGTH ft.	TOTAL LENGTH %	MEAN WIDTH ft.	MEAN DEPTH ft.	MAXIMUM DEPTH ft.	MEAN AREA sq.ft.	TOTAL AREA EST. sq.ft.	MEAN VOLUME cu.ft.	TOTAL VOLUME EST. cu.ft.	MEAN RESIDUAL POOL VOL cu.ft.	MEAN SHELTER RATING	MEAN CANOPY %
33	6	LGR	25	60	1983	26	9	0.2	0.9	195	6423	46	1514	0	13	67
21	3	GLD	16	65	1359	18	11	0.5	2.0	814	17102	580	12184	0	3	75
17	2	RUN	13	63	1079	14	8	0.5	0.9	326	5545	163	2773	0	33	59
8	1	MCP	6	48	385	5	12	1.5	3.2	586	4688	947	7573	846	26	83
3	1	LSL	2	34	101	1	11	1.3	2.1	380	1141	493	1480	553	42	90
15	3	LSR	12	48	715	10	11	1.2	2.8	531	7971	700	10495	611	34	76
13	1	LSBk	10	69	892	12	9	1.2	3.2	689	8954	861	11196	727	18	81
8	2	LSBo	6	64	514	7	11	1.3	3.1	726	5805	1007	8057	857	46	76
1	1	PLP	1	11	11	0	10	0.8	1.4	105	105	84	84	73	60	60
1	1	DPL	1	34	34	0	16	0.5	2.0	517	517	258	258	0	15	80
10	0	DRY	8	44	440	6	0	0.0	0.0	0	0	0	0	0	0	75

TOTAL UNITS	TOTAL UNITS	LENGTH (ft.)	AREA (sq.ft)	TOTAL VOL. (cu.ft)
130	21	7513	58251	55613

Wallace Creek

Drainage: Mill Creek

Table 3 - SUMMARY OF POOL TYPES

Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	TOTAL AREA EST. (sq.ft.)	MEAN VOLUME (cu.ft.)	TOTAL VOLUME EST. (cu.ft.)	MEAN RESIDUAL POOL VOL. (cu.ft.)	MEAN SHELTER RATING
8	1	MAIN	16	48	385	15	12.0	1.5	586	4688	947	7573	846	26
40	8	SCOUR	82	56	2233	84	10.3	1.2	599	23975	783	31312	678	33
1	1	BACKWATER	2	34	34	1	16.0	0.5	517	517	258	258	0	15

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq.ft.)	TOTAL VOL. (cu.ft.)
49	10	2652	29180	39143

Wallace Creek   Drainage: Mill Creek

Table 4 - SUMMARY OF MAXIMUM POOL DEPTHS BY POOL HABITAT TYPES   Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

UNITS MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	<1 FOOT MAXIMUM DEPTH	<1 FOOT PERCENT OCCURRENCE	1-<2 FT. MAXIMUM DEPTH	1-<2 FOOT PERCENT OCCURRENCE	2-<3 FT. MAXIMUM DEPTH	2-<3 FOOT PERCENT OCCURRENCE	3-<4 FT. MAXIMUM DEPTH	3-<4 FOOT PERCENT OCCURRENCE	>=4 FEET MAXIMUM DEPTH	>=4 FEET PERCENT OCCURRENCE
8	MCP	16	0	0	2	25	5	63	1	13	0	0
3	LSL	6	0	0	1	33	2	67	0	0	0	0
15	LSR	31	0	0	8	53	7	47	0	0	0	0
13	LSBk	27	0	0	8	62	4	31	1	8	0	0
8	LSBo	16	0	0	2	25	5	63	1	13	0	0
1	PLP	2	0	0	1	100	0	0	0	0	0	0
1	DPL	2	0	0	0	0	1	100	0	0	0	0

TOTAL UNITS
49

Table 6 - SUMMARY OF DOMINANT SUBSTRATES BY HABITAT TYPE Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

TOTAL HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	% TOTAL SILT/CLAY DOMINANT	% TOTAL SAND DOMINANT	% TOTAL GRAVEL DOMINANT	% TOTAL SM COBBLE DOMINANT	% TOTAL LG COBBLE DOMINANT	% TOTAL BOULDER DOMINANT	% TOTAL BEDROCK DOMINANT
33	6	LGR	0	0	67	0	0	17	17
21	3	GLD	0	67	0	0	0	0	33
17	2	RUN	0	100	0	0	0	0	0
8	1	MCP	0	33	33	0	0	0	0
3	1	LSL	0	0	0	0	0	0	100
15	3	LSR	0	33	67	0	0	0	0
13	1	LSBk	0	100	0	0	0	0	0
8	2	LSBo	0	67	0	0	0	0	0
1	1	PLP	0	0	100	0	0	0	0
1	1	DPL	0	100	0	0	0	0	0
10	0	DRY	0	0	100	0	0	0	0

Wallace Creek — Drainage: Mill Creek

Table 10 - Summary of Shelter Type Areas by Habitat Type — Survey Dates: 09/25/95 to 09/26/95

Confluence Location: QUAD: GUERN/GEYS LEGAL DESCRIPTION: T09NR10WS25 LATITUDE: 38°35'55" LONGITUDE: 122°54'38"

UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	SQ. FT. UNDERCUT BANKS	SQ. FT. SWD	SQ. FT. LWD	SQ. FT. ROOT MASS	SQ. FT. TERR. VEGETATION	SQ. FT. AQUATIC VEGETATION	SQ. FT. WHITE WATER	SQ. FT. BOULDERS	SQ. FT. BEDROCK LEDGES
33	6	LGR	0	0	0	0	33	0	0	129	0
21	3	GLD	136	0	0	0	0	0	0	0	0
17	2	RUN	0	0	0	0	60	0	0	43	0
8	1	MCP	61	0	0	29	378	82	0	108	0
3	1	LSL	24	44	19	21	110	66	0	0	0
15	3	LSR	390	137	170	520	133	294	0	193	0
13	1	LSBk	199	130	101	30	0	93	0	195	0
8	2	LSBo	124	41	0	3	42	82	0	1029	86
1	1	PLP	0	0	0	0	10	0	0	0	23
1	1	DPL	0	0	0	0	0	0	0	82	0
10	0	DRY	0	0	0	0	0	0	0	0	0
TOTAL 130	21		934	352	290	603	766	617	0	1779	109

Summary of Mean Percent Vegetative Cover for Entire Stream

Mean Percent Canopy	Mean Percent Conifer	Mean Percent Decidous	Mean Right bank % Cover	Mean Left Bank % Cover
72.46	51.19	48.81	59.38	77.50

FISH HABITAT INVENTORY DATA SUMMARY

STREAM NAME: Wallace Creek
SAMPLE DATES: 09/25/95 to 09/26/95
STREAM LENGTH: 7513 ft.
LOCATION OF STREAM MOUTH:
USGS Quad Map: GUERN/GEYS
Legal Description: T09NR10WS25
Latitude: 38°35'55"
Longitude: 122°54'38"

SUMMARY OF FISH HABITAT ELEMENTS BY STREAM REACH

STREAM REACH 1

Channel Type: F4	Canopy Density: 72%
Channel Length: 7513 ft.	Coniferous Component: 51%
Flowing Water Mean Width: 9 ft.	Deciduous Component: 49%
Flowing Water Mean Depth: 0.4 ft.	Pools by Stream Length: 35%
Base Flow: 0.0 cfs	Pools >=3 ft.deep: 6%
Water: 57 - 67 °F Air: 59 - 73 °F	Mean Pool Shelter Rtn: 31
Dom. Bank Veg.: Coniferous Trees	Dom. Shelter: Boulders
Vegetative Cover: 68%	Occurrence of LOD: 36%
Dom. Bank Substrate: Cobble/Gravel	Dry Channel: 440 ft.

Embeddness Value: 1. 0% 2. 16% 3. 18% 4. 65%

Mean Percentage of Dominant Substrate

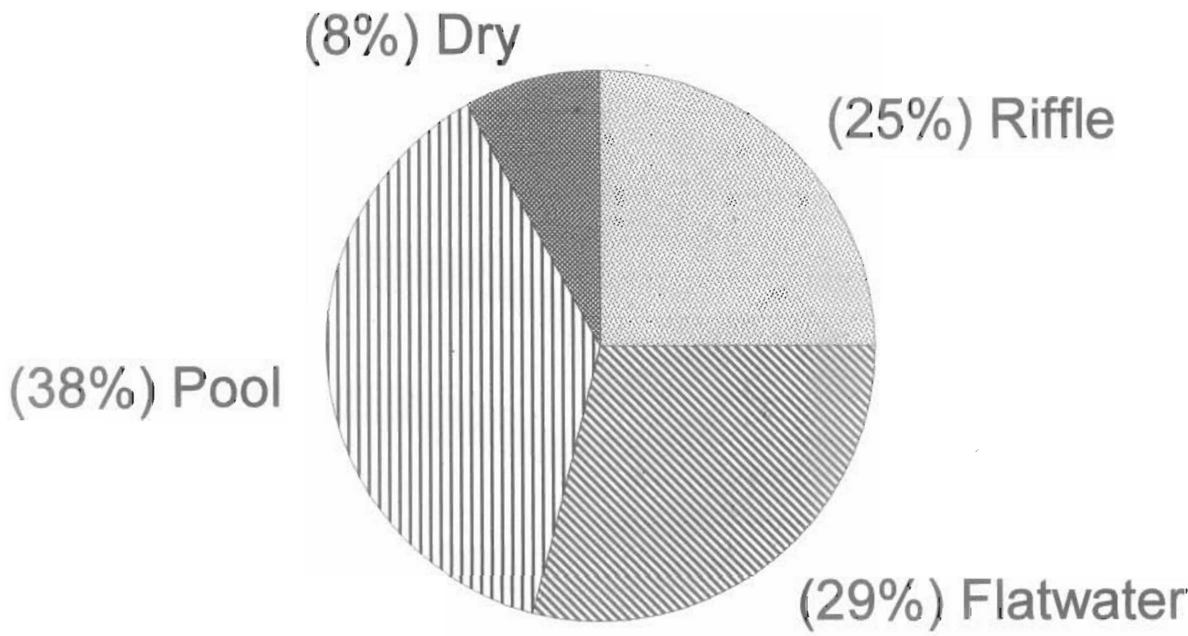
Dominant Class of Substrate	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Bedrock	9	3	25
Boulder	2	0	4.17
Cobble/Gravel	8	13	43.75
Silt/clay	5	8	27.08

Mean Percentage of Dominant Vegetation

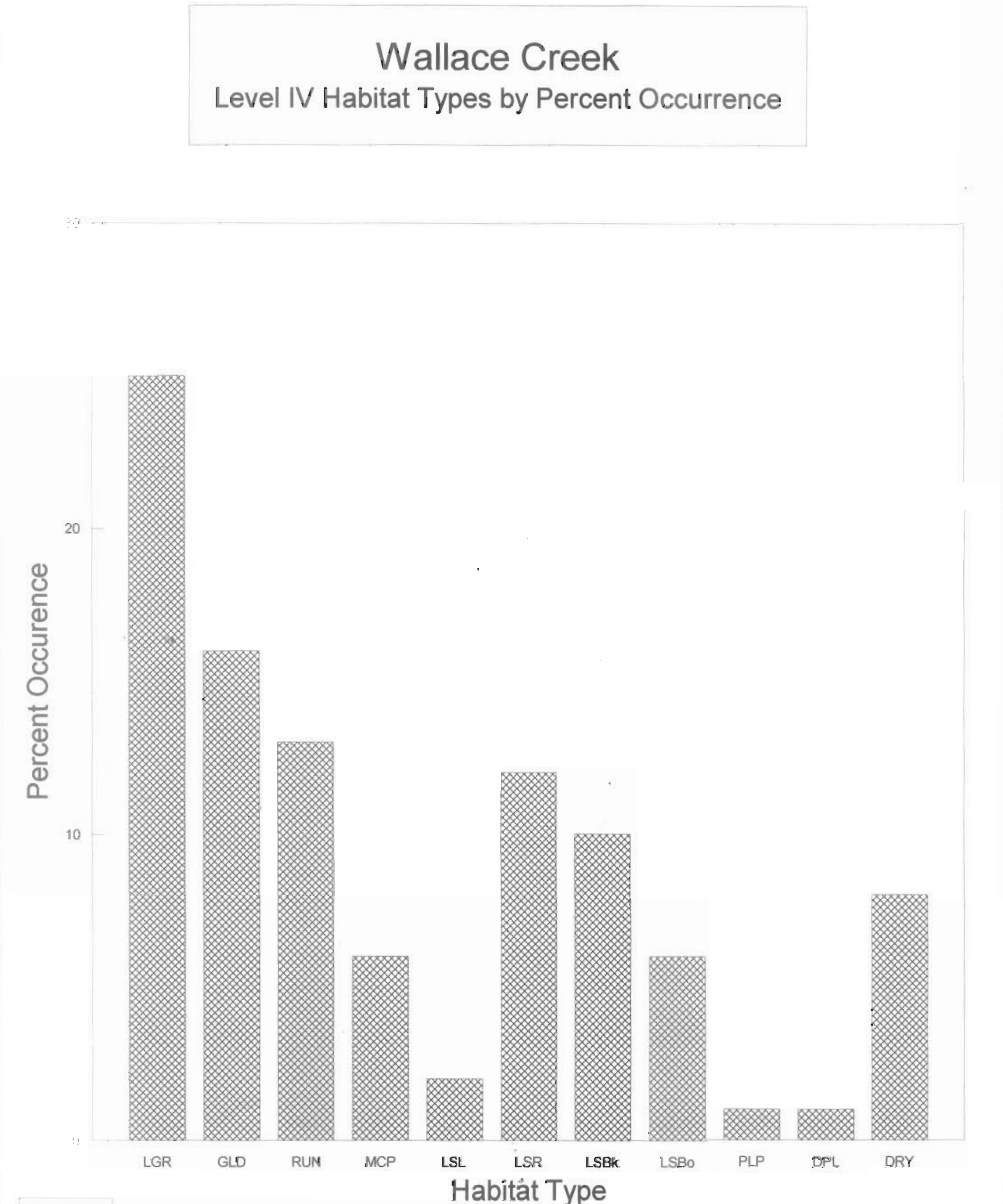
Dominant Class of Vegetation	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Grass	1	2	6.25
Brush	2	2	8.33
Decid. Trees	8	9	35.42
Conif. Trees	12	10	45.83
No Vegetation	1	1	4.17

Wallace Creek

Level II Habitat Types by % Occurrence



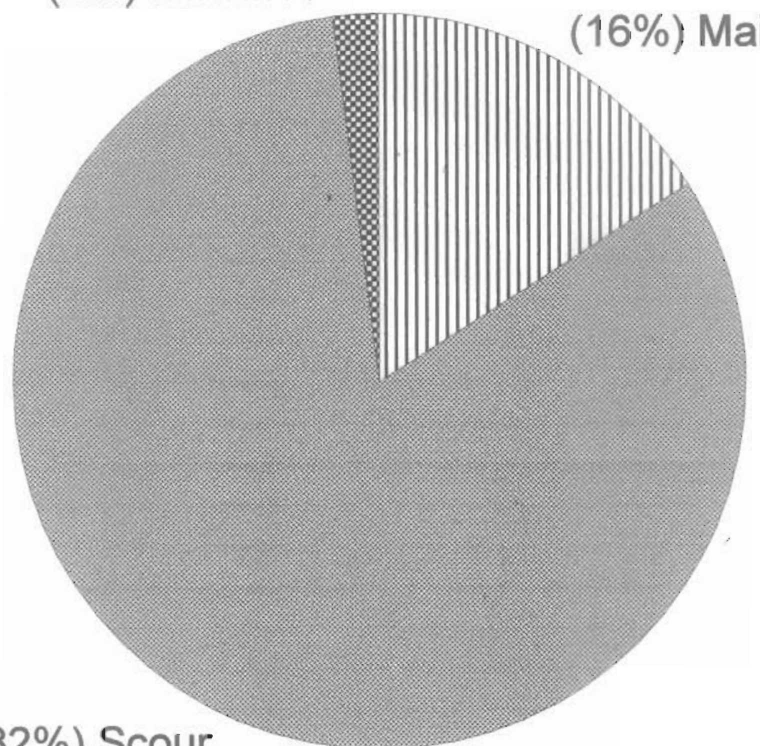
Graph 1


Wallace Creek
Level IV Habitat Types by Percent Occurrence
Percent Occurence
20
10
LGR
GLD
RUN
MCP
LSL
LSR
LSBk
LSBo
PLP
DPL
DRY
Habitat Type

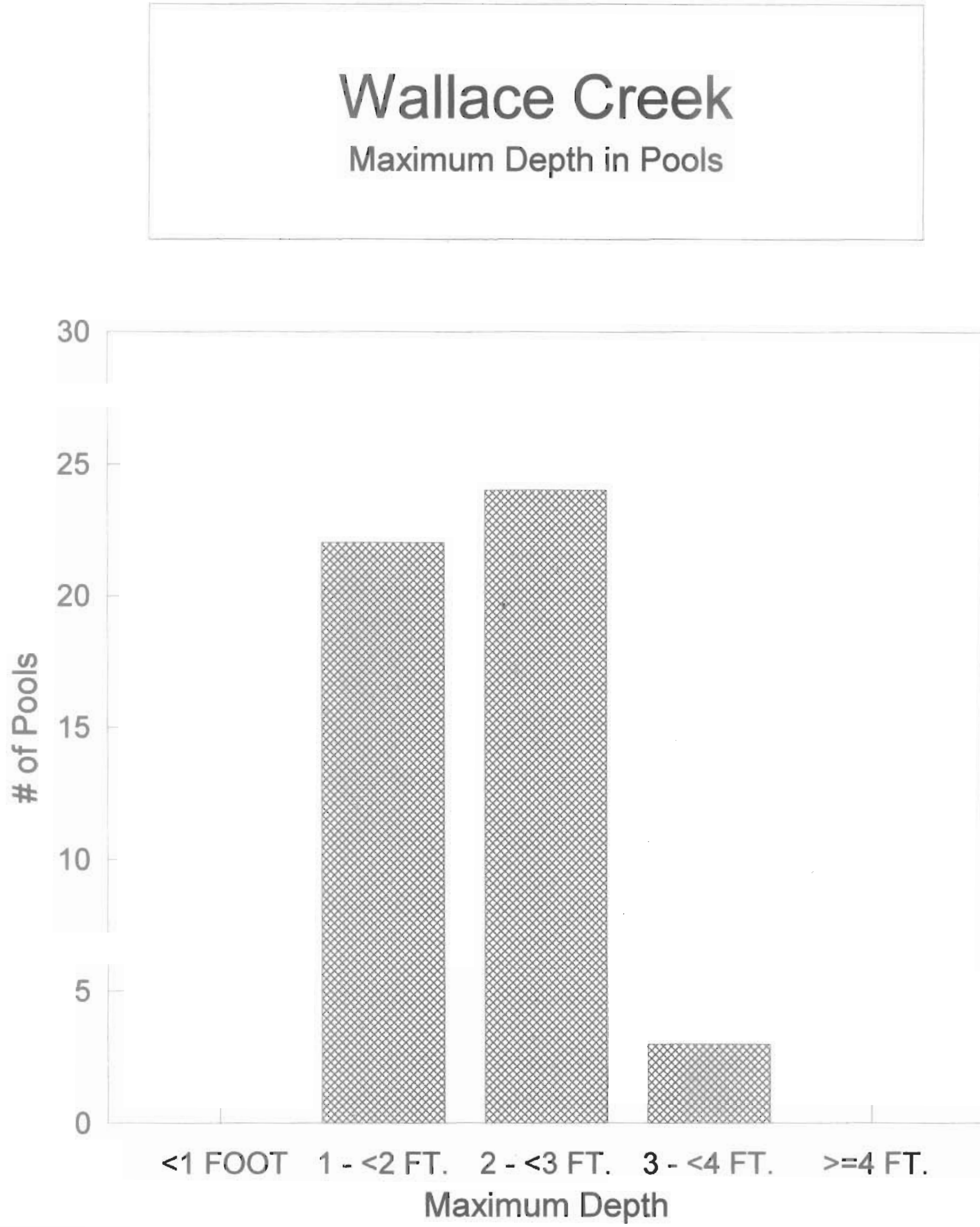
Graph 2

Wallace Creek

Pool Habitat Types by % Occurrence



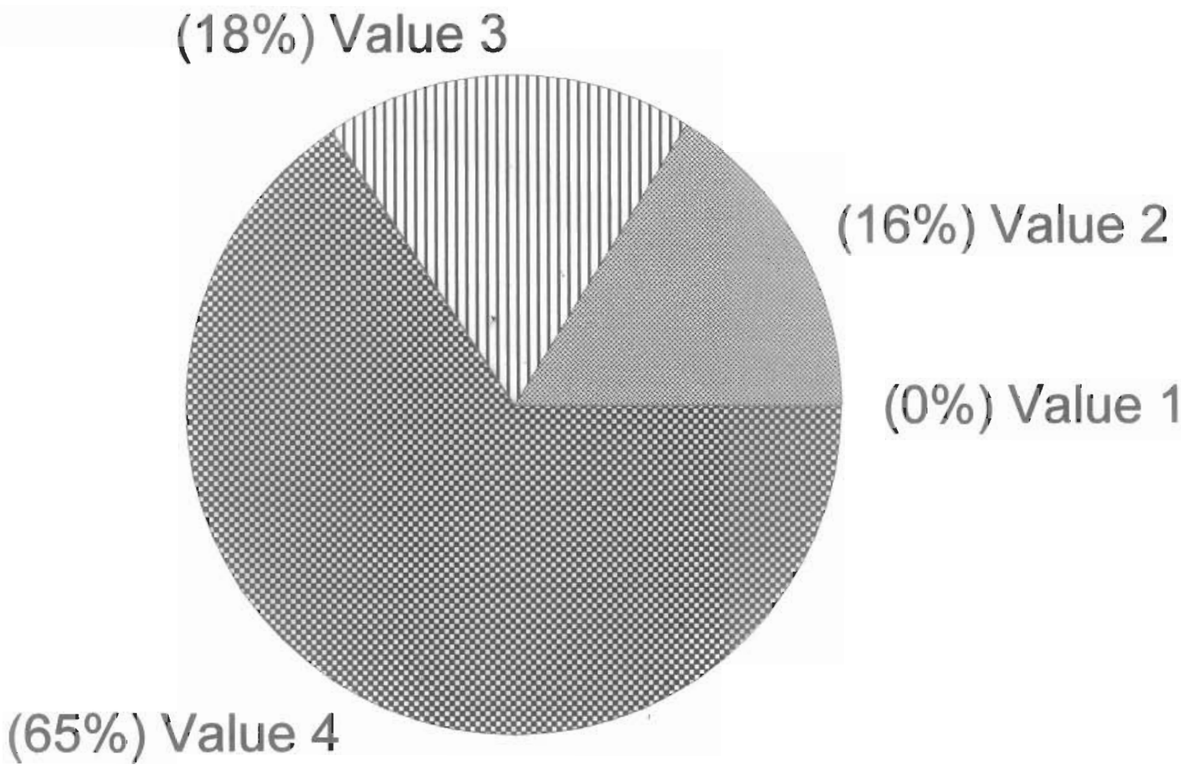
Graph 3


Wallace Creek
Maximum Depth in Pools
30
25
20
15
10
5
0
# of Pools
<1 FOOT
1 - <2 FT.
2 - <3 FT.
3 - <4 FT.
>=4 FT.
Maximum Depth

Graph 4

Wallace Creek

Percent Embeddedness

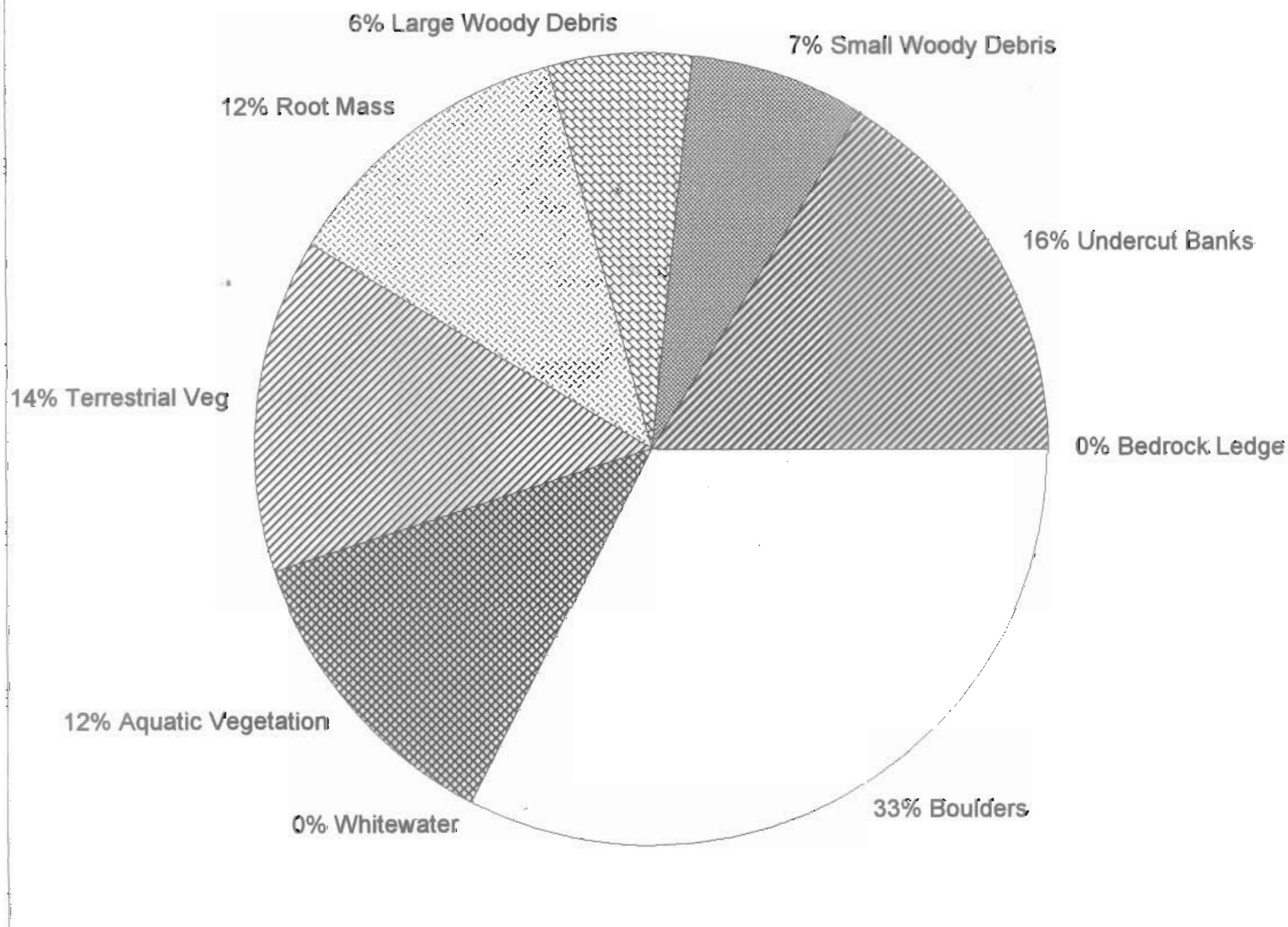


Value 1 = <25% Value 2 = 25-50% Value 3 = 51-75% Value 4 = >76

Graph 5

Wallace Creek

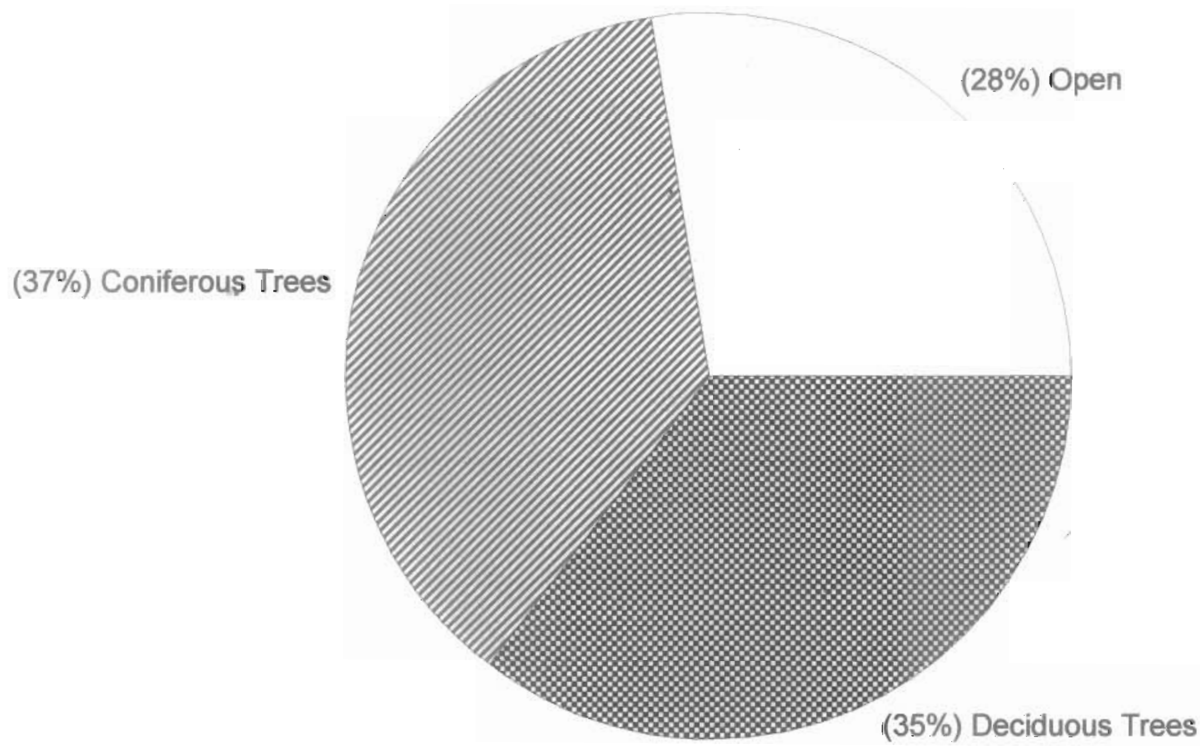
Percent Cover Types in Pools



Graph 6

Wallace Creek

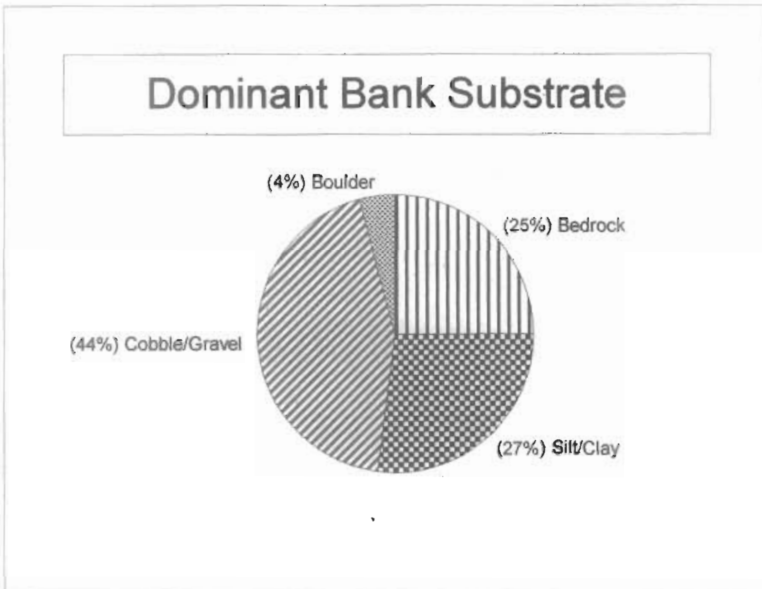
Mean Percent Canopy

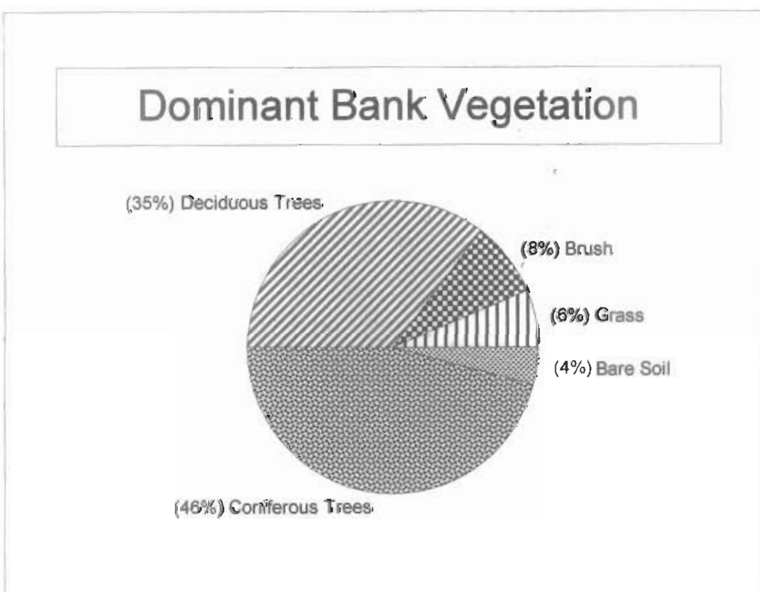


Graph 8

Wallace Creek

Percent Bank Composition





Graph 9

CALIFORNIA DEPARTMENT OF FISH AND GAME
STREAM INVENTORY REPORT
Palmer Creek
Report Revised April 14, 2006
Report Completed 2000
Assessment Completed 1995

INTRODUCTION

A stream inventory was conducted during the summer of 1995 on Palmer Creek to assess habitat conditions for anadromous salmonids. The inventory was conducted in two parts: habitat inventory and biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids in Palmer Creek. The objective of the biological inventory was to document the salmonid and other aquatic species present and their distribution. After analysis of historical information and data gathered recently, stream restoration and enhancement recommendations are presented.

WATERSHED OVERVIEW

Palmer Creek is tributary to Mill Creek, located in Sonoma County, California (Figure 1). The legal description at the confluence with Mill Creek is T09,R10W,S34. Its location is 38°35'5" N. latitude and 123°56'48" W. longitude. Year round vehicle access exists from Palmer Creek Rd., via Mill Creek Rd., which is 5 miles west on Westside Rd. from Highway 101 near Healdsburg.

Palmer Creek is a second order stream and has approximately 3.4 miles of blue line stream, according to the USGS Guerneville 7.5 minute quadrangles. Palmer Creek and its tributaries drain a basin of approximately 3.8 square miles. Summer flow was measured as approximately 0.66 cfs at a location just above the Mill Creek confluence. Elevations range from about 360 feet at the mouth of the creek to 1,300 feet in the headwater areas. Mixed coniferous and deciduous forest dominates the watershed. The watershed is entirely privately owned.

No sensitive plants were listed in DFG's Natural Diversity Database, however, the Northern Spotted Owl *(Strix occidentalis caurina)* is listed as occurring within Mill Creek Watershed.

Stream Surveys:

No surveys have been conducted by The Department of Fish and Game prior to the 1995 summer survey.

METHODS

The habitat inventory conducted in Palmer Creek follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1991). The Americorps members that conducted the inventory were trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG) under the supervision of CDFG's Russian River Basin Planner, Robert Coey in August and September of 1995. This inventory was conducted by a two person team.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Palmer Creek to record measurements and observations. There are nine components to the inventory form.

HABITAT INVENTORY COMPONENTS

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1. Flow:

Flow is measured in cubic feet per second (cfs) at the bottom of the stream survey reach using standard flow measuring equipment, if available. In some cases flows are estimated. Flows were also measured or estimated at major tributary confluences.

2. Channel Type:

Channel typing is conducted according to the classification system developed by David Rosgen (1985). This methodology is described in the California Salmonid Stream Habitat Restoration Manual. Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are four measured parameters used to determine channel type: 1) water slope gradient, 2) channel confinement, 3) width/depth ratio, 4) substrate composition.

3. Temperatures:

Water and air temperatures, and time taken, are measured by crew members with handheld thermometers and recorded at each tenth unit typed. Temperatures are measured in Fahrenheit at the middle of the habitat unit and within one foot of the water surface. Temperatures are also recorded using Ryan Tempmentors which log temperature every two hours, 24 hours/day.

4. Habitat Type:

Habitat typing uses the 24 habitat classification types defined by McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "dry". Palmer Creek habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. Channel dimensions were measured using hip chains, range finders, tape measures, and stadia rods. Unit measurements included mean length, mean width, mean depth, and maximum depth. Pool tail crest depth at each pool unit was measured in the thalweg. All measurements were taken in feet to the nearest tenth.

5. Embeddedness:

The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. In Palmer Creek, embeddedness was visually estimated. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value 4).

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent cover. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All cover is then classified according to a list of nine cover types. In Palmer Creek, a standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) was assigned according to the complexity of the cover. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes. Mechanical substrate sampling was also conducted to quantify the percentage of fine sediment within spawning gravels.

8. Canopy:

Stream canopy is estimated using handheld spherical densiometers and is a measure of the water surface shaded during periods of high sun. In Palmer Creek, an estimate of the percentage of the habitat unit covered by canopy was made from the center of each unit. The area of canopy was further analyzed to estimate its percentages of coniferous or deciduous trees, and the results recorded.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In Palmer Creek, the dominant composition type in both the right and left banks was selected from a list of eight options on the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

BIOLOGICAL INVENTORY

Biological sampling during stream inventory is used to determine fish species and their distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. These sampling techniques are discussed in the California Salmonid Stream Habitat Restoration Manual.

DATA ANALYSIS

Data from the habitat inventory form are entered into the Habitat Program, a dBASE 4.1 data entry program developed by the California

Department of Fish and Game (DFG). This program also processes and summarizes the data.

The Habitat Runtime program produces the following tables:

- Riffle, flatwater, and pool habitat types
- Habitat types and measured parameters
- Pool types
- Maximum pool depths by habitat types
- Dominant substrates by habitat types
- Shelter type areas by habitat types

Graphics are produced from the tables using Lotus 1,2,3. Graphics developed for Palmer Creek include:

- Level II Habitat Types by % Occurrence
- Level IV Habitat Types by % Occurrence
- Pool Habitat Types by % Occurrence
- Maximum Depth in Pools
- Percent Embeddedness by Reach
- Percent Cover Types in Pools
- Substrate Composition in Low Gradient Riffles
- Mean Percent Canopy
- Percent Bank Composition
- Percent Canopy by Reach

HABITAT INVENTORY RESULTS FOR PALMER CREEK

* ALL TABLES AND GRAPHS ARE LOCATED AT THE END OF THE REPORT *

The habitat inventory of August 23 to September 18, 1995 was conducted by Ken Mogan, John Fort and Ken Bunzel. The survey began at the confluence with Mill Creek and continued to the end of survey. The total length of the stream surveyed was 16,639 feet.

Summer base flows were measured on July 29, 1995 at the mouth of Palmer Creek. The flows were determined to be 0.66 cfs.

This section of Palmer Creek has three channel types, with one occurring twice: from the mouth to 3249 feet an F4; next 6152 feet an F3; next 2437 feet an F2 and the upper 4802 feet an F4.

F4 channels are entrenched, meandering riffle/pool channels on low gradients (<2%) with high width/depth ratio and a gravel substrate.

F3 channels are entrenched, meandering riffle/pool channels on low gradients (<2%) with high width/depth ratio and a cobble substrate.

F2 channels are entrenched, meandering riffle/pool channels on low gradients (<2%) with high width/depth ratio and a boulder substrate.

Water temperatures ranged from 52°F to 64°F. Air temperatures ranged from 53°F to 84°F.

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. By percent occurrence, pools made up 43%, flatwater types 29%, and riffles 28% (Graph 1). Pool habitat types made up 35% of the total survey **length**, flatwater 34%, and riffles 28%.

Twenty-one Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent **occurrence** were low gradient riffles, 25%. The percent occurrence of runs was 19%, root wad scours 16%, and mid-channel pools 9% (Graph 2). By percent total **length**, low gradient riffles made up 26%, runs 21%, root wad scours 12%, and mid-channel pools 7%.

One hundred sixty-three pools were identified (Table 3). Scour pools were most often encountered at 69%, and comprised 66% of the total length of pools (Graph 3).

Table 4 is a summary of maximum pool depths by pool habitat types. Depth is an indicator of pool quality. Seventy-one of the 163 pools (44%) had a depth of two feet or greater (Graph 4).

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Pool types had the highest shelter rating at 51. Riffles had the lowest rating with 14 (Table 1). Of the pool types, the scour pools had the highest mean shelter rating at 54, main channel pools rated 45, and backwater pools 38 (Table 3).

Table 10 summarizes total cover by habitat type. Undercut banks and boulders are the dominant cover types for pools in Palmer Creek. Root mass and large woody debris are the next most common pool cover types. Graph 6 describes the pool cover in Palmer Creek.

Table 6 summarizes the dominant substrate by habitat type. Gravel was the dominant substrate observed in 74% of the low gradient riffles measured. Small cobble and sand were the next most frequently observed types, and both occurred in 11% of the low gradient riffles (Graph 7).

The depth of cobble embeddedness was estimated at pool tail-outs.

Of the 163 pool tail-outs measured, 23 had a value of one (14%); 69 had a value of two (42%); 37 had a value of three (23%); and 34 had a value of four (21%). On this scale, a value of one is best for fisheries. Graph 5 shows percent embeddedness broken down by reach.

Thirteen percent of Palmer Creek lacked shade canopy. Thirty-five percent of the stream had canopy consisting of deciduous trees and 53% had a canopy of coniferous trees. Graph 8 describes the overall canopy and graph 11 describes the canopy by reach.

For the stream reach surveyed, the mean percent right bank vegetated was 71% and the mean percent left bank vegetated was 73% (Appendix A). For the habitat units measured, the dominant vegetation types for the stream banks were: 60% coniferous trees and 36% deciduous trees. The dominant substrate for the stream banks were: 53% cobble/gravel, 20% silt/clay/sand, 14% boulder and 12% bedrock (Appendix C, Graph 9).

HABITAT INVENTORY RESULTS FOR NORTH FORK TRIBUTARY OF PALMER CREEK

The habitat inventory of September 21, 1995 was conducted by Ken Mogan and Kurt Gregory. The survey began at the confluence with Palmer Creek and extended to the end of the survey. The total length of the stream surveyed was 2316 feet.

Water temperatures ranged from 57°F to 58°F. Air temperatures ranged from 61°F to 64°F.

By percent ***occurrence****, pools made up 43%, riffle types 33%, flatwater 18% and dry units 6%. Dry units made up 45% of the total survey* ***length****, riffles 27%, pools 16%, and flatwater 11%.*

Ten level IV habitat types were identified. The most frequent habitat types by percent ***occurrence*** *were low gradient riffles, 33%; root wad scours, 24%; glides, 10% and runs, 8%. By percent total* ***length****, low gradient riffles made up 27%, root wad scours, 10%, glides 6%, and runs 5%.*

Twenty-two pools were identified. Scour pools were most often encountered at 86%, and comprised 88% of the total length of pool. Depth is an indicator of pool quality. Three of the 22 pools (14%) had a depth of two feet or greater.

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Pool types rated 51 and riffles rated 0. Of the pool types, the main channel pools had the highest mean shelter *rating at 75 and scour pools rated 48.*

Undercut banks are the dominant cover type for pools. Root masses, boulders and large woody debris are the next most common pool cover types.

Small cobble was the dominant substrate observed in all of the low gradient riffles measured. The depth of cobble embeddedness was estimated at pool tail-outs. Of the 22 pool tail-outs measured, none had a value of 1; seven had a value of 2 (32%); eight had a value of 3 (36%); and seven had a value of 4 (32%). On this scale, a value of one is best for fisheries.

Seven percent of the creek lacked shade canopy. Thirty-two percent of the creek had canopy consisting of deciduous trees and 61% consisted of coniferous trees.

For the stream reach surveyed, the mean percent right bank vegetated was 64% and the mean percent left bank vegetated was 67% (Appendix A). For the habitat units measured, the dominant vegetation types for the stream banks were: 50% coniferous trees, 42% deciduous trees 4% grass and 4% brush. The dominant substrate for the stream banks were: 71% cobble/gravel, 25% silt/clay/sand and 4% bedrock.

SUBSTRATE SAMPLING

Mechanical gravel sampling was not conducted in 1995 on Palmer Creek due to inadequate staffing levels, however, dominant substrate types and embeddedness ratings are presented below.

Pool tail embeddedness is a measure of the suitability of spawning gravel. Seventy-one of the 163 pool tail-outs measured had embeddedness ratings of 3 or 4. Only 23 had a rating of one. On a reach by reach comparison, reach 1 had the best embeddedness ratings with 70% of the tail-outs having either a 1 or 2. Reach 3 had the poorest ratings with only 35% having a 1 or 2. Reach 2 had 61% and reach 4 had 53% with a 1 or 2. Cobble embeddedness measured to be 25% or less, a rating of one, is considered best for the needs of salmon and steelhead. In Palmer Creek, sediment sources should be mapped and rated according to their potential sediment yields, and control measures taken.

BIOLOGICAL INVENTORY

JUVENILE SURVEYS:

A Biological inventory was taken on September 19, 1995 on Palmer Creek. Single pass electrofishing was the method used. Observers were Ken Mogan and Kurt Gregory.

The inventory of reach one was started in habitat unit 1 at the confluence with Mill Creek. In riffle, pool, glide and run habitat types 60 0+, seven 1+ and two 2+ steelhead were observed along with 89 sculpin and 4 crayfish.

The inventory of reach two was conducted 1/8 mile from the second bridge in habitat units 80-89. In pool, run and riffle habitat types 70 0+, twenty 1+ and two 2+ steelhead were observed along with 22 sculpin and 1 crayfish.

The inventory of reach two was continued in habitat units 180-191. In pool, riffle, glide and run habitat types 72 0+, thirteen 1+ and six 2+ steelhead were observed along with 40 sculpin and 4 crayfish.

The inventory of reach 2 was continued 1/2 mile upstream from the third bridge (Palmer Creek Rd.) in habitat units 210-219. In pool, run, riffle and glide habitat types 88 0+, twelve 1+ and four 2+ steelhead were observed along with 67 sculpin and 1 Pacific Giant Salamander.

The inventory of reach 3 was conducted 1/3 mile upstream from bridge #3 in habitat units 220-228. In pool, riffle and run habitat types 75 0+, sixteen 1+ and four 2+ steelhead were observed along with 44 sculpin and 2 Pacific Giant Salamanders.

The inventory of reach 4 was conducted in habitat units 306-320, near Palmer Creek Road bridge #4. In pool, riffle, run and glide habitat types 106 0+, ten 1+ and ten 2+ steelhead were observed along with 4 salamanders and 2 crayfish. A small intermittent tributary below bridge #4 held 0+, 1+ and 2+ steelhead.

The following table summarizes species observed in DFG surveys:

SUMMARY OF SPECIES OBSERVED IN DFG SURVEYS ON PALMER CREEK		
SPECIES	**YEARS**	**Native/Introduced**
Steelhead	1995	N
Sculpin	1995	N
Crayfish	1995	N
Pacific Giant Salamander	1995	N

DISCUSSION

Palmer Creek has three channel types and four reaches: F4 (occurring in two separate reaches), F3, and F2.

The lower 3249 and upper 4802 feet of Palmer Creek are F4 channels. F4 types are good for bank-placed boulders and fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover.

There are 6152 feet of F3 channel type in the middle reach of Palmer Creek. F3 types are good for bank-placed boulders and single and opposing wing-deflectors. They are fair for low-stage weirs, boulder clusters, channel constrictors and log cover.

There are 2437 feet of F2 channel type in the middle reach of Palmer Creek. F2 types are fair for low-stage weirs, single and opposing wing-deflectors and log cover. Any work considered in Palmer Creek will require very careful design, placement, and construction.

The water temperatures recorded on the survey days August 23 - September 18, 1995 ranged from 52°F to 64°F. Air temperatures ranged from 53°F to 84°F. The warmer water temperatures were recorded in Reach 1. These temperatures, if sustained, are at the threshold stress level for salmonids. To make any further conclusions, temperatures need to be monitored for a longer period of time through the critical summer months, and more extensive biological sampling needs to be conducted.

Pool habitat types comprised 35% of the total length of this survey. In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. In Palmer Creek, 71 of the 163 pools had a maximum depth greater than 2 feet (44%). However, these pools comprised only 19% of the length of total stream habitat. In coastal coho and steelhead streams, it is generally desirable to have primary pools comprise approximately 50% of total habitat. Therefore, installing structures that will increase pool habitat is recommended for locations where their installation will not jeopardize unstable stream banks, or subject the structures to high stream energy.

The mean shelter rating for pools was 51. The shelter rating in the flatwater habitats was 31 and riffles had a rating of 14. A pool shelter rating of approximately 100 is desirable. The relatively small amount of pool cover that now exists is being provided primarily by undercut banks and boulders. Large woody debris and root mass are the next most common cover types for pools. Log and root wad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat. Log cover structure provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

Seventy-four percent of the low gradient riffles measured had gravel as the dominant substrate. Eleven percent had small cobble as the dominant substrate. This is generally considered good for spawning salmonids.

Seventy-one of the 163 pool tail-outs measured had embeddedness ratings of 3 or 4. Only 23 had a rating of one. Cobble embeddedness measured to be 25% or less, a rating of one, is considered best for the needs of salmon and steelhead. Embeddedness increases in an upstream direction, indicating sedimentation problems upstream (Graph 5). In Palmer Creek, sediment sources should be mapped and rated according to their potential sediment yields, and control measures taken.

The mean percent canopy for the survey reach was 87%. This is a good percentage of canopy, since 80 percent is generally considered desirable.

Biological surveys were conducted to document fish distribution and are not necessarily representative of population information. The 1995 spring surveys documented many 0+ fish indicating successful spawning in all reaches of Palmer Creek. However, few 1+ fish were observed indicating poor rearing conditions the year before or poor holding-over conditions in general.

SUMMARY

A biological survey was conducted to document fish distribution and is not necessarily representative of population information. Steelhead of all age classes were documented during the 1995 inventory. Although habitat exists for coho, none were found during the survey, likely due to the steep gradient and boulder sections of Palmer Creek.

In general, Palmer Creek is good for steelhead habitat. There are abundant pools with adequate depth but little shelter. Although riffle habitat exists, some of it is impacted from sediment, which increases in an upstream direction. The higher the percent of fine sediment, the lower the probability that eggs will survive to hatch. This is due to the reduced quantity of oxygenated water able to percolate through the gravel, or because of fine sediment capping the redd and preventing fry emergence.

Shade canopy and riparian vegetation are good in Palmer Creek. If the riparian zone is undisturbed, eventually steelhead habitat will improve due to new recruitment of large woody debris into the stream. Since this process may take many decades, and salmonid populations are dwindling quickly, it is advisable to improve conditions with instream structures.

GENERAL RECOMMENDATIONS

Palmer Creek should be managed as an anadromous, natural production stream.

The winter of 1995 and 1996 storms brought down many large trees and other woody debris into the stream, which increased the number and quality of pools. This woody debris, if left undisturbed, will provide fish cover and rearing habitat, and offset channel incision. Many signs of recent and historic tree and log removal were evident in the active channel during our survey. Efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be educated about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

PRIORITY FISHERY ENHANCEMENT OPPORTUNITIES

1) Map sources of erosion on secondary roads and prioritize them according to present and potential sediment yield. Identified sites should then be treated to reduce the amount of fine sediments entering the stream.

2) In Palmer Creek, active and potential sediment sources related to the road system need to be mapped, and treated according to their potential for sediment yield to the stream and its tributaries.

3) A large blowout in Reach 1 is contributing sediment into the stream. This blowout was first noticed in the August -

September, 1995 survey. During a survey in May, 1996 it was observed to have expanded considerably with several redwood logs uprooting and sliding into the stream. These logs could be used to protect against further erosion by rotating them so they lay against the bank. With careful positioning, pool habitat and shelter could also be created. In addition, the log debris accumulation present from the year before could be adjusted to minimize water backup and the resulting bank erosion. This must be done carefully to preserve existing habitat provided by the woody debris.

4) Where feasible, increase woody cover in the pool and flatwater habitat units along the entire stream. Most of the existing cover is from boulders and undercut banks. Adding high quality complexity with larger woody cover is desirable. Combination cover/scour structures constructed with boulders and woody debris would be effective in many flatwater and pool locations in the lower reaches. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion. In some areas the material is at hand.

5) Where feasible, design and engineer pool enhancement structures to increase the number of pools in all reaches. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion.

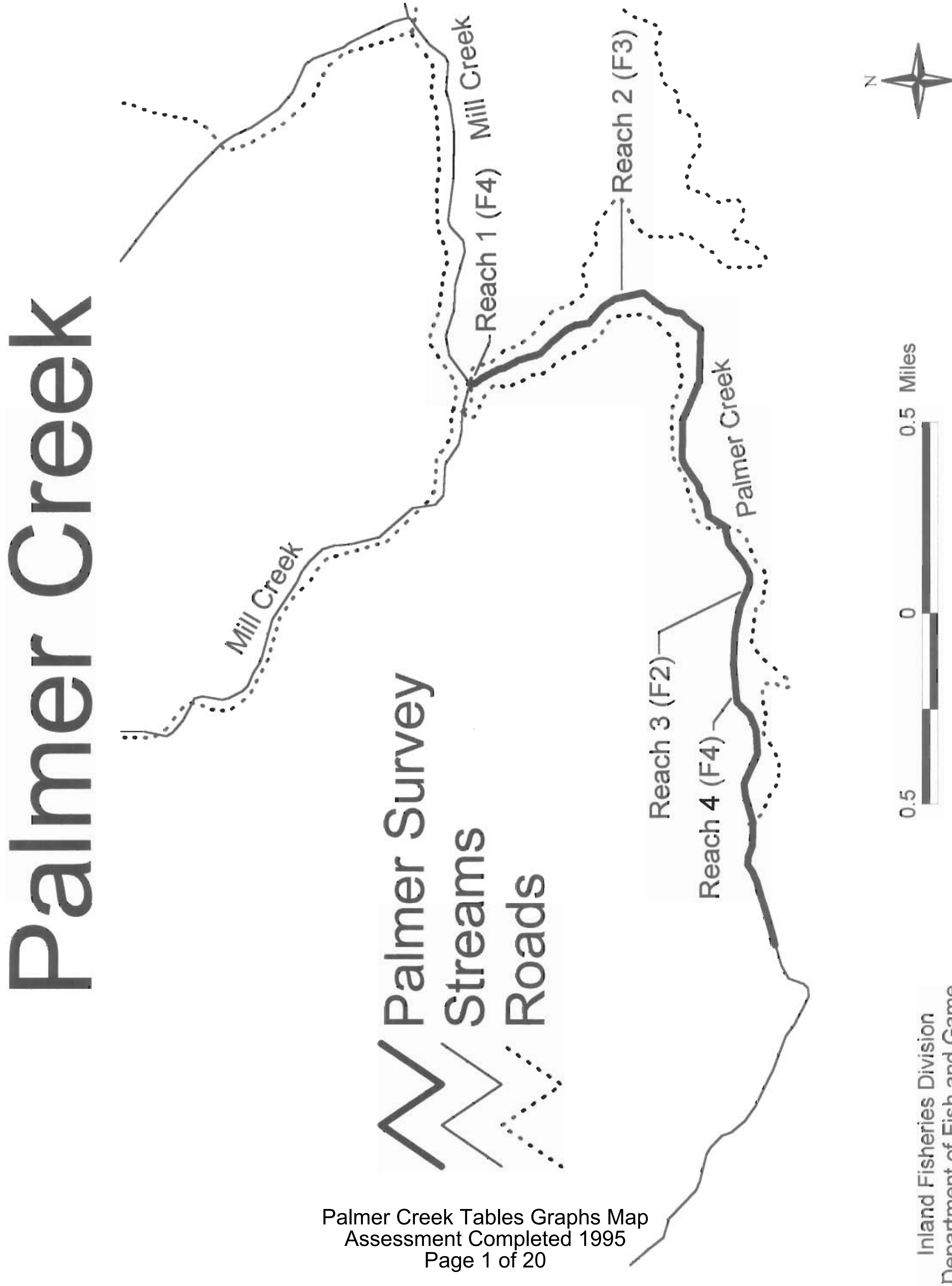
PROBLEM SITES AND LANDMARKS - PALMER CREEK SURVEY COMMENTS

HABITAT UNIT #	STRM_LGNTH	COMMENTS
1.00	201	RT BK SUMMER CROSSING DIRT ROAD THROUGH CREEK; BRIDGE #1 35'W X 11'H X 16'L
7.00	480	LG CRAYFISH
20.00	981	TRIB LF BK 59°F
26.00	1191	SPRING RT BK 58°F
64.00	2894	LARGE BLOWOUT RT BANK 45'H X 110'L LARGE WOODY DEBRIS ACCUMULATION COMBINED WITH SPRINGS
67.00	3043	TRIB RT BK 55°F
71.00	3114	BACKWATER POOL, LOG FORMED
75.00	3325	DRY TRIBS RT & LF BANKS
76.00	3340	ROACH OBSERVED IN POOL
91.00	3797	E.F. SPOT
92.00	3939	LF BK DIRT ROAD
95.00	4136	SPRING LF BK 58°F
98.00	4261	DIRT SUMMER CROSSING RD

101.00	4381	2+ FISH OBSERVED
106.00	4597	1+ & 2+ FISH
124.00	5299	SPRING RT BK 57°F
135.00	5752	DRY TRIB LF BK
136.00	5777	LARGE BLOWOUT AND LOG JAM RT BK
151.00	6263	LF BK DRY TRIB
186.00	7644	LARGE CRAYFISH
190.00	7764	BRIDGE #3
192.00	7846	TRIB. TEMP 58°F
194.00	7956	BIG BLOWOUT 50' UP DRY TRIB.
196.00	8063	RT. BANK BLOWOUT
207.00	8701	ELECTROFISHING AREA
212.00	8950	TRIB RT BANK 57°F
214.00	9093	TRIB RT BK
217.00	9349	OLD SKID CROSSING
238.00	10167	TRIB RT BANK
239.00	10221	2+ FISH
241.00	10374	SPRING 62 F LF BANK; 2+ FISH; CRAYFISH; ROAD RT BANK (GRAVEL)
242.00	10406	1+ FISH
243.00	10549	2+ FISH
244.00	10575	12' DROP
263.00	11690	E.F. SPOT
264.00	11734	REMNANTS OF A SUMMER DAM. 4" X 12" STEEL I BEAM IN CENTER OF CREEK. CONCRETE SILL, 1' DOWN-CUT BELOW
268.00	11999	TRIB RT BANK 59°F
274.00	12283	1+ AND 2+ FISH
281.00	12514	TRIB LF BANK 58°F
294.00	12912	DRY TRIB RT BANK
296.00	12970	SPRING RT BK 59°F
298.00	13015	BLOWOUT RT BANK 18'H X 25'L X 8'D
306.00	13333	TRIB RT BANK END OF UNIT 54°F
332.00	14188	PACIFIC GIANT SALAMANDER
336.00	14323	1+ FISH
346.00	14643	BLOWOUT 25'H X 40'L X 4'D; HIGH WATER FLOWS, DEBRIS INFLUENCED
359.00	15109	E.F. SPOT
360.00	15125	DAM 16'W X 12.5'H X 15'L CONCRETE SILL. NOT DOWN-CUTTING OR HOLDING BACK GRAVEL
361.00	15170	DRY TRIB RT BANK
366.00	15404	TRIB RT BANK; NO FISH; SOUTH FORK PALMER
368.00	15488	DRY TRIB LF BANK
371.00	15642	TWO 2+ FISH

PROBLEM SITES AND LANDMARKS-NORTH FORK PALMER TRIB

STRM_LGNTH	COMMENTS
87	RT BK CEMENT BAGS GIVING WAY
1065	OLD LOGGING ROAD THROUGH CREEK



Palmer Creek
Palmer Survey
Streams
Roads
Mill Creek
Mill Creek
Reach 1 (F4)
Reach 2 (F3)
Palmer Creek
Reach 3 (F2)
Reach 4 (F4)
N
0.5
0
0.5 Miles
Inland Fisheries Division
Department of Fish and Game

Palmer Creek Drainage: Mill Creek

Table 1 - SUMMARY OF RIFFLE, FLATWATER, AND POOL HABITAT TYPES Survey Dates: 8/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	ESTIMATED TOTAL AREA (sq.ft.)	MEAN VOLUME (cu.ft.)	ESTIMATED TOTAL VOLUME (cu.ft.)	MEAN RESIDUAL POOL VOL (cu.ft.)	MEAN SHELTER RATING
106	22	RIFFLE	28	43	4579	28	9.5	0.6	290	30772	187	19804	0	14
111	22	FLATWATER	29	51	5693	34	9.6	0.6	470	52117	279	30921	0	31
163	55	POOL	43	36	5867	35	11.7	1.1	408	66539	485	79019	389	51
1	0	DRY	0	500	500	3	0.0	0.0	0	0	0	0	0	0

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq. ft.)	TOTAL VOL. (cu. ft.)
381	99	16639	149427	129743

Table 2 · SUMMARY OF HABITAT TYPES AND MEASURED PARAMETERS Survey Dates: 8/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

HABITAT UNITS #	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT OCCURRENCE %	MEAN LENGTH ft.	TOTAL LENGTH ft.	TOTAL LENGTH %	MEAN WIDTH ft.	MEAN DEPTH ft.	MAXIMUM DEPTH ft.	MEAN AREA sq.ft.	TOTAL AREA EST. sq.ft.	MEAN VOLUME cu.ft.	TOTAL VOLUME EST. cu.ft.	MEAN RESIDUAL POOL VOL cu.ft.	MEAN SHELTER RATING	MEAN CANOPY %
95	18	LGR	25	45	4291	26	9	0.6	6.0	333	31649	215	20448	0	8	85
9	3	HGR	2	27	241	1	16	0.6	1.0	100	899	60	537	0	38	96
2	1	BRS	1	24	47	0	3	0.6	0.9	47	95	28	57	0	60	90
1	0	POW	0	29	29	0	0	0.0	0.0	0	0	0	0	0	0	0
32	6	GLD	8	37	1192	7	11	0.6	1.2	396	12680	232	7415	0	8	89
72	13	RUN	19	49	3528	21	8	0.6	1.7	365	26304	196	14108	0	25	86
6	3	SRN	2	157	944	6	13	0.7	1.5	1068	6405	730	4382	0	102	94
35	11	MCP	9	32	1111	7	10	1.0	3.6	333	11665	385	13462	312	31	91
4	1	CCP	1	70	280	2	8	1.4	4.1	552	2209	956	3824	808	71	47
5	1	STP	1	101	505	3	9	1.2	4.7	709	3547	851	4255	556	114	93
1	1	CRP	0	59	59	0	7	1.1	1.9	392	392	432	432	392	0	85
13	3	LSL	3	27	355	2	12	1.4	3.9	316	4103	480	6239	354	93	85
61	13	LSR	16	34	2050	12	13	1.1	4.1	438	26717	480	29251	382	55	92
10	6	LSBk	3	37	367	2	11	1.2	3.1	410	4103	479	4786	367	23	87
17	9	LSBo	4	49	829	5	13	1.1	3.3	617	10486	731	12429	618	40	87
11	5	PLP	3	18	200	1	12	1.3	3.1	205	2259	277	3046	234	64	86
1	0	SCP	0	18	18	0	6	0.6	0.9	108	108	65	65	0	0	95
3	3	BPB	1	13	39	0	9	0.7	1.8	114	342	79	237	59	10	85
1	1	BPR	0	40	40	0	12	1.8	2.7	480	480	864	864	480	120	70
1	1	DPL	0	15	15	0	9	1.0	1.5	128	128	128	128	103	75	95
1	0	DRY	0	500	500	3	0	0.0	0.0	0	0	0	0	0	0	0

TOTAL UNITS	TOTAL UNITS	LENGTH (ft.)	AREA (sq.ft)	TOTAL VOL. (cu.ft)
381	99	16639	144571	125965

Palmer Creek Drainage: Mill Creek

Table 3 - SUMMARY OF POOL TYPES Survey Dates: 8/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	TOTAL AREA EST. (sq.ft.)	MEAN VOLUME (cu.ft.)	TOTAL VOLUME EST. (cu.ft.)	MEAN RESIDUAL POOL VOL. (cu.ft.)	MEAN SHELTER RATING
44	13	MAIN	27	43	1896	32	10.1	1.1	396	17420	490	21542	385	45
113	37	SCOUR	69	34	3860	66	12.5	1.1	425	48060	497	56182	399	54
6	5	BACKWATER	4	19	112	2	8.8	0.9	176	1058	216	1294	175	38

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq.ft.)	TOTAL VOL. (cu.ft.)
163	55	5867	66539	79019

Palmer Creek

Drainage: Mill Creek

Table 4 - SUMMARY OF MAXIMUM POOL DEPTHS BY POOL HABITAT TYPES

Survey Dates: 08/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

UNITS MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	<1 FOOT MAXIMUM DEPTH	<1 FOOT PERCENT OCCURRENCE	1-<2 FT. MAXIMUM DEPTH	1-<2 FOOT PERCENT OCCURRENCE	2-<3 FT. MAXIMUM DEPTH	2-<3 FOOT PERCENT OCCURRENCE	3-<4 FT. MAXIMUM DEPTH	3-<4 FOOT PERCENT OCCURRENCE	>=4 FEET MAXIMUM DEPTH	>=4 FEET PERCENT OCCURRENCE
35	MCP	21	0	0	24	69	9	26	2	6	0	0
4	CCP	2	0	0	2	50	1	25	0	0	1	25
5	STP	3	0	0	2	40	0	0	2	40	1	20
1	CRP	1	0	0	1	100	0	0	0	0	0	0
13	LSL	8	0	0	4	31	6	46	3	23	0	0
61	LSR	37	0	0	33	54	22	36	4	7	2	3
10	LSBk	6	0	0	3	30	6	60	1	10	0	0
17	LSBo	10	0	0	12	71	3	18	2	12	0	0
11	PLP	7	0	0	6	55	4	36	1	9	0	0
1	SCP	1	1	100	0	0	0	0	0	0	0	0
3	BPB	2	0	0	3	100	0	0	0	0	0	0
1	BPR	1	0	0	0	0	1	100	0	0	0	0
1	DPL	1	0	0	1	100	0	0	0	0	0	0

TOTAL UNITS
163

Table 6 - SUMMARY OF DOMINANT SUBSTRATES BY HABITAT TYPE Survey Dates: 08/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

TOTAL HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	% TOTAL SILT/CLAY DOMINANT	% TOTAL SAND DOMINANT	% TOTAL GRAVEL DOMINANT	% TOTAL SM COBBLE DOMINANT	% TOTAL LG COBBLE DOMINANT	% TOTAL BOULDER DOMINANT	% TOTAL BEDROCK DOMINANT
95	18	LGR	0	11	74	11	0	5	0
[illegible]	3	HGR	0	0	0	0	33	67	0
[illegible]	1	BRS	0	0	0	0	0	0	100
[illegible]	0	POW	0	0	0	0	0	0	0
[illegible]	6	GLD	0	17	67	17	0	0	0
[illegible]	13	RUN	0	8	62	15	0	15	0
[illegible]	3	SRN	0	0	33	0	33	33	0
[illegible]	11	MCP	0	38	54	0	0	8	0
[illegible]	1	CCP	0	0	100	0	0	0	0
[illegible]	1	STP	0	0	100	0	0	0	0
[illegible]	1	CRP	0	0	100	0	0	0	0
[illegible]	3	LSL	0	67	33	0	0	0	0
[illegible]	13	LSR	0	62	38	0	0	0	0
[illegible]	6	LSBk	0	17	67	0	17	0	0
[illegible]	9	LSBo	0	56	22	0	11	11	0
[illegible]	5	PLP	0	57	43	0	0	0	0
[illegible]	0	SCP	0	0	100	0	0	0	0
3	3	BPB	0	67	33	0	0	0	0
1	1	BPR	100	0	0	0	0	0	0
1	1	DPL	0	0	0	0	0	100	0
1	0	DRY	0	0	0	0	0	0	0

Table 10 - Summary of Shelter Type Areas by Habitat Type

Survey Dates: 08/23/95 to 09/18/95

Confluence Location: QUAD: GUERNEVILL LEGAL DESCRIPTION: T09NR10WS34 LATITUDE: 38°35'5" LONGITUDE: 123°56'48"

	UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	SQ. FT. UNDERCUT BANKS	SQ. FT. SWD	SQ. FT. LWD	SQ. FT. ROOT MASS	SQ. FT. TERR. VEGETATION	SQ. FT. AQUATIC VEGETATION	SQ. FT. WHITE WATER	SQ. FT. BOULDERS	SQ. FT. BEDROCK LEDGES
	95	16	LGR	33	0	0	0	0	0	0	491	0
	9	3	HGR	0	0	0	0	0	0	0	282	61
	2	1	BRS	0	0	0	0	0	0	5	11	0
	1	0	POW	0	0	0	0	0	0	0	0	0
	32	6	GLD	42	0	0	4	0	0	0	99	0
	72	13	RUN	32	22	66	66	0	0	20	654	0
	6	3	SRN	0	0	0	0	0	0	313	1875	0
	35	11	MCP	477	208	533	147	9	0	43	685	31
	4	1	CCP	77	3	47	77	0	0	215	333	254
	5	1	STP	103	13	0	26	0	0	296	905	53
	1	1	CRP	0	0	0	0	0	0	0	0	0
	13	3	LSL	417	187	444	44	0	0	0	62	0
	61	13	LSR	2334	520	1000	1867	59	0	8	183	0
	10	6	LSBk	120	0	0	53	14	0	0	172	168
	17	9	LSBo	294	40	735	643	0	0	36	1307	24
	11	5	PLP	114	35	75	24	0	0	77	85	0
	1	0	SCP	0	0	0	0	0	0	0	0	0
	3	3	BPB	6	0	0	0	0	0	0	30	3
	1	1	BPR	19	0	58	115	0	0	0	0	0
	1	1	DPL	0	0	10	3	0	0	0	20	0
	1	0	DRY	0	0	0	0	0	0	0	0	0
TOTAL	381	97		4068	1028	2968	3069	82	0	1013	7194	594

Appendix A

Summary of Mean Percent Vegetative Cover for Entire Stream

Mean Percent Canopy	Mean Percent Conifer	Mean Percent Decidous	Mean Right bank % Cover	Mean Left Bank % Cover
87.49	60.23	39.77	70.78	73.24

Appendix B

FISH HABITAT INVENTORY DATA SUMMARY

STREAM NAME: Palmer Creek
SAMPLE DATES: 08/23/95 to 09/18/95
STREAM LENGTH: 16639 ft.
LOCATION OF STREAM MOUTH:
USGS Quad Map: GUERNEVILL — Latitude: 38°35'5"
Legal Description: T09NR10WS34 — Longitude: 123°56'48"

SUMMARY OF FISH HABITAT ELEMENTS BY STREAM REACH

STREAM REACH 1

Channel Type: F4
Channel Length: 3249 ft.
Flowing Water Mean Width: 11 ft.
Flowing Water Mean Depth: 0.4 ft.
Base Flow: 0.0 cfs
Water: 59 - 64 °F Air: 74 - 80 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 74%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 85%
Coniferous Component: 68%
Deciduous Component: 33%
Pools by Stream Length: 25%
Pools >=3 ft.deep: 4%
Mean Pool Shelter Rtn: 35
Dom. Shelter: Boulders
Occurrence of LOD: 39%
Dry Channel: 0 ft.
Embeddness Value: 1. 33% 2. 37% 3. 19% 4. 11%

STREAM REACH 2

Channel Type: F3
Channel Length: 6152 ft.
Flowing Water Mean Width: 10 ft.
Flowing Water Mean Depth: 0.8 ft.
Base Flow: 0.0 cfs
Water: 56 - 63 °F Air: 53 - 84 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 74%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 87%
Coniferous Component: 55%
Deciduous Component: 45%
Pools by Stream Length: 40%
Pools >=3 ft.deep: 20%
Mean Pool Shelter Rtn: 55
Dom. Shelter: Boulders
Occurrence of LOD: 43%
Dry Channel: 0 ft.
Embeddness Value: 1. 15% 2. 46% 3. 20% 4. 20%

STREAM REACH 3

Channel Type: F2
Channel Length: 2437 ft.
Flowing Water Mean Width: 12 ft.
Flowing Water Mean Depth: 0.6 ft.
Base Flow: 0.0 cfs
Water: 58 - 61 °F Air: 65 - 84 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 70%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 91%
Coniferous Component: 47%
Deciduous Component: 53%
Pools by Stream Length: 42%
Pools >=3 ft.deep: 20%
Mean Pool Shelter Rtn: 70
Dom. Shelter: Boulders
Occurrence of LOD: 25%
Dry Channel: 0 ft.
Embeddness Value: 1. 0% 2. 35% 3. 20% 4. 45%

STREAM REACH 4

Channel Type: F4
Channel Length: 4802 ft.
Flowing Water Mean Width: 6 ft.
Flowing Water Mean Depth: 0.4 ft.
Base Flow: 0.0 cfs
Water: 52 - 59 °F Air: 59 - 70 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 70%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 89%
Coniferous Component: 71%
Deciduous Component: 29%
Pools by Stream Length: 33%
Pools >=3 ft.deep: 4%
Mean Pool Shelter Rtn: 48
Dom. Shelter: Undercut Banks
Occurrence of LOD: 34%
Dry Channel: 500 ft.
Embeddness Value: 1. 9% 2. 44% 3. 29% 4. 18%

Appendix C

Mean Percentage of Dominant Substrate

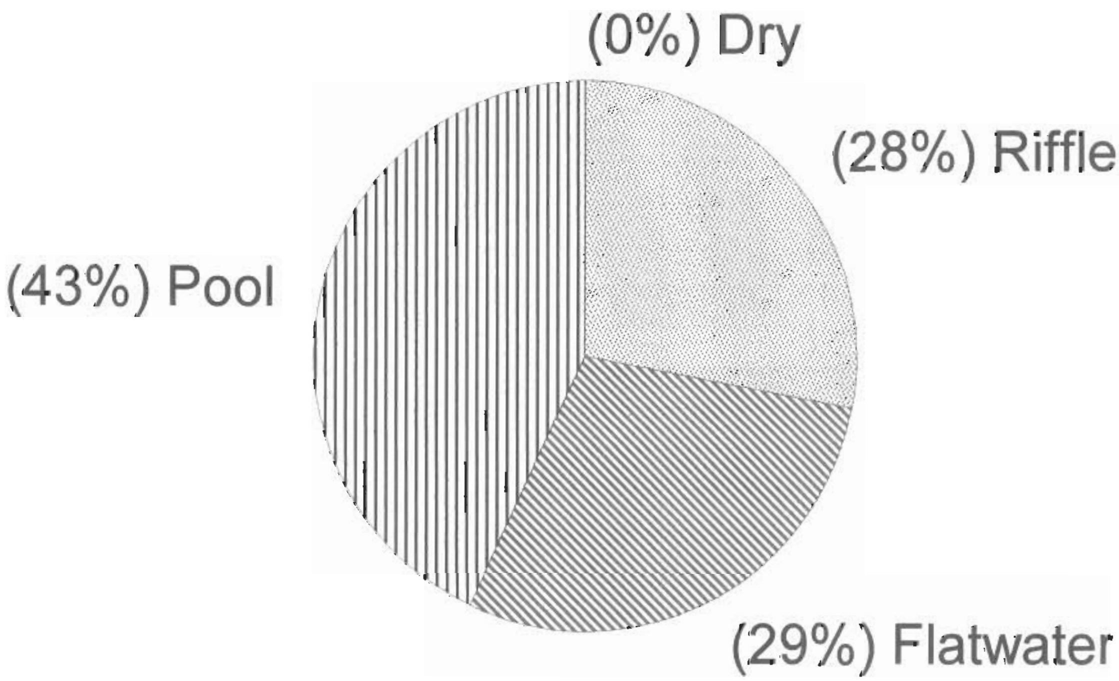
Dominant Class of Substrate	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Bedrock	14	10	11.88
Boulder	18	11	14.36
Cobble/Gravel	48	60	53.47
Silt/clay	21	20	20.30

Mean Percentage of Dominant Vegetation

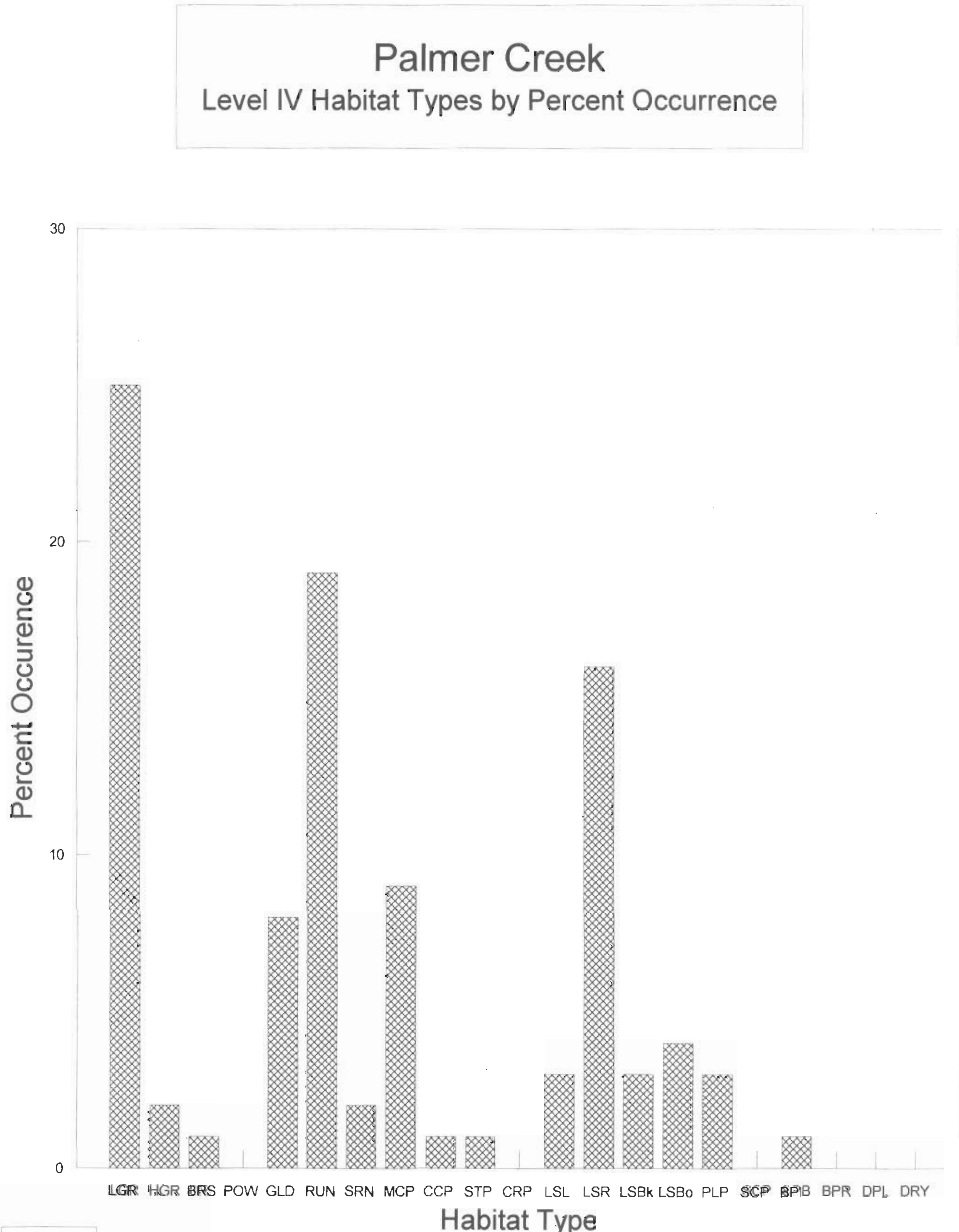
Dominant Class of Vegetation	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Grass	1	0	0.49
Brush	1	2	1.47
Decid. Trees	32	41	35.78
Conif. Trees	65	57	59.80
No Vegetation	3	2	2.45

Palmer Creek

Level II Habitat Types by % Occurrence



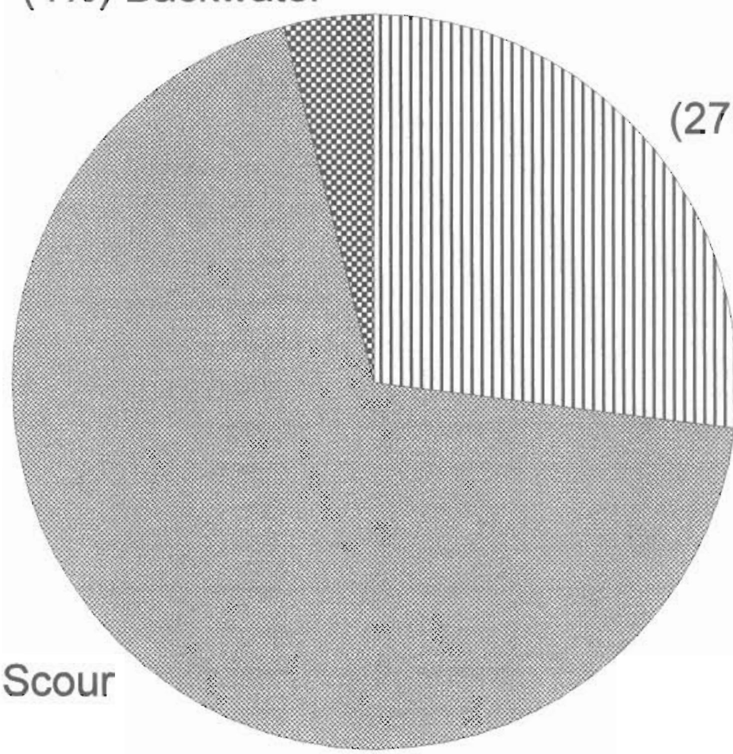
Graph 1


Palmer Creek
Level IV Habitat Types by Percent Occurrence
30
20
10
0
Percent Occurence
LGR HGR BRS POW GLD RUN SRN MCP CCP STP CRP LSL LSR LSBk LSBo PLP SCP BPB BPR DPL DRY
Habitat Type

Graph 2

Palmer Creek

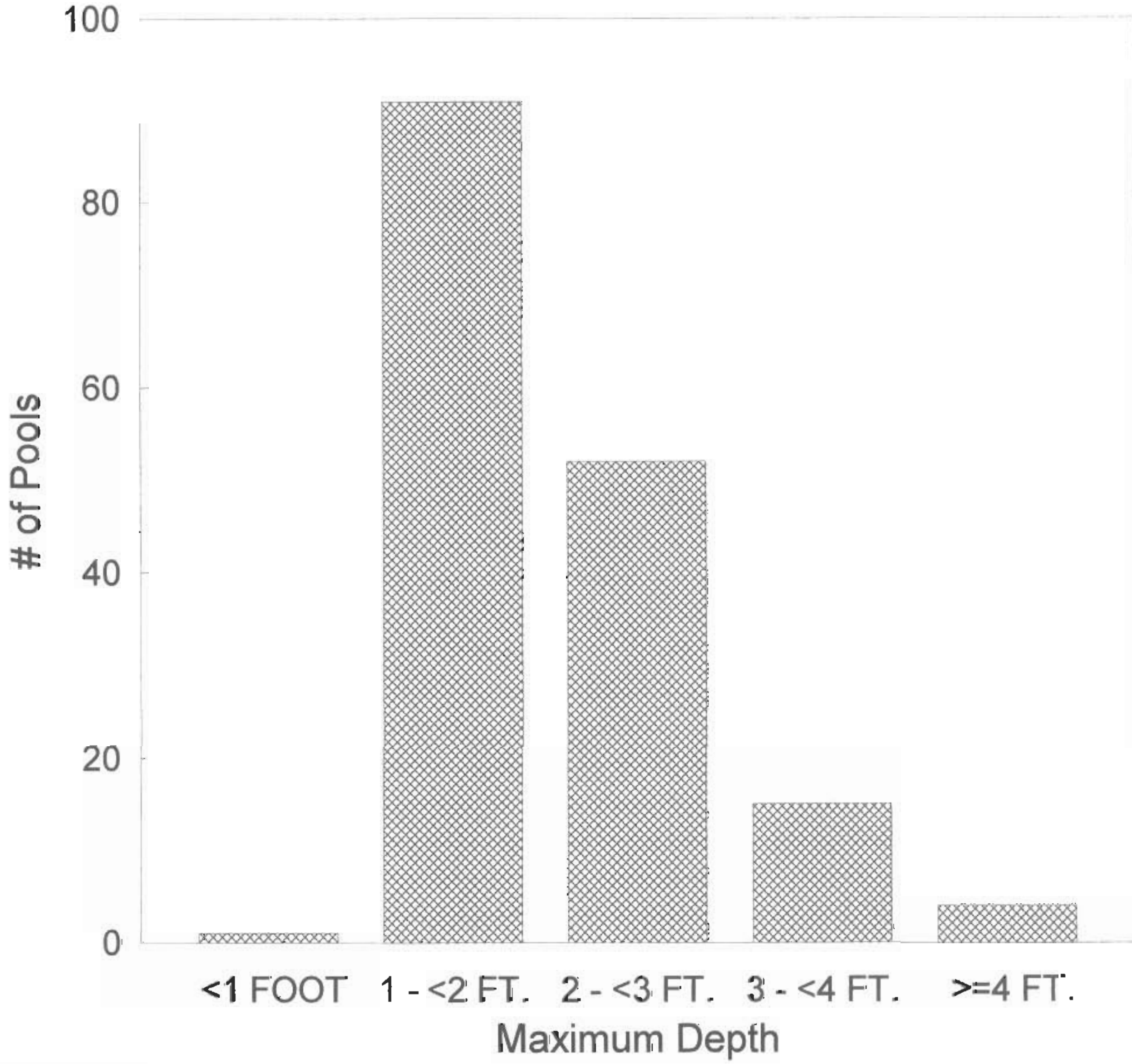
Pool Habitat Types by % Occurrence



Graph 3

Palmer Creek

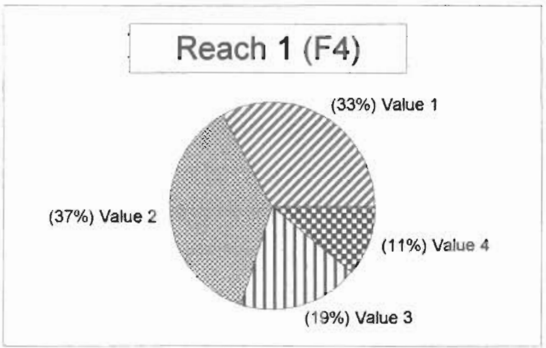
Maximum Depth in Pools

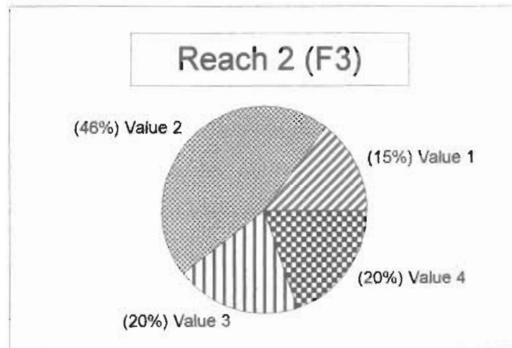


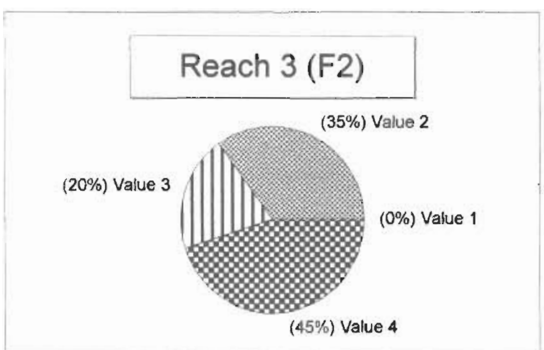
Graph 4

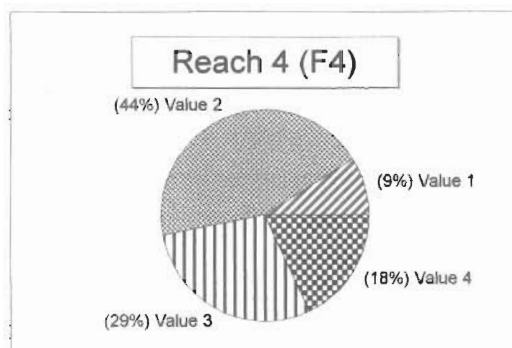
Palmer Creek

Percent Embeddedness by Reach







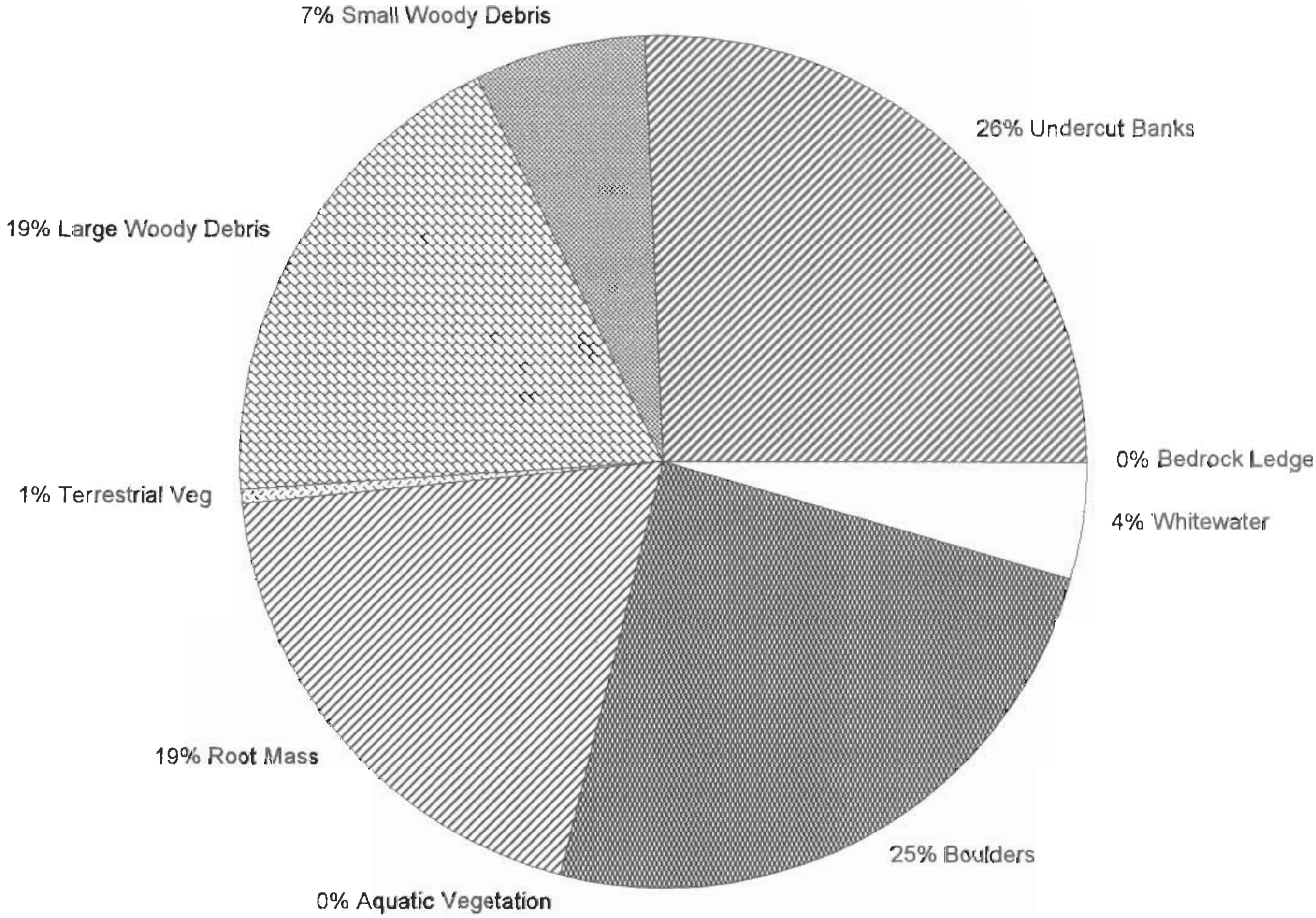


Value 1 = <25% Value 2 = 25-50% Value 3 = 51-75% Value 4 = >76%

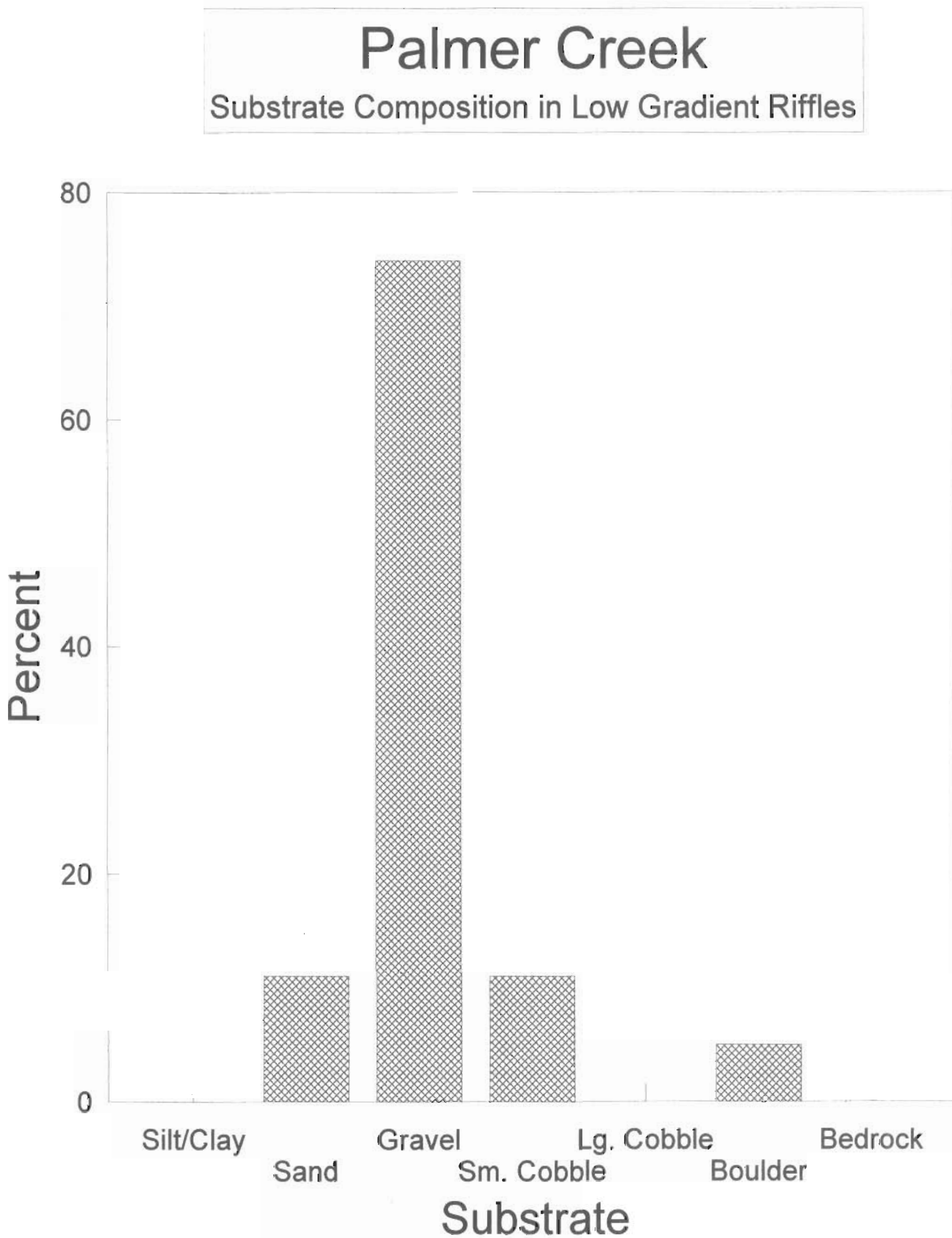
Graph 5

Palmer Creek

Percent Cover Types in Pools



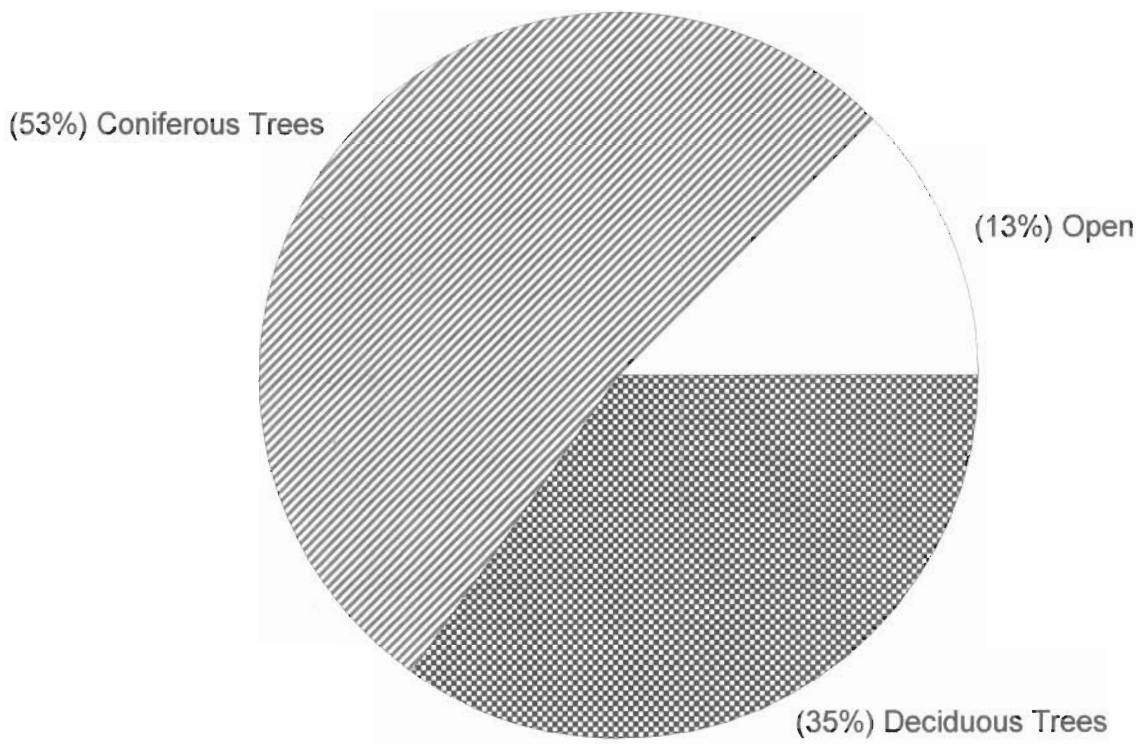
Graph 6


Palmer Creek
Substrate Composition in Low Gradient Riffles
80
60
40
20
0
Percent
Silt/Clay
Sand
Gravel
Sm. Cobble
Lg. Cobble
Boulder
Bedrock
Substrate

Graph 7

Palmer Creek

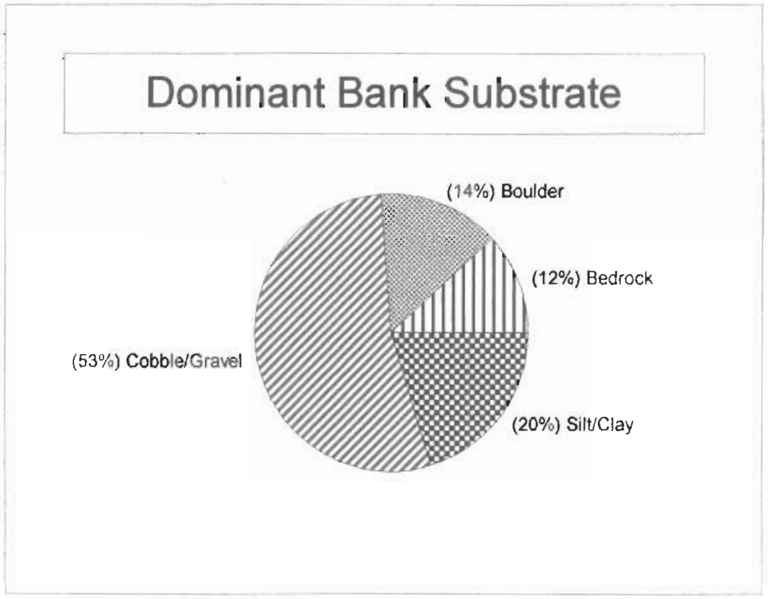
Mean Percent Canopy

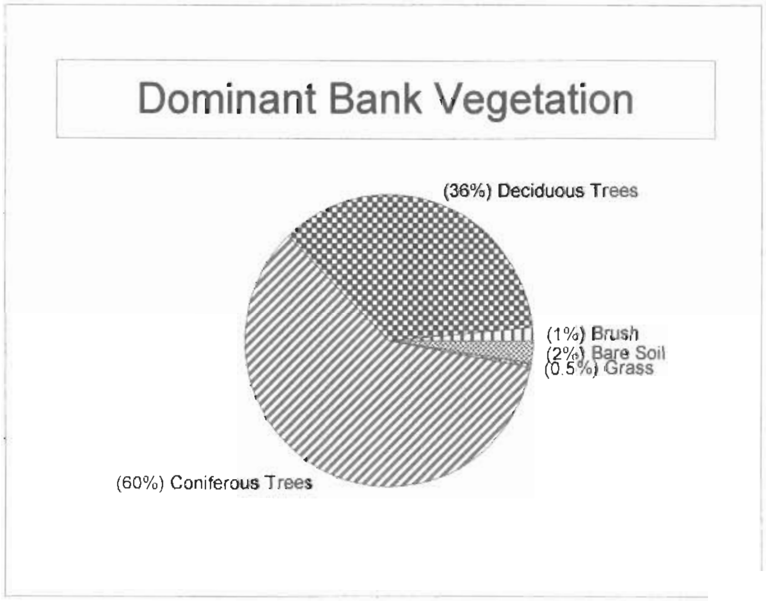


Graph 8

Palmer Creek

Percent Bank Composition

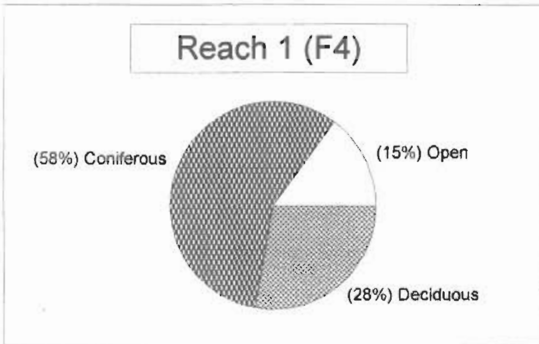


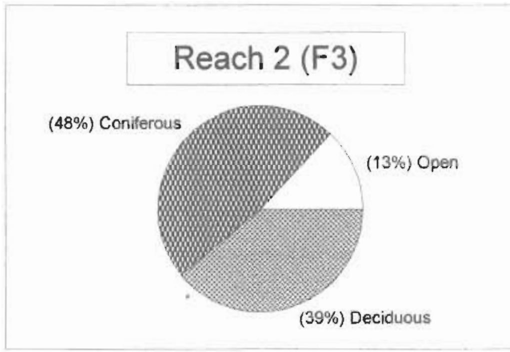


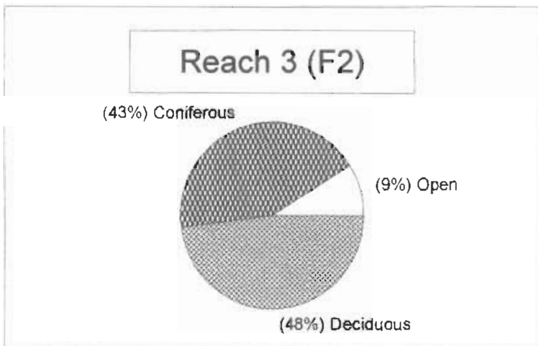
Graph 9

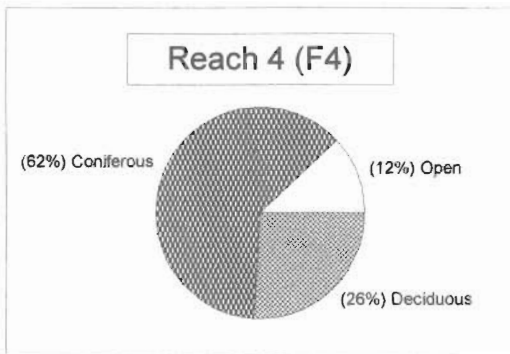
Palmer Creek

Percent Canopy by Reach









Graph 11

CALIFORNIA DEPARTMENT OF FISH AND GAME
STREAM INVENTORY REPORT
Angel Creek
Report revised April 14, 2006
Report Completed 2000
Assessment Completed 1995

INTRODUCTION

A stream inventory was conducted during the summer of 1995 on Angel Creek to assess habitat conditions for anadromous salmonids. The inventory was conducted in two parts: habitat inventory and biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids. The objective of the biological inventory was to document the salmonid and other aquatic species present and their distribution. After analysis of historical information and data gathered recently, stream restoration and enhancement recommendations are presented.

WATERSHED OVERVIEW

Angel Creek is a tributary to Mill Creek, which is a tributary to Dry Creek which empties into the Russian River, located in Sonoma County, California (See Angel Creek map). The legal description at the confluence with Mill Creek is T9N,R10W,S28. Its location is 38°36'20" N. latitude and 122°58'45" W. longitude. Year round vehicle access exists from a private road, via Mill Creek Rd., via Westside Rd. near Healdsburg.

Angel Creek is a second order stream and has approximately 1.23 miles of blue line stream, according to the USGS Guerneville 7.5 minute quadrangle. Angel Creek drains a basin of approximately 1.1 square miles. Flow was measured as approximately 0.15 cfs on July 29, 1995 near the confluence with Mill Creek. Elevations range from about 520 feet at the mouth of the creek to 1000 feet in the headwater areas. Coniferous forest dominates the watershed.

The endangered Northern Spotted Owl *(Strix occidentalis caurina)* is listed in DFG's Natural Diversity Database as occurring within Mill Creek Watershed. No sensitive plants were listed.

METHODS

The habitat inventory conducted in Angel Creek follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1991). There are 9 components to the inventory: flow, channel type, temperatures, habitat type, embeddedness, shelter rating, substrate composition, canopy, and bank composition. The AmeriCorps members that conducted the inventory were trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG) under the supervision of DFG's Russian River Basin Planner, Robert Coey in May, 1995. This inventory was conducted by a two person team. See parent stream inventory report (Mill Creek) for a complete discussion of methods.

HABITAT INVENTORY COMPONENTS

A standardized habitat inventory form has been developed for use in California stream surveys and can be found in the California Salmonid Stream Habitat Restoration Manual. This form was used in Mill Creek to record measurements and observations. There are nine components to the inventory form.

1. Flow:

Flow is measured in cubic feet per second (cfs) at the bottom of the stream survey reach using standard flow measuring equipment, if available. In some cases flows are estimated. Flows were also measured or estimated at major tributary confluences.

2. Channel Type:

Channel typing is conducted according to the classification system developed by David Rosgen (1985). This methodology is described in the California Salmonid Stream Habitat Restoration Manual. Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are four measured parameters used to determine channel type: 1) water slope gradient, 2) channel confinement, 3) width/depth ratio, 4) substrate composition.

3. Temperatures:

Water and air temperatures, and time taken, are measured by crew members with handheld thermometers and recorded at each tenth unit typed. Temperatures are measured in Fahrenheit at the middle of the habitat unit and within one foot of the water surface. Temperatures are also recorded using Ryan Temp-mentors which log temperature every two hours, 24 hours/day.

4. Habitat Type:

Habitat typing uses the 24 habitat classification types defined by

McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "dry". Angel Creek habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. Channel dimensions were measured using hip chains, range finders, tape measures, and stadia rods. Unit measurements included mean length, mean width, mean depth, and maximum depth. Pool tail crest depth at each pool unit was measured in the thalweg. All measurements were taken in feet to the nearest tenth.

5. Embeddedness:

The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. In Angel Creek, embeddedness was visually estimated. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value 4).

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent cover. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All cover is then classified according to a list of nine cover types. In Angel Creek, a standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) was assigned according to the complexity of the cover. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes. Mechanical substrate sampling was also conducted to quantify the percentage of fine sediment within spawning gravels.

8. Canopy:

Stream canopy is estimated using handheld spherical densiometers and is a measure of the water surface shaded during periods of high sun. In Angel Creek, an estimate of the percentage of the habitat unit covered by canopy was made from the center of each unit. The area of canopy was further analyzed to estimate its percentages of coniferous or deciduous trees, and the results recorded.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In Angel Creek, the dominant composition type in both the right and left banks was selected from a list of eight options on the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

SUBSTRATE SAMPLING

Gravel sampling is conducted to determine the percentage of fine sediment present in probable fish spawning areas. These areas are generally found in low gradient riffles at the tail-outs of pools. Two substrate samples were taken in potential spawning riffles in Angel Creek between December 4-7, 1995. One sample was in Reach 1 and the other was in Reach 2. Each sample consisted of one 12" McNeil sample to characterize each reach.

The samples were placed through a series of sieves with diameters of .85mm, 2.37mm, 4.7mm, 12.5mm, 25.4mm, 50.8mm, 76.2mm and 150mm. Displacement volumes were measured for particles in each size classification. Finally, the remaining sample <0.85mm was placed in Imhoff cones for 1 hour with the volume of fines settled out and measured.

BIOLOGICAL INVENTORY

Biological sampling during stream inventory is used to determine fish species and their distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. These sampling techniques are discussed in the California Salmonid Stream Habitat Restoration Manual.

DATA ANALYSIS

Data from the habitat inventory form are entered into the Habitat Program, a dBASE IV data entry program developed by the California Department of Fish and Game (DFG). This program also processes and summarizes the data.

The Habitat Runtime program produces the following tables:

- Riffle, flatwater, and pool habitat types
- Habitat types and measured parameters
- Pool types
- Maximum pool depths by habitat types
- Dominant substrates by habitat types
- Shelter type areas by habitat types

Graphics are produced from the tables using Lotus 1,2,3. Graphics developed for Angel Creek include:

- Level II Habitat Types by % Occurrence
- Level IV Habitat Types by % Occurrence
- Pool Habitat Types by % Occurrence
- Maximum Depth in Pools
- Percent Embeddedness by Reach
- Percent Cover Types in Pools
- Substrate Composition in Low Gradient Riffles
- Percent Canopy by Reach
- Percent Bank Composition

HABITAT INVENTORY RESULTS FOR ANGEL CREEK

** ALL TABLES AND GRAPHS ARE LOCATED AT THE END OF THE REPORT *

The habitat inventory of September 7 to October 2, 1995 was conducted by Ken Mogan, Kurt Gregory, John Fort (AmeriCorps) and Julie Maggi (NRCS). The survey began at the confluence with Mill Creek and extended up Angel Creek to the end of survey at a log jam. The total length of the stream surveyed was 5413 feet.

Flow was measured at 0.15 cfs on July 29, 1995 near the confluence with Mill Creek.

This section of Angel Creek has 2 channel types: from the mouth to 2046 feet an F4 and the upper 3367 feet an A4.

F4 channels are entrenched meandering riffle/pool channels on low gradients (<2%) with high width/depth ratio and a gravel substrate.

A4 streams are steep, narrow, cascading step-pool streams with high gradient (4-10%), gravel substrate and high energy/debris transport associated with depositional soils.

Water temperatures ranged from 56°F to 65°F. Air temperatures ranged from 56°F to 87°F.

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. By percent **occurrence**, riffles made up 44%, pools 34%, and flatwater 16% (Graph 1). Riffle habitat types made up 65% of the total survey **length**, pools 16%, and flatwater 13%.

Twelve Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent **occurrence** were low gradient riffles, 40%. Percent occurrence of plunge pools was 11%, runs 10%, and root wad scour pools 9% (Graph 2). By percent total **length**, low gradient riffles made up 62%, runs 7%; root wad scour pools 5%, and plunge pools 4%.

Forty-six pools were identified (Table 3). Scour pools were most often encountered at 72%, and comprised 68% of the total length of pools (Graph 3).

Table 4 is a summary of maximum pool depths by pool habitat types. Depth is an indicator of pool quality. Only six of the 46 pools (13%) had a depth of two feet or greater (Graph 4).

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Pool types had the highest mean shelter rating at 61. Flatwater had a mean shelter rating of 10, and riffles 3 (Table 1). Of the pool types, the scour pools had the highest mean shelter rating at 76 and main channel pools rated 20 (Table 3).

Table 10 summarizes mean percent cover by habitat type. Root masses are the dominant cover type for pools in Angel Creek. Undercut banks and large woody debris are the next most common pool cover types. Graph 6 describes the pool cover in Angel Creek.

Table 6 summarizes the dominant substrate by habitat type. Gravel was the dominant substrate observed in all of the seven low gradient riffles that were measured.

The depth of cobble embeddedness was estimated at pool tail-outs. Of the 46 pool tail-outs measured, 8 had a value of one (17%); fifteen had a value of two (33%); sixteen had a value of three (35%); and seven had a value of four (15%). On this scale, a value of one is best for fisheries. On a reach by reach comparison, Reach 1 was best with 78% of the pool tail-outs having either a 1 or 2 embeddedness value while Reach 2 had only 25% with a 1 or 2 (Graph 5).

Substrate samples were taken in the field by Mogan, Fort and Huber (AmeriCorps). Laboratory analysis was done by Hards (SSU Intern), Huber, Nossaman and Sanchez (AmeriCorps) in May of 1996. The data was then summarized and analyzed with a computer program written by Dwain Goforth, National Park Service.

The analysis showed sample 1 (Reach 1) to be 8.7% fines (<0.85 mm) and sample 2 (Reach 2) to be 8.9% fines. The combined summary of both samples averaged 8.8% fines. The combined summary showed 75% of the substrate to be less than 42mm, 50% to be less than 19mm and 25% to be less than 4.82mm (see Grain Size Distribution Plot). No stratification in fines was evident by reach.

Twelve percent of Angel Creek lacked shade canopy. Seventy-three percent of the stream had canopy consisting of coniferous trees and 15% had a canopy of deciduous trees.

For the stream reach surveyed, the mean percent right bank vegetated was 71% and the mean percent left bank vegetated was 70% (Appendix C). For the habitat units measured, the dominant vegetation types for the stream banks were: 84% coniferous trees, 9% deciduous trees, 5% brush and 2% grass. The dominant substrate for the stream banks were: 78% cobble/gravel, 21% silt/clay/sand and 2% bedrock (Appendix C, Graph 9).

HABITAT INVENTORY RESULTS FOR N.F. TRIB. TO ANGEL CREEK

The habitat inventory of October 3, 1995 was conducted by Ken Mogan and Kurt Gregory. The survey began at the confluence with Angel Creek and extended up N.F. Trib to Angel Creek to the end of survey. The total length of the stream surveyed was 1552 feet.

This section of N.F. Trib to Angel Creek is an F4 channel type. F4 streams are entrenched, meandering riffle/pool gravel channels on low gradients with high depth/width ratio.

Water temperatures ranged from 55°F to 58°F. Air temperatures ranged from 59°F to 66°F.

*By percent **occurrence**, pools made up 31%, riffles 31%, and flatwater 26% of the habitat.*

Nine Level IV habitat types were identified. The most frequent *habitat types by percent* ***occurrence*** *were low gradient riffles, 28%. The percent occurrence of glides was 15%; log enhanced scour pools, 15%; and dry stream bed, 13%. By percent total* ***length****, dry stream bed made up 45%, low gradient riffles 28%, glides 8% and log enhanced scour pools 5%.*

Twelve pools were identified. Scour pools were most often encountered at 83%, and comprised 80% of the total length of pools. Only one of the 12 pools had a depth of two feet or greater.

Pool types had the highest shelter rating at 86. Riffles had a mean shelter rating of 13 and flatwater had the lowest rating at 2. Large woody debris is the dominant cover type.

Gravel was the dominant substrate observed. Of the 12 pool tail-outs measured for depth of cobble embeddedness, 59% had a value of either 1 or 2.

Approximately 13% of N.F. Trib to Angel Creek lacked shade canopy. For the stream reach surveyed, the mean percent left bank vegetated was 65% and the mean percent right bank vegetated was 55%. For the habitat units measured, the dominant vegetation types for the stream banks were: 79% coniferous trees, 8% deciduous trees, 8% brush and 4% bare soil. The dominant substrate for the stream banks were: 71% cobble/gravel, 13% bedrock, 13% silt/clay/sand and 4% boulder.

BIOLOGICAL INVENTORY

JUVENILE SURVEYS:

On October 10, 1995 a biological inventory was conducted in Angel Creek to document the fish species composition and distribution at several locations. Each site was single pass electrofished using one Smith Root Model 12 electrofisher. Fish from each site were counted by species, and returned to the stream. Air and water temperatures were not taken at this time. The observers were Ken Mogan and Kurt Gregory.

The inventory of Reach one was conducted starting 100 yards upstream from the confluence with Mill Creek in habitat units 3-24. In pool riffle, run and glide habitat types 45 0+, three 1+ and three 2+ steelhead were observed along with 51 sculpin, 3 largemouth bass and 5 Pacific Giant salamanders.

The inventory of Reach two was conducted starting 1/4 mile above the green gates on the private access road in habitat units 68-81.

In pool, riffle and run habitat types 25 0+, zero 1+ and one 2+ steelhead were observed along with 13 sculpin and 3 Pacific Giant salamanders.

The following table summarizes species observed in DFG surveys:

SUMMARY OF SPECIES OBSERVED IN DFG SURVEYS ON ANGEL CREEK		
SPECIES	**YEARS**	**Native/Introduced**
Steelhead	1995	N
Sculpin	1995	N
Largemouth Bass	1995	I
Pacific Giant Salamander	1995	N

DISCUSSION

Angel Creek has two channel types: F4 and A4. The lower 2046 feet is an F4 channel type. F4 channels are good for placed boulders and fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover.

The upper 3367 feet of Angel Creek is an A4 channel. The high energy and steep gradient of A4 channels makes them generally unsuitable for instream enhancement structures. However, bank-placed boulders are often appropriate. Any work considered on Angel Creek will require careful design, placement and construction.

The water temperatures recorded on the survey days September 7 - October 2, 1995 ranged from 56°F to 65°F. Air temperatures ranged from 56°F to 87°F. For steelhead, maximum summertime temperatures should be kept below 65°F. The warmest water temperature at 65°F was recorded in Reach 1 on September 7.

Riffle habitat types comprised 65% of the total **length** of this survey; pools 16%; and flatwater 13%. The pools are relatively shallow with 13% having a maximum depth greater than 2 feet. In coastal coho and steelhead streams, it is generally desirable to have primary pools comprise approximately 50% of total habitat. In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. Therefore, installing structures that will increase pool habitat is recommended for locations where their installation will not jeopardize unstable stream banks, or subject the structures to high stream energy.

In Angel Creek, the mean shelter rating for pools was 61. In the North Fork, shelter rating was 86. However, a pool shelter rating of approximately 100 is desirable. The relatively small amount of pool cover that now exists is being provided primarily by root masses, undercut banks and large woody debris. Log and root wad cover structures in the pool and flatwater habitats are needed to improve both summer and winter salmonid habitat. Log cover structure provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

All low gradient riffles measured had either gravel or small cobble as the dominant substrate. This is generally considered good for spawning salmonids.

In Reach 1, 78% of the pool tail-outs measured had embeddedness ratings of either 1 or 2. However, embeddedness ratings were much better in Reach 1 than in Reach 2 (Graph 5). Cobble embeddedness measured to be 25% or less, a rating of one, is considered best for the needs of salmon and steelhead. In Angel Creek, sediment sources should be mapped and rated according to their potential sediment yields, and control measures taken.

The gravel program analyzed the substrate sample data for egg to emergence survival rates for steelhead and coho. The survival rates are based on a 95% confidence interval and used the Fredle Index. Based on this index and the data on Angel Creek, the mean egg to emergence survival rate would be 79% for steelhead and 62% for coho salmon.

The mean percent canopy for the survey reach was 88%. This is good, since 80 percent is generally considered desirable. Water temperatures may be higher due to past removal of mature canopy trees. Larger trees required to contribute shade would improve streambank stability and eventually provide a long term source of large woody debris needed for instream structure.

SUMMARY

A biological survey was conducted to document fish distribution and is not necessarily representative of population information. The survey documented many 0+ steelhead, indicating successful spawning. However, few 1+ fish were observed indicating poor rearing conditions the year before or poor holding-over conditions in general. Although coho were not found in this creek, they were found in Mill Creek near the confluence. If the temperature regime and shelter value were improved, coho might utilize Angel Creek.

In general, Angel Creek is fair for steelhead habitat. There are relatively few pools with adequate depth and shelter. Although riffle habitat exists, much of it is impacted from sediment, making it marginal for spawning. Shade canopy is good on Angel Creek, although it mostly consists of younger trees.

Both reaches are good for bank placed boulders. Reach 1 is fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover.

GENERAL RECOMMENDATIONS

Angel Creek should be managed as an anadromous, natural production stream.

The winter 1995/96 storms brought down many large trees and other woody debris into the stream, which increased the number and quality of pools since the date of this survey. This woody debris, if left undisturbed, will provide fish cover and rearing habitat, and offset channel incision. Many signs of recent and historic tree and log removal were evident in the active channel during our survey. Past efforts to increase flood protection or improve fish access in the short run, have led to long term problems in the system. Landowners should be educated about the natural and positive role woody debris plays in the system, and encouraged not to remove woody debris from the stream, except under extreme buildup and only under guidance by a fishery professional.

PRIORITY FISHERY ENHANCEMENT OPPORTUNITIES

1) Several treated landslides exist in the headwater areas. These sources of erosion should be corrected. Alternatives need to be explored with the landowner and appropriate funding agencies.

2) Map sources of upslope and in-channel erosion, and prioritize them according to present and potential sediment yield. Identified sites should then be treated to reduce the amount of fine sediments entering the stream.

3) Where feasible, increase woody cover in the pool and flatwater

habitat units along the entire stream. Adding high quality complexity with larger woody cover is desirable. Combination cover/scour structures constructed with boulders and woody debris would be effective in many flatwater and pool locations in the upper reaches. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion. In some areas the material is at hand.

4) Where feasible, design and engineer pool enhancement structures to increase the number of pools in the upper reaches. This must be done where the banks are stable or in conjunction with stream bank armor to prevent erosion.

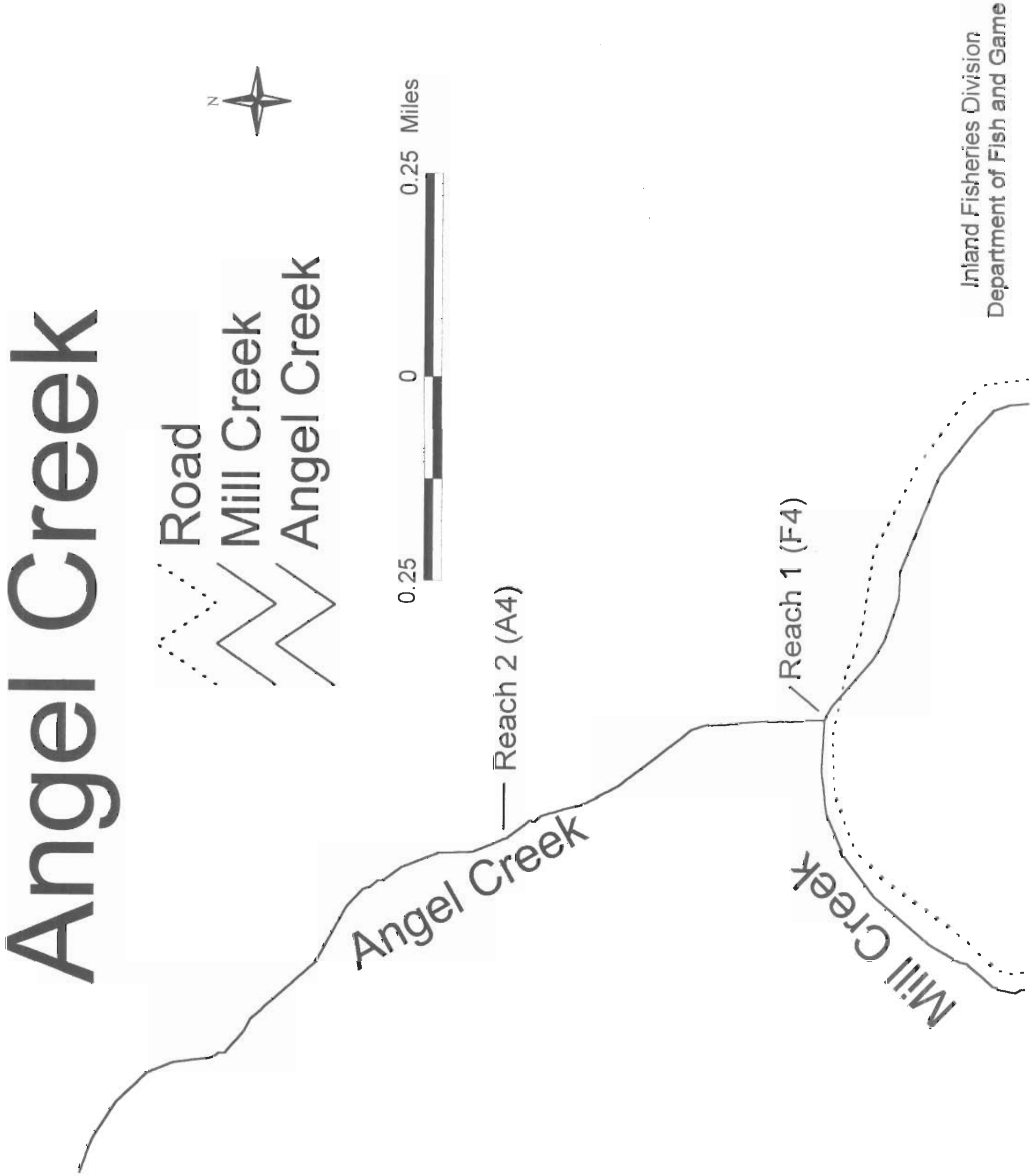
PROBLEM SITES AND LANDMARKS - ANGEL CREEK SURVEY COMMENTS

STREAM LENGTH (FT)	COMMENTS	HABITAT UNIT #
76	2+ FISH	
97	CULVERT 21'L X 5' DIAM.; ANGEL CREEK RD	
807	CRAYFISH;SPRING	
857	GIANT PACIFIC SALAMANDER 12" LONG AT LOG JAM	
936	BRIDGE #1; TRIBUTARY LF BANK (CULVERT)	029
1066	CULVERT 42' LONG	
1078	CRAYFISH	
1123	CRAYFISH	
1373	LOG JAM	
1403	LOG JAM	043
1475	0+ SALMONIDS; CRAYFISH	048
1577	ELECTROFISHING SPOT	
1614	ELECTROFISHING SPOT	
2374	GULLY 20'L X 25'W X 15'D UPSLOPE, HIGH WATER; ROAD ABOVE SLIDE	
2427	LOG JAM	
2877	2+ FISH; TRIBUTARY RT BK 56°F	075
3239	LOGGING ROAD THROUGH CREEK	
3249	ELECTROFISHING SPOT; 6-0+ FISH	
3510	LOG JAM; RT BANK EROSION 35'L X 30'W X 18'D HIGH WATER FLOW AND DEBRIS INFLUENCE	
3522	ELECTROFISHING SPOT; 0+ FISH	
3786	LOG JAM 10'L X 6'H X 25'W; OLD ROAD THROUGH CREEK	096
3891	PACIFIC GIANT SALAMANDERS	
3900	LARGE FROG	
4113	LARGE LOG JAM	
4129	LARGE LOG JAM CONTINUED	
4231	SPRING RT BANK 59°F	
4295	SPRING RT BANK 59°F	

4331 LOG JAM BELOW DRY UNIT 5'H X 15'W X 9'L RETAINING GRAVEL 108
4866 PACIFIC GIANT SALAMANDER
4957 DRY TRIB LF BANK
5176 SLIDE LF BANK 15'L X 20'W X 6'D
5303 SPRING LF BANK; IRON DEPOSITS BOTH LF AND RT BANKS
5314 FINE SILT ON TOP OF CREEK SUBSTRATE; SPRING LF BANK
5414 NO CULVERT FOR NEW ROAD BUILT ABOVE HERE ON RT BANK 135

PROBLEM SITES AND LANDMARKS - N.F. TRIB TO ANGEL CREEK SURVEY

STREAM LENGTH (FT)	*COMMENTS*
164	*CULVERT AGGRADING, 41' LONG INSTREAM*
184	*3' CULVERT INSTREAM 20' L NEW LOGGING ROAD*
514	*E.F. SPOT; 0+ SALMONIDS*
584	*SCULPINS*
676	*IRON DEPOSITS 4' X 6' CAUSED BY HIGH WATER AND ROAD THROUGH CREEK*
711	*2+ SALMONIDS*
753	*OLD LOGGING ROAD THROUGH CREEK*
786	*DEAD SCULPIN*
817	*CRAYFISH; E.F. SPOT*
881	*5 PC LG WOODY DEBRIS*
909	*SPRING RT BK; OLD LOGGING RD THROUGH CREEK*
928	*DRY TRIB RT BK*
934	*PACIFIC GIANT SALAMANDER; LOG JAM*
1152	*END OF SURVEY*


Angel Creek
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Inland Fisheries Division
Department of Fish and Game
Reach 2 (A4)
Reach 1 (F4)
Angel Creek
Mill Creek

Angel Creek   Drainage: Mill Creek

Table 1 - SUMMARY OF RIFFLE, FLATWATER, AND POOL HABITAT TYPES   Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0"   LONGITUDE: 0°0'0"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	ESTIMATED TOTAL AREA (sq.ft.)	MEAN VOLUME (cu.ft.)	ESTIMATED TOTAL VOLUME (cu.ft.)	MEAN RESIDUAL POOL VOL (cu.ft.)	MEAN SHELTER RATING
59	8	RIFFLE	44	60	3530	65	4.8	0.2	126	7418	26	1555	0	3
22	6	FLATWATER	16	31	692	13	3.8	0.4	135	2978	46	1011	0	10
46	11	POOL	34	19	853	16	7.0	0.9	125	5765	111	5088	90	61
8	0	DRY	6	42	338	6	0.0	0.0	0	0	0	0	0	0

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq. ft.)	TOTAL VOL. (cu. ft.)
135	25	5413	16160	7653

Table 2 - SUMMARY OF HABITAT TYPES AND MEASURED PARAMETERS Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0" LONGITUDE: 0°0'0"

HABITAT UNITS #	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT OCCURRENCE %	MEAN LENGTH ft.	TOTAL LENGTH ft.	TOTAL LENGTH %	MEAN WIDTH ft.	MEAN DEPTH ft.	MAXIMUM DEPTH ft.	MEAN AREA sq.ft.	TOTAL AREA EST. sq.ft.	MEAN VOLUME cu.ft.	TOTAL VOLUME EST. cu.ft.	MEAN RESIDUAL POOL VOL cu.ft.	MEAN SHELTER RATING	MEAN CANOPY %
54	7	LGR	40	62	3344	62	5	0.2	0.8	137	7379	29	1549	0	3	86
5	1	HGR	4	37	186	3	3	0.2	0.3	38	192	8	39	0	0	95
7	2	GLD	5	31	215	4	4	0.4	0.7	114	796	40	279	0	0	91
14	3	RUN	10	28	385	7	4	0.3	1.1	121	1698	43	605	0	13	88
1	1	SRN	1	92	92	2	4	0.3	0.7	221	221	66	66	0	20	95
8	1	MCP	6	14	108	2	7	0.9	1.6	104	834	96	767	76	16	90
5	1	CCP	4	33	163	3	7	0.8	1.9	231	1154	200	998	168	26	89
1	1	CRP	1	27	27	0	8	1.0	2.0	216	216	216	216	173	0	90
5	3	LSL	4	12	62	1	7	0.7	1.5	83	416	64	318	51	109	81
12	3	LSR	9	25	294	5	6	0.8	3.1	145	1739	117	1408	91	43	91
15	2	PLP	11	13	199	4	7	1.0	2.3	95	1424	93	1389	79	96	93
8	0	DRY	6	42	338	6	0	0.0	0.0	0	0	0	0	0	0	89

TOTAL UNITS	TOTAL UNITS	LENGTH (ft.)	AREA (sq.ft)	TOTAL VOL. (cu.ft)
135	25	5413	16070	7632

Angel Creek Drainage: Mill Creek

Table 3 - SUMMARY OF POOL TYPES Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0" LONGITUDE: 0°0'0"

HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	MEAN LENGTH (ft.)	TOTAL LENGTH (ft.)	PERCENT TOTAL LENGTH	MEAN WIDTH (ft.)	MEAN DEPTH (ft.)	MEAN AREA (sq.ft.)	TOTAL AREA EST. (sq.ft.)	MEAN VOLUME (cu.ft.)	TOTAL VOLUME EST. (cu.ft.)	MEAN RESIDUAL POOL VOL. (cu.ft.)	MEAN SHELTER RATING
13	2	MAIN	28	21	271	32	7.0	0.8	153	1988	136	1764	111	20
33	9	SCOUR	72	18	582	68	7.0	0.9	114	3765	100	3313	82	76

TOTAL UNITS	TOTAL UNITS	TOTAL LENGTH (ft.)	TOTAL AREA (sq.ft.)	TOTAL VOL. (cu.ft.)
46	11	853	5753	5078

Table 4 - SUMMARY OF MAXIMUM POOL DEPTHS BY POOL HABITAT TYPES   Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0" LONGITUDE: 0°0'0"

UNITS MEASURED	HABITAT TYPE	HABITAT PERCENT OCCURRENCE	<1 FOOT MAXIMUM DEPTH	<1 FOOT PERCENT OCCURRENCE	1-<2 FT. MAXIMUM DEPTH	1-<2 FOOT PERCENT OCCURRENCE	2-<3 FT. MAXIMUM DEPTH	2-<3 FOOT PERCENT OCCURRENCE	3-<4 FT. MAXIMUM DEPTH	3-<4 FOOT PERCENT OCCURRENCE	>=4 FEET MAXIMUM DEPTH	>=4 FEET PERCENT OCCURRENCE
8	MCP	17	1	13	7	88	0	0	0	0	0	0
5	CCP	11	0	0	5	100	0	0	0	0	0	0
1	CRP	2	0	0	0	0	1	100	0	0	0	0
5	LSL	11	1	20	4	80	0	0	0	0	0	0
12	LSR	26	1	8	10	83	0	0	1	8	0	0
15	PLP	33	0	0	11	73	4	27	0	0	0	0

TOTAL UNITS
46

Angel Creek Drainage: Mill Creek

Table 6 - SUMMARY OF DOMINANT SUBSTRATES BY HABITAT TYPE Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0" LONGITUDE: 0°0'0"

TOTAL HABITAT UNITS	UNITS FULLY MEASURED	HABITAT TYPE	% TOTAL SILT/CLAY DOMINANT	% TOTAL SAND DOMINANT	% TOTAL GRAVEL DOMINANT	% TOTAL SM COBBLE DOMINANT	% TOTAL LG COBBLE DOMINANT	% TOTAL BOULDER DOMINANT	% TOTAL BEDROCK DOMINANT
54	7	LGR	0	0	100	0	0	0	0
5	1	HGR	0	0	100	0	0	0	0
7	2	GLD	0	0	100	0	0	0	0
14	3	RUN	0	33	67	0	0	0	0
1	1	SRN	0	0	100	0	0	0	0
8	1	MCP	0	100	0	0	0	0	0
5	1	CCP	0	0	100	0	0	0	0
1	1	CRP	0	0	100	0	0	0	0
5	3	LSL	0	67	33	0	0	0	0
12	3	LSR	0	0	100	0	0	0	0
5	2	PLP	0	0	100	0	0	0	0
8	0	DRY	0	0	0	0	0	0	0

Table 10 - Summary of Shelter Type Areas by Habitat Type

Survey Dates: 09/07/95 to 10/02/95

Confluence Location: QUAD: LEGAL DESCRIPTION: LATITUDE: 0°0'0"   LONGITUDE: 0°0'0"

UNITS MEASURED	UNITS FULLY MEASURED	HABITAT TYPE	SQ. FT. UNDERCUT BANKS	SQ. FT. SWD	SQ. FT. LWD	SQ. FT. ROOT MASS	SQ. FT. TERR. VEGETATION	SQ. FT. AQUATIC VEGETATION	SQ. FT. WHITE WATER	SQ. FT. BOULDERS	SQ. FT. BEDROCK LEDGES
54	7	LGR	25	7	10	10	0	0	0	3	0
5	1	HGR	0	0	0	0	0	0	0	0	0
7	2	GLD	0	0	0	0	0	0	0	0	0
14	3	RUN	21	0	5	0	13	0	0	2	0
1	1	SRN	0	0	0	7	0	0	29	0	0
8	1	MCP	22	0	22	36	0	0	0	7	13
5	1	CCP	3	16	3	47	26	0	5	32	0
1	1	CRP	0	0	0	0	0	0	0	0	0
5	3	LSL	31	37	113	2	0	0	0	0	0
12	3	LSR	111	22	25	116	0	0	0	5	0
15	2	PLP	83	57	157	219	0	0	40	0	6
8	0	DRY	0	0	0	0	0	0	0	0	0
TOTAL: 135	25		296	139	335	437	39	0	74	49	19

Appendix A

Summary of Mean Percent Vegetative Cover for Entire Stream

Mean Percent Canopy	Mean Percent Conifer	Mean Percent Decidous	Mean Right bank % Cover	Mean Left Bank % Cover
88.15	83.42	16.58	71.21	70.17

Appendix B

FISH HABITAT INVENTORY DATA SUMMARY

STREAM NAME: Angel Creek
SAMPLE DATES: 09/07/95 to 10/02/95
STREAM LENGTH: 5413 ft.
LOCATION OF STREAM MOUTH:
USGS Quad Map: Latitude: 0°0'0"
Legal Description: Longitude: 0°0'0"

SUMMARY OF FISH HABITAT ELEMENTS BY STREAM REACH

STREAM REACH 1

Channel Type: F4
Channel Length: 2046 ft.
Flowing Water Mean Width: 5 ft.
Flowing Water Mean Depth: 0.3 ft.
Base Flow: 0.0 cfs
Water: 58 - 65 °F Air: 66 - 87 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 76%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 85%
Coniferous Component: 84%
Deciduous Component: 16%
Pools by Stream Length: 23%
Pools >=3 ft.deep: 5%
Mean Pool Shelter Rtn: 77
Dom. Shelter: Undercut Banks
Occurrence of LOD: 51%
Dry Channel: 11 ft.
Embeddness Value: 1. 39% 2. 39% 3. 22% 4. 0%

STREAM REACH 2

Channel Type: A4
Channel Length: 3367 ft.
Flowing Water Mean Width: 4 ft.
Flowing Water Mean Depth: 0.3 ft.
Base Flow: 0.0 cfs
Water: 56 - 59 °F Air: 56 - 75 °F
Dom. Bank Veg.: Coniferous Trees
Vegetative Cover: 65%
Dom. Bank Substrate: Cobble/Gravel
Canopy Density: 91%
Coniferous Component: 83%
Deciduous Component: 17%
Pools by Stream Length: 11%
Pools >=3 ft.deep: 0%
Mean Pool Shelter Rtn: 45
Dom. Shelter: Large Woody Debris
Occurrence of LOD: 45%
Dry Channel: 327 ft.
Embeddness Value: 1. 0% 2. 25% 3. 46% 4. 29%

Appendix C

Mean Percentage of Dominant Substrate

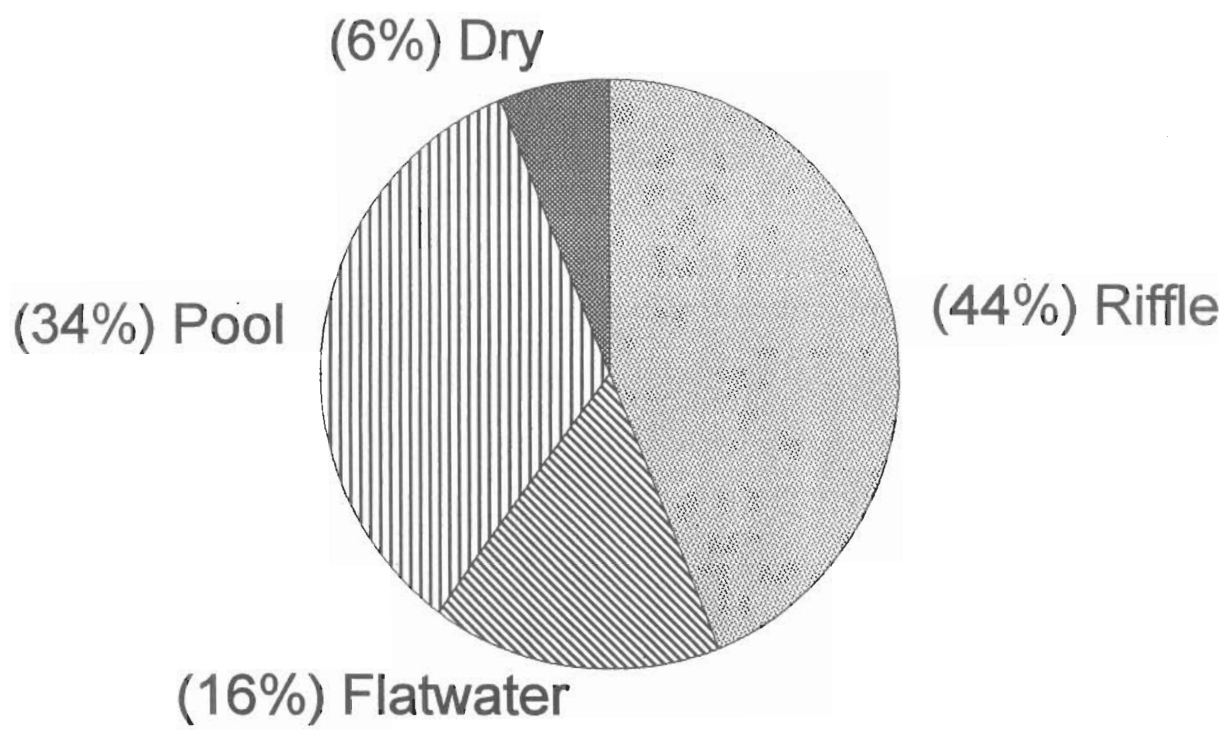
Dominant Class of Substrate	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Bedrock	0	1	1.72
Boulder	0	0	0
Cobble/Gravel	26	19	77.59
Silt/clay	3	9	20.69

Mean Percentage of Dominant Vegetation

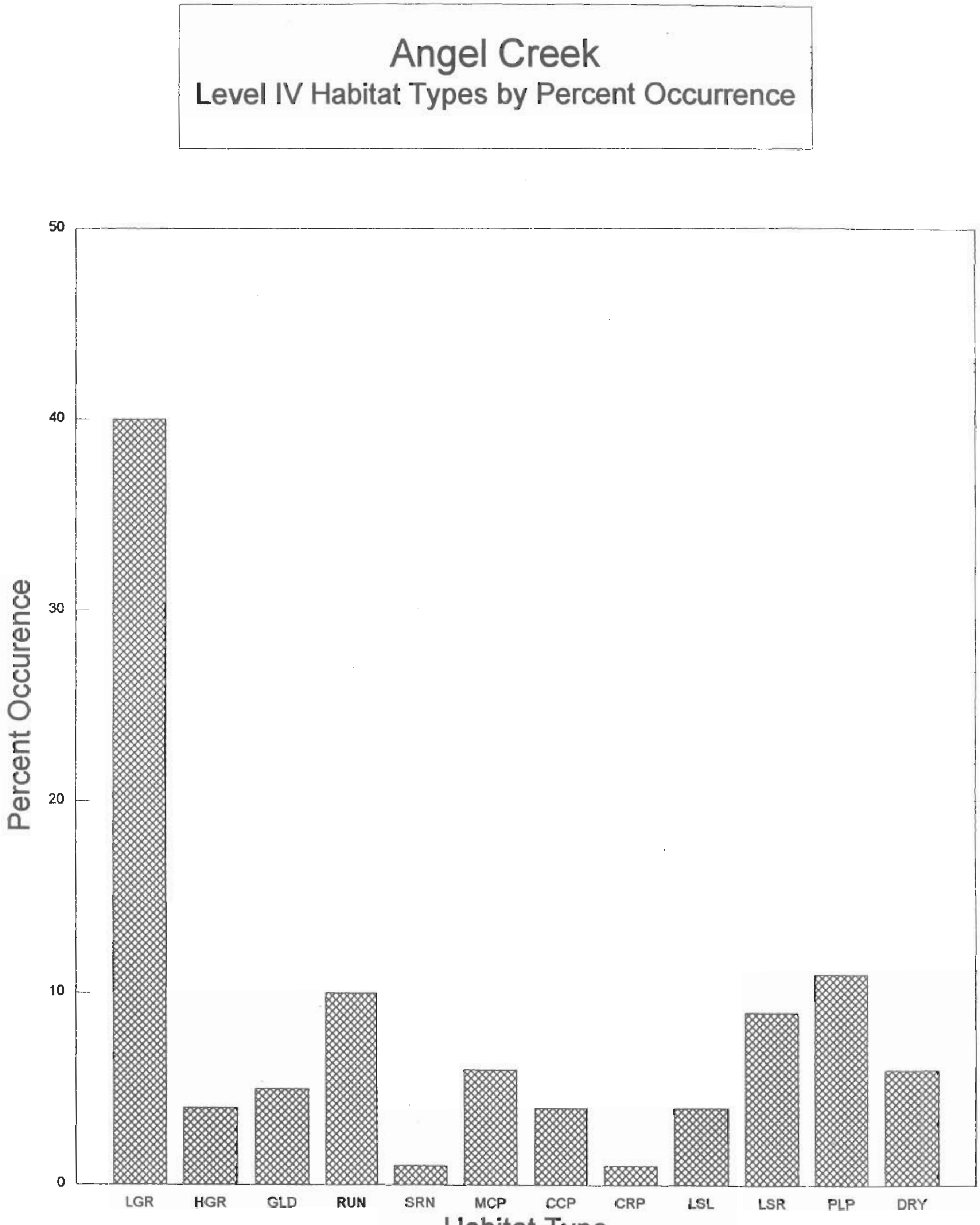
Dominant Class of Vegetation	Number Units Right Bank	Number Units Left Bank	Total Mean Percent
Grass	0	1	1.72
Brush	2	1	5.17
Decid. Trees	2	3	8.62
Conif. Trees	25	24	84.48
No Vegetation	0	0	0

Angel Creek

Level II Habitat Types by % Occurrence



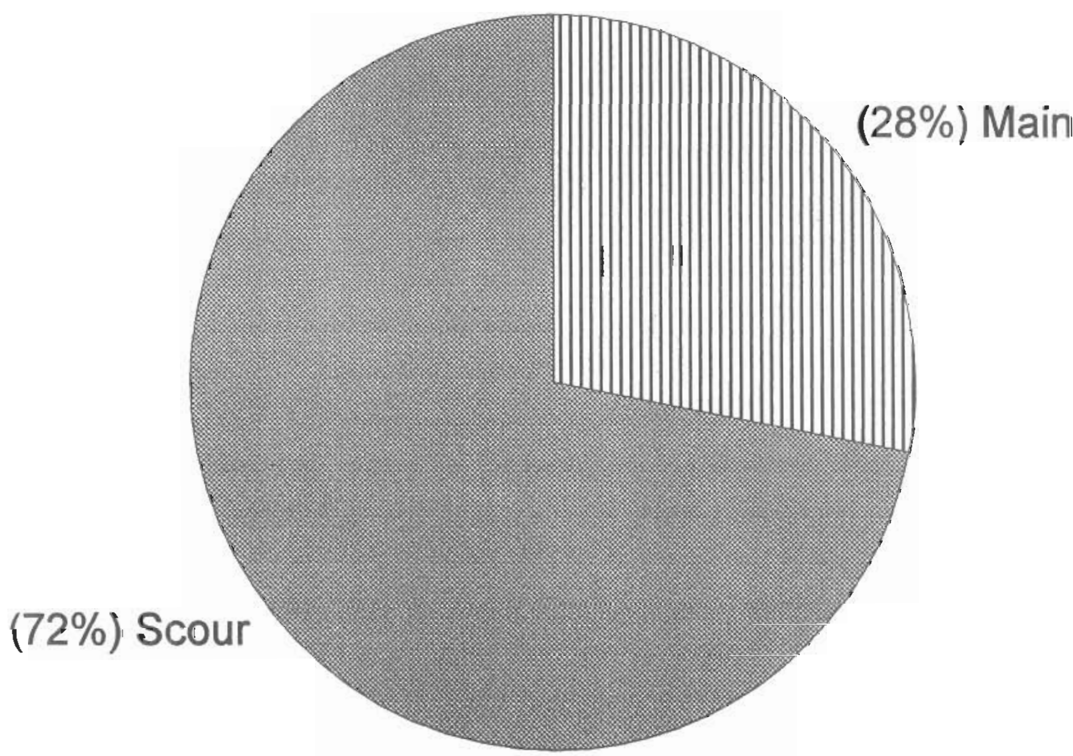
Graph 1


Angel Creek
Level IV Habitat Types by Percent Occurrence
50
40
30
20
10
0
Percent Occurence
LGR
HGR
GLD
RUN
SRN
MCP
CCP
CRP
LSL
LSR
PLP
DRY
Habitat Type

Graph 2

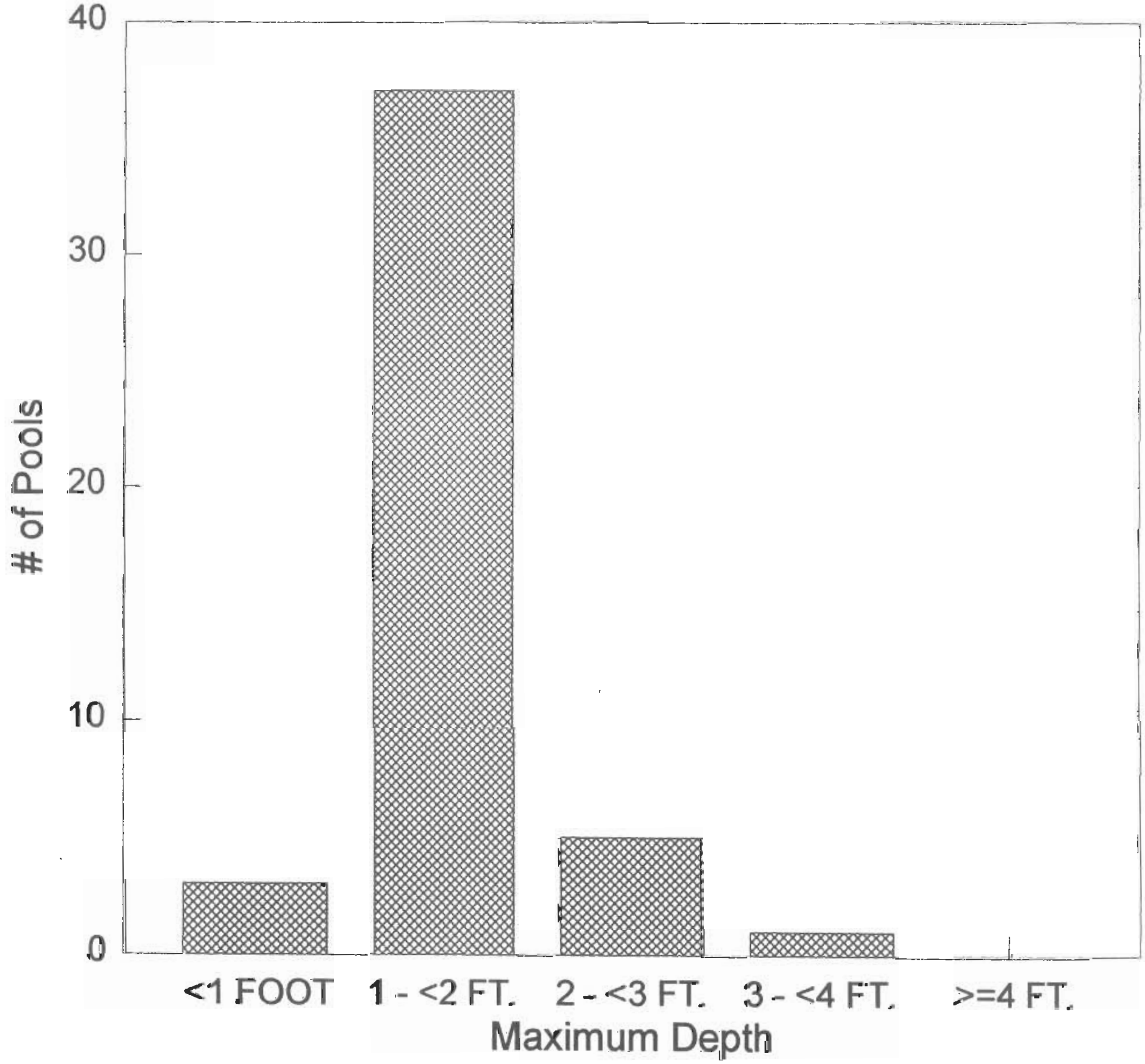
Angel Creek

Pool Habitat Types by % Occurrence



Graph 3

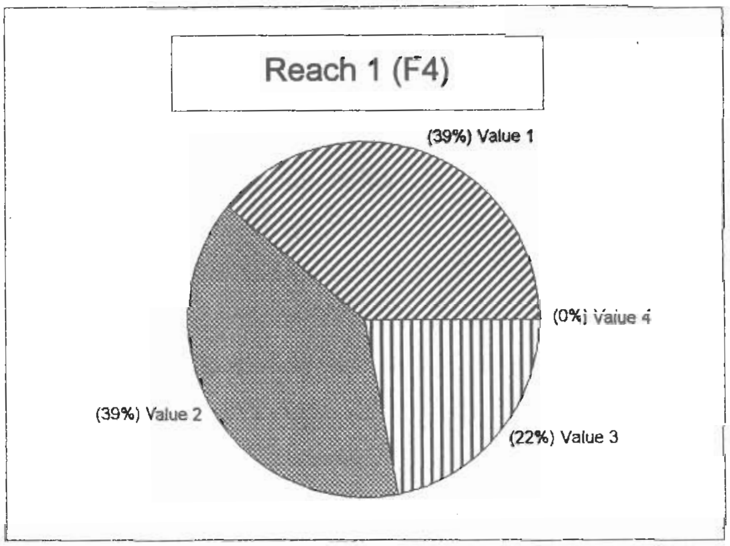
Angel Creek
Maximum Depth in Pools

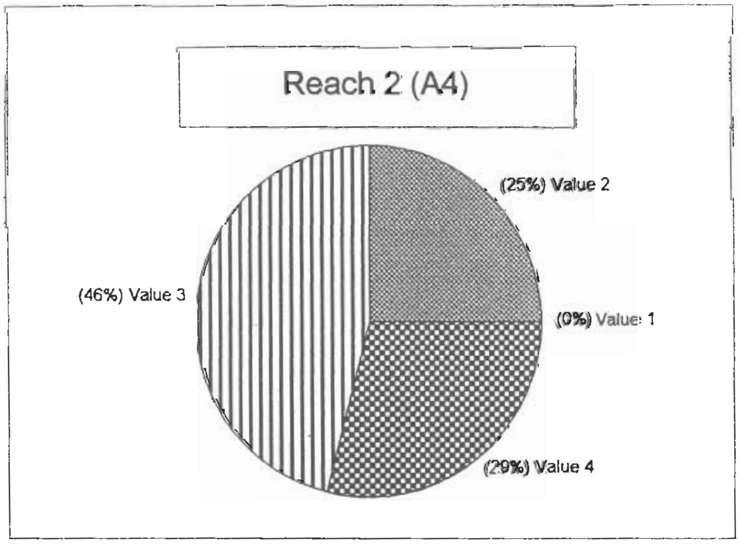


Graph 4

Angel Creek

Percent Embeddedness by Reach



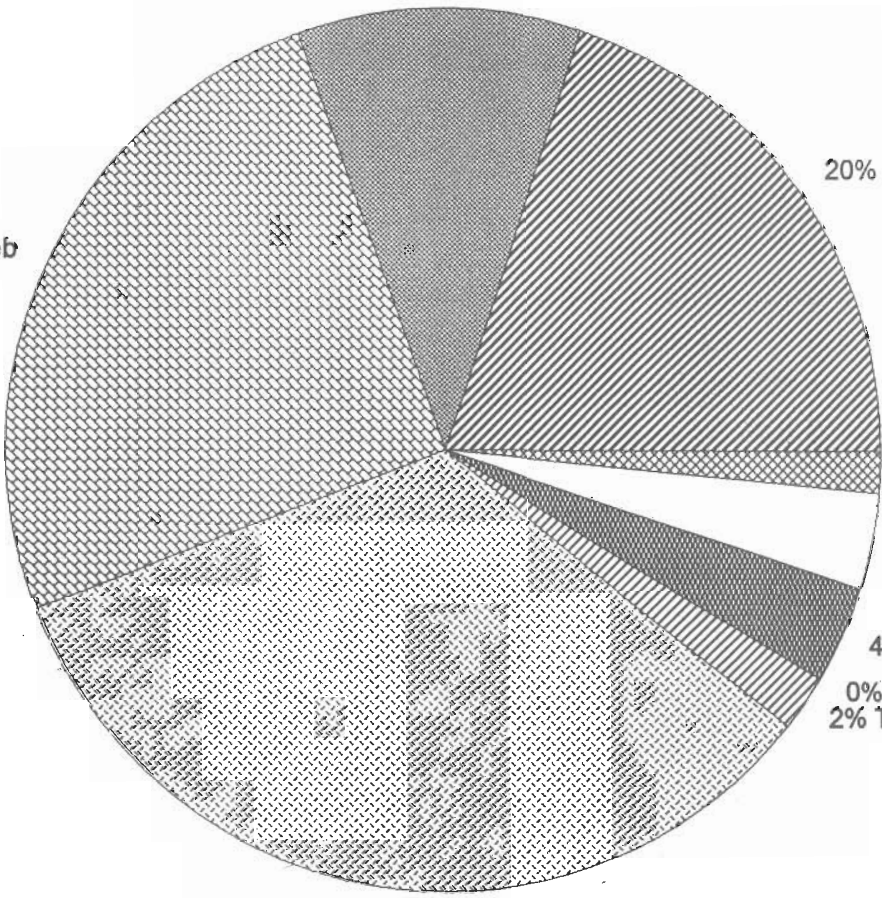


Value 1 = <25% Value 2 = 25-50% Value 3 = 51-75% Value 4 = >76%

Graph 5

Angel Creek

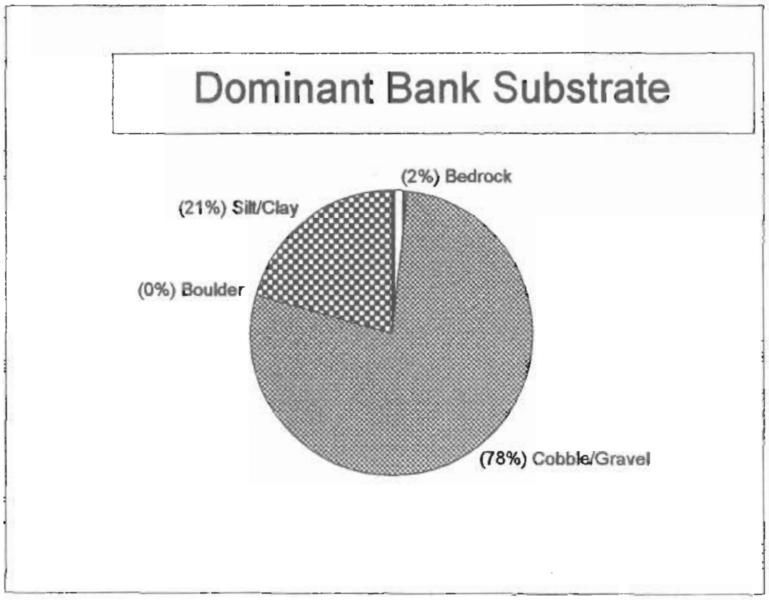
Percent Cover Types in Pools

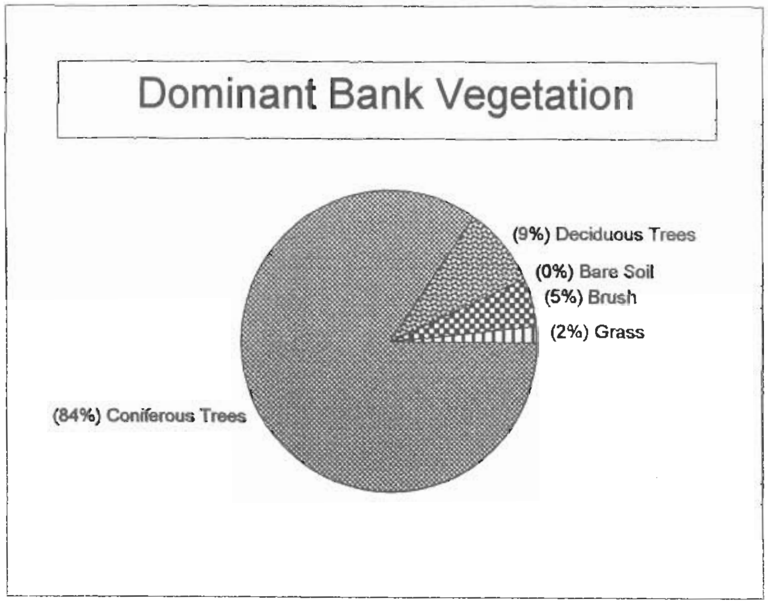


Graph 6

Angel Creek

Percent Bank Composition

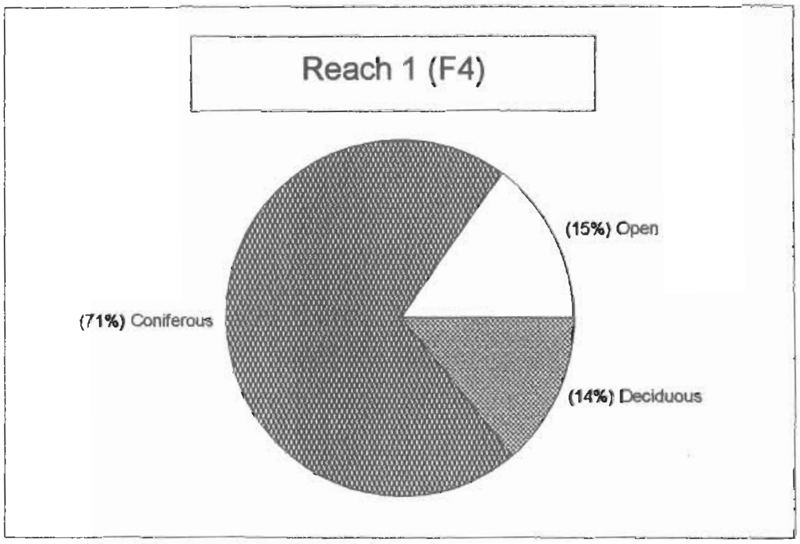


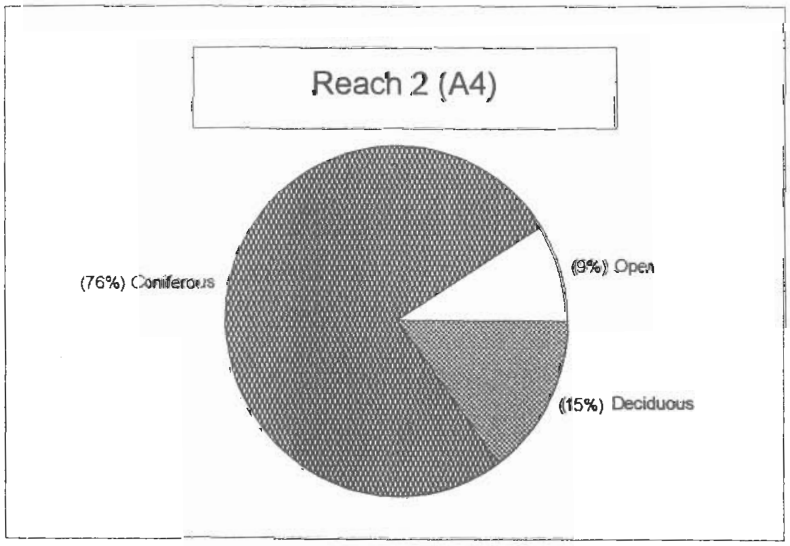


Graph 9

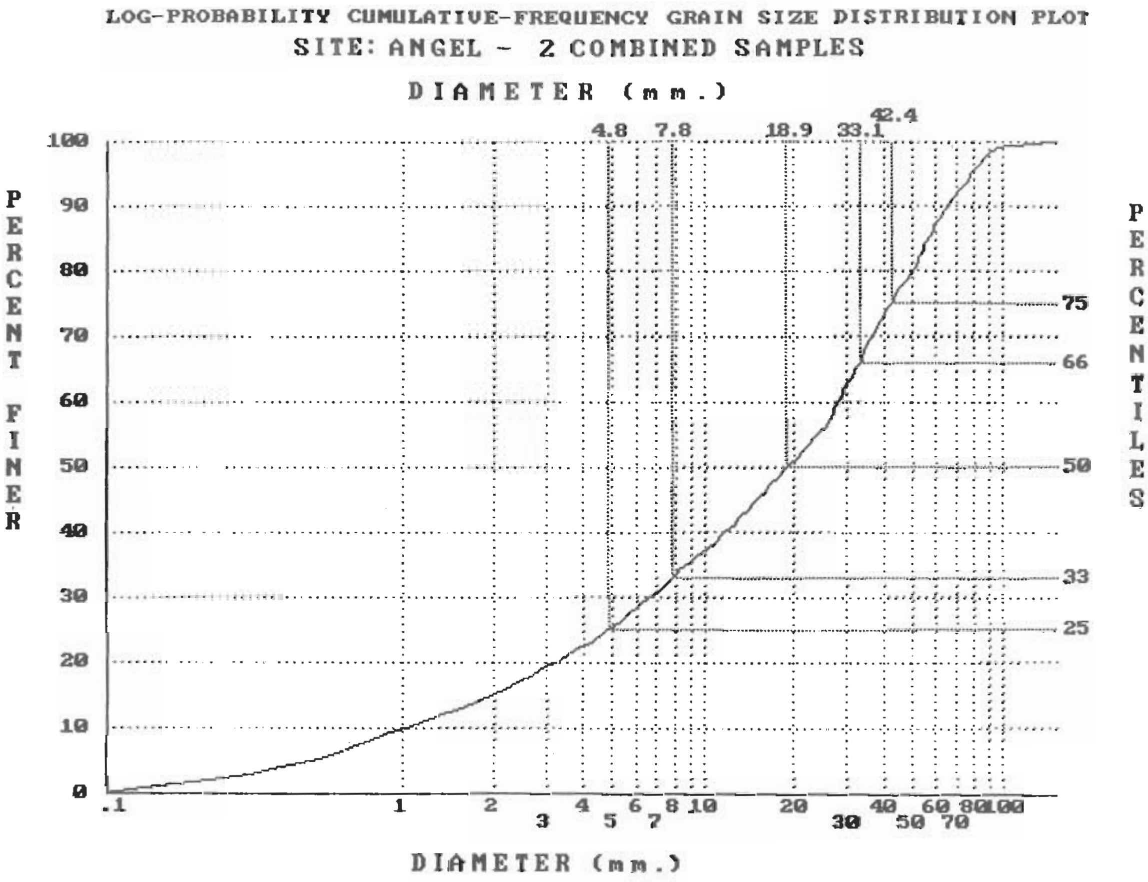
Angel Creek

Percent Canopy by Reach





Graph 11


LOG-PROBABILITY CUMULATIVE-FREQUENCY GRAIN SIZE DISTRIBUTION PLOT
SITE: ANGEL - 2 COMBINED SAMPLES
DIAMETER (mm.)
4.8
7.8
18.9
33.1
42.4
PERCENT FINER
100
90
80
70
60
50
40
30
20
10
0
PERCENTILES
75
66
50
33
25
.1
1
2
3
4
5
6
7
8
10
20
30
40
50
60
70
80
100
DIAMETER (mm.)

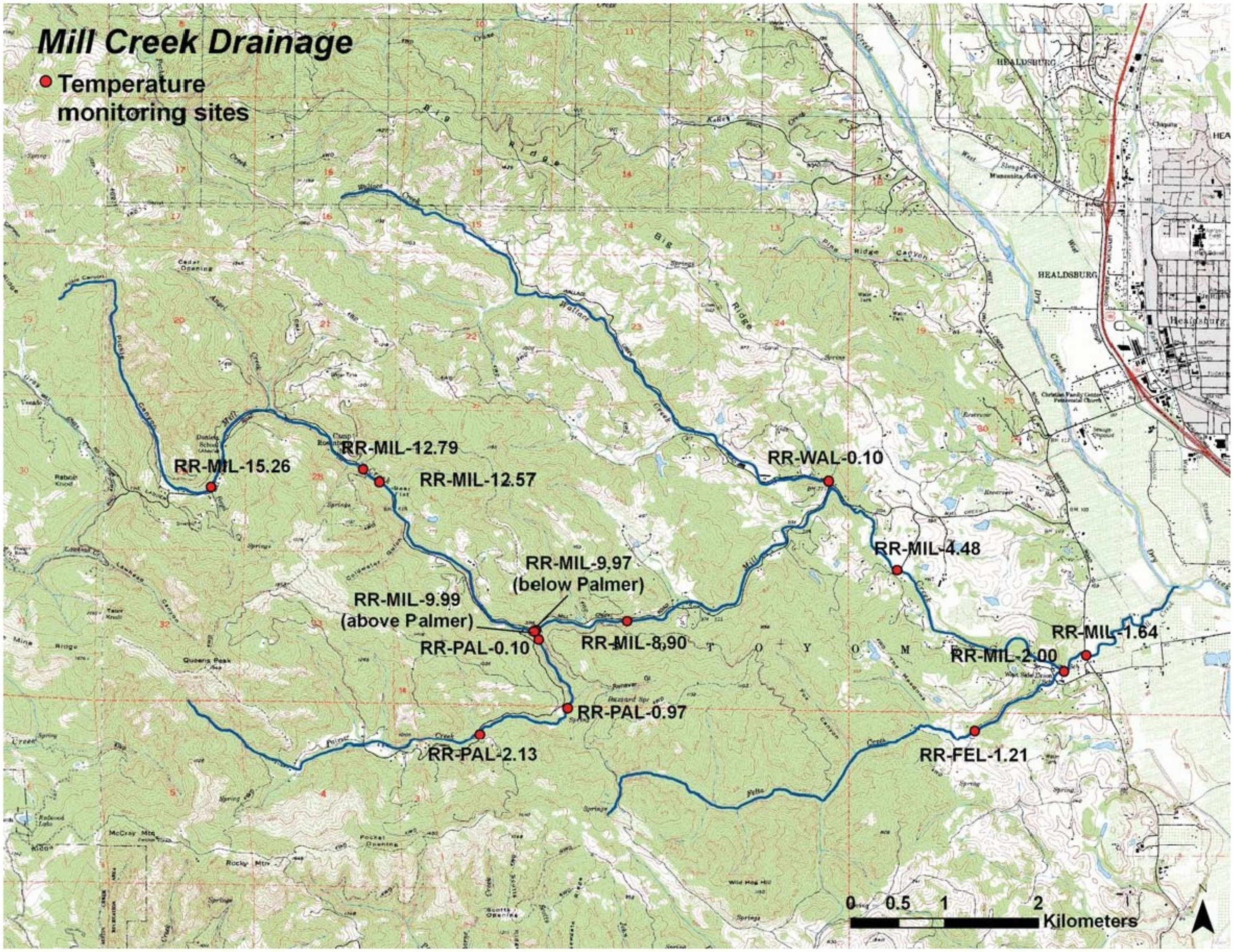
Appendix F

Supporting and Supplementary Data

UCCE WQ data and maps

Table F-1. Summary of temperature data collected between June 15 and October 15 at various sites on Russian River tributaries, 2005, 2006, and 2007. MWAT was calculated as the maximum running weekly average temperature between the start and end dates. MWMT was calculated as the maximum running weekly maximum temperature between the start and end dates.

						Temperature (°C)				
Year	**Tributary**	**Site**	**Start Date**	**End Date**	**Comments**	**Mean**	**Min**	**Max**	**MWAT**	**MWMT**
2005	Mill	RR-MIL-9.99	6/22/05	10/15/05		14.88	10.20	20.50	17.85	20.11
2005	Mill	RR-MIL-12.79	6/22/05	10/15/05		14.84	10.70	19.37	17.42	19.05
2005	Mill	RR-MIL-15.26	6/22/05	8/5/05		15.98	12.10	18.60	17.27	18.43
2005	Palmer	RR-PAL-0.10	6/22/05	10/15/05		14.75	10.18	19.32	17.74	18.94
2005	Palmer	RR-PAL-0.97	6/22/05	10/15/05		14.79	10.14	19.30	17.71	18.90
2005	Palmer	RR-PAL-2.13	6/22/05	10/15/05		14.57	10.41	18.73	17.17	18.38
2006	Felta	RR-FEL-1.21	6/22/06	10/15/06		15.97	11.78	22.64	20.23	21.48
2006	Mill	RR-MIL-1.64	6/15/06	10/6/06		16.39	6.26	22.88	19.35	22.18
2006	Mill	RR-MIL-2.00	6/15/06	10/15/06		16.09	6.38	23.66	20.22	22.53
2006	Mill	RR-MIL-4.48	6/15/06	10/15/06		17.03	11.65	25.08	21.71	23.70
2006	Mill	RR-MIL-9.97	6/15/06	10/15/06		15.66	10.24	23.18	20.38	22.39
2006	Mill	RR-MIL-12.79	6/15/06	10/15/06		15.21	10.53	21.47	19.25	20.88
2006	Palmer	RR-PAL-0.10	6/22/06	10/15/06		15.42	10.34	22.10	20.10	21.37
2006	Palmer	RR-PAL-2.13	6/22/06	10/15/06		15.08	10.28	21.52	19.49	20.80
2006	Wallace	RR-WAL-0.10	6/22/06	10/15/06		15.30	11.32	20.17	18.27	19.11
2007	Mill	RR-MIL-4.48	6/22/07	9/7/07	PIT reach, dewatered	18.50	14.27	24.52	19.89	23.56
2007	Mill	RR-MIL-8.90	7/2/07	10/15/07	PIT reach	15.83	10.08	21.00	18.51	19.81
2007	Mill	RR-MIL-9.97	6/22/07	10/15/07		15.53	9.29	21.79	18.16	20.43
2007	Mill	RR-MIL-12.57	7/2/07	10/15/07	PIT reach	14.95	10.11	18.24	16.95	17.53
2007	Mill	RR-MIL-12.79	6/22/07	10/15/07		15.40	9.46	20.34	17.57	19.09
2007	Palmer	RR-PAL-0.10	6/22/07	10/15/07		14.74	9.50	18.59	16.71	17.51
2007	Palmer	RR-PAL-2.13	6/22/07	10/15/07		15.13	9.31	20.01	17.33	18.80
2007	Wallace	RR-WAL-0.10	6/22/07	10/15/07		14.75	9.92	17.42	16.42	16.85
2007	Felta	RR-FEL-1.21	6/22/07	10/15/07		15.28	7.76	20.17	17.30	19.63



Map F-2. Temperature monitoring sites on Mill, Felta, Wallace, and Palmer Creeks, 2005, 2006, and 2007.

Map F-3. Mill and Palmer Creeks study reaches, flow gauges, antennas, and temperature loggers, 2010.

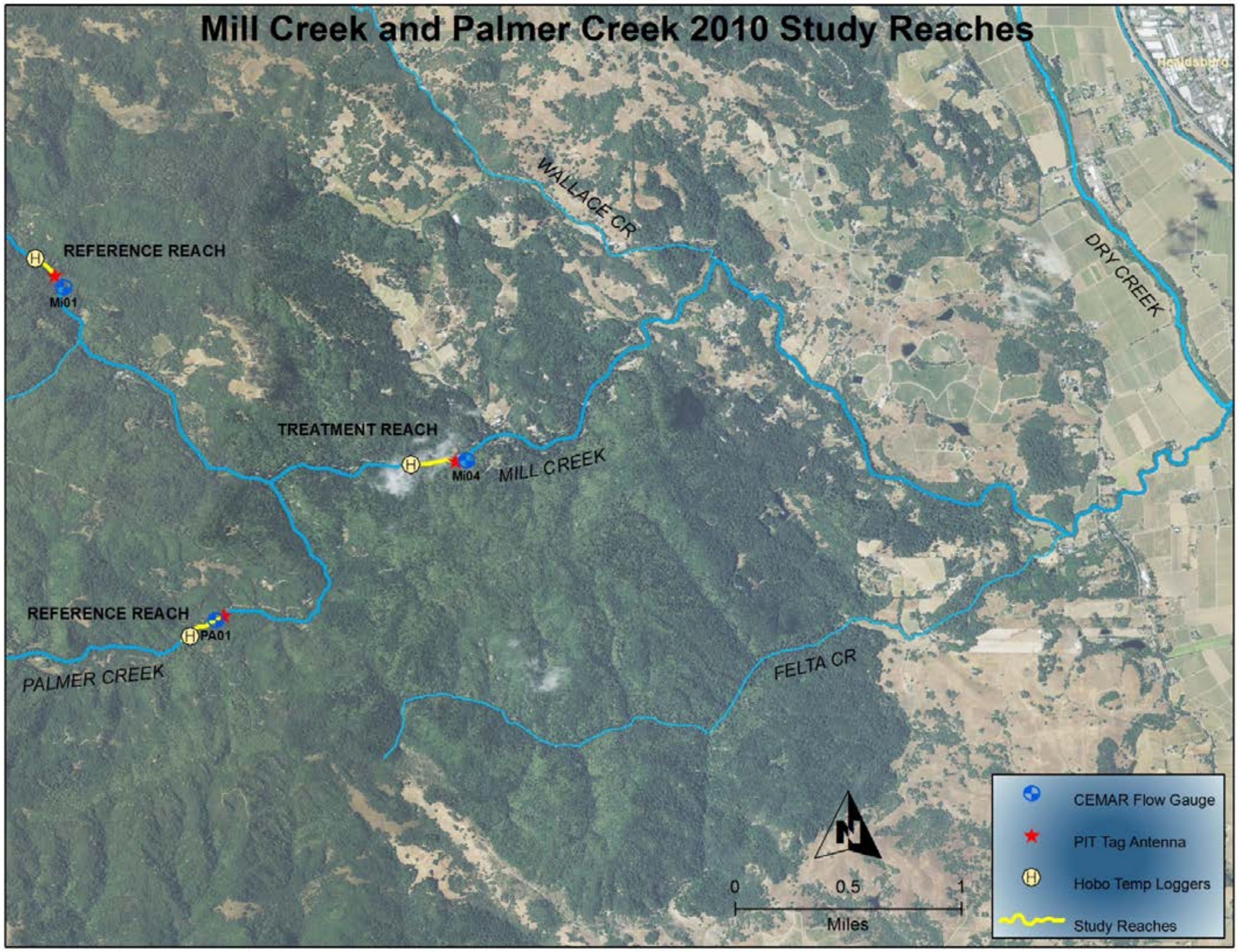


Table F-2. Average monthly DO by Mill Creek and Palmer Creek reaches between June and October, 2010.

Reach	Sample month	Number of pools sampled (n)	Average DO (mg/L) +/- 1 SD
MIL Treat	June	10	9.5 +/- 0.1
	July	10	9.6 +/- 0.1
	August	10	9.9 +/- 0.1
	September	10	10.0 +/- 0.2
	October	10	9.0 +/- 0.3
MIL Ref	June	14	9.9 +/- 0.0
	July	14	9.6 +/- 0.1
	August	14	9.4 +/- 0.1
	September	14	10.5 +/- 0.2
	October	14	10.7 +/- 0.2
PAL Ref	June	15	10.1 +/- 0.1
	July	15	9.5 +/- 0.1
	August	15	10.1 +/- 0.1
	September	15	11.1 +/- 0.4
	October	15	8.8 +/- 0.2

APPENDIX G

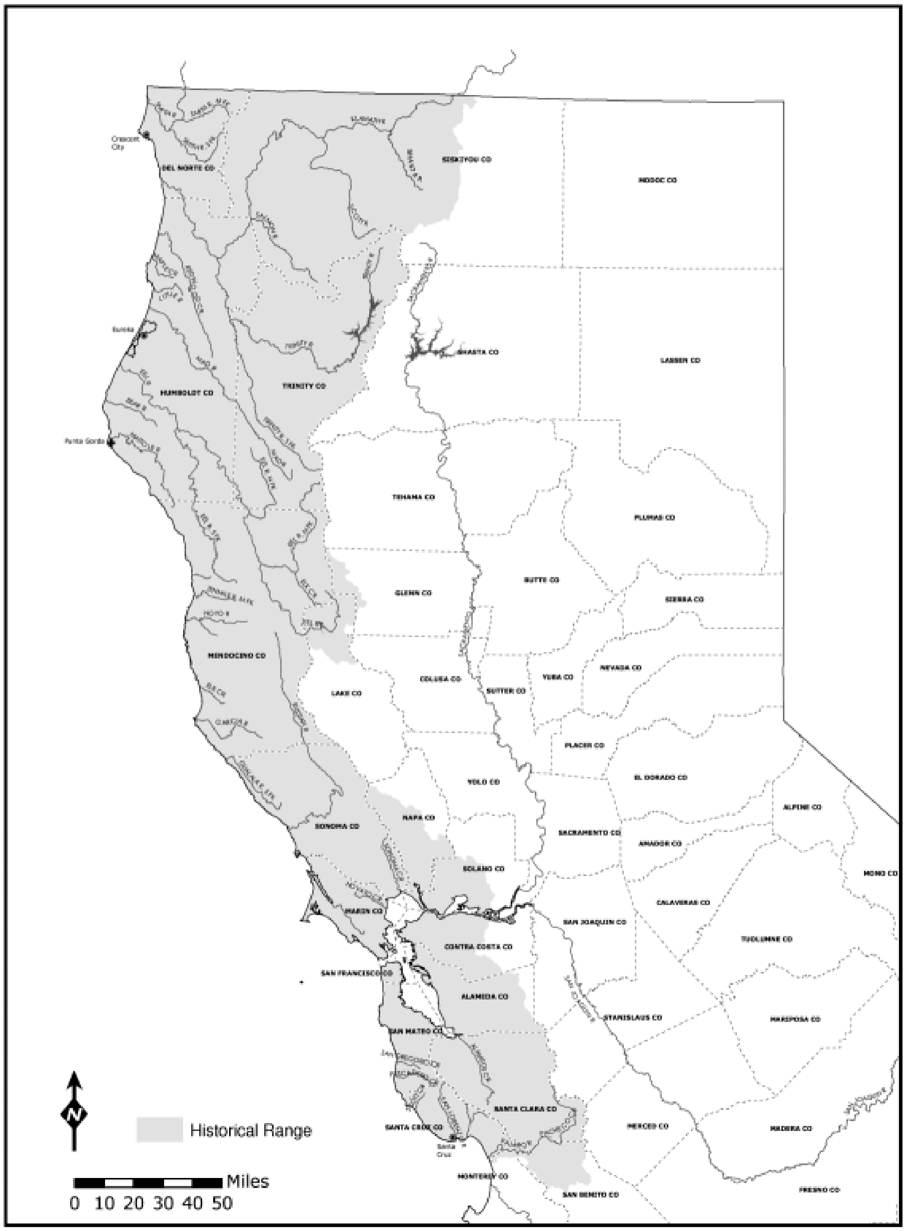
2012 – 2013 Large Wood Assessment

INTRODUCTION

Pacific salmon (*Oncorhynchus spp.)* numbers have been in decline for over one hundred years. Today, Pacific salmon have vanished from approximately 40 percent of their historic ranges in Washington, Oregon, California and Idaho (Gresh, Lichatowitch & Schoomaker, 2000). Their productivity has declined by 80% (Lichatowich, 1999). The complexities of salmonid life histories prohibit attributing one single threat to this loss (NOAA, 2012a). Individually, water storage, withdrawal, hydropower, irrigation and flood control have all contributed to the reduction and/or elimination of significant salmonid historical ranges (NOAA, 2012a). Combined, these actions magnify losses as even greater amounts of historically accessible habitat are lost (NOAA, 2012a). Beaver trapping, logging, agriculture, overfishing, urban and industrial development and even salmon hatcheries have all been slated as culprits (Gresh, Lichatowitch & Schoomaker, 2000; Sheuerell & Williams, 2005). Recreational and commercial harvesting has also contributed to salmon population decline (NOAA, 2012a, Scheuerell & Williams, 2005). Condensed, these actions have been referred to as the "4 Hs": habitat degradation and loss, harvesting, hydro-electric and other dams and hatchery production (Scheuerell & Williams, 2005; USFWS, 2012).

California Coast coho (*Oncorhynchus kisutch*), are not immune to the effects of the "4-Hs" and have suffered drastic population losses. California Coast Coho historically have been reported in as many as 582 streams from the Smith River, just north of the

California-Oregon border, to the San Lorenzo River in the Central Coast of California (Brown, Moyle & Yoshiyama, 1994) (Map 1).



Map 1: Historical range of California Coho

Brown and Moyle (1991) reported that only 42% of the streams ranging from the Smith River near the Oregon border to Big Sur River on the Central Coast were now reported to support coho. Of those reporting the presence or absence of coho, actual fish surveys indicated that 54% contained coho and that 46% did not. Additionally, Brown and Moyle (1991) reported that within the state of California the general trend is that the further south a stream is located, the greater the chance the creek has of losing its coho population. For example, in Del Norte County, 45% of the streams containing reliable fish data have lost their coho populations. This drops to 31% in Humboldt County, rising to 41% in Mendocino County and 86% in Sonoma County (Brown & Moyle, 1991).

By the early 1990s these coho populations were estimated to be less-than one percent of what they were in the 1940s and a 70% decline since the 1960s (Brown & Moyle, 1991; Brown, Moyle & Yoshiyama, 1994). Recognizing that early coho population estimates were “ball-park” figures established by fisheries managers, Brown, Moyle & Yoshiyama (1994) used catch statistics and estimated that there were approximately between 200,000 and 500,000 coho spawning in California in the 1940s. This number decreased to 100,000 fish in the 1960s (Brown, Moyle & Yoshiyama, 1994). By the 1980s the number of California coho was just 33,500. Of these, less than 5,000 were thought to be wild fish. The balance was hatchery populations (Brown & Moyle, 1991). Many streams contain fewer than 100 coho, below what is thought to be the minimum required to preserve genetic integrity of the fish and to protect it from natural disasters (Brown & Moyle, 1991).

The California Department of Fish and Wildlife (2002) estimated the decline of California coho salmon populations, including hatchery stock, between 6 and 15 percent of their abundance in the 1940s. California coho have declined as much as 70% since the 1960s (California Department of Fish and Wildlife, 2002). Presently in California Central California Coast coho numbers are less than one percent of their peak number, estimated to be 500,000 in the 1940s (Prado, 2010). In 1994 the California Department of Fish and Wildlife reported that in many streams and in some watersheds, adults were observed one out of every three years indicating that two of the three spawning lines have died (Giannico & Heider, 2001).

Not surprisingly, in an effort to reduce these alarming trends, a significant amount of time and energy was aimed at restoring the overall health of watersheds. Scientists, resource managers and the general public have become increasingly involved in watershed health, specifically stream restoration and enhancement projects (Bash & Ryan, 2002). California has been at the forefront of restoration efforts with billions of dollars being allocated through legislation and voter-approved bonds (Christian-Smith, & Merenlender, 2010). In Northern California, the Russian River watershed has been part of these efforts with over 787 restoration projects conducted since 1987 (Christian-Smith & Merenlender, 2010).

Recognizing the importance of satisfying all the life history requirements of salmonids, those involved in restoration efforts have begun to focus on spatially and temporally connecting both horizontal and vertical linkages within watersheds. Headwaters must be linked to downstream channels, allowing the transport of water, sediment, nutrients and material (NOAA, 2011b). Like the Russian River Watershed, Mill Creek Watershed, located in Sonoma County California, has been targeted for CCC coho restoration by various government agencies, organizations and residents alike. Mill Creek Watershed is a sub-watershed of the larger Russian River Watershed and linking the smaller to the larger serves as an example of re-establishing a vital connection.

For decades the region of Sonoma County that now includes Healdsburg, Dry Creek Valley and Mill Creek Watershed has witnessed an array of land-use changes and alterations. Initial prehistoric settlement consisted mainly of Southern Pomo and Western Wappo- speaking people (Healdsburg Museum and Historical Society, 2012). These peoples cultivated the land in traditional ways through burning, tilling, sowing and pruning native plants. American and European settlers began arriving in the early 1800s, and by 1841 the area was included within the 48,800 acre Mexican land grant deeded to Henry Fitch termed Rancho Sotoyome, named after the local tribal chief known as Chief Soto (Healdsburg Museum and Historical Society, 2012). American settlers quickly found that the fertile soils of the area supported an assortment of crops as well as livestock and forestry. Healdsburg hosted its first agricultural fair in 1858 (Sonoma

County Historical Society, 2012). Grain became an early mainstay of the watershed and a mill was installed on Mill Creek to produce flour. Gold was mined along Mill Creek in the early 1850s. Returns were poor and operations were typically short-lived (Healdsburg Museum and Historical Society, 2004).

The logging industry was an integral part of the local economy in early 19^{th} century Healdsburg. The first sawmill in northern Sonoma County was erected on Mill Creek in 1850, and remained in operation until 1881. Large stands of redwood and other timber were harvested and fed into an ever-increasing number of sawmills dotted along the Russian River (Healdsburg Museum and Historical Society, 2005). Harvested redwood supplied beams for construction and for railroad development. During the Civil War, milled redwood was railed to the North for use as railroad ties. Lumber companies formed over 100 years ago are still in operation to this day (Healdsburg Museum and Historical Society, 2005). In the nearby town of Santa Rosa tan oak was used in tanning and curing operations, particularly in the manufacture of gloves (Healdsburg Museum and Historical Society, 2005).

The building of a railway in 1871 opened access to new agricultural markets and Healdsburg began to flourish as an agricultural community. Grapes for wine production, lumber and hops provided the bulk of the region’s revenue in the 1880s (Healdsburg Museum and Historical Society, 2012). By the late 1890s Healdsburg had three fruit processing plants and shipped thousands of cases of fruit and vegetables to the Midwest and East Coast of the United States as well as to Europe and Australia (Healdsburg Museum and Historical Society, 2004).

The Russian River, from Healdsburg to the ocean, quickly developed into a favorite tourist destination (Healdsburg Museum and Historical Society, 2004). Houses, resorts and vacationers from all over the Bay Area frequented the region. The flood of visitors led to improved rail services, an increase in the number of roads and means of transportation (Healdsburg Museum and Historical Society, 2004). Previously inaccessible regions soon became open to exploitation. Ferry systems across the Bay and the construction of the Golden Gate Bridge in 1937 facilitated the demand for faster and improved access to the Russian River recreation areas (Healdsburg Museum and Historical Society, 2004).

By the early 1900s, a quarry was established in the watershed and is still in operation today (Healdsburg Museum and Historical Society, 2005). By 1900, Sonoma County had 69 wineries and led the state in wine production (Sonoma County Historical Society, 2012). However, Prohibition and the passing of the Volstead Act (1919) impacted the wine industry. Despite the repealing of Prohibition in 1933, many vineyards were replaced with prune orchards. By 1967 prunes were the most important industry and cash crop in Healdsburg (Healdsburg Museum and Historical Society, 2012). The 1970s witnessed a re-birth of the wine industry and today vineyards and wine are the primary agricultural industry the area (Healdsburg Museum and Historical Society, 2012).

In 1837 the population of Sotoyome and other Indian groups in Sonoma County was depleted by smallpox. From 1830-1850 an estimated 75,000 perished. By 1916 the Native American population within the county was just 100 (Sonoma County Historical Society, 2012). However, the non-native population grew steadily. In 1857 the population of Healdsburg was 300 in 1857. By 1910 the population rose to 2011, to 2507 in 1940, to 5410 in 1970 and to 10,722 in 2000 (Russian River Recorder, 2004; Healdsburg Museum and Historical Society, 2004).

Today logging and cattle ranching continues throughout Mill Creek Watershed. Other land-uses have resulted in sections of Mill Creek (located near the confluence of Mill Creek and Palmer Creek) being categorized a superfund site by the U.S. Environmental Protection Agency (EPA). In 2009, two uncontrolled and abandoned hydrogen chloride canisters as well as solid waste from methamphetamine drug manufacturing, both of which threatened human health and the environment, were removed from the site (USEPA, 2009). In 2007, Sonoma County wine production, the leading crop, was valued at U.S. $417 million (Healdsburg Museum and Historical Society, 2004).

Despite these land-use changes, Mill Creek Watershed has been targeted by various agencies, such as the California Department of Fish and Wildlife and the Sotoyome Resource Conservation District, as a high priority watershed for coho recovery. Important juvenile coho summer rearing habitat has been identified within the watershed (Russian River Coho Water Resources Partnership, 2012). Juvenile coho have been released into the watershed from the Russian River Coho Salmon Captive Broodstock Program annually since 2004. Several other habitat enhancement projects have been completed or are underway in the watershed. This purpose of this paper is to assess existing in-stream, low-flow juvenile coho habitat in Mill Creek Watershed. This was achieved by (i) measuring length, diameter and volume of all qualifying naturally occurring and CDFW- installed LWM, (ii) assessing current functioning status of CDFW-installed LWM (iii) measuring all pools with a residual pool depth (RPD) of at least 30.5 cm (1 foot) and (iv) analyzing current and potential LWM recruitment. These data was analyzed to provide recommendations for fisheries managers and restoration practitioners in an effort to understand better, and improve, juvenile coho habitat within the watershed.

LITERATURE REVIEW

(i) Pacific Salmon

Pacific salmon are part of the family Salmonidae and the genus *Onchorhynchus*. *Onchorhynchus* originating from the Russian word meaning "hooknose" referring to the hooked upper jaw that develops during mating. Coho salmon are one of five species of Pacific Salmon comprising chinook, chum, coho, pink and sockeye (FWS, 2012). Native

Americans sometimes likened salmon swimming to “lightning following one another” (Lichatowich, 1999). Today, many see salmon as a symbol of determination, courage and strength, a species that overcomes no matter how numerous and insurmountable the obstacles may be.

Belonging to a group called anadromous fish, Pacific salmon are amongst the oldest natives of the Pacific Northwest. Over millions of years they have colonized almost every marine habitat and have penetrated hundreds of miles inland inhabiting mountainous freshwater streams (Lichatowich, 1999). Pacific salmon hatch and live the initial part of their lives in freshwater before migrating to the ocean where they spend their adult lives (FWS, 2012; NOAA, 2012b&d; Shapovalov & Taft, 1954). Depending on the species, the saltwater phase ranges from six months to seven years. Upon reaching sexual maturity they return to the freshwater stream of their origin to breed. Unlike Atlantic salmon who may repeat the cycle several times, Pacific salmon return to the place of their birth only once. Migrating during all seasons throughout the year, salmon deposit eggs in a variety of freshwater habitats, from intertidal habitat to high mountain streams (FWS, 2012; NOAA, 2012b). One of their greatest strengths is their ability to reach, and reproduce in, this assorted array of habitats found throughout the Pacific Northwest (Lichatowich, 1999).

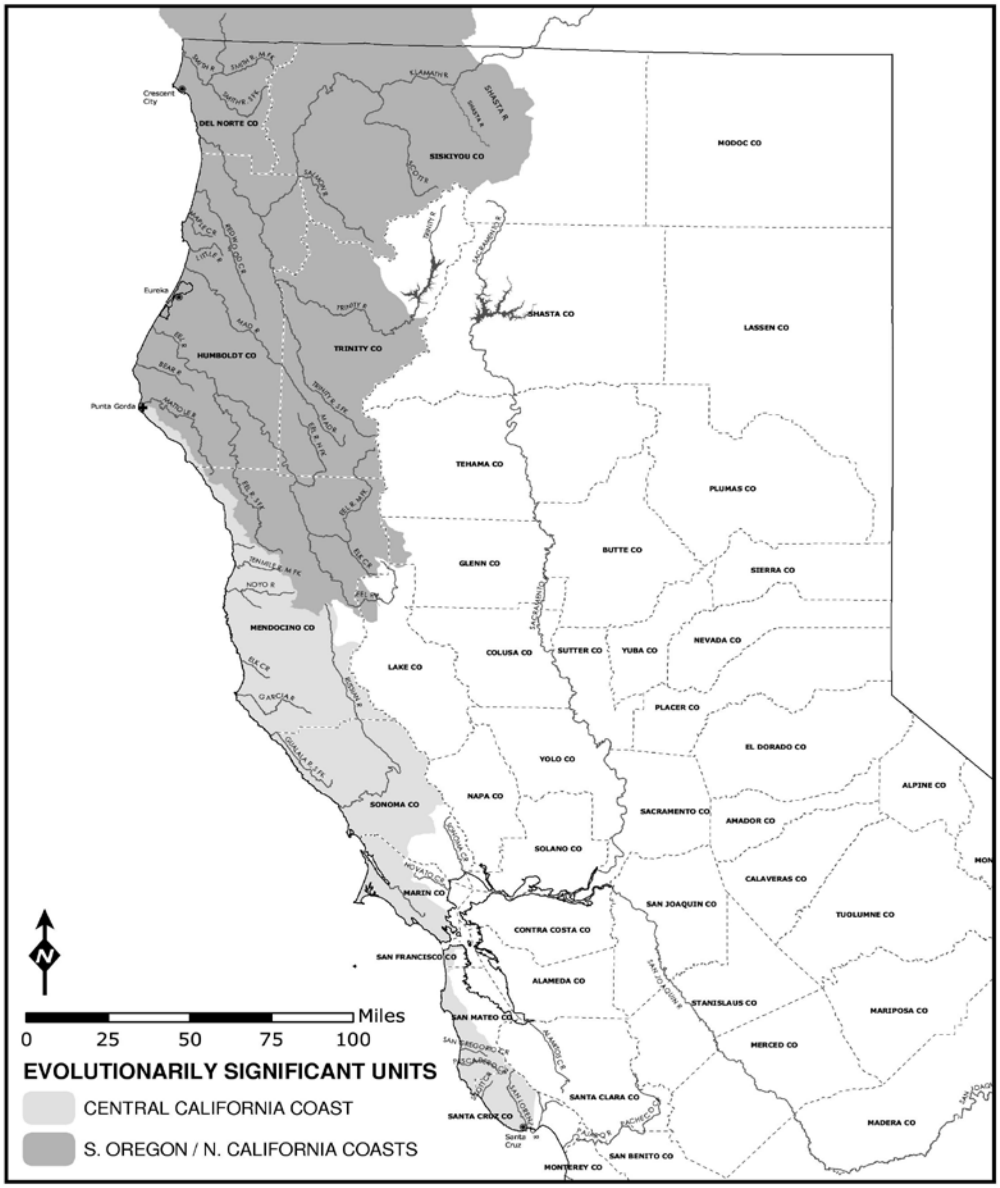
Throughout the journey from saltwater back to freshwater, sometimes thousands of miles, salmon do not feed. Those who have failed to accumulate enough body fat reserves perish. Hazards are plentiful and include nets, pollution, dams, waterfalls, rapids, natural predators and finally, each other. Males battle each other for access to females, females battle females as they challenge for nesting sites (FWS, 2012; NOAA, 2012b).

In 1991, in an effort to protect declining salmon populations, National Oceanic and Atmospheric Administration (NOAA) fisheries was petitioned to list Northwest salmon runs under the Endangered Species Act. In order to achieve this, both the Northwest and Southwest Fisheries Science Centers needed to determine how a “species” of salmon were to be defined under the Act. The resultant policy classified salmon into distinct population segments if it were an evolutionary significant unit (ESU). The two criteria for satisfying ESUs are: i) the population must show substantial reproductive isolation; and ii) there must be an important component of the evolutionary legacy of the species as a whole (NOAA, 2012d). Currently there are 37 ESU’s of Pacific salmon in Washington, Oregon and California. Four are listed as endangered, 13 as threatened, two as species of concern and the remainder as either undetermined or unwarranted (NOAA, 2012e). On account of declining populations, on October 31, 1996, Central California Coast coho (CCC) salmon ESU was listed threatened under the Endangered Species Act. Despite the listing, continued population decline ensued and on June 28, 2005, CCC coho salmon status was downgraded from threatened to endangered (NOAA, 2012c; Spence & Williams, 2011). Coho salmon occur over a broad range of territory and range from the

North Pacific Ocean to the Bering Sea, from northern California to northwest Alaska and from northern Hokkaido, Japan to the Anadyr River in Russia (Crone & Bond, 1976).

(ii) California coho

California coho are divided into two ESUs (Map 2). The northern-most population is the Southern Oregon/Northern California Coho ESU and the southern population is the Central California Coast (CCC) Coho ESU. The range of the CCC coho ESU includes naturally spawned populations of coho from Punta Gorda in northern California south to and including the San Lorenzo River in central California, as well as populations in tributaries of the San Francisco Bay. However, it excludes the Sacramento-San Joaquin River system and four artificial propagation programs (NOAA, 2012f).



Map 2: Current California coho ESU ranges

(iii) Coho characteristics and habitat requirements

Young coho typically remain in freshwater systems between one and three years before emigrating to saltwater (Crone & Bond, 1976). After approximately 14 to 18 months at sea, they sexually mature (Crone & Bond, 1976). Size has been shown to play a role in escape and survivability. Larger coho at the end of summer are more likely to survive to smolt the following spring than smaller coho (Quinn & Peterson, 1996). Larger coho emigrating from freshwater are more likely to return to spawn than smaller coho (Crone & Bond, 1976). Upon returning, larger coho are also more fecund than smaller coho (USFWS, 1983; Bilton, 1978, Drucker, 1972). Variations in food availability and temperature affect growth rates of coho within a stream and also between different streams (USFWS, 1983). High winter flow increase juvenile coho emigration and may effect smolt production (Giannico & Healy, 1998). Quantity of woody material and density of habitats are strongly linked to juvenile coho overwintering survival (Quinn & Peterson, 1996).

Juvenile coho are visual predators requiring an abundance of drifting aquatic and terrestrial insects in order to maintain rapid growth for predator evasion and to prevent early downstream displacement to saltwater environments (Giannico & Johnson, 2001; Nielsen, 1992; USFWS, 1983; Mundie, 1969). As juvenile coho age their diets shift toward fish, particularly salmon fry, and on occasion, crustaceans (USFWS, 1983; Healy, 1978). Coho aquatic and terrestrial food production is influenced by substrate composition, riffles and riparian vegetation, such as large wood (Mundie, 1969; Giger, 1973; Reiser & Bjornn 1979). Gravel, rubble and bedrock are important associates of aquatic and benthic invertebrates (Pennak & Van Gerpen, 1947; Giger, 1973; Reiser & Bjornn, 1979; USGS, 1983). Migrating spawning coho do not feed (USFWS, 1983).

Young coho exhibit aggressive territorial behavior as early as a week after emerging from the gravel (Puckett & Dill, 1985). They typically defend a teardrop shaped territory, darting out to capture prey or to fend off intruders (Puckett & Dill, 1985). When they first begin to feed, those juvenile that fail to establish their own territory often die of starvation (Nielsen, 1992; Gerking, 1978). Gerking (1978) found that mortality among juvenile coho was density-dependent above fairly low population densities. Coho emerging earlier from gravel enjoy ecological advantages over later emerging coho and tend to be larger at any given time (Mason & Chapman, 1965). Pools tend to be the primary security feature utilized by juvenile coho (Mason & Chapman, 1965). The size of coho territory is inversely related to food and cover availability. A reduction in food and cover results in fewer, larger territories, an increase in younger coho (parr) emigration and reduced growth rates among the remaining fish (Dill *et al.*, 1981). Intra-specific competition may be more of a population limitation than inter-specific competition (Chapman, 1965). More recent studies confirm juvenile coho mobility, (referred to as nomads) but stress that this mobility is not necessarily an indicator of inferior competitiveness, rather displacement by rapid currents, typically at the onset of the wet-season. However, Tschaplinski (1987) showed that these losses were in streams lacking adequate amounts of deep pools, LWM, rootwads and log jams, and stable undercut banks. Unstable stream banks collapsed during periods of high flow and coho were displaced. Furthermore, streams with adequate cover maintained greater numbers over winter than those with inadequate cover (Tschaplinski, 1987).

Critical coho habitat has been described as areas with adequate cover, cool water, sufficient food as well as a diversity of pools and riffles (Flosi *et al*., 1998). Coho move into deeper pools and riffles as they age (USFWS, 1983). Juvenile coho will occupy virtually all pool types, but actively seek out, and are most abundant in, deep, complex pools with slow moving cool water (Giannico & Heider, 2001; Flosi *et al*. 1998; Reeves *et al*., 1989; Bisson, Sullivan & Nielsen, 1988; Sheppard & Johnson, 1985). They tend to avoid riffles, glides, rapids and cascades (Bisson, Sullivan & Nielsen, 1988). Brown *et al*. (1994) determined that pools of 1m (3 ft) depth, or more, are necessary for rearing of juvenile coho salmon. Large woody material creates these deep pools.

Juvenile coho congregate near in-stream and bank cover seeking protection in logs, roots, overhanging vegetation and undercut banks (Flosi *et al*., 1998). Giannico (2000) determined that pools combining open foraging areas with abundant food with moderate amounts of large woody material accumulations were favored most by juvenile coho. Pools with slower moving water promote energy conservation; be it for rest, maintenance or feeding on drifting invertebrates (Giannico & Heider, 2001; Nielsen, 1992). Large woody material often provides a visual screen from other coho, reducing competition among juvenile coho and potentially increasing the number of fish in any given region (Dolloff, 1986; Giannico, 2000; Giannico & Heider, 2001). It also provides cover and refuge from predatory fish and other aquatic predators (Giannico & Heider, 2000). In-stream logs, both naturally occurring and placed, improve coho habitat conditions (Flosi *et al*. 1998).

In addition to providing cover and resting sites, in-stream and riparian materials minimize creek water temperature extremes (Giannico & Heider, 2001). Juvenile coho prefer water temperatures between 8.9^{o} – 15.6^{o} C (48^{o}-60^{o} F) (Flosi *et al*., 1998). Coho are less tolerant of warm water than steelhead (Frissell, 1992). In a study on the Matolle River in northern California, juvenile coho were absent in water where weekly maximum average temperatures exceeded 18.1^{o} C (64.5^{o} F) (Welsh *et al*., 2001).

Survival of juvenile coho is positively related to body size and habitat quality and negatively related to competition (Pess *et al*., 2011). Comparing certain morphological features of coho salmon, steelhead and cutthroat trout, Bisson, Sullivan and Nielsen (1998) determined that juvenile coho salmon possessed deeper, more laterally compressed bodies than the other subjects. Additionally, their fins were longer than either of the trout species. These physical characteristics, they maintained, reflected the requirements needed in order to occupy the hydraulic spaces they did (Bisson, Sullivan and Nielsen, 1998). Unlike steelhead, coho possess a deep, laterally compressed body with large fins. These characteristics are better suited for deeper pools with slow moving water where increased maneuverability for hunting and evasion is required. Large surface-area to body-volume ratio and large fin surface-area are undesirable physiological traits in fast moving aquatic environments, such as riffles, as they increase drag. Steelhead body shape and fin structure are better-suited for faster moving water (Bisson, Sullivan & Nieslen, 1998).

(iv) Threats

Modified natural flows no longer provide essential functions supporting multiple life-stage salmonid survival. The flushing of fine sediment resulting in gravel beds essential for spawning and rearing is interrupted or eliminated entirely (NOAA, 2011a). Natural processes that both clear out and recruit large woody material vital for the rearing of juvenile salmonids have been systematically and fundamentally altered (NOAA, 2011a). Logging, agriculture, road building and livestock have directly and indirectly affected the quality and quantity of habitat (NOAA, 2011a). Resource extraction has diminished both the quality and quantity of fish habitat (NOAA, 2011a). It is estimated that in most western states in the United States, between 80 to 90 percent of historic salmonid riparian habitat has been lost (NOAA, 2011a).

Recreational and commercial harvesting has also contributed to salmon population decline (NOAA, 2011a, Scheuerell & Williams, 2005). Historically, coho salmon have been caught for both sport and commercial enterprises. In California in the 1980s approximately 83,000 coho were caught annually, 30,200 of which were caught for sport (Brown, Moyle & Yoshiyama, 1994; Sheehan, 1991). It is believed that 90% of the total catch of coho in California originated in Oregon (Brown & Moyle, 1991). Salmon continue to be a target species for recreational fisheries. Commercial fishing on unlisted, healthier populations has been suspected of causing damage to weaker stocks of salmon (NOAA, 2011a). Illegal driftnet fishing may be responsible in some way for a reduction in the number of salmon (NOAA, 2011a). Predation by natural predators is not considered a cause of decline in Pacific salmon populations. However, these predators may have an effect on local populations where other prey is absent and where human-made physical conditions, such as culverts, locks or spillways result in unnatural concentrations of salmon (NOAA, 2011a).

Impaired systems are characterized by altered streambanks and channel morphology, changes in ambient water temperature, reductions in food supplies, removal of riparian vegetation, changes in large woody material recruitment, establishment and function, increased sediment deposition into spawning and rearing zones, a reduction in channel complexity and the number and depth of pools (NOAA, 2011a). In Washington the number of large, deep pools has decreased by 58 percent, due largely to sediment deposition and lack of pool-forming structures such as large wood and boulders. On private, coastal lands in Oregon, the number of large, deep pools has decreased by 80 percent (NOAA, 2011a).

(v) Large Woody Material, Pools and coho

Watershed restoration has become one of the central fronts in efforts to reverse these trends. Concerted efforts in the Pacific Northwest of the United States have been directed at restoration, with over U.S. $ 500 million being spent on recovery between the years 2000 to 2003 (Ashley Steel *et al*. 2008).

One in-stream restoration technique widely used throughout the Pacific Northwest is the placement of large wood. It is widely accepted that large woody material (LWM) is integral in establishing and maintaining both function and structure of forest stream ecosystems, possibly for centuries (Harmon *et al*., 1986; Abbe & Montgomery, 1996). Material has been shown to influence the formation, size and location of pools (Bisson, *et al*., 1987; Abbe & Montgomery, 1996; Cederholm *et al*., 1997; Hilderbrand et al., 1998). In some small streams it is estimated that 80 percent of all pools are formed as a result of LWM (Flosi *et al*., 1998). Pools associated with LWM are deeper than those formed by other structures, and contain rough surfaces that provide hiding-cover-resting places and diverse habitat for juvenile salmon of all age classes (Van Zyl de Jong, Cowx and

Scrutton, 1997). Rosenfeld, Porter and Parkinson (2000) determined that pools formed by LWM scour on average are 10 percent deeper than those formed by any other structure. Juvenile coho actively seek out deeper pools with cool water as they age.

Wood influences the deposition of spawning gravel and has been shown to impact the number of over-wintering juvenile coho and overall coho smolt yields (Harmon *et al*., 1986; Cederholm *et al.,* 1997). It serves as an energy and nutrient source, as habitat and shelter for organisms and as a sediment transport and storage (Harmon *et al*., 1986). Large woody material has a significant impact on geomorphic processes and is responsible for establishing and maintaining habitat diversity (Chen, *et al*., 2008; Harmon *et al*., 1986). Longer pieces of LWM, those 1.5-2 times channel width, are more stable than shorter pieces. Aggregates of LWM tend to be more effective in creating and maintaining pools than single pieces. Stable aggregates contain significantly longer pieces than unstable aggregates (Hilderbrand *et al.,* 1998).

PROJECT PURPOSE AND DESIGN

1) Purpose

Mill Creek Watershed has been targeted by various agencies as a high priority watershed for coho recovery. Important juvenile coho summer rearing habitat has been identified within the watershed (Russian River Coho Water Resources Partnership, 2012). Juvenile coho have been released into the watershed from the Russian River Coho Salmon Captive Broodstock Program annually since 2004. Several other habitat enhancement projects are underway in the watershed. The Sotoyome Resource Conservation District (RCD) is currently compiling a Watershed Management and Action Plan as part of the Fisheries Restoration Grant Program, sponsored by the California Department of Fish and Wildlife (Sotoyome Resource Conservation District, 2012). This paper serves as part of Action Plan.

1) Study Area

Mill Creek watershed is located within the Russian River watershed Hydrologic Unit and the Warm Springs Hydrologic Sub-Basin as classified by Cal-Watershed 2.2a. The Warm Springs sub-basin runs along the western edge of the Russian River basin in Sonoma County and contains the vast expanse of the Dry Creek watershed and Lake Sonoma, which now occupies the majority of the sub-basin watershed. This sub-basin is named after Warm Springs Dam, constructed in 1982. Lake Sonoma lies behind the dam wall. Primary ownership throughout the sub-basin is private. However, the U.S. Army Corps of Engineers (USACE) owns and manages Lake Sonoma (Sotoyome Resource Conservation District, 2012).

Major tributaries within the Dry Creek watershed below the dam include Pena Creek and Mill Creek. Mill Creek is the second largest tributary system in the Dry Creek watershed and joins Dry Creek just above the confluence of Dry Creek with the Russian River. Major tributaries of Mill Creek include Felta, Wallace, Palmer and Angel Creeks along with a smaller tributary Boyd Creek (Map 3). Together the area drains a basin of approximately 62 square kilometers (24 square miles). The system has a total of 47 kilometers (29 miles) of blue line (perennial) stream and includes both 2nd and 3rd order streams. Elevations range from about 18 meters (60 feet) at the mouth of Mill Creek proper to 427 meters (1400 feet) in the headwater areas (Russian River Coho Water Resource Partnership, 2012).

The Mill Creek watershed is located within a picturesque, rural setting that is made up of private residences, family-owned wineries and small-scale agricultural operations. The nearest major city is Healdsburg which is located approximately three kilometers (two miles) to the east. Timber sales help to support the local economy and are typically small-scale selective harvests designed to manage forest health rather than for large economic benefit (Sotoyome Resource Conservation District, unpublished).

Insert map: MCwatershedFI

See general watershed Map 2.2 on page 15 of the main document

Today, the Mill Creek watershed is completely privately owned. Coniferous and hardwood forests make up 43% of the land cover (8,825 acres); while grasslands make up 32% of land cover (6,658 acres); vineyards make up 16% (3,271 acres); rural residential 9% (1,858 acres); orchards (70 acres) and other miscellaneous categories include camps, roads and schools making up the remaining 37 acres (Sotoyome Resource Conservation District, 2012, unpublished). Most privately held land parcels are less than 600 acres in size. In the lower elevations where Mill Creek converges with Dry Creek, land use is primarily made up of vineyards and wineries. Higher up the watershed, higher elevations where the valley narrow, steep forest-covered hills limit agricultural activities. Throughout the watershed many of the landowners engage in an assortment of land use activities that include residential dwellings, wine grape growing, vegetable farming, fruit production and small-scale livestock production (Sotoyome Resource Conservation District, 2012, unpublished).

Sonoma County, California experiences cool, warm dry summers and cool, moist winters. The vegetation within this particular watershed is typical of North Coast Mediterranean vegetation, with oak woodlands dominating areas of higher temperature and shallow soils, and mixed evergreen and oak woodland dominating cooler and wetter areas with deeper soil. Coast redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) dominate in cooler, moister areas, whereas hardwood evergreens, such as tan oak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), Coast live oak (*Quercus agrifolia*) and California bay laurel (*Umbellularia californica*) occur on well-drained slopes. Much of the grassland in the watershed is a result of land cleared of hardwoods and conifers for the purposes of livestock grazing (Sotoyome Resource Conservation District, 2012, unpublished).

METHODS

The assessment was conducted over five reaches (Map 4). The reaches were Mill Creek to Puccioni Road Bridge (hereafter known as Mill Creek reach), Palmer Creek to Mill Creek (Palmer Creek reach), F1a: Felta Creek, F1b: Felta Creek and F2: Felta Creek. The total length of all five reaches was approximately 4.1 kilometers (2.5 miles). Reaches were selected by land-owner access rights and all contained naturally occurring and installed LWM. Wherever present within each reach, data on large wood, pools and recruitment were gathered.

Using a hand-held Trimble, all data were collected by walking the creek. These geo-referenced points were entered into ArcGIS for analysis. In an effort to protect in-stream habitat and to reproduce creek thalweg, I walked the creek bed adjacent to the water in the creek wherever possible. I entered the creek to obtain actual measurements. Data gathering commenced at a pre-determined downstream location and terminated at a pre-determined up-stream location. These locations were also based largely on access rights.

Insert map 4: entire sampled section with 5 reaches included see

LandmapsinsertThesis

See maps in Appendix H

This project specifically assessed juvenile coho habitat in the low-flow dry period, the season prior to consistent winter rains typical of Northern California climate. Naturally occurring pieces of wood touching low-flow creek water were measured and counted. Pieces suspended above low-flow creek water were not assessed. However, as part of the study was to assess the current functioning status of CDFW-installed LWM, all installed pieces were measured, regardless of placement and whether they were designed as low-flow or high-flow structures. Large wood installed by CDFW was identified by the use of attachment cables and bolts (Figure 1) and by metal identification tags secured to living trees on either bank.

Figure 1: Attachment cable and bolts identifying CDFW-installed LWM.

At each potential LWM site, several steps were followed in the assessment. Large wood was immediately classified as either naturally occurring, intentionally installed or a combination of both, typically at a debris jam. The diameter and length of pieces meeting or exceeding the 30.5 cm (12”) diameter and 1.8 m (6’) length criteria established by Flosi *et al*., (1998) were recorded. A diameter at base height (DBH) tape and measuring tape were used to measure diameter and length, respectively. Diameter measurement was taken at the midpoint of the piece. The total number of qualifying pieces was recorded. Each LWM occurrence was geo-referenced using a hand-held Trimble. Large wood pieces were identified and classified as either conifer or hardwood. The presence of small woody material (SWM) was also noted if present. These pieces were not measured or counted. Part of this study was to assess current functioning status of CDFW-installed LWM. Examples of functioning criteria included if the piece was still properly attached or if it had moved, if the piece was broken and/or decaying, if a pool attributable to the LWM was present, and if the piece still met the accepted LWM length and diameter criteria established by Flosi *et al*. (1998). These criteria were recorded for analysis.

Within the four reaches, any pool with a residual pool depth equal-to or greater-than 30.5 (1 foot) were measured, recorded and geo-referenced using a hand-held Trimble. Residual pool depth reflects the low-flow conditions of the stream and is independent of stream discharge (Lisle, 1987). It is calculated by subtracting the pool tail crest from the maximum pool depth of the entire pool system. Pools and pool tail crests were measured using a stadia rod. Wherever possible, the structure or agent resulting in pool formation was/were determined and recorded. Structures included LWM, boulders, or a combination. The type of pool was also recorded, wherever possible. Types of pool include boulder-, root wad-, bedrock- and log-enhanced lateral scour pool. Creek bed materials were also noted and classified as either bedrock, very large, double-head or single head-size boulders, large, medium, small or fine gravel or silt.

A visual assessment of left and right banks was conducted. This served to identify causes of LWM recruitment not only at that particular site, but also to establish an overall assessment of the dominant recruitment method(s) in the watershed, a particular creek or a designated reach. Recruitment methods included bank slides, bank undercut, intentional placement, other causes or a combination of the aforementioned. In an effort to better understand LWM recruitment outside and beyond creek banks, any other factors affecting LWM recruitment were also recorded. Examples include roads, bridges, buildings, railroads, and predominant land use.

Surrounding predominant land-use was noted and classified as agriculture, livestock, dairy, forestry, agriculture, other, or a combination. Land ownership was also reported and classified as private, public or other. Any easements attached to the land were also noted.

RESULTS and DISCUSSION

This section comprises five parts. The first consists of a summary of data analysis and observations from all reaches. Following the summary are four detailed reach-by-reach analysis containing analyses of LWM, pools and recruitment with recommendations.

1) Summary

A total of four reaches were sampled from Mill Creek, Palmer Creek and Felta Creek (Map 4). Mill Creek is a third order creek, while Palmer and Felta are both second order creeks. The first section of the results and discussion with recommendations will include a summary of all sampled reaches. Following that will be an analysis of the only third order creek, Mill Creek. A summary of the second order creeks will follow as will a more detailed analysis of each reach.

(i) overview

The total length of all creeks surveyed was approximately 4.4 km (2.7 miles). Mill Creek reach sampling commenced at the confluence of Palmer Creek, terminated at the Puccioni Road Bridge, and was approximately 2 km (1.25 miles) in length. Palmer Creek reach sampling terminated at its confluence with Mill Creek and was 914 m (3,000 feet) in length. Felta Creek (F1a & F1b) sample reach consisted of two sub-reaches, totaling approximately 335 m (1,100 ft). Felta Creek F1a commenced and terminated on a single land-owners property. F1b ran through multiple properties and terminated at the Felta Road bridge. Felta F2 sample reach was entirely in a single landowner's property and was approximately 1,103 m (3,620 ft).

The predominant land-use throughout the survey is either forestry, albeit on a small scale, and agriculture, predominantly grape growing. The dominant cover throughout is a mixture of conifer and hardwood, including Douglas fir (*Pseudotsuga menziesii*), Coast redwoods (*Sequoia sempervirens*), California bay laurel (*Umbellularia californica*) and alders (*Alnus spp*.).

(ii) Large Wood

Large wood was sampled at 57 sites. These sites comprised 38 natural LWM sites, 16 CDFW-installed sites and three combination natural and CDFW-installed sites, together consisting of 125 pieces of wood. Rootwads were present at 23 sites (Table 1a). The mean diameter of all measured wood was 41 cm (16 in), ± 17.5 cm (7 in) and the mean length was 7 m (23 feet), ± 4.1 m (13.6 ft) (Table 1b). The mean volume of LWM per thousand feet was xxx. Based on these figures, additional wood should be placed in xxx creek(s).

***Table 1a**: Summary of LWM sites, pieces and rootwad occurrences in each sampled reach and combined reaches.*

Creek:	Natural LWM sites	CDFW LWM sites	Both sites	Pieces	Rootwads
Mill	20	2	0	49	11
Palmer	6	2	0	15	3
F1a & b	1	10	0	17	2
F2	11	2	3	44	7
Combined	**38**	**16**	**3**	**125**	**23**

***Table 1b**: Summary of mean LWM diameter (in) and length (ft) for all sampled creeks and combined creek data*

Creek:	Pieces	Mean Diam (in)	Std dev Diam (in)	Mean Length (ft)	Std dev length (ft)
Mill	49	17	7	27.9	12.8
Palmer	15				
F1a & b	17				
F2	44				

Combined	**125**	**16**	**7**	**23**	**13.6**

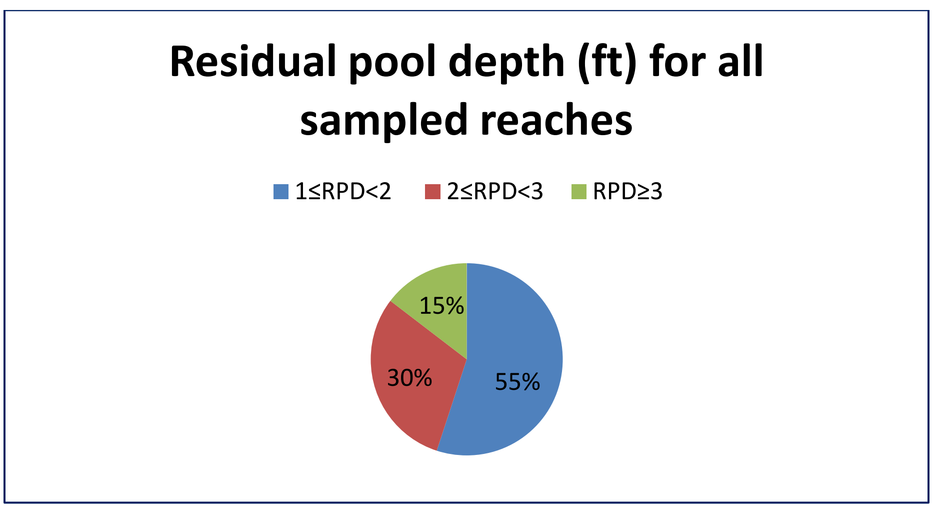
The overall functioning effectiveness of CDFW installed LWM is mixed. Mill, Palmer and Felta (F1a & b) reaches contained CDFW-installed pieces of LWM that no longer qualified as LWM. The diameter of these pieces was less than the minimum requirement of 30.5 cm (12 in). In Palmer Creek, a piece of LWM suspended over low-flow water (not measured for statistical analysis) had snapped into two pieces due to decay. In Felta (F1a & b) a structure consisting of four pieces of LWM cabled and bolted together, and anchored to the bank, had separated completely with pieces now lying on either side of the creek. At a different site in the same reach, a piece of LWM lay disconnected, 12 m (40 ft) away from the original structure. However, the effectiveness of installed LWM creating pools reveals different results.

(iii) Pools and creek-bed

Eighty-nine pools in all five reaches were sampled. The mean depth was 61 cm (2 ft) and the standard deviation was 24cm (9.5 in). The deepest pool measured was 111 cm (3 ft 8 in). Forty-nine pools (55.1%) had a residual depth greater-than or equal-to 30.5 cm (1 ft) but less than 61 cm (2 ft), 27 pools (30.3%) had a residual depth of greater-than or equal-to 61 cm (2 ft) but less than 91.5 cm (3 ft) and 13 pools had a residual depth greater-than or equal to 91.5 cm (3 ft) (Table 2 and graph 1).

Table 2: *Summary of RPD(y) by classification for all 89 sampled pools*

Creek:	30.5cm/1ft≤y<61cm /2feet	61cm/2ft≤y<91.5cm/3ft	y>91.5cm/3ft
Mill	13	8	4
Palmer	10	1	2
Felta: F1a & b	11	9	4
Felta: F2	15	9	3
Combined	**49**	**27**	**13**
Combined %	**55%**	**30.3%**	**14.6%**



Graph 1: Residual pool depth for all sampled pools

A comparison of the mean RPD of pool associated with CDFW LWM (single and multiple pieces and attached to boulders) and naturally occurring LWM in all reaches indicates that installed LWM is functioning just like naturally occurring LWM (Table 3). The mean RPD of all types of installed LWM (single and multiple pieces, combinations of installed and natural pieces and structures containing CDFW wood and boulders) is 67 cm (2 ft 2in). The mean residual depth of all sampled pools associated with naturally occurring LWM is (2 ft 1in) and the mean residual depth of pools containing rootwads is 65 cm (2 ft 2 in). These data suggest that CDFW LWM, whether installed with just CDFW wood, a combination of CDFW and naturally occurring wood, or using a combination of wood attached to boulders, is functioning as well as naturally occurring LWM and rootwads. However, over time CDFW-installed pieces are decaying. What is unclear is if they will continue to function by replicating natural structures as they continue to decay. A future study on this topic may answer this question.

Table 3*: Summary of RPD and naturally occurring LWM, CDFW LWM and rootwads*

	Mean RPD (ft in)					
Feature:	**Mill**	**Palmer**	**Felta (F1a&b)**	**Felta (F2)**	**all reaches**	**occurrences**
Natural LWM	2'2"	2'6"	1'4"	2'3"	2'1"	28
CDFW LWM, both, & boulders	0	2'	2'5"	2'3"	2'2"	16
Rootwads	2'4"	2'4"	1'8"	2'2"	2'2"	21

Throughout the sampled sections, the creek bed material ranges from silt and sand to gravel of assorted sizes. All creeks contain boulders of varying sizes, but Palmer Creek contains some noticeably large boulders constricting creek flow. Felta (F1a and b) contains several boulder weirs, unlike the other sampled reaches. Scour pools are the predominant pool type throughout the watershed. The majority of pools are log-, rootwad-, boulder- and bedrock-enhanced scour pools.

(iv) Recruitment

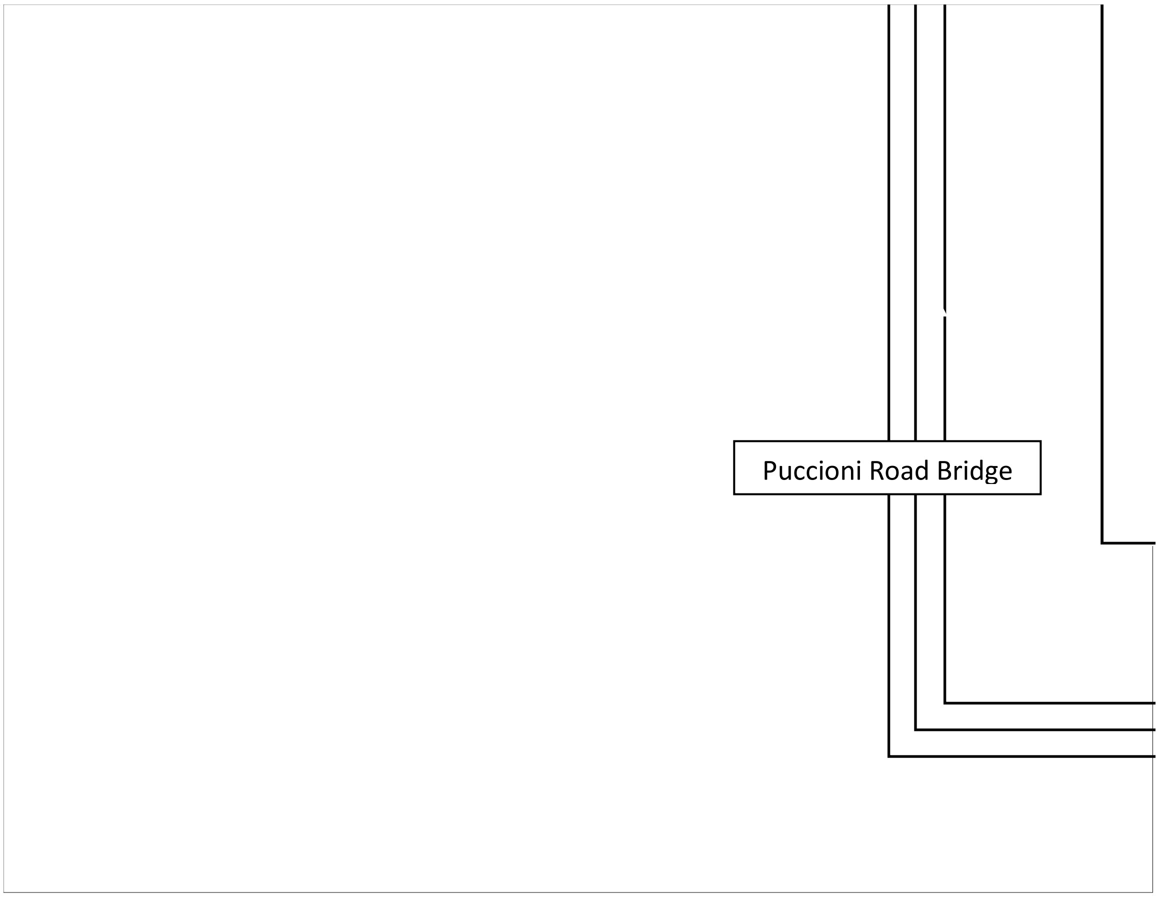
Large wood recruitment opportunities throughout the sampled reaches are mixed. A significant inhibitor of large wood in Mill Creek is the presence of Mill Creek Road. Used primarily by homeowners in the watershed, this paved road serves as the major access artery in and out of the valley. The importance of this road limits the potential for LWM recruitment as falling wood would quickly be cut and cleared, ensuring the road remains open to traffic. Felta Creek Road, although smaller, acts similarly and appears to be impacting LWM recruitment. Palmer and Felta (F2) do not suffer the same recruitment limitations as Mill and Felta (F1a and b). Other factors influencing recruitment are selective timber harvesting and restoration projects adjacent to Mill, Palmer and Felta (F2) Creeks. Grape growing within the sampled reaches is predominantly adjacent to

Felta (F1a and b) Creek. Clearing of stands to make way for agriculture continues to impact LWM recruitment, especially where natural buffers between areas under cultivation and creeks are narrow. Land-ownership throughout the watershed is private, potentially reducing protection of future LWM sources.

2) Mill Creek: from confluence with Palmer Creek to Puccioni Road Bridge

(i) Overview

Mill Creek is a tributary to Dry Creek which is a tributary to the Russian River. It is a perennial third order stream with approximately 12 miles of blue line stream. Sampling commenced at the confluence of Palmer Creek, terminated at the Puccioni Road Bridge, and was approximately 2 km (1.25 miles) in length (Map 5).



Map 5: *Mill Creek sample sites commencing at confluence with Palmer Creek and terminating at Puccioni Road bridge*

Mill Creek Road runs adjacent to the sampled section of Mill Creek, above the left bank. There are numerous bridges spanning the creek, homes adjacent to the creek, swimming holes and pedestrian access points. Mill Creek Road can be described as a local rural road and primarily serves as an access route to homes and private properties in the area. The road, as well as the activities, structures and people it supports, all have, and still, play a role in effecting coho habitat in Mill Creek.

(ii) Large Wood

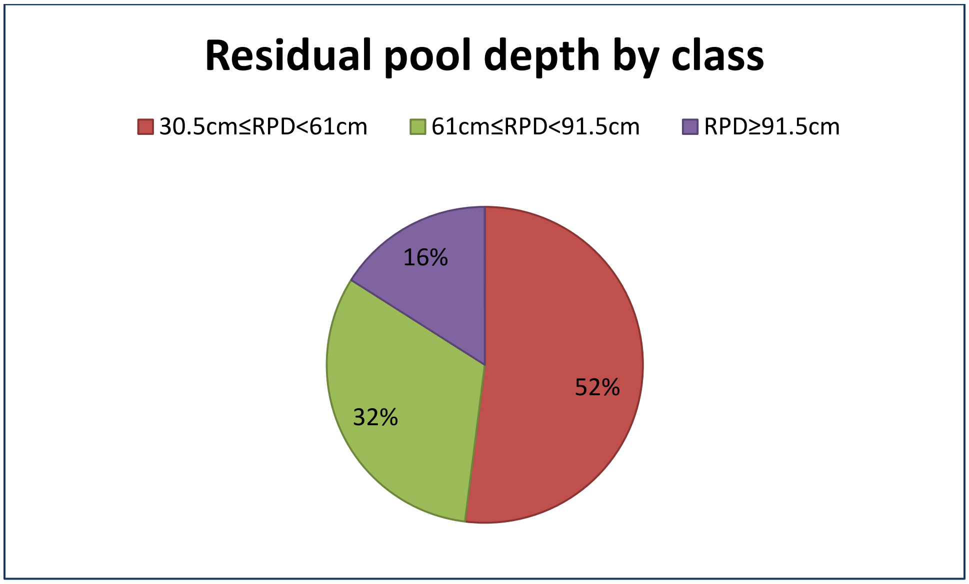
Large woody material was measured at 20 sites; 18 of which contained naturally occurring wood and 2 contained CDFW installed wood. In all, 49 pieces of large woody material were measured. The mean diameter of natural LWM was 17 in, ± 7 in, and CDFW LWM was 18 in, ± 0 in. The mean length of natural LWM was 27.9 ft, ±12.8 ft, and 29.5 ft, ± 6 ft for CDFW LWM. Despite the mean diameter and length of natural CDFW LWM being similar, neither of the two CDFW LWM installations formed a qualifying pool (residual pool greater than 30.5cm (1 ft). This suggests that CDFW wood is not mimicking natural LWM and is not functioning as designed. Rootwads were recorded at 11 sites. 25 sites had either LWM or rootwads. Thirteen of 18 sites (72%) with natural LWM contained pools and nine of the 11 (82%) sites containing rootwads had pools (Table 4).

***Table 4**: Summary statisics of LWM and rootwads for Mill Creek sample reach.*

	Sites	Qualif pieces	Mean Diam (in)	Std dev (in)	Mean Lgth (ft)	Std dev (ft)	pools
Natural LWM	18	45	17	7	27.9	12.8	13
CDFW LWM	2	4	18	0	29.5	6	0
Both	0	0	0	0	0	0	0
Rootwads	11	11	na	na	na	na	9
total	**25**	**60**	**na**	**na**	**na**	**na**	**22**

(iii) Pools and creek-bed

Using pools as an indicator of LWM effectiveness at creating juvenile coho habitat revealed more about naturally ocurring LWM, installed LWM and rootwads. A total of 25 pools deeper than 30.5cm (1 ft) were measured in the sample section. The mean residual depth for all pools was 65 cm (25.5 in), ± 22.5 cm (9 in). The deepst pool had a residual depth of 111cm (44 in) and contained naturally occurring LWM. Typically, third order creeks containing pools with a maximum depth of over 90.5 cm (3 ft) are considered ideal coho habitat. Eight pools (32%) had a maximum depth of over 90.5 cm (3 ft). When residual pool depth was broken down into classes, 13 pools (52%) were greater-than 30.5cm (1 ft) and less-than-or-equal-to 61cm (2ft), 8 pools (32%) were greater-than 61cm (2ft) and less-than-or-equal-to 91.5cm (3ft) and 4 pools were deeper than 90.5 cm (3 ft) (Graph 1 and Table 5).



Graph 2

Table 5*: Residual pool depth breakdown by class and pool-forming structure*

Pool class	**30.5cm/1ft≤y<61cm /2feet**	**61cm/2ft≤y<91.5cm/3ft**	**y>91.5cm/3ft**
Number of pools	13	8	4
Natural LWM sites	5	7	1
CDFW LWM sites	0	0	0
Both	0	0	0
CDFW LWM & boulders	0	0	0
Rootwads	4	3	2
Rootwads OR any	6	7	3

LWM			
Rootwads AND any LWM	3	3	0

Installed material, both wood and boulders, were absent from all qualifying pools and only naturally occurring LWM and rootwads were present. Fifty-four percent of naturally ocurring LWM formed pools with residual depth between 2 ft-to-3 ft. Rootwads or natural LWM are present at pools deeper than 90.5 cm (3 ft). When naturally occurring LWm and rootwads are at the same pool site, pools over 90.5 cm (3 ft) do not exist. As none of the CDFW LWM have created pools, I recommend that future additions to the creek include rootwads. If LWM is to be added, I recommend closer attention be paid to the location, attachment and number of pieces of naturally occurring LWM as these are the structures creating pools.

Large wood, rootwads and bedrock are present at 22 of the 25 pools (80%). Log-enhanced, rootwad-enhanced and bedrock-enhanced lateral scour pools are prevalent throughout the sampled reach and are the dominant pool-type. Two backwater pools were recorded as was 1 plunge pool. A 1995 assessment determined scour pools made up 70% of all pool-type indicating pool-type has remained consistent over 18 years.

(iv) Recruitment

Determining a single LWM recruitment method was challenging as often more than one force was responsible for the recruitment. In these situations, where recruitment was often a combination of bank undercut caused by scour pools and heavy flow, and slides, recruitment method was simply recored as “other”. This combination was the dominant throughout the sample reach accounting for as much as 75% of naturally occurring LWM. Undercut alone acocunted for 30% of LWM recruitment.

Bank undercut accounted for 33% of recruitment technique, the highest of the individual techniques. However, the category “other” accounted for 53%. Here, it was indeterminate if there was a single recruitment method. In some cases recruitment relied upon a combination of causes, such as bank undercut and slide, or intentional and upstream delivery. Having surveyed the area and conducted the assessment, it is my opinion that bank undercutting is the predominant recruitment method delivering LWM to the sytem. However, this recruitment method will be tempered by the presence of the road, bridges and homes as creek banks are artificially buttressed and supported in efforts to manipulate and control water flow and direction. As Mill Creek Road is the main access road in the watershed, I feel it is unlikely that any potential LWM in the form of fallen trees would enter the creek. Large wood blocking access both into and out. It is difficult, if not impossible, to determine how far upstream the source of LWM is, so recruitment at any given spot may not necessarily reflect how that individual piece arrived and lodged at that specific place.

Large wood recruitment potential in Mill Creek has declined steadily over time. It has diminished in areas where creek sinuosity has been reduced. Where Mill Creek Road and Mill Creek are in close proximity to each other, large amounts of rip rap have been added to support the banks and stream channel. Bags filled with concrete line the left bank at Puccioni Road Bridge to reinforce the bank. These stabilizers reduce the likelihood of LWM falling into the creek due to bank undercut associated with creek sinuosity.

California Department of Fish and Wildlife reported historical evidence indicating that large wood and rootwads had been removed for flood control and firewood throughout Mill Creek (Sotoyome Resource Conservation District, 2012 unpublished). After inspection, I suspect large wood has been removed from swimming holes to improve the overall swimming experience. Boulders may also have been removed from swimming holes as very few large boulders are visible. Numerous trails link swimming holes and the creek with Mill Creek Road. A bridge accessing a land-owners property on the right bank of Mill Creek was recently repaired, using rip rap to support both banks and to control flow direction. There is little evidence suggesting a cessation of these activities, all of which result in fewer structures in the creek and less recruitment potential.

The presence of the road itself significantly reduces large woody material recruitment potential. Wood on the opposite side of Mill Creek Road from Mill Creek is likely to be removed to maintain accessibility. As the road runs very close to the creek, recruitment potential may be reduced by as much as 50% (Figure 2).

Figure 2: The close proximity of Mill Creek Road to Mill Creek imfluencing LWM recruitment.

Current recruitment appears to be exclusively from the opposite bank and beyond. Landslides are recruitment events resulting in the deposition of LWM into creeks. Evidence of landslides above Mill Creek Road suggests recruitment potential, but it is doubtful any large wood from the slide would enter the creek as it would probably be cleared off the road (Figure 3).

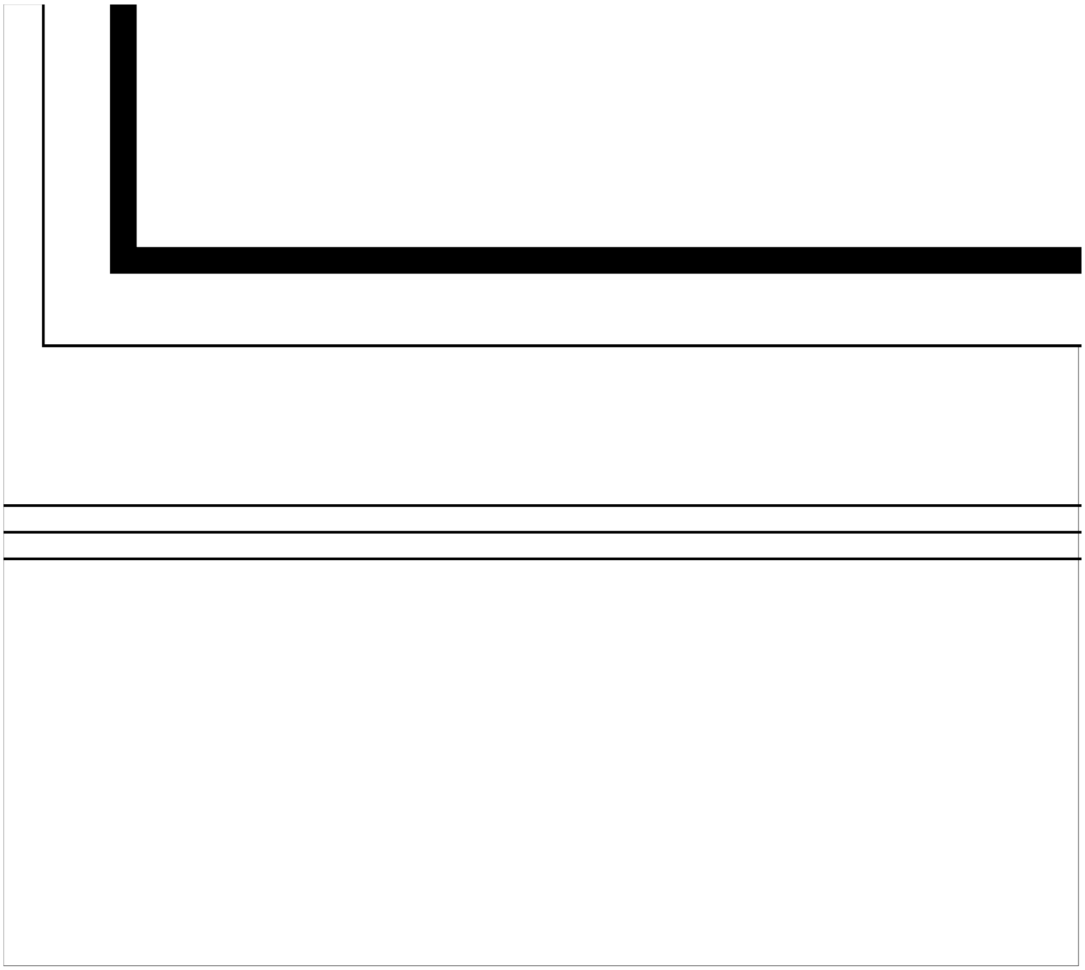
Figure 3: Evidence of potential LWM recruitment from landslides above Mill Creek Road.

2) Palmer Creek

(i) Overview

Palmer Creek is a tributary to Mill Creek. It is a second order creek with approximately 5.4 km (3.8 mi) of blue line stream. Palmer Creek is privately owned by several landowners. In 1995 the CDFW (CDFG at the time) conducted a biological inventory. The recommendations after the survey included structures to increase the number and depth of pools and to increase the LWM cover in existing pools. A total of seven (three complex, four simple) cover/scour structures were installed during the Summer/Fall of 1998 commencing at the confluence of Mill Creek extending 915 m (3,000 ft) upstream. Approximately 1,500 alder trees were also planted as part of the habitat enhancement plan (California Department of Fish and Wildlife, 1998).

This study did not encompass all of Palmer Creek and was limited to those pools and structures in the creek within a single landowner's property (Map 4). Data gathered for statistical analysis were limited to in-stream structures and pools. However, high-flow CDFW structures current functioning status was also assessed as part of the project's overall scope.



Map 4: *Palmer Creek sample sites to confluence with Mill Creek*

Palmer Creek is characterized by steep banks, several very large in-stream boulders and a recruitment zone consisting predominantly of mixed hardwood and conifer cover (Figure 3). The only road impacting the creek is a dirt/gravel fire control access roads constructed and maintained by the landowner. Unlike Mill Creek, this fire/access road only intermittently runs adjacent to the creek. What little vehicle traffic that uses the road is typically heard and not seen.

Figure 3: Palmer Creek. Note the very large bedrock and boulders in foreground.

(ii) Large Wood

Large woody material was measured at eight sites; 6 of which contained naturally occurring wood and 2 contained CDFW installed wood. In all, 15 pieces of LWM were measured. The mean diameter of natural LWM was 14.4 in, ± 2.6 in, and CDFW LWM was 14.5 in, ± 3 in. The mean length of natural LWM was 35.5 ft, ±18.1 ft, and 24.75 ft, ± 2 ft for CDFW LWM. Naturally occurring LWM formed five pools and CDFW LWM foremd two pools. Three rootwads were located in the reach and all formed pools. There was an additonal site containing CDFW installed wood, but it was installed for high-flow purposes and was not measured. The wood at this site was badly decomposed and one piece had broken into two pieces (Figure 4).

Figure 4: Broken piece of CDFW LWM. Break point located at tip of arrow.

As all in-stream low-flow CDFW wood formed pools, this wood appears to be functioning as designed. However, as a high-flow piece has decayed and broken, it is possible the life-expectancy of some of the installed wood may be coming to an end. I recommend additonal pieces be added to the creek to supplement decaying, or soon-to-decay, wood. Rootwads were recorded at three sites. Nine sites had either LWM or rootwads. Five of 6 sites (83%) with natural LWM contained pools, all (100%) sites containing CDFW LWM contained pools and all sites (100%) with rootwads had pools (Table 6).

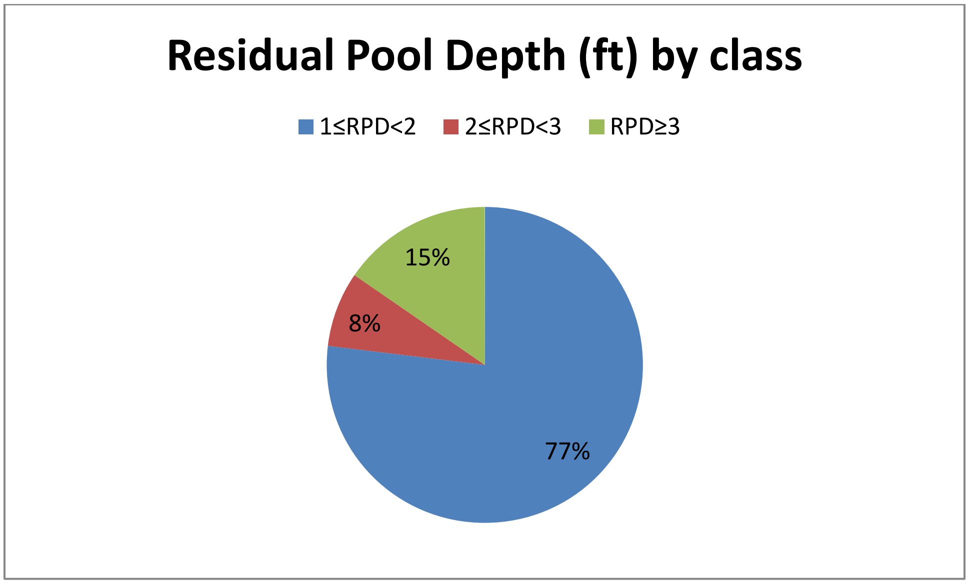
Table 6*: Summary statisics of LWM and rootwads for Palmer Creek sample reach.*

	Sites	Qualif pieces	Mean Diam (in)	Std dev (in)	Mean Lgth (ft)	Std dev (ft)	pools
Natural LWM	6	11	14.4	2.6	35.5	18.1	5
CDFW LWM	2	4	14.5	3	24.75	2	2
Both	0	0	0	0	0	0	0
All LWM	8	15					
Rootwads	3	3	na	na	na	na	3
total	**11**	**18**	**na**	**na**	**na**	**na**	**10**

(iii) Pools and creek-bed

A total of 13 pools with residual depths of at least 30.5 cm (1 ft) were sampled. The mean residual depth of all pools was 58 cm (23 in), ±27 cm (9 in). The range of residual pool depth was 79 cm. Ten pools (77%) had residual pools depths of greater-than or equal-to

30.5 cm (1 ft) and less than 61 cm (2 ft). Three pools (23%) had a residual depth equal-to or greater-than 61 cm (2 ft) (Graph 3).



Graph 3

Only three pools have residual depths of at least 61 cm (2 ft) or more. These three pools contain natural LWM and rootwads (Table 7). Four log jams produced the deepest pools with residual depths of 110cm (3.6 ft), 110cm (3.6 ft), 88cm (2.9 ft) and 60 cm (2 ft) (Picture 4). Two of the three rootwads were present at the log jams. Two log jams comprised natural LWM and two installed LWM. Three of the log jams contained upstream silt traps. These jams, comprised natural, installed and rootwads are providing essential habitat creation as they produce the deepest pools, the greatest amount of cover and provided a silt trap (Figure 5). I recommend future design and in-stream site location considerations in this reach be based on these four natural log jam due to their effectiveness in creating coho habitat.

***Table 7**: Residual pool depth breakdown by class and pool-forming structure*

Pool class	**30.5cm/1ft≤y<61cm /2ft**	**61cm/2ft≤y<91.5cm/3ft**	**y>91.5cm/3ft**
Number of pools	10	1	2
Natural LWM sites	2	0	2
CDFW LWM sites	1	1	0
Both	1	0	0
CDFW LWM & boulders	0	0	0
Rootwads	1	0	0
Rootwads OR any LWM	5	1	2
Rootwads AND any LWM	1	0	1

Creek-bed material consisted of several very large boulders, bedrock and gravel of assorted sizes. The lack of silt may be attributable to the effectiveness of the debris jams. Visual assessment confirmed that silt had been trapped upstream of the jams. Pool formation was bedrock-, boulder- and log-enhanced. Most boulders were natural and were consistently located throughout the sample reach.

Figure 51: Log jam in Palmer Creek.

(iv) Recruitment

Current recruitment potential in the reach is not limited by the presence of an important entry/exit artery like Mill Creek Road. The fire access road that periodically runs adjacent to Palmer Creek is predominantly used and maintained by a single landowner. Evidence indicates historic logging occurred in the watershed. Selective harvested for timber is on-going, potentially further impacting LWM recruitment. Current restoration efforts within the watershed have removed trees, but plans do call for replacement plantings.

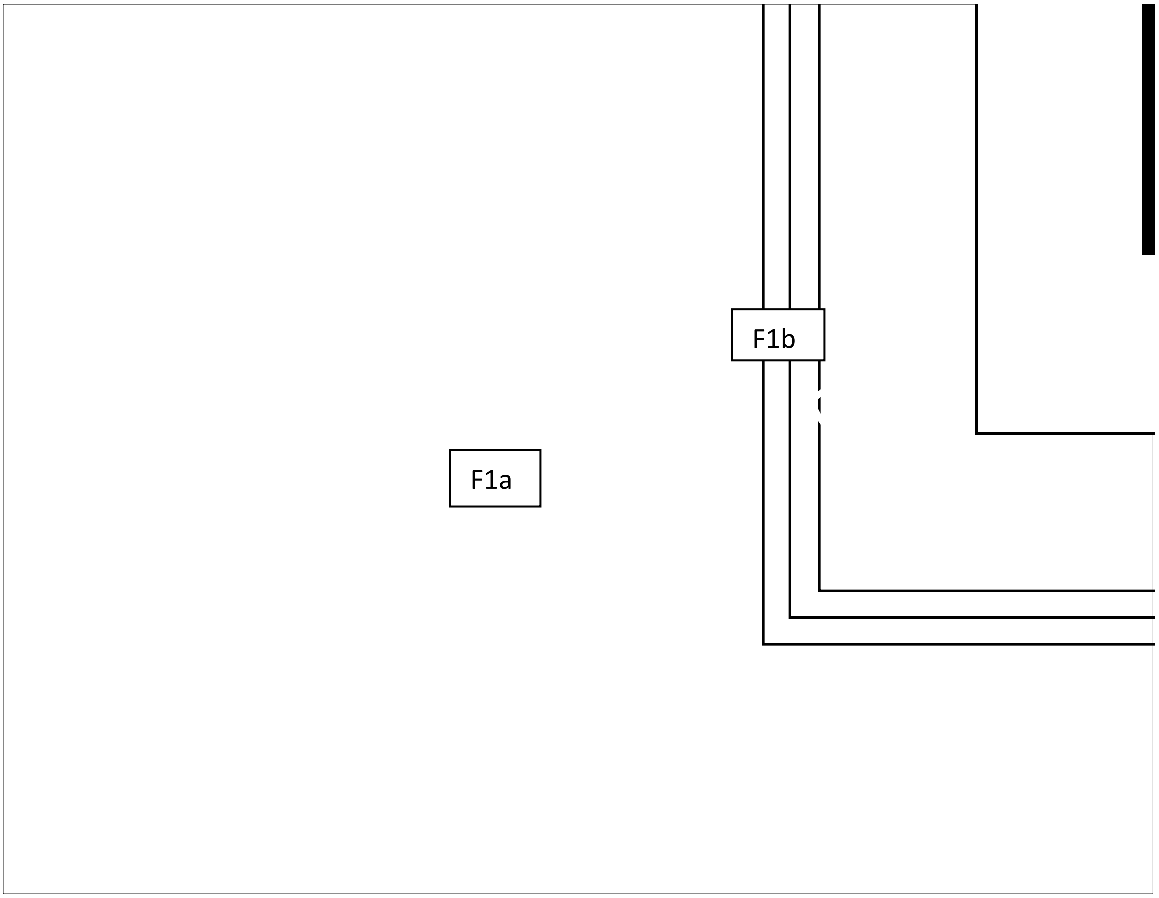
Evidence suggests that landslides are recruitment agents, particularly in the lower sections of the reach. Landslides were recorded at three locations and were on steep hill sides particularly where the creek narrowed. Bank undercut is a recurring recruitment agent throughout the reach and was recorded at six locations. The combination of steep banks and very large boulders result in an increase in creek velocity, particularly in periods of high flow. Combined with natural sinuosity, banks are undercut, resulting in trees falling into the creek. At several sites more than one recruitment agent was responsible for large wood deposition, including both slides and bank undercut. Here recruitment was recorded as “other”. This classification was recorded six times, suggesting that slides and undercut are at work throughout the reach.

3) Felta Creek: F1a and F1b

(i) Overview

Felta Creek is a tributary to Mill Creek. Felta Creek is a second order stream and has approximately 8 km (5 mi) of blue line stream. Felta Creek watershed drains approximately 9.5 square kilometers (3.7 square miles). Felta Creek is privately owned. The upper reaches of the watershed were logged in the past and selectively harvesting continues today. The lower section supports grape growing for wine production (Figure 6). This section of Felta Creek was targeted for enhancement by CDFG after a survey of the creek in 1995. Details of the plan called for the installation of 10 boulder weir structures to create pools and to add woody cover to the newly formed pools. These structures were designed to create scour, increasing pool depth and frequency for coho and steelhead. The project consisted of two sections, F1a and F1b. Sampling for this study was conducted at both locations (Map 6).

Figure 6: Felta Creek (F1)



Map 6: Felta Creek F1a and F1b sample sites

(ii) Large wood and boulders

Natural LWM occurred at one site and CDFW LWM at 10 sites. Natural LWM comprised 2 pieces and CDFW 15 pieces. Two rootwads were recorded. The mean diameter of all LWM was 35 cm (13.6 in), ± 7 cm (2.7 in) while the mean length was 5.4 m (17.7 ft), ± 3.5 m (11.4 ft). Nine of the 10 CDFW installations combined large wood with attached boulders. The remaining structure comprised four pieces of large wood.

The California Department of Fish and Wildlife installed several large in-stream boulder weirs and combination LWM-boulder weirs. These structures were connected to each other using a series of bolts and cables (Figure 7). Some boulder clusters contained more than 20 large boulders spanning low-flow creek water levels. Several of these structures are no longer functioning as designed as bolts and connecting cables have separated (Figure 8).

Figure 7: Felta Creek (F1b): an example of LWM attachment to boulder using bolts and cable

Figure 8: A disconnected bolt from CDFW LWM.

At waypoint 11 (see attribute table) all pieces of CDFW LWM were unattached and loose. Two pieces, still attached to each other, but loose, lay 40 m downstream from the original attachment point (Figure 9). At waypoints 17 and 18 CDFW LWM remained attached, but individual pieces had decayed, rendering piece diameter too small to be classified as LWM. A broken attachment bolt lay in the creek bed further upstream. It is unknown where this bolt originated from, or if the all remaining pieces are attached and intact. However, the boulder weirs appear to be functioning well and are still very secure.

Where CDFW boulder weirs and LWM are combined and still intact, mean residual pool depth is over 77 cm (2.5 ft). In conjunction with LWM, attached boulders are effective at creating deep pools with varied stream bed material essential for coho survival.

Figure 9: Two attached pieces of CDFW LWM that has broken apart from original anchoring. These pieces are loose and will likely move in periods of high flow.

Both naturally occurring and installed boulders are integral in pool formation throughout the sample reach (Table 8). In second order streams, pools with a maximum depth, (as opposed to residual depth) of at least 60.5 cm (2 ft) are considered ideal coho habitat. In F1a and F1b, natural and installed boulders are present at over 75% of all pools with a maximum and residual depth of at least 60.5 cm (2 ft). Installed structures combining both boulder weirs and LWM produce more pools than any other structure. However, installed combinations incorporating LWM with boulders created pools with a mean RPD 17 cm (7 in) deeper than pools formed by natural boulders alone. Large wood, root wads and log jams are infrequent throughout the sampled reach and, individually, play very little role in pool formation.

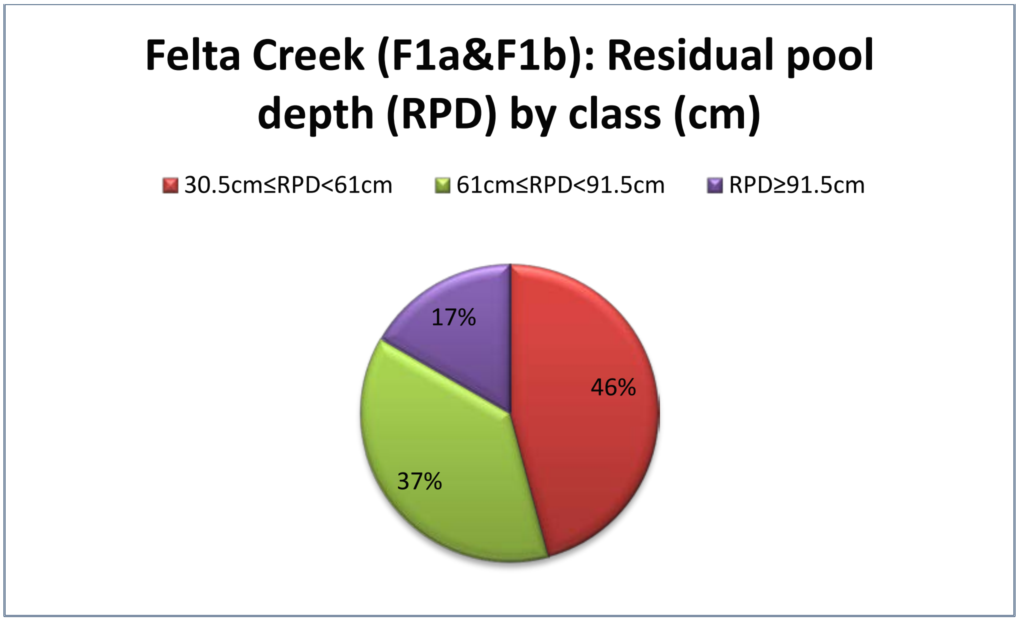
Table 8*: Structure and pools (F1a and F1b)*

	Sites	Number of pools	Mean RPD (cm/in)
Natural boulder	8	8	56/22
Natural LWM	2	1	41/16
Both	0	0	0
CDFW LWM	0	0	0
CDFW boulders	2	2	46/18
both	8	8	73/29

The long-term effectiveness of CDFW structures is mixed. Currently, installed structures are performing as designed, mimicking naturally occurring structures. Thirteen pools have a residual depth of over 61 cm (2 ft). Seven contain CDFW structures and six contain natural structures. However, some of the anchoring at CDFW installations within the reach has broken apart. I suspect this may be a combination of heavy creek flow and large wood decay. It is my recommendation that all future structure additions incorporate boulder weirs combined with LWM, provided anchoring techniques are improved for long-term viability and the safety of homes, bridges and other structures in the watershed. LWM should also be incorporated as it presents additional in-stream cover for fish of all age classes. The lack of this cover currently may prove costly to fish and might be the focus of a future study.

(iii) Pools and creek-bed characteristics

Twenty-four pools greater-than or equal-to 30.5 cm (1ft) were assessed in this reach. Mean residual pool depth was 63 cm (2 ft), ±24 cm (0.8 ft). The range of residual pool depth was 71 cm (2.3 ft). Eleven pools (46%) had a residual depth greater-than or equal-to 30.5 cm (1 ft) and less-than 61 cm (2 ft). Nine pools were greater-than or equal-to 61 cm (2 ft) and less-than 91.5 cm (3 ft) (Graph 3). In second order streams, pools with a maximum depth, (as opposed to residual depth) of at least 60.5 cm (2 ft) are considered ideal coho habitat. In F1a and F1b, natural and installed boulders are present at over 75% of all pool sites with a maximum or residual depth of at least 60.5 cm (2 ft). Four pools (16.5%) had a residual depth equal-to or greater-than 91.5 cm. These pools were formed by naturally occurring boulders and did not contain any LWM.



Graph 3

Boulders play a significant role in pool formation and were present at 19 of the 24 pools (79%) and 11 of the 13 (85%) of pools with residual depth equal-to or greater-than 61 cm. Of the 24 pool sites, nine (37.5%) contain CDFW boulders, and 10 (42%) naturally occurring boulders. One-third of pool contains LWM and boulders of any origin. By contrast, only one pool (4%) has LWM without any boulders (Table 9). Future plans for additional structures should consider this and, when attempting to create deeper pools, should incorporate both boulders and LWM together at any given site. In this reach, boulders are creating deeper pools and LWM is providing cover.

Table 9: *RPD(y) classification and structures abundance*

	30.5cm/1ft≤y<61cm /2ft	61cm/2ft≤y<91.5cm/3ft	y>91.5cm/3ft
Number of pools	11	9	4
Sites containing natural boulders	6	2	2
Sites containing CDFW boulders	2	7	0
Sites containing LWM only	1	0	0
Sites containing LWM and boulders	1	7	0

Small, medium and large gravel as well as sand are the dominant bed material, providing ample habitat structure for redds. Creek bed material in this sample reach consists mainly of various-sized, unattached boulders, assorted gravel and sand.

(iv) Recruitment

The upper reaches of the sample section are characterized by mixed hardwood forest (Figure 11), the lower portion by vineyards and fields cleared for agriculture. The banks of the creek are moderately sloped with recruitment coming largely from bank undercut. Privately-owned properties of varying size are located on both sides of creek. Access to this section of Felta Creek commences at the junction of Felta Creek Road and Felta Road. Felta Creek Road, a single-lane dirt and gravel road, follows the creek on the left bank of the sample reach (Figure 10). Periodically, where the road and creek are in close proximity, vehicle traffic is both audible and visible. The access road is maintained by, and predominantly used by, homeowners. Despite such light traffic, it has an effect on LWM recruitment. It is the major access artery into the watershed and it is likely that any large wood falling on the road is cut and hauled out immediately, maintaining access. The road acts as a buffer for large woody material from entering the stream, reducing actual and potential recruitment by as much as 50%.

In-stream recruitment is largely limited to bank undercut. As there is not a lot of LWD in the system, the majority of the sampled sites consist of installed LWM. The possibility of LWM entering the creek in reached higher up the watershed would need to be explored to determine long term recruitment potential. Trees moving down the creek during periods of high flow may not even make it to lower reaches as they may lodge themselves against bridges. If this were to happen, they would surely be removed for safety purposes. Recruitment potential in this reach is very different to, and much lower than, Felta Creek (F2) due to the number of landowners in this watershed compared to just one in F2. There is a greater likelihood of LWM material getting cleared for safety or access reasons in areas with higher populations than those with lower numbers. I suspect this is contributing to the low amount of LWM in Felta F1a and F1b.

Figure 10: Felta Creek Road and its potential influence on LWM recruitment.

4) Felta Creek: F2

(i) Overview

Like Palmer Creek, this reach of Felta runs entirely through the property of a single landowner. The dominant vegetation is mixed hardwood forests (Figures 9 & 10). Felta Creek is a tributary to Mill Creek. Felta Creek is a second order stream and has approximately 8 km (5 mi) of blue line stream. Felta Creek watershed drains approximately 9.5 square kilometers (3.7 square miles). Felta Creek is privately owned. The upper reaches of the watershed were logged in the past and selectively harvesting continues today. The CDFW Felta Creek F2 enhancement project resulted in eight structures (log and boulder weirs) and 300 native alder trees to be installed and planted in the reach. The sample reach was approximately 1,100 m (3,620 ft) and 33 pools and structures were assessed (Map 7).

Figure 9: Felta Creek (F2)

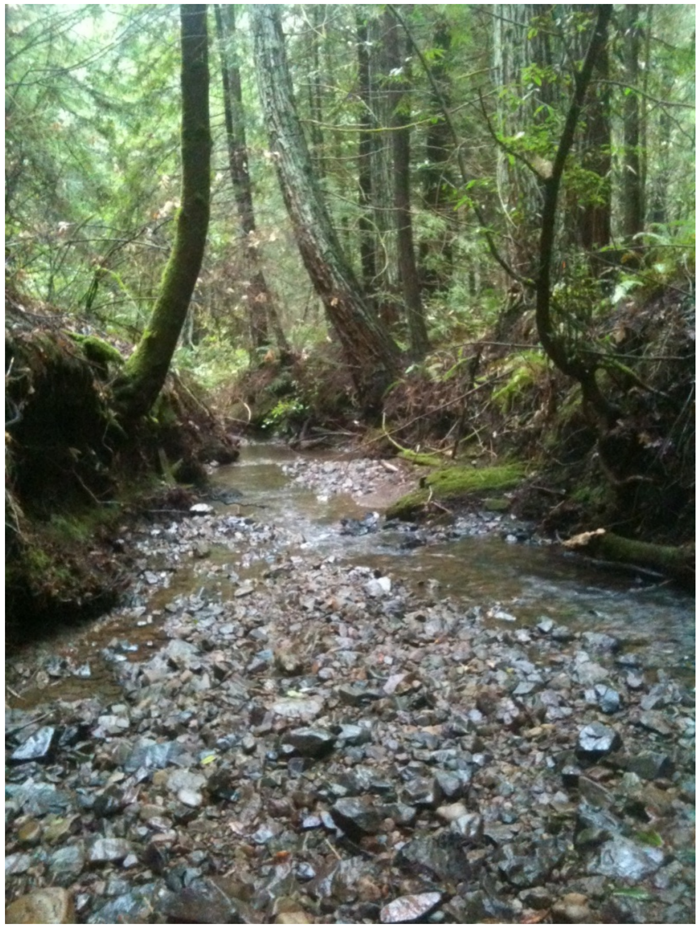
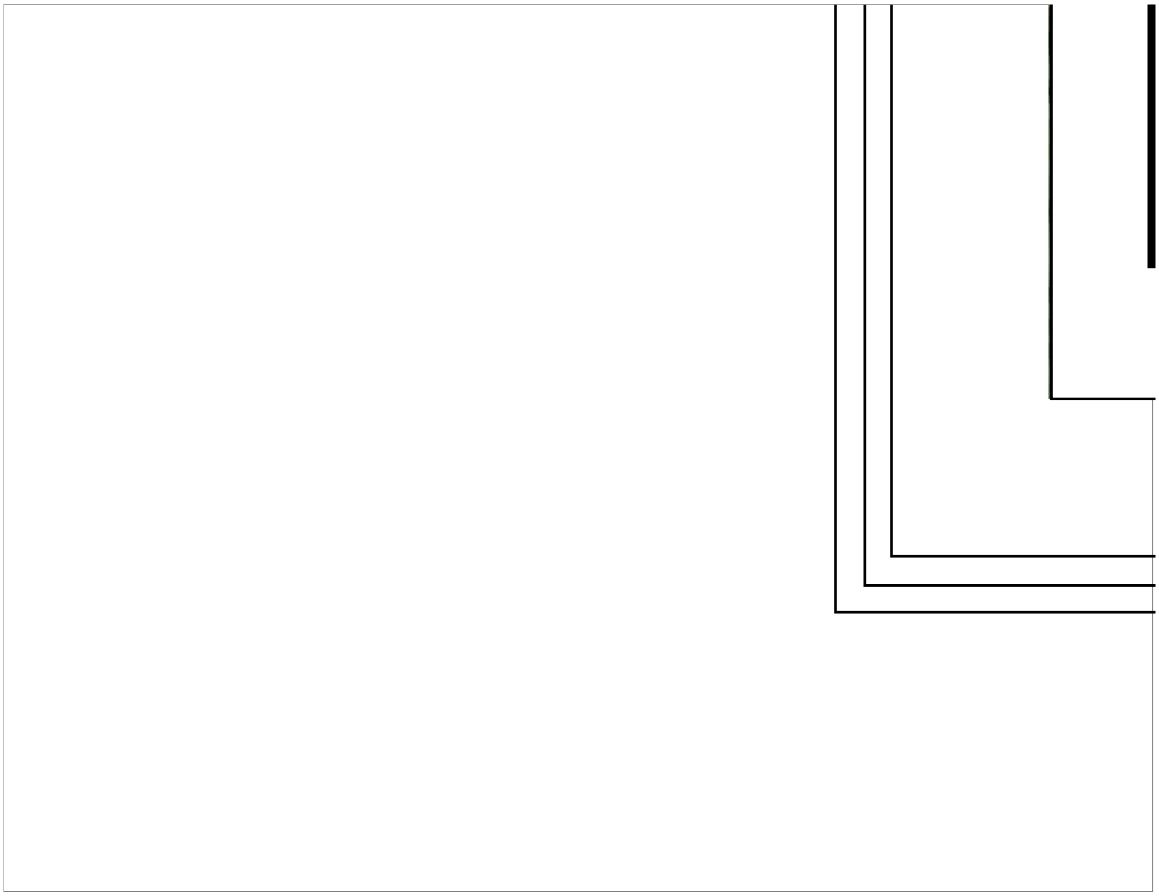


Figure 10: Felta Creek (F2)



***Map 7**: F2: Felta Creek*

(ii) Large Wood

Large wood was present at 16 sites and comprised a total of 44 pieces. The mean diameter of all LWM was 43cm (17 in), ± 23cm (9in). Mean length was 5 m, (16.4 ft), ± 3.3 m (10.8 ft) (Table 9).

***Table 9**: Summary statisics of LWM and rootwads for Felta Creek F2 sample reach.*

	Mean Diameter (in)	Diameter Std Dev	Mean Length (ft)	Length Std Dev	Number of pools
Natural LWM	8.5	5.8	50.8	24.2	9
CDFW LWM	6	1.7	26.2	9.1	2
Both natural and CDFW LWM	7	2.5	91	91	3
Combined LWM	17	9	16.4	10.8	14
Rootwads	na	na	na	na	7

Ninety-four percent (15) of LWM occurrences were associated with pools with at least 30.5 cm (1 ft) residual depth. Ten of the 15 occurrences were naturally occurring, two were CDFW wood and three were a combination. Seven rootwads and 19 boulders were present in the sample reach. All rootwads were associated with qualifying pools and 17 (89%) of boulders were (Table 10). Large wood, rootwads and boulders are all responsible for creating pools.

__Table 10__: RPD(y) classification and structures abundance

	30.5cm/1ft≤y<61cm /2ft	61cm/2ft≤y<91.5cm/3ft	y>91.5cm/3ft
Sites containing natural LWM	4	4	2
Sites containing CDFW LWM	1	1	0
Sites containing both LWM	0	2	1
Sites containing rootwads	2	4	1
Sites containing boulders	13	4	0

Only five CDFW LWM sites were located and assessed. As some of these were identified by tags attached to live trees on the creek banks and not on the LWM pieces, it was difficult to determine how these pieces were actually performing. In some instances it was not clear if the pieces were attached, making it impossible to determine if they had moved, if the attachment methods were still functioning and if all pieces in the original design were still present. Identification tags did not clearly describe the structure, resulting in assumptions about which pieces within the structure were CDFW wood and which were natural pieces. However, using RPD as an indicator of functioning effectiveness, four of the five pools containing CDFW (exclusively or combined with natural wood) were deeper than 61 cm (2 ft). The mean depth of these five pools was 71 cm (2.3 ft).

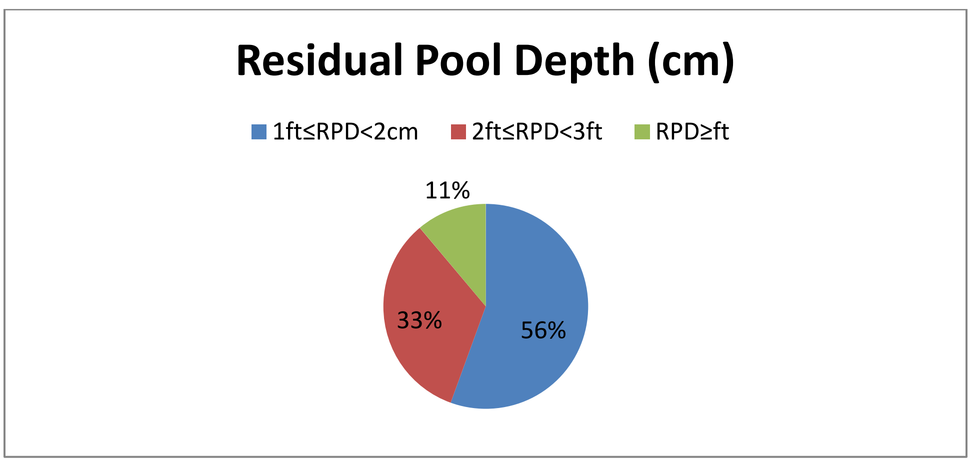
A total of seven rootwads were in the sample reach. The mean maximum pool depth associated with them was 74 cm (2.4 ft). The mean RPD for the seven pools associated with rootwads was 66 cm (2.2 ft). Indications are that some of the installed LWM may include installed rootwads, but confirming this by identifying attachment was difficult. It appears that three rootwads were intentionally installed. Of these, two were combined with naturally occurring wood and one exclusively CDFW wood. The mean RPD for the three pools associated with these rootwads was 81 cm (2.7 ft). Regardless of whether rootwads were intentionally installed, alone or in conjunction with natural wood, or were naturally occurring, they appear to be creating ideal coho habitat in second order streams as mean maximum pool depth was RPD is consistently deeper than two feet considered ideal pool depth for juvenile coho in second order creeks.

(iii) Pools and creek-bed characteristics

A total of 27 pools were measured were measured in this reach (Map 6). The mean residual pool depth was 58 cm (22.8 in), ± 24 cm (9 in). The deepest pool measured 105 cm (41 in) and the range was 74 cm (29.1 in). Typically, second order stream pool depth of 61 cm or more is considered ideal coho habitat. In this reach of Felta Creek, 12 pools (44%) had maximum and residual depths greater-than or equal-to 61 cm (2 ft) (Table 11 and Graph 4).

Table 11: *RPD count by classification*

	30.5cm/1ft≤y<61cm /2ft	**61cm/2ft≤y<91.5cm/3ft**	**y>91.5cm/3ft**
Number of pools	15	9	3



Graph 4

Boulders appear to be contributing disproportionately to pools with residual depths between 30.5 cm (1 ft) and 61 cm (2ft) as 76% of all boulder sites are at these pools. Natural LWM, CDFW LWM, combinations of both and rootwads are also present at pools within this class, but boulders account for 65% of these structures. Large wood and rootwads appear to be contributing to pools deeper than 60 cm (2 ft). Natural LWM, installed LWM, combinations of the two, rootwads and boulders are present at 19 different pools. Large wood and rootwads are present at 79% of them (Table 10). I recommend that any future additions use combinations of rootwads and LWM as together they appear to be providing deeper pools. Both the rootwads and LWM will also provide cover for fish.

The stream bed of this second order creek predominantly consists of assorted gravel, sand as well as large and very large boulders. Bedrock is consistent throughout the reach. Log-, boulder-, rootwad- and bedrock-enhanced lateral scour pools are the dominant pool-type in the watershed.

(iv) Recruitment

Unlike the other sampled section of Felta Creek (F1), no working road on either bank restricts large wood recruitment possibilities from both beyond either bank. However, there is evidence of a gravel/dirt access road that is no longer in use that may have impacted recruitment when it was in use. The current impact of this road on recruitment is likely to have lessened due to lack of use. Like Palmer Creek, the predominant land use practice surrounding the creek and on the property is selective forestry and restoration.

The recruitment sources bank undercut and “other” are consistent throughout the watershed. Unlike Palmer Creek, landslides do not play a major role in recruitment. The natural sinuosity of the, coupled with large boulders constricting flow and increasing water velocity, undercut banks. Trees, both hardwood and conifer, enter the creek and form structures. Historically, logging has occurred in the watershed. Logging typically commenced in and around creeks, leaving stumps along creek banks. With continued bank undercut, these stumps eventually enter the creek and form rootwads. I believe this is the reason why there are as many rootwads as there are in this creek. Compared to Mill Creek and the lower reaches of Felta Creek, this reach is relatively inaccessible. In other, more accessible creeks, stumps and rootwads are more likely to have been removed. Here, rootwads enter the creek, remain in the creek, enhancing coho habitat over time. The only other source of LWM recruitment is from higher up the watershed. Wood may be entering the system and traveling down during periods of high flow, lodging in lower sections such as this sample reach.

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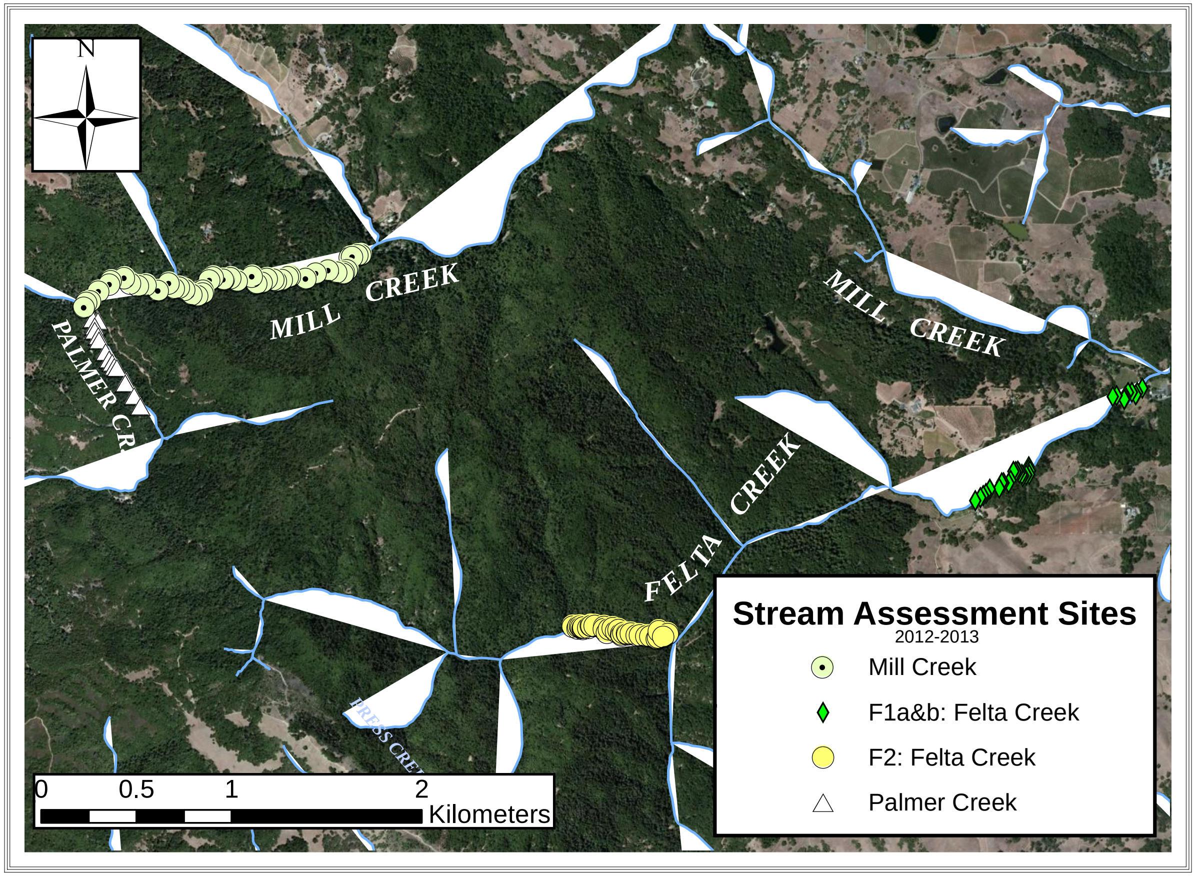
APPENDIX H

Additional Maps

Large Wood Assessment Sites

Large Wood Assessment Reaches

CA Department of Fish and Wildlife Stream Survey Reaches



Project sample reaches, Mill Creek Watershed, Sonoma County CA.

Figure 1 – Mill Creek Large Wood 1998 Project and 2012 Assessment Reach

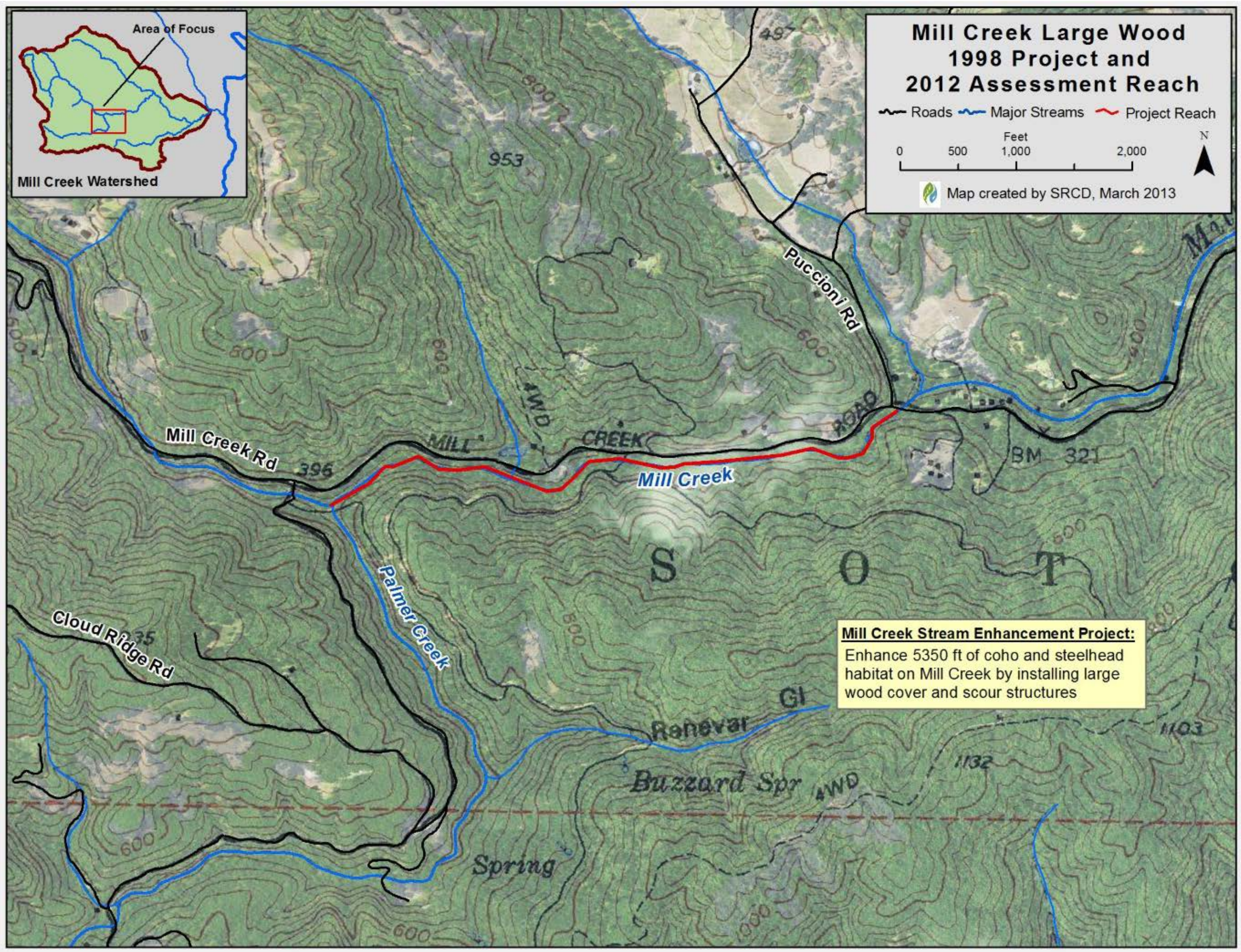


Figure 2 – Felta Creek Large Wood 1998 Projects and 2012 Assessment Reaches

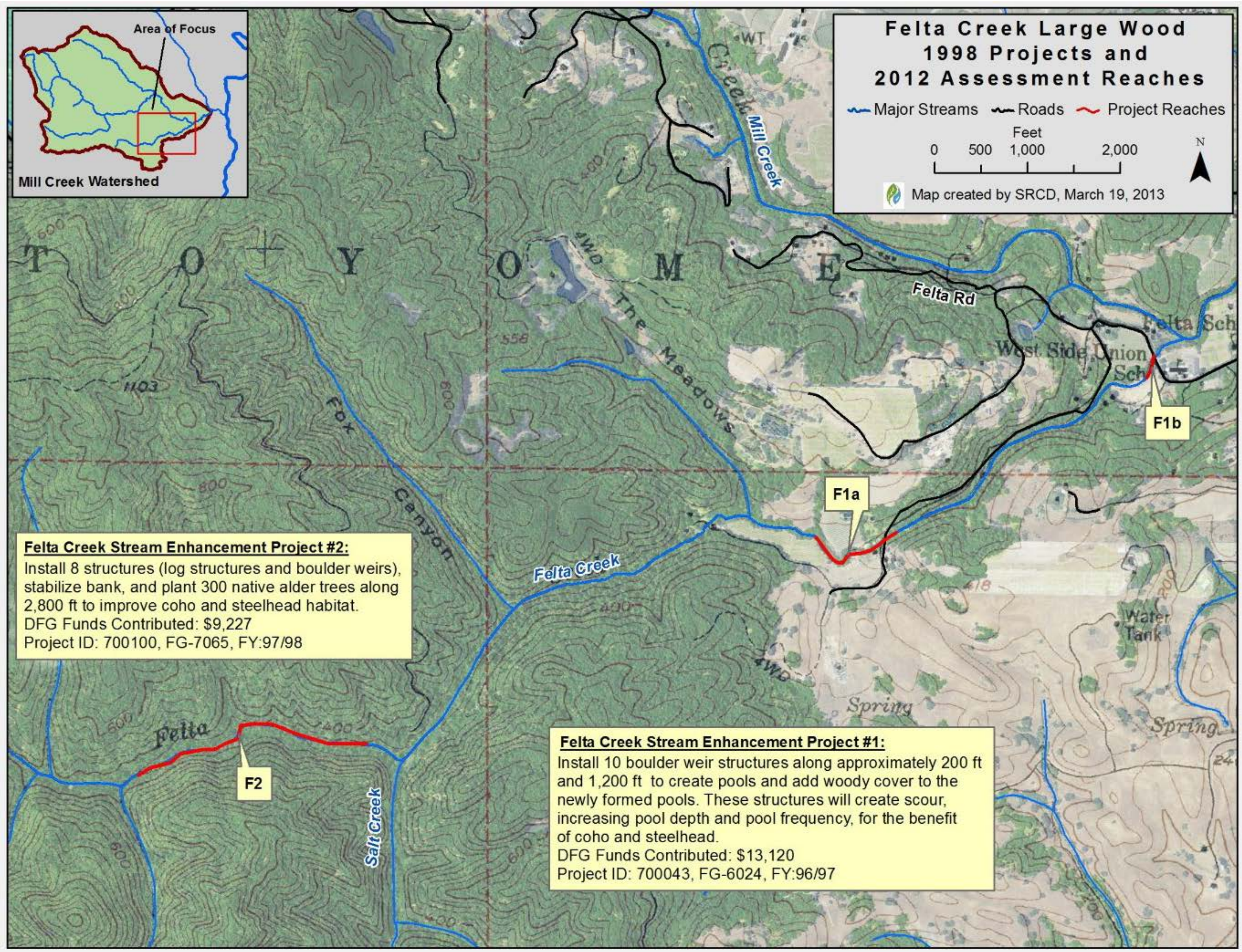


Figure 3 – Palmer Creek Large Wood 1998 Project and 2012 Assessment Reach

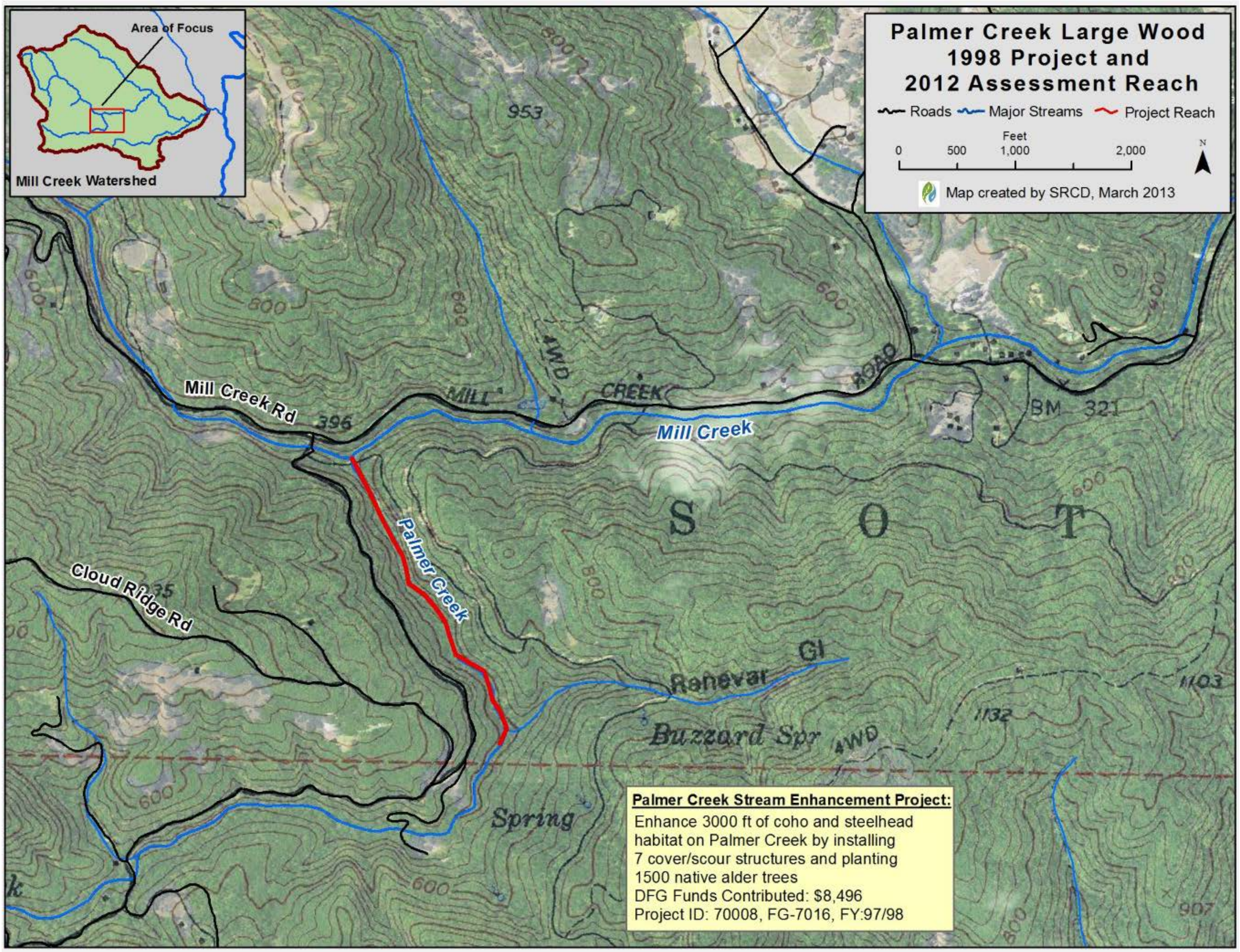


Figure 4 – Mill Creek Stream Inventory Reaches as Defined by the California Department of Fish and Wildlife

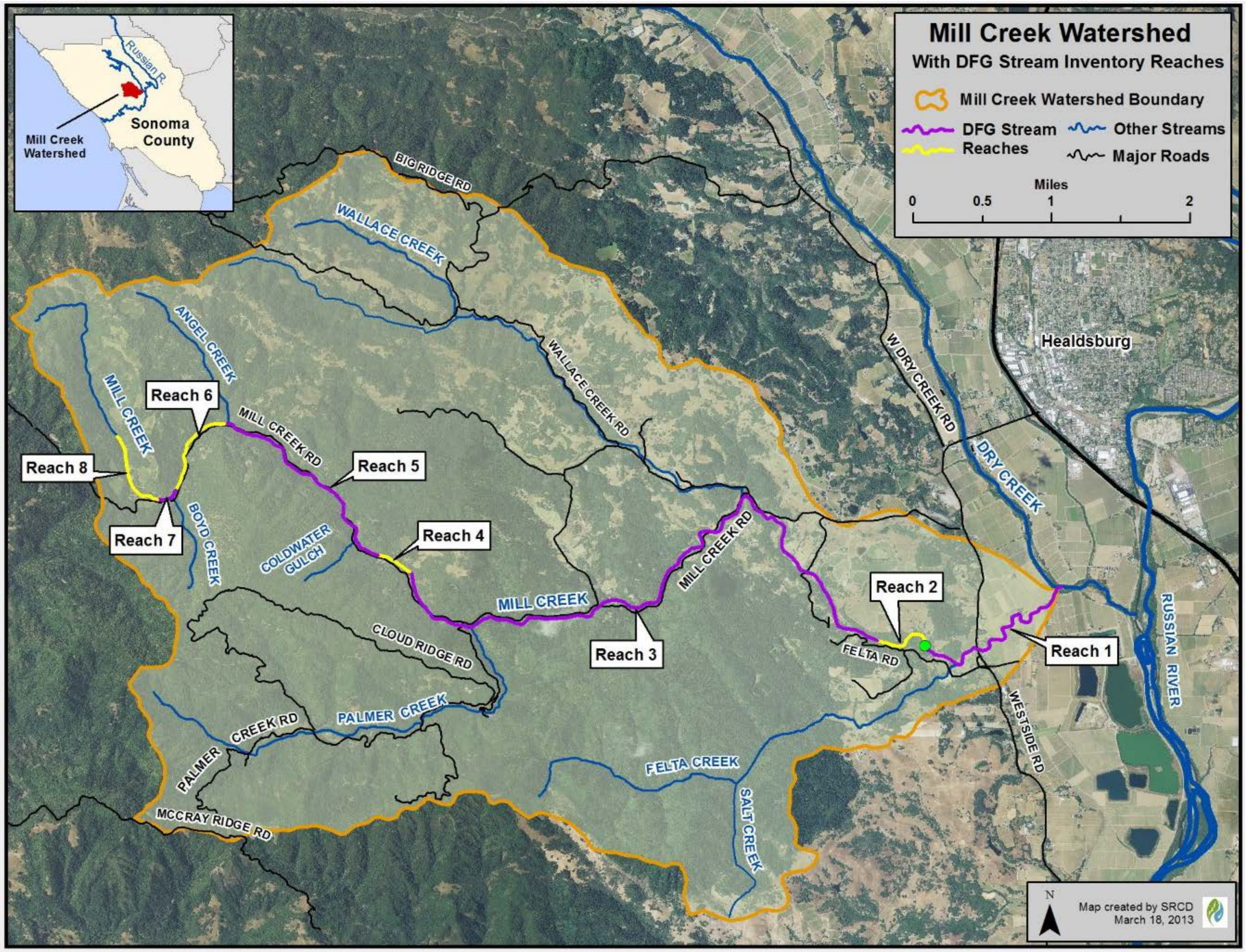
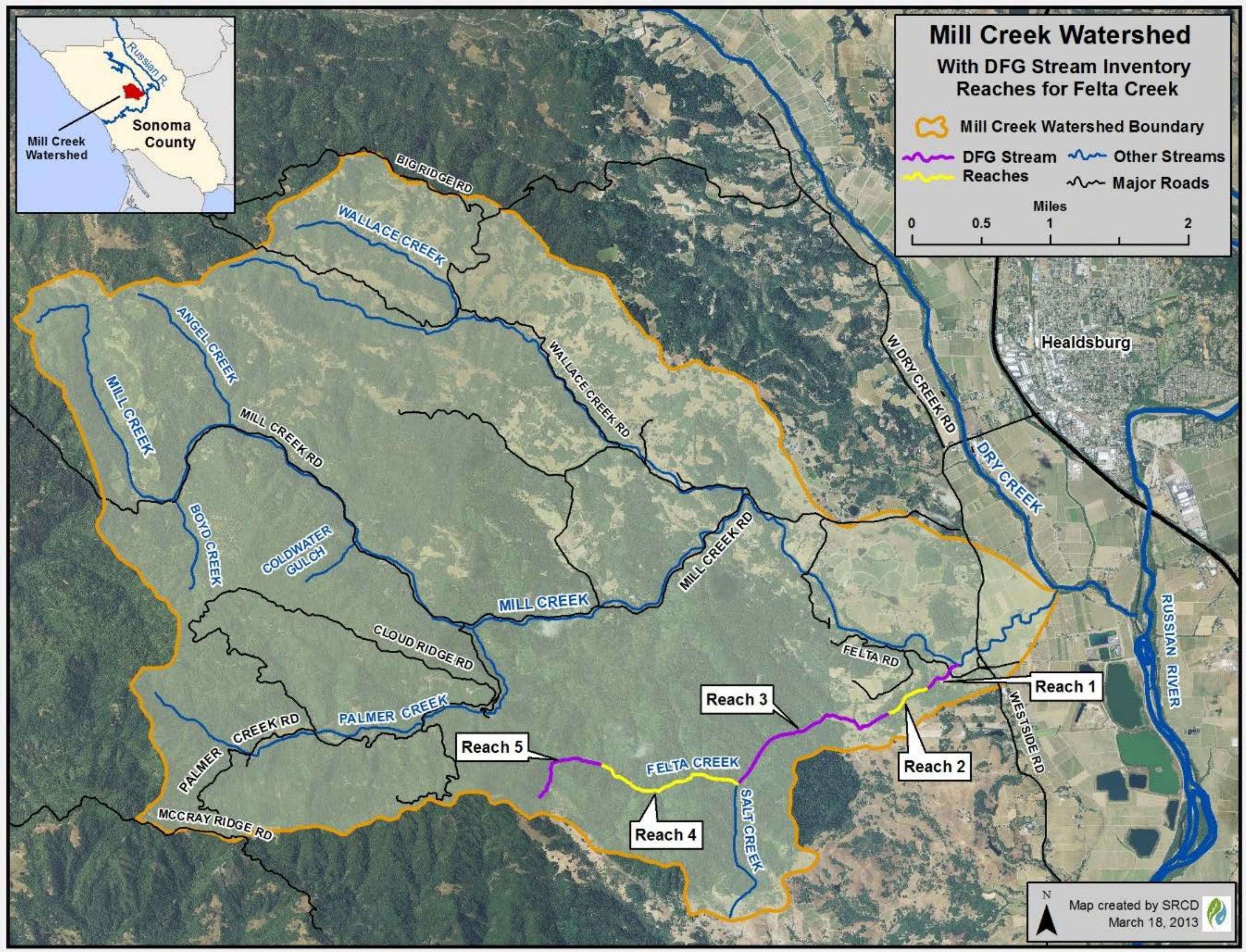


Figure 5 – Felta Creek Stream Inventory Reaches as Defined by the California Department of Fish and Wildlife



APPENDIX I

Additional Agency Recommendations

Steelhead Restoration and Management Plan for California (CDFW, 1996)

This document describes the major drainages in the state where steelhead populations occur. The Russian River watershed is described in terms of the current threats to steelhead populations and their long-term survival. General basin-level recommendations are given including an assessment of instream flow requirements, the need for a habitat restoration plan, and a caution against using hatchery fish to re-populate streams containing healthy wild populations.

Draft Russian River Basin Fisheries Restoration Plan (CDFW, 2002)

The focus of this report is to identify and prioritize recommended management actions to benefit coho salmon populations and their habitat in the Russian River watershed. A description of the watershed is broken down by hydrologic sub-units along with a summary of the limiting factors to salmonid survival. The findings and recommendations are based on the results of CDFW stream inventories conducted between 1994-2001, updated in 2006 (see summary above).

Table 2.12c. Excerpt taken from Table 19 in the *Draft Russian River Basin Fisheries Restoration Plan* (CDFW 2002). Summary of limiting factors to coho survival specific to Warm Springs (Dry Creek) sub-basin (1=Highest priority, 2=2nd highest priority, etc. to 6).

Tributary	Migration	Gravel Quality	Gravel Quantity Degraded/Aggraded		Riparian Stability	Water Temp	Pool Shelter	Pool Number	Comments
Felta		1				2	4	3	
Mill	5	1	4				2	3	Passage
Palmer		1							
Wallace		1					2	3	

Table 2.12d. Summary of Prioritized Habitat Recommendations. Excerpt from Table 20: Prioritized Habitat Recommendations specific to Warm Springs (Dry Creek) sub-basin (1=Highest priority, 2=2nd highest priority, etc. to 6).

Tributary	Barriers	Canopy	Gravel	Map Roads	Fix Roads	Erosion	Shelter	Create Pools	Monitor
Felta		2				1	4	3	
Mill	5	1	4			1	2	3	6
Palmer					1				
Wallace					1	2	3	4	

Recovery Strategy for California Coho Salmon (California Department of Fish & Wildlife, 2004)

In 2004, DFG released its *Recovery Strategy for California Coho Salmon*, which included recommendations to facilitate coho recovery in hydrologic subareas (HSAs) throughout the North and Central coasts of California. The following tasks were determined for the Warm Springs HSA for the Middle Russian River:

- ID: RR-WS-01, ESU: CCC, Level: E, Priority 3
  Task: Develop plans to improve riparian vegetation in Dry Creek and its tributaries
- ID: RR-WS-06, ESU: CCC, Level E, Priority 3
  Task: Modify flows in Dry Creek to provide summer rearing habitat for coho salmon

- ID: RR-WS-09, ESU: CCC, Level E, Priority 3
  Task: Assess, prioritize, and develop plans to treat sources of excess sediment
- ID: RR-WS-11, ESU: CCC, Level D, Priority 3 Stream Complexity
  Task: Increase habitat structure in Dry Creek (and its tributaries) to enhance habitat diversity, including depositional areas for spawning gravels for coho salmon
- ID: RR-WS-12, ESU: CCC, Level E, Priority 3 Land Management Planning
  Task: Develop riparian vegetation and floodplain enhancement plans

Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon (NMFS, 2008)
The Central California Coast ESU population of coho salmon was classified as endangered in 2005. NMFS, as the agency responsible for listing CCC Coho Salmon as federally endangered, is responsible for developing and implementing a plan for species recovery. The authors designated three categories for implementing restoration activities: the first and highest priority areas are termed "core areas” and include Felta, Wallace and Palmer Creeks within the Mill Creek watershed and an implementation timeline is suggested for 2009-2014. The highest priority threats to coho salmon recovery as stated by the plan are: 1) agricultural practices; 2) droughts; 3) roads and railroads; 4) water diversions and impoundments. Priority recovery actions are: 1) to reduce and prevent water diversions to improve summer baseflow; 2)improve agricultural practices to reduce sediment delivery and improve riparian vegetation; 3)increase large wood debris to improve pool frequencies and shelter ratings; 4)increase shade canopy to reduce stream temperature; and 5) reduce road densities within riparian areas and across the watershed.

Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation District in the Russian River Watershed. (NMFS, 2008)
This document is the result of 10 years of discussion, studies, analysis, planning and modeling of the impacts of the water control operations conducted at Coyote and Warm Springs Dams by the U.S. Army Corps of Engineers on behalf of the Sonoma County Water Agency and the Mendocino County Russian River Flood Control and Water Conservation Improvement District are having on Central California Coast (CCC) steelhead, chinook, CCC coho salmon, each of which is protected as threatened or endangered under the ESA. It was concluded that the negative impacts to salmonids and their habitat are: high summertime flows in the Russian River and Dry Creek, high flow velocities in Dry Creek and breaching the sandbar at the estuary in Jenner. The opinion outlines recommendations for a 15-year recovery plan, called the Russian River Instream Flow and Restoration Project. In this recovery plan it is recommended that:

1. Summertime flows in the river be reduced below existing flows mandated by the State Water Resources Control Board
2. Restore 6 miles of habitat in Dry Creek
3. Create a freshwater lagoon in the estuary during the summer months
4. Carefully monitor both habitat and fish in Dry Creek, the estuary, and the river
5. Eliminate impediments to fish spawning or improve habitat in several streams
6. Enhance the existing coho broodstock program

As a major tributary to Dry Creek, Mill Creek was included in the analysis and found to be an important coho stream where “most of the qualifying summer rearing habitat” is located within the Russian River watershed. Two restoration projects were identified as priorities for SCWA to implement in the Mill Creek watershed:

1. Wallace Creek Fish Passage Enhancement - at the Wallace Creek Rd/Mill Creek Rd. crossing was ranked as a high priority for removal.
2. Mill Creek Fish Passage Improvement - a recently undermined flashboard dam on private property exists midway in the watershed which is a partial barrier to migration for adult and juvenile coho and steelhead.