Dutch Bill Creek
Streamflow Improvement Plan

Prepared by:

The Russian River Coho Water Resources Partnership

SONOMA RESOURCE CONSERVATION DISTRICT

Sea Grant California

UC CE

WATER INSTITUTE
OCCIDENTAL ARTS & ECOLOGY CENTER

TROUT UNLIMITED

cemar rehabilitating California coastal streams

GOLD RIDGE RESOURCE CONSERVATION DISTRICT

With Support from:

SONOMA COUNTY WATER AGENCY

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Acronyms

AF	Acre-Feet or Acre-Foot
ACOE	United States Army Corps of Engineers
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
CMRPD	Camp Meeker Recreation and Park District
CSG	California Sea Grant
DO	Dissolved Oxygen
EDSU	Emergency Small Domestic Use (Registration)
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
eWRIMS	Electronic Water Right Information Management System
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
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
OCSD	Occidental Community Services District
PIT	Passive Integrated Transponder
POD	Point of Diversion
PPT	Precipitation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RM	River Mile
SAR	Smolt to Adult Survival Ratio
SD	Standard Deviation
SDU	Small Domestic Use (Registration)
SCWA	Sonoma County Water Agency
SIP	Streamflow Improvement Plan
SIU	Small Irrigation Use (Registration)
SRCD	Sonoma Resource Conservation District

SWRCB	State Water Resource Control Board
TU	Trout Unlimited
TUCP	Temporary Urgency Change Petition
UC	University of California Cooperative Extension and California Sea Grant's Russian River Coho Monitoring Program
USGS	United States Geological Survey
VDI	Voluntary Drought Initiative
WY	Water Year
YOY	Young-of-the-Year (age 0+ fish)

Streamflow Improvement Plan Overview

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 and the Sonoma County Water Agency. 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 SIP is a roadmap for prioritizing and implementing streamflow improvement projects with multiple public benefits and a diversity of approaches in the Dutch Bill Creek watershed. Dutch Bill Creek is the third of five watersheds for which we are developing SIPs. The Grape Creek SIP and Mill Creek SIP are complete, and the SIPs for Green Valley Creek and Mark West Creek will be completed if funding is available.

Executive Summary

The purpose of the Dutch Bill Creek SIP is to identify specific measures to moderate the impact of dry season water demand and improve instream flow for coho salmon and ecosystem function in the Dutch Bill Creek watershed. Our goal is to work with water users to maintain a flow regime that is protective of the various life history stages of salmon by managing water demand through water conservation, seasonal storage, and other modifications to diversion practices and by augmenting flow through recharge, spring reconnection, and other strategies.

Section 1 provides an introduction to the Russian River Coho Water Resources Partnership, reviews our rationale for selecting Dutch Bill Creek as a focal watershed under the Keystone Initiative, and describes the purpose of the SIP. Section 1 also outlines how the Partnership's work on streamflow and water quantity fit with – and evolved out of – a long history of restoration efforts in the Dutch Bill Creek watershed.

Section 2 describes watershed conditions in the Dutch Bill Creek drainage, including land use, rainfall, and streamflow. This section describes the impacts of both diversions and drought on summer streamflow conditions.

Section 3 analyzes human water needs relative to available water supply and streamflow at different temporal scales. It concludes that there is sufficient water in the Dutch Bill Creek watershed to meet human needs on an annual basis if we can reduce the disparity between discharge in the rainy versus dry season and use in the dry versus rainy season.

Section 4 summarizes the history and status of coho salmon in Dutch Bill creek, describes current population monitoring efforts, examines flow-related bottlenecks to survival, and presents an ongoing study of juvenile oversummer survival in Dutch Bill Creek designed to both describe the relationship between survival and environmental metrics and evaluate the effectiveness of streamflow improvement projects. One of the conclusions of the study is that pool connectivity is a key factor in oversummer survival.

Section 5 uses the information in Sections 2, 3 and 4 to provide recommendations for improving streamflow with the specific (minimum) goal of improving juvenile oversummer survival in priority reaches. This section provides a roadmap for achieving both the physical/infrastructure and social/management changes necessary to ensure streamflow improvement. It also provides a preliminary evaluation of proposed projects by estimating their flow benefits relative to metrics we developed pertaining to maintaining pool connectivity.

Section 6 describes permitting considerations associated with the recommendations in Section 5. It also provides a preliminary calculation of water availability for permitting purposes (based on the criteria provided by the State Water Board), identifies strategies to ensure durable results, and details possible long-term threats to the water savings recommended in this SIP.

1 Introduction

1.1 The Russian River Coho Water Resources Partnership

The Russian River Coho Water Resources Partnership (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 dramatically since 2000, with estimated returns ranging from 192 to 536 over the last six years. 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 subwatersheds 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; (3) increase water supply reliability for water users in each focal watershed; and (4) increase knowledge and public awareness about watershed processes and their impacts on streamflow and fish. 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 conservation hatchery releases, and conduct coho life-cycle monitoring is unique, and the 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 (NMFS 2012) (see Appendix A). 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
- NOAA recently named the CCC coho salmon population as a "Species in the Spotlight"
- The California Water Action Plan identified Mark West Creek as one of five stream systems in the state where the California Department of Fish and Wildlife (CDFW) and the State Water Resources Control Board (State Water Board) will "implement a suite of individual and coordinated administrative efforts to enhance flows"
- CDFW and NOAA selected four Russian River tributaries for their Voluntary Drought Initiative (VDI) program

1.2 Rationale for selecting Dutch Bill Creek

Dutch Bill Creek (Figure 1) was chosen as a focal watershed because it provides the critical intersection of feasibility of salmon restoration, degree of stream impairment 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 identified Dutch Bill Creek as a Core Area for protection and restoration (see Figure 2) and deems 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).

Because of its importance to coho, Dutch Bill Creek has also been a priority watershed for agency drought action. In spring 2015, CDFW and NMFS identified Dutch Bill Creek as one of four Russian River tributaries (and one of nine streams in the state) for their VDI program and asked water users along Dutch Bill Creek to reduce their reliance on water from the creek and its adjacent shallow aquifer in order to protect native coho salmon and steelhead. In summer 2015, the State Water Board adopted an emergency conservation regulation for Dutch Bill Creek and three other Russian River tributary streams (SWRCB 2015a).

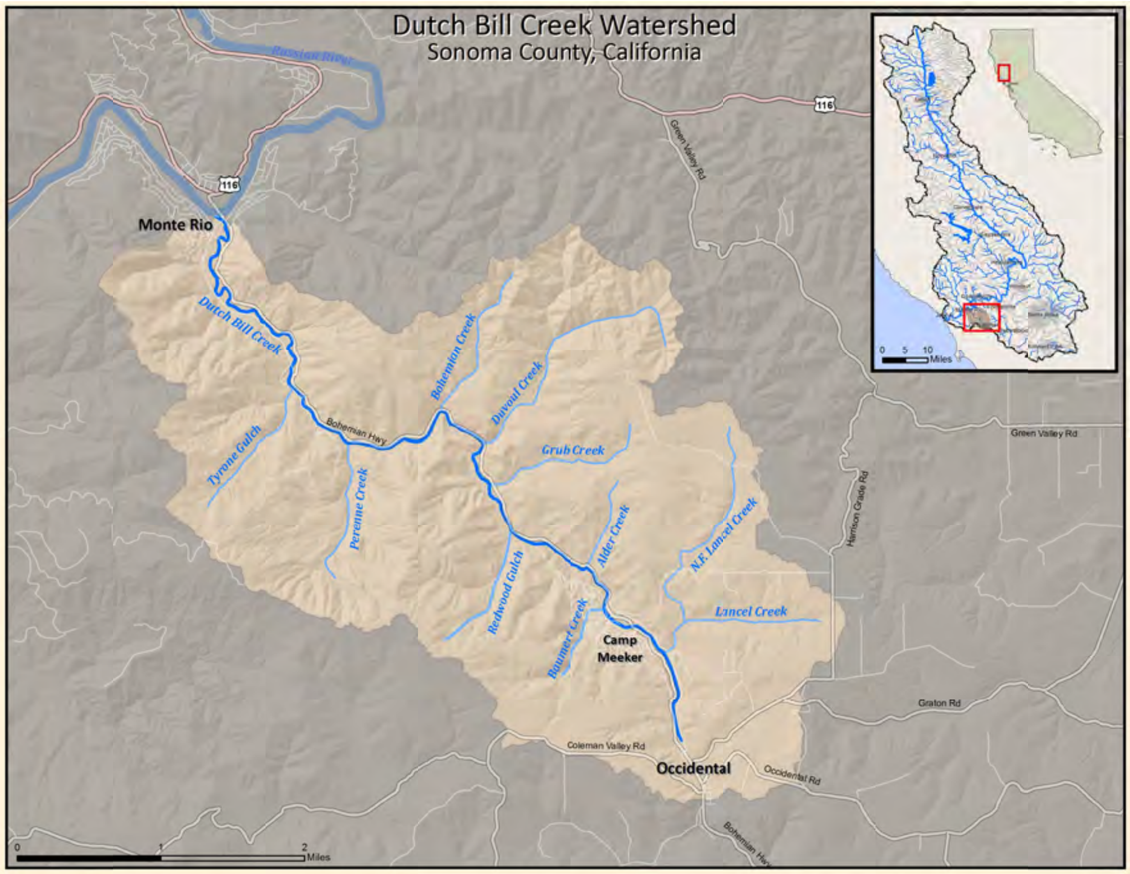


Figure 1. Dutch Bill Creek Watershed Overview.

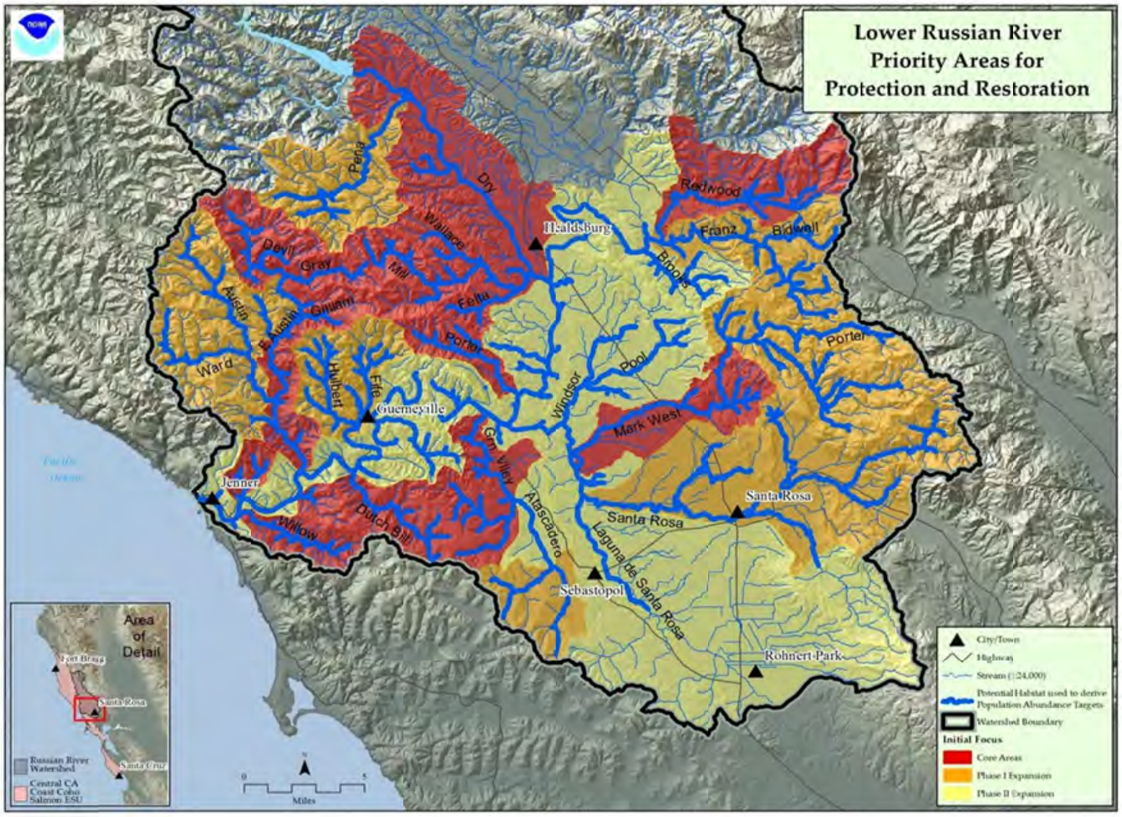


Figure 2. Core Areas identified in the NMFS CCC Coho Recovery Plan (NMFS 2012).

1.3 Streamflow in the context of land (and water) use change in Dutch Bill Creek

After millennia of dwelling in what would later be called Dutch Bill Creek watershed, the ancestors of the present-day Coast Miwok and Southern Pomo had their lives upturned by the sudden, dramatic influx of European immigrants. The watershed's namesake, a Danish sailor who jumped ship in 1849 with gold fever, only to change his identity and become Dutch Bill Howard, was an early settler in awe of the densely forested watershed. Many others followed, drawn to the "red gold" to be won by clear-cutting the primeval redwood forests, which cloaked most of the Dutch Bill watershed -- especially the riparian creek corridors and northeast-facing, cool, water-producing upland slopes. By the mid-1860s Melvin "Boss" Meeker's lumber mills were in full swing with hardy lumberjacks wielding "misery whips" and oxen trains driving this new "wood rush." Over the ensuing decades, they proceeded to deforest the watershed of its original coniferous covering.

To facilitate the transfer of lumber demanded by the burgeoning new urban growth to the south, the narrow gauge North Pacific Coast Railroad was constructed, beginning around 1874, for the express purpose of hauling lumber to Sausalito, where it was barged across the bay to the new city of San Francisco. With a railroad that literally ran the length of the Dutch Bill watershed -- from the river mouth in Monte Rio to the ridgeline divide in Occidental -- it was guaranteed that no tall timber would be left standing there. After the 1906 earthquake and fire, the pace quickened and, in short order, remnant coast redwood and Douglas fir were cut to rebuild the toppled and charred cities nearby. In the post-World War II era of returning GIs in need of housing, a new wave of logging ensued throughout the region and much of the regrowth from the first cut was again harvested, although now misery whips were traded in for motorized chainsaws, and converted tanks for tractor-skidders and cable-yarders.

The hydro-modifications that resulted from 150 years of deforestation have resulted in altered drainage networks and dehydration of the landscape. This is, fundamentally, the original flow diversion issue still affecting the hydrological and biological carrying capacity of the Dutch Bill Creek watershed. Towering redwood forests were evolved to soak up the abundant winter rain, comb the critical summer fog and keep the living sponge of the land hydrated -- all of which yielded a consistent release of water into the creeks during the summer/fall months critical for rearing salmonids. In trade for attenuated winter hydrographs, ample summer flow, bountiful instream shelter, shade, food, and spawning gravels, the runs of salmon and steelhead contributed their precious accumulation of marine nutrients via their spawned-out and decomposing carcasses, which fertilized the native forests and the organisms dependent upon them. Today the challenges and opportunities to ensure adequate flows for fish and water security for human communities in our modified watersheds are legion; yet the lasting legacies of significant alterations to current hydrologic condition and function remain very real and pressing.

It is within this context that the Partnership strives to find science-based solutions for streamflow improvement which meet the needs of both naturally productive anadromous streams and human communities that dwell within, and depend upon, the same watersheds.

1.4 Streamflow as a component of restoration in Dutch Bill Creek

An important consideration in our selection of Dutch Bill Creek as a focus for flow improvement efforts is the recent history of community stewardship and watershed enhancement activities intended to tackle many of the legacy problems that resulted from the scale of land use change described above. Those actions -- community engagement, outreach, education and celebration, instream habitat assessment, water quality monitoring, fish passage projects, instream structure and large wood placement, sediment reduction projects, upland recharge, coho salmon releases and monitoring, and others -- have improved conditions for coho salmon in the watershed. The number of adult coho salmon returning to Dutch Bill Creek since the winter of 2007/08 has generally increased, which is notable because UC has observed a decline in Russian River basin-wide returns over a similar period (Obedzinski et al. 2016). The extent of the work completed in Dutch Bill Creek, along with the impressive level of community and partner investment within the watershed, provides a solid foundation for addressing streamflow and issues of water quantity, filling an important gap in efforts to restore coho salmon populations.

Figure 3. Community-created Dutch Bill Creek watershed map (courtesy of David Berman and Westminster Woods Camp and Conference Center).

We highlight some of the milestones in Dutch Bill Creek watershed restoration efforts since 1995 below. This overview is intended to provide context for our focus on flow restoration in this SIP, rather than a comprehensive history of restoration efforts.

Milestones in salmon and steelhead restoration in Dutch Bill Creek since 1995

1995

1995-present: Occidental Arts and Ecology Center (OAEC) creates an 80-acre conservation hydrology demonstration site, including sediment reduction, gully mitigation and groundwater recharge projects, fish-friendly roads, exotic plant removal, and upland wildlife habitat enhancement projects. Over the next two decades, OAEC implements roofwater harvesting, greywater reuse, composting toilets and other water conservation measures, publishes a number of free downloadable guidebooks, and hosts dozens of public tours and educational workshops.

1997: Dutch Bill Creek Watershed Group (DBCWG) forms. By early 1998, the group is actively meeting, engaging landowners, and talking about fish restoration. Watershed tours and monthly meetings are held for a number of years in Camp Meeker.

1997: California Department of Fish and Game (CDFG) biologists complete Dutch Bill Creek habitat surveys. The Instream Habitat Report details lack of habitat diversity, excessive sediment loading and fish passage issues, and informs DBCWG efforts to target restoration ideas and identify partnerships and funding.

1998: Salmon Creek Watershed Council hosts the first Salmon Creek Watershed Day, which later becomes West County Watershed Day. These public celebrations bring together neighbors, landowners and agencies to focus on the celebration and restoration of various west county watersheds.

1999-2000: DBCWG initiates instream habitat projects and works to address fish passage barriers, including the Camp Meeker Dam. DBCWG forms the Dam Plan Committee with several Camp Meeker community members.

2000: OAEC develops the first 5-day "Basins of Relations: Starting and Sustaining Community Watershed Groups" training. Community members utilize the training to found and further develop several Sonoma County watershed groups, including DBCWG, Green Valley/Atascadero Watershed Council, Salmon Creek Watershed Council, and Friends of Mark West Creek.

2000: Basins of Relations alumni come together to create the West County Watershed Network.

2000-2001: DBCWG begins organizing for the Camp Meeker Dam Removal and Market Street culvert retrofit projects. DBCWG approaches the Camp Meeker Recreation and Park District (CMRPD) with the idea, and CMRPD forms a Citizens Advisory Committee. Commitment of planning funding from the National Oceanic and Atmospheric Administration (NOAA) helps legitimize the idea within the Camp Meeker Community, and several years of planning and negotiation follow.

2000

2000

2000-2002: Gold Ridge Resource Conservation District (GRRCD), DBCWG, and OAEC collaborate on outreach to landowners for a Dutch Bill Creek sediment reduction project focusing on roads.

2001: A "Watershed Moment": Coho spawn in Dutch Bill Creek! Westminster Woods environmental education staff find and document spawning coho in the reach adjacent to the camp.

2002: CDFG biologists find wild juvenile coho in Dutch Bill Creek. A percentage of these fish are collected for the new Russian River Coho Salmon Captive Broodstock Program (later renamed the Coho Salmon Conservation Program). DNA analysis shows they are distinct from the other fish in the program (from adjacent Green Valley Creek). NOAA and CDFG recognize Dutch Bill Creek as a key watershed for coho recovery.

2001-2002: Dragonfly Stream Enhancement installs large wood structures in the creek along the Alliance Redwoods and Westminster Woods properties in partnership with CDFG, Sonoma County Water Agency, and GRRCD.

2003: Bohemia Ranch hires Pacific Watershed Associates to upgrade its road network, reducing sediment loading in Dutch Bill Creek by controlling erosion.

2003: Ross Taylor & Associates publishes the Russian River Stream Crossing Inventory and Fish Passage Evaluation. It is the key document used to start organizing to remove barriers in the Dutch Bill Creek watershed.

2003

2004

2004-2005: OAEC secures funding from the State Coastal Conservancy to install watershed divide and creek signs in West County.

2004 (approx.): The first project to address a fish passage barrier is completed. The project replaces a pair of culverts with a flatcar bridge at the Tyrone Road crossing of Tyrone Gulch, a Dutch Bill Creek tributary.

2004: First Flush. Dutch Bill Creek community members collect water quality data on runoff from the town of Occidental.

2004-2005: Dragonfly Stream Enhancement, supported by labor and funding from the Redwood Empire Chapter of Trout Unlimited, modifies the curbs on the 1930s era "fishway" downstream of Westminster Woods. Dragonfly Stream Enhancement then commences work on a number of channel-spanning rock weirs with jump pools below the fishway.

2005: Wild juvenile coho are observed in Dutch Bill Creek for the last time until 2011.

2005-2007: Dutch Bill Creek Roads Implementation Project is completed. GRRCD and Pacific Watershed Associates treat 80 erosion sites and upgrade or decommission 10.6 miles of road, preventing thousands of cubic yards of sediment from entering the stream.

2006-2008: Dutch Bill Creek Large Woody Debris Project is implemented. Dragonfly and GRRCD install large wood at 13 sites.

2006

2006

2006-2007: OAEC staff, in collaboration with the West County Watershed Network, Southern Sonoma RCD and county supervisors, implement the West & South Sonoma County Watershed and Creek Signage Pilot Project. Numerous signs are installed throughout the western and southern regions of the county.

2006: The Russian River Coho Salmon Captive Broodstock Program (later renamed the Coho Salmon Conservation Program) begins releasing juvenile coho into Dutch Bill Creek, with over 5,000 juveniles released that fall.

2008: To aid fish passage, Dragonfly Stream Enhancement installs baffles inside the Grub Creek box culvert crossing of Bohemian Highway.

2009: Following a meeting of community members and NFWF staff, the Russian River Coho Water Resources Partnership forms. The Partnership focuses on restoration of instream flows and coho recovery.

2009: The Big One! With the support of the Camp Meeker community, GRRCD implements the Camp Meeker Dam Removal and Market Street Fish Passage Project.

2009: Community Clean Water Institute publishes the Dutch Bill Creek Water Quality Study.

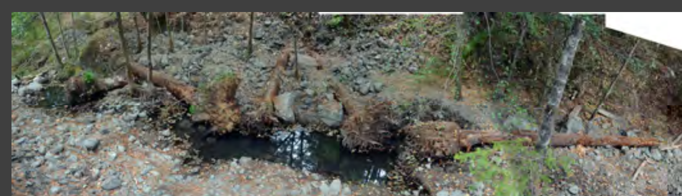
2009

2010

2010-2011: Adult coho are observed returning to Dutch Bill Creek after five years with no adult or juvenile observations.

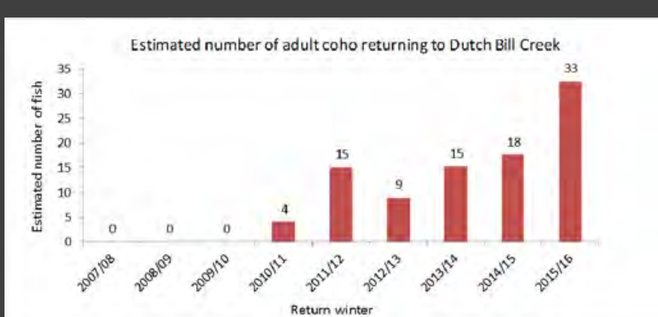
2014: Grub Creek Large Woody Debris Project is implemented. CDFW, Doug Gore, Streamline Engineering, GRRCD, and the Parish Family install 12 large wood structures.

2013-2016: Dutch Bill Creek Large Woody Debris Project is implemented; 27 large wood structures are installed.



2014-2016: Westminster Woods Water Conservation and Storage Project is constructed. The project eliminates Westminster Woods' summer diversion from Dutch Bill Creek through a combination of water conservation, tank storage and an instream dedication.

Recent adult returns to Dutch Bill Creek:



2015 & 2016: CMRPD releases flow into Dutch Bill Creek to maintain pool connectivity for coho salmon during the drought.

2016

1.5 Purpose of the Dutch Bill 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. It is intended to build on the foundational and ongoing restoration work of so many in the Dutch Bill Creek watershed and it is intended to be a living document.

2 Watershed conditions

2.1 Land use

The Dutch Bill Creek watershed empties into the Russian River approximately seven miles upstream of the Pacific Ocean. The creek originates just north of Occidental in the hills of western Sonoma County. Lancel Creek enters Dutch Bill just south of the town of Camp Meeker. Dutch Bill Creek then continues northwest, receiving outflow from several small tributaries including Alder Creek, Grub Creek and Duvoul Creek. Dutch Bill Creek feeds into the Russian River at Monte Rio.

Dutch Bill Creek's eastern subwatersheds have areas of undeveloped forested lands, shrub/scrub lands, vineyards, grasslands, and small clusters of rural residential homes. Land use in the western subwatersheds is primarily undeveloped forested lands, with denser clusters of rural residential development, summer camps and conference centers concentrated around the creek, including the towns of Camp Meeker and Monte Rio (Figure 4).

As described above, the Dutch Bill Creek watershed has experienced dramatic alterations in land use over the past 150 years. The clear cutting of the redwood forests, building of the railroad, and development of towns have resulted in long-lasting, immeasurable impacts to the watershed's geomorphology, hydrology and ecosystem health. In the following sections we describe the watershed's recent rainfall, discharge and streamflow conditions. We do not have data on pre-settlement conditions, so our research attempts to tease apart present-day natural and unnatural fluctuations in streamflow so that we can better understand how best to manage the watershed's resources for both human and environmental needs.

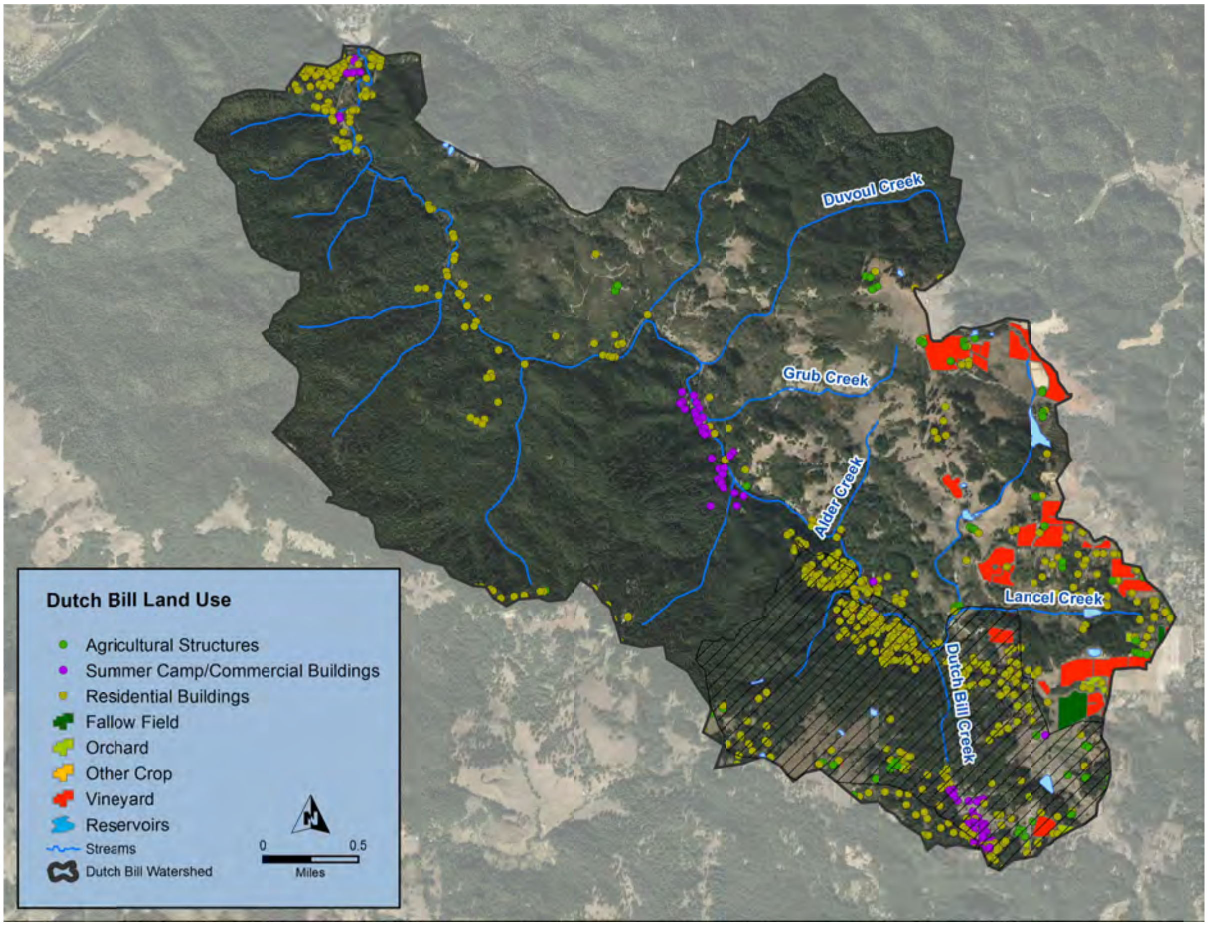


Figure 4. Land use in the Dutch Bill Creek watershed.

2.2 Rainfall

The Dutch Bill Creek watershed has a climate similar to most of coastal California, which is characteristically Mediterranean – with warm and dry summers, and cool and wet winters. Precipitation occurs almost exclusively as rainfall (i.e., snowfall is very rare), and mostly during wet winter months. Rainfall data recorded over a 65-year period at a weather station in Occidental (located in the headwaters of Dutch Bill Creek) show that 89 percent of the average annual rainfall occurs between November and April; less than 2 percent of the average annual rainfall occurs from June through September (Figure 5).

Computer models indicate that the Dutch Bill Creek watershed receives approximately 56 inches of rainfall in an average year, with up to 61 inches occurring at higher elevations in the watershed and 39 inches occurring in the lower elevations (Figure 6).[1]

Long-term records from Occidental indicate that rainfall can be highly variable from one year to the next. Over the 65-year period 1951 through 2015, annual rainfall has varied from as little as 18 inches (1977) to as much as 102 inches (1983), with extended periods of low and of high rainfall throughout the historical record (Figure 7). The four-year drought of 2012-2015 represents one of at least three periods of below-average rainfall for four or more consecutive years. Others include 1959-1962 (four years) and 1987-1992 (six years). (Figure 7 indicates additional consecutive periods of below average rainfall after 2000, but annual rainfall records were often incomplete during the period 2002 to 2010, so such assessments during this nine-year period are likely inaccurate.)

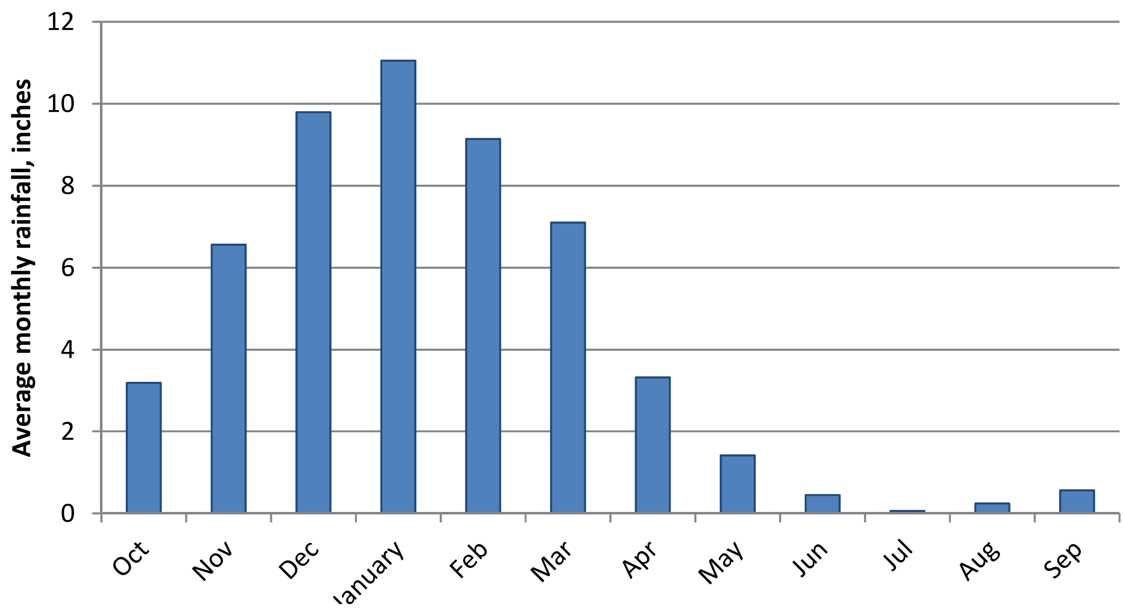


Figure 5. Average monthly rainfall recorded at Occidental, CA, 1951-2015.

[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 (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.

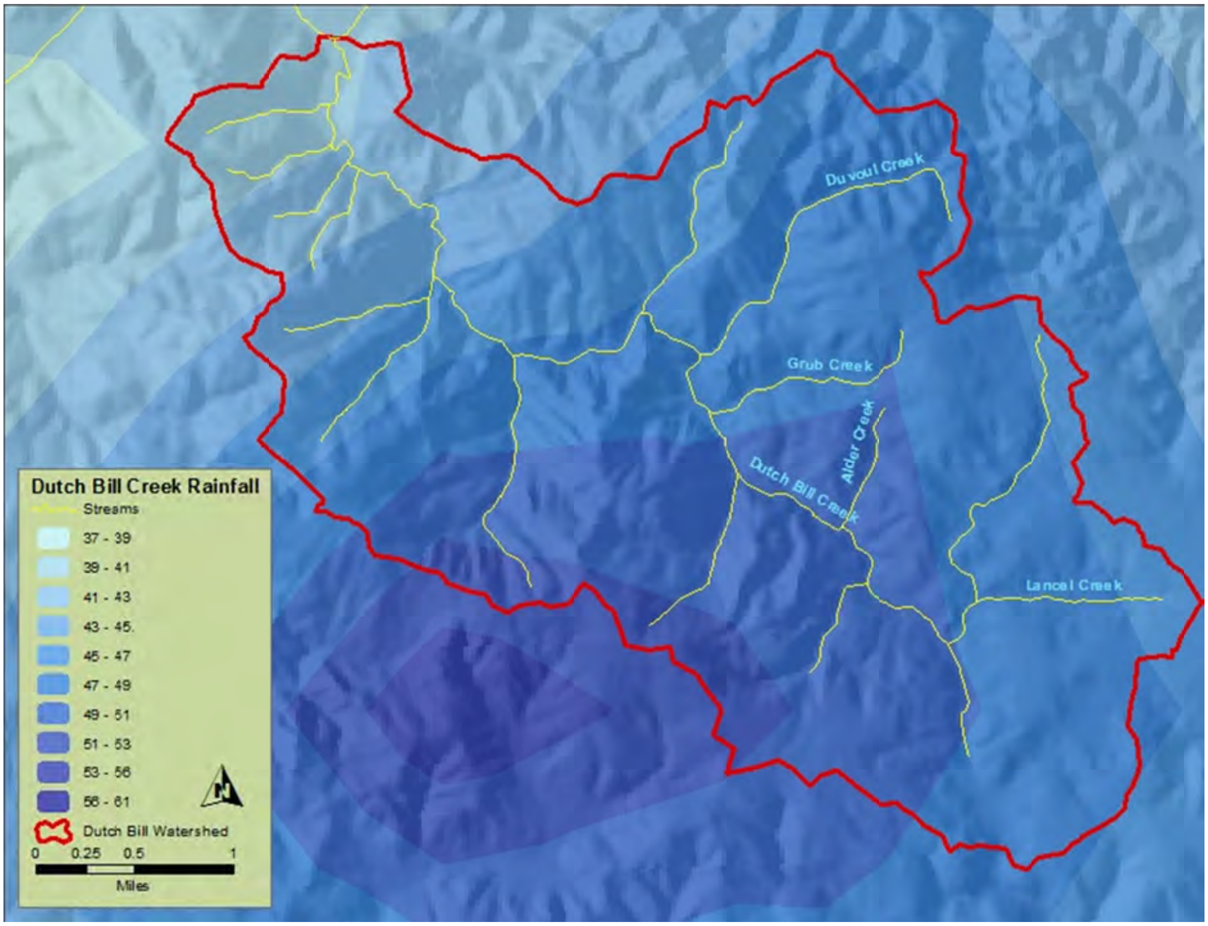


Figure 6. Average annual rainfall over the Dutch Bill Creek watershed, based on PRISM data.

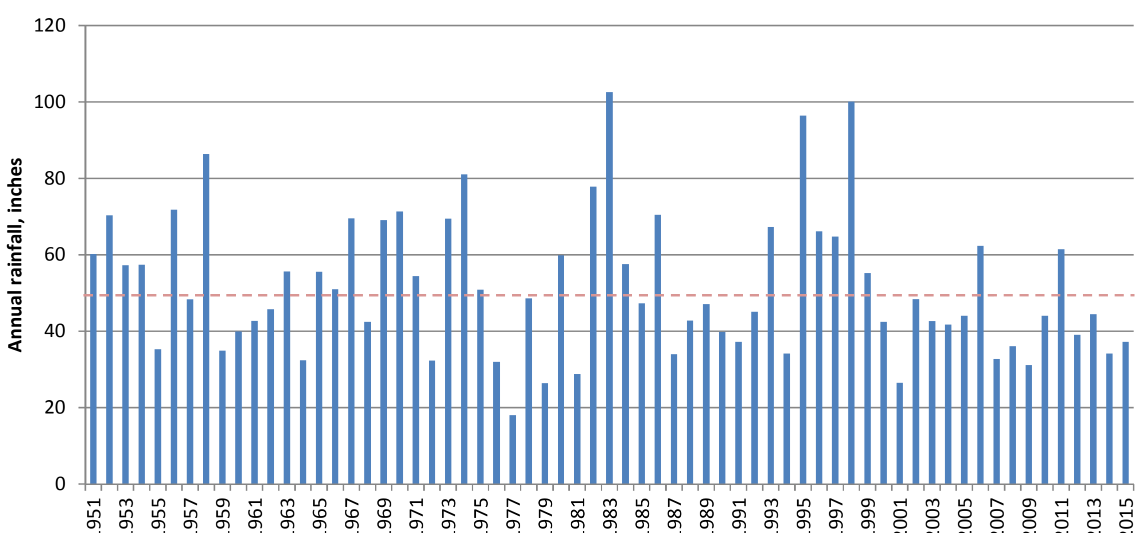


Figure 7. Annual rainfall, 1951-2015, in Occidental, CA (red dotted line showing average annual rainfall).

2.3 Streamflow

Streamflow is a vital component for understanding the interaction between humans and the surrounding ecosystem in the Dutch Bill Creek watershed. Streamflow data provide the foundation for many applications, such as quantifying the magnitude of impairment caused by water diversions and helping to identify reaches that will benefit most from winter water storage and dry season forbearance. The data 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 document the effectiveness of reducing diversions or releasing water after implementation.

We installed pressure transducers at three locations in the Dutch Bill Creek watershed to serve as streamflow gauges over the course of the project (DB01, DB02, DB04; Figure 8). Each pressure transducer was operated following United States Geological Survey (USGS) standard procedures (Rantz 1982). We 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 measured streamflow values, we developed rating curves to correlate streamflow with discharge at each site. In addition, we installed staff plates to detect 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.

Streamflow in Dutch Bill Creek shows seasonal trends that mirror rainfall patterns, with most flow concentrated in the wet season (November to April). In 2011 (the last year when flow during winter was measured), as much as 96% of annual discharge occurred during half the year. In this case, 7% of discharge occurred during a very wet October, so the wet half of the year was October to March; less than 4% of the discharge occurred from April through September (Figure 9).

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 elevated baseflow (Figure 10, Figure 11). Streamflow begins to recede following rainfall events at the onset of the dry season and moves toward (and often reaches) intermittence in summer.

This climatic regime poses several significant challenges to people living and working in the region, as well as aquatic organisms that use the Dutch Bill Creek drainage network for their life cycles. Aquatic organisms such as steelhead and coho salmon are exposed to the high-flow conditions that occur periodically through winter, and then must persist through the summer dry season until the

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[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.

rainy season brings water to streams once again. For people, streams can be an unreliable source of water during the prolonged summer dry season.

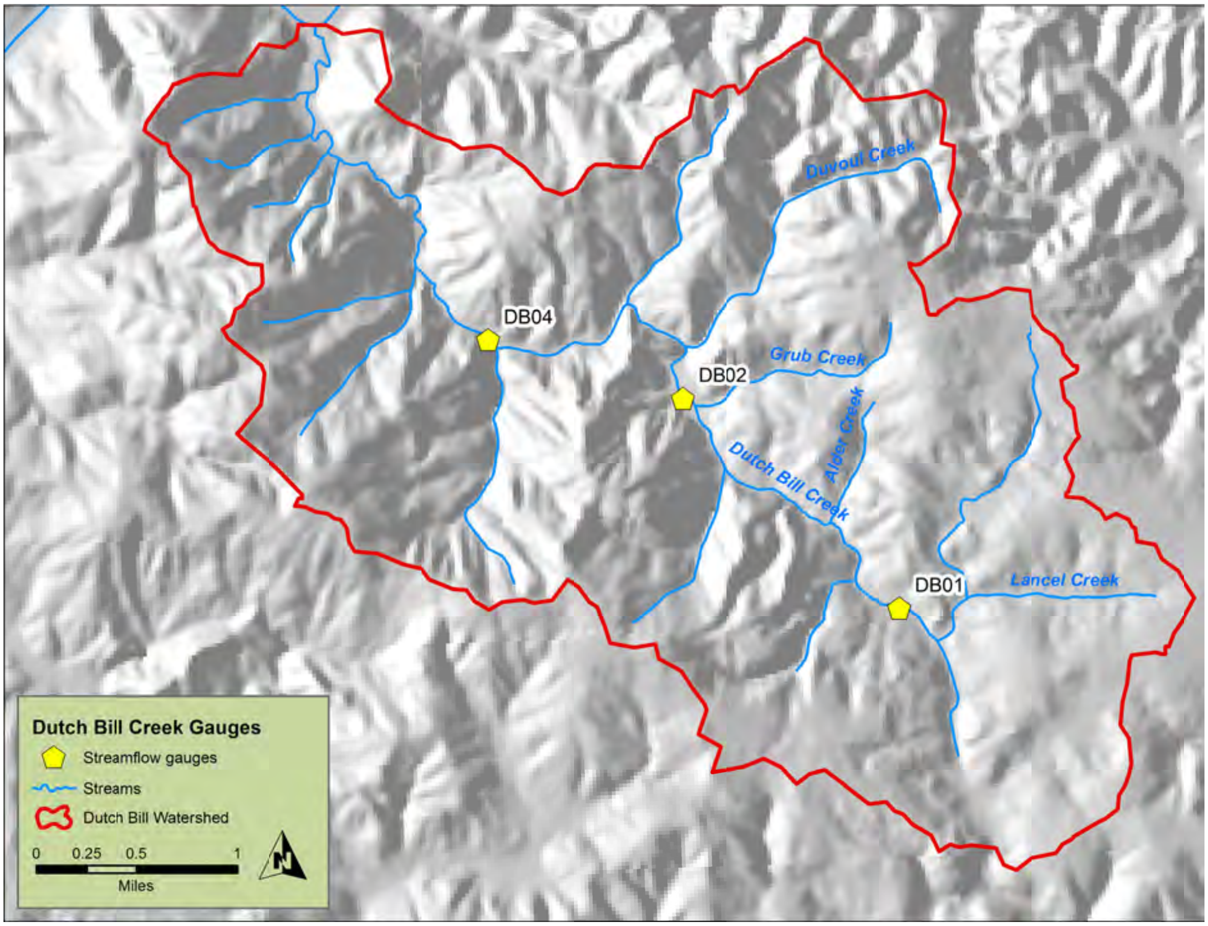

Figure 8. Streamflow gauge locations in the Dutch Bill Creek watershed.

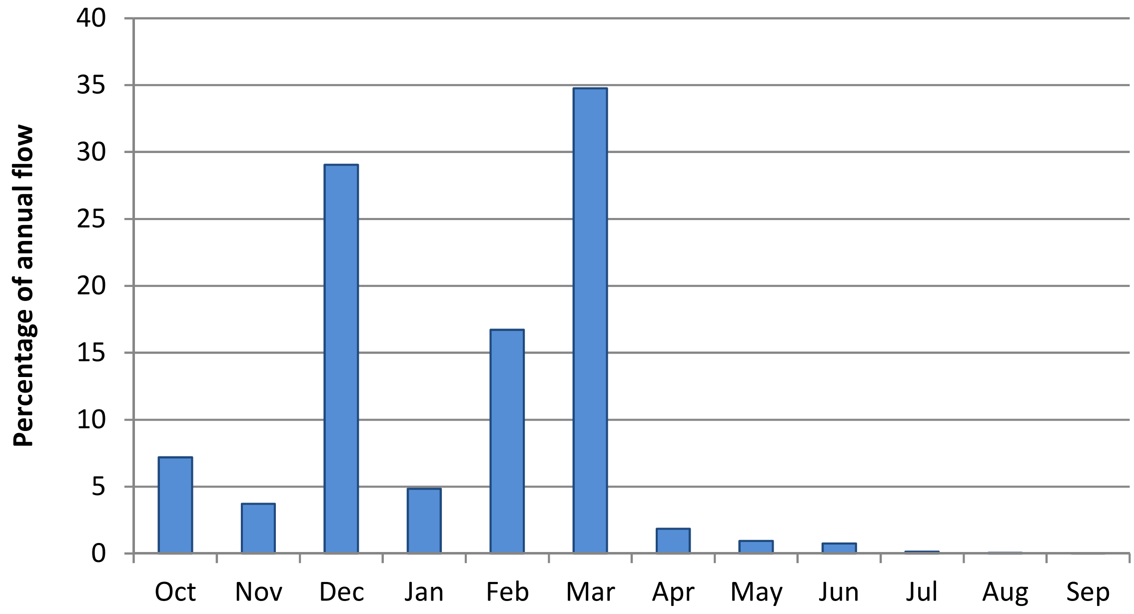

Figure 9. Percent of annual flow by month in Dutch Bill Creek in 2011.

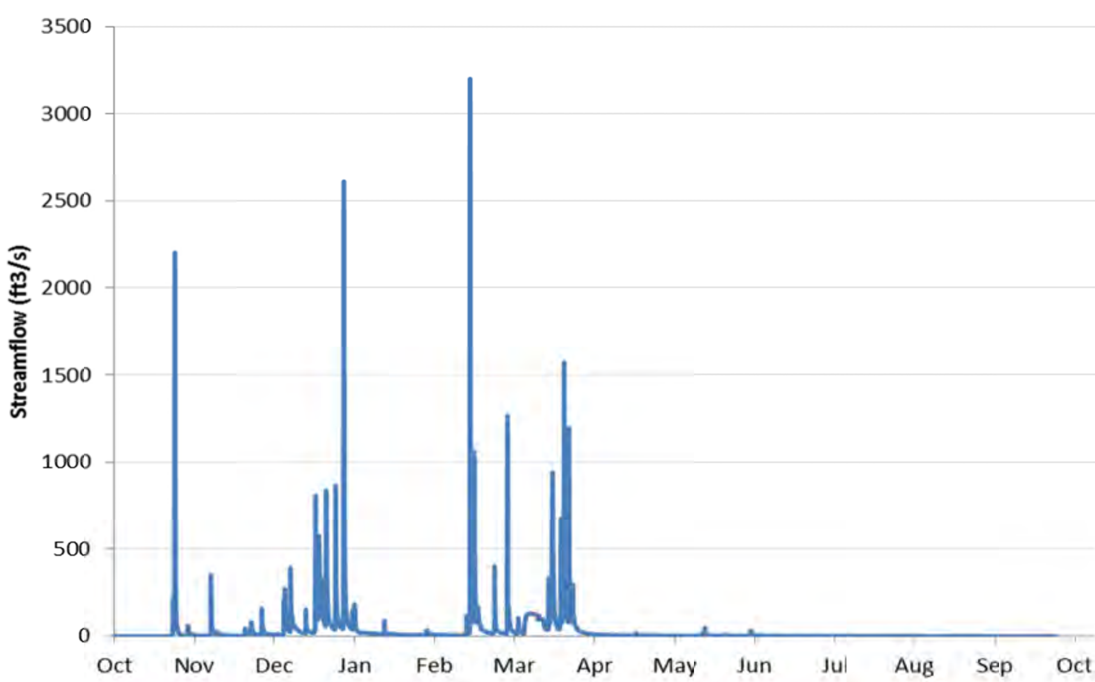

Figure 10. Streamflow recorded in Dutch Bill Creek near Grub Creek, water year 2011.

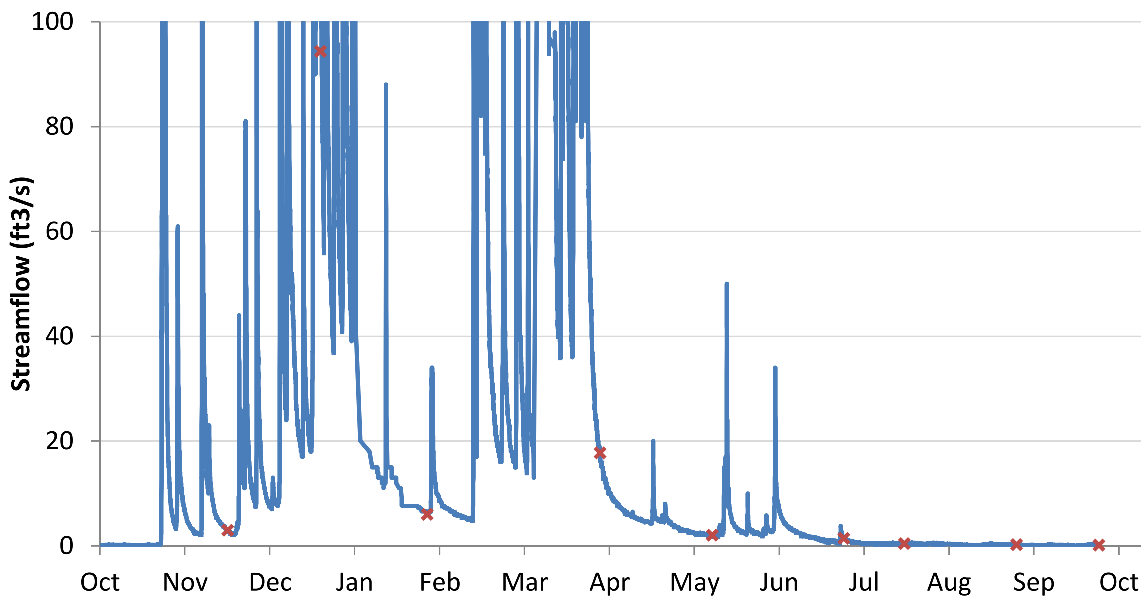

Figure 11. Streamflow in Dutch Bill Creek near Grub Creek, water year 2011, showing flow below 100 ft^3/s to illustrate the magnitude of flow recession through the year. (Each "x" indicates a streamflow measurement.)

2.4 Summer baseflow

Summer baseflow is a critical limiting factor for coho salmon and steelhead trout survival in coastal California watersheds. Our streamflow monitoring is focused on understanding how summer flow conditions vary from year to year and on how human water diversion impacts summer baseflow. Figure 12 shows a summer hydrograph at (DB01) Dutch Bill Creek at Camp Meeker in WY2011, and illustrates the summer recessional flow regime typical to many coastal watersheds. In late spring/early summer 2011 the watershed receives a few rain events causing water levels and streamflow to rise. As the summer continues, the stream begins to recede to a baseflow derived from groundwater inputs and local springs. Figure 12 shows that streamflow begins receding in early summer, and is lowest by late September. In late September/early October, riparian trees begin losing their leaves and decreasing the amount of water they uptake, causing a slight increase in water levels during the driest time of the year. Streamflow is maintained at baseflow until the first rain event of the year in early October 2011.

Field observations and anecdotal evidence support the idea that a significant portion of Dutch Bill Creek's summer baseflow is derived from several areas of perennial springs on the forested, northeast-facing slopes on the southwest side of the creek. Although we have not gauged these springs, our field reconnaissance and spot streamflow surveys indicate that, at the lower portions of the watershed near our gauge on Dutch Bill Creek above Tyrone Road, summer baseflow is significantly influenced by a small southwest tributary that maintains water during most summers. Additionally, the camps and conference centers in the area rely on springs in these areas to meet their summer water needs, indicating that springs in the Dutch Bill Creek watershed play an important role in summer baseflow and as a human water source during the dry season.

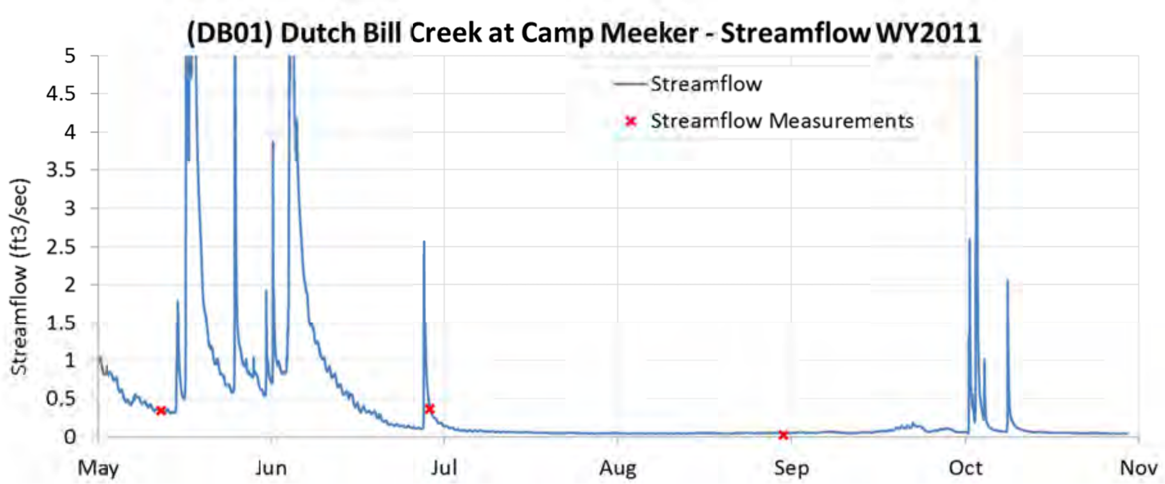

Figure 12. Streamflow in Dutch Bill Creek at Camp Meeker, water year 2011, showing summer baseflow to illustrate the magnitude of flow recession through the dry season. (Each "x" indicates a streamflow measurement.)

2.5 Impact of diversions on streamflow

Surface water direct diversions, groundwater diversions from wells located near creeks, and diversions from springs can have significant effects on streamflow conditions during the summer season. We discuss some of the impacts of surface, groundwater, and spring diversions below.

Surface water diversions tend to have episodic impacts on water levels and streamflow conditions. When water is diverted directly from a stream, the diversion causes an immediate decrease in water levels and streamflow. After the diversion has stopped, water levels and streamflow will return to previous conditions. Surface water diversions also have a distinct signal in the hydrograph, from which we can calculate the impact of the diversion.

As streamflow recedes towards baseflow in spring and summer, surface water users can divert much and sometimes all of the stream's flow in a reach. Streamflow data from DB02 help to illustrate how instream diversions affect flow through the summer recession (Figure 13). Our streamflow data show that a direct surface water diversion at our gauge site was causing streamflow to drop by 0.07 – 0.25 ft^3/s (approximately 66% to 100% of streamflow). This decrease in streamflow may have had significant effects on the wetted area of the channel, reducing the habitat available for fish and aquatic invertebrates (fish food). During the later summer months, the diversion caused the stream to become disconnected. Data from DB04 (Figure 14) show that those large impacts measured at the upstream gauge did not propagate downstream in the same magnitude, but they may have resulted in overall lower discharge through the day.

Groundwater diversions and diversions from springs tend to have a more chronic impact on water levels. Compared to surface water diversions, the hydrological effects of groundwater diversions from cavities in rocks (cracks or fractures in bedrock) or alluvial aquifers are relatively difficult to predict, and any predictions are normally subject to uncertainty (Werner et al. 2013). While we may not be able to determine the ecological impacts of groundwater diversions as precisely, we do know that, over larger time scales, decreases in groundwater levels can result in decreases in surface water levels and can have significant impacts to aquatic habitats.

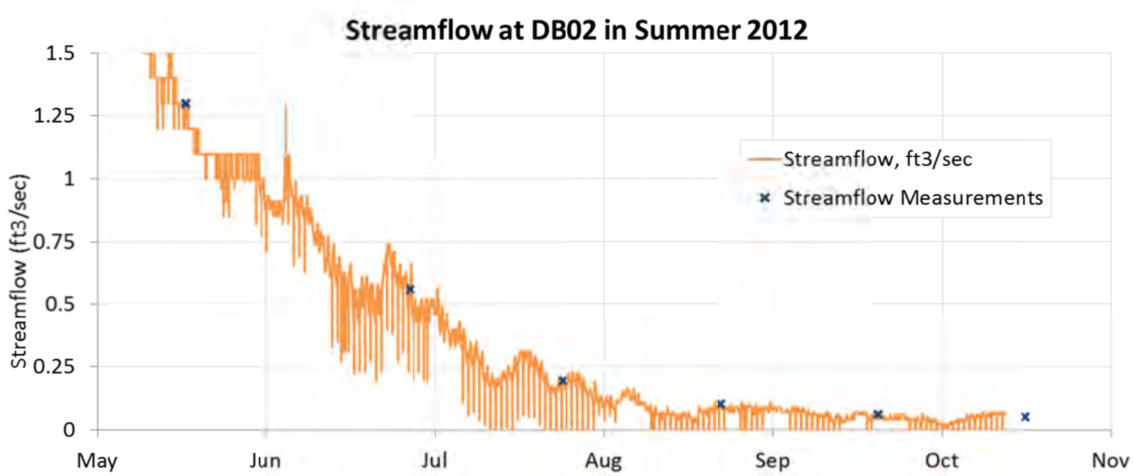

Figure 13. Streamflow at DB02-Dutch Bill Creek near Grub Creek during water year 2012.

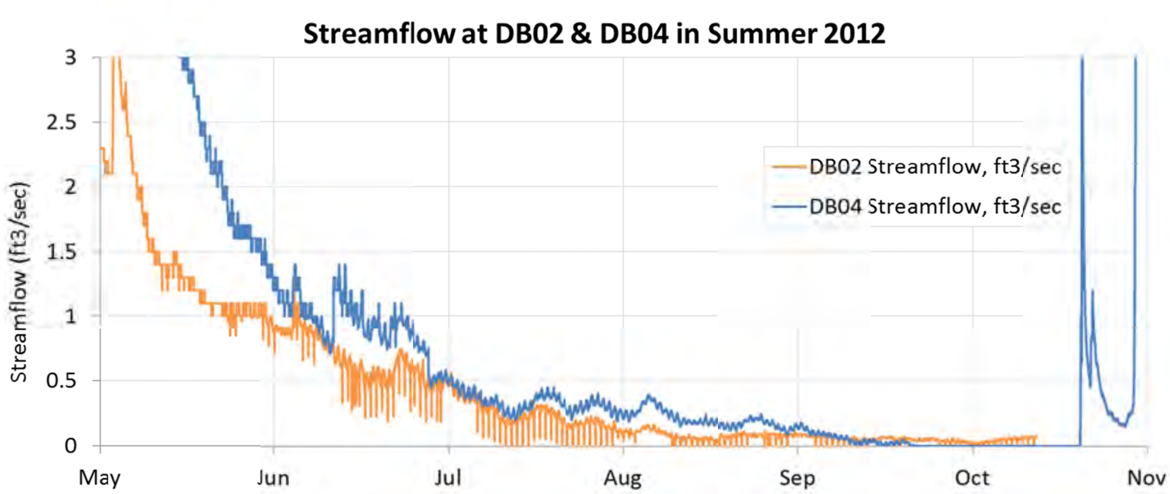

Figure 14. Streamflow at DB02-Dutch Bill Creek near Grub Creek and DB04-Dutch Bill Creek near Tyrone Rd during water year 2012.

2.6 Impact of droughts on streamflow

Droughts are a common and fundamental feature of California's climate. The 2012 to 2015 drought in northern coastal California ranks among the three most prolonged periods of below-median annual rainfall in the past 65 years. Extended periods of low rainfall influence the watershed processes that convert precipitation into streamflow and groundwater. The recent drought has had measurable and profound impacts on streamflow conditions through each sequential summer. Data from DB02 (Dutch Bill Creek near Grub Creek) and DB04 (Dutch Bill Creek above Tyrone Road) illustrate the impact the recent multi-year drought had on streamflow conditions (Figure 15 and Figure 16). Water years 2010 and 2011 were considered to be average to wet years, and both study sites maintained flow through much of the dry season. In contrast, water years 2012 through 2015 show the cumulative impact the drought had on streamflow, with conditions decreasing with each year of the drought. For example, streamflow at DB04 in early May was above 5 ft^3/s in water year 2012. The following year, streamflow in early May started around 4 ft^3/s, and showed a 1 ft^3/s decrease in early summer flow. By water year 2015, early May flow conditions began below 1 ft^3/s (Figure 16).

Total monthly discharge data from our gauges further illustrate the impact of the continued drought on streamflow. Total monthly discharge during the drought was significantly lower each month with each progressing year (Figure 17). In September and October 2015, the Camp Meeker Recreation and Park District (CMRPD) released water into Dutch Bill Creek to enhance streamflow conditions. The water release is highlighted in Figure 17 in the blue bars showing that the released water significantly improved total monthly discharge compared to the other drought years.

Total summer discharge through the drought was significantly lower than in water years 2010 and 2011. Using water year 2010 as a reference year, summer discharge in 2012 was 23 percent of 2010 discharge, and 2013 and 2014 summer discharge was 15 percent and 11 percent, respectively, of 2010 summer discharge. Even with the water release by CMRPD in 2015, total summer discharge in summer 2015 was less than 10 percent of 2010 summer discharge (Figure 18).

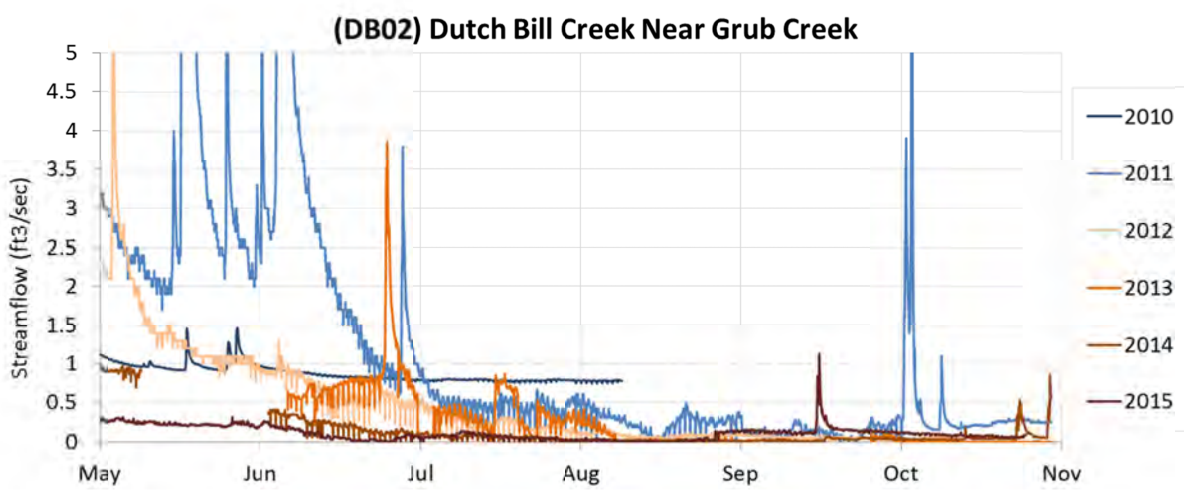

Figure 15. Streamflow at DB02-Dutch Bill Creek near Grub Creek during water years 2010-2015.

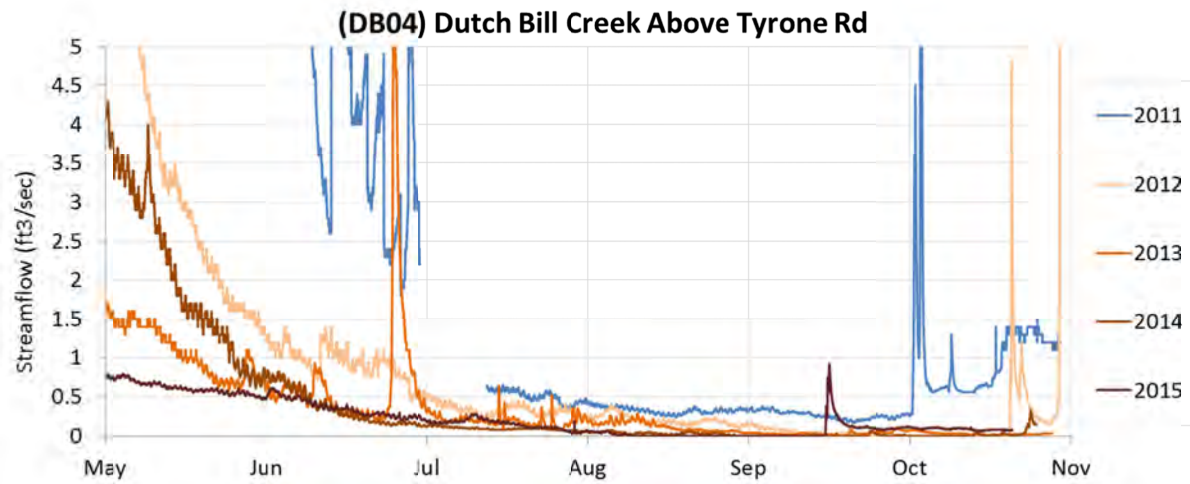

Figure 16. Streamflow at DB04-Dutch Bill Creek above Tyrone Road during water years 2011-2015.

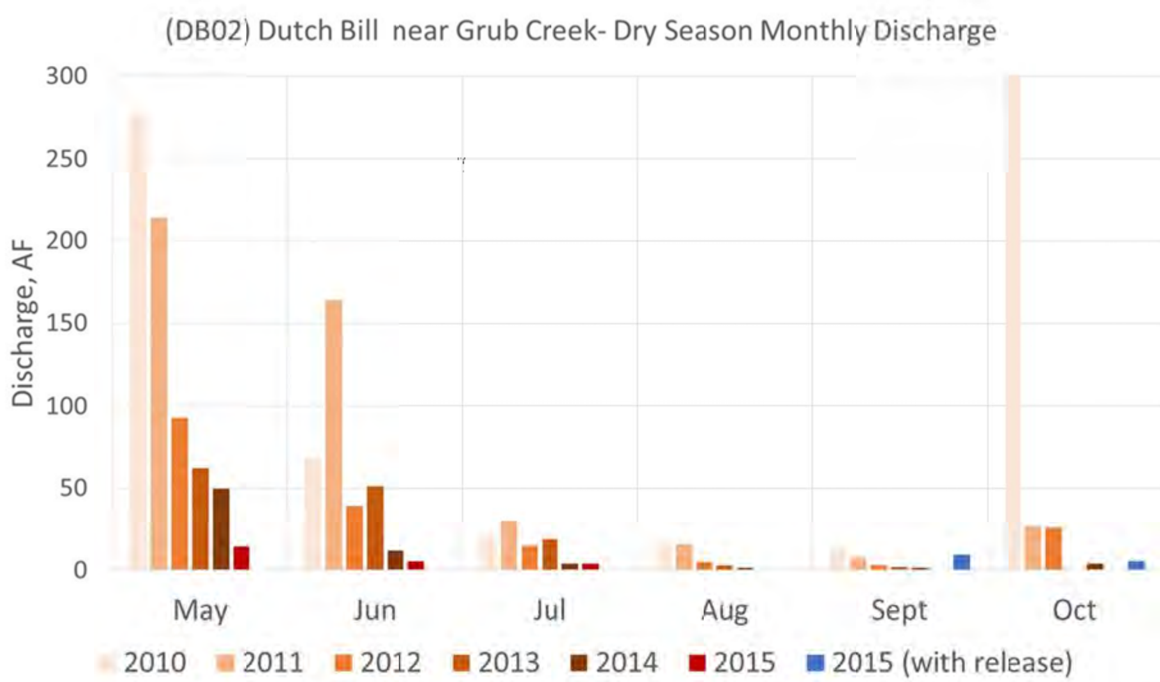

Figure 17. Monthly discharge at DB02 in WY2010 through 2015.

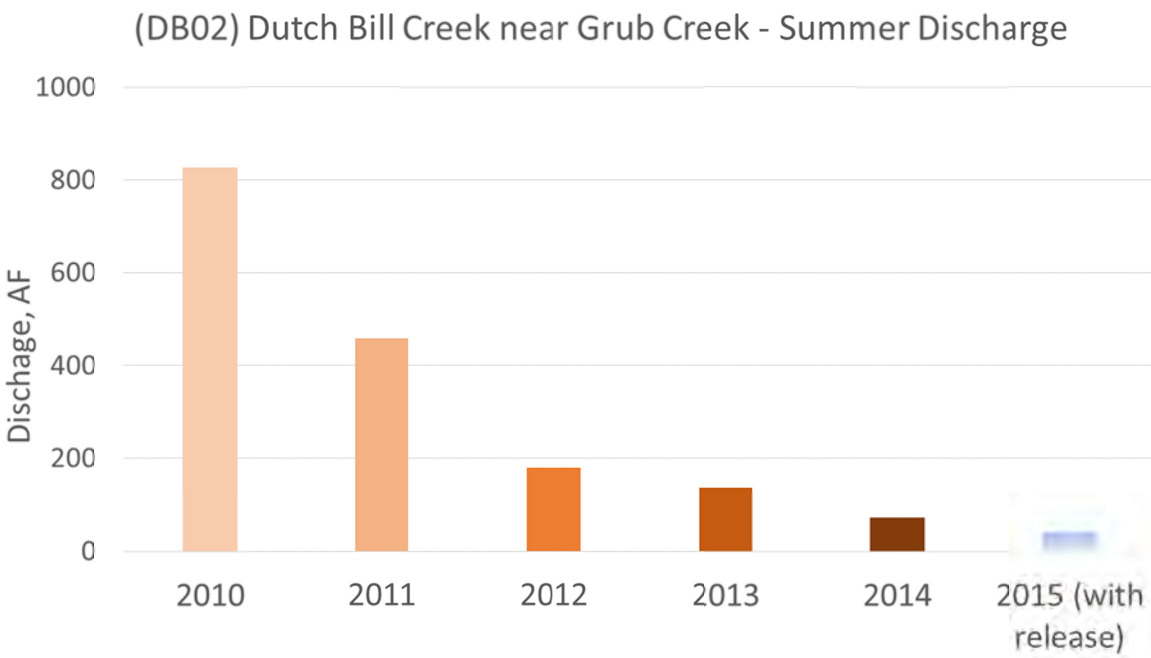

Figure 18. Total summer discharge at DB02 in WY2010 through 2015.

2.7 Summary

The data collected in Dutch Bill Creek over the past six years show seasonal trends that are characteristic of Mediterranean-climate streams and heightened by drought. Winter flow conditions are punctuated by rainfall events, and as rainfall decreases through spring and summer, streamflow decreases and some reaches of the stream become disconnected.

Streamflow data also capture the measurable impact of instream diversion on streamflow during the summer dry season. Our streamflow data (from site DB02) show that a direct surface water diversion at our gauge site was causing streamflow to drop by 0.07 – 0.25 ft^3/s. During the later summer months, the diversion caused the stream to become disconnected. The diversion caused substantial reductions in flow, which propagated downstream from the site throughout the dry season.

The multi-year drought of 2012-2015 caused summer flow conditions to decrease with each subsequent drought year, such that summer baseflow in each consecutive dry year was less than the year before. The water release by CMRPD in summer 2015 substantially increased streamflow in September and October, showing the benefit of water releases as emergency tools during severe drought conditions.

3 Human water needs

This SIP outlines a strategy to address and improve Dutch Bill Creek's streamflow in the dry season. One benefit of the watershed's Mediterranean climate is the relative abundance of water during the winter months. As stated earlier, the Dutch Bill Creek watershed receives between 39 and 61 inches of rainfall in an average year, with 90 percent occurring between November and May. However, the dry season (May through October) is the period when water needs are greatest for residential and agricultural uses alike.

This SIP hypothesizes that we can increase the amount of water in streams in the Dutch Bill Creek watershed in the summer months by finding ways for people to reduce their water use and/or switch their period of diversion from summer to winter. This section provides an analysis of and rationale for changing current water management. We conclude that there is sufficient water available to meet human needs on an annual scale, but not in the summer, and that sufficient water could be available to meet this summer need through winter diversion and storage.

3.1 Comparing human water needs to water in Dutch Bill Creek

As described above, streamflow data suggest that direct stream diversions and near-stream wells can adversely affect streamflow through spring and summer. While insufficient water quantity in the dry season clearly indicates a need for projects to restore summer streamflow, preliminary hydrologic evaluation can help to determine whether there is sufficient water available on an annual scale to meet human water needs with minimal ecological impacts.

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 from 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 human use. Discharge also integrates several watershed processes, such as evapotranspiration and groundwater recharge, that affect the fraction of rainfall that is converted to streamflow through the year.

3.2 Rainfall and discharge

As described above, the Dutch Bill Creek watershed receives considerable rainfall in an average year: we estimate the average rainfall in the watershed is 56 inches, with a range of 61 inches in the headwaters to 39 inches near the confluence with the Russian River. This results in a total of 36,000 acre-ft of water falling onto the 7,722-acre Dutch Bill Creek watershed in an average year.

To estimate average discharge in Dutch Bill 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 Austin Creek near Cazadero, CA guided the discharge estimates used for Dutch Bill 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 Dutch Bill 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 watershed (i.e., Austin Creek). This equation appears in Appendix B of the State 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 permit a new water right (SWRCB 2014). Further, an evaluation by the USGS (Mann et al. 2004) found that the basin area-ratio transfer method generally performed better than rainfall-based methods of estimating streamflow in this region. We calculated the discharge value for Dutch Bill Creek modeled from Austin Creek for this report. The resulting streamflow information is summarized in Table 1.

Table 1. Basin hydrology characteristics Austin Creek and Dutch Bill Creek.

Stream	Watershed area, acres	Average annual rainfall, inches	Average annual rainfall volume, ac-ft	Average annual discharge volume, ac-ft
Austin	40,384	54	181,700	118,007 (measured, 1960-2013)
Dutch Bill	7,722	56	36,000	23,374 (estimated)

3.3 Human need

Human water need describes the amount of water needed for human uses over a period of time, such as a year (Deitch et al. 2009). By assessing current human water consumption we can determine if these needs can be met on a seasonal scale. Land use in the Dutch Bill Creek watershed includes rural residential, timberland, pasture, camps and conference centers, and a limited number of orchards and vineyards. The watershed also contains the community of Camp Meeker, and parts of the communities of Occidental and Monte Rio.

Domestic water needs typically include requirements for household use and landscaping. The water needs for camps and conference centers include domestic uses and landscape irrigation -- in particular, large areas of irrigated grass. Vineyards typically require water for irrigation in summer and may also need water for frost protection in spring. Water needs at locations such as schools and small businesses can include restrooms and landscape irrigation.

This analysis focused on potential streamflow enhancement related to recreational (i.e., camps and conference centers), agricultural, and rural residential water use -- consistent with our ongoing work in other coastal California watersheds. We compiled related datasets (such as camp locations, agricultural field areas and locations, and building structure locations) using aerial imagery in ArcMap to construct a model of the human development footprint in the watershed (Figure 19).

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

Agricultural. We used digitized agricultural coverage to estimate the total acreage of 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).[3]

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 websites). We relied on various

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

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 vineyard).

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 per house. 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. In calculating residential water needs, we omitted those houses that are within the service areas of the Sweetwater Springs Water District, which supplies portions of Monte Rio, Camp Meeker Recreation and Park District water system (CMRPD), and Occidental Community Services District (OCSD).

Camps/Conference Centers. We determined the annual potable water use for Alliance Redwoods Conference Grounds and Westminster Woods Camp and Conference Center based on USGS-determined school water-use rates. We used a rate of 4.5 gallons of water per day, per person for toilet use, hand-washing and drinking, and estimated outdoor irrigation at a rate of 2.5 acre-feet/year per irrigated acre, based on our work in a nearby watershed. Our approach assumes that the camps operate year-round. We estimated that Alliance Redwoods can accommodate 350 people per day; and Westminster Woods, 200 per day. Based on information obtained from active water rights, non-potable water used for irrigation at both the Alliance Redwoods Conference Grounds and Westminster Woods Camp and Conference Center is estimated to be 2.26 acre-feet per annum.

Human water need for the Dutch Bill Creek watershed was estimated based on the water-use rate factors described above. We count 313 rural residences in the Dutch Bill Creek watershed (excluding residences within the service areas of the Sweetwater Springs Water District, CMRPD, and OCSD). The total amount of water needed for these residences is approximately 248 acre-feet per year. Based on the number of individuals the Alliance Redwoods Conference Grounds and Westminster Woods Camp and Conference Center can accommodate annually, we determined that the total amount of water needed to operate camps and conference centers in the Dutch Bill Creek watershed is 2.8 acre-feet per year. Five wineries are located within the watershed, with varying amounts of production. Based on individual winery production estimates, the total amount of water used by all Dutch Bill Creek watershed wineries annually is 0.4 acre-feet. Dutch Bill Creek has approximately 165 acres of vineyards, requiring 99 acre-feet of water annually for irrigation (Table 2). Dutch Bill Creek has 8.2 acres of orchards located within the watershed which require approximately 18.9 acre-feet per year for irrigation. There are approximately 0.1 acres of other crops within the Dutch Bill Creek watershed that require 0.06 acre-feet annually for irrigation.

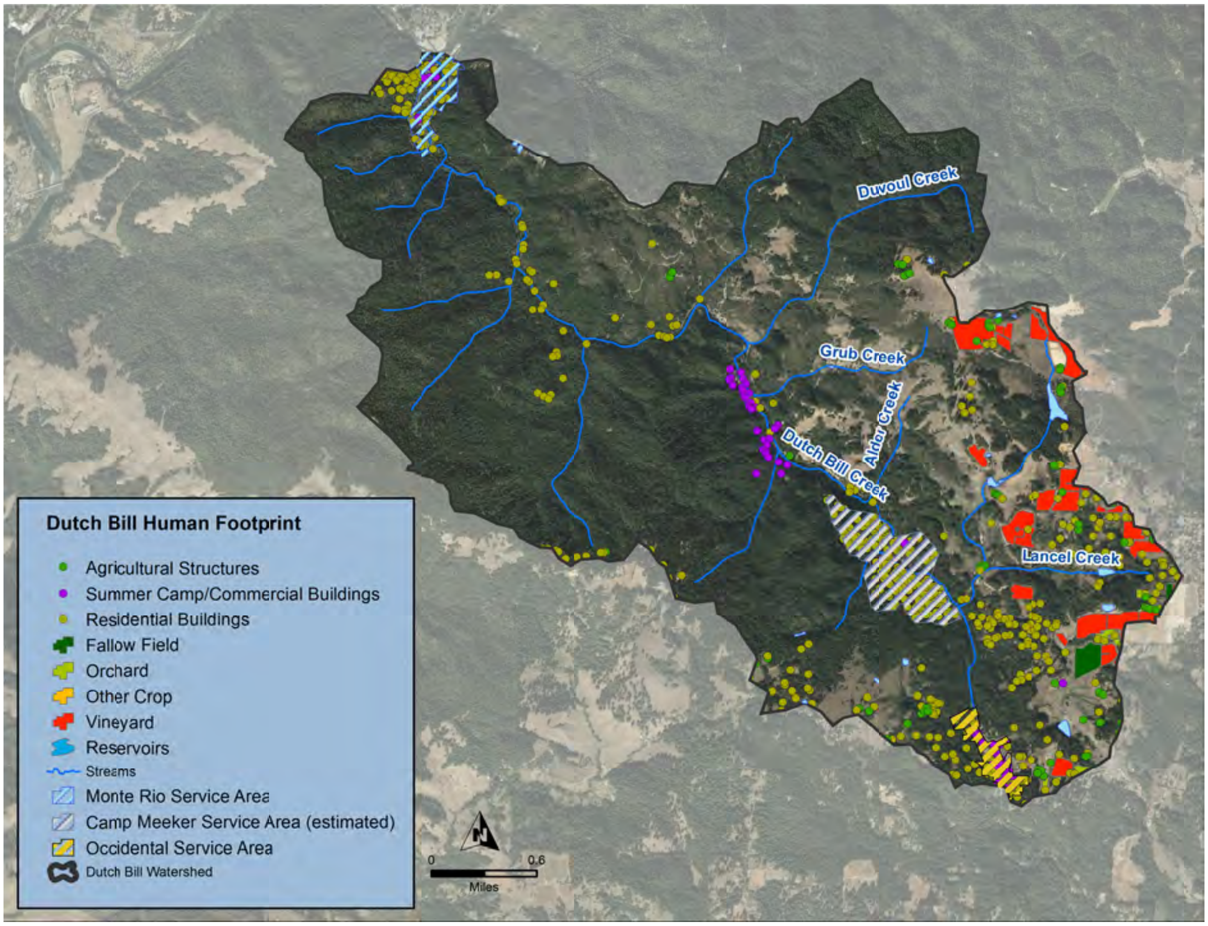

Figure 19. Human footprint in Dutch Bill Creek watershed, used to estimate water need.

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

No. of Residences	No. of Camps	No. of Wineries	Vineyards (acres)	Orchards (acres)	Other Crops (acres)	Total human water need (acre-ft/yr)
313	2	5	165	8.2	0.1	369

3.3.1 Annual scale

Comparing the human water needs in Dutch Bill Creek watershed to the average rainfall and discharge provides an initial assessment of whether these needs can be met through the water resources available, on an annual scale. Our analysis indicates that demand comprises a small fraction (approximately 2%) of the total discharge available (Figure 20).

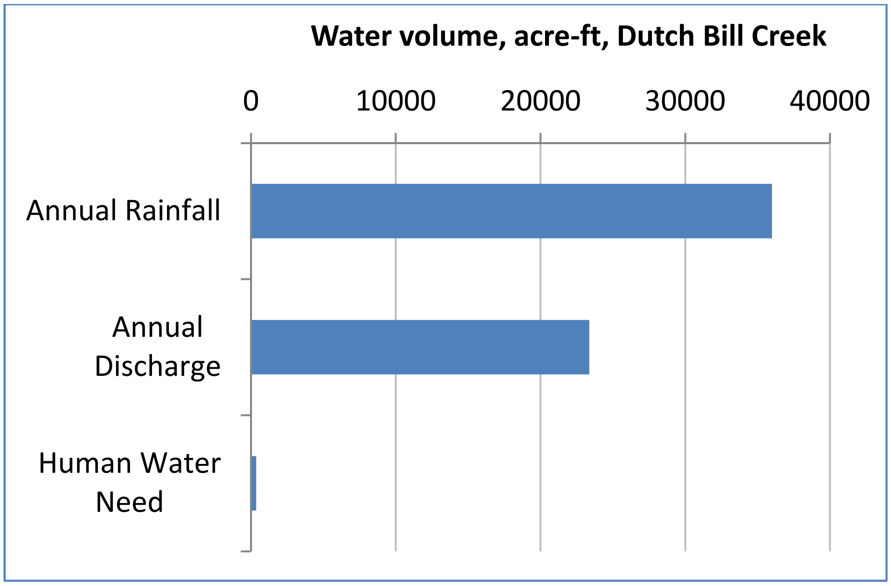

Figure 20. Comparison of rainfall, streamflow and human water need in the Dutch Bill Creek watershed.

3.4 Water rights in the Dutch Bill Creek watershed

Water rights records provide another window into scale, spatial distribution and type of human water needs across the Dutch Bill Creek watershed, as well the methods and basis of right used to obtain and manage water across the landscape.

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 each user is required to submit a Statement 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. 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 put 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; and registration holders are required to file water user reports annually.[4]

3.4.2 Water rights in the Dutch Bill Creek watershed

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 Dutch Bill Creek watershed, as of February 2017, eWRIMS lists 14 appropriative rights (13 licensed and one pending), two stockpond registrations, five small domestic use registrations (a sixth was revoked), and 10 riparian claims (two are inactive) (Figure 21).

Water rights may not be the most accurate way to estimate water need in the Dutch Bill Creek watershed, as they under-represent the number of diversions. The eWRIMS database does not capture uses for which a permit or license is not required (e.g., diversions from springs that meet certain criteria or pumping from percolating groundwater), riparian or pre-1914 water rights if the water user has not submitted a Statement of Water Diversion and Use, 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] One resource for water right reporting compliance guidance is Brownstein, Hyatt, Farber, Schreck, "California Water Rights: Compliance Checklist for 2016" (Jan. 20, 2016) available at: http://documents.jdsupra.com/303353c9-3e8b-4393-a74c-961b708a5cdf.pdf.

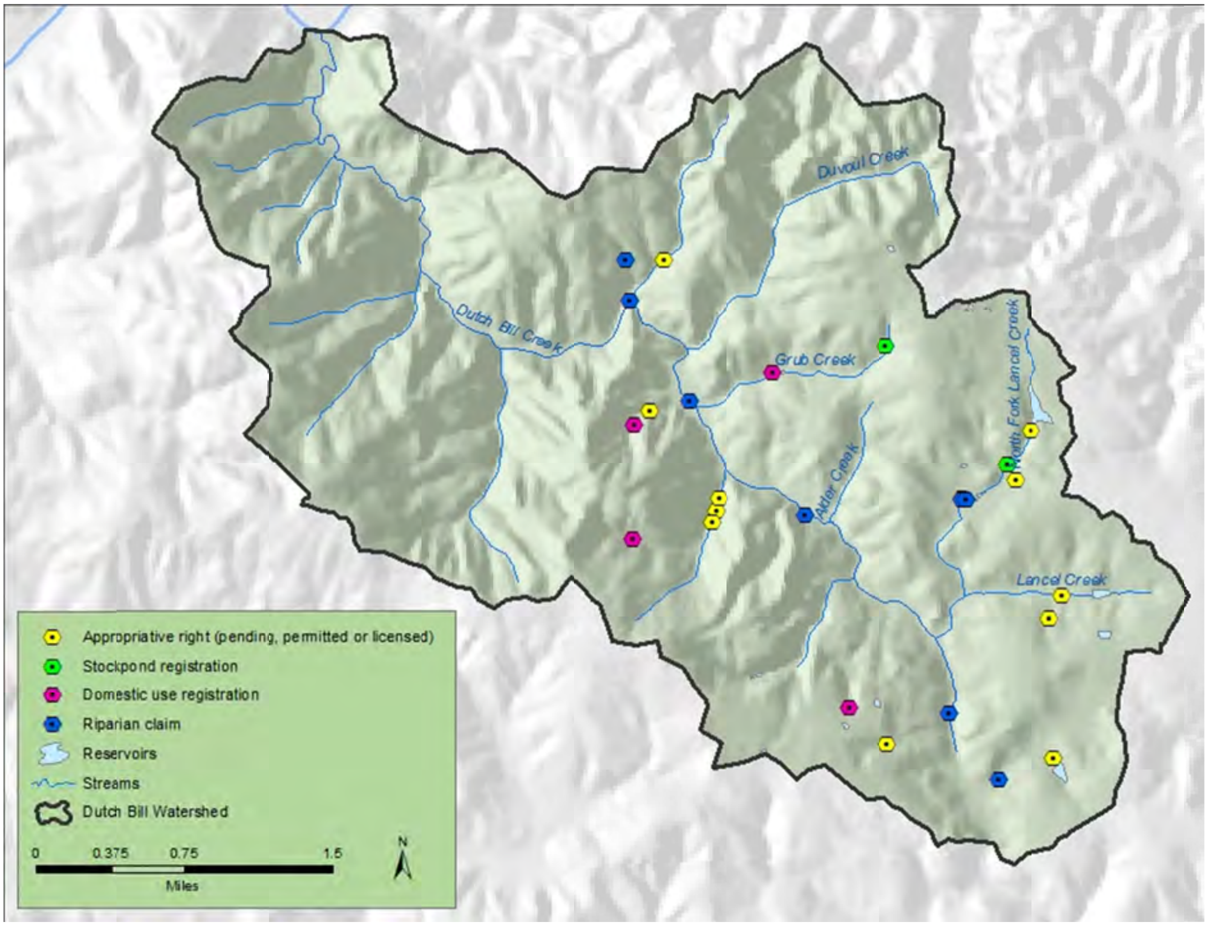

Figure 21. Locations of water rights in the Dutch Bill Creek watershed in eWRIMS as of February 2017.

3.4.3 Data from the 2015 State Water Board Informational Order

Additional detail about the diversion and use of water within the Dutch Bill Creek watershed was collected by the State Water Board under its 2015 Informational Order (SWRCB 2015b). The Order went beyond the standard reporting requirements for water rights holders by, for example, including well users and requiring users to report on both monthly water use and projected water use from January 2014 through December 2015. The State Water Board produced summary maps from the reported data (see Figure 22).

As of January 1, 2016, 85.8% of the parcels in the watershed had submitted responses. They reported 154 groundwater wells, 28 surface diversions and nine spring diversions. Reliance on water suppliers in Dutch Bill Creek was significant; 46.5% of the parcels reported receiving water from a water supplier, while 34.3% used no water, 12.7% relied exclusively on groundwater, 1.1% relied exclusively on surface water, 4% had multiple sources, and 1.4% received water under contract. The majority of the reporting parcels used water for domestic purposes (approximately 700), as compared with less than 50 reports for agriculture and for mixed use. The State Water Board did not provide information regarding the volume of water used by reporting parcels or by beneficial use.

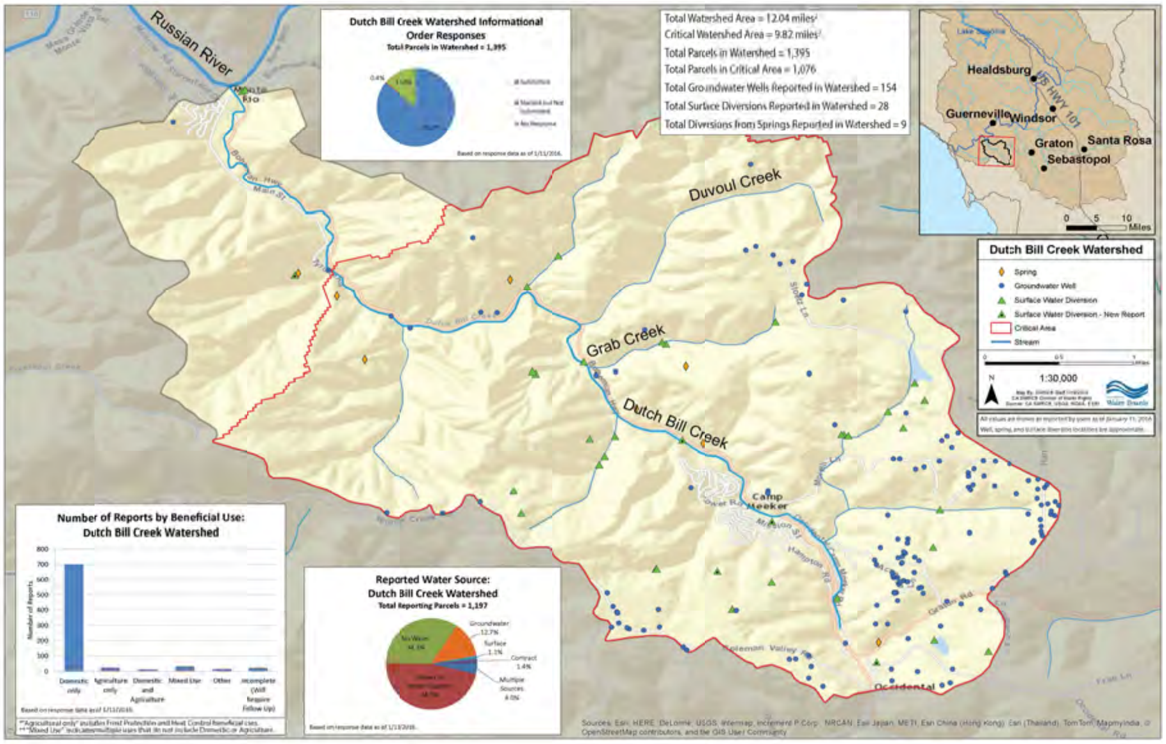

Figure 22. Information reported to the State Water Board under its 2015 Informational Order (as of Jan. 11, 2016).[5]

3.5 Summary

The above data provide important insights into the complexities of water management in the Dutch Bill Creek watershed. The watershed receives, as rainfall, approximately 100 times the total amount of water that we estimate people need for residential, institutional, and agricultural uses in the watershed, even under dry-type conditions. We estimate that average annual discharge is approximately 65 times the total human water need. In a dry year (i.e., a year with rainfall that is exceeded by 90% of all years), when rainfall is approximately half of the average, rainfall would still greatly exceed the amount of water needed for all of the known human uses in the Dutch Bill Creek watershed. These results indicate that there is ample water in the Dutch Bill Creek watershed *on an annual scale* to meet human and environmental needs, even in a dry-type year.

Despite this abundance of water, the seasonality of its availability is the greatest challenge associated with ecologically-sustainable water management. Our streamflow data corroborate this idea; many small diversions from the Dutch Bill Creek drainage network and adjacent shallow aquifers can cumulatively reduce streamflow during the dry season. The data suggest that

[5] http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/pstr/db_pstr_web.pdf

streamflow enhancement projects that reduce demand and/or modify the timing of diversion from summer to winter can lead to increased summer baseflow if water users are willing to store water in the wet season and use that stored water to reduce or replace water diverted in the dry season. Such projects should be conditioned to maintain environmental flows in winter and may provide additional water security for human use. Given the changes in rainfall patterns predicted in coming decades (described above), such projects will be critical for maintaining reliable water supplies for human water needs and for maintaining ecological processes in the Dutch Bill Creek watershed. We return to these strategies in Section 5.

4 Fish and habitat

This section summarizes the history and status of coho salmon in Dutch Bill Creek, describes current population monitoring efforts, examines flow-related bottlenecks to survival, and presents the results of an ongoing study of juvenile oversummer survival in Dutch Bill Creek designed to describe the relationship between survival and environmental metrics. Detailed information on survival study methods and results is included in Appendix B.

4.1 Historic presence

The Russian River watershed historically supported native runs of anadromous coho salmon (*Onchorhynchus kisutch*) and pink salmon (*O. gorbuscha*), as well as steelhead trout (*O. mykiss*) (Steiner 1996). Due to a lack of historical survey records, it is unknown whether Chinook salmon (*O. tshawytscha*) 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.[6] Russian River coho salmon populations were once abundant 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).

Over the past century, salmonid populations in the Russian River watershed have experienced steep declines, along with other populations across the Pacific Coast. Pink salmon are now extirpated from the system, coho salmon are listed as endangered under the state and federal Endangered Species Acts, and Chinook salmon and steelhead are listed as threatened under the Federal Endangered Species Act (ESA).

Early documentation of salmonid presence in the watershed is limited, but coho salmon presence prior to 2006 hatchery releases (see Section 1.2) was confirmed in Dutch Bill Creek in 1952, 1953, 1954, 1963[7], 1966, 1968[7,8], 1969[7], 1970[7,8], 1971[8], 2002, and 2005 (Spence et al. 2005, CDFW 2000a, Conrad 2005, UC unpublished data). CDFW records indicate that coho salmon were stocked into Dutch Bill Creek from an unknown source in 1969 (10,000) and from the Noyo River in 1970 (10,010) (CDFW 2000a). There is no record of historical coho salmon presence in the tributaries to Dutch Bill Creek, but steelhead presence has been documented in historical and recent surveys in Dutch Bill Creek and most of the major tributaries within the system, including Tyrone Gulch, Duvoul, Grub, and Lancel creeks (CDFW 2000a, CDFW 2000b, UC unpublished data). Chinook salmon have been observed in the lower reaches of Dutch Bill Creek on occasion, but it is likely that they moved in from the Russian River for short periods of time rather than completing their life cycles in Dutch Bill Creek (SCWA and UC, unpublished data).

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[6] http://www.scwa.ca.gov/chinook/
[7] CDFW records show transfers of coho salmon from Dutch Bill to Austin Creek.
[8] CDFW records show transfers of coho salmon from Dutch Bill Creek to the Russian River.

4.2 Coho Salmon Conservation Program

The CCC Evolutionarily Significant Unit (ESU) of coho salmon (which extends from Punta Gorda in southern coastal Humboldt County south to Aptos Creek in Santa Cruz County, and includes the Russian River population) was estimated to have numbered in the tens of thousands as recently as the early 20th century (Steiner 1996), and the Russian River had the largest coho salmon population within this ESU (NMFS 2012). Although no consistent long-term monitoring effort for salmonids existed historically, evidence from opportunistic surveys indicates a clear decline for coho populations, which has been especially rapid in recent decades and has pushed CCC coho to the brink of extinction. The number of coho salmon smolts migrating to the ocean from the Russian River system is estimated to have declined by 85 percent between 1975 and 1991 (NMFS 2012). Extensive surveys by CDFW in the early 2000s found coho salmon to be present in low numbers in only four of 39 confirmed[9] historical coho streams within the basin, including Dutch Bill Creek, and only one stream, Green Valley Creek, had three consecutive year classes (Conrad 2005, Spence et al. 2005). By the time coho salmon became the focus of local resource agencies in the mid-1990s, numbers had dwindled to the point of near collapse throughout the Russian River.

Private landowners, organizations, and agencies responded to the decline of coho by conserving and enhancing 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 formed to restore self-sustaining runs of native coho salmon to streams within the watershed that historically supported them. The Coho Salmon Conservation Program (Coho Program), formerly known as the Russian River Coho Salmon Captive Broodstock Program, represents a broad partnership involving the CDFW, NMFS, US Army Corps of Engineers (ACOE), SCWA, UC, and hundreds of private landowners. This multi-year program was built on the use of native coho salmon juveniles as broodstock for the production of juvenile salmon for release into historical coho salmon streams. Coho Program partners carefully capture wild juvenile coho salmon from Russian River tributaries, rear them to adulthood at the Don Clausen Fish Hatchery at Warm Springs Dam, 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 salmon that return to spawn in those same streams two to three years after their release as juveniles.

Coho Program partners captured the first coho salmon broodstock from remnant wild populations in a total of four Russian River tributaries from 2001 through 2003 and began releasing their offspring as juveniles into designated streams in October of 2004 (Conrad 2005). In 2002, 78 juvenile coho salmon were collected from Dutch Bill Creek for the broodstock effort. Dutch Bill Creek was first stocked in 2006, a year when no wild coho salmon were observed there (Conrad 2005), and has been stocked each year since (Ben White, ACOE, unpublished data). A total of 137,895 juvenile coho salmon from the Coho Program were planted into Dutch Bill Creek from fall

[9] Number of streams with coho “presence confirmed” or “high likelihood of presence,” as defined in Spence et al. (2005). Another 11 streams were deemed as having “equivocal” or “unsupported evidence of presence”.

2006 through spring 2016 (cohorts 2006-2015) (Table 3). Over that time, these releases have averaged approximately 11% of all annual releases into Russian River tributaries, ranging from 9% to 14% (Ben White, ACOE, unpublished data).

Table 3. Number of Coho Program juvenile coho salmon stocked into Dutch Bill Creek, years 2006 – 2016 (Ben White, ACOE, unpublished data).

Cohort (hatch year)	Release year(s)	Total release
2006	2006	5,286
2007	2007	7,945
2008	2008	9,997
2009	2009/10	11,258
2010	2010/11	16,788
2011	2011/12	15,834
2012	2012/13	17,144
2013	2013/14	19,303
2014	2014/15	19,325
2015	2015/16	15,015
TOTAL		**137,895**

Following the hatchery releases by the Broodstock Program, coho salmon have been observed in recent years within the Dutch Bill Creek watershed during all freshwater periods of their life stages (2011, 2012, 2013, 2015, 2016; see Section 4.3 [SCWA and UC, unpublished data]).

4.3 Coho Program monitoring

UC's Russian River Salmon and Steelhead Monitoring Program conducts ongoing monitoring of salmonid populations in tributaries to the lower Russian River (including Dutch Bill Creek) in order to evaluate the effectiveness of the Coho Program, and to apply advances in scientific knowledge to its management. Working in conjunction with the California Coastal Monitoring Program, UC is documenting the abundance, survival, and distribution of wild and Coho Program coho salmon throughout the southern portion of the Russian River basin over time. Both wild and hatchery stocks of Dutch Bill Creek coho salmon have been the subject of year-round monitoring since the first Coho Program planting in 2006, with incidental documentation of steelhead and Chinook salmon.

Since 2012, UC biologists have maintained a paired, flat-plate Passive Integrated Transponder (PIT) tag antenna array upstream of the mouth of Dutch Bill Creek to track the movement and survival of PIT-tagged program coho salmon at all life stages (Figure 23). A downstream migrant smolt trap has been operated by SCWA downstream of the antenna site (Figure 23) each spring since 2010 to estimate the number of juvenile fish migrating out of Dutch Bill Creek and into the Russian River. Additional fish monitoring activities include spawner surveys throughout the winter months to document adult returns and snorkel surveys in the summer to document the presence and relative abundance of juveniles. Data from all of these monitoring activities have been used to generate estimates of smolt abundance and overwinter survival, number of adult returns, and natural production (juvenile presence and relative abundance), which are summarized in the following sections.

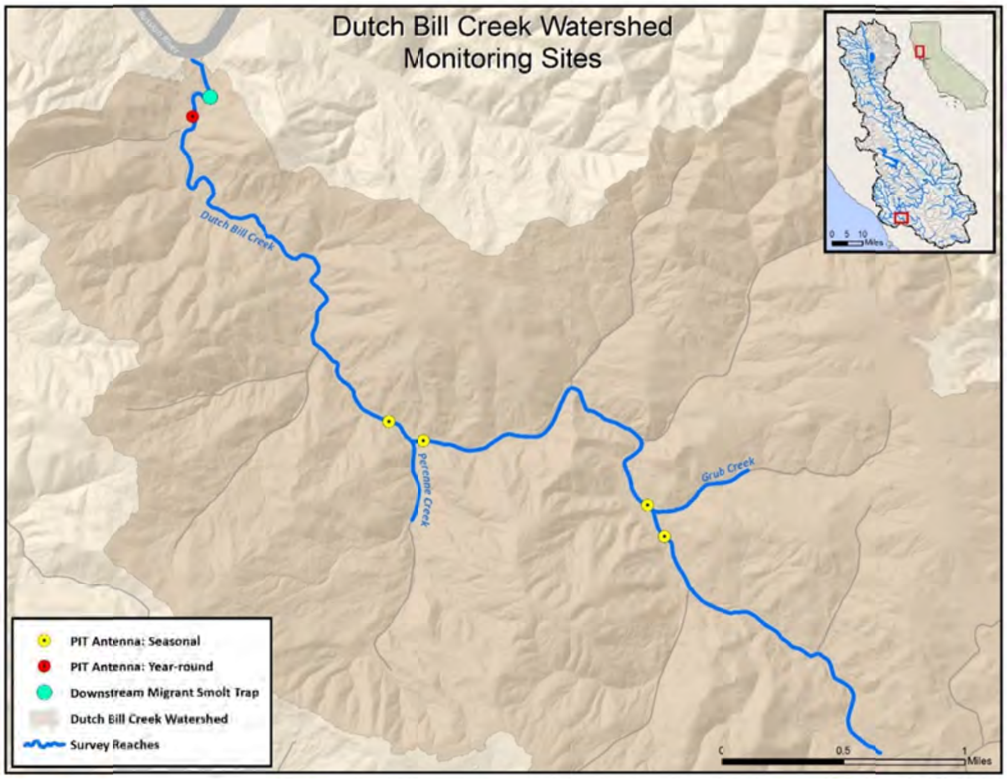

Figure 23. Fish monitoring stations in the Dutch Bill Creek watershed, including UC's PIT tag antenna locations and SCWA's downstream migrant smolt trap site.

4.3.1 Smolt abundance and overwinter survival

Overwinter survival probabilities of fall-released juveniles to the smolt stage ranged from 0.12 (0.10-0.15) in 2012/13 to 0.29 (0.28-0.31) in 2013/14, falling within rates observed in neighboring wild populations in Marin County (Reichmuth et al. 2006, Carlisle et al. 2008). Between 2012 and 2016, the estimated number of smolts emigrating from Dutch Bill Creek each year has ranged from 513 (385-641) to 6,978 (6,039-7,917).

4.3.2 Adult returns

A combination of spawner surveys (2007/08-2015/16), and operation of PIT tag antenna arrays (2012-2016) have been used to estimate the number of adult coho salmon returning to Dutch Bill Creek each year, beginning in the winter of 2007/08 (Figure 24). Comparing the estimated number of smolts leaving each year with the estimated number of adults returning approximately one and a half years later, smolt to adult return (SAR) ratios (survival from the mouth of Dutch Bill as smolts, through the river, to the ocean, and back to Dutch Bill as adults) was 1.6% for the 2012 cohort and 1.0% for the 2013 cohort. Figure 25 displays the distribution of redds observed during annual winter spawner surveys conducted from the winters of 2007/08 through 2015/16, combined. The number of adult coho salmon returning to Dutch Bill Creek since the winter of 2007/08 has generally increased (Figure 24). This is notable in that UC has observed a decline in Russian River basin-wide returns over a similar period (Obedzinski et al. 2016).

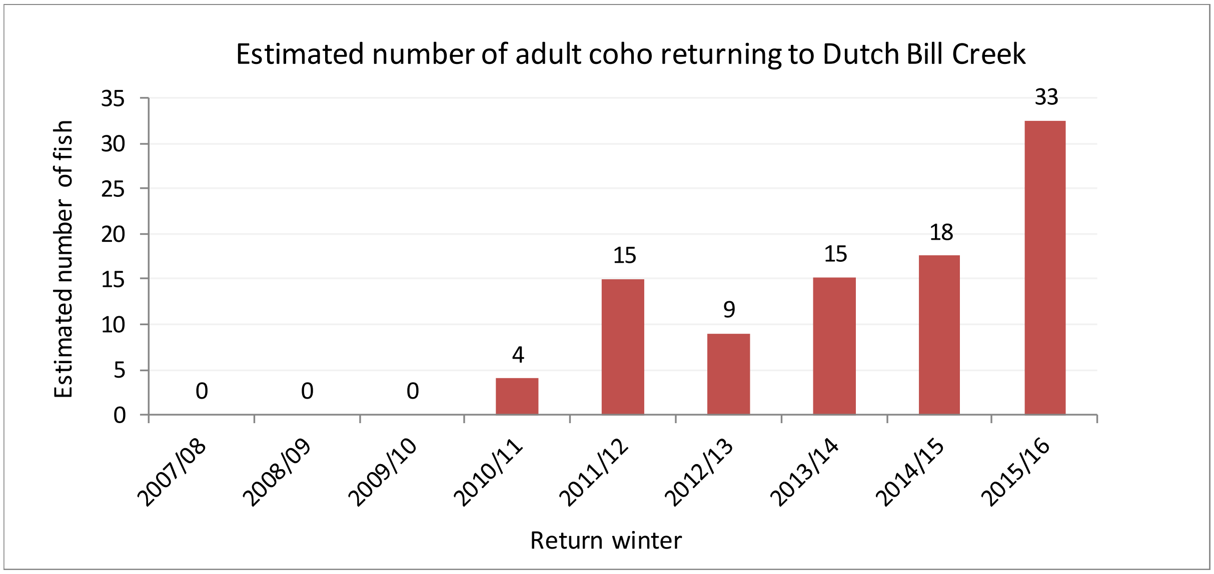

Figure 24. Estimated number of adult coho returning to Dutch Bill Creek each winter. Numbers from 2007/08 through 2011/12 were based on spawner survey observations, while numbers from the following years were derived from PIT tag antenna data.

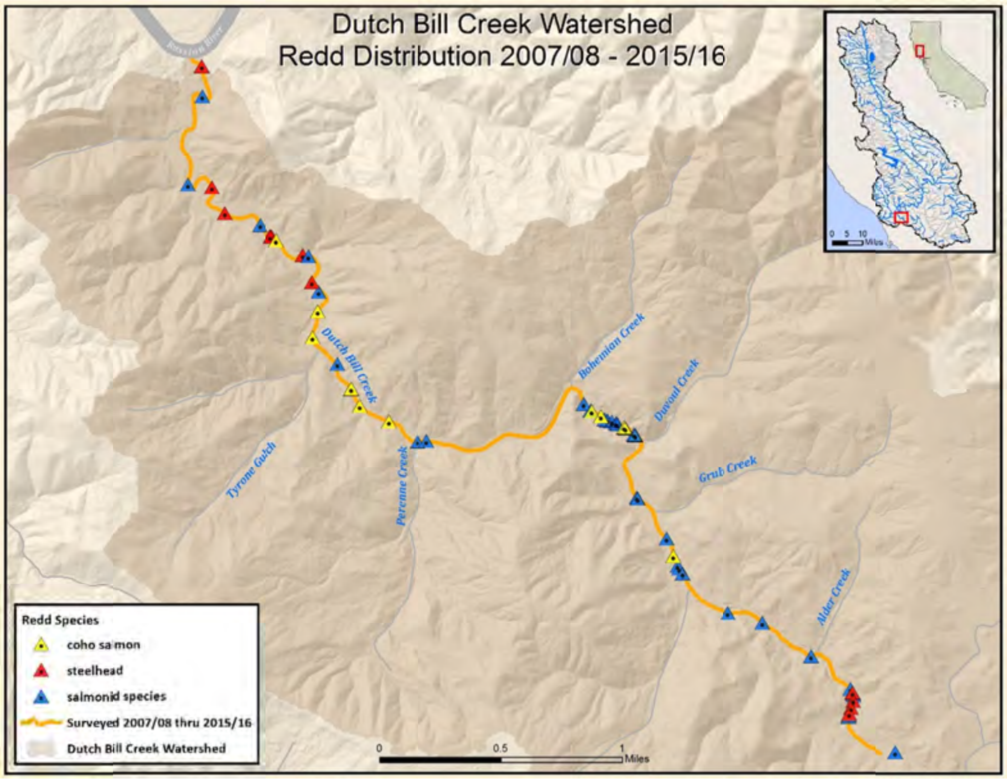

Figure 25. Map showing salmonid redds observed in Dutch Bill Creek from winter 2007/08 through winter 2015/16.

4.3.3 Natural production

Each summer (June-August), UC and SCWA conduct snorkeling surveys in the Dutch Bill Creek watershed to document the presence and relative abundance of wild juvenile coho salmon, which provides evidence that successful spawning of adults occurred the previous winter. These surveys include the mainstem of Dutch Bill Creek, and more recently have included sections of Perenne, Duvoul and Grub creeks, major tributaries of Dutch Bill Creek (Figure 1). Since the inception of the Coho Program, the number of wild young-of-year (yoy) observed each year has ranged from 28 to 1,960 (Table 4). The low number observed in 2014 is likely explained by poorer ocean conditions than in previous years, as well as drought conditions during the winter of 2013/14 that prevented adult coho from accessing Dutch Bill Creek until early February, after the peak spawning months of December and January.

Table 4. Total estimated minimum count of wild coho salmon yoy observed during presence/absence snorkel surveys in the Dutch Bill Creek watershed.

Year	Dutch Bill	Perenne	Duvoul	Grub
2005	118 [1]	n/a	n/a	n/a
2006	0	n/a	n/a	n/a
2007	0	n/a	n/a	n/a
2008	0	n/a	n/a	n/a
2009	0	n/a	n/a	n/a
2010	0	n/a	n/a	n/a
2011	559	n/a	n/a	n/a
2012	1,960	n/a	n/a	n/a
2013	935 [2]	0	9 [3]	0
2014	28 [2]	0	0	0
2015	292 [4]	2 [3]	n/a	0

[1] *From remnant, wild population; prior to Coho Program releases.*
[2] *Conservative estimate of wild coho; observed count of coho - number stocked + any pre-stocking observations.*
[3] *Observed in lower reach; likely moved in from Dutch Bill.*
[4] *Conservative estimate; 650 fish observed when snorkeled every second pool, expanded to 1,300 and subtracted stocked fish.*

4.4 Flow-related bottlenecks to survival

Coho salmon need sufficient streamflow 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 Dutch Bill Creek between March and June through the Russian River on their way to the ocean. As adults returning from the ocean at age-2 or age-3, they need sufficient flows to migrate back upstream and into Dutch Bill Creek to spawn in December through February. Flow limitations have been documented in relation to smolt and adult migration (discussed below in Section 4.4.1), as well as for juveniles rearing in Dutch Bill Creek discussed below in Section 4.4.2).

4.4.1 Flow limitations impacting smolts and adults

In some years, lack of surface flow has cut off the migration corridor for smolts attempting to leave Dutch Bill Creek in the spring. For example, during the springs of 2013, 2014, and 2015, Dutch Bill Creek became disconnected from the Russian River in May, prior to typical completion of the smolt run on other Russian River tributaries (SCWA and UC, unpublished data). Although we do not have the ability to accurately quantify the percentage of smolts that became trapped in these years because stream disconnectivity occurred upstream of the smolt trap location, based on run timing in other Russian River tributaries, it is possible that as many as 25% of the smolts may have become cut off from their emigration to the ocean.

During the winter of 2013/14, coho salmon adults were documented entering the Russian River during October through December 2013, but due to lack of flow, were not able to access spawning habitat in Dutch Bill Creek until after the first significant rain event in early February, after the prime spawning months had passed. These conditions likely contributed to far lower natural production the following summer. Although this extreme winter drought event was unique over the last 10 years of monitoring, the flashier nature of winter flow conditions in recent years appears to be influencing access to streams during the winter, as well as potentially exposing redds between storm events.

4.4.2 Flow limitations to juvenile rearing

As part of an effort to identify flow-impaired reaches in Dutch Bill Creek, in 2012 UC began conducting annual wet/dry mapping surveys to document the wetted habitat available to fish during the driest point each year. Each September between 2012 and 2015, the stream was walked with a GPS unit and spatial data was recorded characterizing stream conditions as dry, intermittent (wet pools but no surface flow connecting them), or wet (wet pools connected by surface flow) (Figure 26 - Figure 29). Overall, wetted habitat conditions were fairly consistent over the four-year time span, with the proportion of wet habitat ranging from 0.38 in 2014 to 0.59 in 2012 (Figure 30). In all survey years, the lower reaches of Dutch Bill Creek, below the confluence with Tyrone Gulch, became dry or nearly dry and, with progressively drier years, the distance of dry and intermittent habitat extended further upstream over time, encroaching on reaches that remained wet throughout the summer in previous years (Figure 26 - Figure 29). The exception to this was in 2015, when there was slightly more wetted habitat documented than in the 2014 survey (Figure 30), likely due to the release of 0.1 ft^3/s (44 gpm) of water into the stream from the CMRPD water filtration facility between August 24 and December 9 (Russian River Utility 2016).

In order to understand the impact of streamflow conditions on juvenile coho that are rearing in the stream during the summer months, the wetted habitat data was overlaid with juvenile count data from July snorkeling surveys to estimate the proportion of juveniles that were observed in reaches that later dried out or became intermittent during the summers of 2013 through 2015 (no spatial snorkeling data was available in 2012) (Figure 31 - Figure 33). In each map, the distribution and densities of coho salmon and steelhead yoy observed during July snorkeling surveys are shown in relation to the wetted habitat conditions that the fish experienced the following September. The proportion of rearing juveniles that were observed in reaches that became dry or intermittent in September varied by year and species (Figure 34 - Figure 35), ranging from 24% to 70% for coho salmon and 19% to 97% for steelhead. These proportions were influenced by the number and distribution of spawning adults the previous winter (Obedzinski et al. 2016, CA Sea Grant unpublished data) (i.e., if, during the previous winter, adults spawned in reaches that tend to go dry, a higher proportion of juveniles were found in reaches that became dry in late summer).

At the time snorkeling surveys were conducted, surface flows were already extremely low and it is unlikely that fish had the opportunity to move out of drying reaches into reaches that remained wet. PIT tag antenna data collected in summer survival study reaches indicated that almost no movement occurred between July and October of each year. We therefore conclude that salmonids observed in reaches that later became dry had no chance of surviving the summer. These data indicate that low streamflow is a significant contributor to juvenile salmonid survival during the summer rearing season.

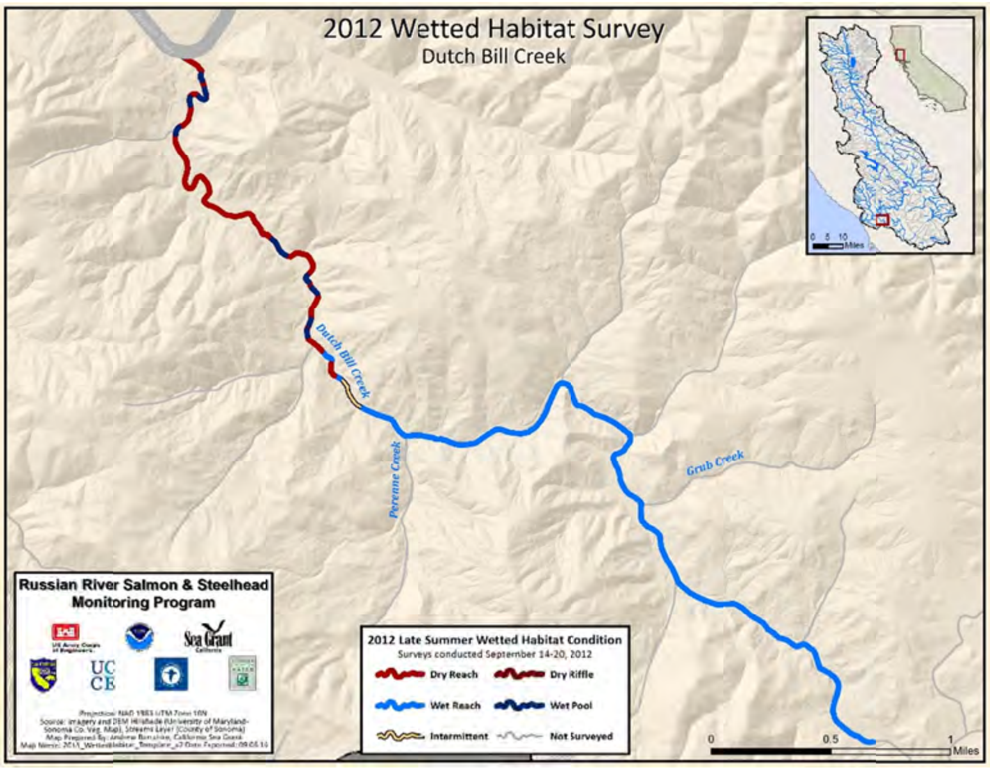

Figure 26. Map showing wetted habitat conditions in Dutch Bill Creek in September 2012.

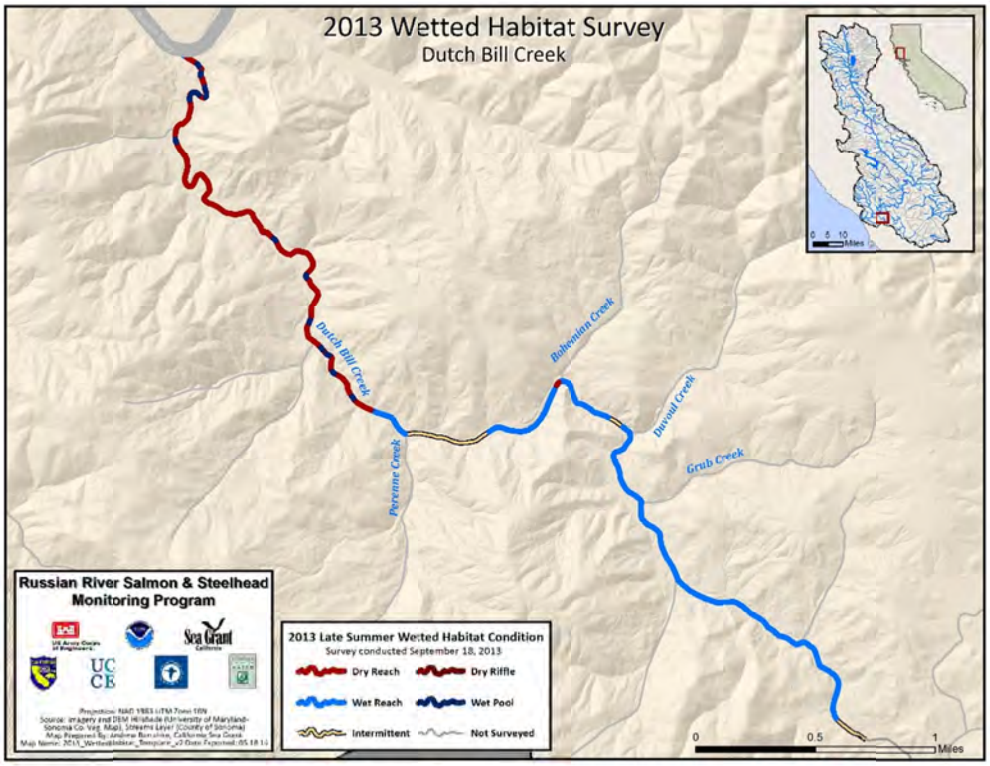

Figure 27. Map showing wetted habitat conditions in Dutch Bill Creek in September 2013.

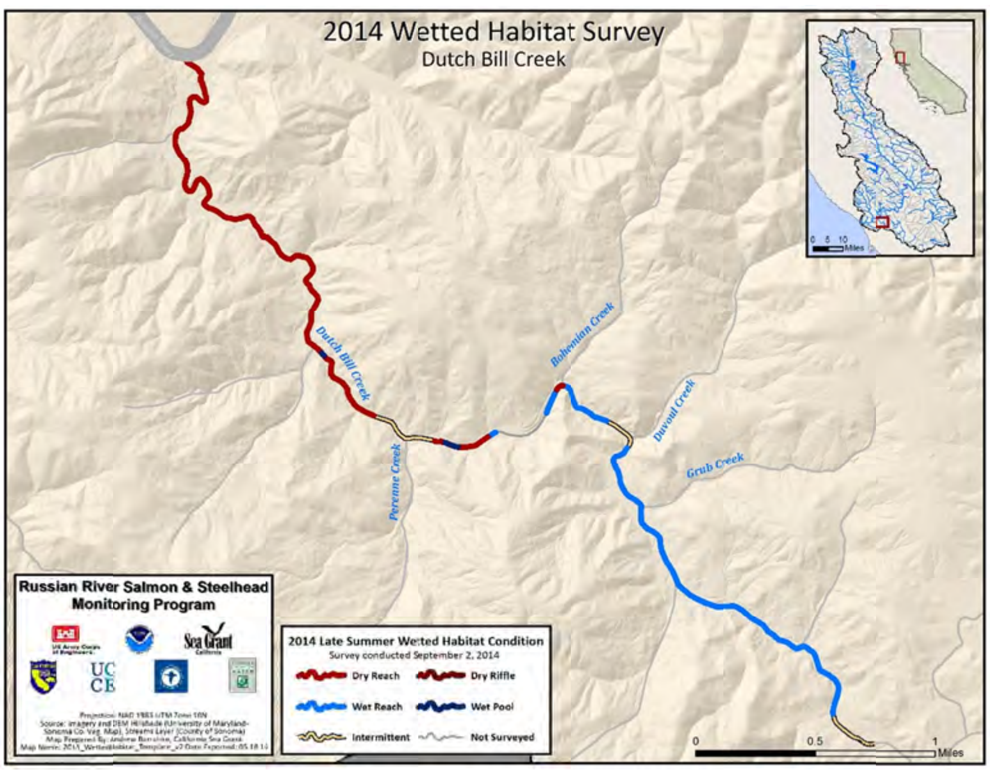

Figure 28. Map showing wetted habitat conditions in Dutch Bill Creek in September 2014.

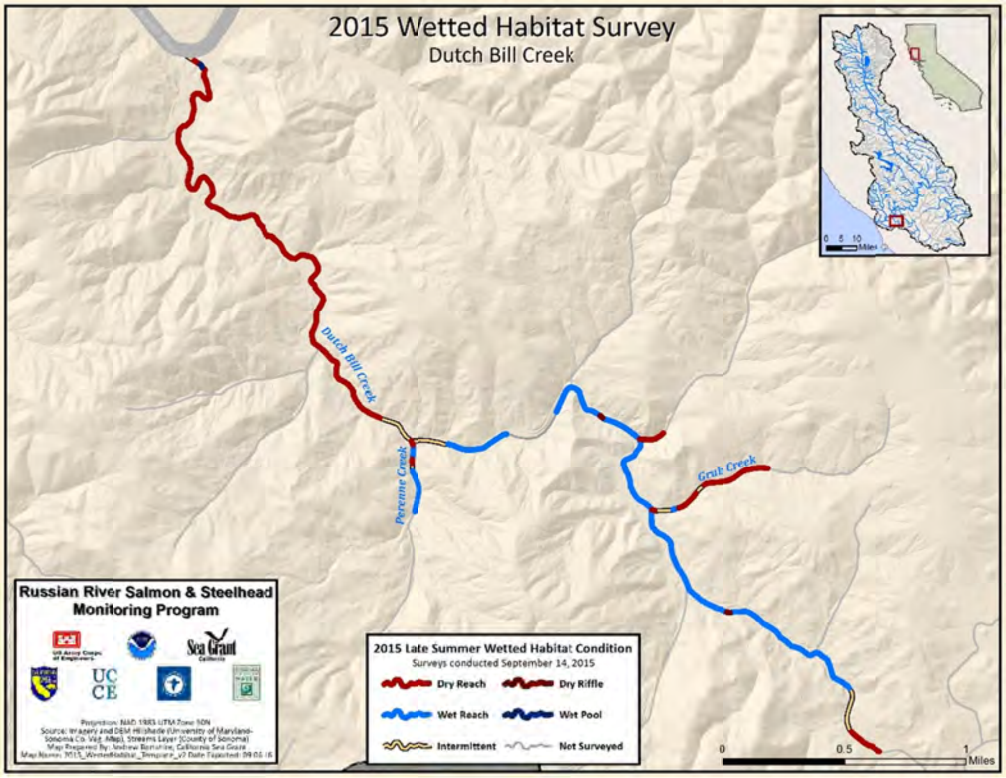

Figure 29. Map showing wetted habitat conditions in Dutch Bill Creek in September 2015.

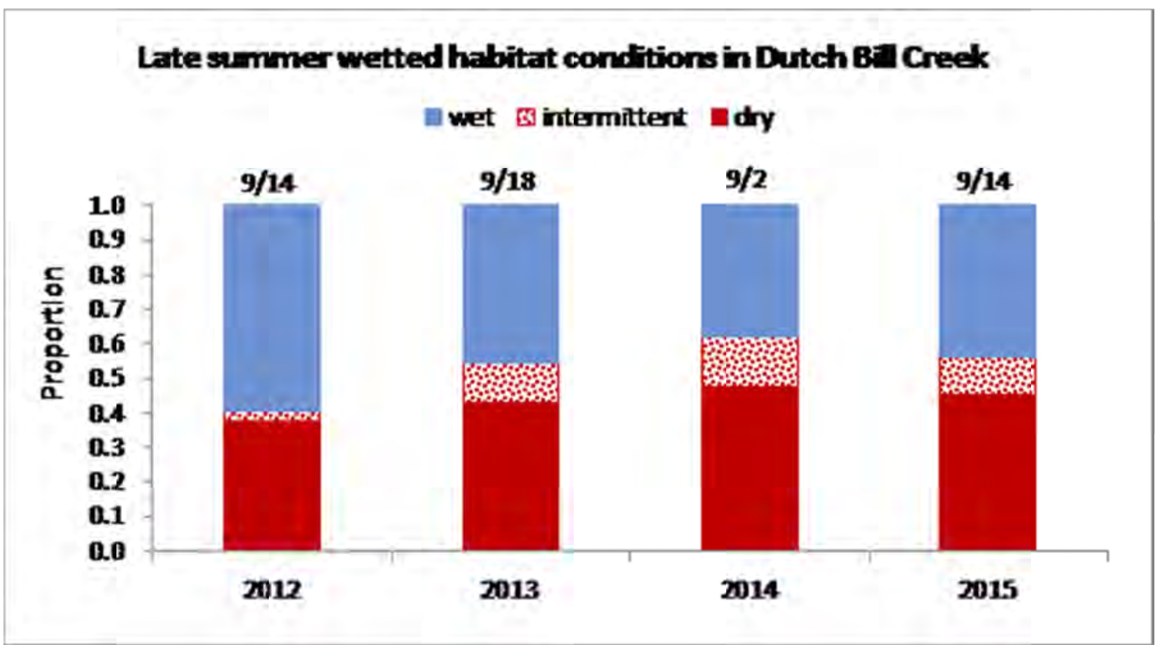

Figure 30. Proportion of dry, intermittent, and wet habitat in Dutch Bill Creek surveyed in September, years 2012-2015.

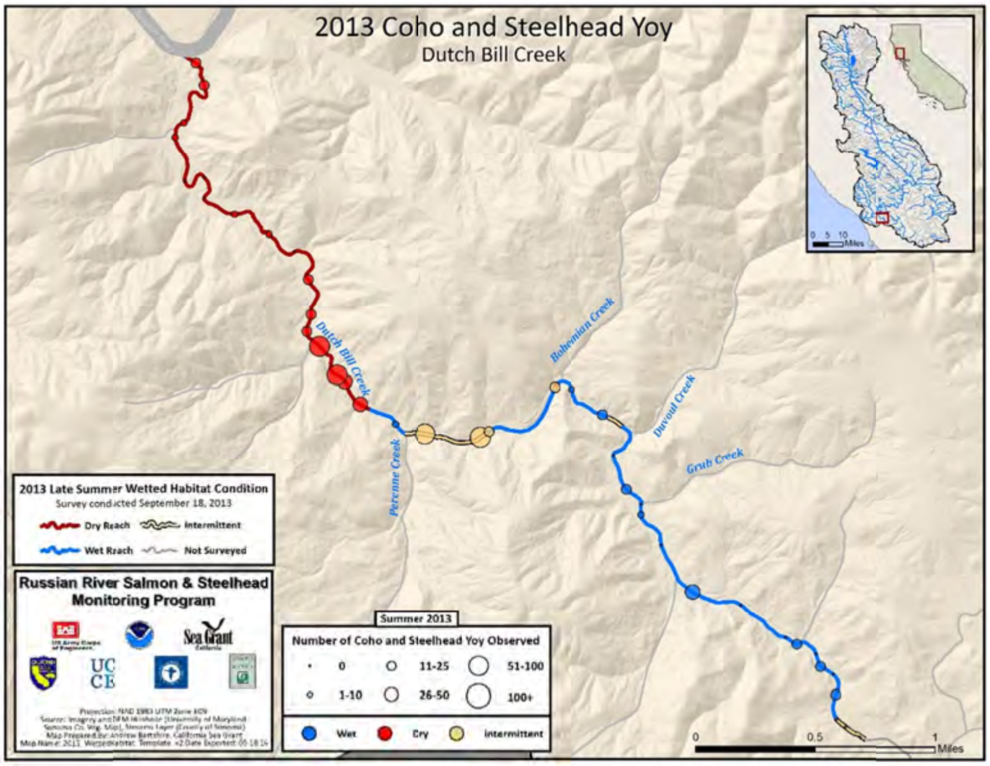

Figure 31. Early summer salmonid yoy observations and late summer wetted habitat conditions in Dutch Bill Creek, 2013.

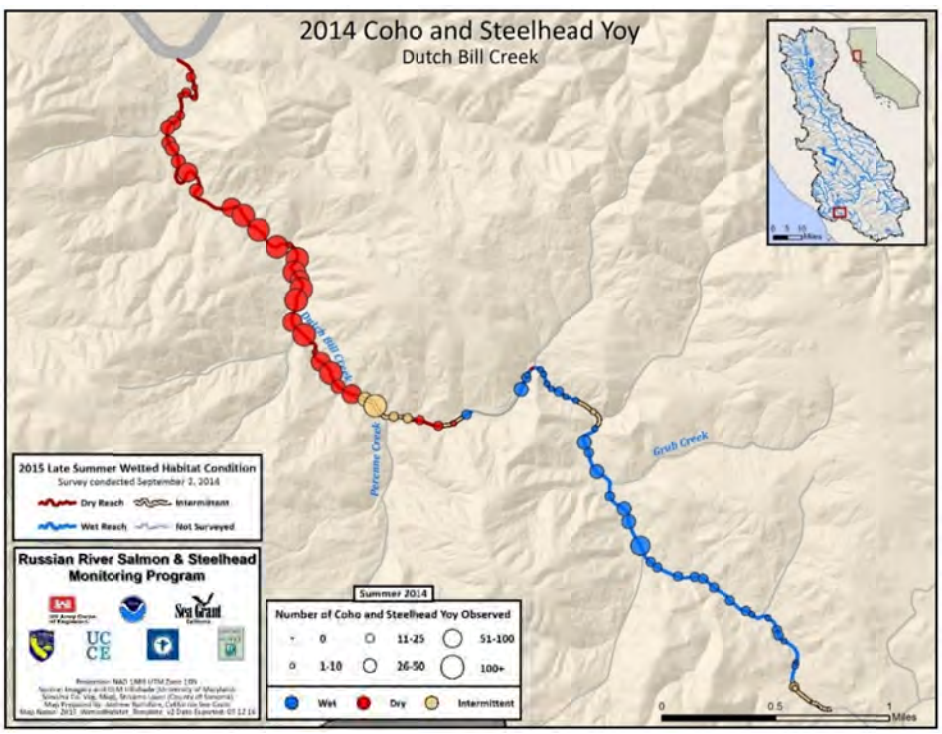

Figure 32. Early summer salmonid yoy observations and late summer wetted habitat conditions in Dutch Bill Creek, 2014.

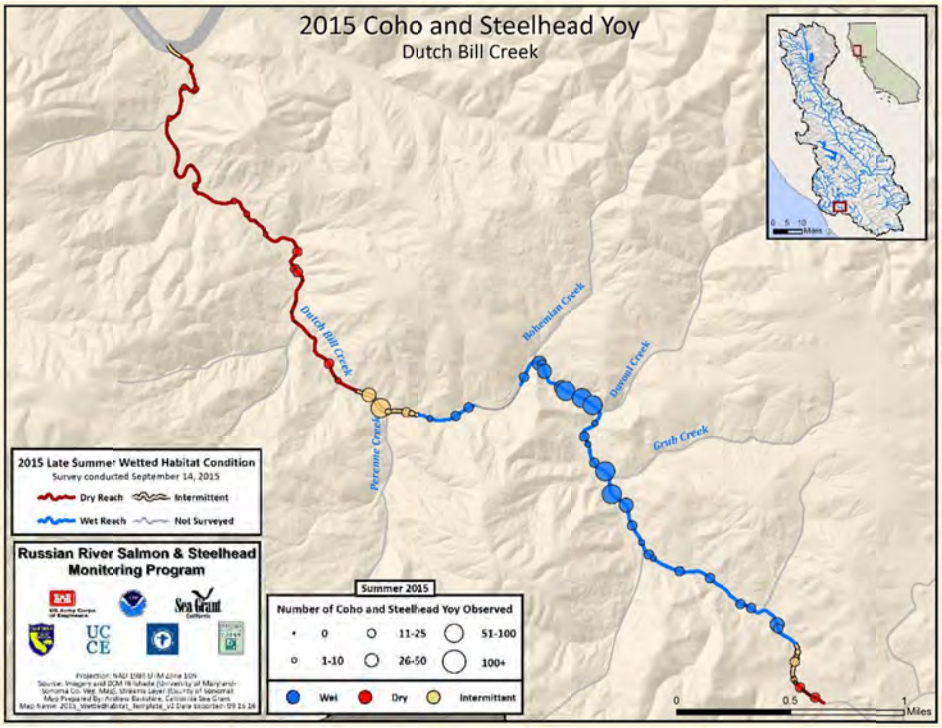

Figure 33. Early summer salmonid yoy observations and late summer wetted habitat conditions in Dutch Bill Creek, 2015.

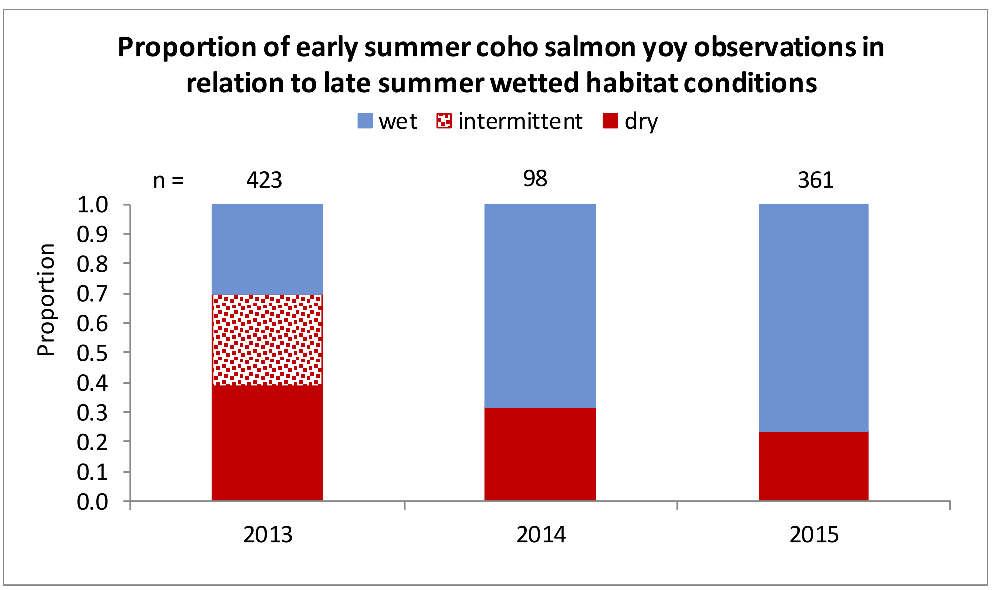

Figure 34. Proportion of early summer coho salmon yoy observed in habitat that was wet, intermittent, or dry during September in Dutch Bill Creek, years 2013 through 2015. Note that counts in stocked reaches were excluded from proportion calculations.

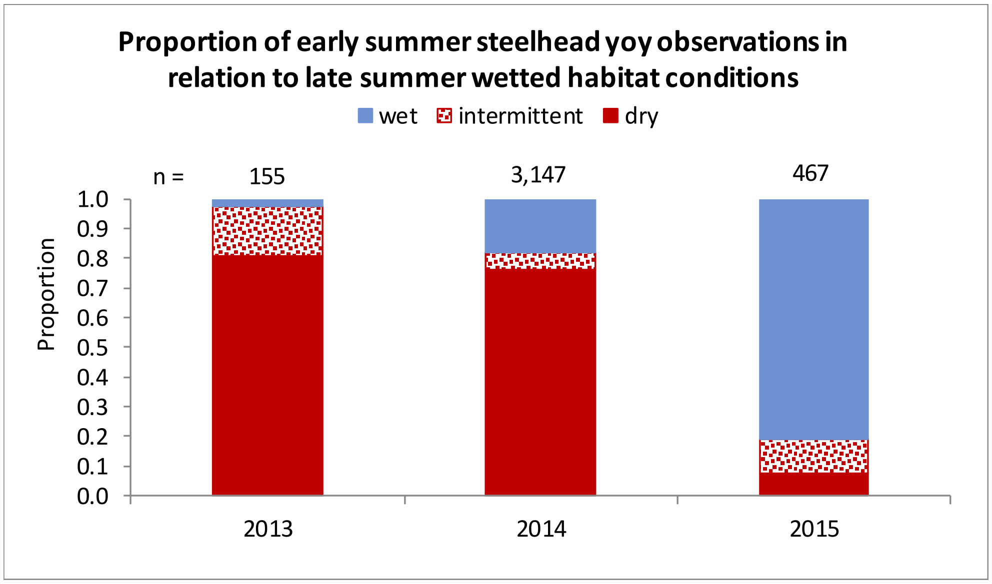

Figure 35. Proportion of early summer steelhead salmon yoy observed in habitat that was wet, intermittent, or dry during September in Dutch Bill Creek, years 2013 through 2015.

4.5 Survival and flow monitoring

Through its work with the Partnership, UC has been conducting an ongoing study of oversummer survival of juvenile coho salmon in relation to flow and other environmental factors in Dutch Bill Creek since 2011, along with three other Russian River tributaries -- Mill, Green Valley and Grape creeks -- since 2010. The objectives of this study are to describe the relationship between juvenile coho salmon oversummer survival and environmental metrics in these streams, and to evaluate the effectiveness of Partnership streamflow enhancement projects at increasing coho salmon survival.

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.

The following sections describe the Dutch Bill Creek study reaches and oversummer survival of juvenile fish in relation to environmental parameters sampled. For an overview of methods and study outcomes related to survival, streamflow, pool connectivity, wetted volume, temperature, dissolved oxygen, and oversummer growth, see Appendix B.

4.5.1 Survival study reaches

UC biologists selected two survival study reaches in each stream: a treatment reach, which was likely to be influenced by streamflow improvement projects, and a reference reach, which was less likely to be influenced by projects. The Dutch Bill Creek treatment reach begins at river kilometer 3.87, encompasses the confluence with Perenne Creek, and extends upstream for 290 meters (Figure 36). It is located in an area of marginal surface flow, at the upstream end of a length of stream that generally loses connectivity in late summer. While the downstream end of the treatment reach usually stays connected, in most years the reach becomes disconnected upstream of Perenne Creek. The Dutch Bill Creek reference reach begins at river kilometer 6.51 (adjacent to Westminster Woods), encompasses the confluence with Grub Creek, and extends upstream for 260 meters (Figure 36). This reach maintains relatively steady depth and flow levels throughout the summer, even in drought years. These reaches have been included in the survival study from 2011-2015 and ongoing assessment is expected.

Rosgen channel type (1994), canopy cover and tree composition, shelter rating, and pool depths were used to describe general morphological conditions and physical habitat characteristics within the Dutch Bill Creek treatment and reference reaches in the interest of understanding relative habitat quality. Overall, physical habitat characteristics in the study reaches are similar. Both received the same channel-type classification from CDFW (F channel), though the treatment reach has a predominantly gravel substrate, while the reference reach has a predominantly cobble substrate (CDFW 2000a). Both reaches have high over-channel canopy cover, are dominated by hardwood trees, and have similarly low shelter ratings. In general, the treatment reach has greater pool depth, with a higher proportion of pools meeting CDFW's established depth benchmark for suitable salmonid habitat (Flosi et al. 1998). See Appendix B for specific habitat values and a discussion of how they relate to established habitat benchmarks for coho.

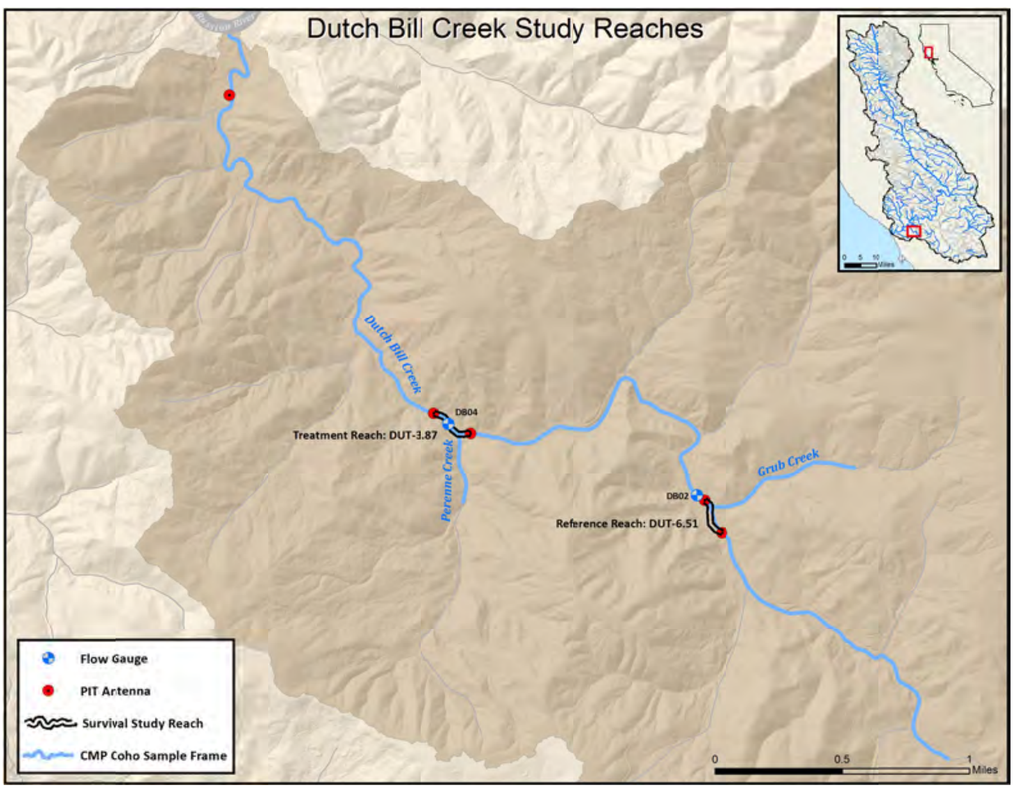

Figure 36. Location of oversummer survival study reference and treatment reaches in Dutch Bill Creek.

4.5.2 Survival in relation to environmental parameters

Over the past five summers, survival was estimated at defined intervals for a study population of approximately 500 PIT-tagged juvenile hatchery coho salmon in each reach, and these results were compared with streamflow, pool connectivity, wetted pool volume, temperature, and dissolved oxygen (DO) data collected within each reach. The frequency of intervals varied depending on the resources available in a given year. For example, in 2011 and 2012, survival and environmental metrics were estimated over five intervals, whereas in 2013, they were only estimated for three intervals. This section discusses oversummer survival of juvenile fish in relation to these environmental parameters. For an overview of methods and results for each parameter sampled, including a discussion of existing conditions in relation to established habitat and water quality benchmarks for California's North Coast streams, see Appendix B.

Relationships between reach-level survival and environmental metrics were evaluated at two scales within each reach; an annual scale and a within-year interval-specific scale. For the annual scale (2011 to 2015), annual overall summer survival (June 15 through October 15 of each year) was compared to summary statistics of environmental metrics representing the same time period during each year (e.g., average discharge between June 15 and October 15). Within-year interval-specific comparisons related survival estimates over each interval to summary statistics of environmental data during that same interval (e.g., June survival was compared with average discharge in June, July survival was related to average discharge in July, etc.). The number of intervals varied by year (ranging from three to five) which precluded our ability to use a nested design in comparisons at the annual scale.

To examine annual patterns, we graphed oversummer survival estimates with summary statistics of environmental metrics between June 15 and October 15 of each year. To test the influence of environmental factors on survival probability at the annual scale, we incorporated the environmental summary statistics as covariates into survival models following the guidelines of Burnham and Anderson (2002). At the annual scale, none of the models tested demonstrated support for an influence of environmental metrics on survival. We attribute this finding to the coarse level of the analysis that did not make use of the interval-specific data, along with the fact that survival estimates were not extremely variable over the five-year period. At this scale of analysis, it could take many years and/or extreme interannual differences to detect statistical relationships. In future analyses, we hope to develop models that can make use of the finer scale data, despite the differences in the number of intervals of data collected each year. Despite the lack of statistical relationships, we included summary graphs of survival and environmental metrics for each parameter in the following sections, as we found them useful in characterizing conditions in the Dutch Bill Creek study reaches (Figure 37 - Figure 47).

For interval-specific comparisons within each reach, in each year, we used a similar modeling approach in which reach-scale average discharge, average minimum discharge, days of pool disconnection, cumulative days of pool disconnection, maximum weekly average temperature (MWAT), maximum weekly maximum temperature (MWMT), and average dissolved oxygen

(DO) were incorporated as covariates into survival models to test the influence of these factors on survival probabilities. The same guidelines (Burnham and Anderson 2002) were used to interpret results; models with ΔAICc values ≤ 4 were considered to explain the data well (high model support), while models with ΔAICc values > 4 and ≤ 7 indicated moderate support, and models > 7 indicated low support. In models achieving either high or moderate support, we examined the beta value corresponding to the environmental covariate in question and if the 95% confidence intervals of that beta did not overlap zero, we considered the relationship significant. Covariates evaluated in the analysis included reach-scale average discharge, average minimum discharge, days of pool disconnection, cumulative days of pool disconnection, MWAT, MWMT, and average DO.

At the within-year interval-specific scale, models demonstrating high or moderate support were found for some of the environmental metrics in some years. The results for each metric are summarized in the following sections.

4.5.2.1 Streamflow

While annual decreases in survival in the Dutch Bill Creek treatment reach appear to correspond to decreases in flow over the first three study years, data from the next two years do not support a clear multi-year relationship (Figure 37). Annual oversummer survival estimates of juvenile coho salmon in the reference reach did not appear correlated to discharge among years (Figure 38).

Interval-specific survival models including either average discharge or average minimum discharge had high or moderate support in the Dutch Bill Creek treatment reach in years 2012, 2013 and 2014, and in the reference reach in years 2011, 2014, and 2015. Significant positive correlations between these metrics and survival were observed in both reaches in 2014. Surprisingly, a significant negative correlation was observed in the reference reach in 2015, but it is possible that results may have been confounded by the CMRPD flow release, which increased flows during the last two intervals of the season after fish had already been impacted by the low streamflow conditions they experienced earlier in the summer.

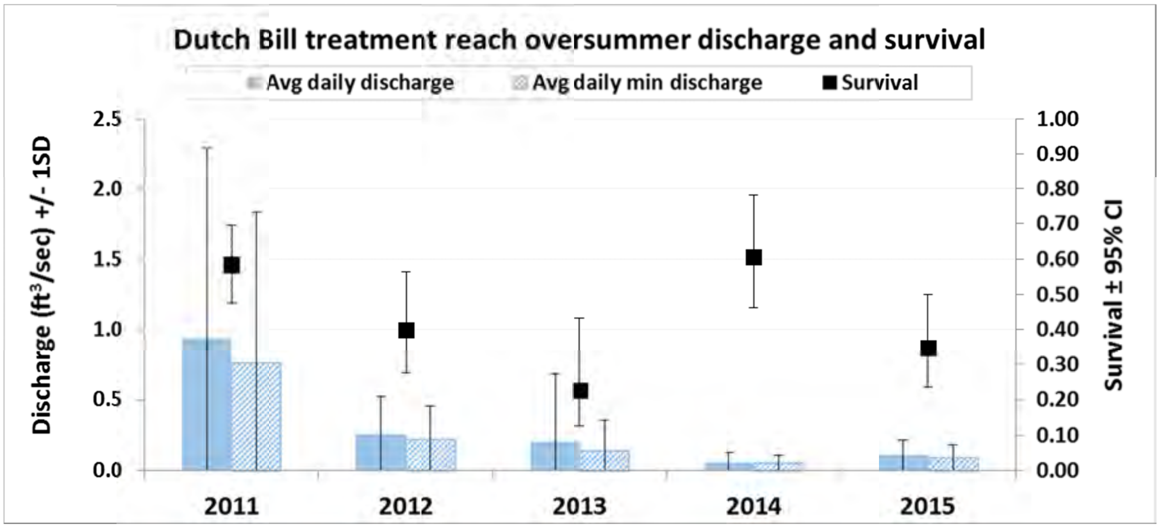

Figure 37. Stream discharge and survival in the Dutch Bill Creek treatment reach between June 15 and October 15, 2011-2015.

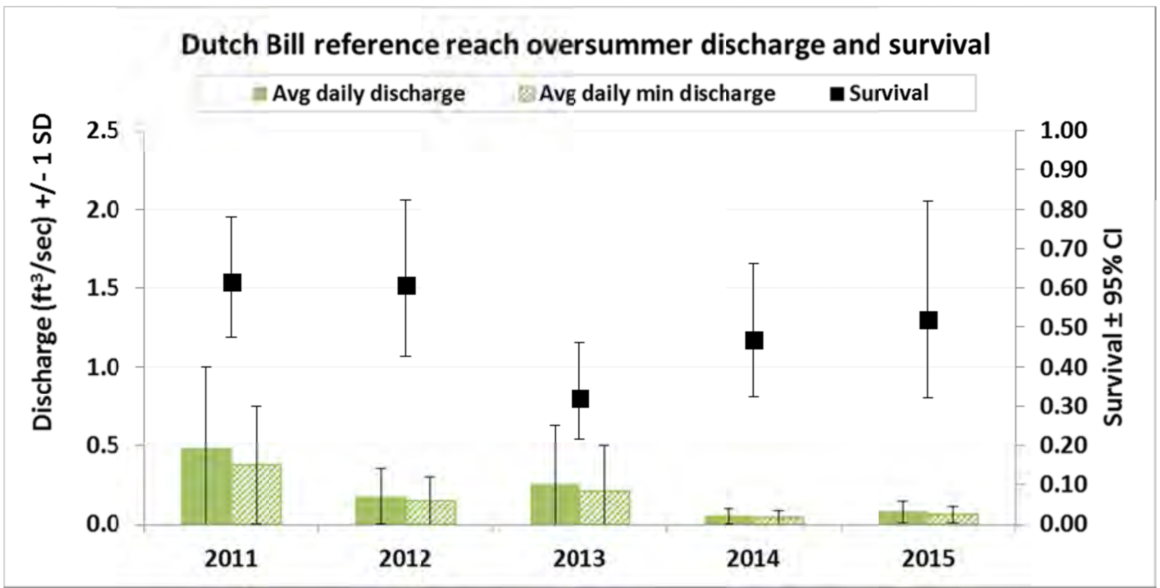

Figure 38. Stream discharge and survival in the Dutch Bill Creek reference reach between June 15 and October 15, 2011-2015. Missing discharge values from 2013 were estimated based on correlations between the two study reach streamflow gauges.

4.5.2.2 Pool connectivity

Although no clear patterns between days of pool disconnection and survival were observed on an annual scale (Figure 39, Figure 40), when examined at an interval-specific level within each reach and year, patterns were observed, with decreases in survival corresponding to increased days of pool disconnectivity (e.g., Figure 41). Interval-specific survival models including days of disconnection or cumulative days of disconnection had high support in the treatment reach in all years except 2011, and in the reference reach in all years except 2013. Significant negative relationships between these metrics and survival were observed in the treatment reach in 2012, 2014, and 2015 and in the reference reach in 2011, 2014, and 2015.

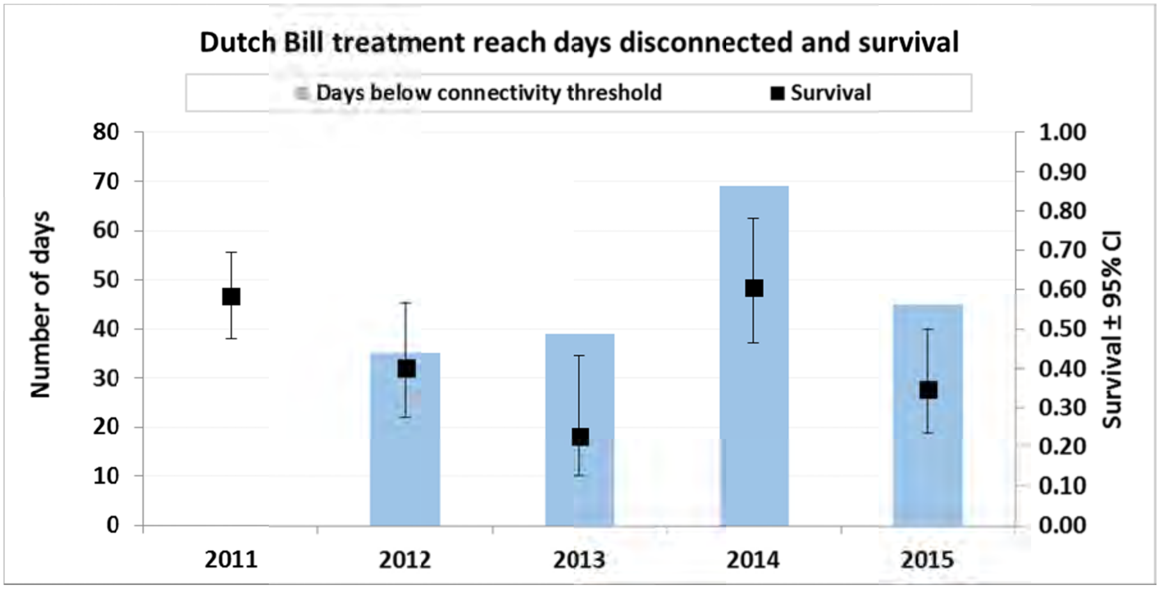

Figure 39. Days of pool disconnection and survival in the Dutch Bill Creek treatment reach between June 15 and October 15, years 2011-2015.

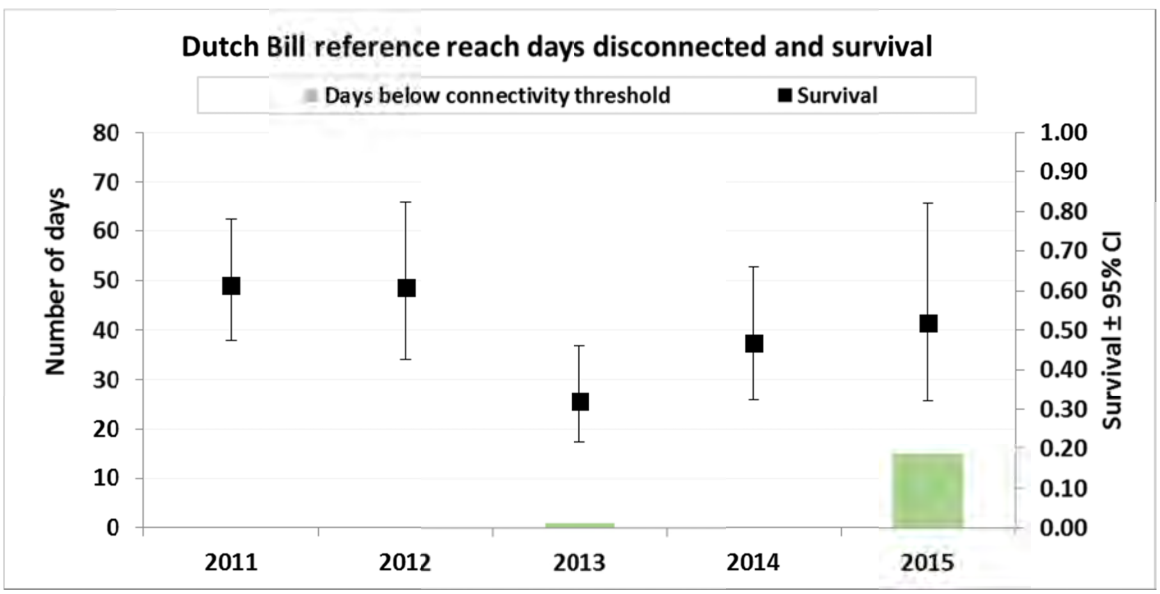

Figure 40. Days of pool disconnection and survival in the Dutch Bill Creek reference reach between June 15 and October 15, years 2011-2015. Missing discharge values from 2013 were estimated based on correlations between the two study reach streamflow gauges and used to calculate days disconnected.

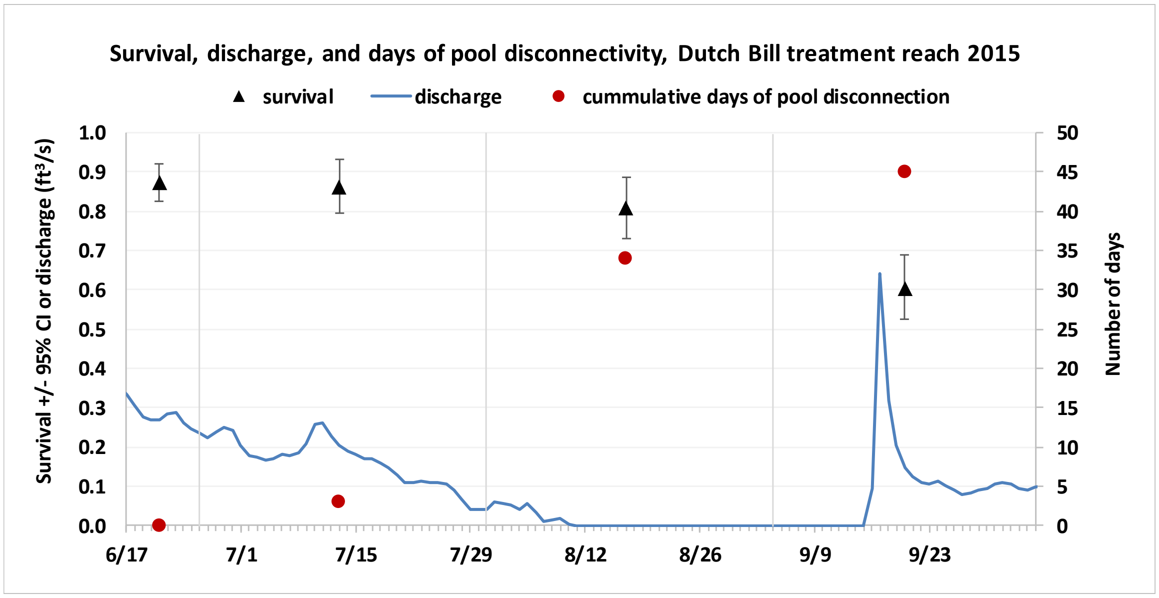

Figure 41. Example of negative relationship between survival and days of pool disconnection in Dutch Bill Creek treatment reach in 2015.

4.5.2.3 Wetted volume

The highest total wetted volume each year in Figure 42 and Figure 43 is the amount of water present during the June sample and the lowest is the amount remaining at the driest point of the season (generally in September). The difference between these two values represents the total change in wetted volume over the summer study period. While oversummer survival exhibits similar patterns to wetted volume in the treatment reach for the first three study years, this annual trend did not continue in 2014 or 2015 (Figure 42). Wetted volume in the reference reach remained relatively stable from 2011-2015, as did survival, with the exception of 2013 (Figure 43).

Interval-specific models including wetted volume as a covariate had high or moderate support in the treatment reach in years 2012 through 2014 and in the reference reach in 2011 through 2014. Significant positive relationships between wetted volume and survival were documented in the treatment reach in 2014 and in the reference reach in 2013 and 2014.

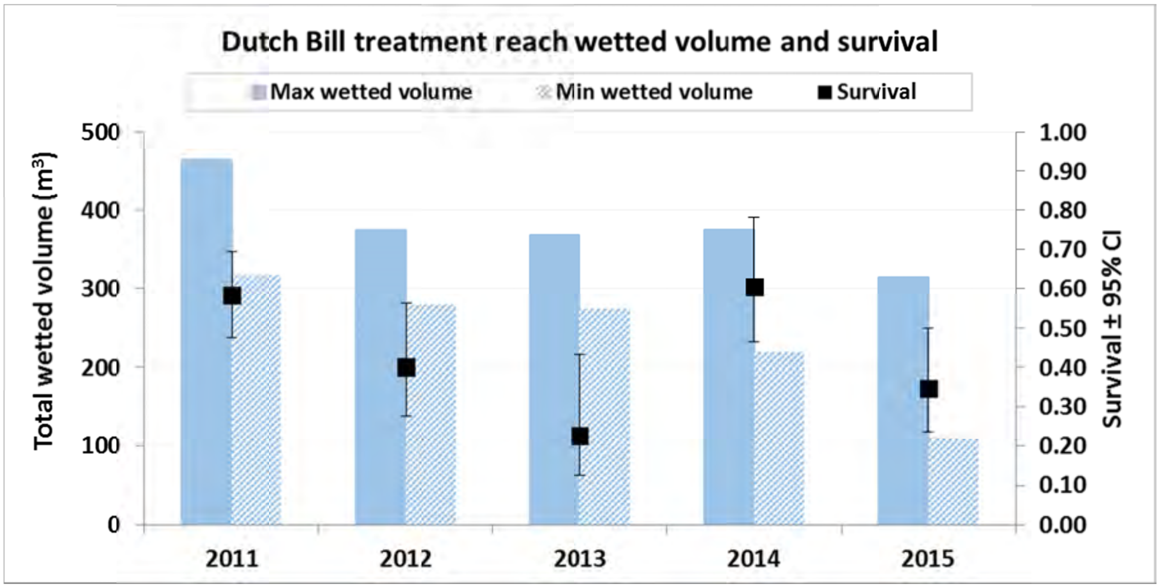

Figure 42. Total wetted volume by year at the wettest (June) and driest points in the season plotted with oversummer survival in the Dutch Bill Creek treatment reach.

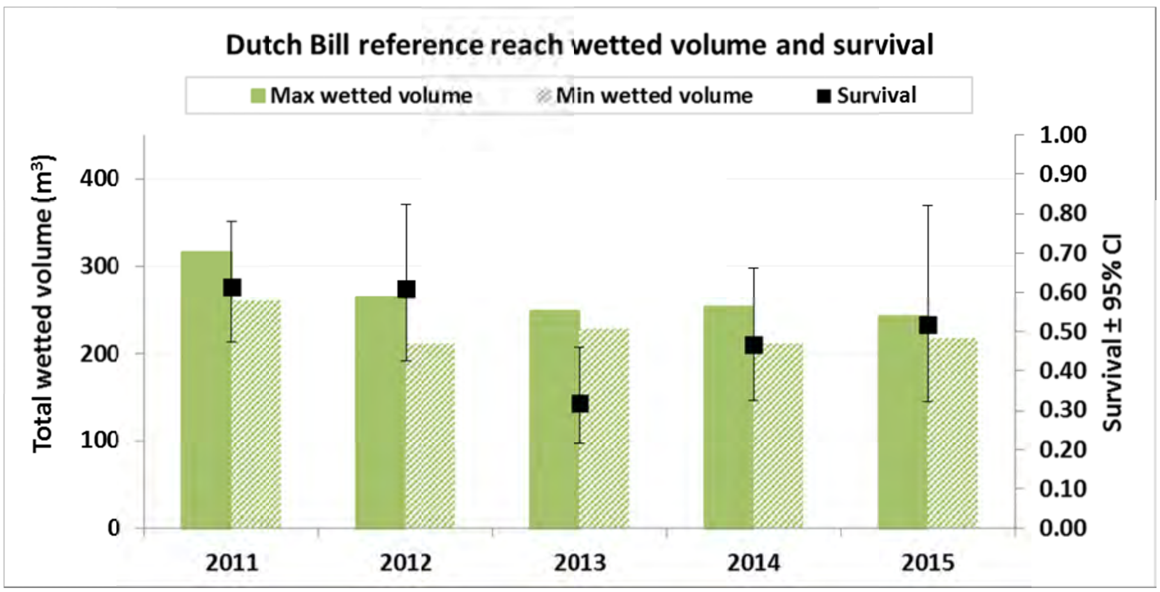

Figure 43. Total wetted volume by year at the wettest (June) and driest points in the season plotted with oversummer survival in the Dutch Bill Creek reference reach.

4.5.2.4 Water temperature

At an annual scale, the significantly lower survival estimates observed in both study reaches in 2013 correspond with the warmest temperatures recorded, suggesting an inverse relationship between survival and water temperature above a certain threshold (Figure 44, Figure 45). According to evaluations of preliminary data, increases in temperature did not appear to influence survival until MWAT and MWMT were more than 1.0°C above defined threshold levels for coho.

Interval-specific survival models within each reach in each year that included MWAT showed high to moderate support in the treatment reach in 2011 through 2013, and in the reference reach in 2014, while models including MWMT showed high support in the treatment reach in all years except 2012. Few significant correlations were observed between survival and MWAT or MWMT and the direction of the relationship varied. No significant correlations at the interval-specific scale were observed in 2013 when avoidance thresholds were exceeded.

Uncertainty surrounding these results is likely an effect of the fact that the relationship between survival and temperature may change above or below certain thresholds (i.e., higher temperatures may improve survival until an avoidance threshold is reached). Because temperatures generally remained below avoidance thresholds in almost all years, it is also likely that we did not have sufficient data to clearly evaluate the relationship between survival and temperature.

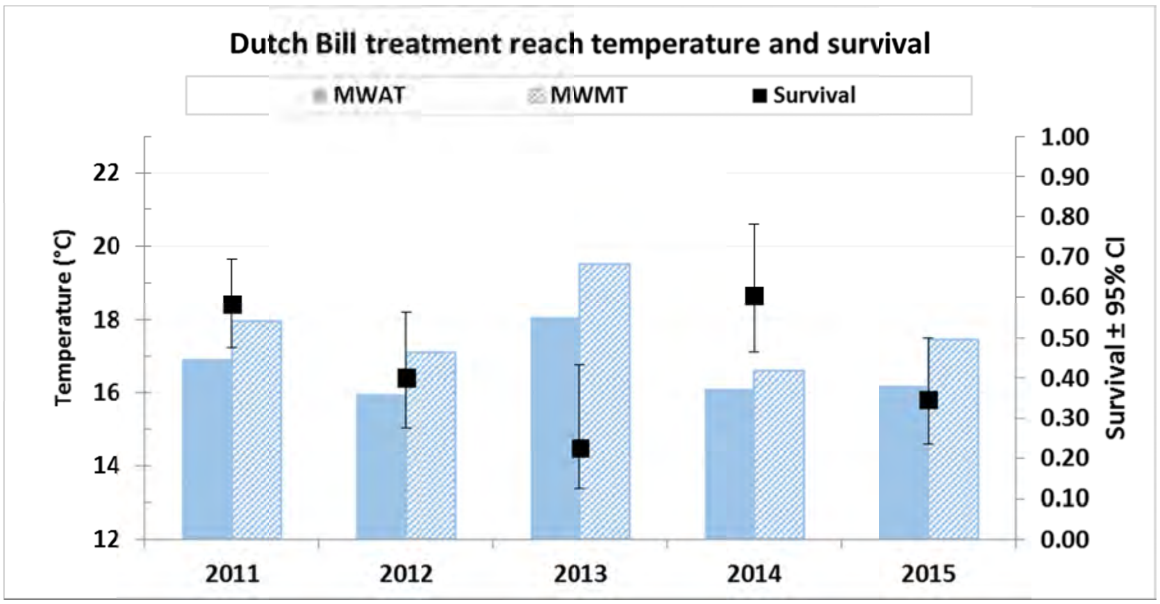

Figure 44. MWAT, MWMT, and oversummer survival of juvenile coho in the Dutch Bill Creek treatment reach each year from 2011 through 2015.

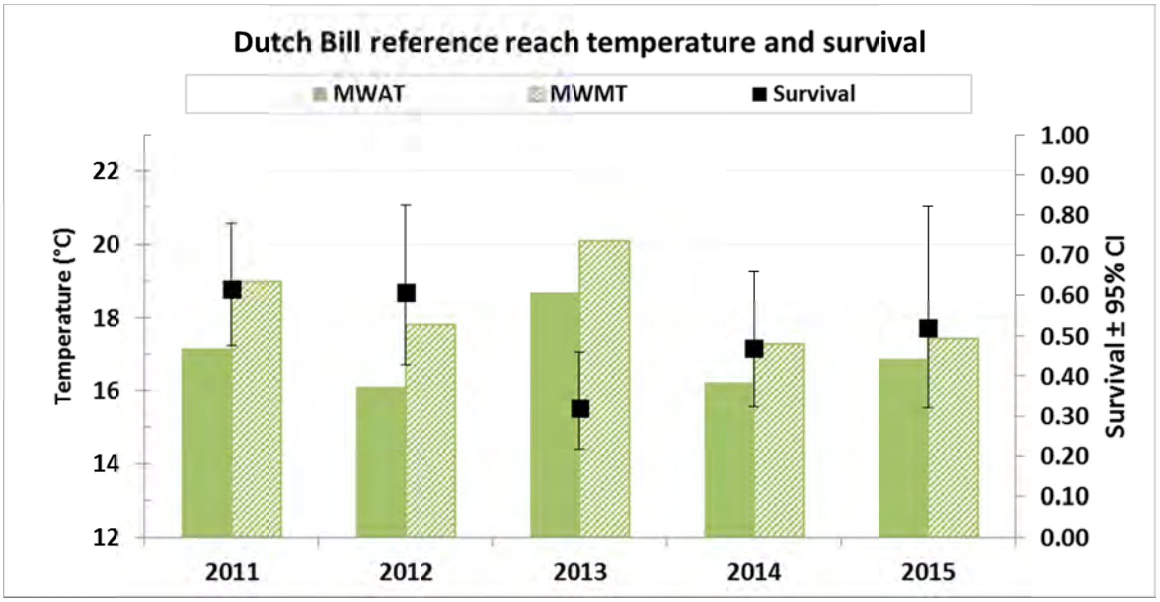

Figure 45. MWAT, MWMT, and oversummer survival of juvenile coho in the Dutch Bill Creek reference reach each year from 2011 through 2015.

4.5.2.5 Dissolved oxygen

Average oversummer DO in the Dutch Bill Creek treatment reach decreased steadily from 2011 to 2015; however, annual oversummer survival did not reflect this same trend (Figure 46). In the Dutch Bill Creek reference reach, average DO concentrations over the summers of 2011 to 2015 remained above the North Coast Regional Water Quality Control Board's (NCRWQCB) recommended objective of 7.0 mg/L, even at the lowest points, and with the exception of 2013, survival also remained relatively consistent among years (Figure 47).

Examining patterns in survival and DO within year-specific intervals, particularly in years when DO levels fell below objectives (2014, 2015), offered a little more insight into the relationship between survival and DO. Survival models including DO demonstrated high to moderate support in the treatment reach in 2012 and 2013 and in the reference reach in 2011, 2013 and 2014; however, the only significant correlations observed were positive correlations in the reference reach in 2013 and 2014.

The apparent lack of correlation between survival and DO is likely due to multiple factors. In general, DO conditions were suitable to fish and therefore likely did not have a strong influence on survival in these reaches during these years. Even in 2014 and 2015 in the treatment reach, when DO levels fell below objectives, they may not have been low enough to dramatically impact survival. Inconclusive results may also be an artifact of collecting DO data on only one sampling occasion per interval, rather than using continuous data loggers. Begininning in 2015, we deployed continuous DO loggers in each reach with the goal of gaining additional insight into this complex relationship.

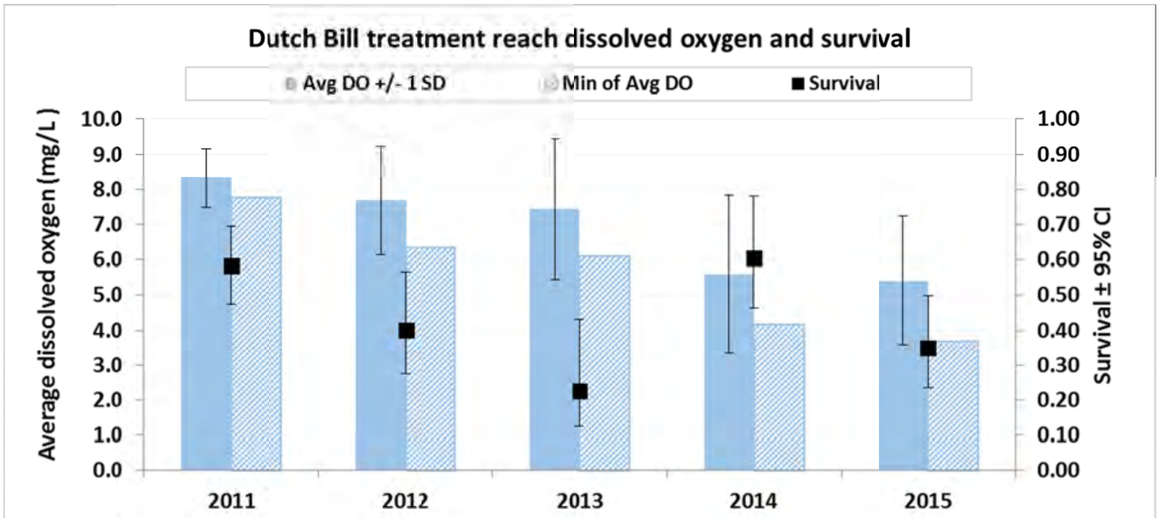

Figure 46. Average of reach-scale dissolved oxygen concentrations in the Dutch Bill Creek treatment reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

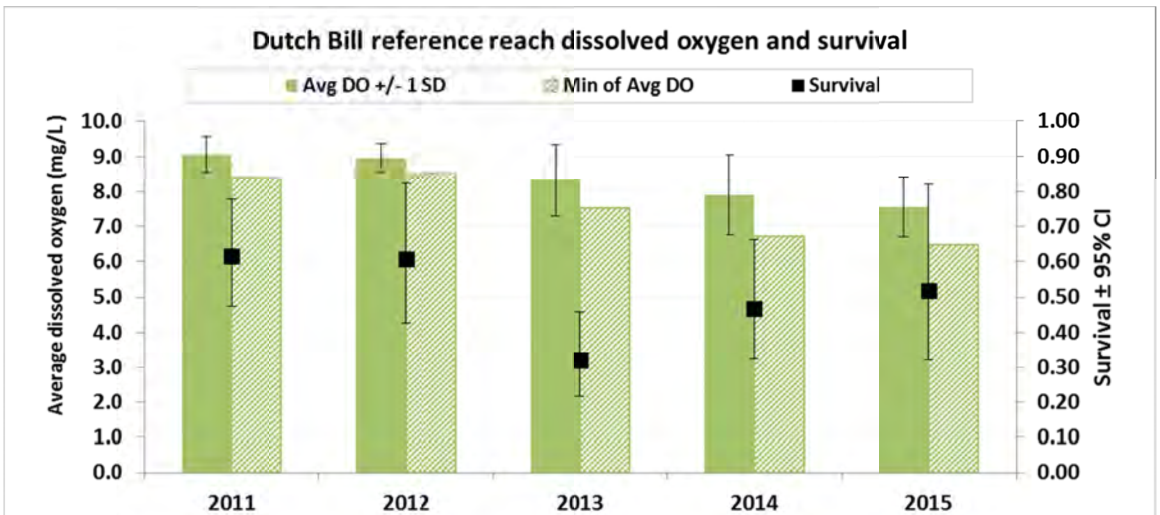

Figure 47. Average of reach-scale dissolved oxygen concentrations in the Dutch Bill Creek reference reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

4.6 Summary and discussion

Overall, average survival of juvenile coho salmon in Dutch Bill Creek (0.47) was just above the average observed in all Russian River tributaries across streams and years studied (0.42), and it was remarkably consistent, even in progressive drought years when flows fell below 0.5 ft^3/s (3.74 gal/s). Only the Mill Creek reference reach exhibited less variability in survival among years than the Dutch Bill Creek reference reach, and the Dutch Bill Creek treatment reach had the least variability in annual oversummer survival of any of the four treatment reaches in the study.

The consistency of survival among years may be explained in part by the relative consistency of some of the environmental parameters examined. Although streamflow fell below 0.5 ft^3/s much of the time, pools retained water, temperatures generally remained cool, and DO concentrations never fell below acute mortality thresholds. In streams where survival fell to extremely low levels, pools became nearly (or completely) dry and DO fell below acute mortality thresholds.

As we have observed in other Russian River study streams, a strong environmental predictor of summer survival of juvenile coho salmon in Dutch Bill Creek is the number of days of pool disconnectivity, with increased days of disconnectivity having a negative effect on survival. Based on the results of this analysis, the Partnership has made attaining pool connectivity in the priority stream reaches a primary goal, as described in Section 5. Comparisons of streamflow data with wetted habitat data have indicated that flows as low as 0.01 ft^3/s and 0.05 ft^3/s were sufficient to keep pools connected in the Dutch Bill Creek reference and treatment reaches, respectively. These data have been used to develop an approach for identifying, prioritizing, and evaluating projects in terms of their cumulative ability to attain pool connectivity throughout priority reaches (see Section 5.3, Metrics).

Other environmental predictors of survival at the reach and interval-specific scales in Dutch Bill Creek included average and minimum daily flow, wetted volume and DO. Significant positive correlations between these metrics and survival were observed in 2014, in either one or both reaches of Dutch Bill Creek. As with relationships at an interannual scale, the fact that significant correlations were not observed within other years likely results from the fact that there was little variation in interval-specific survival and/or environmental metrics in those years, rather than a lack of importance of these variables on survival (i.e., a sufficient range in survival and/or the environmental metric of interest is necessary to establish a correlation or determine that there is no correlation). Despite the extreme drought years, pool connectivity, wetted volume, temperature, and DO levels may not have reached levels that severely impact survival.

At the interval-specific scale, temperature was not a good predictor of survival, and this is likely because temperatures rarely rose above avoidance thresholds, even in extreme drought years. In general, we have found that when flows fall to extremely low levels during the summer season (e.g. <0.05 ft^3/s), temperatures typically remain low, likely a result of increasing groundwater influence. It is not until pools become disconnected from the water table that temperatures begin to spike and, by that point, other factors such as low DO and wetted volume have already severely impacted survival. It is notable, however, that on an annual scale, the lowest survival observed in both reaches was in 2013, when water temperatures were highest, rising more than 1°C above avoidance thresholds described in Welsh et al. (2001). Because of the complex relationships between flow, temperature and survival, we do not expect to develop a clear relationship between temperature and survival in streams such as Dutch Bill Creek, which remain cool even in low flow conditions; rather temperature may serve as a useful metric in explaining diversions from expected outcomes, such as in 2013.

Oversummer survival in the treatment reach in 2014 was unexpectedly high compared to other years, given the relatively low streamflow conditions, high number of days of pool disconnection, and relatively low wetted volume and DO levels. Although interval-specific relationships were observed between survival and environmental factors in 2014, it is possible that confounding factors that were not quantified in this study, such as predation, could have obscured among-year relationships between survival and environmental conditions. For example, otters have been known to regularly inhabit both the treatment and reference reaches, and large resident steelhead have been observed during electrofishing surveys. Predation of juvenile coho could have contributed to decreased survival in some years and not others (e.g., reduced predation in 2014 may have led to higher survival in that year), confounding among-year relationships between survival and the metrics included in our study.

Although survival was above average in both reaches of Dutch Bill Creek, it was not as high as survival observed in other study stream reaches with similar or even lower streamflow levels, such as the reference reaches in Green Valley and Mill creeks. This is also potentially explained by higher predation or other factors not related to flow. Although predation was not quantified in this study, more anecdotal observations of otters occurred in Dutch Bill Creek than in any other study stream. Habitat improvement projects that include increased woody debris or other forms of shelter could help juvenile coho avoid predators, thus increasing survival. Because flows have been extremely low during the course of this study, we have not been able to evaluate whether or not increased flow will increase survival to higher levels observed in reaches of Russian River tributaries.

In this study, we observed juvenile coho salmon surviving at flows that dropped below 0.5 ft^3/s. These low surface flows that sustain connectivity should be considered minimum persistence flows for the Dutch Bill Creek watershed, and not levels that support high growth or sufficient production. Although fish may be able to persist at extremely low flows in Dutch Bill Creek, if they are in poor condition at the end of the summer (e.g., 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. It has been shown that the amount of foraging habitat available to fish in a stream is a function of streamflow (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.

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 streamflow, invertebrate drift and juvenile rainbow trout growth increased. Similarly, Nislow et al. (2004) found increased growth in juvenile Atlantic salmon rearing in a stream in years with higher streamflow. Based on these findings, we can expect that increasing summer discharge 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 Dutch Bill Creek, however, in the treatment reach, which generally had higher flow, we observed higher growth rates than in the reference reach in all years except for 2015 (Figure 77).

Achievement of long-term 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. 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 slightly larger watershed than Dutch Bill 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 streamflow targets relative to specific goals (e.g., minimum persistence, population stability, population growth).

The results of this study indicate that increasing daily discharge, pool connectivity, wetted volume, and DO concentrations in salmonid rearing reaches would support increased survival of salmonids through the juvenile life stage. Each of these parameters could be positively affected by enhancing streamflow. Furthermore, the literature shows that increasing summer discharge beyond minimum persistence flows would likely promote higher growth in juvenile salmon and, in turn, more adults returning to spawn. Based on the results of this study, we conclude that efforts to improve streamflow in Dutch Bill Creek would be a critical step towards coho salmon recovery in the watershed.

UC will continue its monitoring effort in the Dutch Bill 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. For evaluating the direct effect of project implementation on coho salmon survival, we intend to continue estimating survival in the reference and treatment reaches each year. Beginning in 2016, we anticipate increased flows, and, in turn, increased survival in the treatment reach resulting from the cessation of the diversion at Westminster Woods Camp and Conference Center (downstream of the reference reach and upstream of the treatment reach) as well as a flow release by CMRPD upstream of both reaches. However, because of the location of certain projects in relation to our study reaches, as well as potential confounding factors (e.g., differing rates of predation, extreme drought, water contributions from multiple projects, etc.), it will not always be possible to document the direct effects of each project on survival. In cases where direct evaluation is not possible, we will use the relationships we have identified between survival and streamflow metrics to estimate the effects of projects on survival. For example, if streamflow increases as a result of project implementation to the point where pools reconnect in a given reach, we will assume that streamflow is no longer limiting the minimum persistence of juvenile coho throughout the summer season. See Section 5.3 for examples of this approach.

5 Recommendations: Flow improvement strategies

The previous sections have identified flow as a limiting factor for coho salmon in Dutch Bill Creek, and demonstrated that pool connectivity is a key factor in supporting the persistence of juvenile fish throughout the dry season, and shown that projects that keep pools connected by collectively increasing streamflow as little as 0.01 - 0.05 ft^3/s have the potential to improve survival of juvenile coho salmon throughout the summer rearing season. Drawing from the streamflow, human water need, and fish monitoring data provided above, this section recommends strategies to achieve the Partnership's primary goal of maintaining pool connectivity within Dutch Bill Creek. Section 5 reviews our priority reaches, provides a suite of recommendations, and evaluates whether those recommendations -- if and when implemented -- are sufficient to improve pool connectivity. For this exercise, we use metrics developed through the fish and flow monitoring work described above.

5.1 Reach prioritization for instream flow projects

Partnership members have identified two priority reaches that will serve as the focus of the Partnership's effort to improvement streamflow within Dutch Bill Creek (Figure 48). These reaches were selected by evaluating habitat survey data collected by CDFW, as well as streamflow, fish distribution, and wetted habitat data collected by the Partnership. Importance as fish habitat, level of flow impairment, and feasibility of improving flows within the 12-year timeframe of NFWF's Keystone Initiative were all considered in priority reach selection.

The reaches were characterized as follows:

- The reach of Dutch Bill Creek downstream of the confluence with Tyrone Gulch is heavily flow-impaired, as verified by recurring drying in all recent years of record (CDFW 2000a, UC published data). This reach is likely underlain by a losing aquifer and has little chance of sustaining perennial flows, even in the case of significant streamflow enhancement efforts. Despite salmonid presence in this reach, it will not be a primary focus of Partnership efforts because the level of improvement needed is outside of the scope and timeframe of NFWF's Keystone Initiative.
- The reach of Dutch Bill Creek between Tyrone Gulch and the confluence with Duvoul Creek (Priority Reach A, Figure 48) is marginally flow-impaired. Because this reach contains important coho salmon spawning and rearing habitat and partners believe it is likely to respond favorably to flow enhancement projects, it was designated as a priority reach.
- The reach upstream of the confluence with Duvoul Creek to the upper extent of anadromy (Priority Reach B, Figure 48) is also important for fish but generally sustains perennial flow in non-drought years and contains relatively high-quality habitat. Coho salmon survival and production would likely benefit from increases in streamflow in this reach so it was also designated as a priority reach. Because this reach will not require the same level of flow increases to improve coho salmon survival, it was distinguished from Priority Reach A (Figure 48).

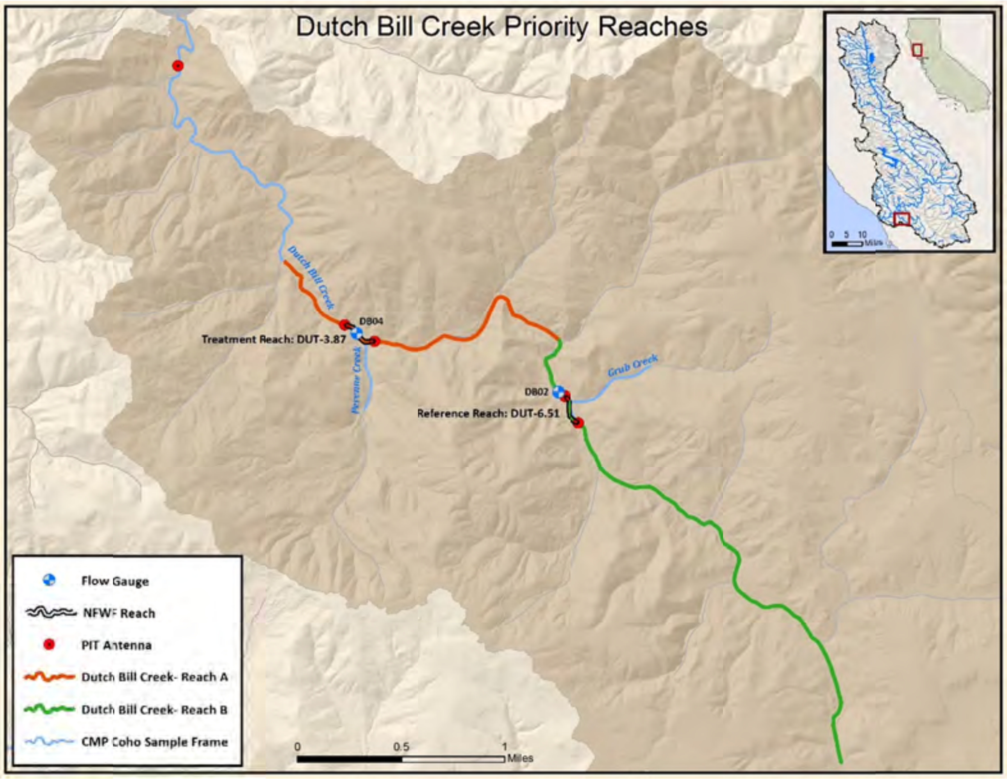

Figure 48. Location of priority focus reaches in Dutch Bill Creek.

5.1.1 Consistency with other priority reach identification

This prioritization is largely consistent with the conclusions of other efforts to identify priority reaches for addressing low summer streamflow and implementing flow enhancement projects in Dutch Bill Creek.

For its 2016 report, O'Connor Environmental Inc. (OEI) performed an analysis of "the spatial and temporal distribution of stream flow throughout [Dutch Bill Creek] relative to coho habitat requirements to assist in prioritizing restoration efforts and developing strategies to maintain or improve summer streamflow" (O'Connor Environmental Inc. 2016). It did so by developing and calibrating a hydrologic model that simulated surface-groundwater interactions and estimated summer baseflow across the drainage network.

The report concludes: "During both dry and average Water Year conditions, the 4.3 river miles of Dutch Bill Creek between the confluence with Lancel Creek and the Tyrone Road crossing provide perennial habitat for juvenile coho, however the entire creek may be considered flow-impaired given that water depths drop below optimal passage depths even during average Water Year conditions." The report then recommends focusing flow augmentation projects in the reach from the confluence with Lancel Creek to the Grub Creek confluence (see DB1, Figure 49) because this reach is where "[s]mall changes in flows… may be expected to yield significant increases in habitat quality" (O'Connor Environmental 2016). The reach is included among our priorities. Table 5 summarizes OEI's characterization of the Dutch Bill Creek reaches.

During the State Water Resources Control Board's regulatory efforts in 2015, the Board identified the portion of Dutch Bill Creek upstream of the confluence with Tyrone Gulch as the "critical rearing portion" of the watershed (see Figure 50). Similarly, the Partnership identified Tyrone Gulch as the lower bound of our priority reaches for streamflow projects.

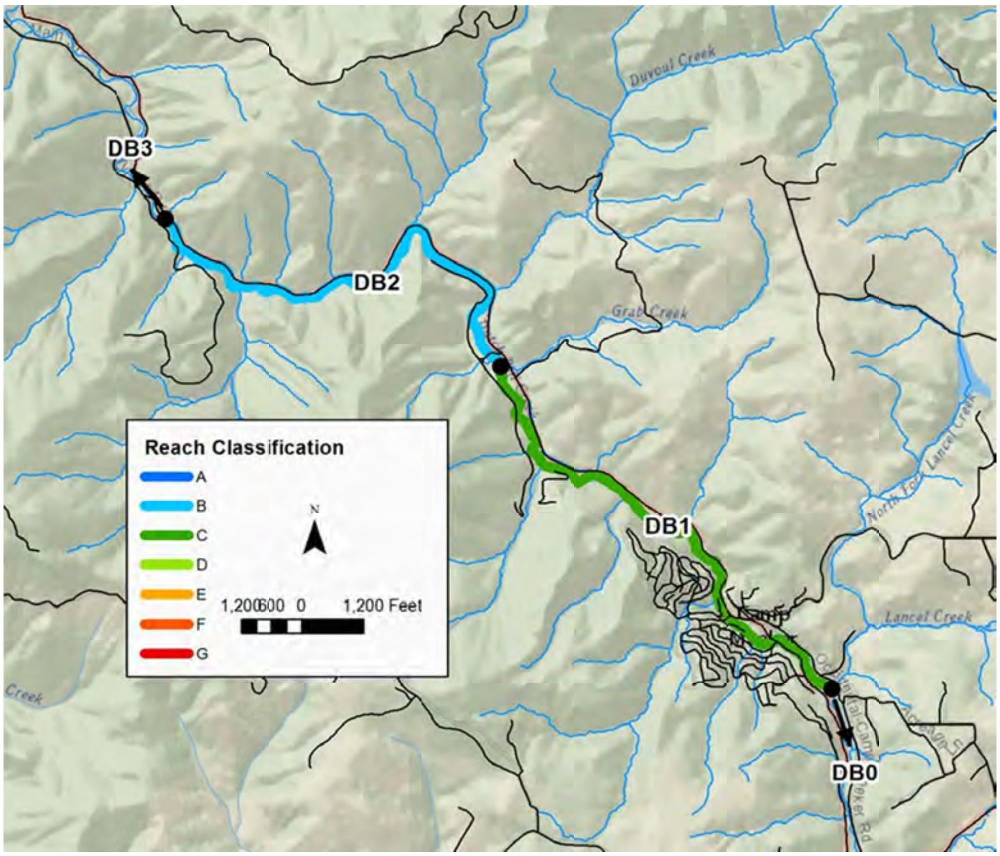

Figure 49. Flow availability and restoration recommendation reach classifications for the Dutch Bill Creek watershed (O'Connor Environmental Inc. 2016).

Table 5. Reach characterization and restoration recommendations (O'Connor Environmental Inc. 2016).

Reach	Location	Reach Category[10]	Recommendation
DB0	Above Lancel Creek confluence	H - Inadequate flow conditions	Habitat enhancement and flow augmentation projects are not recommended
DB1	Lancel Creek confluence to Grub Creek confluence (2.2 river miles)	C - Marginal flow conditions	Medium priority reach for flow augmentation projects; medium priority reach for habitat enhancement projects
DB2	Grub Creek confluence to 0.1 miles above Tyrone Road crossing (2.1 river miles)	B - Good flow conditions[11]	High priority reach for habitat enhancement projects
DB3	0.1 miles above Tyrone Road crossing to Russian River confluence	H - Inadequate flow conditions	Habitat enhancement and flow augmentation projects are not recommended

[10] A – Highest Priority for Instream Projects; B – High Priority for Instream Projects; C – Medium Priority for Instream Projects; D – Investigate Water Quality; E – High Priority for Flow Augmentation; F – Investigate Effects of Diversions; G – Highest Priority for Flow Augmentation; H – Projects not Recommended.

[11] Note that the Partnership did not classify Grub Creek to Tyrone Road as "good flow conditions" in its prioritization. Rather than basing our ranking of flow-impairment on flow levels alone, we based it on whether a reach remains hydrologically connected throughout the dry season. For example, while average flow levels were generally higher in priority reach A (Tyrone Gulch to Duvoul) as compared to priority reach B (Duvoul to upper end of anadromy), in September of most study years, we observed portions of priority reach A becoming disconnected, and therefore classified it as marginally flow-impaired.

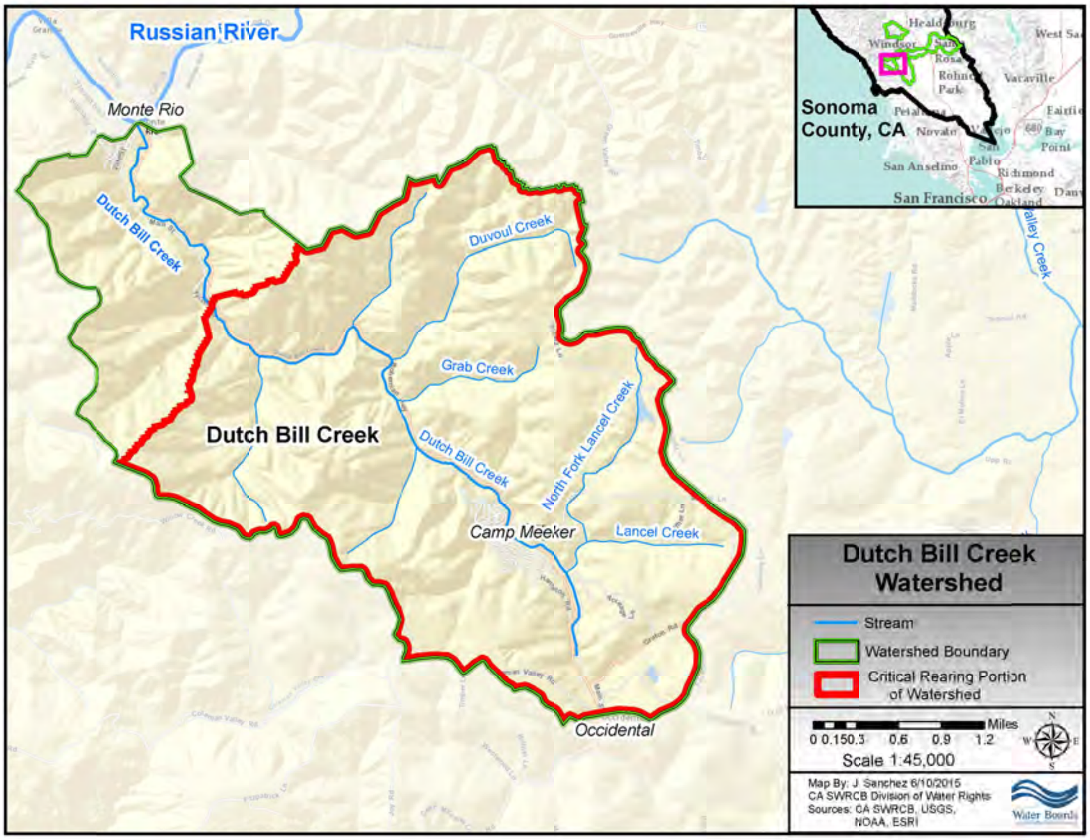

Figure 50. State Water Board map of Dutch Bill Creek identifying the critical rearing portion of the watershed for enhanced conservation measures during 2015 drought actions.

5.2 Flow improvement strategies

Our suite of recommended strategies includes:

- Reduce or eliminate direct dry season diversions from mainstem Dutch Bill Creek and its tributaries by institutional and residential users (5.2.1).
- Pursue flow releases and spring-to-surface-water reconnection (5.2.2).
- Assess the impact of stormwater runoff, explore infiltration and groundwater recharge opportunities, and investigate the possibility that overstocked, even-aged forestlands are having a detrimental effect on streamflow throughout the forested areas of the watershed (5.3.3).

5.2.1 Reduce or eliminate direct diversions from Dutch Bill Creek (and tributaries) during the dry season

We recommend developing and implementing projects in partnership with institutional and residential water users that reduce or eliminate both direct and alluvial well-based dry season diversion from Dutch Bill Creek and its tributaries. The projects could include some or all of the following components:

- Reduce demand where possible through conservation, water use efficiency improvements, reductions in irrigated acreage, etc.
- Evaluate and develop alternative sources of water such as rainwater catchment, graywater re-use and others.
- Construct water storage to facilitate changes in the timing of diversion from the dry to the wet season.
- Reduce individual and cumulative diversion impacts relative to streamflow through regulatory storage (e.g., diverting at a low rate into storage and pulling from that storage at a higher rate), rotation of diversions with other users, and changes in points of diversion.

We describe the institutional and residential user approaches separately below.

5.2.1.1 Institutional users

We recommend working with the institutional water users along Dutch Bill Creek, especially the camps and conference centers, to reduce or eliminate demand from the creek during the dry season. Such partnerships can present tremendous opportunities to improve flow, in large part because of the magnitude of water demand at these sites and because demand typically peaks during the dry season.

The Partnership has worked with the Westminster Woods Camp and Conference Center to develop a project that demonstrates a combined approach of water conservation and storage/forbearance, which is described in the case study below.

The Partnership is in the early stages of developing a project with the Alliance Redwoods Conference Grounds (just upstream of Westminster Woods), which we are optimistic can eliminate all surface and spring water diversion for both potable and non-potable uses. The project is likely to include a suite of approaches, including the development of alternative water sources for the site, construction of water storage, and implementation of water conservation strategies.

Case Study: Westminster Woods water conservation and storage project[12]

Westminster Woods Camp and Conference Center has long been a partner in efforts to restore healthy salmonid populations to Dutch Bill Creek. The camp has worked with GRRCD and multiple fisheries agencies to implement a number of habitat improvement and sediment reduction projects, and partnered with the Coho Salmon Conservation Program on the reintroduction of coho salmon by hosting facilities for the acclimatization of juvenile fish prior to their release.[13]

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[12] More information is available at: http://www.westminsterwoods.org/, and http://www.goldridgercd.org/htm/instream-flow-enhancement.htm. Project partners included Westminster Woods Camp and Conference Center, the Partnership, Prunuske Chatham, Inc., CDFW, California Department of Water Resources, NFWF, and NOAA's Habitat Blueprint and Restoration Center.

[13] http://www.westminsterwoods.org/dutch-creek/

Since 2011, Westminster Woods has worked with the Partnership to change the way it irrigates its playing fields to improve summer streamflow for the benefit of coho salmon and steelhead. This process has resulted in the design and construction of a project which eliminated Westminster Woods's direct summer diversion from Dutch Bill Creek, while still allowing for the maintenance of irrigated playing fields through the implementation of three strategies:

1. **Reducing the irrigated area.** The area of irrigated grass was reduced by approximately 25%, from a total of one acre before project implementation to less than ¾ of an acre after the project was built. This was accomplished by converting marginal or high-use areas from grass to a non-irrigated surface.

2. **Implementing water conservation measures.** To ensure that irrigation water demand was no greater than necessary and that water was not being wasted, a suite of water conservation measures was included in the project, including replacement of the existing grass with more drought-resistant turf, amendment and aeration of the soil, and installation of a new, more efficient irrigation system featuring soil moisture sensors and smart irrigation controllers.

3. **Shifting the rate, timing and place of water diversion through the construction of water storage.** This was the most critical component of the project. Two water storage tanks with a combined capacity of 175,000 gallons were constructed, which facilitated changes in the rate, timing and place of diversion (see Figure 51). The ability to store water for later use allowed the diversion rate to be reduced by 99%, from 100-120 gallons per minute (approximately 0.3 ft^3/s) to 1.3 gallons per minute (approximately 0.003 ft^3/s). The place of diversion was moved from Dutch Bill Creek to a series of springs that were already in use by the camp as a potable water supply, and the timing of diversion was shifted from the summer/fall dry season to the winter rainy season. The springs flow at a relatively high rate throughout the winter and into the early summer, so the new diversion regime has essentially no impact on winter streamflow. This is in sharp contrast to the old summer diversion, which often extracted enough water to exceed the rate of surface flow, disconnecting riffles and drying the streambed for some distance downstream of the diversion site.

The implementation of these strategies made it possible for Westminster Woods to satisfy its irrigation water demand while eliminating its direct summer diversion of water from Dutch Bill Creek. Westminster Woods applied for a new appropriative water right for wet season diversion and petitioned the State Water Board to dedicate the water previously diverted for irrigation under its riparian right to instream flow and to designate the place of use as Dutch Bill Creek. The project provides a reliable source of water to meet the camp's irrigation needs, while ensuring that irrigation does not reduce instream flow for salmon and steelhead during the dry season. A series of maps, prepared by CEMAR and submitted as a component of Westminster Woods's Water Availability Analysis, depict the estimated benefit of the project, using the month of September as an example (see Figure 52).

Figure 52 shows modeled unimpaired streamflow before and after project implementation. Pre-project, flow below S024280 (Westminster Woods's original point of diversion, indicated with a star) ranges between 0 and 60% of modeled unimpaired flow (or alternatively 40-100% impaired flow) under typical September flow conditions. Post-project, flow ranges between 75 to 90% of modeled unimpaired flow from the pre-project point of diversion.

Beyond modeling, stream gauge data also illustrate the effect of the Westminster Woods project during the dry season.

Figure 53 below shows a benefit to flow from *partial* completion of the project in summer 2015 (data shown in blue). At the time, Westminster Woods had completed some water conservation efforts, but was not yet relying on stored water (as the tanks had not yet been constructed). The figure shows a substantial reduction in the magnitude of the Westminster Woods diversion, which is especially striking when compared with previous years (2011 and 2014). The frequency and magnitude of the diversion has decreased since the partial completion of the project. Based on our streamflow and survival studies (Section 4), we predict that these small changes in surface flow may prevent pools from becoming disconnected, and, in turn, allow juvenile coho to persist through the summer season.

Figure 51. Westminster Woods Project. Left: Two tanks (total capacity 175,000 gallons) which store winter water to irrigate the camp's playing fields in the summer; Right: Valves installed as part of the new irrigation system.

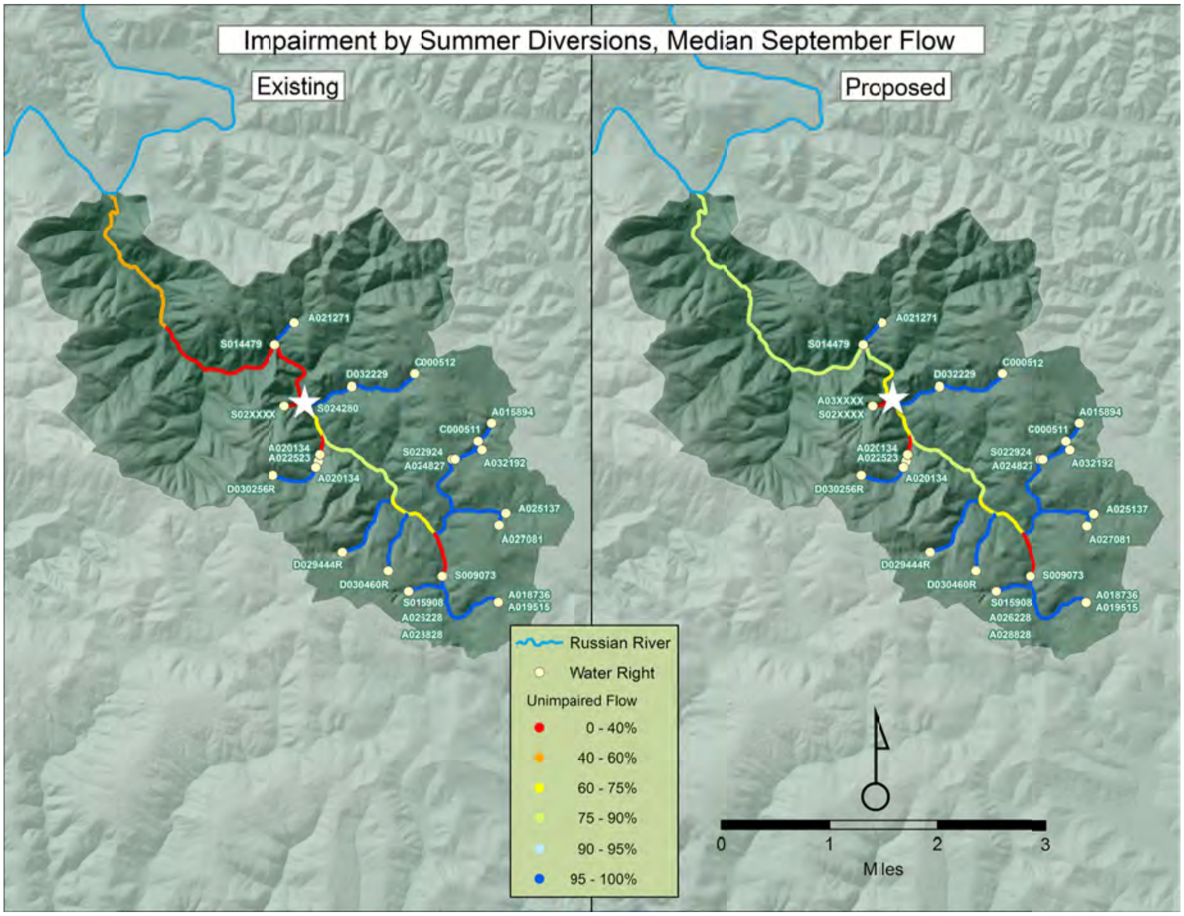
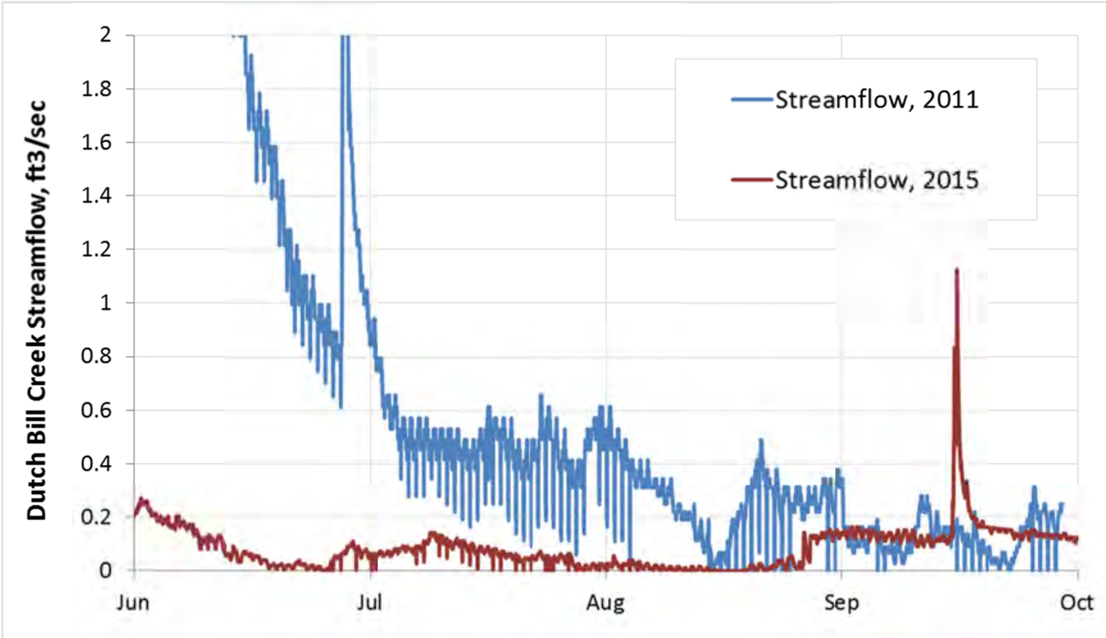


Figure 52. Modeled impairment of flow in Dutch Bill Creek before (left) and after (right) implementation of the Westminster Woods Project (Westminster Woods 2015).



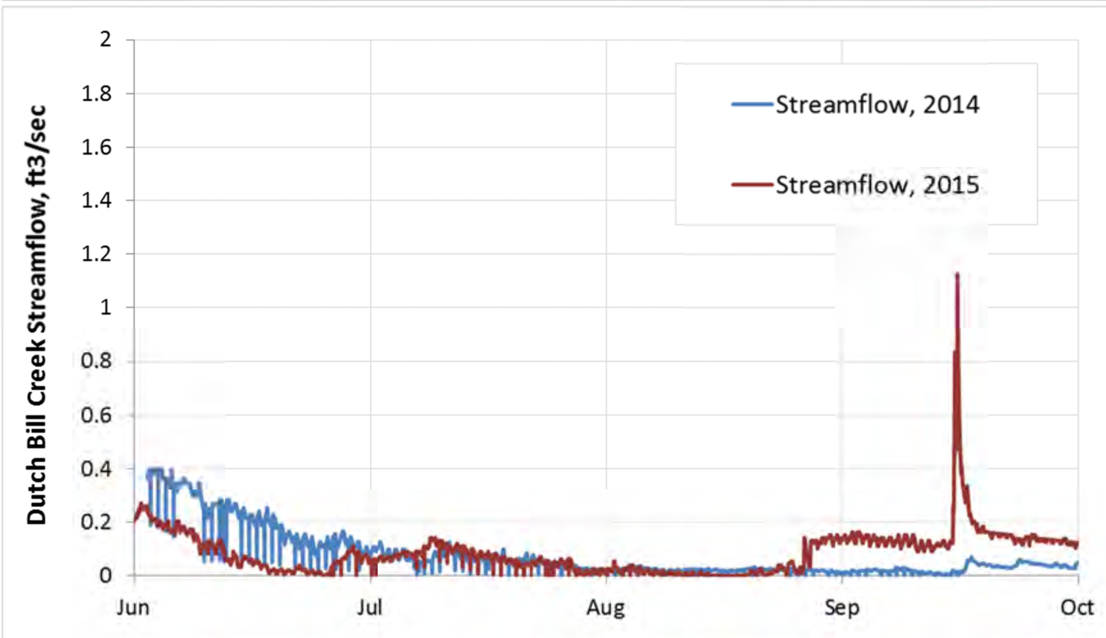


Figure 53. Hydrographs after partial implementation (conservation) of the Westminster Woods project in 2015 as compared with previous years (2011 and 2014).

In sum, the Westminster Woods Water Conservation and Storage Project demonstrates how flow improvement can be accomplished through a combination of approaches: reduction of irrigated acreage, irrigation efficiency upgrades, turf replacement with more drought tolerant species, seasonal storage, and reductions in diversion rates.

We recommend learning from and expanding that toolbox as necesssary to meet the particular site and other constraints with other institutional users (i.e., Alliance Redwoods Conference Grounds).

5.2.1.2 Residential use: storage and forbearance

Many residential users are served by one of the water suppliers which source their water from outside the Dutch Bill Creek watershed, so the cumulative effects of such diversions may not be as pronounced as in other Russian River tributaries. We estimate that there are over 313 residences that are not served by one of the water suppliers, with a cumulative demand of approximately 248 acre-feet per year. Domestic use, incidental domestic uses such as landscape irrigation, and other uses (i.e., for small agricultural operations) may reduce streamflow. We recommend continuing to develop alternative water source, water storage and forbearance projects with residential users, and we recommend prioritizing projects on streamside properties with direct diversions from or alluvial wells near Dutch Bill Creek and its tributaries.

For this reason, we recommend continuing a program (like that provided by the Partnership in the Russian River tributaries and GRRCD/OAEC in nearby Salmon Creek) that provides technical and financial assistance to landowners whose residential water use may be impacting streamflow and who are interested in developing alternatives. A typical project would include (a) evaluating the parcel to identify water conservation opportunities, (b) installing water storage tanks to be filled with water from sources most suitable for each parcel (e.g., roofwater, surface water, springs, or wells), and (c) executing an agreement with the landowner to forbear use of his or her direct diversion or alluvial well during critical low-flow periods. 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, GRRCD has implemented a successful roofwater harvesting storage and forbearance program in Salmon Creek, and the Partnership has implemented other such projects in upper Green Valley, Mill and Mark West creeks. In addition, we recommend continuing the existing Flow-for-Fish Rebate Program in the Russian River, which provides a rebate payment to water users working with the Partnership or acting on their own to offset the cost of storage tanks and accompanying permits.[14]

[14] http://www.cohopartnership.org/program-rebate.html

5.2.2 Beyond straws in the creek: flow releases and spring-to-surface water reconnection

Flow augmentation can be an important part of the flow restoration toolbox. Strategies include flow releases and spring-to-surface water reconnection.

Flow releases: During 2015, at the height of the drought, streamflow augmentation through flow releases emerged as a key strategy for preventing coho mortality. Gallo Glass Company (Porter Creek), Chris Panym and Michael Paine (Green Valley Creek) and Jackson Family Wines (Green Valley Creek) released water from agricultural ponds to benefit coho downstream. A slightly different approach was taken in Dutch Bill Creek, where CMRPD released water sourced from Monte Rio via its supply pipeline and water treatment facility.

- We recommend that, to the extent CMRPD is willing and to the extent it is necessary, the flow release continue as feasible as a supplement in drought years to a long-term, comprehensive effort to restore dry season baseflow. A case study of the CMRPD flow release is below.
- Anecdotal evidence suggests that Lancel Creek, at one point, had some of the best fish returns and consistent year-round flow in the Dutch Bill Creek watershed. Information collected through the State Water Board's 2015 Informational Order demonstrates that there are few direct diversions or alluvial wells in the greater Lancel Creek watershed, so we recommend additional outreach to water users in Lancel Creek and North Fork Lancel Creek to explore the potential for dry season reservoir releases to benefit coho and steelhead.

The pipeline that supplies water to the communities of Camp Meeker and Occidental has been a unique part of the flow restoration strategy in Dutch Bill Creek, but we caution that flow releases should be considered an important part of an emergency drought or dry year response rather than an annual strategy. For planning purposes, we assume that flow releases will not necessarily be available on an ongoing basis, and therefore do not constitute a sustainable, long-term solution to the problem of low dry season baseflow. The capacity and willingness of a landowner or water supplier to release flow are likely to be based on factors beyond the control of the Partnership and should not be assumed. In the absence of long-term agreements that guarantee flow releases (which are extremely unlikely), the Partnership intends to plan and implement projects sufficient to meet our flow goals independent of flow releases.

Spring-to-surface water reconnection: In addition, we recommend exploring opportunities to pursue spring reconnection in the watershed.

Case Study: Camp Meeker Recreation and Park District flow release

To complement water conservation efforts mandated by the State Water Board in 2015, NMFS, CDFW, and the Partnership approached CMRPD in July of 2015 about voluntarily augmenting streamflow in Dutch Bill Creek. The CMRPD Board, which has been a partner in efforts to improve instream habitat conditions and remove barriers to fish migration in Dutch Bill Creek, enthusiastically agreed to participate. The project, first implemented in 2015, utilized existing water infrastructure to add untreated well water to Dutch Bill Creek in order to maintain a minimum subsistence condition for juvenile coho salmon and steelhead rearing in the main channel downstream of the CMRPD filtration facility. The project required a Temporary Urgency Change to CMRPD's existing appropriative water right permit, which temporarily added fish and wildlife enhancement to the purpose of use and Dutch Bill Creek to the place of use. CMRPD filed a Temporary Urgency Change Petition (TUCP) and an instream flow dedication petition (instream flow petition) with the State Water Board. The petition proposed to divert water from the Monte Rio well at a rate ranging from 0.05 to 0.2 ft^3/s for release, untreated, from its pipeline into Dutch Bill Creek.

Water was released from CMRPD's water filtration facility at the Alliance Redwoods Conference Grounds, approximately four miles upstream of the Monte Rio well. The Partnership installed an above-ground temporary pipeline to convey the water into a rock-lined drainage channel about 500 feet from the facility; the water then flowed into Dutch Bill Creek. The rate of release averaged approximately 0.1 ft^3/s, and continued from August 24 through December 9, 2015. The estimated total volume of water released was 16.1 AF.

The project substantially improved surface flow, as demonstrated by an increase from near-zero values to over 0.1 ft^3/s after August 24th at the DB02 gauge, located about half a kilometer downstream of the release site (Figure 54). Because, flows ranging from 0.01 to 0.05 ft^3/s have been shown to maintain pool connectivity in Dutch Bill Creek (see Section 4), we concluded that the increase in flows to 0.1 ft^3/s following the release ensured that low streamflow was not hindering persistence of juvenile coho through the remainder of the summer dry season. An increase in surface flow was not documented at the DB04 streamflow gauge, located about three kilometers downstream of the release site, until a significant rain event on September 16 (Figure 55). Given the extreme drought conditions in 2015, we suspect that the pore space in the streambed in the lower reaches had to refill before increases in surface flow could occur further downstream. In less severe drought conditions, we believe that a similar flow release would show more immediate benefits further downstream of the release site.

This effort was a significant contributing factor to maintaining rearing habitat in a wetted condition in priority reach B (Figure 48), despite it being the worst drought condition in recent history. UC data suggest that 76% of the juvenile salmonids observed in Dutch Bill Creek at the beginning of the rearing season were occupying habitat that remained wetted throughout the summer period. This was far more than what was observed in the four other streams included in the study (Figure 56).

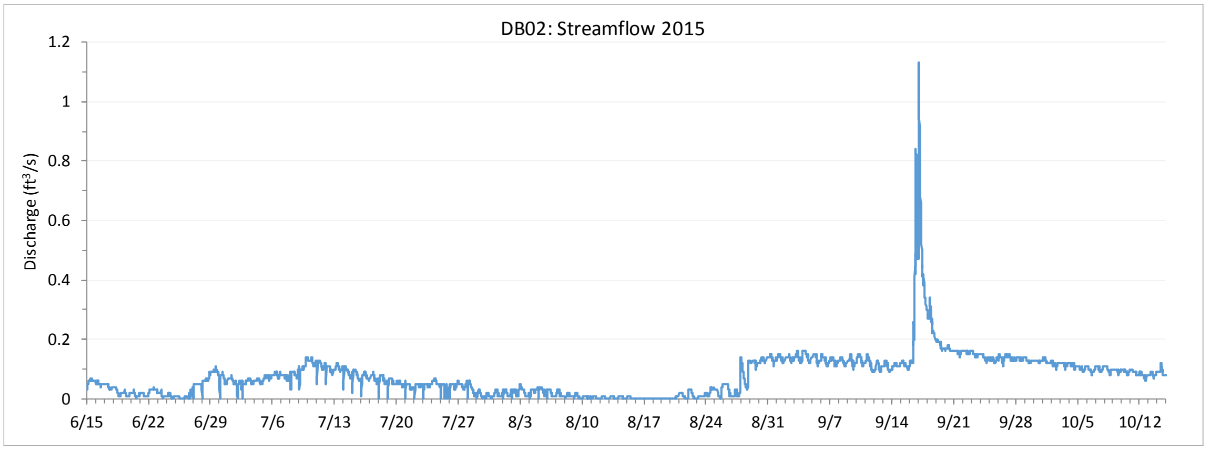


Figure 54. Streamflow data collected at DB02 (0.50 km downstream of CMRPD flow release) in 2015.

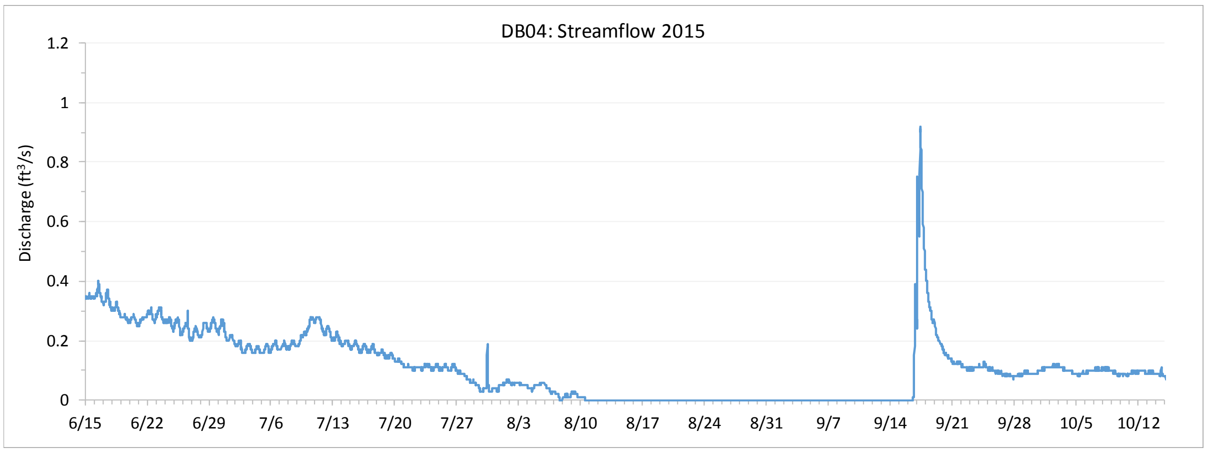


Figure 55. Streamflow data collected at DB04 (2.95 km downstream of CMRPD flow release) in 2015.

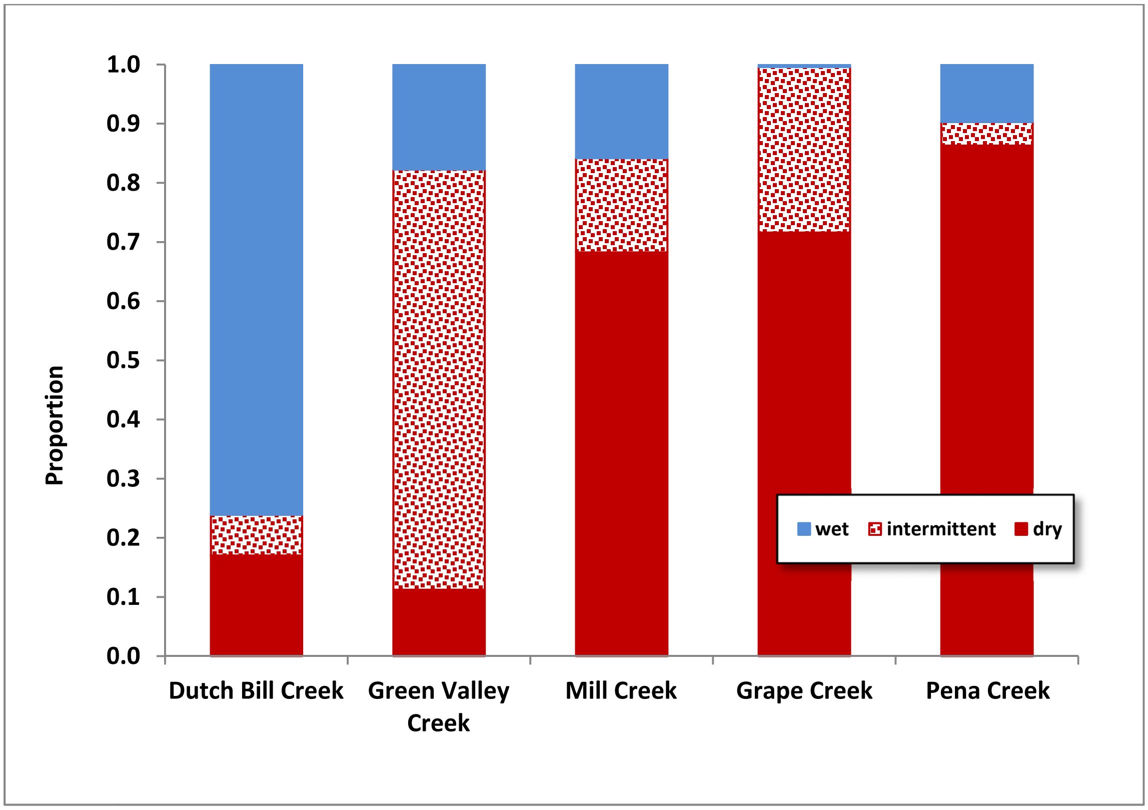


Figure 56. The proportion of juvenile salmonids observed in relation to wet, intermittent and dry stream reaches in five priority streams studied by the UC's coho monitoring program in the summer of 2015.

During the summer of 2016, CMRPD again released water into Dutch Bill Creek to maintain wetted habitat conditions in downstream reaches. The release began in August of 2016 and ended in October 2016. CMRPD filed a second Temporary Urgency Change Petition for this release, and intends to submit a long-term Petition for Change to permanently add fish and wildlife preservation and enhancement to the purpose of use and place of use to its water right. The Partnership supports this long-term change petition. The flow release has the potential to reconnect pools and can be an especially effective tool if used to supplement other flow improvement efforts.

5.2.3 Infiltration and recharge

The Partnership's analysis of the location and magnitude of known and suspected water diversions and impoundments in the Dutch Bill Creek watershed leads us to believe that reducing or eliminating dry season water extraction, both directly from streams and indirectly via alluvial wells, may not be sufficient by itself to maintain sufficient flows for oversummer survival of juvenile coho in the Dutch Bill Creek mainstem during severe multi-year droughts. A review of the history of the watershed (see Section 1.3 above) and evaluation of the current level of development reveal land use impacts on a widespread scale that are likely impacting both the infiltration of rainfall into the soil column and the landscape's capacity to generate summer baseflow. Although we have not directly researched these impacts in the Dutch Bill Creek watershed, we believe the landscape has become desiccated relative to historical, pre-European settlement conditions, and that summer baseflow is likely being depressed by a combination of the following:

1. Landscape-scale coniferous forest conversion, from predominantly diverse, multi-story canopy with abundant old growth to a largely even-aged forest. Research in other regions has shown that coniferous trees in certain age classes take up more water from the soil than older trees, and that conversion of forest with a range of age classes to even-aged stands results in less available groundwater to provide summer baseflow.
2. Hardening of the landscape through urban and rural residential development and agricultural conversion creates larger areas of impervious and semi-permeable surfaces, along with a denser drainage network. These changes reduce infiltration and cause a greater proportion of rainfall to be converted to runoff, resulting in less water entering the soil column and becoming available for baseflow.
3. The presence of a dense, greatly extended drainage network, primarily in the form of poorly drained roads. When constructed using methods almost universally accepted over the past century or so (insloped, with undersized and inadequately spaced drainage structures), roads become hydrologically connected to the stream network and act as extensions of that network. Road cutslopes intercept overland and shallow subsurface flow, while compacted or paved road surfaces generate runoff, and inboard ditches collect runoff generated on adjacent impervious or semi-permeable surfaces (see 2 above). Inboard ditches and poorly shaped and maintained road surfaces convey that water (and abundant fine sediment) to stream channels quickly and efficiently. Besides damaging instream habitat through erosion and sediment delivery, this process results in the rapid removal from the landscape of a greater proportion of rainfall than was the case historically. The ubiquitous presence of roads on the landscape means that few areas of the watershed have been left untouched by these impacts.

To address this landscape-scale desiccation, we recommend the following actions:

- A broad-scale effort to improve upland recharge: Opportunistic actions to reduce the area of impervious surface and improve permeability and hydrologically disconnected impervious surfaces, as well as the construction of retention basins and decommissioning of unnecessary drainage systems that concentrate surface and shallow subsurface flow.
- A road drainage improvement program, on both paved and unpaved roads throughout the watershed, with a focus on areas that drain to reference and treatment reaches. Such efforts have been criticized in the recent past as being overly expensive and only benefitting road owners, but we believe the hydrologic and erosion control benefits are both significant and self-evident.

We note that because the impacts described above are widespread on the landscape, a program to mitigate their impacts must necessarily be implemented on a landscape scale. It will therefore be expensive relative to the discrete projects undertaken by the Partnership to date, and progress will likely be measurable only on a longer time scale.

5.2.4 Habitat Improvement Projects

As a complement to flow improvement efforts, we recommend continuing to implement habitat projects that improve conditions for coho and steelhead by increasing stream channel complexity in the mainstem of Dutch Bill Creek. Such projects should focus on the installation of cover structures to improve shelter in the reference and treatment reaches, the installation or recruitment of additional pool scour structures in the reference reach, and structures for high flow refugia. A number of instream habitat enhancement projects have been constructed by GRRCD and our partner organizations in recent years, and these efforts are likely to continue on an opportunistic basis. We recommend that project proponents consider and integrate flow information and instream flow project locations into their project selection and design.

5.3 Evaluation of project recommendations

The Partnership has developed metrics to help us estimate the flow benefit of projects and to evaluate our progress in restoring flow in Dutch Bill Creek. Section 5.3.1 describes the metrics. Our primary flow restoration goal is to improve juvenile over summer survival. As described below, we used pool connectivity as a predictor of over summer survival, and developed thresholds for pool connectivity in our treatment reach.

Section 5.3.2 estimates the flow benefits of the projects recommended above and compares the estimated benefit to the connectivity thresholds. We estimated the flow benefits of each of our projects by calculating average daily flow contributed across the dry season (defined as June 15 through October 15). Since we are interested in the effectiveness of the projects collectively, and each operates over different time and stream reach scales, we created schematics that compare the collective estimated flow benefit to connectivity thresholds.

5.3.1 Overview of metrics

The Partnership's primary monitoring goal is to determine whether or not oversummer survival of juvenile coho salmon is increasing as a result of project implementation. Because survival monitoring is resource-intensive on a stream-wide scale, we have worked to develop relationships between summer survival and environmental parameters (flow, temperature, wetted volume, and DO) with the intention of using less resource-intensive measurements of these physical parameters as predictors of survival when evaluating the long-term success of streamflow projects.

As described in Section 4.5.2.2, we have identified pool connectivity as a key factor in juvenile coho persistence through the summer season, and for the purposes of project planning and evaluation, we have chosen this metric as a predictor of juvenile coho survival. A primary goal of the Partnership and this Streamflow Improvement Plan is to complete projects that will keep pools connected by surface flow throughout the summer dry season (June through October), and in turn increase the probability of juvenile coho surviving the summer season. Although *flows greater than those required to maintain minimum connectivity will ultimately be necessary to increase juvenile production and achieve full population recovery*, for the immediate future we are focusing on increasing flows to levels that will allow minimum persistence of juvenile coho and prevent extinction.

The flow at which pools become disconnected does not always equate to zero flow through a stream reach. In the case of the Dutch Bill Creek study reaches, the treatment reach, further down in the watershed, is a gravel-dominated alluvial substrate without significant water holding capacity, while the cobble and bedrock dominated reference reach approximately three kilometers upstream has better water holding characteristics and tends to exhibit more stable flow and depth patterns throughout the summer. In order to determine the specific flow level at which pools become disconnected in each of the Dutch Bill Creek reaches (connectivity thresholds), we compared field observations of pool connectivity during habitat surveys with hydrographs developed from gauges operated in each reach in an attempt to quantify the flow, in cubic feet per second (ft^3/s), at which pools become disconnected from surface flow. In the treatment reach, we observed the early stages of disconnection at an average daily flow of 0.036 ft^3/s in 2014 and 0.043 ft^3/s in 2015, so we estimated a connectivity threshold of 0.05 ft^3/s (Table 6). We never observed disconnected conditions in the Dutch Bill Creek reference reach, so we used the lowest flows at which we observed pool connectivity, 0.008 ft^3/s in 2014 and 0.013 ft^3/s in 2015, to estimate a connectivity threshold of 0.01 ft^3/s (Table 6). We assumed that connectivity thresholds in the survival study reaches represented the amount of flow needed to ensure connectivity in the entire priority reach in which the survival study reach was located (Figure 36). Ground-truthing by conducting repeated wet/dry mapping surveys on the priority reaches throughout the summer season and comparing the results with streamflow data collected at multiple gauges would help to support the validity of this assumption.

Table 6. Estimated connectivity thresholds for survival study and priority reaches in Dutch Bill Creek.

Survival study reach	Survival study reach river km range	Priority reach	Priority reach river km range	Kilometers in priority reach	Representative flow gauge	Connectivity threshold (ft^3/s)
treatment	3.87 - 4.16	A	3.14 - 5.97	2.83	DB04	0.05
reference	6.51 - 6.77	B	5.97 - 10.59	4.62	DB02	0.01

For each priority reach, our long-term goal is hydrologic connectivity throughout the summer season. Projects that keep pools connected by collectively increasing streamflow as little as 0.01 - 0.05 ft^3/s have the potential to improve survival of juvenile coho salmon throughout the summer rearing season. Figure 57 depicts 0.05 ft^3/s of water as gallons per minute and also as a volume if supplied for the dry season (June 15 – October 15).

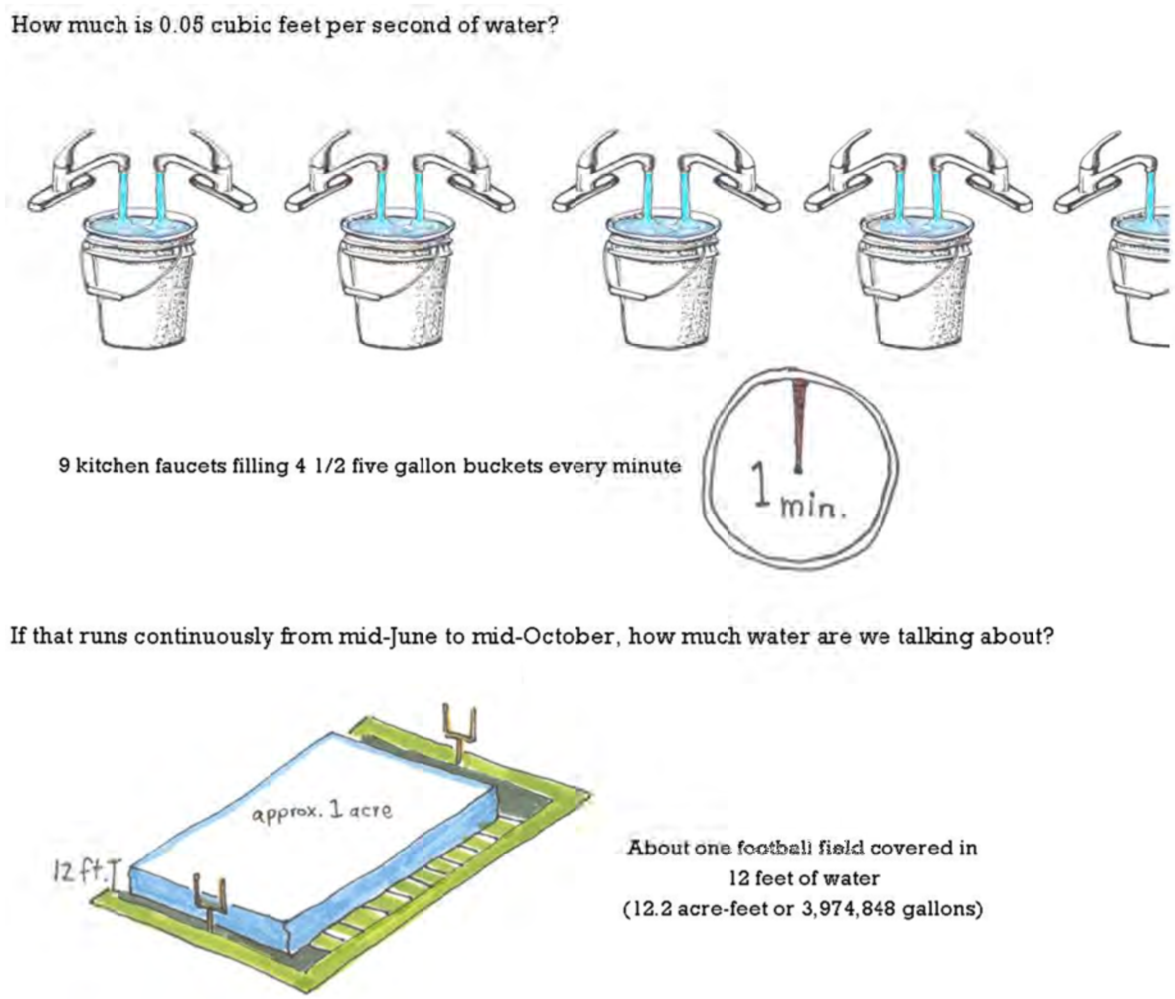


Figure 57. Depictions of 0.05 ft^3/s.

Three metrics will be estimated for each project to help determine the project's contribution towards the goal of connectivity:

1. Quantity of water repurposed to the stream, expressed as average daily flow (ft^3/s) over the period of benefit or forbearance,
2. Duration of time the project will contribute (or forbear diversion of) the target amount of water, expressed as number of days between June 15 and October 15,
3. Length of stream the project will benefit, expressed as number of kilometers between project and downstream end of Priority Reach A.

Projects will be considered collectively to determine whether or not connectivity is likely to be achieved. Our intent is to identify and implement a series of projects that collectively improve flow enough to connect pools throughout both priority reaches for the duration of the summer dry season.

To gauge overall program success, flow data collected at representative gauges within the watershed will be compared to connectivity thresholds to quantify the number of days of disconnectivity that occur in each priority reach between June 15 and October 15 each year, both pre- and post-project implementation (e.g., Figure 65, Figure 66). Over time, we anticipate observing fewer days of disconnection as a result of project implementation. Ultimately, we plan to quantify the effects of changes in days of disconnection on survival by using predictive models.

Because the streamflow levels we are attempting to enhance are relatively small and are heavily influenced by the stream's connection to groundwater, larger-scale climatic and hydrologic factors beyond our control will likely influence whether or not pool connectivity is actually achieved in a given year, even if we complete projects that are estimated to contribute the equivalent of connectivity thresholds. For example, it is possible that severe extended drought could cause the water table to drop to a point where reaches become "losing" and projects that may benefit coho in an average year would not be sufficient to keep pools connected throughout the summer season for the full extent of the priority reaches (e.g., surface flows from the CMRPD flow release in 2015 increased flows 0.5 km downstream of the release point immediately, but they did not increase flows 3 km downstream until a rain event occurred). Given these underlying factors, we do not anticipate full pool connectivity throughout all reaches in all years.

Ultimately, the Partnership recognizes that our efforts may not be enough to overcome large-scale climatic and hydrologic factors during years of extreme drought. Our goal is to increase the overall length of stream in which flows are sufficient to retain pool connectivity, increase the duration of connection, and increase the proportion of years during which these conditions are maintained and that juvenile coho salmon have a higher probability of surviving the summer season. Because of the number, complexity and variability of the large-scale climatic and hydrologic factors that influence streamflow, we believe that this trend of improvement will actually be measurable only over a decadal or longer time scale.

5.3.2 Application of metrics on Dutch Bill Creek

Table 7 lists possible instream flow projects in the Dutch Bill Creek watershed. They are in varying stages of development: some have been completed (e.g., Westminster Woods Camp and Conference Center), some are in the planning phase, and some have only been identified as recommendations above.

For each project on Dutch Bill Creek, we estimated the length of time the project will contribute (or forbear diversion of) the target amount of water, the quantity of water repurposed to the stream in ft^3/s as an average daily flow over the period of benefit or forbearance, the average daily flow expressed as a percentage of the treatment reach goal, and the length and location of the stream reach that the project will benefit.[15] As noted above, the reference reach connectivity threshold is

[15] For example, a project that stores 40,000 gallons over the winter, replacing an instream diversion from June 15 to September 30, provides an average benefit of 328 gallons (0.00051 ft^3/s) per day for 107 days. We would also evaluate the length of the priority reach that the project would benefit by documenting the project's distance from the downstream end of Priority Reach A, as well as its location in relation to other projects.

0.01 ft^3/s and the treatment reach connectivity threshold is 0.05 ft^3/s. For this exercise, we used the more conservative of the two in our project evaluation.

Table 7. Past and potential future projects included in evaluation.

Project Name	Season	Avg. Daily Flow (ft^3/s)	% Treatment Reach Goal	Km of Stream Project will Benefit
Non-Flow Release Projects				
Alliance Redwoods - non-potable	6/15-10/15	0.007	14%	4.05
Alliance Redwoods - potable	6/15-10/15	0.017	34%	4.05
Westminster Woods Camp and Conference Center	6/15-10/15	0.011	23%	3.31
Hittenmiller	6/15-10/15	0.0003	1%	1.61
Sub-Total Non-Flow Release Projects		**0.0353**	**71%**	
Flow Release Projects				
Future Project (release)	8/1-10/15	0.05	100%	5.56
Camp Meeker Recreation and Park District Release	7/1-10/15	0.1	200%	3.83
Sub-Total Flow Release Projects		**0.15**	**300%**	
Total		**0.185**	**371%**	

Table 7 also distinguishes between flow release and non-flow release projects. While flow release projects are extremely effective at immediately increasing flows to avoid disconnection, we view them as a temporary solution that should be considered separately because they may not be reliable sources of water from year to year (see Section 5.2.2). Alternatively, we view non-flow release projects as durable contributions to flow that are key toward achieving lasting hydrologic connectivity. With this in mind, we strive to reach 100% of our treatment reach goal with non-flow release projects alone, and view the flow releases as an added benefit that will be particularly critical in years of extreme drought.

Each project has particular spatial and temporal impacts; some projects provide water over the whole season chosen for our project evaluation (mid-June to mid-October), while others operate for a shorter time, and the spatial impact of a project can vary depending on the project's magnitude, location, and antecedent conditions in the reach downstream. In order to better depict these elements, we created schematics for the months of June, July and August (see Figure 58 - Figure 60). The schematics include only projects upstream of the treatment reach and assume that any flow contributed by a project remains instream through the treatment reach. In other words, the schematics do not account for losing reaches or other factors; this is discussed in more detail below.

Figure 58 shows the calculated average daily flow which will be contributed by the projects operating in June (Alliance Redwoods, Westminster Woods and Hittenmiller). The schematic depicts cumulative benefit; the graphic adds the average daily flow for each project in operation as it moves downstream. Under this scenario, the identified projects are estimated to meet 71% of the treatment reach goal through the reach.

For this exercise, we assume the CMRPD release begins in the month of July. With the release added (Figure 59), the projects cumulatively exceed the treatment reach goal downstream of the CMRPD flow release site.

When the future flow release project comes online in August (Figure 60), the projects cumulatively add sufficient flow for the creek to meet and exceed the connectivity threshold from the most upstream project through the reference and treatment reaches. The schematics include flow releases which, as described above, we view primarily as a stopgap during dry years, rather than a permanent solution. If the flow releases were removed from the schematic in August, the map would be the same as the June depiction.

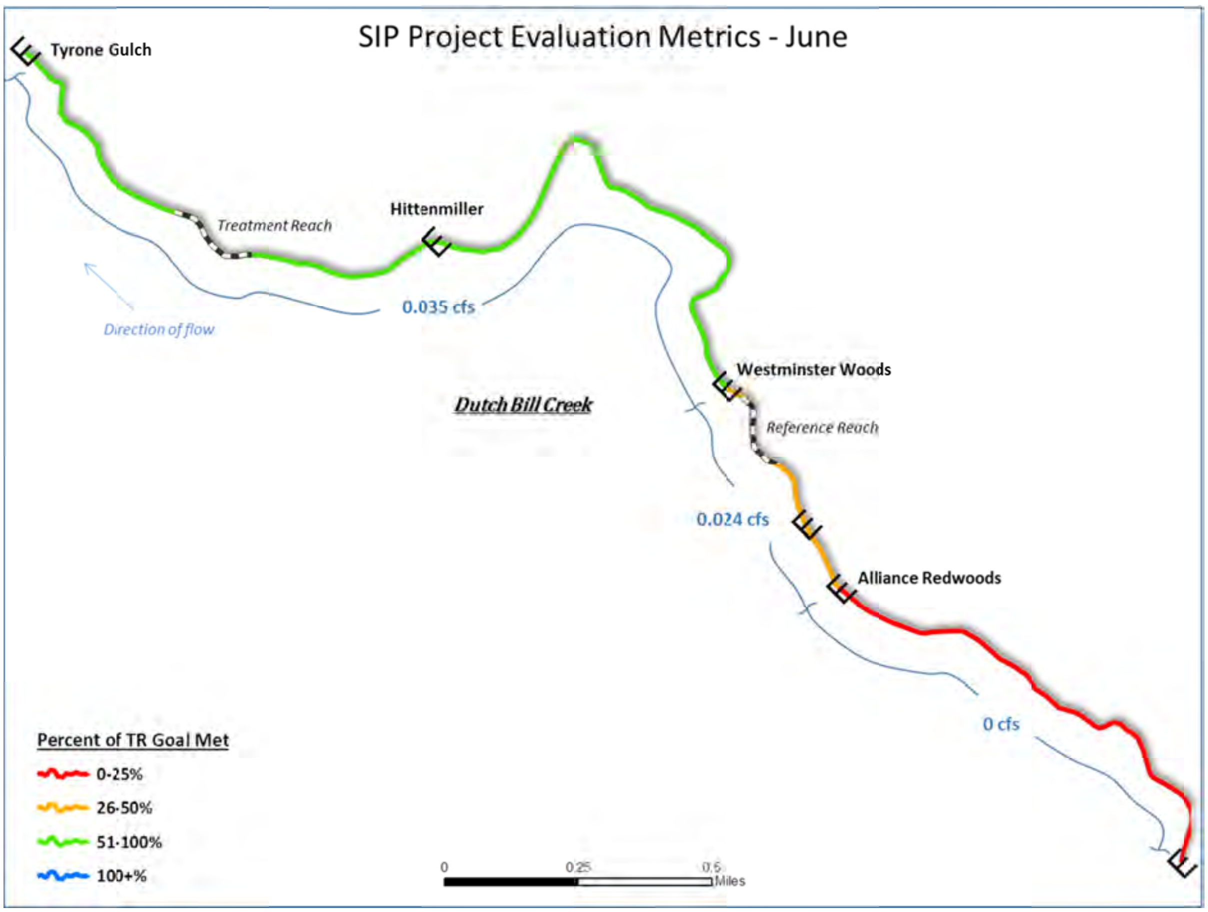


Figure 58. Project Evaluation Metrics: Daily average flow contributed by and percent of treatment reach goal met through identified projects in the month of June.

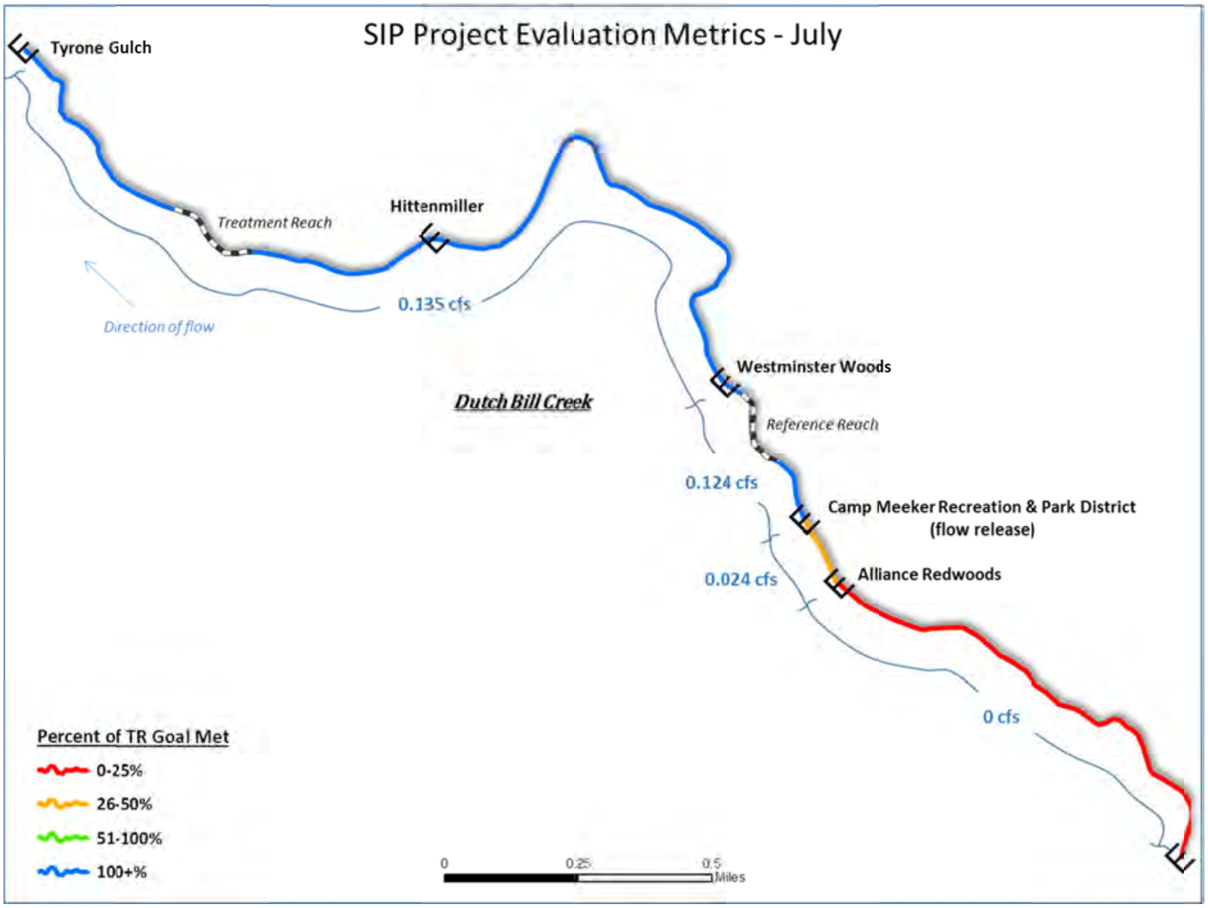


Figure 59. Project Evaluation Metrics: Daily average flow contributed by and percent of treatment reach goal met through identified projects in the month of July.

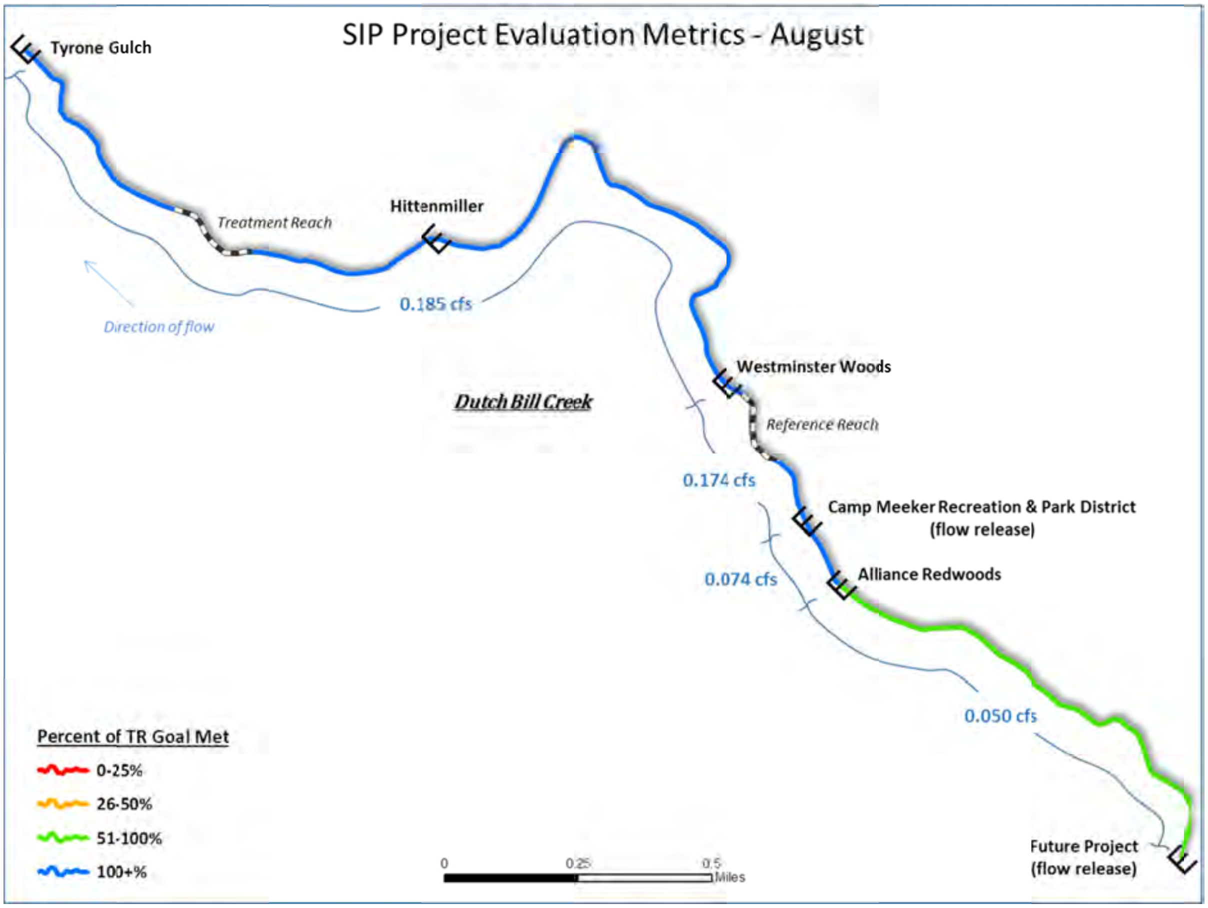


Figure 60. Project Evaluation Metrics: Daily average flow contributed by and percent of treatment reach goal met through identified projects in the month of August.

The schematics are also useful in identifying reaches where projects are needed in order to achieve connectivity. For example, the Partnership might seek (or prioritize) projects located high in the watershed where the only planned contributions are from a future flow release occurring in August. Non-flow release projects contributing to the upper-most reach beginning in June would be of highest priority. Ideally, we would complete non-flow release projects at the uppermost extent of the reach, beginning in June, that collectively contribute a minimum of 0.01 ft^3/s (connectivity goal for Priority Reach B). This would allow us to meet 100% of our goal throughout the full extent of the priority reaches without contributions from flow release projects.

Through future streamflow gauging, we will continue to document the estimated days of pool disconnection in each priority reach in each year. These data will aid in determining whether projects are increasing the probability of juvenile survival during the summer season or whether additional work will be required.

6 Permitting and long-term considerations

This section provides an overview of permitting considerations for projects that are developed under the strategies described above, as well as tools to ensure that any summer water use offset through winter storage remains and is protected instream.

This SIP is not intended to be a comprehensive guide to permitting requirements. It should be viewed as information only, and not as legal advice. Anyone considering an instream flow project -- or any change to a water right -- should consider seeking the advice of an attorney with expertise in water rights law.

6.1 Permitting considerations

Some of the projects recommended above will require new water rights and/or changes to existing water rights. For example, projects that divert water to seasonal storage (e.g., divert in winter for summer use) will require an appropriative water right if the source is a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 6.1.4). 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 some of the likely water rights permitting pathways for various project types.

6.1.1 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 California legislature has clarified that a water right permit is not required for rainwater capture and storage.[16] For projects that reduce the quantity of water that users divert in the dry season with the intention of improving streamflow, landowners, project partners, and funders should ensure that reductions in water use under existing water rights are realized as instream benefit (e.g., through an instream dedication and/or forbearance agreement) (see Section 6.2).

This approach has been implemented successfully in Salmon Creek (Sonoma County)[17] where GRRCD, OAEC, Prunuske Chatham Inc., and NOAA Restoration Center (NOAA-RC) piloted an approach to offset dry season use through winter rainwater harvesting,[18] and in Chorro Creek where Morro Bay National Estuary Program and NOAA-RC installed rainwater tanks on Cal Poly San Luis

[16] Water Code §10574; http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml

[17] http://salmoncreekwater.org/cs/Roofwater_Harvesting.pdf

[18] http://salmoncreekwater.org/bodega-pilot-program.html; "Restoring Salmon Creek" video at http://link.brightcove.com/services/player/bcpid1094074675001?bckey=AQ~~,AAAAmZfSubE~,RcH_vKEgcc8rO41NFM8ONh0xjXYYADXb&bclid=3639409231001&bctid=3447931845001

Obispo campus.[19] In both cases, landowners agreed to cease summer use and signed a forbearance agreement.

6.1.2 Residential tank storage

Where residential users switch the timing of their diversions from a 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 enough to qualify for a Small Domestic Use Registration (SDU) or Emergency Small Domestic Use Registration (ESDU).[20]

The ESDU streamlines the process for obtaining an 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."[21]

This residential tank storage approach has been implemented successfully in the Mattole River watershed through Sanctuary Forest's Water Storage and Forbearance Program (and elsewhere), and more information is available in Legal Options for Streamflow Protection (Sanctuary Forest 2008). Sanctuary Forest's approach has included installing tank storage sufficient to satisfy residential potable water demand 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 diverters when streamflow falls below certain thresholds. These terms and conditions are implemented through the 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.

6.1.3 Agricultural water storage

Projects with agricultural water users that rely on diversion from a 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 Use Registration (SIU), a type of appropriative right.[22] For projects that rely 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 6.1.4).

A summary of the registration options is provided in Table 8.

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[19] https://issuu.com/cafes.calpoly.edu/docs/agriview_fall_2013 (see page 11)
[20] http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/
[21] http://cdfgnews.wordpress.com/2014/03/13/state-streamlines-domestic-water-tank-storage-process-in-response-to-drought/
[22] http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/

Table 8. Summary of water right 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
LSAA req?	Yes	No	Yes
Renewal	Every 5 years	Every 5 years	Every 5 years
Renewal Fee	$100	$100	$100
Reporting	Annual	Annual	Annual

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 establishment (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.

6.1.4 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 Dutch Bill Creek watershed is included as Figure 61. If the well lies outside of a subterranean stream, the water diverted from the well may be considered percolating groundwater, and may not be subject to the permitting jurisdiction of the State Water Board.[23]

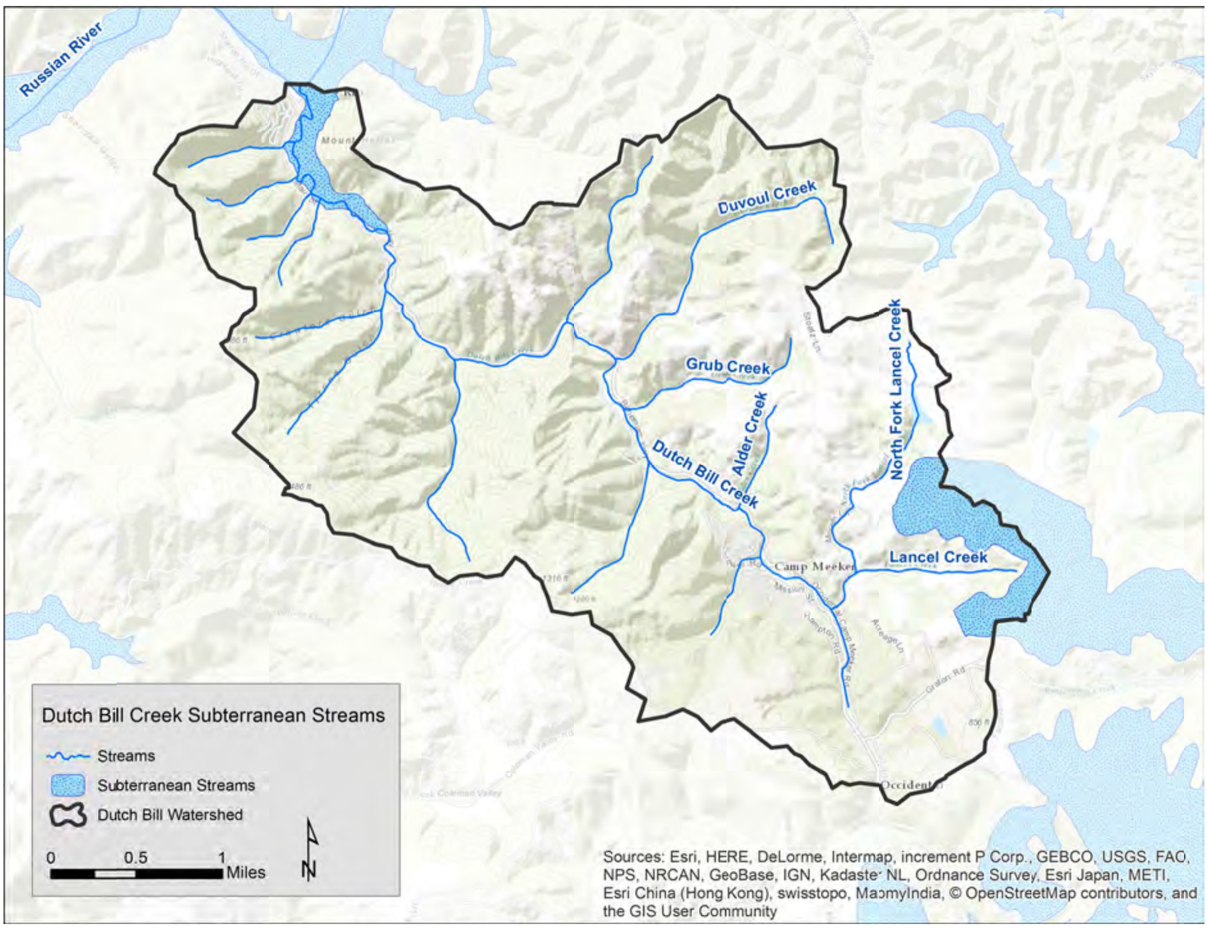

Figure 61. Rendering of Subterranean Streams and Potential Stream Depletion Areas (using data from Stetson 2008).

[23] 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

6.1.5 Flow releases

The permits required for a flow release will vary depending on the source of the water being released and the nature of the release. At a minimum, a water user interested in a flow release should consult with the State Water Board, the Regional Water Board, CDFW, and NOAA/NMFS to determine what permits are necessary.

A water user or project proponent will first want to confirm that the water intended for release was obtained legally. Water right permitting requirements will vary depending on (a) the nature of the water being released (the source, the method in which it was obtained, whether it was stored, and the basis of right under which it was obtained), and (b) the nature and purpose of the flow release. One of the major questions is whether a water right change is necessary to implement the flow release. Traditionally, this has included adding a new purpose of use (fish and wildlife preservation and enhancement) and a new place of use (a reach of stream). For more information about these types of changes (which occur under Water Code Section 1707), see Section 6.2.2. In general, it is easier to do a flow release where the water user can demonstrate a recent history of consumptive use. Examples of water rights changes for flow release projects include Gallo Glass Company's flow release on Porter Creek (Russian River tributary) and CMRPD's release on Dutch Bill Creek.

Regional Water Board permits may or may not be required, depending on the nature of the discharge. Water that has been previously captured and stored pursuant to a water right (e.g., in an agricultural pond) may not require a discharge permit, though it may be necessary to perform some water quality testing to ensure that the release will not adversely impact the receiving stream (by increasing water temperature, for example). The Regional Board may also want to inspect the source pond for blue-green algae concerns. Discharges of groundwater to surface water may require a discharge permit. In many places in Sonoma County, most associated with ultramafic geology, wells yield water with relatively high arsenic, chrome, copper, nickel and other constituents that may pose a concern. The Regional Board encourages projects involving flow releases that benefit the environment, has waived fees for flow releases to benefit salmonids in the past, and will collaborate with parties to streamline permitting that is required.

Water users should consult with NMFS regarding the federal Endangered Species Act (ESA) and CDFW regarding the California ESA. Depending on the nature of the release, it could also fall under CDFW's authority under Fish and Game Code Section 1600.

Section 9 of the federal ESA prohibits the taking of any species listed as either Threatened or Endangered under the Act. Taking, in this context, means to kill, harm or otherwise interfere with the survival of listed species. While the objective of a flow release program has quite the opposite intention (i.e., to protect species), some program participants may elect to acquire incidental take coverage from NMFS to protect themselves from potential legal liability in the event something unintentionally goes wrong that results in harm to the fish. Several incidental take permitting options exist that NMFS can apply, and the agency is currently working with CDFW on recommendations for the most efficient permitting pathway for flow release projects. Those interested in obtaining such permits should contact a NMFS or CDFW representative.

Flow release projects implemented to date have obtained regulatory assurances from NMFS and CDFW by signing Voluntary Drought Initiative (VDI) Agreements. These agreements describe conditions under which the agencies will choose to exercise enforcement discretion, without actually providing an incidental take permit, and they are limited to the current emergency drought declaration period established by the state of California. VDI's have traditionally clarified the roles and responsibilities of each party as they relate to the flow release and specified the decision-making process used to determine the timing (start and end dates) and rate of the release.

6.1.6 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 existing 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 Dutch Bill Creek watershed, we performed a preliminary set of calculations required for a Water Availability Analysis.

These calculations represent 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[24] to the amount of water requested by existing documented water rights holders (including appropriative and riparian rights). The resulting statistic of this analysis is the 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 five percent of unappropriated discharge, it is possible for more water to be appropriated.

We calculated Water Supply Tables (Table 9 - Table 11) for the water rights in the Dutch Bill Creek watershed (similar to those 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 information:

- 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 Austin 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.

[24] 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.

- 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.
- 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 calculate the Remaining Impaired Discharge for all Dutch Bill 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 9, below), as well as the months of April and May for additional comparison for water availability from a regulatory perspective (Table 10, Table 11). The tables below show the Water Supply Tables for the 31 points of diversion in the watershed.

Our analysis indicates that there is additional water available for appropriation during the winter diversion season of December 15 through March 31, and possibly in April as well: the percentage of remaining unappropriated water remains above 94 percent at all existing diversion points along Dutch Bill Creek and its major tributaries. The data presented in the first table indicate that additional appropriations from Dutch Bill Creek may be possible during this winter diversion season. Along with the analysis of human water needs described in Section 3, these data indicate that there is substantial opportunity to store water in winter for use in summer in the Dutch Bill Creek watershed while maintaining water needed for environmental processes.

Table 9. Winter season (December 15 through March 31) Draft Water Supply Table for the 31 water right points in the Dutch Bill 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 (%)
S024280	3,658.84	55.05	8,131.67	0.00	117.22	8014.06	98.55
S025957	2,588.52	55.30	5,779.23	0.00	22.69	5756.15	99.61
S009073	580.10	55.65	1,303.27	3.73	20.17	1283.10	98.45
S022924	468.91	53.83	1,019.16	0.00	65.84	953.32	93.54
A024827	468.76	53.82	1,018.64	11.51	65.84	952.80	93.54
S024666	412.02	53.80	894.88	0.00	54.33	840.55	93.93
S014479	324.77	54.36	712.74	0.09	0.18	712.56	99.98
A020134	320.99	56.65	734.18	3.74	12.23	721.95	98.33
A022523	312.46	57.02	719.38	2.96	8.49	710.89	98.82
A020134	298.78	57.89	698.33	3.74	5.53	692.80	99.21
C000511	277.65	53.71	602.01	0.45	42.22	559.79	92.99
D032229	252.12	54.32	552.94	0.00	0.01	552.93	100.00
S025784	249.13	54.15	544.64	0.00	13.78	530.86	97.47
A015894	242.88	53.56	525.23	41.77	41.77	483.45	92.05
A025137	195.98	54.02	427.40	9.13	9.13	418.28	97.86
A021271	163.66	54.62	360.88	0.09	0.09	360.79	99.98
D029444R	93.46	57.94	218.60	2.89	2.89	215.71	98.68
A032372	71.46	54.54	157.37	0.39	0.86	156.12	99.21
S02YYYY	71.46	54.54	157.37	0.47	0.47	156.90	99.70
D030256R	66.20	59.40	158.76	1.79	1.79	156.97	98.88
A018736	63.53	54.57	139.97	13.78	13.78	126.20	90.16
A019515	63.53	54.57	139.97	13.78	13.78	126.20	90.16
S025816	61.82	54.40	135.77	0.00	0.00	135.77	100.00
C000512	60.47	54.36	132.71	0.01	0.01	132.70	100.00
D032559R	48.95	56.20	111.06	0.43	9.13	101.94	91.78
A026228	41.66	57.06	95.97	2.67	2.67	93.30	97.22
A028828	41.66	57.06	95.97	2.67	2.67	93.30	97.22
S015908	41.66	57.06	95.97	2.67	2.67	93.30	97.22
A032192	22.98	53.56	49.70	12.11	12.11	37.58	75.63
A027081	20.83	54.02	45.43	0.90	0.90	44.53	98.03
D030460R	10.01	57.06	23.05	6.05	6.05	17.00	73.75

Table 10. Draft Water Supply Table, month of April, for the 31 water right points in the Dutch Bill 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 (%)
S024280	3,658.84	55.05	1,083.95	0.00	29.93	1053.91	97.23
S025957	2,588.52	55.30	770.37	0.00	4.62	765.75	99.40
S009073	580.10	55.65	173.73	1.04	5.60	168.12	96.77
S022924	468.91	53.83	135.85	0.00	17.84	118.02	86.87
A024827	468.76	53.82	135.78	1.60	17.84	117.95	86.86
S024666	412.02	53.80	119.29	4.51	16.24	103.05	86.39
S014479	324.77	54.36	95.01	0.02	0.05	94.96	99.95
A020134	320.99	56.65	97.87	1.04	2.90	94.96	97.04
A022523	312.46	57.02	95.89	0.82	1.86	94.03	98.06
A020134	298.78	57.89	93.09	1.04	1.04	92.05	98.88
C000511	277.65	53.71	80.25	0.12	11.73	68.52	85.39
D032229	252.12	54.32	73.71	0.00	0.00	73.70	100.00
S025784	249.13	54.15	72.60	0.00	3.83	68.77	94.73
A015894	242.88	53.56	70.01	11.60	11.60	58.41	83.43
A025137	195.98	54.02	56.97	2.54	2.54	54.44	95.55
A021271	163.66	54.62	48.11	0.02	0.02	48.08	99.95
D029444R	93.46	57.94	29.14	0.80	0.80	28.34	97.24
A032372	71.46	54.54	20.98	0.11	0.24	20.73	98.84
S02YYYY	71.46	54.54	20.98	0.13	0.13	20.84	99.37
D030256R	66.20	59.40	21.16	0.00	0.00	21.16	100.00
A018736	63.53	54.57	18.66	3.83	3.83	14.83	79.49
A019515	63.53	54.57	18.66	3.83	3.83	14.83	79.49
S025816	61.82	54.40	18.10	0.00	0.00	18.10	100.00
C000512	60.47	54.36	17.69	0.00	0.00	17.69	99.99
D032559R	48.95	56.20	14.80	0.12	2.54	12.27	82.88
A026228	41.66	57.06	12.79	0.74	0.74	12.05	94.21
A028828	41.66	57.06	12.79	0.74	0.74	12.05	94.21
S015908	41.66	57.06	12.79	0.74	0.74	12.05	94.21
A032192	22.98	53.56	6.62	0.00	0.00	6.62	100.00
A027081	20.83	54.02	6.06	0.25	0.25	5.81	95.89
D030460R	10.01	57.06	3.07	0.00	0.00	3.07	100.00

Table 11. Draft Water Supply Table, month of May, for the 31 water right points in the Dutch Bill 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 (%)
S024280	3,658.84	55.05	329.06	0.00	25.51	303.44	92.21
S025957	2,588.52	55.30	241.66	0.00	1.98	239.68	99.18
S009073	580.10	55.65	54.50	1.07	5.79	48.71	89.38
S022924	468.91	53.83	42.62	0.00	16.65	25.96	60.92
A024827	468.76	53.82	42.60	0.00	16.65	25.94	60.90
S024666	412.02	53.80	37.42	4.66	16.65	20.77	55.49
S014479	324.77	54.36	29.80	0.03	0.05	29.75	99.83
A020134	320.99	56.65	30.70	1.07	3.00	27.70	90.23
A022523	312.46	57.02	30.08	0.85	1.92	28.16	93.60
A020134	298.78	57.89	29.20	1.07	1.07	28.13	96.32
C000511	277.65	53.71	25.17	0.00	11.99	13.18	52.35
D032229	252.12	54.32	23.12	0.00	0.00	23.12	100.00
S025784	249.13	54.15	22.77	0.00	3.95	18.82	82.64
A015894	242.88	53.56	21.96	11.99	11.99	9.97	45.40
A025137	195.98	54.02	17.87	0.08	0.08	17.79	99.53
A021271	163.66	54.62	15.09	0.03	0.03	15.07	99.83
D029444R	93.46	57.94	9.14	0.83	0.83	8.31	90.92
A032372	71.46	54.54	6.58	0.11	0.24	6.34	96.30
S02YYYY	71.46	54.54	6.58	0.13	0.13	6.45	97.98
D030256R	66.20	59.40	6.64	0.00	0.00	6.64	100.00
A018736	63.53	54.57	5.85	3.95	3.95	1.90	32.43
A019515	63.53	54.57	5.85	3.95	3.95	1.90	32.43
S025816	61.82	54.40	5.68	0.00	0.00	5.68	100.00
C000512	60.47	54.36	5.55	0.00	0.00	5.55	100.00
D032559R	48.95	56.20	4.64	0.12	0.08	4.56	98.18
A026228	41.66	57.06	4.01	0.77	0.77	3.25	80.93
A028828	41.66	57.06	4.01	0.77	0.77	3.25	80.93
S015908	41.66	57.06	4.01	0.77	0.77	3.25	80.93
A032192	22.98	53.56	2.08	0.00	0.00	2.08	100.00
A027081	20.83	54.02	1.90	0.00	0.00	1.90	100.00
D030460R	10.01	57.06	0.96	0.00	0.00	0.96	100.00

6.2 Mechanisms for protecting saved water

As mentioned above, water users, project managers, and funders should ensure that any summer water use offset through winter storage remains and is protected instream. There are several mechanisms through which this can be accomplished, and these can also benefit landowners and water users. More information is available in A Practitioner's Guide to Instream Flow Transactions in California (SWIFT 2016).

6.2.1 Forbearance agreements

Forbearance agreements are one of the tools for protecting instream flow gains achieved through storage and other water conservation projects, and have been widely used across coastal California. A forbearance agreement is a covenant that runs with the land and is recorded with the county on the property deed. 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 operated, and those under they must be ceased.

6.2.2 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 benefit of an instream water right dedication is 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[25]). 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.

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

A water right 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 also be cases where an instream water rights dedication is not as 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 rainwater harvesting). More information is available in A Practitioner's Guide to Instream Flow Transactions in California (SWIFT 2016).

6.3 Potential threats

A significant amount of work has been completed to improve instream flow for fish populations in Dutch Bill 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. The human footprint remains limited in the Dutch Bill Creek watershed, 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 streamflow improvement depends on our ability to continue to recruit new landowners and to ensure that the benefits of projects are not undermined by downstream diverters. This is necessary not only to reach our 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, a high rate of participation creates a cultural climate conducive to water conservation and discourages water waste.
- Lack of funding for projects. 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 the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (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 and support 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 Dutch Bill 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 a 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.

Conclusion

Dutch Bill Creek is a critically important watershed for coho salmon and steelhead. The Partnership's work to restore a more natural flow regime and address the threat to summer rearing juvenile fish from water diversions complements a long history of restoration efforts in the watershed.

The Partnership's monitoring work suggests that human water use and diversion have an impact on streamflow during the dry season and that pool connectivity is a key factor in juvenile oversummer survival.

Our data suggest that there is sufficient water in the Dutch Bill Creek watershed to meet human needs on an annual basis. They also suggest that projects that keep pools connected by collectively increasing streamflow as little as 0.01 - 0.05 ft^3/s have the potential to improve survival of juvenile coho salmon throughout the summer rearing season.

As such, a primary goal of the Partnership is to complete projects that will keep pools connected by surface flow throughout the summer dry season (June through October), and in turn increase the probability of juvenile coho surviving the summer season and prevent extinction. We recommend – and are pursuing – projects that:

- Reduce or eliminate direct dry season diversions from mainstem Dutch Bill Creek and its tributaries by institutional and residential users
- Involve flow releases and spring-to-surface-water reconnection
- Assess the impact of stormwater runoff and explore infiltration and groundwater recharge opportunities

Using metrics developed for the SIP, we estimate that the Partnership's suite of current and anticipated future projects could cumulatively add sufficient flow for the creek to meet estimated pool connectivity thresholds through our reference and treatment reaches. Flows greater than those required to maintain minimum connectivity will ultimately be necessary to increase juvenile production and achieve full population recovery.

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Appendix A. Recovery Plan actions implemented by the Coho Partnership

The 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 Dutch Bill 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 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 oversummer 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 Partnership's efforts are consistent with DFW'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).

California Water Action Plan

This project implements the following actions in the California Water Action Plan (California Natural Resources Agency et al. 2014):

- Action 4 – Protect and Restore Important Ecosystems
  - Restore Coastal Watersheds: "The Department of Fish and Wildlife in coordination with other state resource agencies and other stakeholders, as appropriate, will develop at least 10 off-channel storage projects…along the California coast in strategic coastal estuaries to restore ecological health and natural system connectivity, which will benefit local water systems and help defend against sea level rise."
  - Enhance Water Flows in Stream Systems Statewide

Appendix B. UC oversummer survival and flow study methods and results

Study reach habitat characterization

Each summer between 2011 and 2015, UC assessed fish habitat in the Dutch Bill Creek treatment and reference reaches at pre-established intervals using a protocol adapted from CDFW's California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). Habitat units were classified as pool, flatwater, or riffle and unit length, width, and average and maximum depth were measured. In addition, measurements of over-channel canopy cover and composition, shelter value and percent cover, and substrate were collected. Canopy, shelter, and maximum pool depth from the first annual survey (in June of each year) were used, along with the Rosgen (1994) channel type assigned by CDFW, to describe general morphological conditions and physical habitat characteristics within each study reach to allow for a better understanding of relative habitat quality (Table 12). Both reaches were classified as F channel types; entrenched, meandering, riffle-pool channels on low gradients with a high width-to-depth ratio (CDFW 2000a). The treatment reach, an F4 channel, has a predominantly gravel substrate, while the reference reach, an F3 channel, has a predominantly cobble substrate (Flosi et al. 1998; Table 12).

Over-channel canopy cover in both reaches exceeds CDFW's habitat benchmark of ≥80% (Flosi et al. 1998) and canopy is only nominally better in the reference reach (Table 12). Both reaches are dominated by hardwood forests, with a roughly 20 to 30 percent occurrence of coniferous trees in the riparian corridor (Table 12). Instream shelter, while nominally higher in the reference reach, is also similar between reaches and falls significantly short of CDFW's established shelter rating criterion of ≥80 for suitable salmonid habitat (Flosi et al. 1998; Table 12). 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). When June depths were averaged over all years, the reference reach did not meet this benchmark and the treatment reach exceeded it (Table 12).

Table 12. Dutch Bill Creek study reach characteristics, averaged between 2011 and 2015.

Reach	Channel type[1]	Avg canopy (%) +/- 1 SD	Avg coniferous cover (%) +/- 1 SD	Avg shelter rating +/- 1 SD	Avg % pools (by total length) >3.0'D +/- 1 SD
Dutch Bill treatment	F4	94.2 +/- 5.6	33.0 +/- 16.8	15.3 +/- 10.8	45.3 +/- 27.2
Dutch Bill reference	F3	96.8 +/- 3.8	21.7 +/- 12.7	17.8 +/- 12.0	23.7 +/- 19.0

[1] *Rosgen stream channel classification from CFDW stream reports.*

Survival

Each study year, UC biologists worked with the Coho Program to implant PIT tags in approximately 1,000 coho yoy produced at the Don Clausen Fish Hatchery at Warm Springs Dam, and released approximately 500 tagged fish into each of the Dutch Bill Creek treatment and reference reaches in June. The average size of stocked fish was approximately 66 mm and 3.6 grams (ACOE, unpublished data).

Between June and early October of each year, UC biologists conducted surveys at defined intervals (4-6 paired sampling occasions and 3-5 intervals per summer, depending on available resources), using a custom-built, portable PIT tag detection system, or “wand.” On each sampling occasion, biologists waded the habitat units in each reach from downstream to upstream, waving the wand through the water column to detect PIT-tagged fish. Detected tags were recorded on a PIT tag transceiver attached to the wand and this data was used to build encounter histories for individual fish released into the reach in June.

Prior to the release of PIT-tagged coho yoy, UC constructed and installed PIT-tag antennas at the downstream and upstream boundaries of the reaches to document emigration throughout the summer season. Any individuals detected leaving the study reach were excluded from the survival estimates for all intervals that occurred after the date the fish was detected leaving the reach.

Because mortality of fish can occur within the study reach, resulting in tags that become lodged in the streambed (“dead tags”), on each sampling occasion, we conducted a dead tag wanding survey to document individuals that perished within the reach since the previous sampling occasion. Dead tags were distinguished from live fish by the fact that they do not move as the wand is waved through the water column. All known mortalities were converted from detections to non-detections beginning on the sample in which their mortality was documented.

The robust design mark-recapture model (Lebreton 1982, Kendall 1997) was used in program MARK (White and Burnham 1999) to estimate interval-specific survival for each reach between June and October using the individual encounter histories developed from the PIT tag wanding samples. For cumulative survival estimates from when the fish were released until the last sampling occasion, interval specific survival estimates were multiplied. To standardize the summer survival interval to June 15 and October 15 for each year in each reach, daily survival estimates generated from the first and last intervals of each reach and year were used to adjust survival estimates in the first and last intervals to match the desired timeframe.

Patterns in annual oversummer survival probabilities differed between the treatment and reference reach over the study periods of 2011 through 2015, with estimated survival being 0.04 to 0.21 higher in the reference reach in all years except for 2014, when survival was higher in the treatment reach (Figure 62). In both reaches between 2011 and 2013, we observed a decline in survival; survival in the treatment reach decreased by 0.35 and survival in the reference reach decreased by 0.30 (Figure 62). In 2014, survival in both reaches increased, and was 0.14 higher in the treatment reach than in the reference reach. In 2015, survival increased in the reference reach and decreased in the treatment reach (Figure 62). It should be noted that 95% confidence intervals overlapped between both reaches among all years, with the exception of the Dutch Bill Creek treatment reach in years 2013 (as compared to 2011 and 2014).

When evaluated collectively with the six other study reaches on Green Valley, Mill, and Grape creeks, average oversummer survival between 2011 and 2015 in the Dutch Bill Creek treatment reach (0.43) and reference reach (0.51) were higher than average survival in all treatment and reference reaches over the 2011 to 2015 study period (0.28 and 0.49, respectively). One notable occurrence in the Dutch Bill Creek reference reach is the relative consistency of oversummer survival; only one other reach, the Mill Creek reference reach, has had a lower disparity in survival over the study years.

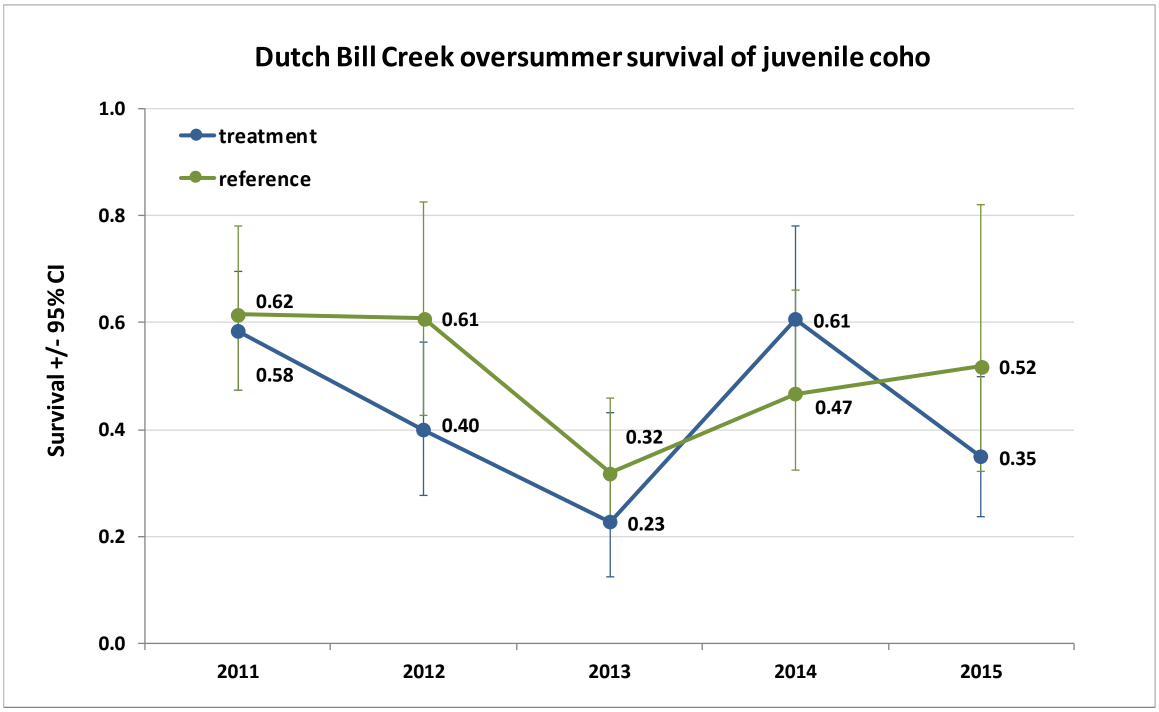

Figure 62. Estimated juvenile coho salmon survival in the Dutch Bill Creek treatment and reference reaches from June 15-October 15, years 2011-2015.

Streamflow

Streamflow data was generated using TU's pressure transducer gauges; one within the Dutch Bill Creek treatment reach and another just downstream of the reference reach. Data was summarized as average daily flow (Figure 63, Figure 64). Because the reference reach gauge was impacted by diversions over the summers of 2011 to 2015 that were not experienced by fish in the reference reach upstream, streamflow datasets for this site were adjusted to remove the daily signals created by the diversion, in order to more accurately reflect reference reach flow conditions; therefore they are slightly different than the hydrographs presented in Section 2.6. Furthermore, there were 42 days of missing data in 2013, due to gauge failure. Discharge for missing data points was estimated by TU hydrologists based on correlations between discharge at the reference reach gauge location and the treatment reach gauge.

Both reaches experienced a general decline in streamflow between 2011 and 2015 (Figure 63, Figure 64), likely related to the progression of drought over that period. Streamflow was generally higher in the treatment reach, which can be partially explained by the fact the treatment reach is located almost three kilometers downstream of the reference reach, so encompasses a larger watershed area. The increase in average daily flow in the reference reach in late summer of 2015 is likely related to the continuous release of 0.1 ft^3/s from CMRPD, approximately three kilometers upstream of the treatment reach and 0.5 kilometers upstream of the reference reach, which began August 24 and ran through December (Figure 64).

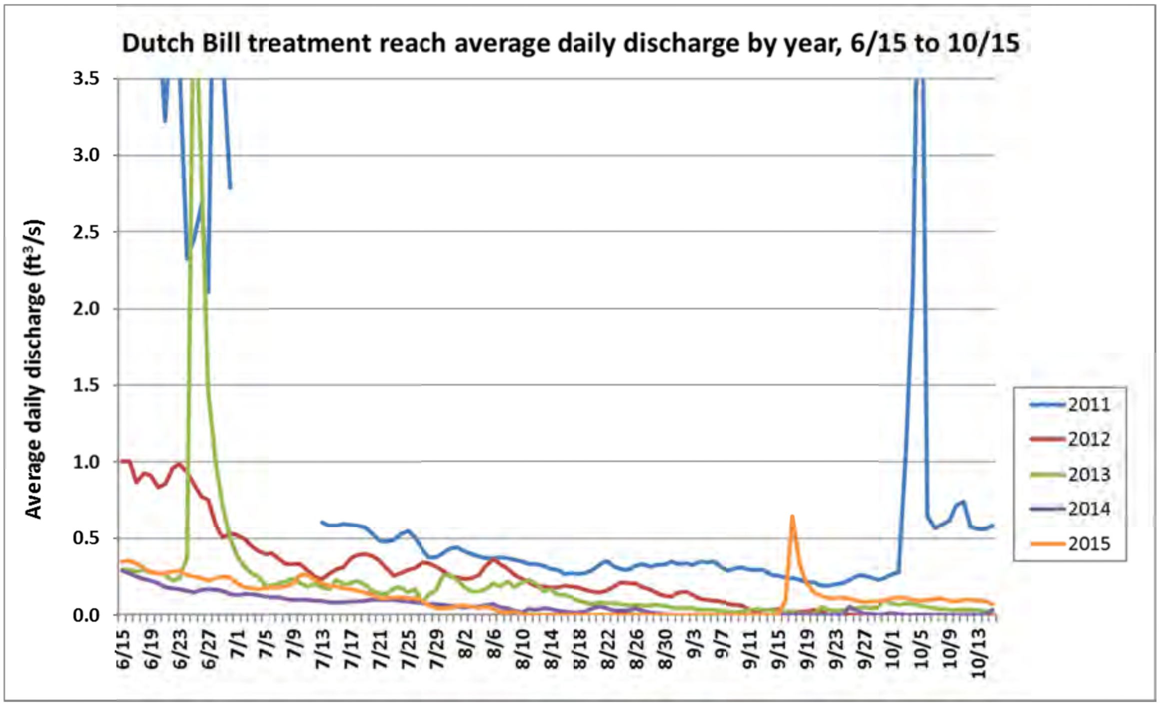

Figure 63. Average daily discharge in the Dutch Bill Creek treatment reach between June 15 and October 15, 2011-2015. Note that the peak flow of the June and October 2011 storms were cut off in order to offer a better view of low flow patterns.

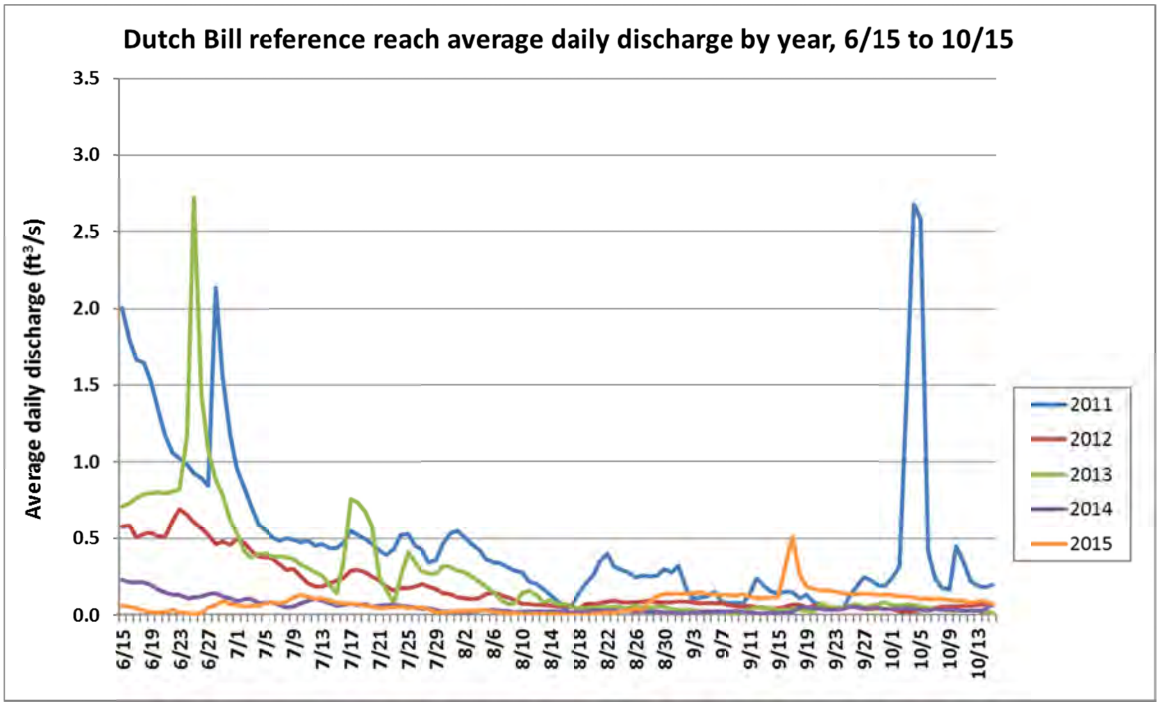

Figure 64. Average daily discharge in the Dutch Bill Creek reference reach between June 15 and October 15, 2011-2015. Note that the peak flow of the early June 2011 storm was cut off in order to offer a better view of low flows.

Pool connectivity

Pool connectivity, defined as the state of pools being connected to neighboring habitat units by continuous surface flow, was used as an additional metric to describe extremely low flow conditions during the summer dry season. In order to calculate the number of days that pools were disconnected between June 15 and October 15 in each reach in each year, reach-specific connectivity thresholds were first estimated, because the flow at which pools become disconnected does not always equate to zero flow through each stream reach. In both survival study reaches, we compared field observations of pool connectivity with hydrographs in order to determine the specific flow level at which pools became disconnected in each of the Dutch Bill study reaches, as described in Section 5.3.1. These connectivity thresholds were then used to calculate the number of days of estimated pool disconnection (flow below connectivity thresholds) in each reach for all years of data collection (Table 13, Figure 65, Figure 66).

Extremely low surface flows in most years resulted in pool disconnectivity for extended periods in the treatment reach (Figure 65). Pool disconnection was first observed in this reach in September of 2012 and extended through the end of the study period in October (Figure 65). Between 2011 and 2015, disconnection began progressively earlier each year due to increasing drought conditions (Figure 65). In 2015, pools became disconnected at the end of July and did not reconnect until September 16, following a rain event (Figure 65).

In the Dutch Bill Creek reference reach, patterns in pool connectivity differed from the treatment reach (Figure 65, Figure 66). Overall, there were significantly fewer days of pool disconnection in the reference reach, which did not become disconnected for an extended period until August of 2015, the driest year of the study (Figure 66). The reconnection of pools on August 24, 2015 can be attributed to the CMRPD flow release occurring upstream of the flow gauge. Without that release, the period of disconnectivity most likely would have continued until the rain event on September 16.

Table 13. Days below connectivity threshold in reference and treatment reaches between June 15 and Oct 15 each year (123 days/year).

Reach name	Connectivity threshold (ft^3/s)	Number of days below threshold				
		2011	2012	2013	2014	2015
Dutch Bill treatment	0.05	0	35	39	68	45
Dutch Bill reference	0.01	0	0	1	0	15

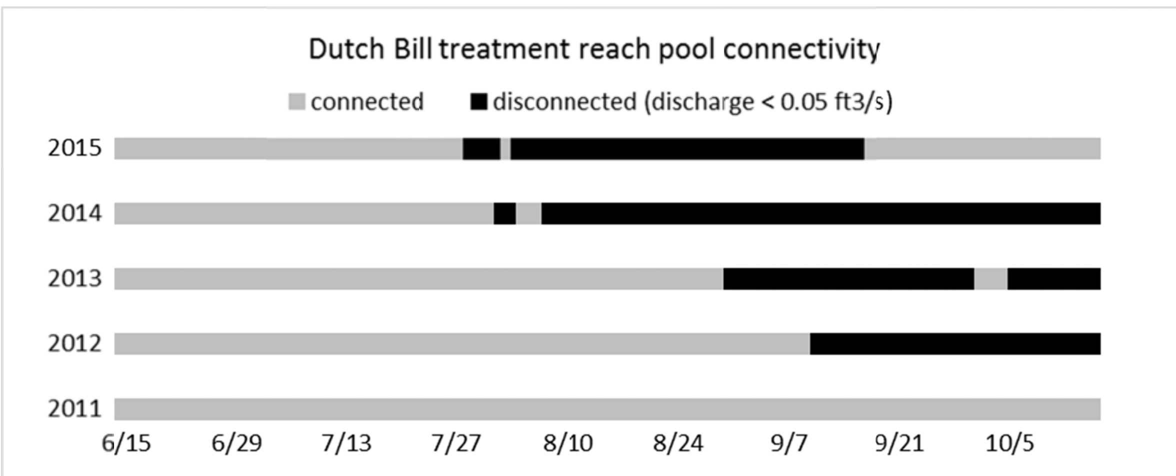

Figure 65. Days of pool disconnection in the Dutch Bill Creek treatment reach between June 15 and October 15, years 2011-2015. Disconnection was assumed when surface flow was below a connectivity threshold of 0.05 ft^3/s in this reach. Discharge data missing 7/1/13 to 7/12/13; connectivity assumed based on previous and subsequent discharge values.

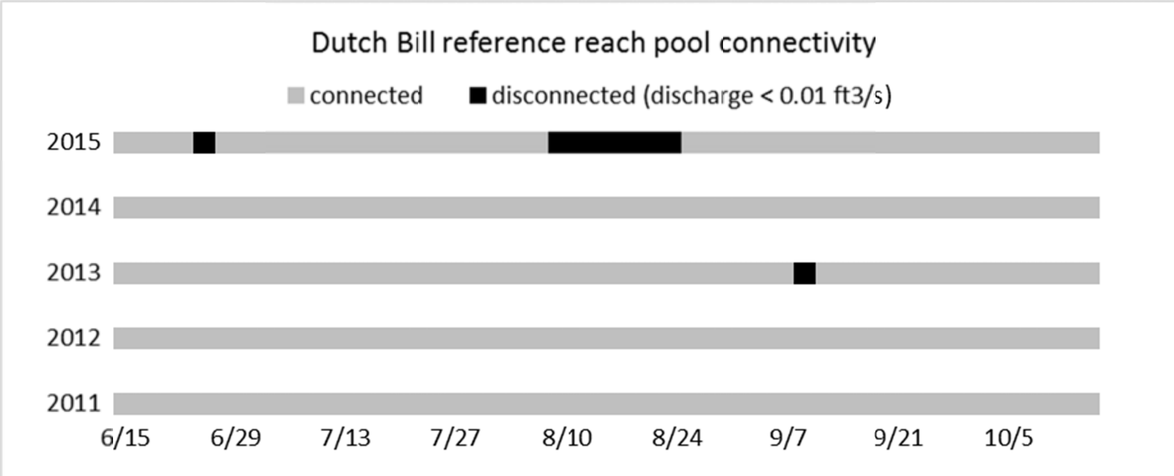

Figure 66. Days of pool disconnection in the Dutch Bill Creek reference reach between June 15 and October 15, years 2011-2015. Disconnection was assumed when surface flow was below a connectivity threshold of 0.01 ft^3/s in this reach. Missing discharge values from 2013 were estimated based on correlations between the two study reach streamflow gauges.

Wetted volume

Habitat characteristics were quantified in each of the Dutch Bill Creek study reaches at pre-established intervals of approximately four to eight weeks between June and October, 2011 through 2015, using a protocol adapted from CDFW's California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). During the initial habitat assessment, habitat units were defined and characterized as pool, riffle, or flatwater. Transects were established within each unit at two to six points (depending on unit size and configuration) that, collectively, represented average unit width and depth. At every sample interval, wetted channel width and average depth were measured at each transect, along with habitat unit wetted length, to ascertain the total wetted volume of each habitat unit. Total wetted volume for all pools and flatwaters (those units providing rearing habitat for fish) was calculated and evaluated at a reach-scale, along with oversummer changes in wetted volume.

The maximum wetted volume in Figure 67 and Figure 68 below is the amount of water available in all pool and flatwater units in each reach during the June sample and the minimum is the amount remaining at the driest point of the season (generally in September). The difference between these two values represents the total change in wetted volume over the summer study period.

Wetted volume in the Dutch Bill Creek treatment reach decreased between 2011 and 2015 (Figure 67). Total *change* in wetted volume over the summer period in the treatment reach averaged 38% for all years and was most drastic in 2015, when total wetted volume in late summer dropped to just 111 m^3; a decrease of 65% from June (Figure 67). Even in 2015, however, no pools in the reach were observed drying completely and 80% of pools within the reach retained sufficient water for juvenile rearing through late summer. All of those pools were downstream of Perenne Creek, a small, perennial tributary, while the single pool above Perenne experienced a 93% decrease in wetted volume and, by late summer, was not capable of supporting fish.

Wetted volume in the reference reach remained notably stable, with an average oversummer decline of only 15% over the five-year study period (Figure 68). Even in the year with the most extreme disparity, 2012, wetted volume decreased by only 20% over the entire summer and remained relatively high at 217 m^3 (Figure 68). Though flows were supplemented in 2015, the relative stability of streamflow and wetted volume in the reference reach indicates that local springs, groundwater inflow, and other sources of water were capable of sustaining summer baseflow through, at least, the third consecutive drought year (2014); and upstream human water uses over 2011-2015 were not significant enough to deplete these sources before reaching the reference reach.

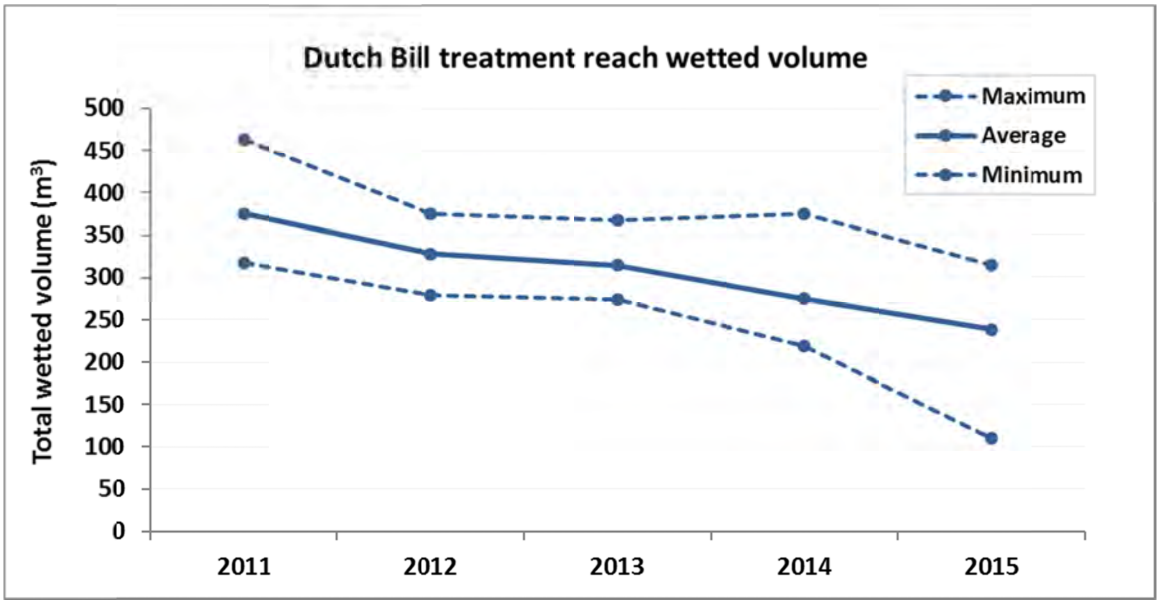

Figure 67. Maximum, average, and minimum oversummer wetted volume in the Dutch Bill Creek treatment reach from 2011-2015.

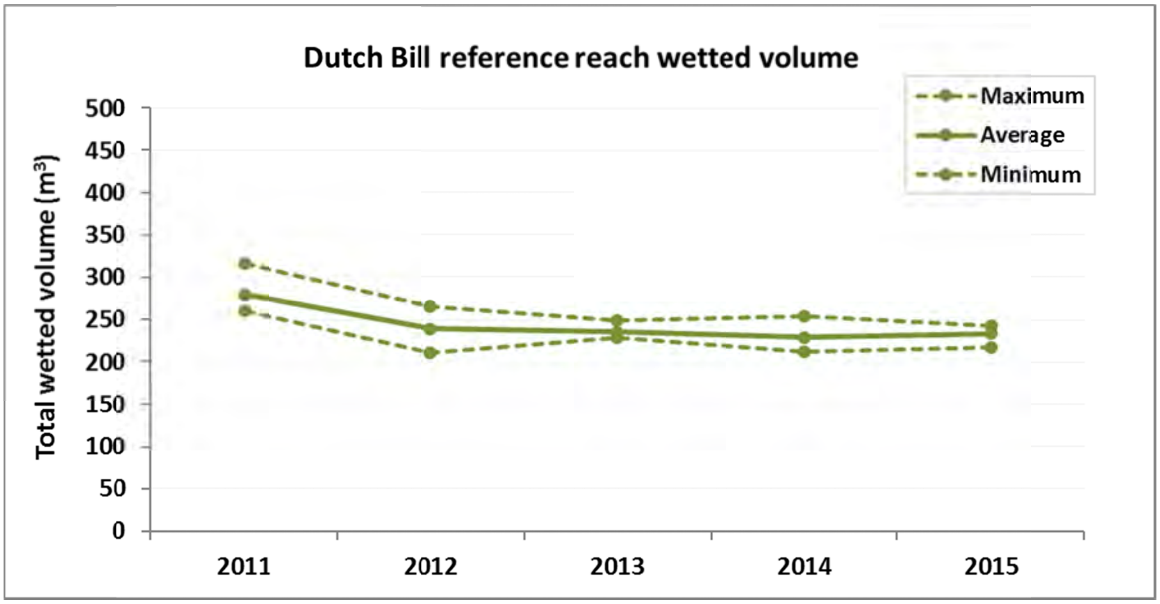

Figure 68. Maximum, average, and minimum oversummer wetted volume in the Dutch Bill Creek reference reach from 2011-2015.

Temperature

Hourly water temperature data was collected throughout the study period by an Onset HOBO Water Temp Pro v2 continuously-recording temperature logger, deployed in a representative pool within each reach. Each logger measured temperature at 60-minute intervals and data was summarized as daily average temperature, maximum weekly average temperature (MWAT), and maximum weekly maximum temperature (MWMT). To obtain MWAT, we averaged daily mean temperatures for each seven-day period and selected the highest average for the summer study season; to obtain MWMT, we averaged daily maximum temperatures for each seven-day period and then selected the highest average for the entire summer, as described in Welsh et al. (2001).

Water temperatures in the Dutch Bill Creek study reaches were evaluated in relation to scientifically-established benchmarks for salmonids. Optimal instream temperatures for coho salmon are between 10°C 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 higher, coho experience significant decreases in swimming speed, increased mortality from disease and cease to grow (McMahon 1983). MWMT above 22.5°C can lead to a reduction of more than 20% of maximum growth (Carter 2005). Temperatures exceeding 25-26°C are lethal to coho salmon (NMFS 2012). CDFW established a maximum desired temperature 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).

When averaged over each summer sample period from 2011 through 2015, water temperatures in the Dutch Bill Creek treatment reach were at the upper end of the optimal range for coho salmon, ranging from 14.3°C to 15.5°C. When evaluated continuously by year, average daily temperatures in the treatment reach exceeded the optimal threshold for coho for the majority of the study period in most years, excluding 2012, though they never exceeded the impairment threshold (Figure 69). In the treatment reach in years 2011 through 2015, oversummer MWAT ranged from 16.0°C to 18.1°C and MWMT ranged from 16.6°C to 19.5°C, with temperatures below, or only slightly above, the avoidance threshold for coho in all years except for 2013, when they were significantly higher (Figure 70).

Daily water temperature in the Dutch Bill Creek reference reach, when averaged over each summer sample period from 2011 through 2015, also ranged from 14.3°C to 15.5°C—at the upper end of the optimal range for coho. When evaluated continuously by year, average daily temperatures exceeded the optimal threshold for coho for the majority of the study period in most years, excluding 2012, and neared the impairment threshold in the hottest period during July, 2013 (Figure 71). Oversummer MWAT ranged from 16.1°C to 18.7°C and MWMT ranged from 17.3°C to 20.1°C and exceeded the avoidance threshold in 2011 and in 2013 (Figure 72).

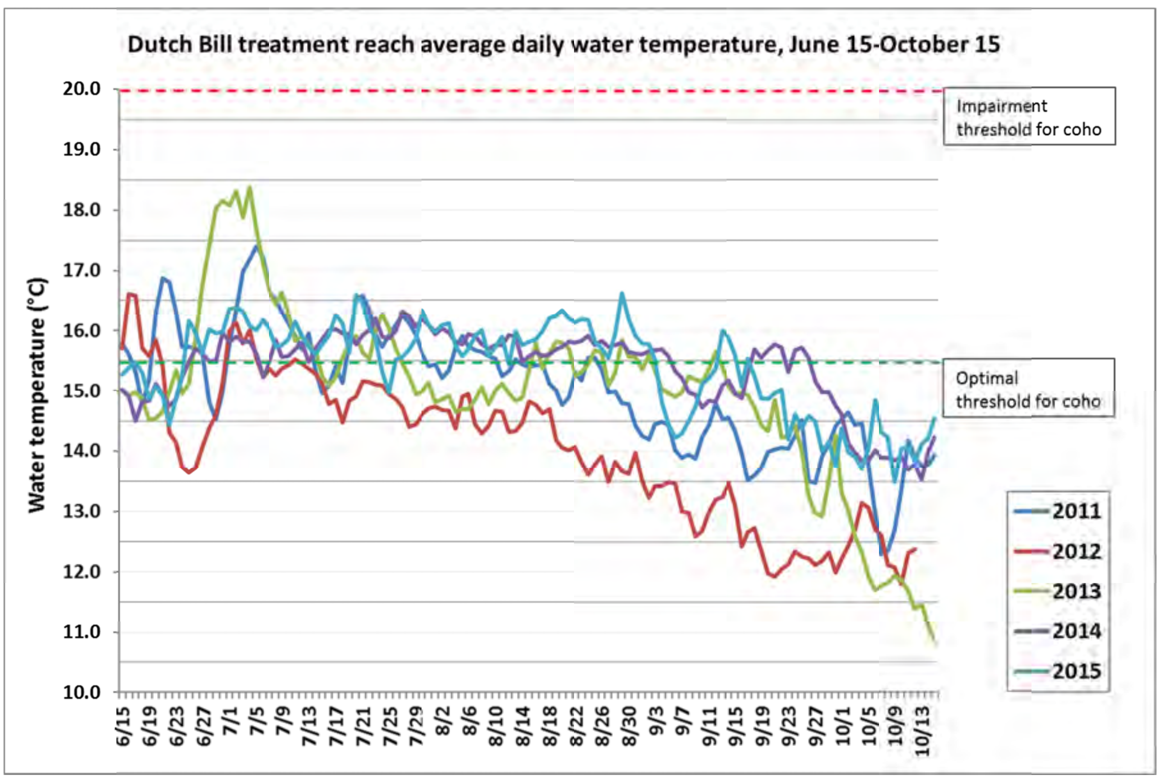

Figure 69. Average daily water temperatures in the Dutch Bill Creek treatment reach over the summers of 2011-2015, in relation to thresholds described in McMahon (1983) and Flosi et al. (1998).

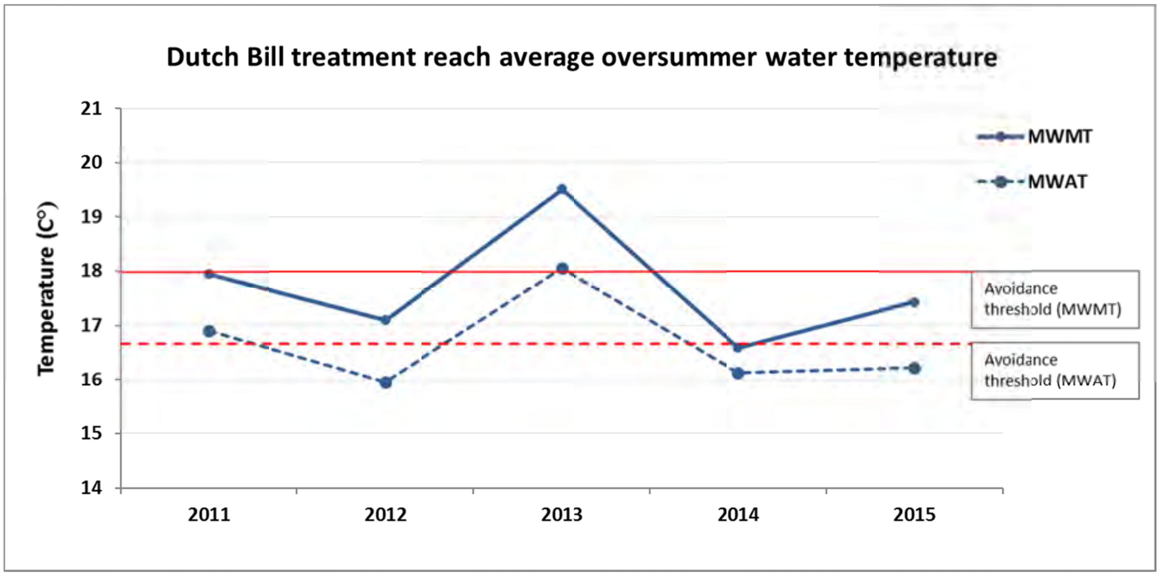

Figure 70. Oversummer MWMT and MWAT in the Dutch Bill Creek treatment reach from 2011-2015, in relation to thresholds described in Welsh et al. (2001).

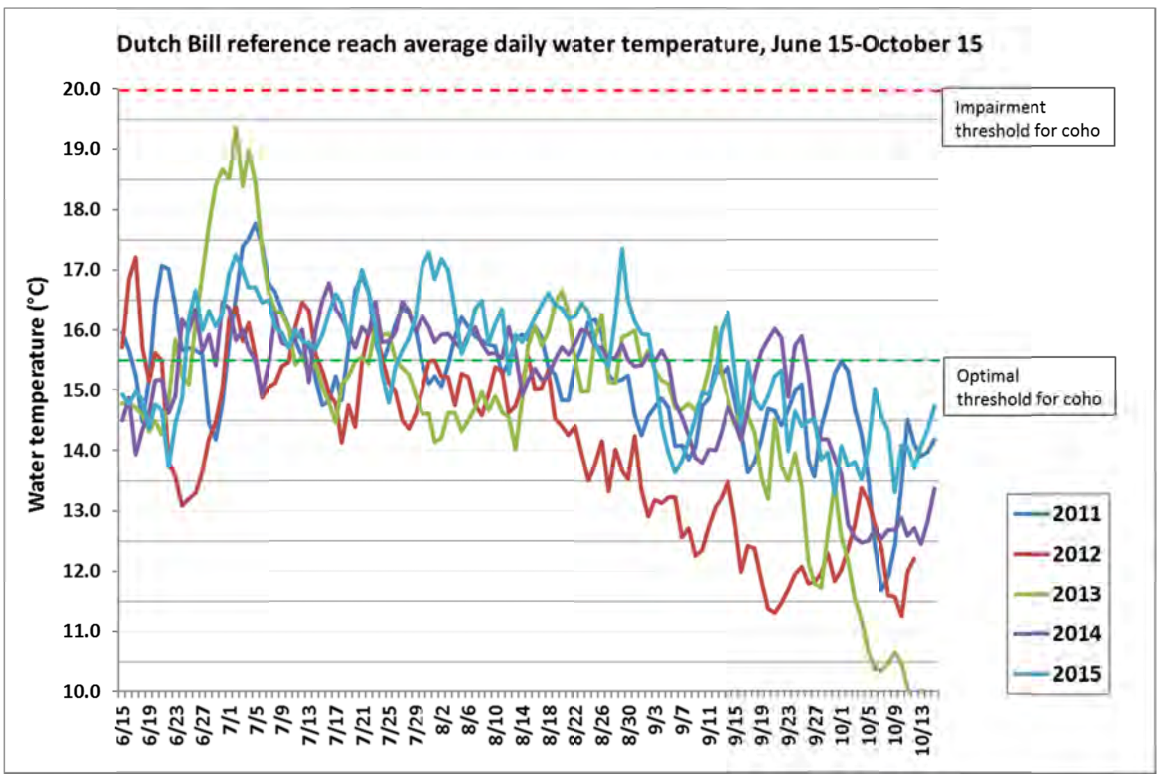

Figure 71. Average daily water temperatures in the Dutch Bill Creek reference reach over the summers of 2011-2015, in relation to thresholds described in McMahon (1983) and Flosi et al. (1998).

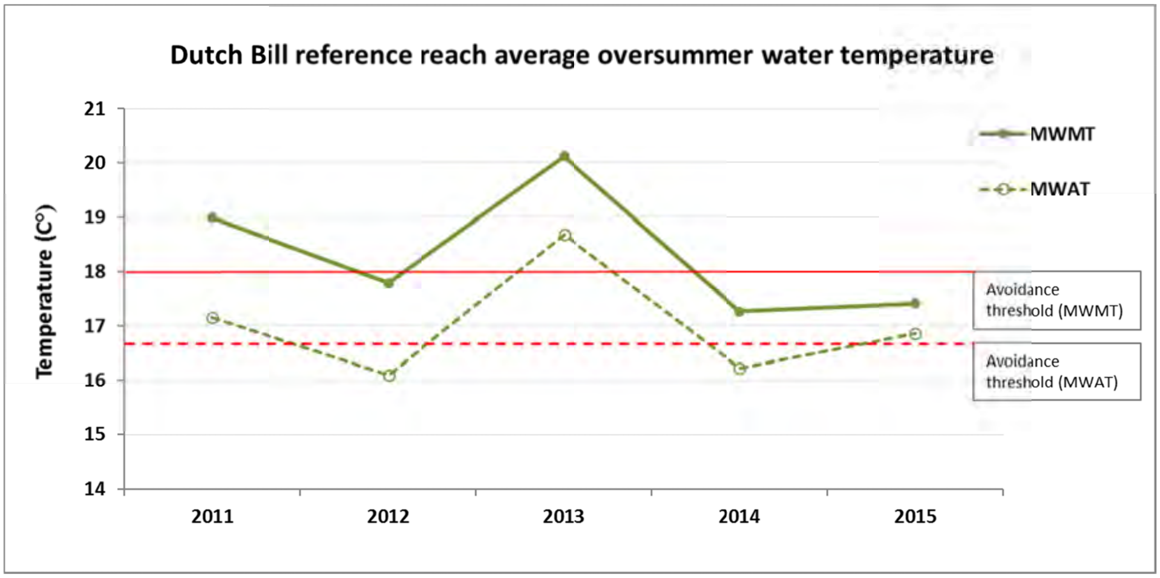

Figure 72. Oversummer MWMT and MWAT in the Dutch Bill Creek reference reach from 2011-2015, in relation to thresholds described in Welsh et al. (2001).

Dissolved oxygen

Dissolved oxygen (DO) data was collected at survival sample intervals in each study reach using a YSI handheld DO sensor (YSI 55D or YSI Pro20, depending on year). Readings were taken in every pool, at a consistent location and depth, within a window of two-and-a-half hours in late morning (8:50-11:20 a.m., for all samples). It is important to note that DO readings at the sample times did not necessarily reflect 24-hour minimum values. Continuous DO loggers placed in a single, representative pool within each reach in 2015 indicated that diel lows in DO generally occurred during late night and early morning hours. DO data was summarized as a reach-scale average for each sample interval on each study reach.

The resulting values were compared to established objectives and tolerance thresholds for salmonids to evaluate the suitability of DO concentrations in the study reaches. The 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).

DO concentrations ranged from 5.41 mg/L to 8.32 mg/L in the Dutch Bill Creek treatment reach *when averaged at a reach scale over each annual summer study season* (Figure 73). DO concentrations in the Dutch Bill Creek treatment reach, measured at four to eight week intervals between June and October in years 2011 through 2015, ranged from 3.69 mg/L to 9.15 mg/L, when averaged at a reach scale *for a single interval* (Figure 74). These concentrations exceeded NCRWQCB's water quality objective in all sample intervals of 2011 and most of 2012, as well as in June of every year, but fell below this threshold in every sample period after June in 2013, 2014, and

2015 (Figure 74), as drought conditions led to lower surface flows and earlier intermittence. All intervals past the June sample had reach average concentrations near or below production impairment levels in 2014 and 2015, with the lowest values observed in late July 2015 (Figure 74).

Annual, reach-average DO in the reference reach ranged from 7.55 mg/L to 9.06 mg/L and averaged 8.4 mg/L (+/- 0.4 mg/L SD) for all years combined (Figure 75). DO concentrations in the reference reach were higher than in the treatment reach and more consistent between pools, ranging from 6.48 mg/L to 9.85 mg/L, when averaged at a reach scale *for a single interval* between June and October of 2011 to 2015 (Figure 76). These concentrations were above NCRWQCB's water quality threshold and within the suitable range for salmonid fry at 90% of sample intervals; every sample except for early September, 2014 and late July, 2015, when DO dropped to concentrations associated with moderate production impairment of salmonids (Figure 76). The lowest DO values recorded in the reference reach (in July 2015) were still above impairment values (Figure 76). The relatively high DO concentrations observed in this reach can likely be explained by the consistent inflow of aerated water into pools due to riffle connectivity.

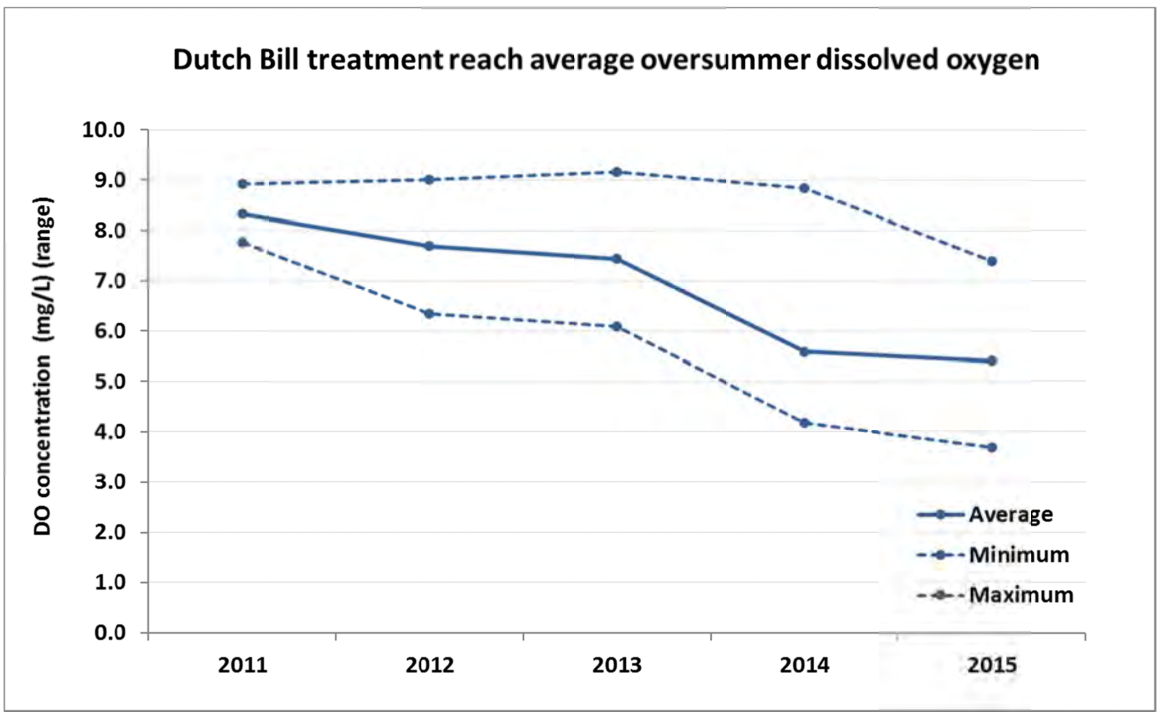

Figure 73. Average, minimum, and maximum reach-scale dissolved oxygen concentrations in the Dutch Bill Creek treatment reach over the summers of 2011-2015.

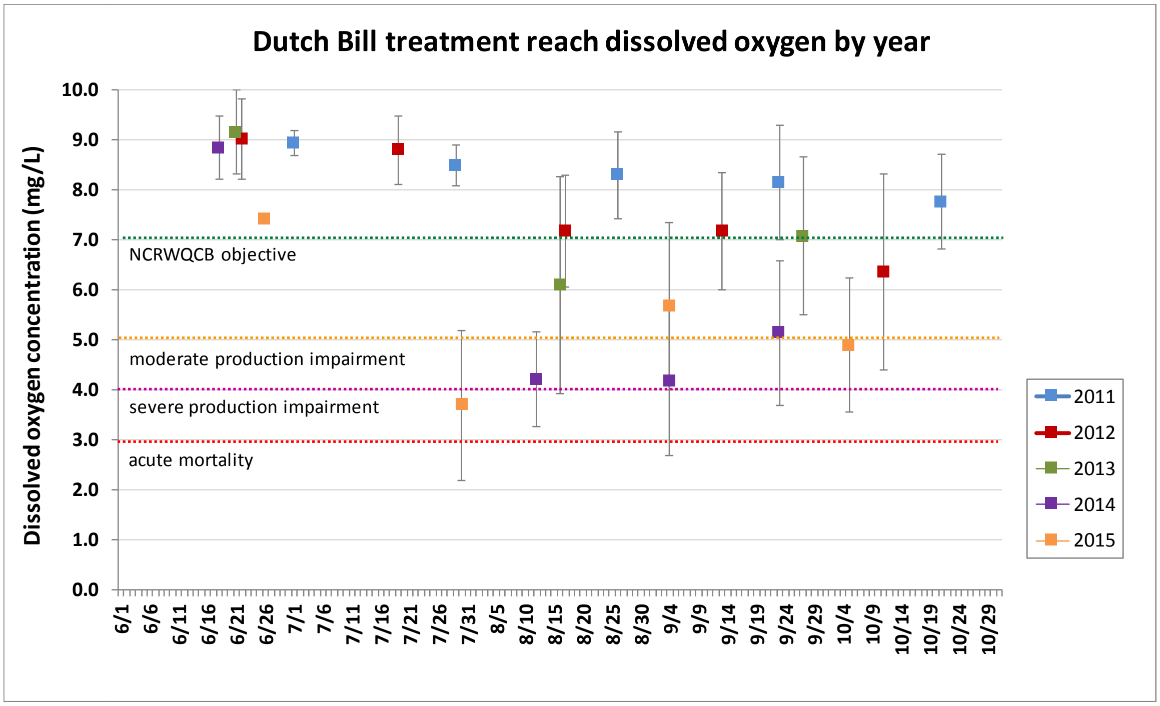

Figure 74. Reach average dissolved oxygen concentrations in the Dutch Bill Creek treatment reach for all sample intervals in 2011-2015, in relation to thresholds described in NCRWQCB (2007) and McMahon (1983).

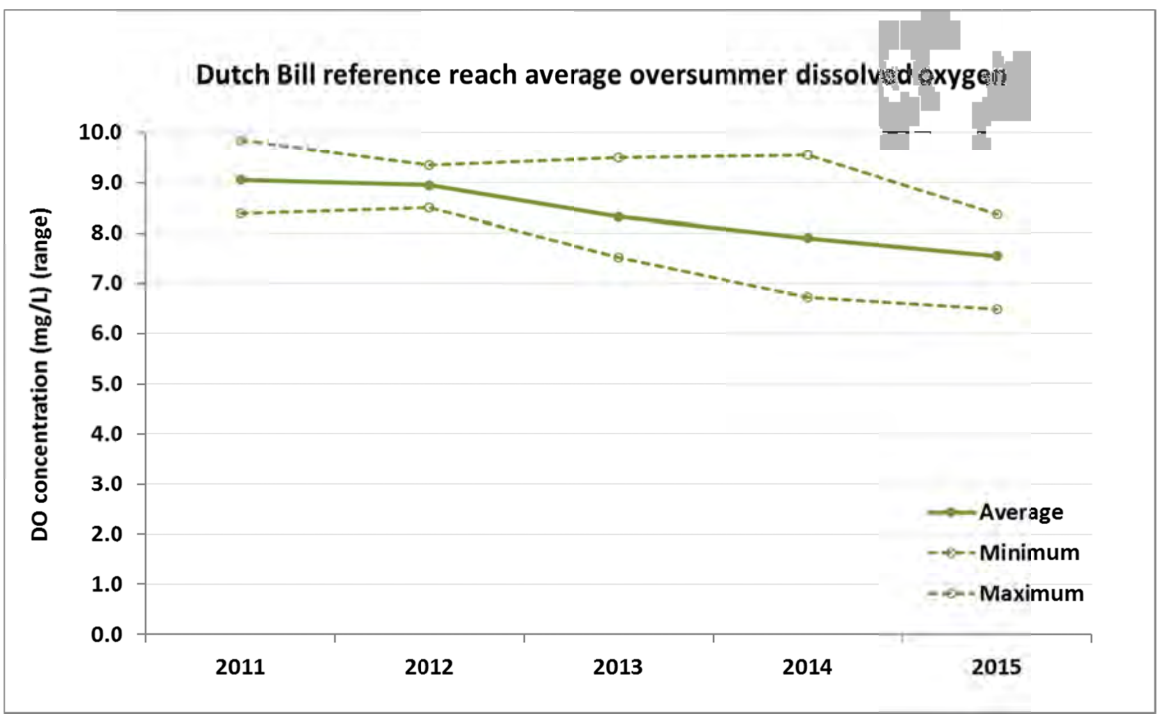

Figure 75. Average, minimum, and maximum dissolved oxygen concentrations in the Dutch Bill Creek reference reach over the summers of 2011-2015.

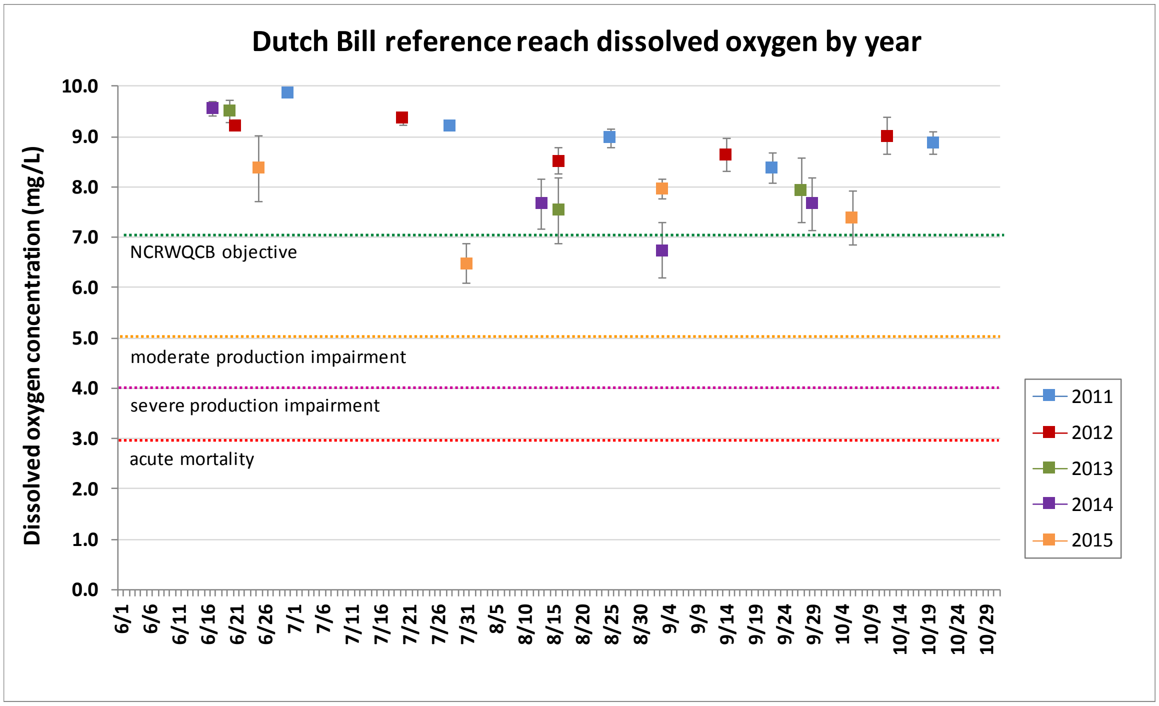

Figure 76. Reach average dissolved oxygen concentrations in the Dutch Bill Creek reference reach for all sample intervals in 2011-2015, in relation to thresholds described in NCRWQCB (2007) and McMahon (1983).

Oversummer growth

A multiple-day electrofishing survey was conducted on each study stream reach in late September or early October to measure coho salmon in order to estimate oversummer growth. Fork length and weight of each individual fish was measured during PIT tagging prior to the June release and, again, at recapture during electrofishing surveys. The increase in fork length was divided by the number of days in the study period and summarized as average daily growth rate, in fork length.

Over the summers of 2011 to 2015, juvenile coho in the Dutch Bill Creek treatment reach experienced an average daily growth rate, in fork length, of 0.07 mm/day, while fish in the Dutch Bill Creek reference reach grew an average of 0.06 mm/day. Growth rates in both reaches were at or slightly lower than the average growth observed in treatment and reference reaches in all four study streams for that period; 0.08 and 0.06 mm/day, respectively. Growth was higher in the Dutch Bill Creek treatment reach than in the reference reach (Figure 77), which is possibly explained by the fact that the treatment reach, which is lower in the stream system, tends to have greater wetted volume and deeper pools and, in turn, lower fish densities than the reference reach in the upper watershed. Growth was relatively high in 2013, when temperatures were warmer and oversummer survival was lowest (Figure 62, Figure 77).

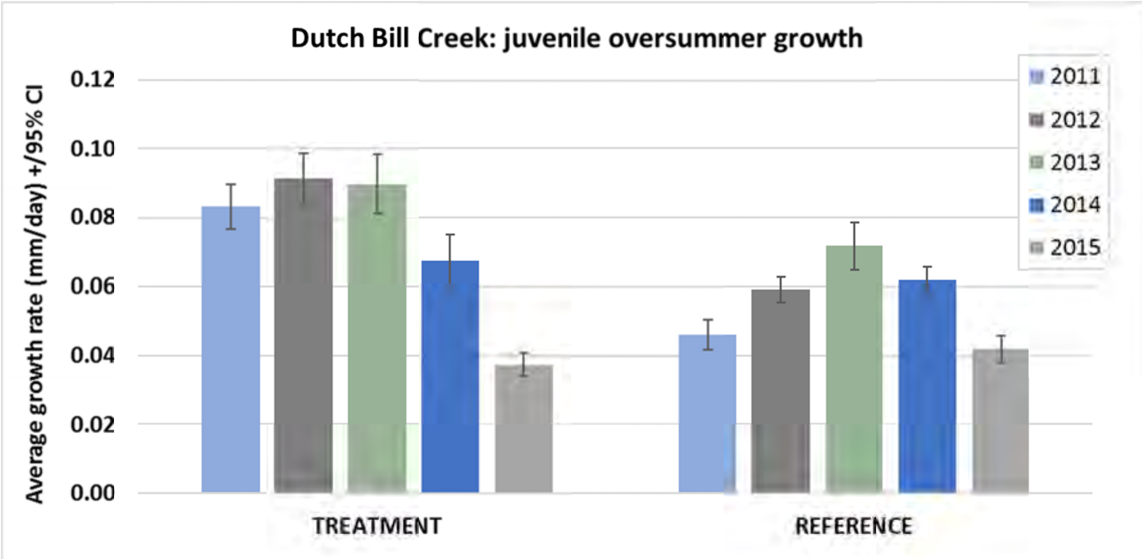

Figure 77. Average daily oversummer growth rate, in fork length, by year in the Dutch Bill Creek study reaches.