Green Valley Creek
Watershed Management Plan

DRAFT

A Living Document to Facilitate the Stewardship of the Green Valley Creek Watershed

Gold Ridge RCD March 2013

The Green Valley Creek

Watershed Management Plan DRAFT

Phase II, March 2013

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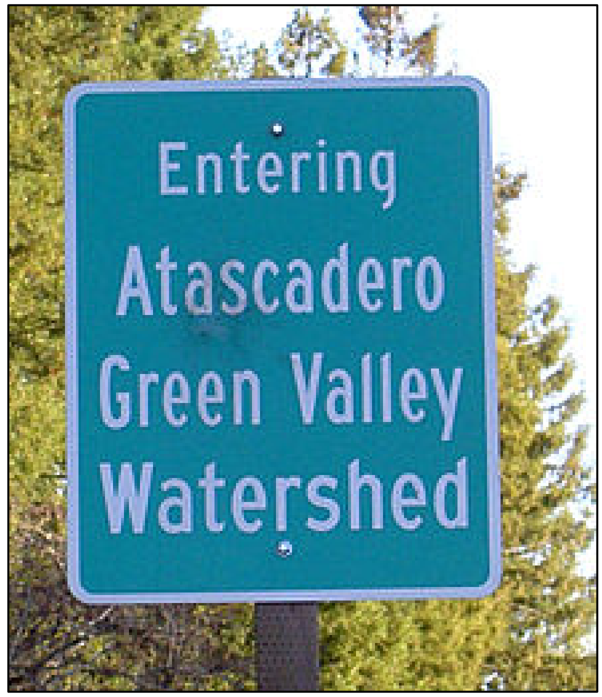


The Green Valley Creek (GVC) watershed is located in the Russian River Hydrologic Unit in western Sonoma County, California and has been identified by state and federal government as priority recovery habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). The Green Valley Creek Watershed Management Plan (Plan) provides a description of existing watershed conditions, identifies data gaps, identifies and prioritizes habitat enhancement projects for immediate implementation and provides recommendations for management practices to support restoration of watershed function.

Since the goal of this plan is to propose a prioritized plan of action for the recovery watershed function and ultimately a self-sustaining coho population, emphasis is being placed on feasible solutions that can be implemented under the current conditions and landownership. Therefore, efforts have focused on identifying restoration priorities that work within the context of current watershed conditions and demographics. The goal being to recover coho salmon in partnership with the existing residential and agricultural communities.

The Green Valley Creek watershed is a sub-basin of the Atascadero-Green Valley watershed, a tributary of the Russian River. Terrain in the watershed is varied, with gently rolling hills in the east and steep forested slopes in the west. It has a Mediterranean climate, with hot dry summers and cool wet winters. The watershed is composed of Franciscan Complex, Wilson Grove Formation, and Great Valley Complex geology. Much of the watershed, in particular steep slopes underlain by Franciscan Complex, is highly susceptible to erosion. Soils in the watershed are composed mostly of Gold Ridge sandy loam with Hugo and Josephine loams present in the steep, forested areas of the UGV Creek watershed (USDA 2008).

The watershed has been inhabited for roughly six thousand years, first by the Southern Pomo, and more recently by European and American settlers. With the arrival of Euro-Americans, land use in the watershed changed drastically with natural resource extraction occurring at scales previously unencountered – redwood forests were cleared for timber, and riparian forests, woodlands, and grasslands were cleared and utilized for agriculture. Orchards were the primary crop in the early 20th century, giving way to vineyards in the early 21st century. The

Green Valley Creek watershed is almost completely privately owned. Primary land uses in 2013 include rural residential development, apple and pear orchards, vineyards, livestock pasture and the towns of Graton and Forestville. Twenty-two cultural resources from both prehistoric and historic times have been recorded in the watershed.

Water supply is governed by a series of Water Rights Decisions and Water Rights Orders by the State Water Resources Control Board. Surface water in the watershed is fully appropriated between June 15 and October 31 yearly (SWRCB 1998). The greatest demand for surface water is for residential and agricultural needs; many ponds and surface diversions have been created. Currently, several entities have formed a partnership to investigate alternatives for water supply.

Water quality has been monitored by Gold Ridge Resource Conservation District (GRRCD) for the past four years (Chapter II, Section B). During this time, monitoring locations have gone dry, water temperature has exceeded preferred temperatures for salmonids, and dissolved oxygen levels have dropped below optimal levels – all during the summer months. During winter months, several instances of turbidity higher than the threshold value for physiological effects to salmonids were recorded. Purrington Creek most often met standards conducive to salmon with the exception of high velocities during winter flows, however, elsewhere in the watershed, the low flows during summer months likely limits salmonid survival.

An analysis of hydrology and instream flow found that rainfall amounts substantially exceed human water use in the watershed; however, the timing of supply and demand is out of sync (Chapter II, Section C). Rainwater catchment and reservoirs are suggested as a means to capture and store surplus winter rains for summer use. To ensure sufficient water supply for environmental water needs, an analysis of cumulative effects on streamflow from capture and storage is recommended.

An analysis of sediment sources and impacts indicate that channel incision, surface erosion, and gullying are factors in sedimentation of Green Valley and Purrington Creeks (Chapter II, Section E). Road assessments conducted over the past few years found private unpaved roads were insufficiently constructed with regard to preventing or controlling erosion, with poorly constructed stream crossings and inadequate road drainage. Impacts to aquatic habitat include higher peak stream discharge, reduced infiltration, and aggradation, which contributes to lower summer baseflows. Green Valley Creek has aggraded dramatically throughout the middle reach, contributing to flooding and potential fish stranding in the Green Valley Road / Korbel Vineyard area. Assessment of watershed and reach-scale geomorphic processes and an expanded assessment of erosion and sediment delivery are recommended to provide a more complete picture of watershed geomorphology, erosion processes, and impacts of erosion. A geomorphic study (Chapter II, Section F) of the upper watershed, including upper Green Valley and Purrington Creeks was conducted and a hydrologic model was created as a tool to evaluate flow conditions and restoration options.

Development of a program to arrest channel incision in lower Purrington Creek and the reduction of anthropogenic erosion and sediment delivery are recommended to reduce sediment load in streams throughout the watershed.

The Green Valley Creek watershed supports a diverse assemblage of biological resources including several native vegetation communities and numerous wildlife species (Chapter II, Section G). Of particular importance are instream and riparian habitats, which support several special status species including coho salmon, steelhead trout, California freshwater shrimp and California red-legged frogs. The value of these habitats for wildlife has been compromised by land use practices such as logging, grazing, agriculture, and rural development. Recommendations to protect and enhance biological resources include protection and enhancement of the riparian corridor, improvement of instream habitat, management of sediment delivery, increasing summer base flows, monitoring and improving water quality, protection and enhancement of upland habitats, monitoring and enhancement of salmonid and other wildlife habitat and collaboration with the agricultural community to promote on-farm enhancement projects.

Because they are the dominate land uses in the watershed, management actions to improve watershed conditions include the promotion of agricultural and rural residential land stewardship. Best management practices for a wide-range of land uses are outlined and resources for enhanced stewardship are provided. Rural residential development is the primary land use in the UGV watershed, comprising about 45% of total land cover. Rural residential development leads to similar land use issues resulting from urbanization – runoff, flood control, groundskeeping/chemical control, and onsite wastewater treatment systems. An aspect not commonly found in urban areas is the construction, use, and maintenance of unpaved access roads. Sources for BMPs from federal, state, and local agencies are provided to assist rural

residents in determining appropriate stewardship practices.

Climate change has become an increasingly important concern with Northern California expected to experience increased temperatures and greater extremes in weather events. Sea level is expected to rise, exacerbating effects of winter storms. Native vegetation and crops are expected to be affected through changes to phenology, possible disruption of pollination processes, and proliferation of pathogens and parasites. Salmonid habitat is expected to experience changes including decreased instream flow and changes to ocean habitat. Additional impacts of climate change include increased electricity demand, reduced water quality, increased air pollution and airborne allergens, and climate-sensitive infectious diseases.

Recommendations for the Plan were developed to support community and watershed health, with an emphasis on coho salmon recovery. Each section of the plan focuses on a component of watershed function and contains topical recommendations. Some of the conditions which have been documented as limiting the recovery of salmonids include: (and are described in greater detail in Chapter II, Section G)

- High turbidity and sediment loads from roads and riparian and gully erosion;
- Low streamflow during dry summer months and late spring throughout critical frost protection times;
- Poor instream habitat from lack of channel complexity; and
- High summer water temperatures from lack of adequate canopy cover.

However, the Technical Work Group has reached the preliminary conclusion that the Green Valley Watershed ecosystem can be considered healthy and functioning if we achieve the following goals and have the ability to measure results. Because the planning process is an ongoing work in progress, these goals will be reviewed and adapted as we continue to move forward. It is ultimately hoped that this plan will lead to improved community understanding, interest and leadership in watershed stewardship and will provide a structure for continued input from and dialogue between all watershed stakeholders.

Green Valley Watershed Management Plan Goals

Goal 1: A wild, self-sustaining population of coho salmon and steelhead trout and other native aquatic species

Goal 2: Water Quality conditions that meet the needs for all beneficial uses

Goal 3: Stream flows support fish and other aquatic organisms at all life stages.

Goal 4: Surface water and groundwater supplies within the watershed are managed to support resident's quality of life, agriculture, and ecosystem needs (to meet Goal 3)

Goal 5: Aquatic and riparian habitats are assessed, protected and restored

Goal 6: Upland habitats are resilient and biologically diverse with intact ecosystems

Goal 7: Landowners are supported in their efforts to live on the land and produce agricultural products while conserving and protecting natural resources

I. Introduction

A. Overview and Purpose

The Green Valley Creek Watershed Management Plan is an inventory of the watershed's many resources and an integrated, sustainable strategy for managing them. Located in western Sonoma County, California, Green Valley Creek and its main tributaries, Atascadero and Purrington Creeks are considered important salmonid streams in the Lower Russian River basin (*Map 1, Atascadero Green Valley Watershed Location*). These creeks are located within the greater Atascadero-Green Valley (AGV) watershed, which has been identified by the California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) as priority recovery habitat for endangered coho salmon (*Oncorhynchus kisutch*). Atascadero-Green Valley is a focus watershed for both CDFG's coho recovery program and the Russian River Coho Salmon Captive Broodstock Program. Upper Green Valley and Purrington Creeks contain critical salmonid habitat; however, CDFG has documented a decline in salmonid habitat conditions in the Upper Green Valley system, and this decline has been accompanied by a collapse in both coho and steelhead trout (*O. mykiss*) populations. Atascadero Creek, though it comprises 53% (~13,000 acres) of the Atascadero Green Valley Watershed, has not been widely studied. Due to the limited scope of this plan, the focus area included upper Green Valley, Purrington and mainstem Green Valley Creek below the confluence with Atascadero Creek.

Over the years, several studies evaluating habitat impairments and potential limiting factors to salmonid survival have indicated a general decline in habitat quality in Upper Green Valley and Purrington creeks (CDFG 1995, 2006, Laurel Marcus and Associates 2002, Merritt Smith 2003). This decline in local habitat quality occurs at a time when coho salmon populations in the region are in danger of extinction (Weitkamp et al. 1995), with the Russian River system experiencing a "catastrophic reduction in coho salmon distribution (CDFG 2002)." Timely action to improve habitat conditions is necessary to increase salmonid populations: Purrington Creek watershed is one of several "core areas" for implementation of priority recovery actions identified in National Marine Fisheries Service's (NMFS) recently released *Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon* (2010).

Historic timber harvest and removal of riparian vegetation, conversion of native habitat to rural residential and agricultural lands, development of timber, agricultural, and rural access roads, and other land use practices have resulted in significant cumulative changes to watershed processes and characteristics. Land uses that potentially contribute to increased sedimentation in the watershed include improperly designed and/or maintained unpaved rural residential and agricultural roads, agricultural and other development practices, and slope instabilities resulting from historic logging practices. Factors that may be contributing to low stream flow in the watershed include agricultural and residential use; periods of increased demand for both residential landscapes and agriculture coincide with periods of increased environmental demand. Additionally, some low-gradient depositional reaches may be impacted by excessive aggradation, which can also contribute to low stream flow.

The Green Valley watershed is almost completely privately owned; primary land uses are agricultural and rural residential. If instream and riparian habitat is to be preserved and enhanced, then cooperation and participation of landowners is necessary. By implementing a variety of best management practices (BMPs) known to reduce sedimentation, conserve water, and improve habitat, landowners can not only help to protect wildlife habitat and fisheries resources, but also increase economic opportunities in the watershed. Implementation of sustainable practices yields social, environmental, and economic benefits – these are described in detail in *Chapter III, Management Considerations*.

This phase of the Green Valley Watershed Management Plan (GVWMP) provides a description of existing conditions in the watershed and identifies data gaps, identifies and prioritizes a set of restoration recommendations built on a scientific foundation reflected in the studies completed under this plan to enhance watershed function and improve coho habitat (instream and/or riparian) for immediate implementation, and provides recommendations for management practices to support agricultural and environmental sustainability. Goals and objectives identified below represent the most recent watershed-specific information; as more data is gathered and effects of management actions become better understood, goals of this plan may change. The Green Valley Watershed Management Plan is intended as a living document, setting a framework for community cooperation for mutual benefit.

Table A-1. Green Valley Watershed Management Plan Goals & Objectives

Goal	Indicator	Potential Source of Impact	Management Objective
Restore self-sustaining coho populations to Green Valley Creek and its tributaries	Population counts; fish trap counts	Low flow during summer months, lack of riparian cover in some reaches due to legacy timber and agricultural practices; lack of instream habitat complexity; summer agricultural and landscape uses of instream water and near-stream groundwater withdrawals	Restore instream habitat complexity; restore hydrologic connectivity of stream channel and floodplain; implement water conservation measures; conjunctive uses (possibility for offstream storage); implement prioritized sediment reduction projects.

Goal	Indicator	Potential Source of Impact	Management Objective
Meet water quality standards for temperature	Temperature	Lack of riparian cover due to legacy timber and agricultural practices; pool filling due to excessive sedimentation; summer agricultural and landscape uses of instream water and near-stream groundwater withdrawals	Restore native riparian vegetation (those not host for Pierce's disease); implement water conservation measures; conjunctive uses (possibility for offstream storage); implement prioritized sediment reduction projects.
Meet water quality standards for dissolved oxygen	Dissolved oxygen	Low flow during summer months, excessive nutrient levels	Implement water conservation measures; conjunctive uses (possibility for offstream storage).
Meet water quality standards for reducing fine sediment	Instream habitat conditions (turbidity, embeddedness); salmonid survival	Unpaved rural roads; bank erosion, upslope gully erosion	Reduce sedimentation from roads, streambanks, gullies, and other sources.
Support agricultural sustainability efforts	Implementation of sustainable management practices	Competitive markets; environmental regulations	Provide technical and funding assistance.
Assess, protect & enhance riparian habitat	Extent and condition of riparian plant communities, habitat connectivity; bird species diversity and richness	Streambank and upland erosion and habitat fragmentation	Map and assess riparian function and condition; improve agricultural management, grazing practices, and rural residential landscaping activities; identify areas for conservation easements or restoration.
Restore aquatic habitat	Riparian vegetation; instream habitat structure	Historic riparian vegetation removal, upland erosion and delivery, historic channel alteration (including large wood removal), fish passage barriers	Reduce sedimentation from roads and other sources; improve aquatic habitat through streambank stabilization and native riparian revegetation (those not host for Pierce's disease); conduct stream habitat typing; remove fish passage barriers; and increase instream habitat structure and complexity.

Goal	Indicator	Potential Source of Impact	Management Objective
Promote native biodiversity in upland habitats	Extent and condition of native plant communities	Historic and current land use practices; invasive species	Map highly invasive species (broom, arundo) and develop eradication plans; encourage native pollinator plantings and backyard habitat projects.

Gold Ridge RCD & Watershed Planning in the Green Valley Watershed

Since the 1940s, the Gold Ridge Resource Conservation District (GRRCD) has supported many conservation-oriented projects and programs to enhance and protect lands in the district. Through decades of cooperative collaboration, GRRCD has formed productive, long-standing relationships with the agricultural community in the Green Valley Watershed. Given GRRCD's proven commitment to protecting both the ecological integrity and economic productivity of the watershed's natural resources, we felt well positioned to produce this document and to facilitate the cooperative planning process on which it is based.

This Green Valley Creek Watershed Management Plan, Phase II has been under development since 2010. The first phase of the plan was funded by The State Coastal Conservancy (SCC) which provided funding to:

- Collect existing information and field data and synthesize into existing conditions report
- Continue to gather support in the watershed for fisheries restoration
- Identify and prioritize sediment reduction and other projects for immediate implementation
- Provide recommendations for improved management practices to support agricultural, environmental, and social sustainability.

This second phase of the plan, funded by the California Department of Fish and Wildlife, is focused on identifying limiting factors to salmonid production and on restoration planning and prioritization to design and implement projects that directly address the identified limiting factors and support the recovery of a self-sustaining coho salmon population. Several of the data gaps identified in the first phase of the plan were addressed through studies completed or underway in this phase of the planning effort.

Technical Work Group Oversight

This planning process has been greatly enhanced by the participation of a diverse and dedicated technical work group (TWG). The TWG is comprised of representatives from technical stakeholders including the California Department of Fish and Wildlife, the National Oceanic and Atmospheric Administration, the North Coast Regional Water Quality Control Board, the University of Cooperative Extension/Sea Grant Program, the Center for Ecosystem Management and Restoration, the Atascadero-Green Valley Watershed Council, O'Connor Environmental, Inc. and Prunuske Chatham, Inc. The TWG members have contributed to and reviewed the technical data collected through this planning process and overseen the restoration recommendations and associated project selection and design.

Related Efforts

The Green Valley Creek Watershed Management Plan, Phase II (GVWMP) represents the second phase of a long-term effort that endeavors to look at restoration on a watershed scale and break down implementation planning in a scientifically justified effort. Identified projects will include instream habitat and riparian restoration, water conservation and supply enhancement practices, enhanced water quality monitoring, and implementation of ecologically appropriate and economically profitable land management practices. As a living document, this plan is intended to provide a framework for future project prioritization and implementation and to complement and contribute to other local and regional planning efforts.

This plan is expected to dovetail with the Russian River Coho Water Resources Partnership (Partnership), a multi-stakeholder effort to ensure sufficient water supply in the Russian River basin to support coho salmon and other aquatic organisms. The Partnership identified Green Valley Creek as one of 5 first priority streams important for salmonid recovery in the Russian River basin. The Partnership's guiding principle is that careful planning and water supply management can provide water for human uses and coho salmon (Sotoyome RCD 2010). GRRCD and their partners in the Partnership are developing streamflow augmentation and water storage; implementation of these projects began in 2011 and will continue into the future.

By implementing the actions recommended in this plan to improve local watershed conditions, stakeholders in the Green Valley Creek watershed are also contributing toward improved regional conditions and attainment of state and local goals. The GVWMP, with its existing conditions report, geomorphic creek characterization, and recommendations can provide a fine level of detail about an important sub-watershed in the Lower Russian River while identifying projects that support the goals of the larger plan. This plan also implements goals of the North Coast Integrated Regional Water Management Plan – salmonid population enhancement and implementation of state goals, such as Total Maximum Daily Loads (TMDL), the SWRCB's Watershed Management Initiative, the CDFW Coho Recovery Strategy (2004) and NMFS Final Recovery Plan for Central California Coast coho salmon (2012).

Additional assessment and monitoring projects underway in the Green Valley watershed include:

- The California State Coastal Conservancy funded Green Valley Creek Coho Habitat Design which includes a feasibility study (which includes an upper watershed sediment source study) and engineered project design to address the flooding of Green Valley Creek at Green Valley Road; a 100% implementation ready design for the "Green Valley Off-Channel Winter Refugia Habitat Enhancement Project", and all associated community and agency coordination, permitting and implementation funding planning for those and other Green Valley watershed restoration projects.
- The California Department of Fish and Wildlife funded "Flow Availability Analysis for Restoration Prioritization Planning" project which will develop and calibrate a model that will simulate all major hydrologic processes responsible for streamflow generation and quantify the spatial and temporal variability in streamflow conditions in Dutch Bill and Green Valley Creek watersheds.
- The Russian River Cooperative Agreement funded by the Sonoma County Water Agency, to continue the water quality monitoring program in Green Valley Creek and conduct limited biological surveys and summer snorkeling surveys in support of the above projects.
- The Pacific States Marine Fisheries Commission funded "Green Valley Creek Off Channel Habitat Study" to procure Light Detection and Ranging (LiDAR) topographic data for the lower Green Valley watershed and to conduct limited ground elevation surveys to ensure accuracy. Potential uses for the LiDAR data include detailed map development for field studies, vegetation delineation for biological studies, and detailed topographic characterization to assist in restoration planning and design work including the development of hydrologic and hydraulic models, including identification of existing and potential off-channel fish habitat.

The implementation of the GVWMP will contribute to the attainment of state goals and objectives. Projects identified and management practices implemented through this plan directly support attainment of TMDL goals for sediment and temperature in the Russian River. This plan also supports goals outlined in the North Coast Regional Water Quality Control Board's Watershed Management Initiative Chapter of the SWRCB's Watershed Management Initiative to protect and maintain groundwater quality and quantity and protect and enhance coldwater fisheries. Likewise, this plan supports CDFG Coho Recovery Strategy Task RR-GU-09, which addresses changes to water diversions in Green Valley Creek. The GVWMP also supports implementation of the recently released National Marine Fisheries Service (NMFS)

Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon (2012). The Recovery Plan calls for implementation of priority recovery actions in the Green Valley and Purrington Creek watersheds; the GVWMP implements a recommended action by promoting the use of BMPs for roads and other land use activities. Additionally, geomorphic surveys and the resulting restoration approaches and reach specific project designs work toward reducing both erosion and hydrologic impacts from bank and channel geomorphic adjustments, a priority for habitat restoration (NMFS 2012).

II. Watershed Description

A. Regional Setting

Watershed Location

The Atascadero/Green Valley (AGV) watershed encompasses about 38 square miles in the Lower Russian River Hydrologic Area[1] in Sonoma County, California (*Figure A-1*). The AGV watershed is part of the Guerneville hydrologic subarea (HSA) and contains almost all of Graton, a significant part of Forestville, and the westernmost part of the City of Sebastopol. Green Valley Creek's primary tributary streams are Atascadero, Jonive, and Purrington Creeks, and it flows into the Russian River near Forestville. The AGV watershed contains the Green Valley Creek, Purrington Creek, and Atascadero Creek Calwater Planning watersheds (*Figure A-2*).

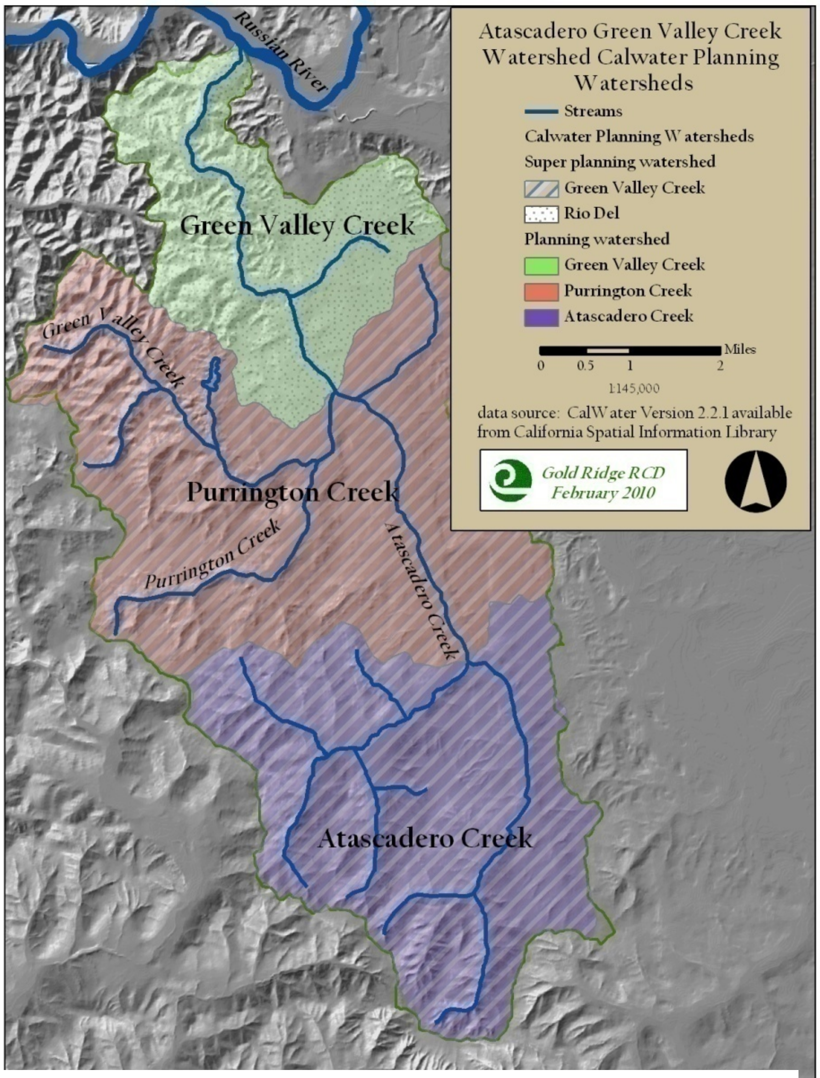


Figure A-1. Atascadero-Green Valley Creek Watershed Location

[1] Hydrologic Units are geographic divisions based on drainage patterns utilized by CALWATER, the watershed mapping system used by the State of California. The CALWATER classification includes, from largest to smallest, hydrologic regions, hydrologic units (HUs), hydrologic areas (HAs), hydrologic subareas (HSAs) and planning watersheds.

Geographic Focus of the Green Valley Creek Watershed Management Plan

The geographic focus of this watershed plan is the Green Valley Creek watershed, which is defined as the watershed of Green Valley Creek excluding the Atascadero Creek subwatershed.(*FigureA-3*). The GV watershed is comprised of the upper and lower Green Valley and Purrington Creek subwatersheds. The creeks in the upper Green Valley and Purrington Creek subwatersheds have been identified by the California Department of Fish and Game (CDFG) as optimal coho spawning and rearing habitat in the Atascadero-Green Valley Creek watershed. Green Valley Creek was one of only three Russian River tributaries in which coho salmon were recorded during the early 21st century (2000 to 2002) (CDFG 2004). In the Russian River Fisheries Restoration Plan (Coey et al. 2002), Green Valley Creek was identified as "the only known stream in the Russian River basin that continues to harbor a recorded, consistent coho run." Stream survey reports (CDFG 2006a, b) recommend management of Green Valley and Purrington Creeks as anadromous, natural production streams. Green Valley Creek has been stocked with coho yearly since 2006; steelhead were stocked in 1970 and 1984 (Obedzinski et al. 2006, CDFG 2006a, b). Salmonids will be discussed in detail in *Section F: Biological Resources*.

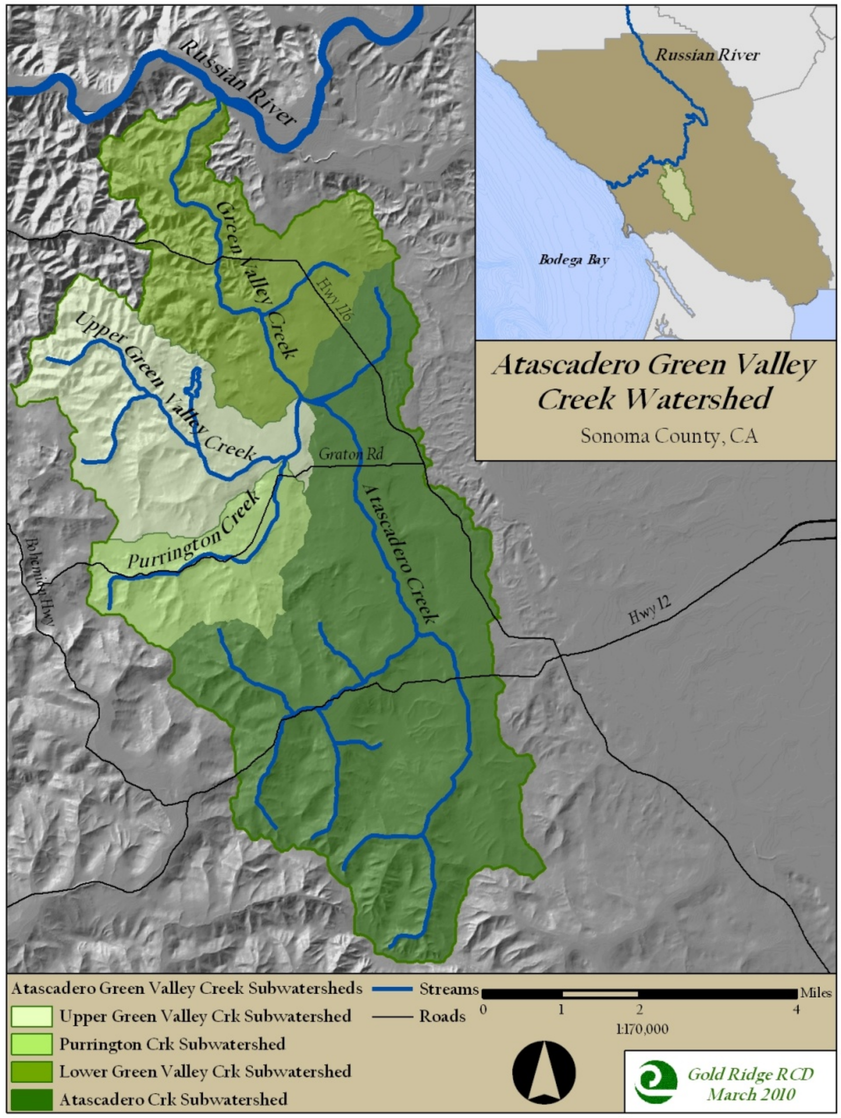


Figure A-2. Atascadero-Green Valley Creek Planning Watersheds

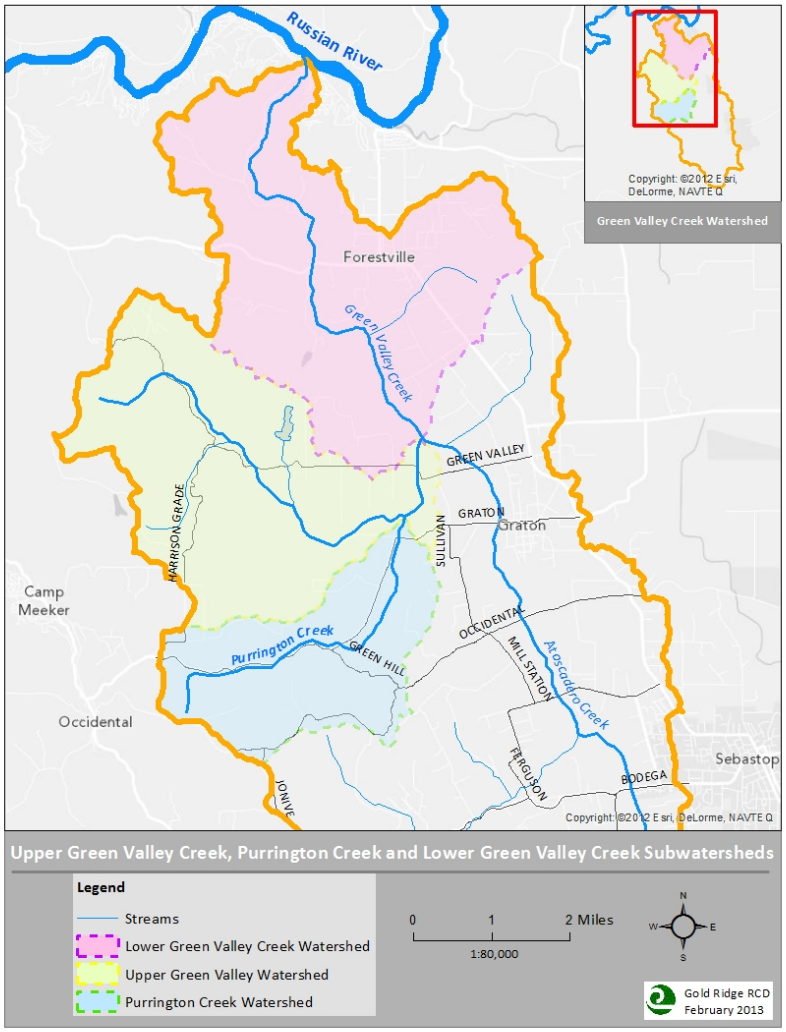


Figure A-3. Upper, Lower Green Valley Creek and Purrington Creek Subwatersheds

The California Central Coast Coho Salmon Recovery Plan (produced by the National Marine Fisheries Service) identifies Green Valley Creek as a Phase I Priority area (NMFS 2012), with a goal for near-term population recovery. The Recovery Strategy for California Coho Salmon (CDFG 2004) identifies the Guerneville HSA as having the greatest coho salmon restoration and management potential in the Central California Coastal Coho Evolutionary Significant Unit (ESU). Upper Green Valley and Purrington Creeks contain spawning and rearing habitat, greater canopy shading and has many opportunities and alternatives for habitat improvement, especially projects that increase pool frequency, volume, and shelter (CDFG 2006a, b).

Geography

The Green Valley Creek watershed is an 11,500-acre, or ~18 square mile, sub-basin of the Atascadero-Green Valley watershed and includes the drainages of Purrington, Harrison, Upper and Lower Green Valley Creeks. The terrain is varied, with gently rolling hills in the lower elevation areas to the east, and steep, forested slopes to the west. Elevation ranges from approximately 30 feet at the confluence of Green Valley Creek and the Russian River to 700 feet in the western hills, outside the town of Occidental. Streams rise in the steep upper valleys, where hillslope gradients frequently exceed 80%, and drain to broad, low-gradient alluvial valleys in the lower watershed.

The climate of the Green Valley Creek watershed is characterized by dry, mild-to-warm summers and cool winters with periods of intense rainfall. Average annual temperature is about 53 to 55 degrees F., although temperatures can reach into the 90s and low 100s in the lower watershed during the hotter months of July through September, and these same areas can drop below freezing during December through April. Occasional freezing events occur annually with lows occasionally dropping into the teens (February 1989, December 1990) (NOAA 2004). Because of the proximity of the Pacific Ocean, the forested uplands experience a more moderate climate, with cooler temperatures and fog during the summer and slightly warmer temperatures during the winter. Most precipitation occurs between November and April; average annual precipitation is between 40 (southeast) and 50 (northwest) inches with a range from 25 – 70 inches (see Chapter II, Section C). The higher elevations to the west typically see more rain (up to 85 inches), while the lower elevations to the east are drier.

Geology

The Green Valley Creek watershed lies in a geologic region that has been subjected to a range of tectonic forces and processes, and consequently the geology is locally very complex, with geologic units that are highly sheared, faulted and deformed. The watershed is dominated by two formations: the variety of rocks associated with the Franciscan Complex, and the sedimentary rocks of the Wilson Grove Formation, with a number of other units occupying smaller areas (Blake et al, 2002).

The Upper Green Valley Creek subwatershed (excluding Purrington Creek) is underlain predominantly by rocks of the Franciscan Complex. This complex is part of an accreted terrane – rocks that formed elsewhere and were transported to their present location by tectonic processes. Consequently, they are highly variable and complex. Franciscan Complex geology in Green Valley includes rocks of two units: sandstones and shales, which occupy most of the Upper Green Valley subwatershed, and melange, which outcrops in the northwesternmost portion of the subwatershed. Franciscan Melange is composed of areas of shale and siltstone, grading into a matrix of highly sheared, weathered and erodible mudstone or sandstone. This matrix contains chunks of more coherent sedimentary and metamorphic rocks. Franciscan Melange is also often associated with blocks of serpentinite, a metamorphic rock with unique characteristics. A serpentinite outcrop occurs in the western portion of Upper Green Valley. Smaller areas of Wilson Grove sandstone (described below) also occur in this subwatershed.

The Purrington Creek subwatershed is dominated by the Tertiary sandstone of the Wilson Grove Formation. Geologically younger than the Franciscan Complex, the Wilson Grove is a massive, fine-grained marine sandstone that formed in a shallow coastal embayment between 2 and 10 million years ago. Outcrops of serpentinite and Franciscan Melange also occur along Purrington Creek and its tributaries in the steep area to the west of Green Hill Road. In the headwaters of the stream, a large area of the Great Valley Complex can be found. The Great Valley Complex is of Jurassic age, and consists of a variety of sedimentary, metamorphic and igneous rocks of deep water origin. In Purrington Creek, two units of the Great Valley Complex can be found: the weakly consolidated shales and fine-grained sandstones of the Knoxville Formation, which occurs in the upper valley of Purrington Creek, and a small area of volcanic tuff and breccias. Rocks of the Great Valley Complex were emplaced in the Purrington Creek subwatershed by processes of faulting.

Throughout both Upper Green Valley and Purrington Creeks, valley bottom areas are composed of alluvial and colluvial deposits of Quaternary age. These are mostly gravels and finer sediments eroded in the uplands and deposited and reworked on the valley floors by mass movements and fluvial processes.

The geology of the Upper Green Valley watershed has produced a steep landscape with large areas that are highly susceptible to erosion. This is particularly true of areas underlain by the Franciscan Complex.

Serpentinite has unique properties that affect both runoff generation and erodibility. Serpentinite is low in minerals necessary for plant growth, but high in toxic metals. This combination discourages vegetative cover, resulting in thin soils with sparse and unique vegetation. These areas are highly erodible and generate abundant runoff.

Soils

Gold Ridge sandy loam is the most extensive soil type in the Upper Green Valley watershed, dominating both the Purrington Creek subwatershed and the lower (eastern) portion of the Upper Green Valley Creek subwatershed (from about Bones Road to the confluence with Atascadero Creek). In the UGV watershed, these deep and fertile soils are typically found on moderate to low-gradient slopes underlain by the Wilson Grove Formation, and have been weathered from this weakly consolidated sandstone. Gold Ridge soils are well-drained, and are considered excellent for growing wine grapes.

Hugo and Josephine loams dominate the steeper, forested areas of the Upper Green Valley Creek watershed. These soils contain more clay than the Gold Ridge soils, and are typically found in areas underlain by the Franciscan and Great Valley formations. These soils are well drained and characterized as highly erodible when disturbed on steep slopes (USDA 2008).

History

The entire Russian River Hydrologic Unit has a long history of human habitation. Among the first inhabitants were the Southern Pomo, who migrated to the Russian River about 6 to 7 thousand years ago (Stewart 1985). Their former territorial lands comprised Sonoma County south of the Russian River and east to the southern Santa Rosa area, and they spoke the Southern Pomo language, which is part of the Hokan language stock (McLendon and Oswalt 1978). They were a seasonally nomadic people who hunted and gathered animals, plant materials, salmon, and seafood. The Southern Pomo are renowned for their skilled basketry and are considered expert flint knappers and clamshell bead makers. The Pomo and neighboring peoples developed a relatively stable society composed of small groups linked by geography, lineage, and marriage. They managed the landscape using fire, pruning, weeding, and selective harvest to promote the growth of desirable plants and create conditions favorable for game animals.

The way of life of the Southern Pomo and all Native Americans dramatically changed following contact with European and American settlers in the late 18th and early 19th century. Land use in the Upper Green Valley Creek watershed also changed drastically – natural resource extraction began at scales previously unencountered. Over the next century, redwood forest was harvested for timber; riparian forests, woodlands and grasslands were cleared for grain, orchards, row crops, and hops production; and the area's rich wildlife was massively harvested.

In the Upper Green Valley Creek watershed, forests were intensively harvested in the 1920s and 1950s followed by heavy grazing (CDFG 2006a). A large part of the natural grasslands and meadows was planted to orchards in the early 20th century (PWA 2008). In 1938, the Army Corps of Engineers and the Sonoma County Flood Control and Water Agency recommended channel clearing of the mainstem Russian River and several tributaries, including Green Valley Creek (Coey et al. 2002). By the 1950s, Green Valley Creek had become polluted by apple processing waste: "many of the pools in the area were covered with scum and the water appeared black, with visibility limited to less than 1 inch" (CDFG 2006a). In the early 1970s, the rural beauty coupled with proximity to urban areas led to a sharp increase in residential development (Sonoma County Community & Environmental Services 1978). Additionally, the period between 1969 and 1994 saw an increase in intensive land uses, continued removal of large wood debris jams from streams, and human population increase. By the late 1970s, increasing development had led to concerns about future water supply, with some areas requiring imported water during summer months (ibid.). Since the 1980s, orchards have been increasingly converted to vineyards in the Green Valley watershed.

Archaeological Resources

A records search conducted by the Northwest Information Center indicates the presence of 22 recorded cultural resources in the Upper Green Valley watershed. Of these, 20 are prehistoric resources associated with Native American activities or occupation and two are historic-era resources. The prehistoric resources include habitation debris, lithic debitage (the sharp-edged waste material remaining when a person creates a stone tool), and bedrock mortars. The historical resources consist of the remains of a sawmill and a homestead. The watershed also contains a California bay (*Umbellularia californica*) that has been designated a Heritage tree. About 35% of the watershed has been investigated in 54 archaeological/cultural resource studies; many more resources are likely in the remaining 65%. Native American resources in this part of Sonoma County have been identified in terrace areas, ridgelines, and benches near fresh water – the Upper Green Valley Creek watershed contains all of these features. Additionally, it is highly likely that additional historic resources will be identified since USGS maps (1914, 1942, and 1952) show several buildings and structures throughout the watershed.

Ownership and Land Use

The Upper Green Valley Creek watershed is almost completely privately owned. Primary land uses include apple orchards, vineyards, livestock pasture, and rural residential development. Over the past three decades, an increasing amount of orchard has been converted to vineyard.

Timber harvest, agriculture, rural residential growth and fire suppression activities have led to the development of an extensive rural road network in the watershed. The Upper Green Valley subwatershed has a medium/high frequency of roads on steep slopes and the Purrington subwatershed is categorized as having a high frequency of roads on steep slopes (LMA 2003). Both the Purrington and Upper Green Valley subwatersheds contain less than 10% urban area or impervious surface (LMA 2003).

Although a portion of the headwaters forest in the Upper Green Valley Creek subwatershed has been developed for agriculture, much of it remains undeveloped. Primary land use in the Upper Green Valley Creek subwatershed is 36% rural residential, 36% agricultural (vineyards, orchards and some pasture) and 24% forest (CDF&FP and USDA FS 2002). Forest/vineyard is identified as the primary land use on steep slopes and land use along creeks mainly includes livestock grazing, vineyard, timber, and roads (LMA 2003). The lower portion of the Upper Green Valley Creek Watershed contains both agricultural and rural residential development (*Map 4*) (CDFG 2006a).

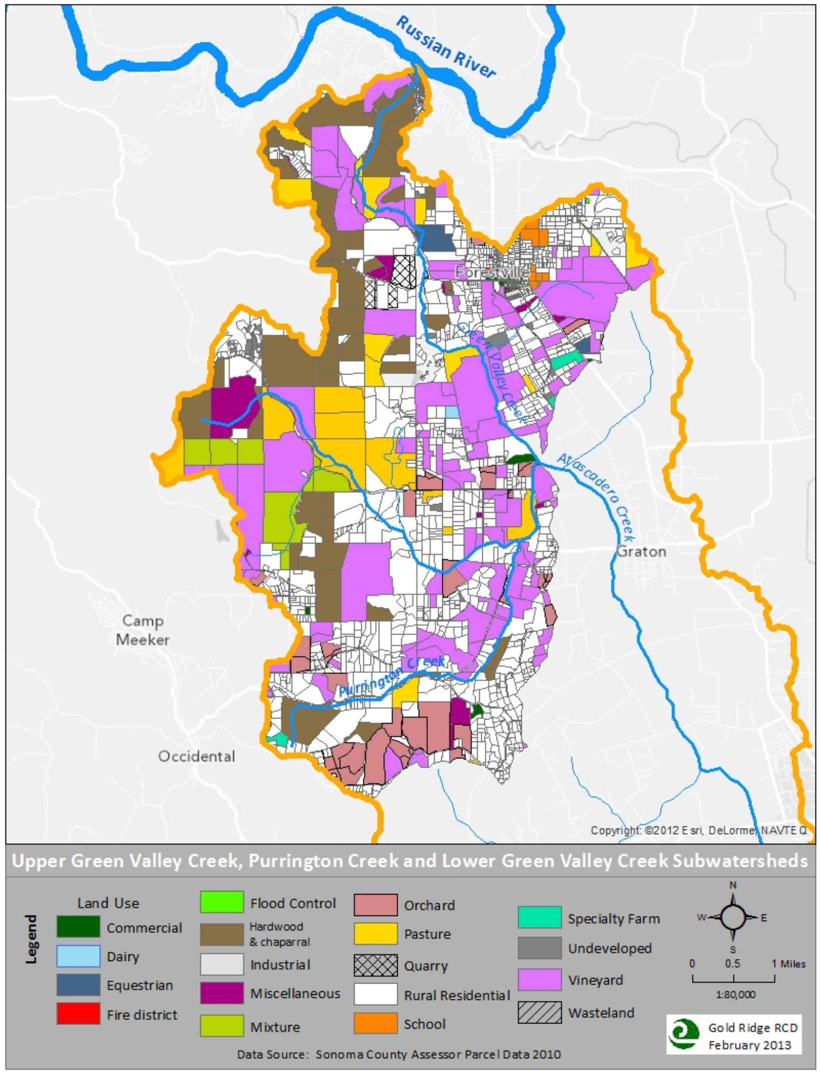


Figure A-4. Land Uses in the Green Valley Creek Watershed

The upper portion of the Purrington Creek subwatershed is also relatively undeveloped with scattered residences, while agriculture and rural residential development comprise the majority of the lower portion. The primary land uses in the Purrington subwatershed are 54% rural residential, 41% agricultural (vineyards, orchards and livestock pasture) and 7% forest (CDF&FP and USDA FS 2002). The primary land use on steep slopes in the Purrington subwatershed is forest/undeveloped, and land uses along creeks consists of roads, vineyard, and forest in this subwatershed (LMA 2003).

Green Valley Creek and Purrington Creek are designated “riparian corridors” in the Sonoma County General Plan. Riparian corridor habitat is protected by several county policies intended to protect and enhance riparian areas and functions while balancing the need for agricultural production, urban development, timber and mining operations, and other land uses. The Harrison Grade Road serpentine association is designated "critical habitat" and Green Valley Road is a designated Scenic Corridor.

Much of the Upper Green Valley Creek watershed and some parcels along Purrington Creek have land under Type I or Type II Williamson Act Land Contracts; these contracts are an agreement with the landowner to maintain land in agricultural or open space condition for reductions in tax obligations (*Figure A-5).*

Table A-2. Land Cover in the Upper Green Valley Creek Watershed		
Subwatershed		
Land Cover	Area (acres)	Percentage
Purrington		
Agriculture	961	41.00%
Conifer	567	24.19%
Hardwood	128	5.46%
Herbaceous	161	6.87%
Mix	522	22.27%
Shrub	5	0.21%
	2344	100%
Upper GV		
Agriculture	932	22.20%
Conifer	524	12.48%
Hardwood	369	8.79%
Herbaceous	518	12.34%
Mix	1801	42.89%
Shrub	32	0.76%
Urban	7	0.17%
Water	16	0.38%
	4199	100%

Water Supply

Water supply in the Russian River Hydrologic Unit is governed by a series of Water Rights Decisions (WRD) and Water Rights Orders (WRO) by the State Water Resources Control Board (SWRCB) that regulate instream flows for the Russian River and its tributaries (see SWRCB WRD1030, WRD1610, WRO86-09, and WRO98-08). All of Green Valley Creek and its tributaries upstream from the confluence with the Russian River are fully appropriated between June 15 and October 31 each year (SWRCB 1998). Water rights in the state of California are based on seniority with a "first in time, first in right" principle governing use during times of scarcity – the most junior rights holders must discontinue use first. Riparian rights, which are associated with a parcel of land adjacent to a surface water source, have a higher priority than appropriative rights. Generally, riparian rights holders' priorities are of equal weight and they must share reductions equally during times of shortage (SWRCB 2007).

In the Upper Green Valley and Purrington Creek subwatersheds, recent analysis of water supply and demand indicates that the greatest demand for surface water may be agriculture. However, further studies need to be conducted in order to evaluate the impact that near channel wells and rural residential water use has on water availability. The Upper Green Valley subwatershed contains many diversions and irrigation ponds (LMA 2003). The times of highest agricultural demand – early spring and mid- to late-summer – coincide with critical periods of environmental demand (see *Chapter II, Section F)*, leading to potential conflict between environmental and human uses. During spring 2009, a fish kill on the Russian River occurred due to rapid drawdown of the river caused by the cumulative effect of frost prevention pumping to protect budding grapevines (Roy undated).

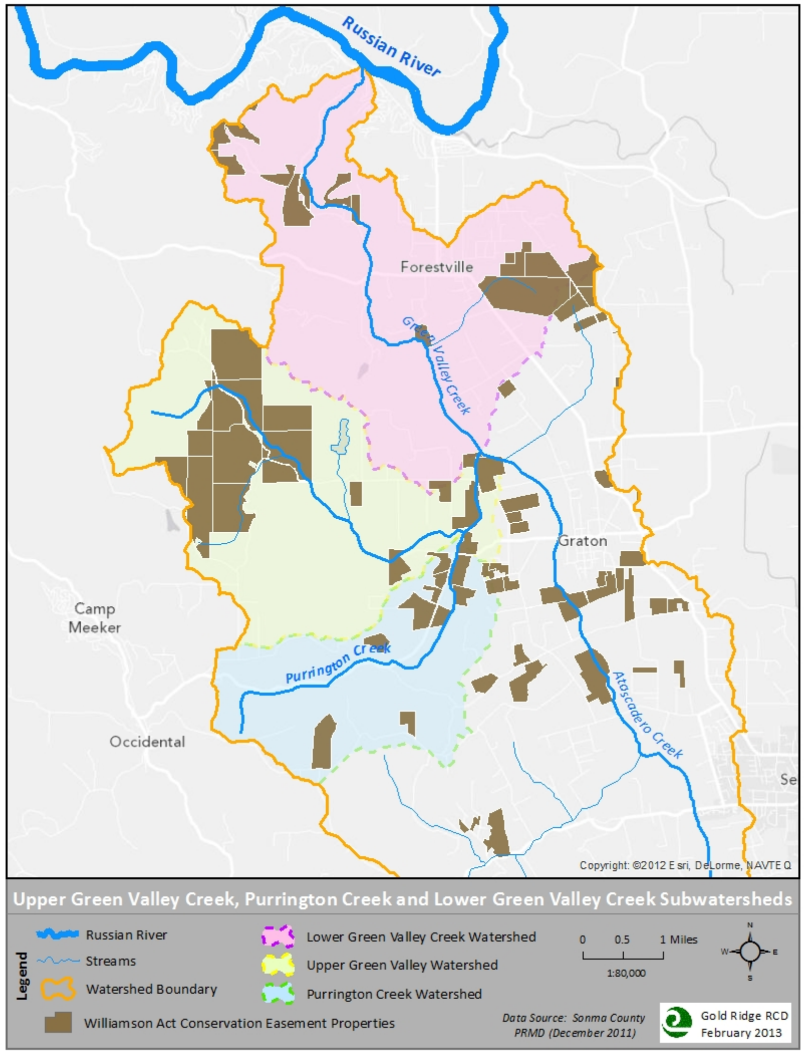


Figure A-5. Land in Williamson Act Land Contracts

The State Water Resources Control Board (SWRCB) recently proposed adding a special regulation to limit diversion of stream water (including "closely connected groundwater") for frost protection between March 15 and June 1. This "Amendment to Division 3 of Title 23 of the California Code of Regulations" states that any diversion of water from the stream system conducted during those dates that the Board determines to be significant shall be considered a violation of Water Code section 100. Water may be diverted if a board-approved water demand management program is in place; such a program would ensure that instantaneous cumulative diversion stayed within amounts that will not harm anadromous fish (DWR 2010).

The Russian River Coho Water Resources Partnership (Partnership), with funding from the National Fish and Wildlife Foundation, has initiated a study investigating the feasibility of utilizing off-stream storage for summer supply in response to concern about agricultural water supply reliability and reductions in instream flow. The Partnership includes the Center for Ecosystem Management and Restoration (CEMAR), the University of California Hopland Research and Extension Center, Trout Unlimited, Occidental Arts and Ecology Center WATER Institute, Sotoyome RCD, and Gold Ridge RCD. The study will initially focus on 5 Lower Russian River subwatersheds – including the Upper Green Valley and Purrington Creek subwatersheds. The Partnership will work with willing landowners and other water users to identify solutions to improve water reliability and flows – from the implementation of water conservation BMPs to increasing water storage capacity (Sotoyome RCD undated). In support of this effort, two flow gauges have been installed in the UGVC watershed – one in each subwatershed. Real-time gauge data is available on the Partnership website: www.cohopartnership.org.

B. Water Quality

Regulatory Context

Water quality affects all beneficial uses of water in a watershed from municipal and agricultural to environmental. According to the US Environmental Protection Agency (US EPA), water quality standards for a watershed must be based on state-designated beneficial uses of its water bodies. These water quality standards are determined by the state and consist of both narrative and numeric water quality objectives. The Guerneville HSA contains twenty beneficial uses identified by the State Water Quality Control Board (NCRWQCB 2007a) (*Table B-1*).

Table B-1. Guerneville HSA Beneficial Uses (* denotes potential uses)

Beneficial Uses
Municipal & Domestic Supply
Agricultural Supply
Industrial Service Supply
Industrial Process Supply
Groundwater Recharge
Freshwater Replenishment
Navigation
Hydropower Generation
Water Contact Recreation
Non-Contact Water Recreation
Commercial and Sport Fishing
Warm Freshwater Habitat
Cold Freshwater Habitat
Wildlife Habitat
Rare, Threatened, or Endangered Species
Migration of Aquatic Organisms
Spawning, Reproduction, and/or Early Development
Shellfish Harvesting*
Estuarine Habitat
Aquaculture*

Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify all water bodies that do not meet water quality standards for their designated uses. Identified water bodies are placed on the 303(d) List. The 303(d) list identifies the pollutant(s) or stressor(s) causing the impairment – when known – and establishes a schedule for developing a plan to address the impairment. This plan usually takes the form of a pollution control plan known as a Total Maximum Daily Load (TMDL). TMDLs establish the maximum amount, or "load" that can be discharged into a water body before water quality is impaired. A TMDL is the sum of allowable loads from all contributing natural and anthropogenic inputs. Once allowable loads are determined, all sources of the pollutant in a watershed are identified and loading rates are allocated among existing sources. Acceptable loading rates are generally allocated based on percent reductions for each source. Once the TMDL is established, stakeholders within the watershed must implement management practices and projects that will achieve TMDL targets.

The CWA recognizes two types of water pollution: pollution discharged by *point sources* and pollution discharged by *nonpoint sources*. Point sources include water treatment plants, factories, and other "discernible confined discrete conveyances." Nonpoint source (NPS) pollution is dispersed throughout a watershed and includes pathogens, bacteria, metals, nutrients or pesticides delivered to water bodies in stormwater runoff.

Table B-2. Potential Sources of Sedimentation and Increased Water Temperature (NCRWQCB 2007b)

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

NPS pollution also includes sediment discharged to water bodies from roads, streambanks, gullies, and sheet and rill erosion. The insidious nature of nonpoint source pollution is that the individual pollutant contributions may be small, but their combined effects can significantly impact aquatic health.

The portion of a TMDL allocated to a point source of pollution is known as a "waste load allocation;" waste load allocations are enforced through waste discharge requirements (WDRs) inserted into a National Pollutant Discharge Elimination System (NPDES) permit. The portion of a TMDL allocated to nonpoint sources of pollutant (including load estimates from natural sources) is known as "load allocation," and is enforced through the state's NPS management program. Nonpoint source pollution is typically controlled through "beneficial management practices" or BMPs.

An agricultural BMP for preventing runoff from land application of manure might require a vegetated buffer strip around farm fields. The US EPA and the U.S. Department of Agriculture (USDA) have developed BMPs for most types of nonpoint source pollution, and have shown that agricultural nonpoint source pollution can be reduced by 20 to 90% through management measures aimed at soil retention and runoff reduction (USDA and NRCS, 1997; US EPA, 2005).

The Guerneville HSA is listed in the 2010 CWA Section 303(d) List of Water Quality Limited Segments for sedimentation/siltation, water temperature, indicator bacteria and low dissolved oxygen impairment. Sediment impacts in tributaries throughout the Russian River HU prompted listing the entire HU for sediment and high water temperatures and have been identified as a major source of impairment of its cold-water fisheries (NCRWQCB 2007b). Potential sources of these impairments are listed in *Table B-2.*

The Russian River HU TMDLs for sediment, temperature and low dissolved oxygen impairment are not currently scheduled, while the pathogen/indicator bacteria TMDL is in the monitoring stage and is scheduled to be presented to the Regional Water Quality Control Board in 2015. Proactive and voluntary measures taken at the watershed scale to reduce nonpoint sources of pollution entering a 303(d) listed water body, can potentially eliminate or significantly minimize a mandatory regulatory process. This watershed plan and the planning process on which it is based are designed to help reduce water quality impairments in the watershed through a collaborative, voluntary planning process.

Water Quality in the Green Valley Watershed

Since late 2008, the Gold Ridge Resource Conservation District (GRRCD) has been monitoring water quality at select locations throughout the Atascadero-Green Valley Creek watershed to document water quality conditions, track trends and ultimately, to determine if water quality conditions are a limiting factor to sensitive aquatic organisms. Surface water samples from creeks (when available, some locations go dry during the summer in some years) were collected monthly from each monitoring location via grab sample. Grab sampling takes a snapshot of the water quality conditions occurring at a specific location at the time of sampling. Parameters including instantaneous temperature, dissolved oxygen (DO), pH, and specific conductivity were measured directly in the field using a YSI hand-held water quality meter; turbidity was also measured using a HACH Turbidimeter. During storm sampling grab samples were collected and sent to a laboratory for nutrient (ammonia, nitrate and orthophosphate) and Total Suspended Solids (TSS) analyses.

In addition to the ongoing monthly grab sampling, two multi-parameter meters were deployed in Green Valley Creek in the summers of 2011 and 2012 to track continuous water quality conditions throughout the summer and early fall. These meters collected water temperature, dissolved oxygen (DO), pH, and specific conductivity measurements every 30 minutes.

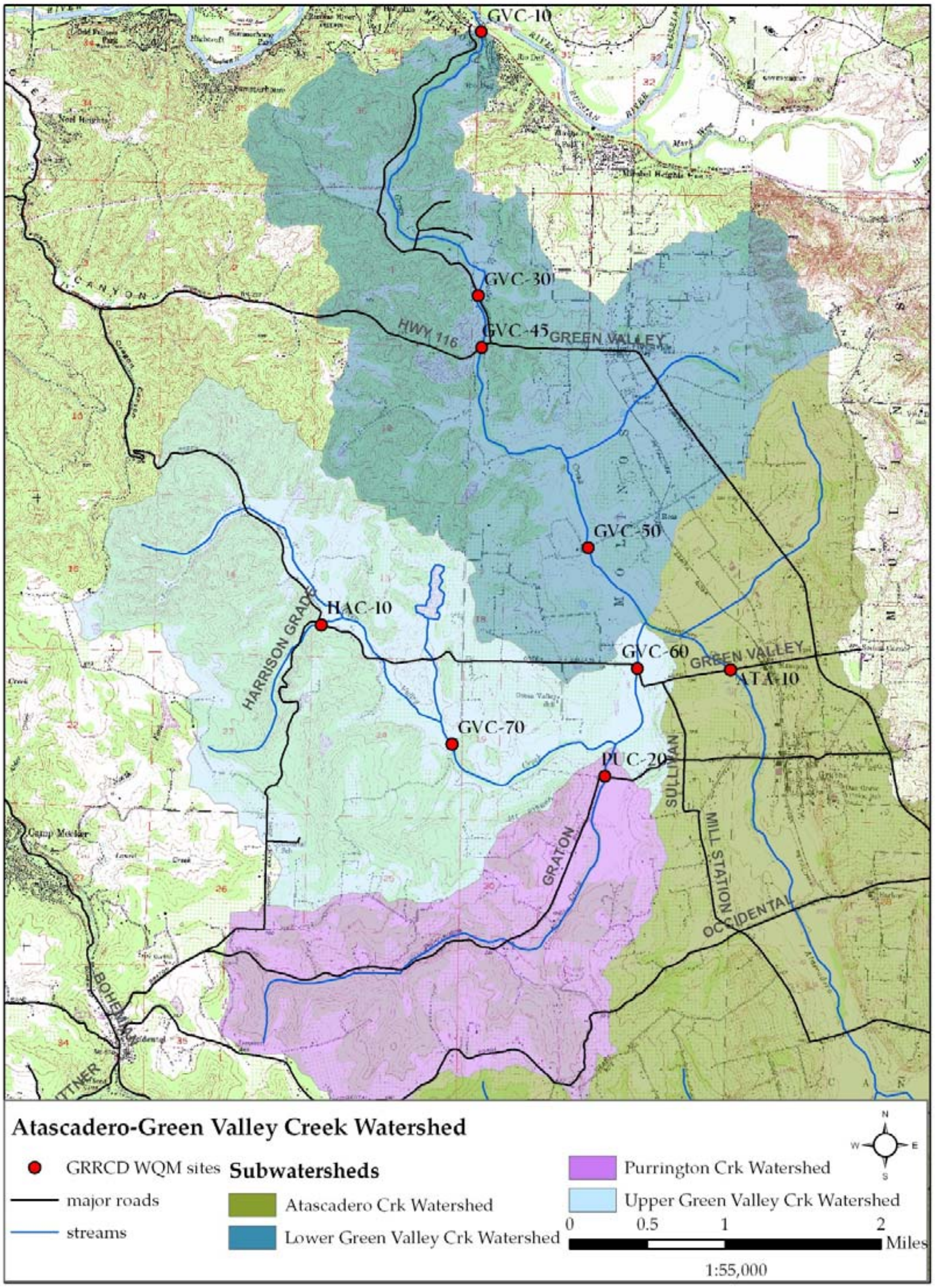
This report summarizes water quality data collected from December 2008 through October 2012 under the California Department of Fish and Wildlife funded Green Valley Creek Watershed Assessment and Enhancement Planning process. The data period includes monthly sampling throughout the year and includes several storm sampling events in 2010 and 2011 and only continuous meter monitoring in 2012.

The sampling locations have been renamed to comply with SWRCB naming convention. See the table below and the associated attached map.

Table B-3. Revised monitoring station IDs

New Station ID	Past Station ID	Description
HAC-10	GV1	Harrison Creek at Green Valley Road bridge
GVC-70	GV2	Green Valley Creek at Bones Road bridge
GVC-60	GV3	Green Valley Creek at Green Valley Road bridge
GVC-57	New station	Green Valley Creek ~300' downstream of the Atascadero Creek confluence
GVC-50	GV4	Green Valley Creek at Ross Station Road bridge (aka Iron Horse Winery bridge)
GVC-47	New station	Green Valley Creek at the end of Giovanetti Road
GVC-45	New station	Green Valley Creek at Hwy. 116 bridge
GVC-30	GV5	Green Valley Creek at Martinelli Road bridge
GVC-10	GV6	Green Valley Creek at Old River Road bridge
ATA-10	GV7	Atascadero Creek at Green Valley Road bridge
PUC-20	GV8	Purrington Creek at Graton Road bridge

Figure B-1. Map of Green Valley Creek Watershed Water Quality Monitoring Stations



Water Quality Objectives/Targets

As with previous GRRCD evaluations of water quality in the Green Valley Creek watershed, the Water Quality Objectives or comparative thresholds are listed in the table below. The North Coast Regional Water Quality Control Board (NCRWQCB) has not set numeric standard water quality objectives for the Green Valley watershed specifically, but has for the Russian River water body (NCRWQCB, 1994). Statewide criteria set by the US Environmental Protection Agency (EPA), Region 9(US Environmental Protection Agency, 2000) and/or the objectives for the Russian River water body by the North Coast Regional Water Quality Control Board (NCRWQCB, 1994) have been used as targets and are outlined in Table 2 below.

Table B-4. Water Quality Objectives.

Parameter (reporting units)	**Water Quality Objectives**	**Source of Objective**
Dissolved Oxygen (mg/l or ppm)	Not lower than 7	North Coast Region Basin Plan Objective for Cold Water Fish
pH (pH units)	Not less than 6.5 or more than 8.5	General Basin Plan objective
Water Temperature (°C)	Not to exceed 21.1	USEPA (1999) 20-22 range, supported by Sullivan (2000)
Conductivity (uS)	None established	N/A
Nitrate as N (mg/l)	Not to exceed 0.3	Cline (1973)
Ammonia-Nitrogen (mg N/l)	Not to exceed 0.26*	USEPA (2009)
Orthophosphate (mg/l)	Not to exceed 0.10	USEPA(2000)
Turbidity	Not to exceed 25 NTU	GRRCD selected threshold, supported by Sigler (1984)

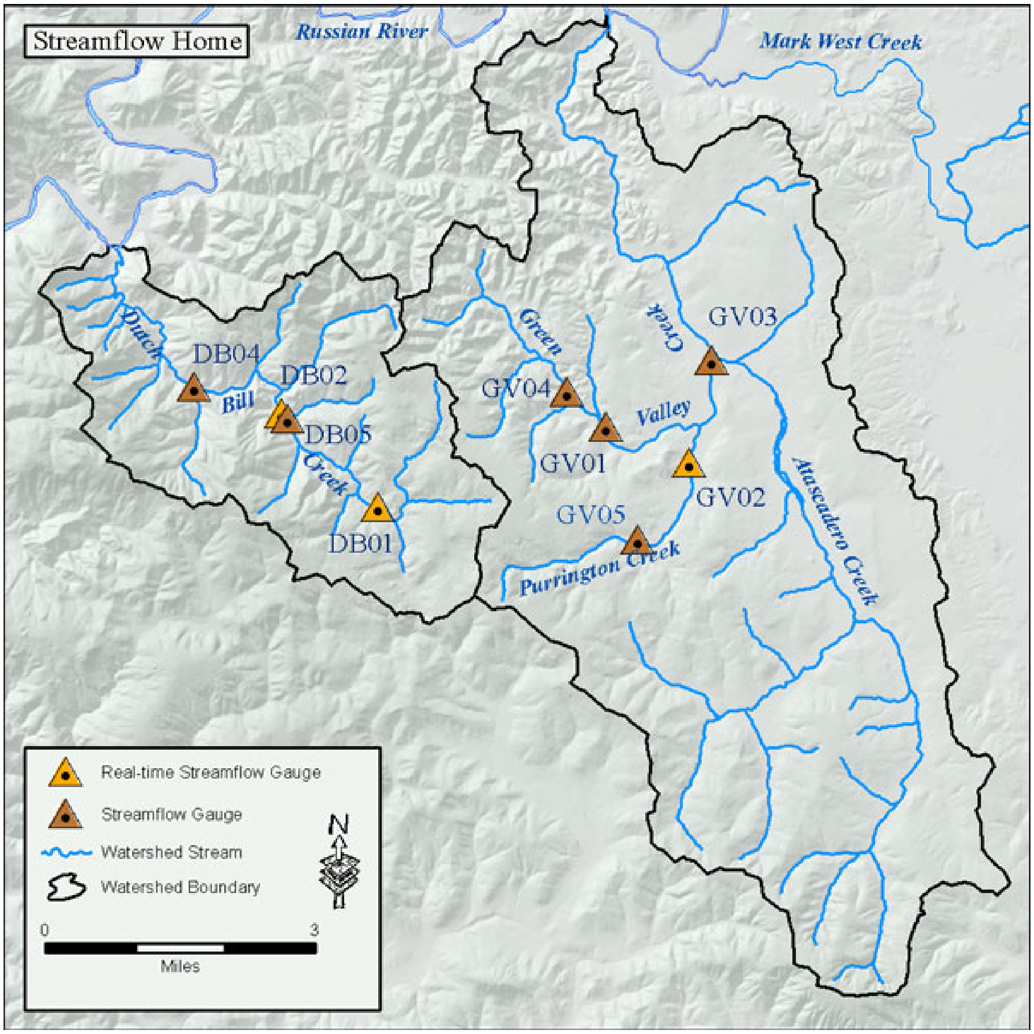
* Draft Ammonia Criteria (at pH 8 and 25°C where mussels are present) (US Environmental Protection Agency, 2009)

Hydrology

With the exceptions of the Harrison Creek (HAC-10) and the downstream-most Green Valley Creek station (GVC-10), all of the stations maintained continuous surface flow throughout the 2010, 2011 sampling period (April 2010 to September 2011). The first significant rainfall event of water year 2011 occurred on October 23-24, 2010 and delivered between 6-9 inches of rainfall in the Green Valley Creek watershed. In 2012, streamflow throughout Green Valley went intermittent, with isolate pools and reaches persisting between reaches of dry channel.

Through the Russian River Coho Water Resources Partnership, streamflow gauges have been established on Purrington Creek at just upstream of the PUC-20 sampling location and on Green Valley Creek just downstream of sampling station GVC-60 and the State Water Resources Control Board has established a streamflow gauge on lower Green Valley Creek between sampling locations GVC-30 and GVC-10.

Figure B-2. Streamflow Gauge Locations



Other Monitoring Efforts

In addition to the GRRCD monitoring effort in the Green Valley watershed, several other monitoring efforts are underway. This is not a complete list of data collected in the Green Valley watershed, but captures some of the current efforts generating data.

- The Atascadero Green Valley Watershed Council in cooperation with the Community Clean Water Institute collect monthly grab sampling data throughout the watershed which can be found at http://www.citizen-science.org/CCWI/rdPage.aspx?rdReport=CCWI2&rdRnd=46851.
- The Russian River Coho Water Resources Partnership, streamflow gauge data can be found at http://cemar.org/DB_GV.html
- Biological data collected by UC Cooperative Extension and California Department of Fish and Game through the Russian River Coho Salmon Captive

Broodstock Program can be found at
http://ucanr.org/sites/RussianRiverCoho/Reports_and_Publications/

Methods

Site Selection

Initial site selection within the Green Valley Watershed was based primarily on public access locations that are representative of both mainstem and significant tributary conditions. Public bridges were used for access to a majority of the sampling sites. One advantage of sampling from public bridge crossings is their accessibility during storm conditions and high flows.

Sampling Method

From 2010 through mid-2011, Gold Ridge RCD field staff made monthly visits to each of the eight monitoring sites to sample for temperature, pH, dissolved oxygen, conductivity, and turbidity. In addition, they conducted storm event sampling two times during wet weather periods (at least 0.5 inches of rainfall in a 12-hour period). Water quality samples were collected, stored, transported, measured, and analyzed in accordance with SWAMP-approved protocols. Data collection methods followed standard protocols established and endorsed by the EPA, NCRWQCB, and the U.S. Geologic Survey. Industry-standardized equipment was used to measure water quality parameters. The program's companion QAPP provides the detailed measures that were followed to ensure data collection accuracy, precision and repeatability.

Dissolved oxygen, pH, conductivity, and temperature were measured with a YSI 600-model meter. The YSI is a handheld display and attached sensor wand used to measure water quality parameters. The sensor is placed directly into a well mixed region of the water column. The meter was pre- and post-calibrated for all parameters prior to each use.

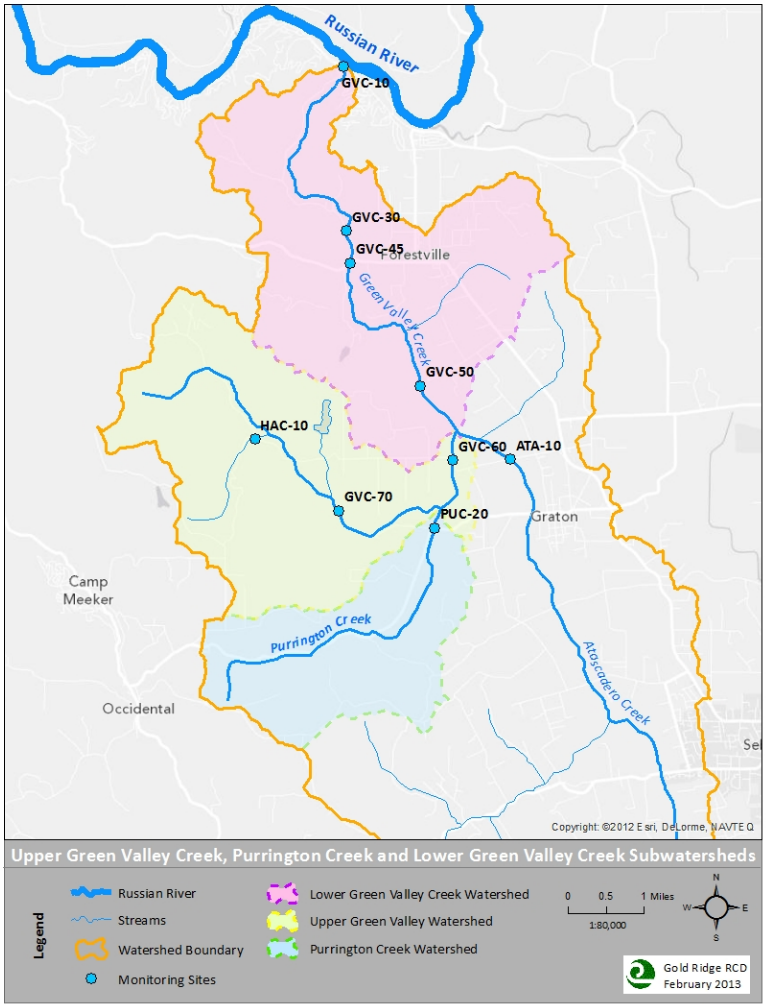


Figure B-3. Water Quality Sampling Locations

Water quality grab samples were collected and analyzed for turbidity in the field using a Hach 2100P Turbidimeter. This is a handheld turbidity meter, which operates by measuring the amount of light that passes through the sample jar. The Model 2100P measures turbidity from 0.01 to 1000 NTU operating on the nephelometric principle of turbidity measurement.

Grab samples for nutrients (orthophosphate, nitrate, and ammonia) and TSS were collected using a sterile plastic bottle and sent to an independent professional laboratory for analysis during the two sampled storm events (the October 23, 2010 first flush and March 23, 2011 flood event).

Additionally, two continuous water quality meters were deployed in Green Valley Creek in June 2011, one just downstream of station GVC-60 and one slightly upstream of GVC-45 at GVC-47. Three meters were deployed in 2012, at GVC-60, GVC-57, approximately 300’ downstream of the Atascadero Creek confluence and GVC-47. These multi-parameter meters measured temperature, dissolved oxygen, specific conductivity and pH every thirty minutes from June 30 through September 9, 2011 and July 4 to October 21, 2012. Unfortunately, due to equipment malfunction data was only retrieved from October 4 to 21, 2012.

Water Temperature

Temperature is an important environmental factor for aquatic habitat and at times is the determining factor for species assemblages; as waterways that were historically cool become warmer, cold water fish can be replaced by species better suited to warmer conditions. Protection and restoration of the Cold Freshwater Habitat beneficial use (see *Table 3, Guerneville HSA Beneficial Uses*) is imperative to restoring coho and steelhead fisheries in the Green Valley watershed. Salmonids are poikilothermic – (cold blooded) – animals, which means that their body temperature is regulated by their environment. Temperature is an important factor in activity level and physiological processes at all stages of the salmonid life cycle; temperature requirements vary depending upon species and developmental stage. Timing of upstream migration is dependent upon flows and temperature; coho salmon enter the Russian River between November and January, with most spawning occurring in December. Steelhead enter the river between December and April, with most spawning occurring from January through March (Coey et al. 2002) (see *Chapter II, Section G* and *Table B-5,*). Summer water temperatures are critical for the survival and health of all salmonid species that occur in the Green Valley Creek watershed. Additionally, temperature affects other aquatic organisms as well as influencing other characteristics of water, including dissolved oxygen (DO), pH, and other physical and chemical characteristics.

Table B-5. Water Temperature (°C) Criteria for Different Life Stages of Steelhead and Coho (Thompson and Larsen 2004, Coey et al. 2002, McEwan and Jackson 1996, KRIS Web undated)

				Juvenile Rearing		
Species	**Migration**	**Spawning**	**Incubation**	**Preferred**	**Optimum**	**Lethal**
Coho	4.44 – 9.44	4.39 – 9.39	4.39 – 13.28	11.78 – 14.61	9 – 15.6	25.78
Steelhead	7.78 – 11.11	3.89 – 9.39	8.89 – 11.11	7.28 – 15.56	10	24.11

Recorded temperatures in the watershed ranged from a low of 7.15° C in January 2009 in Purrington Creek (GV8) to a high of 17.7° C in June 2009 in Green Valley Creek (GV3) (*Chart 1, Water Temperature*). Water temperatures in the watershed slightly exceeded preferred temperatures for salmonids on most sampling dates except late summer and early fall, but did not reach lethal limits. During late summer and early fall of 2009, however, there was another important environmental factor of concern – there was no water at Site 1 beginning in June, and Site 3 was dry in September (no sampling was conducted in August 2009). In October, pools were still connected on Purrington Creek (Site 8), but at Site 2, they were disconnected. Although water had returned to Site 3 in November, Site 1 still had no water.

Since the collected measurements were grab samples, this information is not conclusive that the stream conditions never exceeded the maximum temperature threshold. As was expected, the highest temperatures were observed during the sampling of summer base flow conditions.

Continuous stream monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, should be considered for future monitoring efforts.

Water Temperature, 2008-10

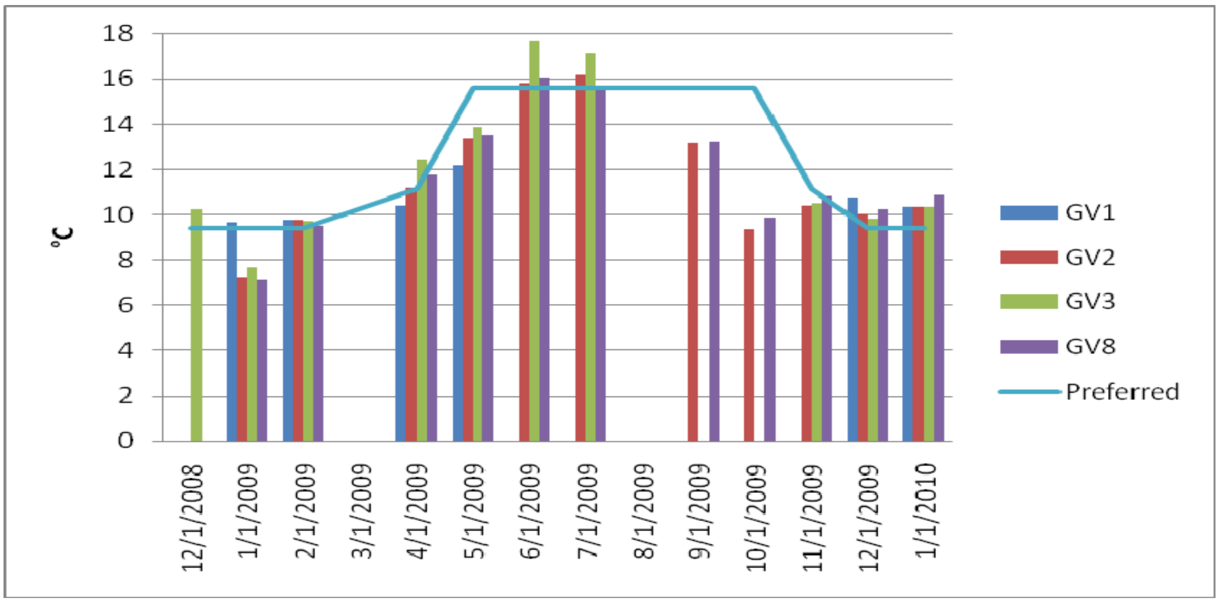
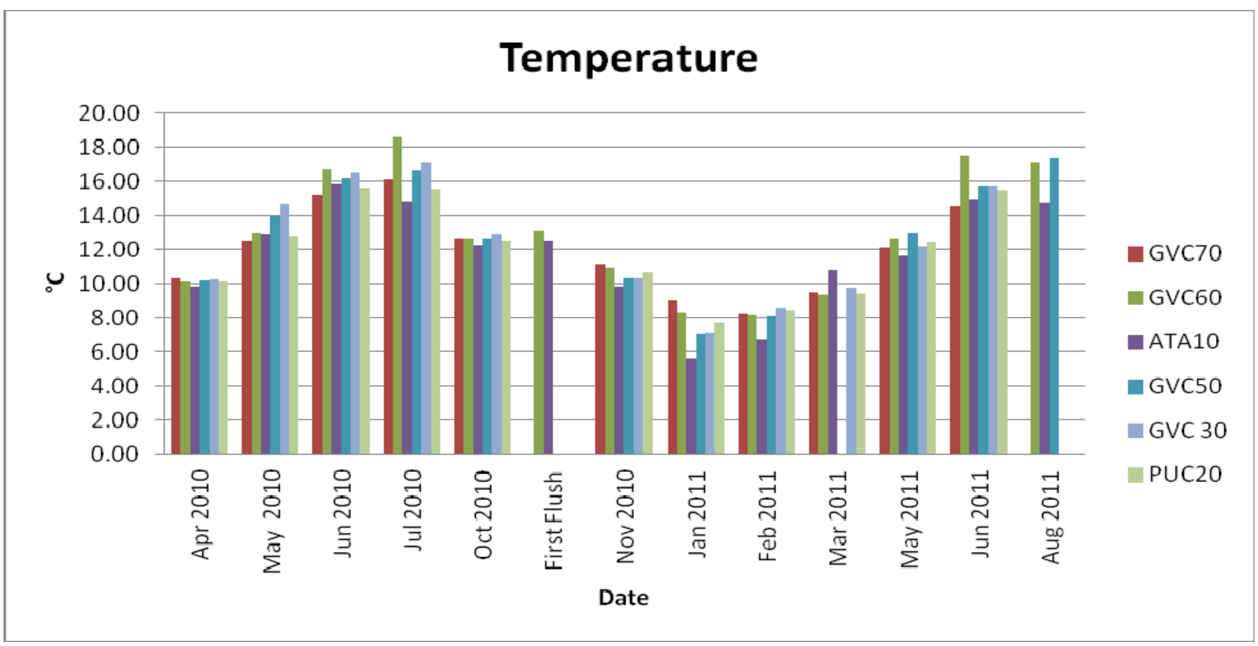


Figure B-5. Water Temperature, 2010-2011



Factors influencing water temperature in the watershed include heat loading from direct sunlight due to lack of riparian vegetation, high turbidity levels due to high rates of sedimentation, and hydrologic disconnection with cold water inputs such as spring flows and seeps. Sediment deposition can cause pool infilling and channel aggradation, which results in shallower water with warmer temperatures as well as other habitat impacts. Human activities associated with sedimentation are discussed in the next section.

Turbidity and Total Suspended Solids

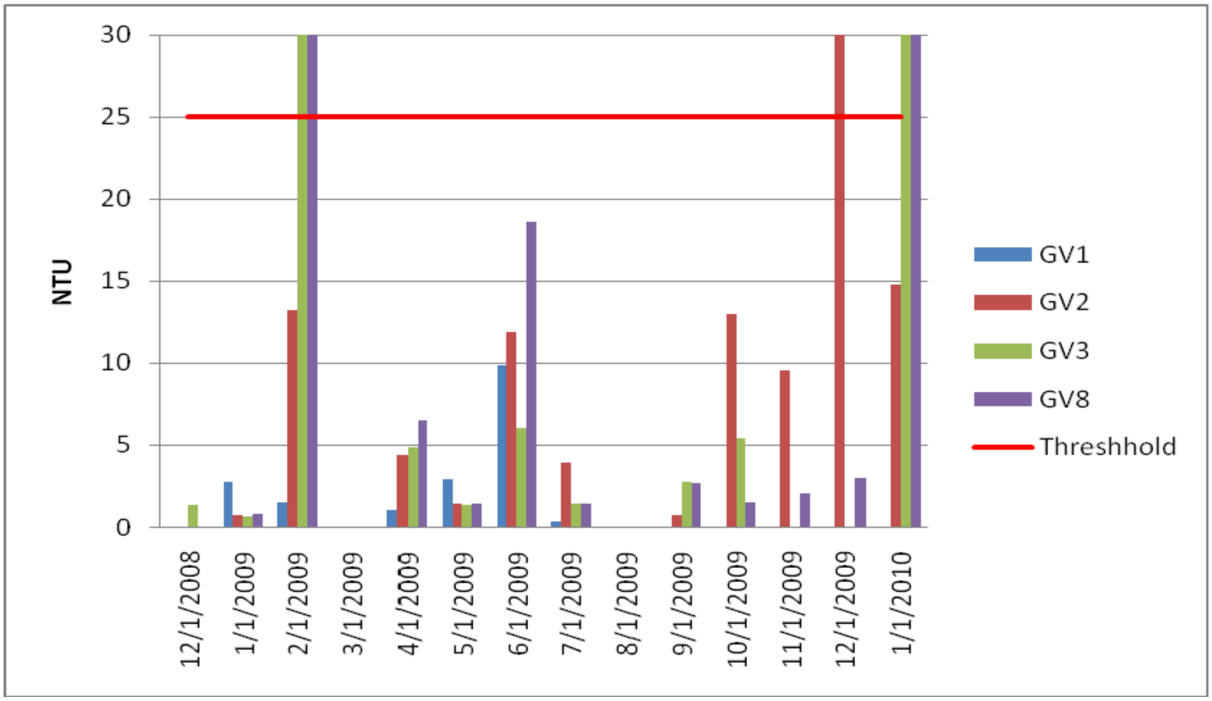
Turbidity, which can make water appear cloudy or muddy, is caused by the presence of suspended and dissolved matter, such as clay, silt, finely divided organic matter, plankton and other microscopic organisms. Sources of turbidity include soil erosion, streambank erosion, animal waste, road and urban runoff, and excessive algal growth. It is usually measured as the relative amount of light reflecting from a water sample. Turbidity measurements provide the most useful information when describing conditions over a specific time period. Amount of turbidity combined with duration of exposure provides a more robust understanding of potential physiological effects of different turbidity levels (Newcombe and MacDonald 1991).

Turbidity affects aquatic life directly by interfering with feeding success and mobility. Additionally, high concentrations of suspended sediment may delay or divert salmonid spawning runs – especially when the suspended sediment load is greater than 4,000 mg/l (CDFG 2004). The longer an episode of high turbidity persists, the greater the impact to aquatic organisms. Coho juveniles exposed to chronic turbidity were smaller in length and weight and grew more slowly than those exposed to clear conditions in laboratory experiments (Sigler et al. 1984, Redding et al. 1987); however, a study on Mad River tributaries in 2004–2006 did not find substantial negative effects on growth due to turbidity conditions (DeYoung 2007). This discrepancy may be explained by the possibility that juveniles in the wild have the capability to escape into tributaries where turbidity is not as great. Other studies have found that long-term changes in the composition and concentration of suspended

Turbid storm flow in Harrison Creek

solids can have potential cumulative lethal and sublethal effects on aquatic organisms including reduction in foraging capability, gill trauma, reduced disease resistance, increased stress, and interference with orientation cues associated with migration (Bash et al. 2001).

Figure B-6. Turbidity measurements 2008-2010



Turbidity for all sites sampled from 2010 to 2012, ranged from 0.80 (GVC60 on pre-storm sampling on 10/20/11) to >1000 NTU (the analytical limit of the Turbidimeter). As shown in both the Turbidity and Total Suspended Solids results, the March 24, 2011 flooding event resulted in the highest suspended sediment load during the sampling period. Figure 9 shows a hydrograph of the March 23, 2011 storm event, which resulted in the highest stage readings of Water Year 2011 and flood conditions throughout the watershed.

Figure B-7. Hydrograph of Purrington Creek during the March 23, 2011 Storm Event

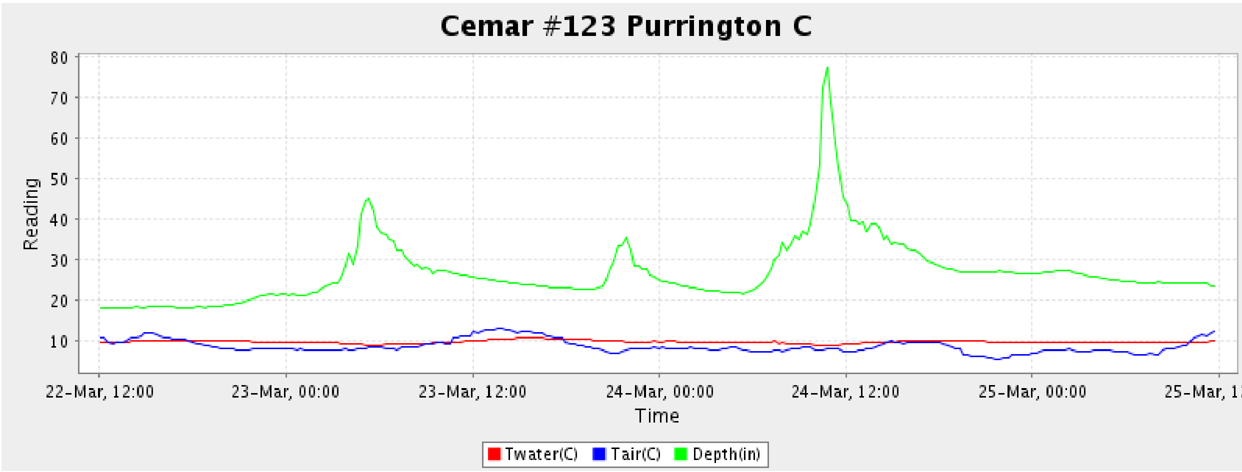


Photo of Green Valley Creek flood waters coursing over Green Valley Road on March 23, 2011

Figure B-8. Turbidity Measurements

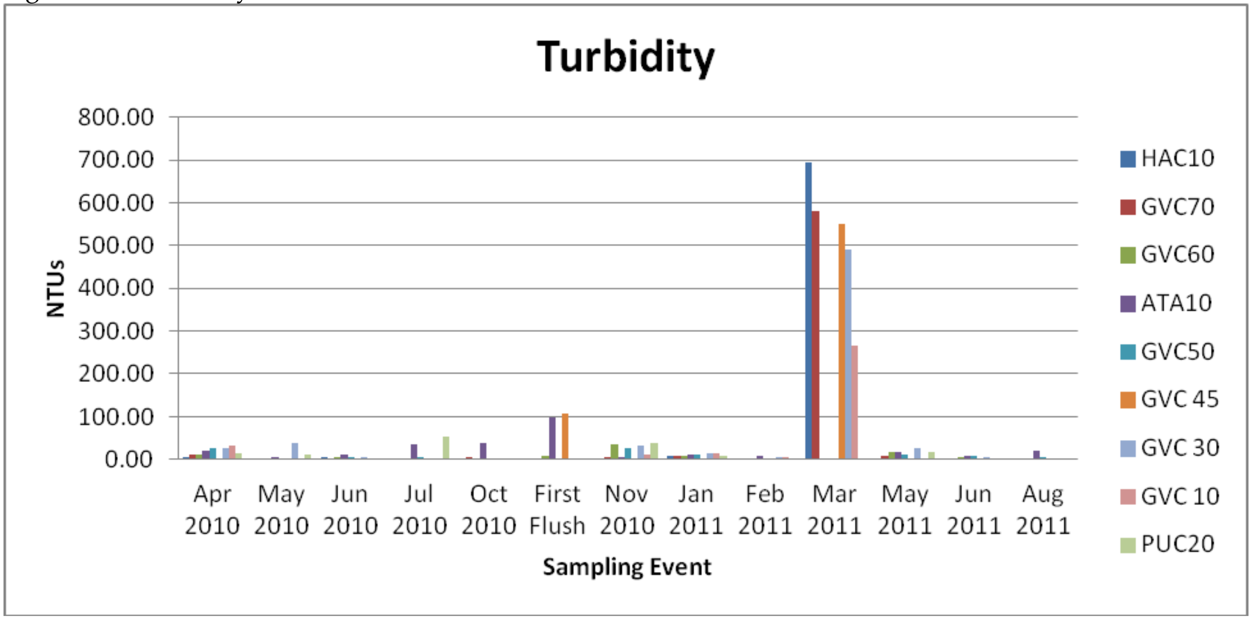


Figure B-9. Turbidity Measurements From Selected Sampling Events

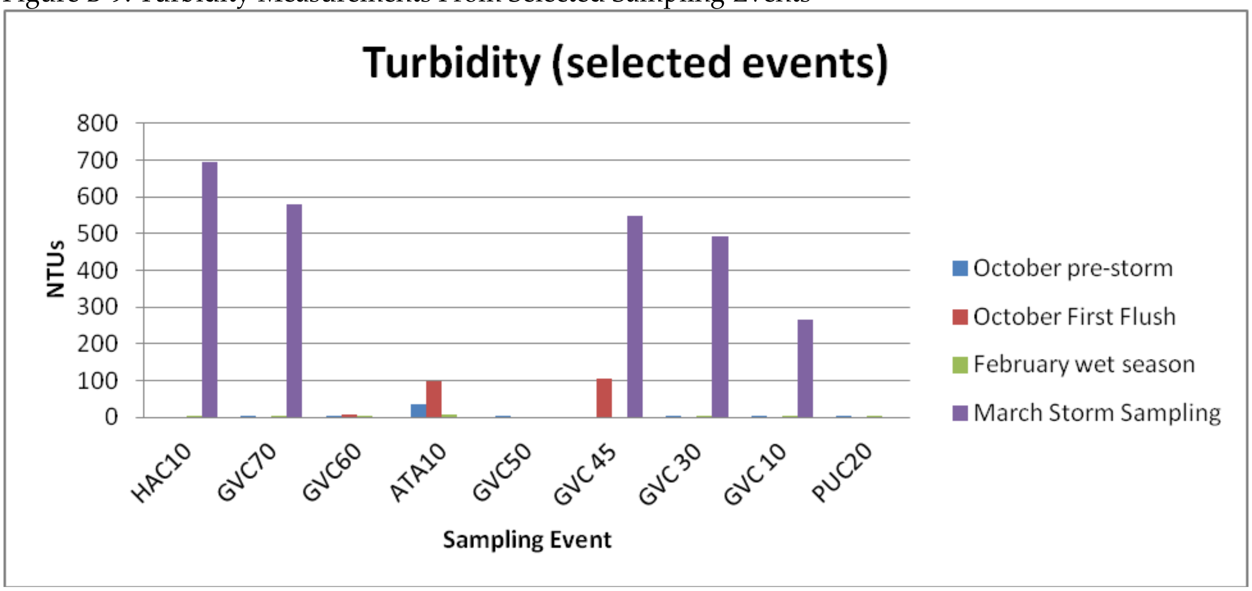


Figure B-10. Total Suspended Solid Measurements for Selected Storm Events

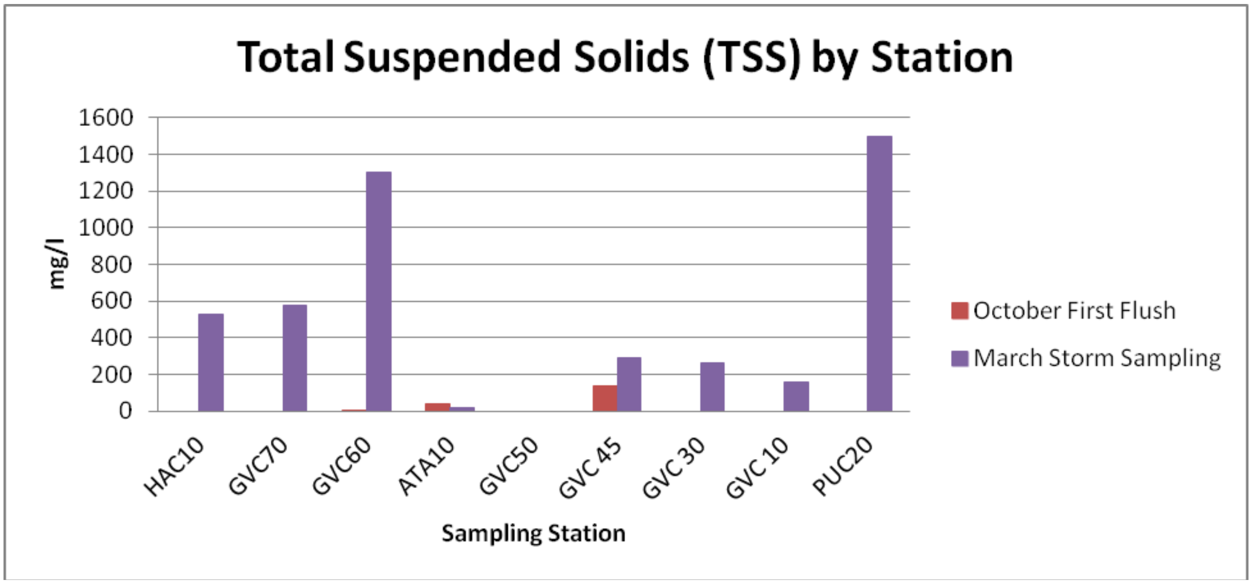
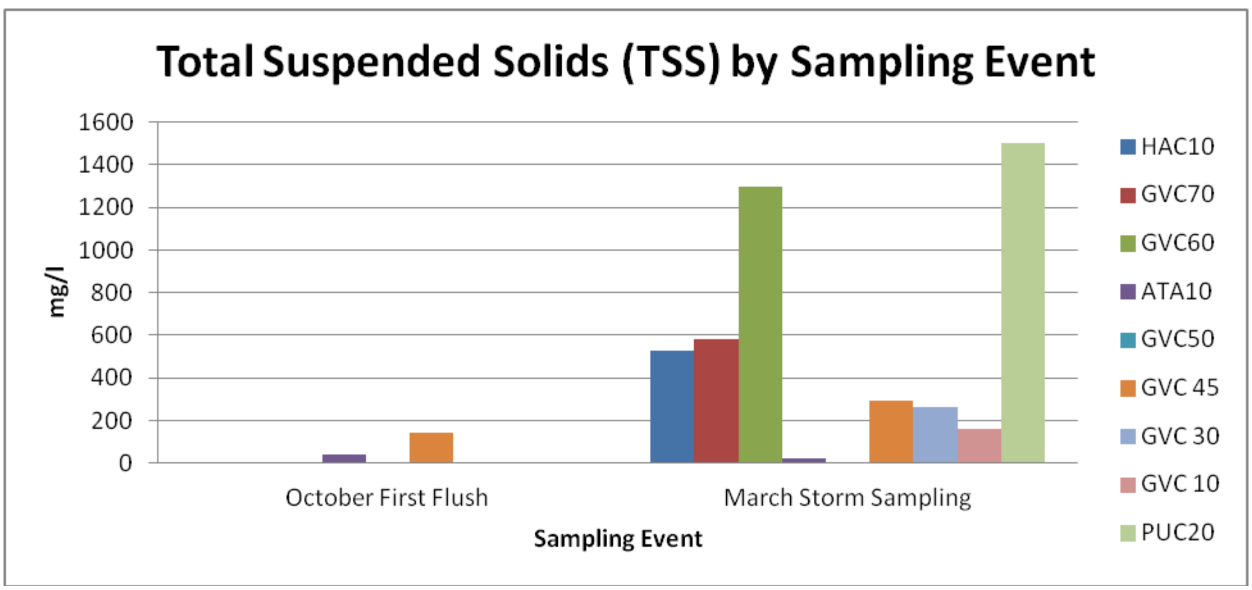


Figure B-11. Total Suspended Solid Measurements from March 2011 Storm Sampling Event



Turbidity can also result in behavioral effects; for example, juveniles in turbid waters were found to be more likely to emigrate (Sigler et al. 1984, DeYoung 2007). Length of exposure, frequency of exposure, water temperature, life stage, size and type of suspended particles, and availability of refugia are some of the factors that influence how turbidity affects salmonids. In addition to the physical effects of suspended solids, Stone and Droppo (1994) suggest suspended solids probably act as the primary transport mechanism for pollutants and nutrients in streams through flocculation, adsorption, and colloidal action (Stone, 1994).

GRRCD, like most resource agencies, measures turbidity in nephelometric turbidity units (NTUs). For this analysis, we conform to the EPA 2006 303(d) list use of Sigler et al.'s (1984) threshold of 25 NTU. During the sampling events over the thirteen months in which the Upper Green Valley Creek watershed has been monitored, turbidity has often been above the 25 NTU suggested by Sigler et al. as a threshold for physiological effects. These events occurred during the rainy season and ranged from 33.8 to 75.8 NTU, but duration was not measured. In January 2009, all four monitoring locations were above the threshold; in January, the Upper Green Valley watershed received a large amount of precipitation. During the spring, summer, and fall, turbidity levels are below the threshold for physiological effects. In general, Site 2 has consistently higher turbidity than the other locations; this may be indicative of an ongoing land-based sediment source upstream.

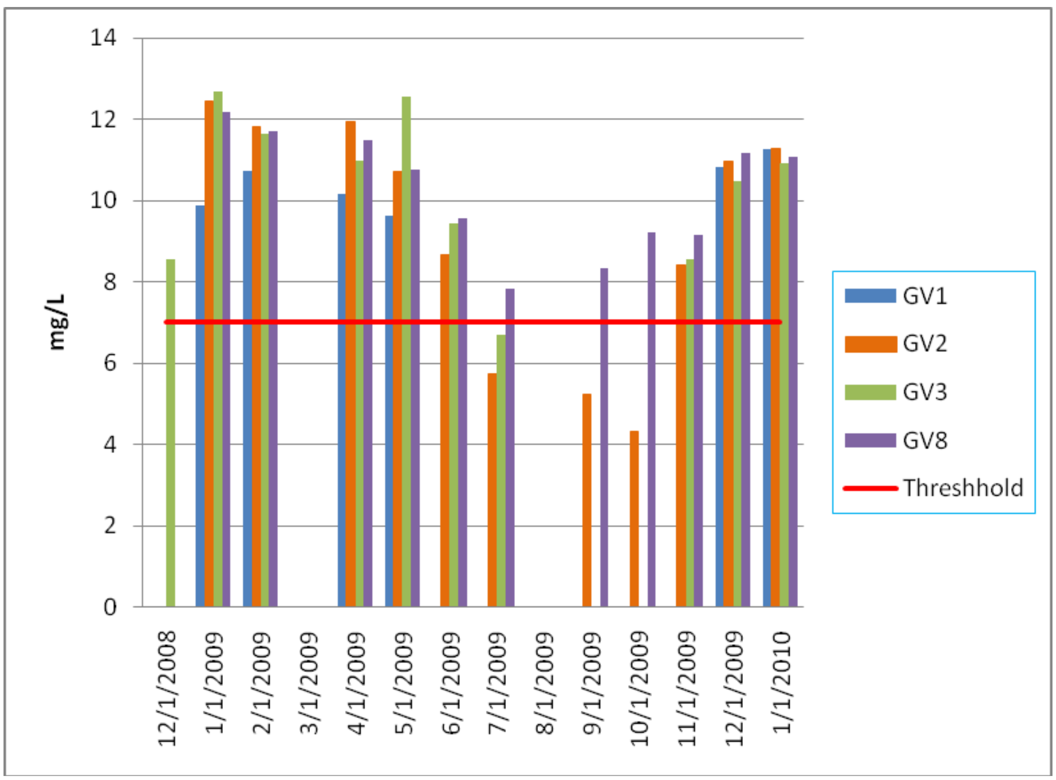
Many factors, both natural and anthropogenic, influence turbidity. In the Green Valley watershed, anthropogenic influences include rural roads, agricultural land use practices associated with vineyards, orchards and livestock pasture, and runoff from rural residential and light commercial development. Natural factors can include the delivery of fine sediment from mass movements (landslides), and natural stream incision related to tectonic processes.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas present in water and available to aquatic organisms; it provides a good measure of general aquatic health. It is added to water through diffusion from air, turbulence, and photosynthesis of aquatic plants, and removed through respiration of aquatic organisms, decomposition of organic material, and other chemical reactions that use oxygen. Additionally, DO passes from the water to the air in response to changes in atmospheric pressure, temperature, or salinity; more oxygen can dissolve in cold water, under greater pressure, and at lower salinity. DO levels are extremely variable; they can change with time of day, weather, and temperature. Continuous dissolved oxygen monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, should be considered for future monitoring efforts, particularly during the summer and fall when temperature tends to be high and streamflow is low.

Dissolved oxygen levels can range from 0 – 18 milligrams per liter (mg/l), but most aquatic ecosystems require at least 5–6 mg/L to support a diverse biological assemblage. When the concentration of DO is greatly reduced, the ability of gills to acquire oxygen for respiration is impaired, potentially leading to chronic effects such as reduced growth, increased susceptibility to disease, or reduced reproductive success. Invertebrate species sensitive to decreasing DO levels include mayfly nymphs, stonefly nymphs, caddisfly and beetle larvae. As DO levels decrease, these organisms are replaced by worms and fly larvae that tolerate water pollution; decreases in DO usually occur after an influx of organic pollutant (Green Media Toolshed and GetActive Software 2005). If DO concentrations fall below 3 to 4 mg/L, fish species such as salmon can experience physiological stress; however, many aquatic organisms can recover from short periods of low DO availability. The optimal DO level for salmon is 9 mg/l with a level of 7-8 mg/l acceptable and 3.5-6 mg/l considered poor. DO levels below 3.5 mg/l are likely to be fatal to salmon; levels below 3 mg/l are stressful to most vertebrates and other forms of aquatic life (Maun and Moulton undated).

Figure B-12: Dissolved Oxygen Measurements 2008-2010



Water Quality Objectives from the North Coast Regional Water Quality Control Plan set minimum dissolved oxygen levels at 7.0 mg/l for the Russian River HU with 7.5 monthly mean (90% Lower Limit[i]) and 10.0 monthly mean (50% Lower Limit[ii]) (NCRWQCB 2007a). DO objectives were developed to protect the 5 beneficial uses related to the preservation and enhancement of fish: marine habitat (MAR), inland saline water habitat (SAL), warm freshwater habitat (WARM), cold freshwater habitat (COLD), and spawning, reproduction, and/or early development (SPWN). The Guerneville HSA includes WARM, COLD and SPWN beneficial uses (see *Table 3, Guerneville HSA Beneficial Uses*).

During the first fourteen months of water quality monitoring in the Upper Green Valley Watershed, DO measurements in at least one location met or exceeded the 7.0 mg/L minimum during every sampling month (*Chart 3, Dissolved Oxygen*). In general, DO levels were higher through the winter months and dropped off during the summer, reflecting the seasonal increase in water temperature and lower stream flow conditions. Although monthly grab samples only give a snapshot of conditions in the watershed, the data suggests that DO conditions in most of the watershed are generally sufficient for salmonid survival. DO was not monitored in August. DO measurements exceeded the minimum at all locations from January through May 2009. Site 1 contained no water from June through November and Site 3 had no water in September and October. Samples from Site 2 were below the threshold in July and remained low until November. Samples from Purrington Creek (Site 8) were above the minimum throughout the year. In general, DO levels were sufficient during the winter and into early summer, but fell below acceptable levels when flows became low during late summer and early fall.

Factors that may be involved in lower than optimal DO in the watershed include nutrient increases associated with agricultural runoff, increased water temperature, which decreases the ability of water to hold oxygen, or decreased turbulence due to decreases in flow. In stream reaches with excessive algal growth, DO concentrations fluctuate significantly throughout the day – supersaturated conditions occur during the day and lower concentrations around dawn when respiration and other reactions during the dark have consumed oxygen. For areas impacted by algae, early morning sampling should be conducted to evaluate the impacts on DO. The decomposition of algae consumes oxygen, and sampling design should consider capturing this impact. Human activities that draw down the water table, add nutrients, or divert surface water during the summer may contribute to reduced DO during the critical summer months.

Figure B-13: Dissolved Oxygen Concentration 2010-2011

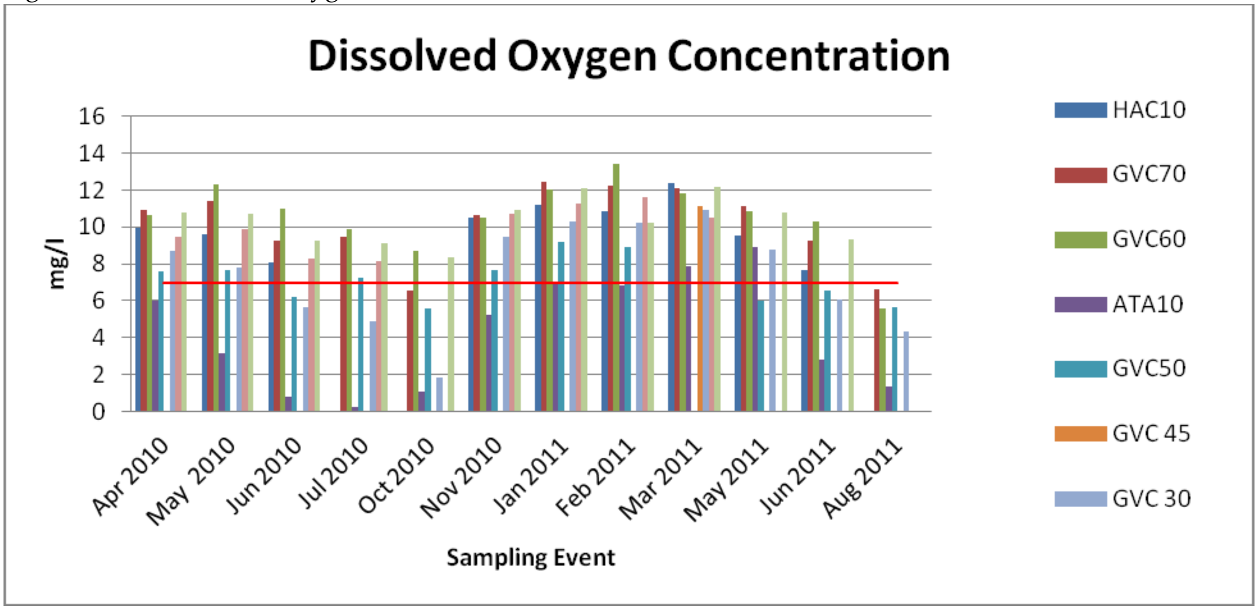
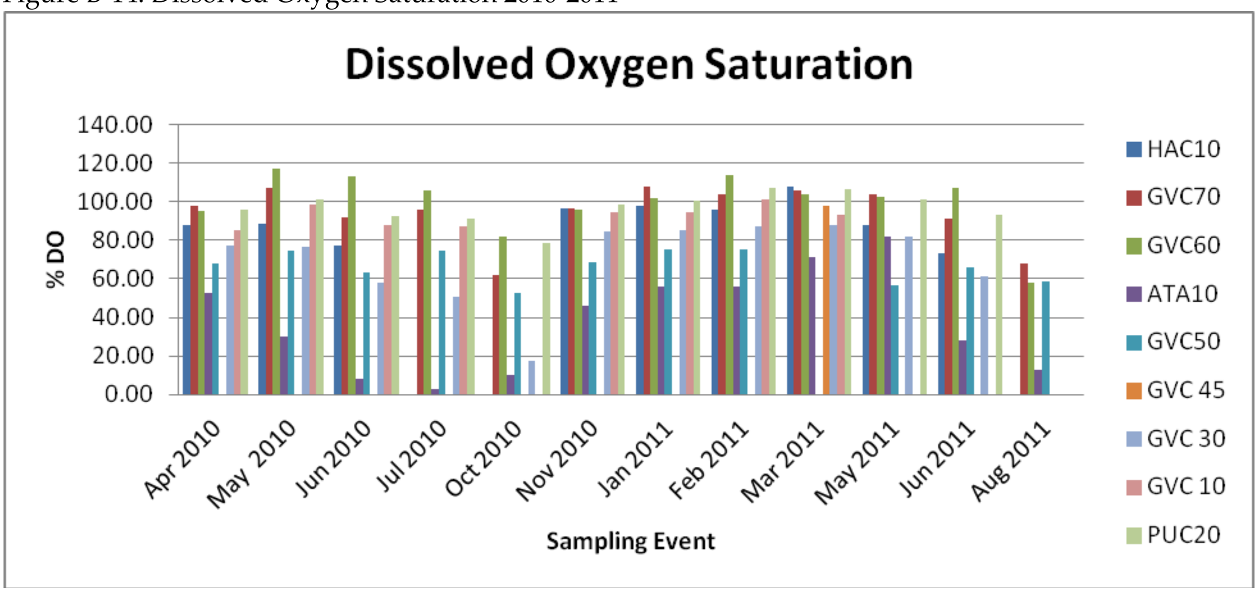


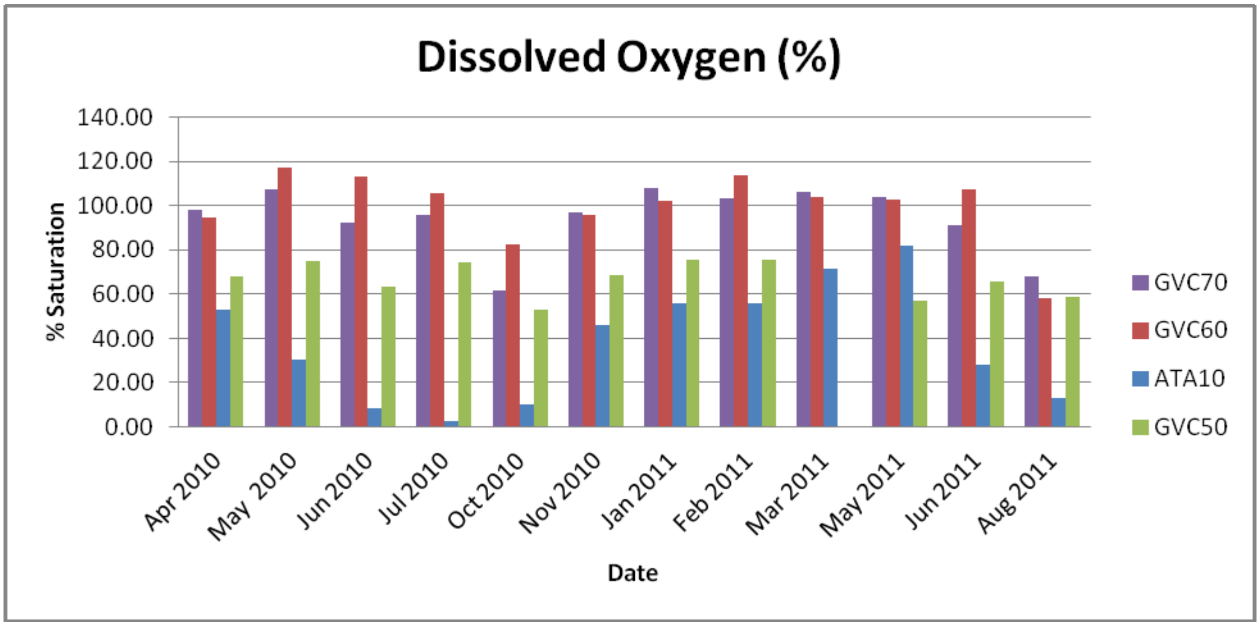
Figure B-14: Dissolved Oxygen Saturation 2010-2011



The affect of the low DO concentrations measured in Atascadero Creek on the Green Valley Creek below the confluence with Atascadero were of particular interest. It appears that the input of Atascadero Creek has a detrimental effect on DO concentrations in lower Green Valley Creek. It is unknown if this is a function of the high nutrient and organic matter conditions of the naturally swampy Atascadero Creek or related to unnatural nutrients sources such as municipal and agricultural runoff and/or waste water discharges.

Figure 7 shows the DO saturation measurements at GVC70 (considered high quality salmonid habitat by the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP) and just downstream of their reference reach), GVC60 (RRCSCBP treatment reach), ATA10 and GVC50, which is downstream of the Atascadero Creek confluence.

Figure B-15: Dissolved Oxygen Measurements at Selected Stations 2010-2011



Based on the DO conditions measured during the monthly sampling events, continuous water quality meters were deployed on Green Valley Creek just upsteam of the Atascadero Creek confluence (GVC-60) and on the Thomas Creek Ranch property approximately 1 mile upstream of the Highway 116 bridge crossing (GVC-45). These locations were selected to measure the water quality conditions upstream and downstream of the Atascadero Creek confluence. These results will be analyzed and discussed in a subsequent summary report.

pH

pH is a measure of how acidic or basic water is on a scale from 0 to 14, with 7 being neutral. A pH of less than 7 indicates acidic conditions, while above 7 is basic. Most freshwater lakes, streams, and ponds have a natural pH in the range of 6 to 8. Acidity in most streams is controlled by the carbonate buffering system – an equilibrium between calcium, carbonate, bicarbonate, carbon dioxide, and hydrogen ions in the water and carbon dioxide in the atmosphere. Poorly buffered waterways – those most susceptible to acidification – are found in watersheds containing slowly weathering minerals and little limestone or other alkaline materials, like the Upper Green Valley watershed. In poorly buffered surface waters with large aquatic plant populations, pH can show high daily variability – increases of several units during the day and similar decreases during the night are not uncommon. The use of CO_2 by plants during photosynthesis removes carbonic acid from water, which can increase daytime pH dramatically. During the night, pH levels can fall just as drastically because plants are not photosynthesizing and carbonic acid can accumulate (US EPA 2008). However, in the Upper Green Valley Creek watershed, aquatic plant populations are not likely to increase to a population level where this type of oscillation occurs.

Figure B-16. pH Measurements 2008-2010

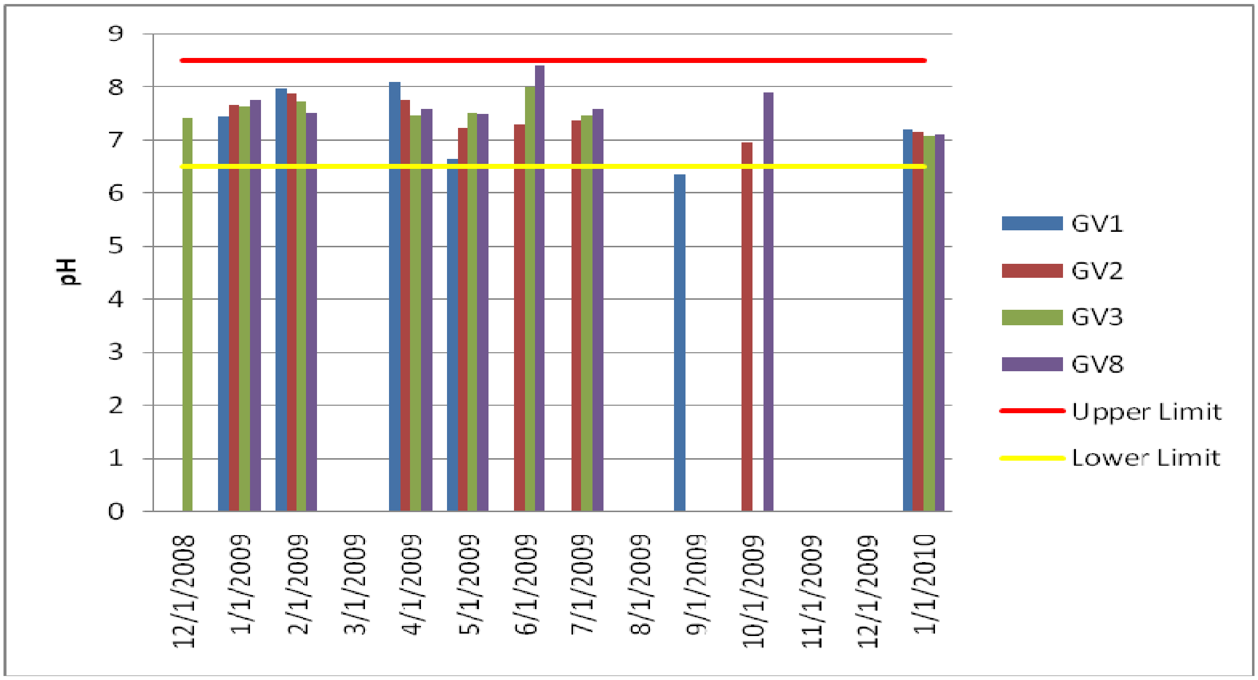
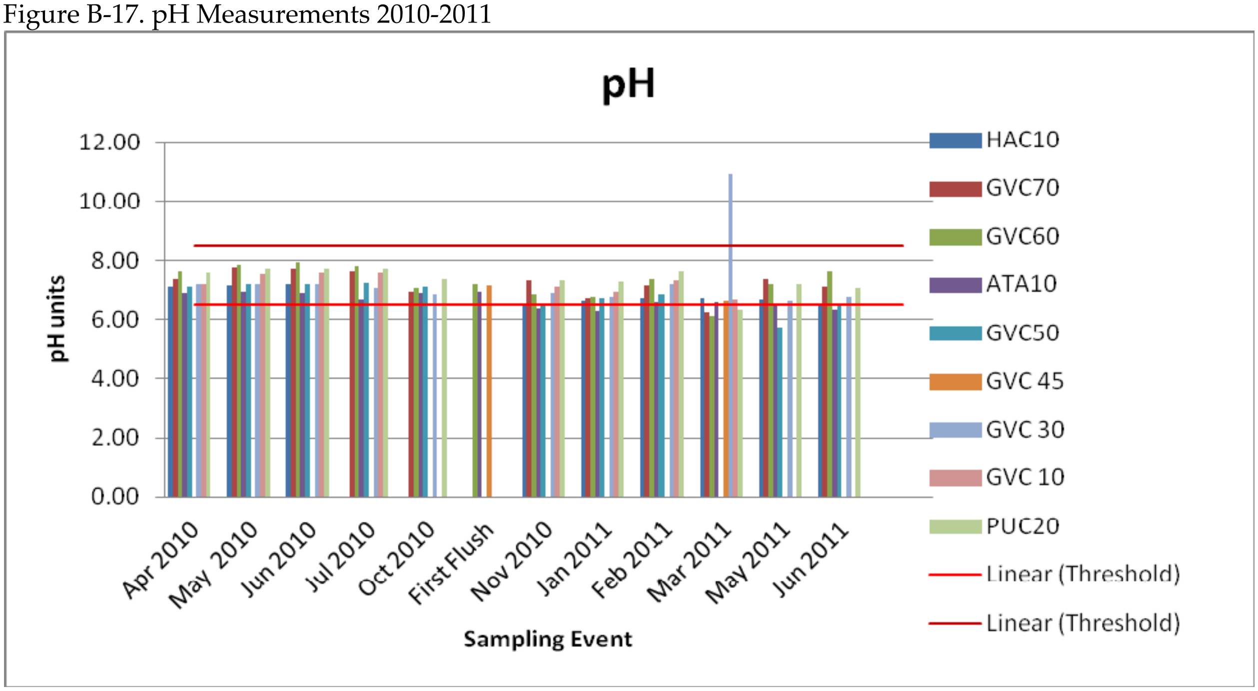


Figure B-17. pH Measurements 2010-2011



For fish, pH above 9.5 can cause death or damage to outer surfaces like gills, eyes, and skin, and result in an inability to dispose of metabolic wastes. Increased pH can also increase the toxicity of other substances, such as ammonia; the effect of ammonia is 10 times greater at pH 8 than at pH 7. When conditions are more acidic (low pH), plankton and mosses may invade, and some fish populations diminish. Water Quality Objectives from the North Coast Regional Water Quality Control Plan set pH 8.5 as the maximum and 6.5 as the minimum for the Lower Russian River Watershed (NCRWQCB 2007a).

Measurements of pH were within limits set by the NCRWQCB during the monitoring period (*Chart 4, pH*). In August 2009, pH was not monitored and in early winter November and December 2009, the pH meter was malfunctioning. Site 1 pH measurements were somewhat variable from month to month and Site 8 increased markedly in June. Since immature stages of aquatic insects and juvenile fish are sensitive to pH, such changes could be detrimental, and a spike indicates the possibility of a pollutant discharge. Continued testing will help to determine whether such increases are regular phenomena or random fluctuations.

Anthropogenic factors that contribute to extreme pH levels include nutrient loading, which can lead to excessive aquatic plant growth, and runoff or point-source pollution that directly alters stream chemistry. Acid rain can also influence pH levels, but it does not generally occur in the western US.

Conductivity

Conductivity – or specific conductance – measures water's ability to conduct an electric current. It is sensitive to variations in dissolved solids such as mineral salts that dissociate into ions. Each ion's electric charge, ion mobility, and water temperature affect conductivity. Because of its sensitivity the temperature (the warmer the temperature, the higher the conductivity), conductivity is reported as conductivity at 25 degrees Celsius.

In streams, conductivity is affected primarily by the geology of the area through which the water flows – streams that run through areas composed of inert material like granite will have lower conductivity than those that run through areas with clay soils or other rocks that ionize when exposed to water. Discharges to streams can change stream conductivity; failing septic or fertilizer runoff would raise conductivity due to the presence of chloride, phosphate, and nitrate. It is not known how conductivity affects salmonids, but streams that support fisheries usually have a range between 150 and 500 μS/cm (US EPA 2006).

Streams tend to have a relatively constant range of conductivity; once a baseline is established, it can be used as a comparison for ongoing monitoring. Significant changes could indicate discharge of a pollutant. In the North Coast RWQCB Water Quality Control Plan, conductivity is set at 375 micro-Siemens per centimeter (µS/cm) at 25° C (90% Upper Limit[1]) and at 285 (µS/cm) at 25° C (50% Upper Limit[2]) (NCRWQCB 2007a).

Figure B-18. Conductivity Measurements 2008-2010

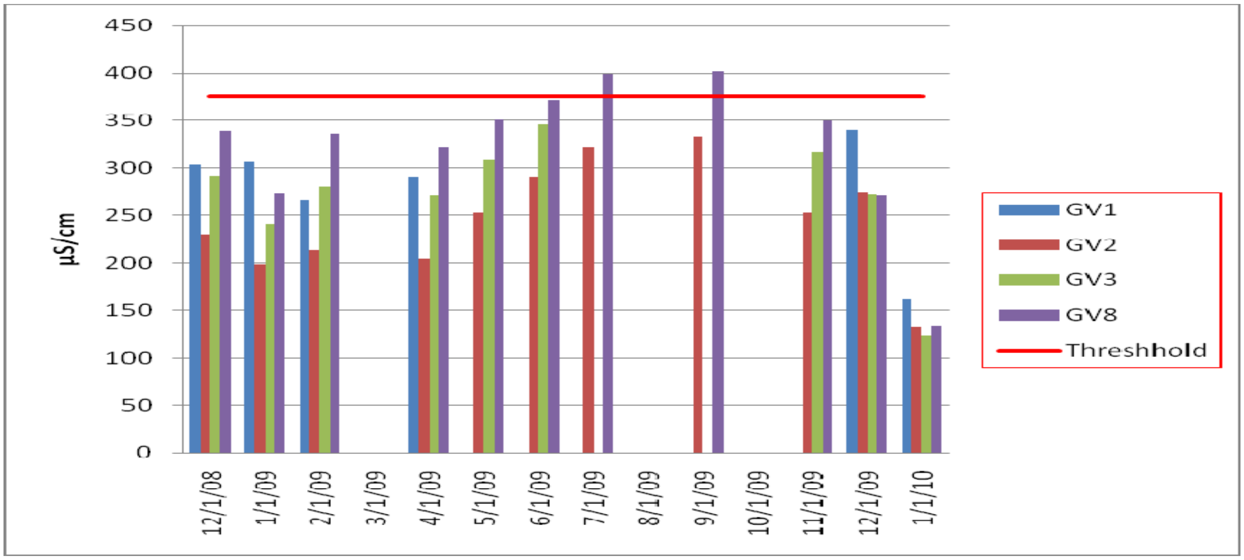
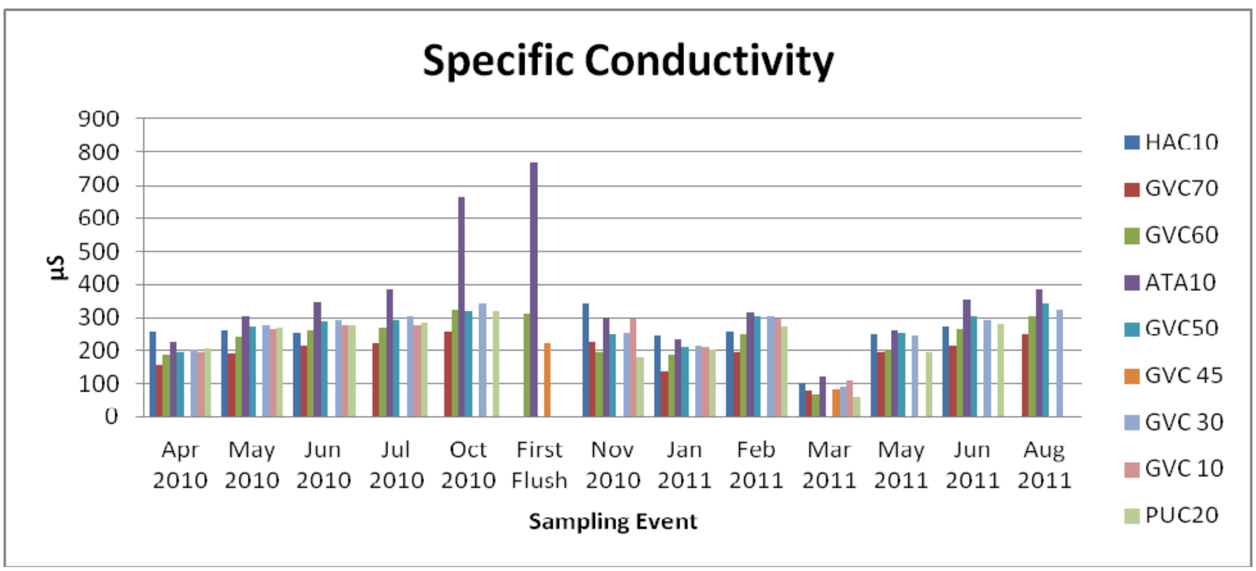


Figure B-19: Specific Conductivity Measurements 2010-2011



[1] 50% upper and lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit.

[2] 90% upper and lower limits represent the 90 percentile values for a calendar year. 90% or more of the values must be less than or equal to an upper limit and greater than or equal to a lower limit.

Specific conductivity measurements ranged from 61 μS (flood conditions) to 768 μS (first flush conditions). Specific conductivity measurements were consistently the highest at the Atascadero Creek station (ATA10). This is likely due to the high nutrient loads that occur in Atascadero Creek, though given the fact that the water temperatures and dissolved oxygen levels are consistently low at this station, the high conductivity readings may be an indicator that groundwater sources are the primary source of streamflow during late summer, low flow conditions.

Nutrients

In 2010, nutrient sampling for selected storm events was added to the Green Valley Creek water quality monitoring program.

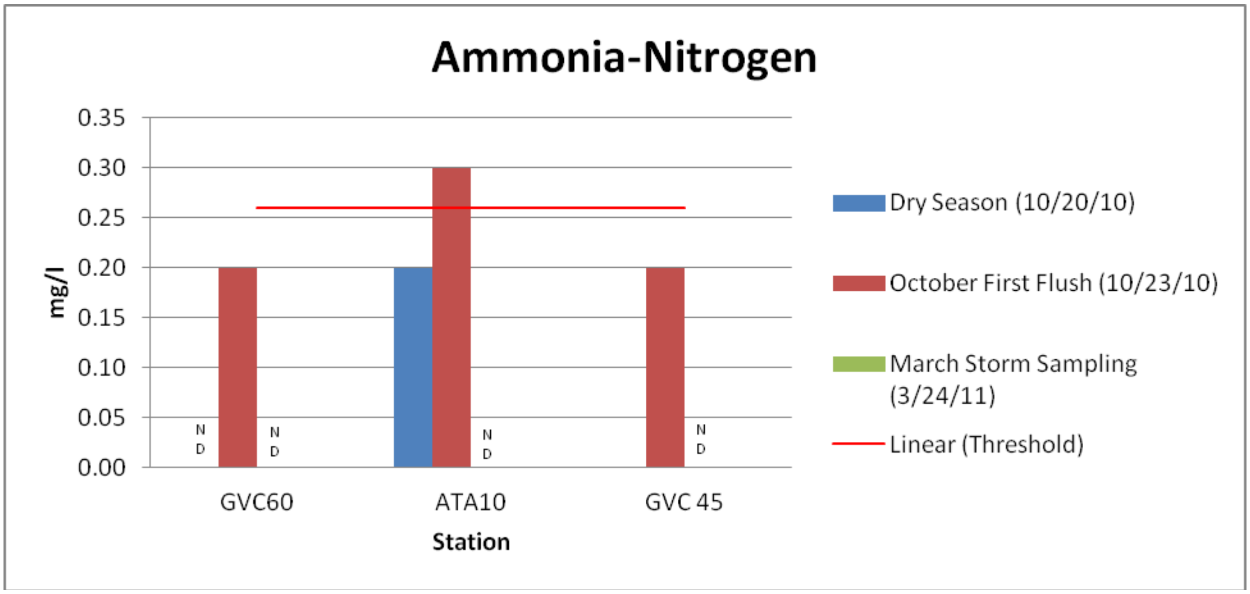
Excessive levels of nutrients can impact aquatic habitat in a variety of ways. Un-ionized ammonia is toxic and can be lethal to aquatic organisms at high concentrations. An indirect impact of nutrient contamination is that nutrients can cause excessive aquatic plant growth and algal blooms. In coastal waters, nitrogen is the nutrient of concern causing overfertilization of aquatic plants. In freshwater systems, phosphorus is the nutrient of concern. The assumption is that where these nutrients are present, there will be excessive plant and algal growth and the resulting diurnal oxygen fluctuations and depletion due to BOD associated with the decay.

Ammonia

Total ammonia is composed of two forms; ionized ammonia (NH_4^+), and un-ionized ammonia (NH_3).Un-ionized ammonia, which primarily results from decomposition of manure and other organic debris by microbes, can be toxic to aquatic organisms in small concentrations. The percent of total ammonia in the harmful un-ionized form increases with higher temperatures and pH values.

Figure 14 depicts the Ammonia results from selected storm events, the ND means that the results were less than <0.20 mg/l or non-detectable given that analytical method. Both Ammonia and Nitrate were sampled during the monthly October sampling (10/20/10) at two selected stations (GVC60 and ATA10) as baseline measurements to compare to the First Flush sampling results (10/23/10). A third sampling event was conducted during storm sampling on 3/24/11 during which, as expected due to the high flow volumes and resulting high dilution rates, all stations had non-detect results.

Figure B-20. Ammonia Measurements from Selected Storm Events

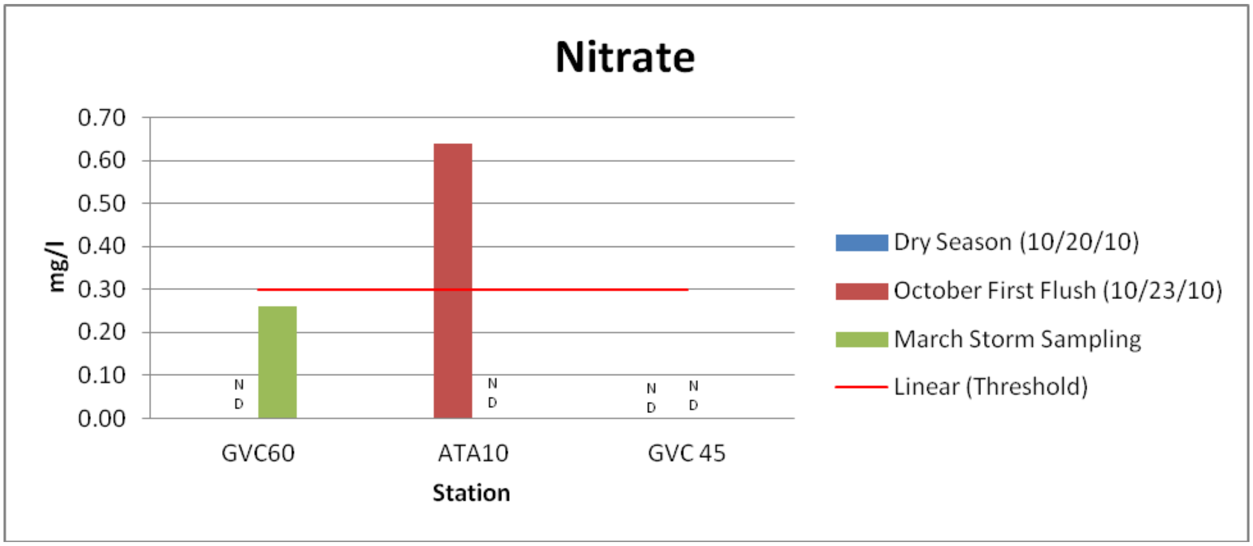


Nitrate

Nitrate-nitrogen, phosphate and phosphorous are not directly toxic to aquatic organisms but, where sunlight is available, these chemical nutrients act as biostimulatory substances that stimulate primary production. Excessive inputs of these nutrients, known as eutrophication, can result in abundant plant growth and resulting decay which depletes dissolved oxygen and can degrade habitat quality. One study indicated that a nitrate concentration of less than 0.3 mg/l would likely prevent eutrophication (Cline, 1973).While the State Water Resources Control Board (SWRCB) has not set numeric targets for nutrients, narrative criteria in the North Coast Basin Plan for "biostimulatory substances", which include nitrate and phosphate, states that, "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance, or that otherwise adversely affect beneficial uses (NCRWQCB, 1994)."

Nitrate (NO_3) is an inorganic form of nitrogen that is soluble and therefore subject to leaching and biological uptake. Nitrate is characterized as a biostimulatory substance. Nitrate values at all sites sampled ranged from <0.20 (the detection limit) to 0.64 mg/l. Figure 15 depicts the Nitrate results from selected storm events, the ND means that the results were less than <0.20 mg/l or non-detectable given that analytical method.

Figure B-21. Nitrate Measurements from Selected Storm Events

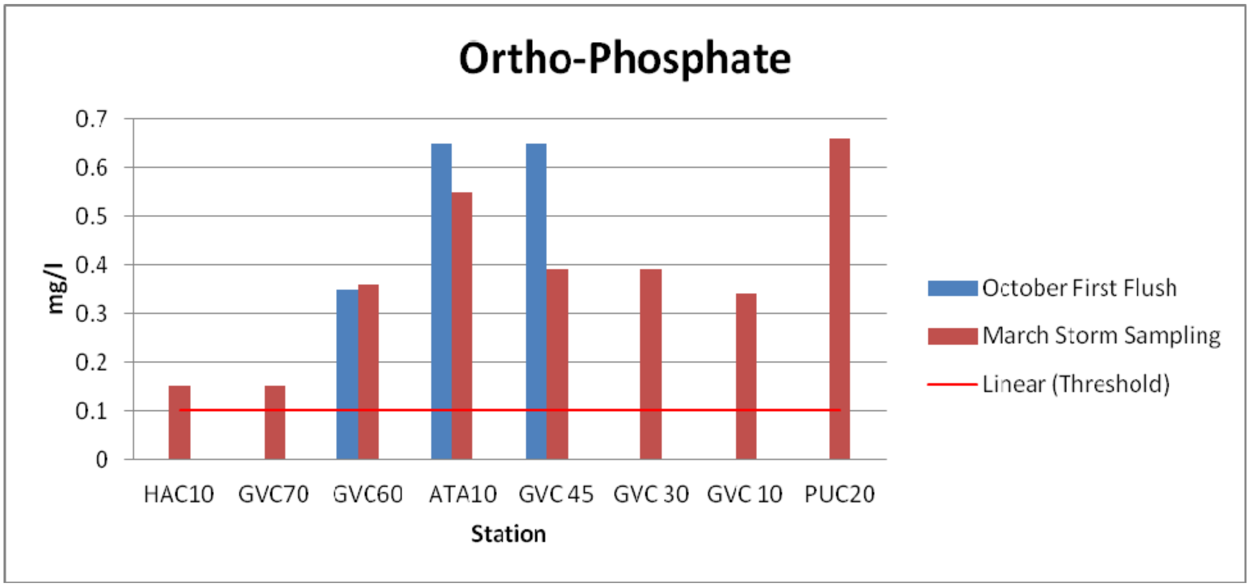


Phosphorus

High concentrations of phosphorus, particularly Ortho-phosphate the most-bioavailable form, are a biostimulant, they overfertilize fresh water bodies resulting in excessive algal production and lowered dissolved oxygen levels.

During the 10/23/10 first flush sampling event, three stations were sampled: GVC-60, ATA-10 and GVC-45. The concentrations ranged from 0.35 to 0.65 mg/l, all of which exceeded the <0.10 mg/l WQO. The second storm sampling event on 3/26/11, all stations were sampled and results ranged from 0.15 to 0.66 mg/l, all of which the <0.10 mg/l WQO. Generally, the first flush sampling showed higher concentrations of Ortho-phosphate. Additional stations were sampled for the 10/5/11 first flush sampling event to better track the nutrient contribution during the first significant rainfall of the season when the landscape is essentially rinsed of constituents accumulated over the dry season.

Figure B-22. Ortho-Phosphate Measurements from Selected Storm Events



In addition to the nutrient and TSS samples taken during the 10/23/10 first flush sampling, water was collected from each station to run bioassays with rainbow trout. All three stations had 100% survival.

Continuous Water Quality Data

As was earlier discussed, two continuous water quality meters were deployed in Green Valley Creek in June 2011, one just downstream of station GVC-60 and one slightly upstream of GVC-45. These multi-parameter meters measured temperature, dissolved oxygen, specific conductivity and pH every thirty minutes from June 30 through September 21, 2011. The meters were re-deployed in July 2012, but due to equipment malfunction, continuous data was only collected in October 2012. The graphical results are included below.

Figure B-23. Continuous water quality data for Green Valley Creek as it runs through GVC47 (6/30/11-7/28/11)

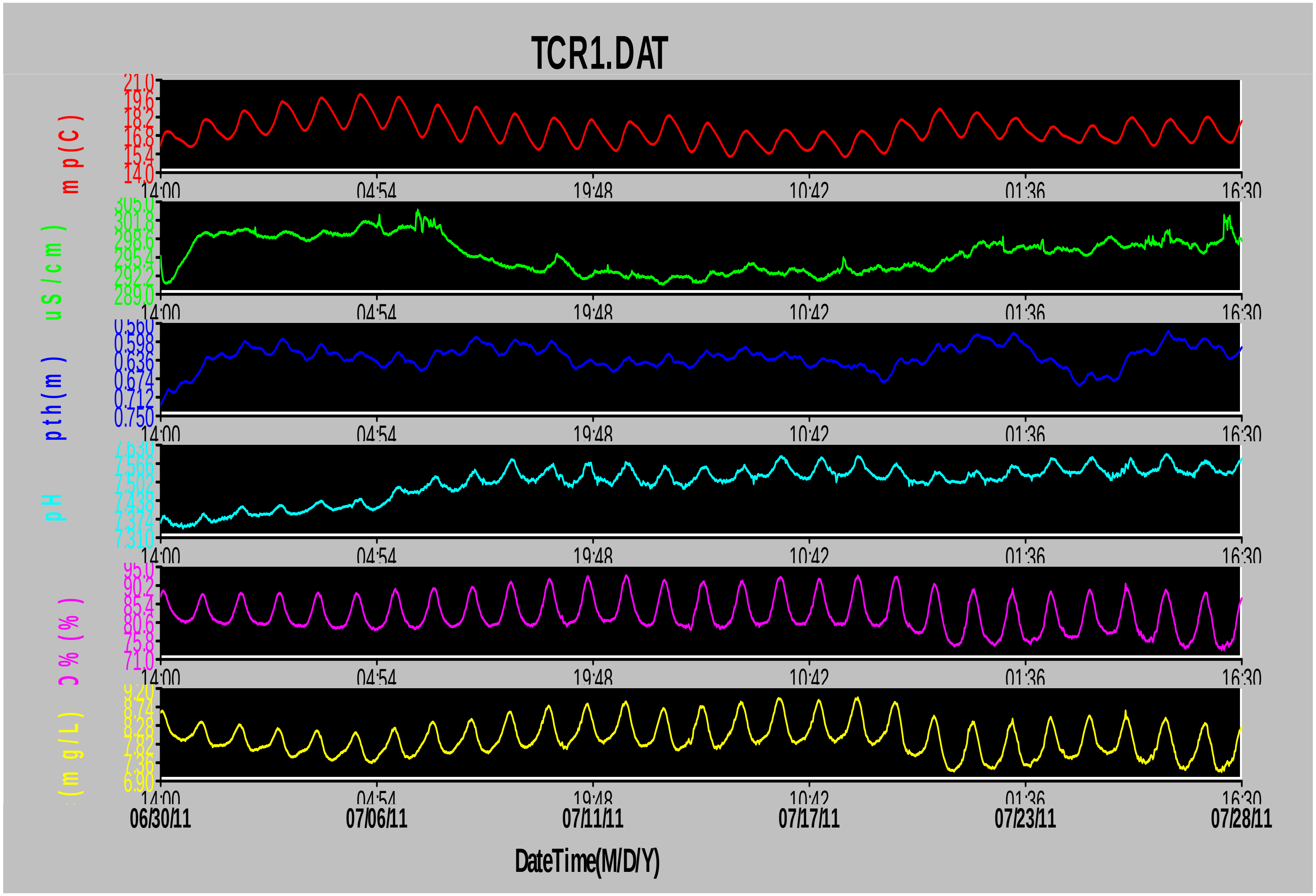


Figure B-24. Continuous water quality data for Green Valley Creek as it runs through GVC47 (7/28/11-8/31/11)

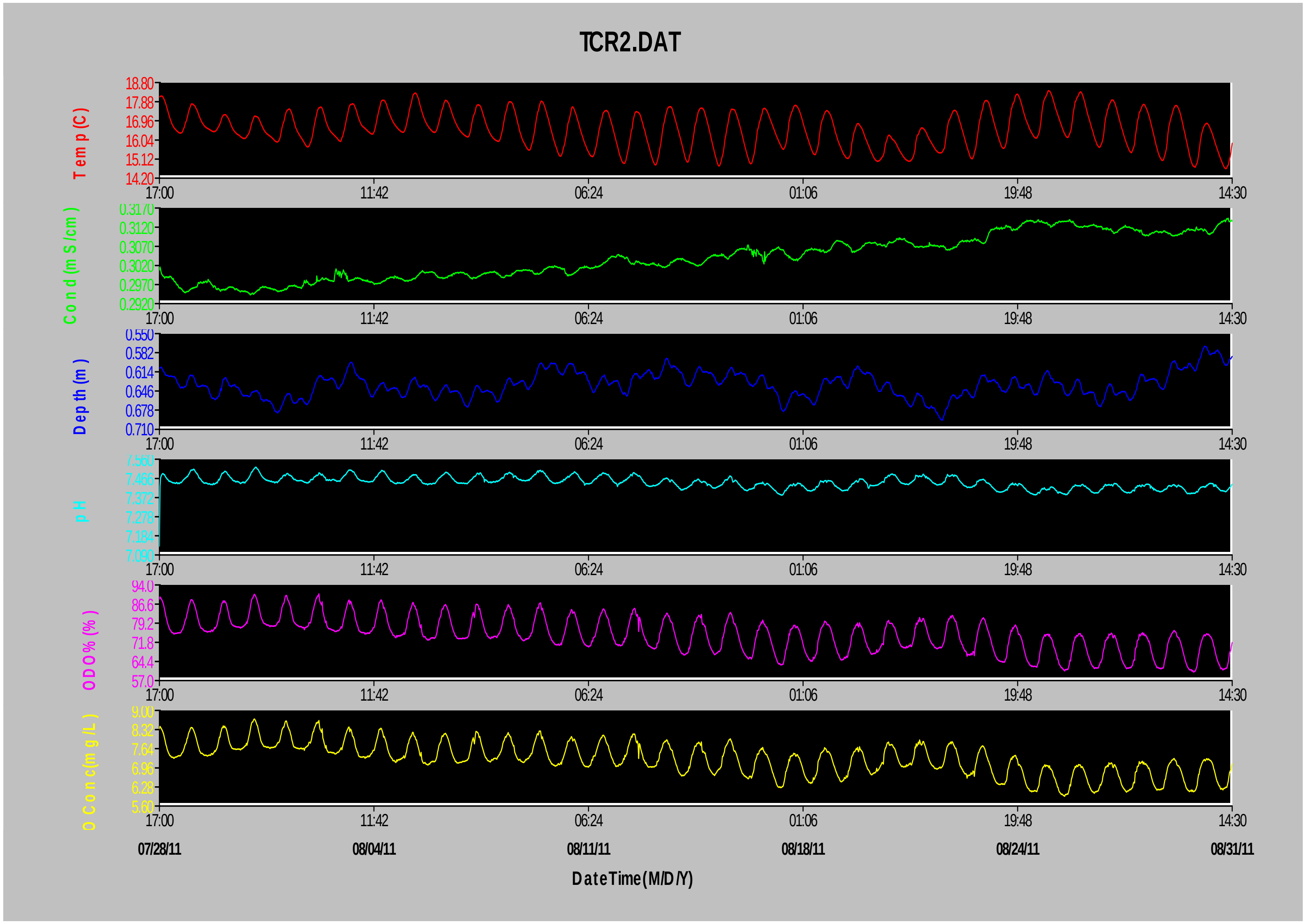


Figure B-25. Continuous water quality data for Green Valley Creek as it runs through GVC47 (8/31/11-9/21/11)

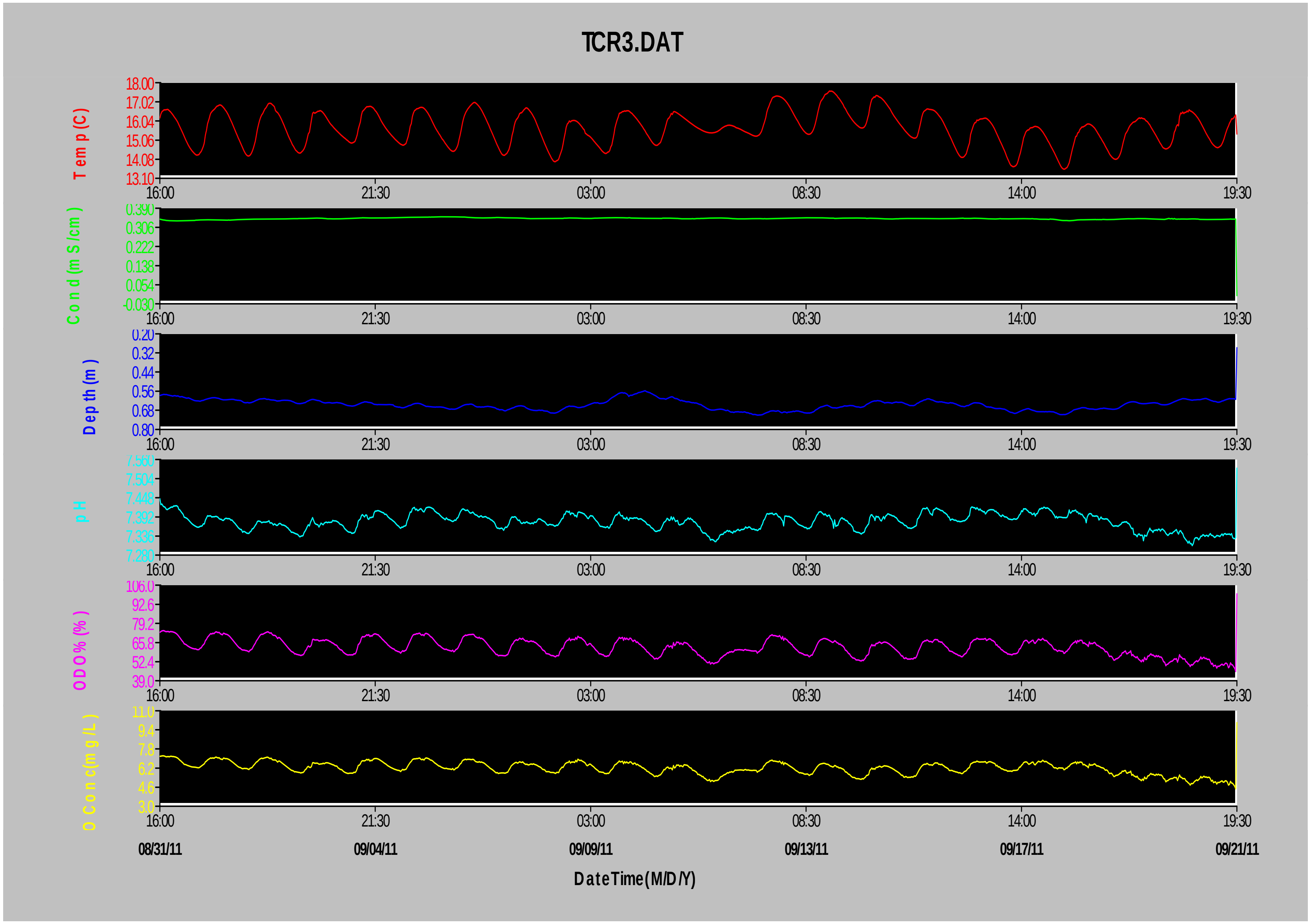


Figure B-26. Continuous water quality data for GVC60, Green Valley Creek downstream of Green Valley Road bridge (6/30-7/28/11)

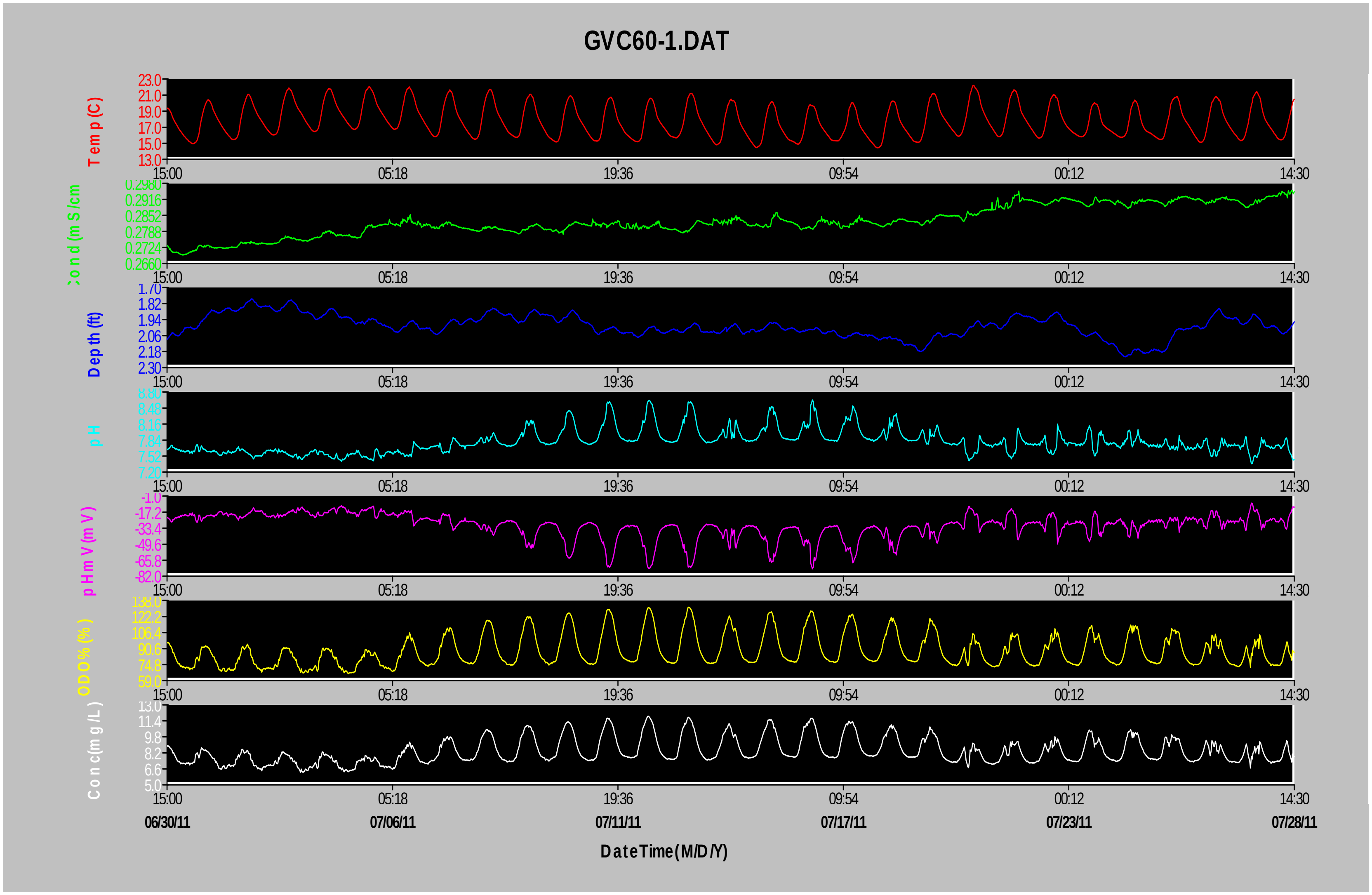


Figure B-27. Continuous water quality data for GVC60, Green Valley Creek downstream of Green Valley Road bridge (7/28-8/24/11)

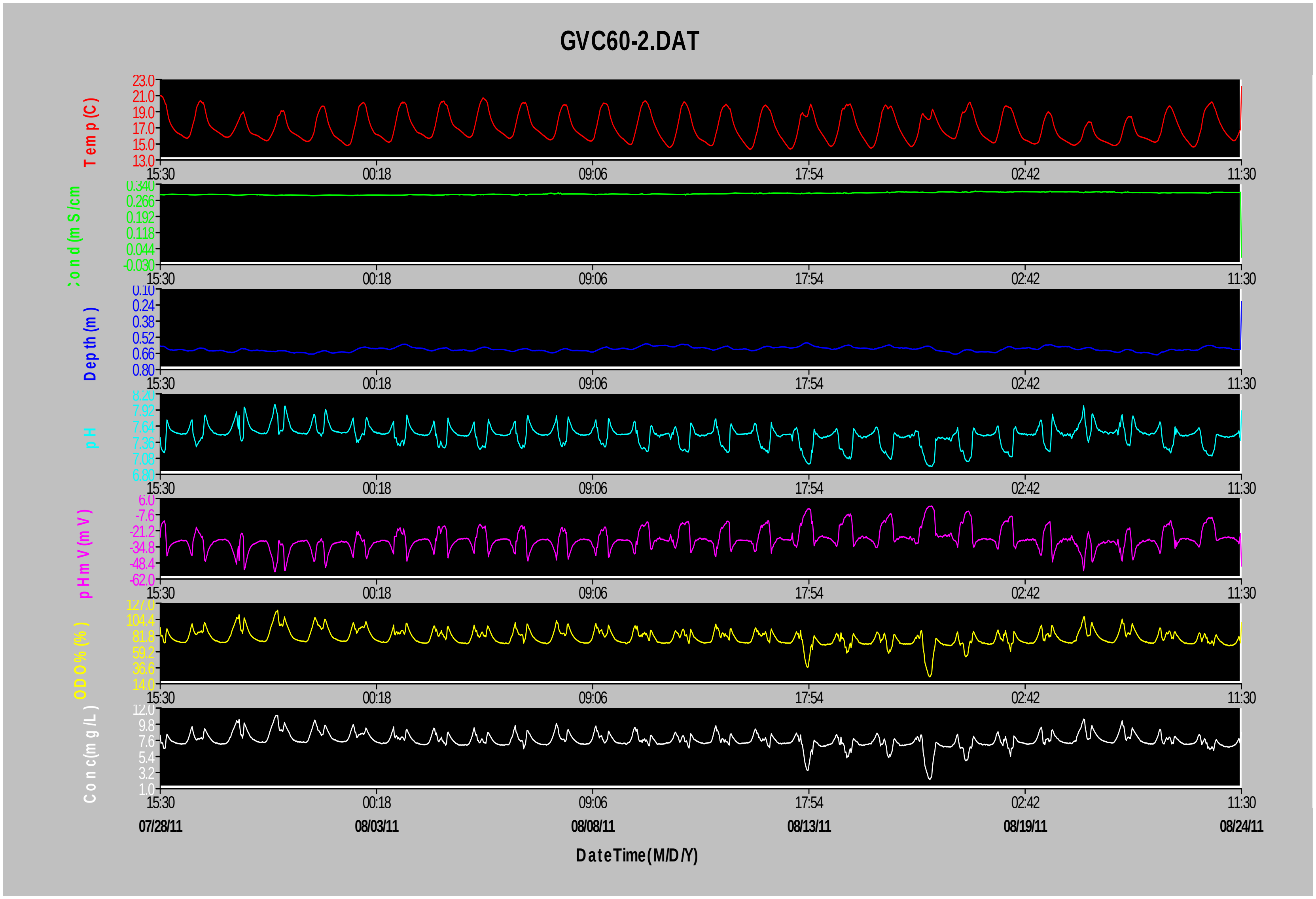


Figure B-28. Continuous water quality data for GVC60Green Valley Creek downstream of Green Valley Road bridge (8/24-9/09/11)

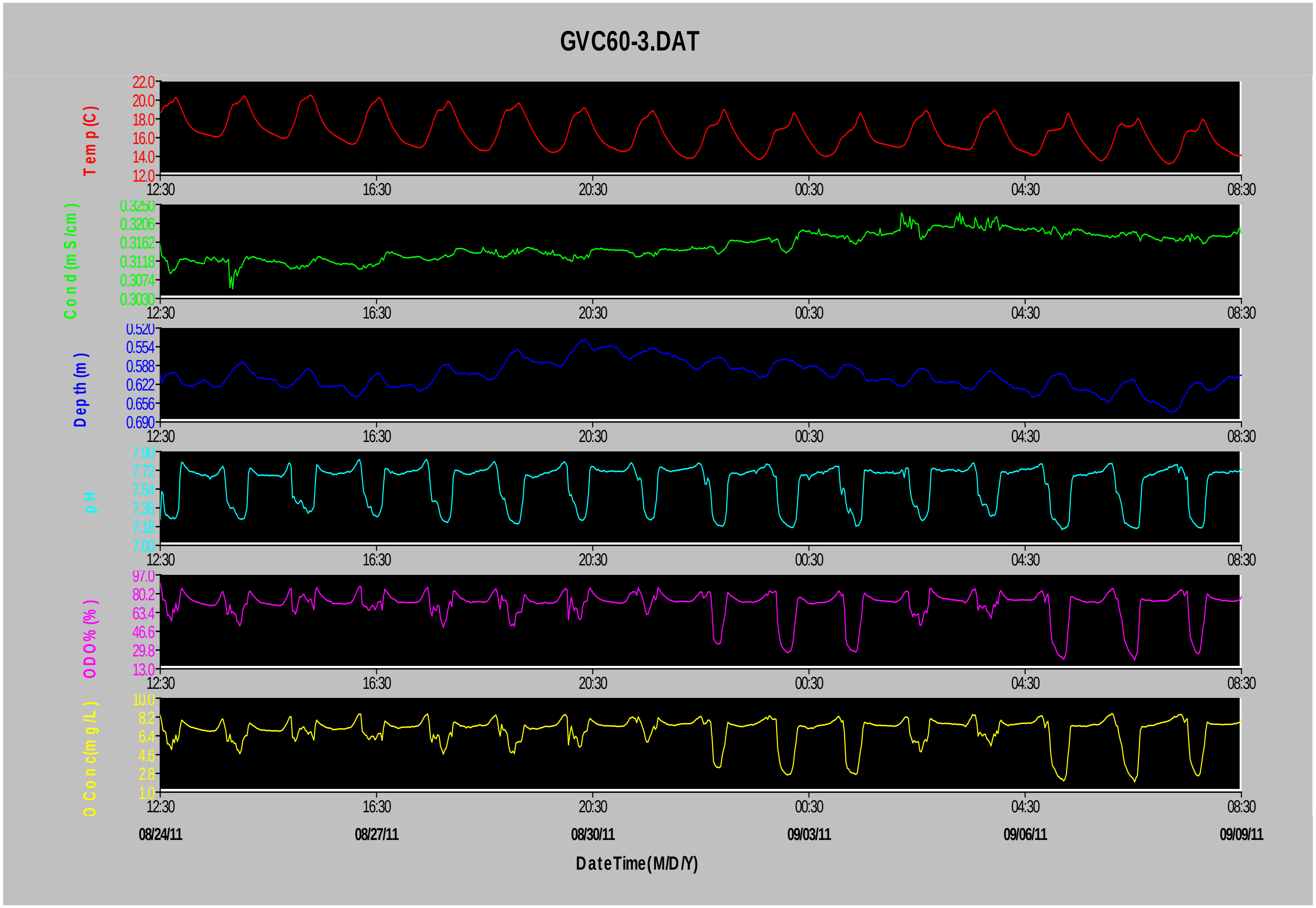


Figure B-29. Continuous water quality data for Green Valley Creek as it runs through GVC47 (10/4-10/29/12)

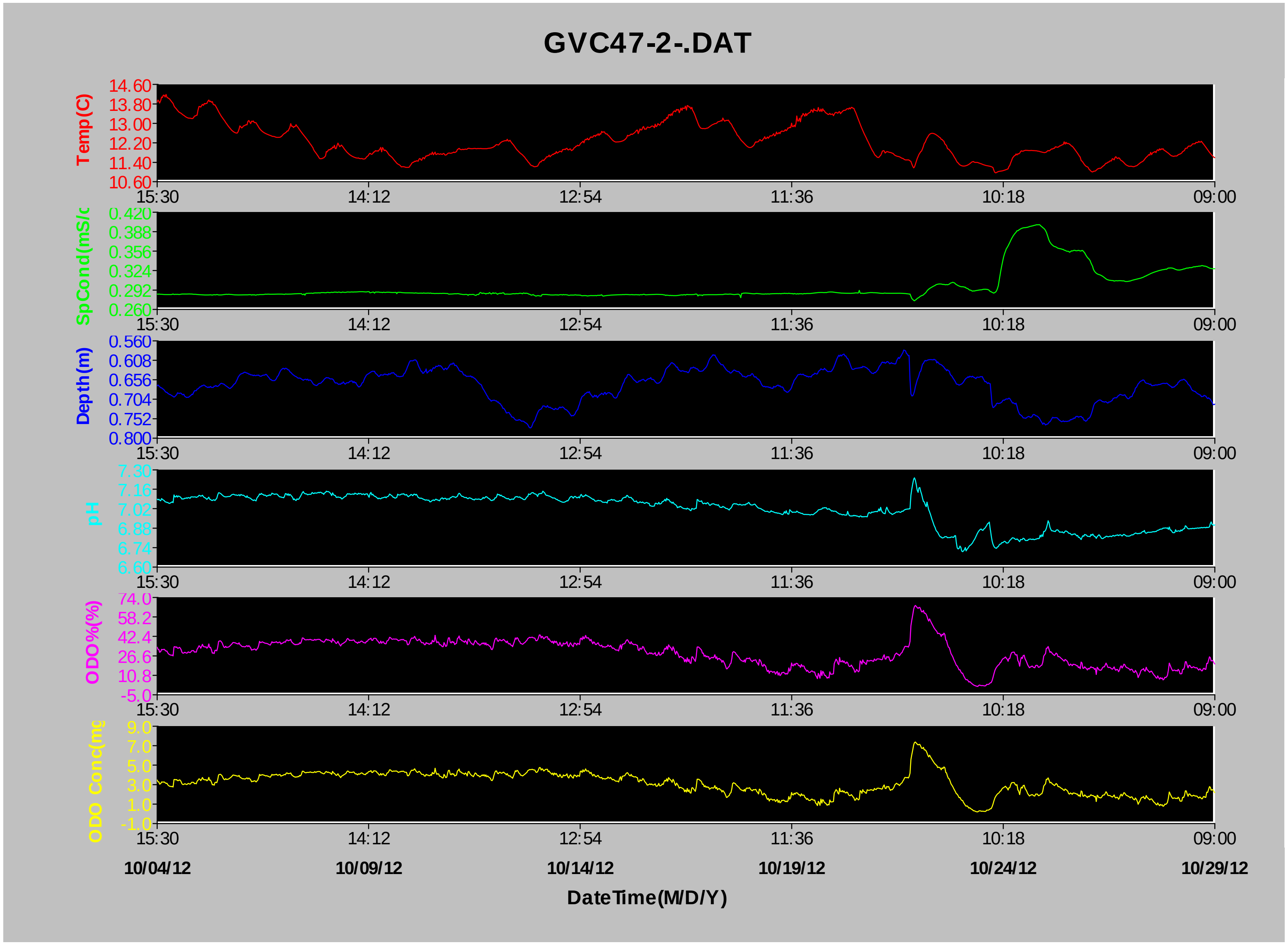
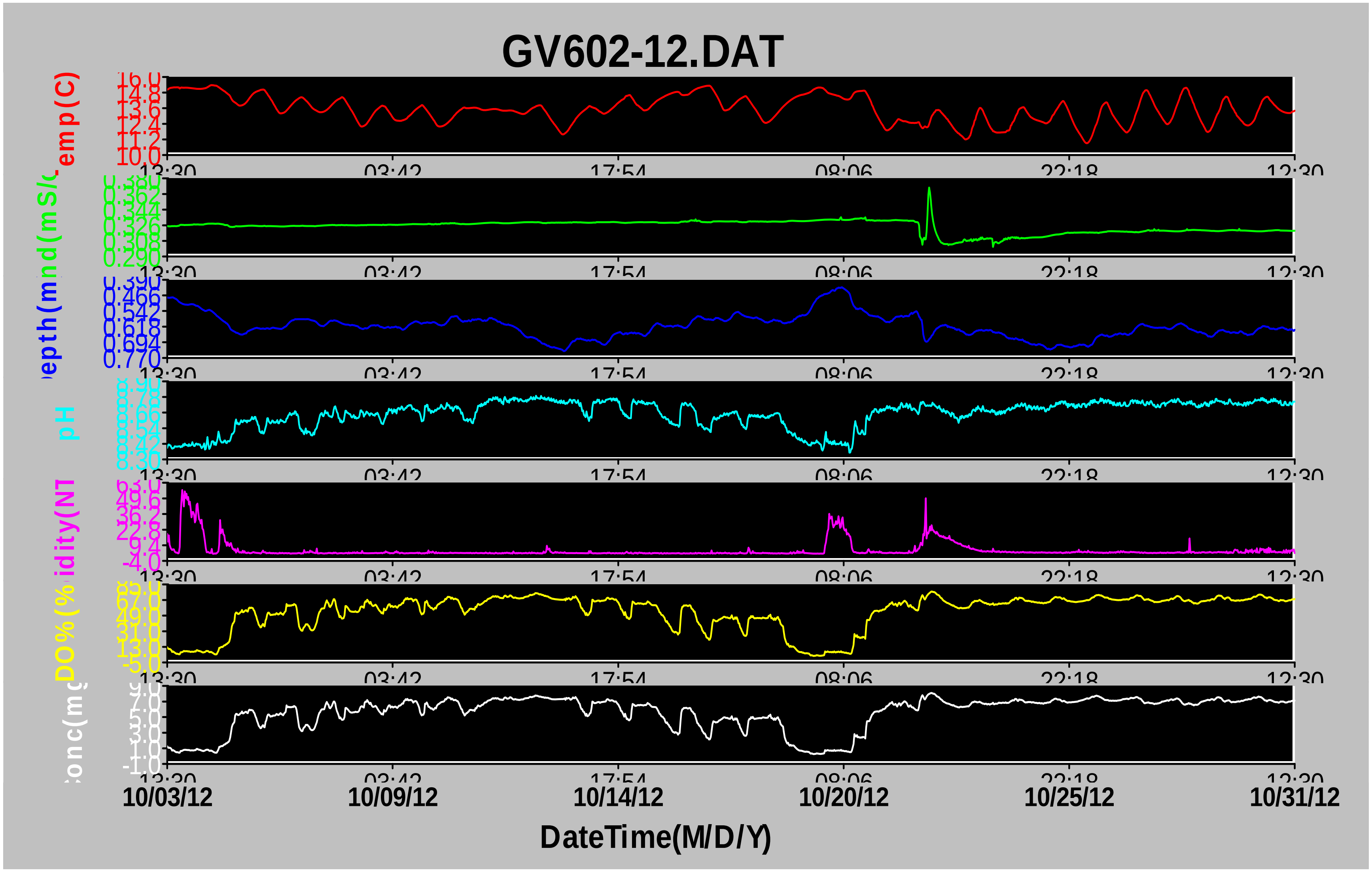


Figure B-30. Continuous water quality data for GV60 Green Valley Creek downstream of Green Valley Road bridge (10/3-10/31/12)



Data Gaps

The past four years of water quality monitoring represent the beginning of GRRCD's focused water quality monitoring program in the Green Valley and Purrington Creek subwatersheds. Continued and enhanced monitoring will provide a more thorough understanding of current water quality conditions and establish a baseline for comparison. Historic water quality data – especially during the periods in which coho were plentiful – would be very valuable to provide targets for management activities and projects.

Conclusion

Results from the past fourteen months of monitoring suggest that overall water quality in the Upper Green Valley Creek watershed meets most standards for salmonid survival at different life stages. The Purrington Creek location (Site 8) most often met standards and retained pool connectivity throughout the summer months. However, the spike in pH in June and conductivity measurements above the threshold in June and July may indicate that a pollutant discharge occurred upstream of Site 8 during the early summer.

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

Water Quality Goals:

1. Promote and protect the Beneficial Uses of the watershed
2. Reduce nonpoint source sedimentation
3. Reduce summer water temperature and provide increased summer flows through a combination of offstream storage and conservation practices

Chapter II, Section D discusses sedimentation in more detail. BMPs that support sustainable agriculture, improve road development and maintenance, and reduce the impact of rural residential development are discussed in detail in *Chapter III, Management Considerations*. Specific, measurable actions that implement BMPs to achieve water quality goals are presented in *Chapter IV, Looking Forward*.

Water Quality Recommendations:

1. Surface water quality monitoring should continue with enhanced equipment at an increased number of sites:
    a. Parameters measured to include continuous stream discharge, temperature, DO, TSS, and nutrients.
    b. Develop SWRCB-approved Monitoring and Assessment Plan and Quality Assurance Project Plan to guide monitoring activities.
    c. Install temperature loggers in select sites through the summer months.
    d. Obtain instrumentation/lab facilities/funding to measure total suspended solids (TSS) as a measure of turbidity. These measurements can be useful to calculate total quantities of material within or entering a stream system and are not possible with NTU measurements.
    e. Obtain repeat TSS measurements during periods of high turbidity to determine duration of high turbidity. This will provide more information about potential impacts to aquatic wildlife.
    f. Conduct bioassessment using benthic macroinvertebrate assemblages as an indicator of aquatic habitat quality.
    g. In stream reaches where algae are consistently present, conduct bioassessment using algal communities as an indicator of nutrient impacts to aquatic habitat quality.
2. Implementation of BMPs to decrease sediment loads.
    a. Road-related sediment reduction measures

    b. Vineyard and orchard cultivation-related sediment reduction measures
    c. Grazing management practices to limit sedimentation
    d. Restoration and enhancement of riparian buffers
3. Implementation of BMPs to decrease summer water temperatures, increase flow, and improve DO.
    a. Winter water storage measures to decrease summer diversions
    b. Vineyard, orchard, and livestock pasture-related water conservation measures
    c. Rural residential and light commercial-related water conservation measures
    d. Restoration and enhancement of riparian buffers

C. Hydrology & Instream Flow

Prepared by Matt Deitch, Center for Ecosystem Management and Restoration

Introduction

The Upper Green Valley Creek watershed fits within a band along the Pacific coast characterized as having a Mediterranean-type climate, distinguished by warm dry summers and mild wet winters, one of 6 such regions with this climatic type on the globe (Conacher and Conacher 1999). Recognizing these unique features, the Greek philosopher Aristotle noted that the Mediterranean climate is the only type suitable for human habitation (James 1959). In addition to this annual pattern of mild rainy winters and warm dry summers, regions with a Mediterranean climate typically share a feature more commonly associated with semi-arid regions – climatic events typically show greater inter-annual variability, such that drought and flooding are common characteristics of this climate type.

The following discussion will describe in detail the defining hydrologic characteristics of the Upper Green Valley Creek watershed and surrounding area. The central tenets of the Mediterranean climate, namely the seasonal and inter-annual patterns described above, can be described in the context of precipitation data gathered in or near the watershed. The discussion will also illustrate how these precipitation trends relate to streamflow in the region, within the same year as well as from one year to the next. It also will examine trends among long-term climate records to identify any differences that may have occurred in recent decades.

Finally, this discussion will describe how the general climatic and hydrologic characteristics of the Upper Green Valley Creek watershed may affect human activities and the potential influence this may have on planning decisions. In addition to describing the volumes of water that reach the watershed and variations among long-term records, this discussion will examine the amount of water needed for human use within the watershed given the current extent of development and consider how changes in climatic characteristics that have occurred in recent decades may influence availability in the near future.

Rainfall

Precipitation is the foundation of hydrology. The timing, magnitude, and form (whether rain or snow) of precipitation dictate the remainder of the hydrologic cycle: how much water leaves as discharge, how much is available to vegetation, and how much becomes groundwater. This section will describe the dynamics of precipitation over time in the Upper Green Valley Creek watershed and surrounding area, with special attention to the basic features of the Mediterranean climate.

One characteristic of Mediterranean-climate regions is large spatial variability in precipitation. Precipitation is partly dictated by terrain, which produces microclimates across the greater landscape (Dallman 1998). Two spatial expressions of precipitation data of the Green Valley Creek watershed and surrounding area generated by computer models illustrate this variation across space: one was created using long-term mean annual precipitation records from USG Geological Survey, California Department of Water Resources, and the California Division of Mines (*Figure C-1, Mean Annual Rainfall in Green Valley Creek Watershed and Surrounding Areas based on Long-term Records*); and the other is based on precipitation models generated by researchers at Oregon State University (referred to as PRISM; *Figure C-2, Mean Annual Rainfall in the Green Valley Creek Watershed and Surrounding Areas based on PRISM*). According to these two data sets, average annual rainfall within 10 miles of the Green Valley Creek watershed may be as high as 60-70 inches, or as low as 25-27 inches (*Figures C-1, C-2*). Though the two models show differing results in some portions of the surrounding region, the Green Valley Creek watershed itself is relatively consistent between models: average annual precipitation according to both models ranges from less than 40 inches to the southeast, to nearly 50 inches in the northwest portion of the watershed. Outputs from both models can be integrated over space to calculate an average annual rainfall for the Green Valley Creek watershed: the lower-resolution model (i.e., fewer bands of equal rainfall, called isohyets) predicts 39 inches, and the higher-resolution model predicts 42 inches.

In general, the isohyets mirror long-term records from precipitation gauges in and near the Green Valley Creek watershed. Five locations with more than 40 years of rainfall records available through NOAA's National Climatic Data Center[3] provide empirical support to the variation of mean annual rainfall across space in the area surrounding the Green Valley Creek watershed predicted by the spatial models discussed above (*Table C-1*).

[3] Locations of long-term precipitation stations were placed in Figures 1 and 2 using corresponding latitude and longitude as provided through NCDC information. See http://www.ncdc.noaa.gov/oa/climate/stationlocator.html

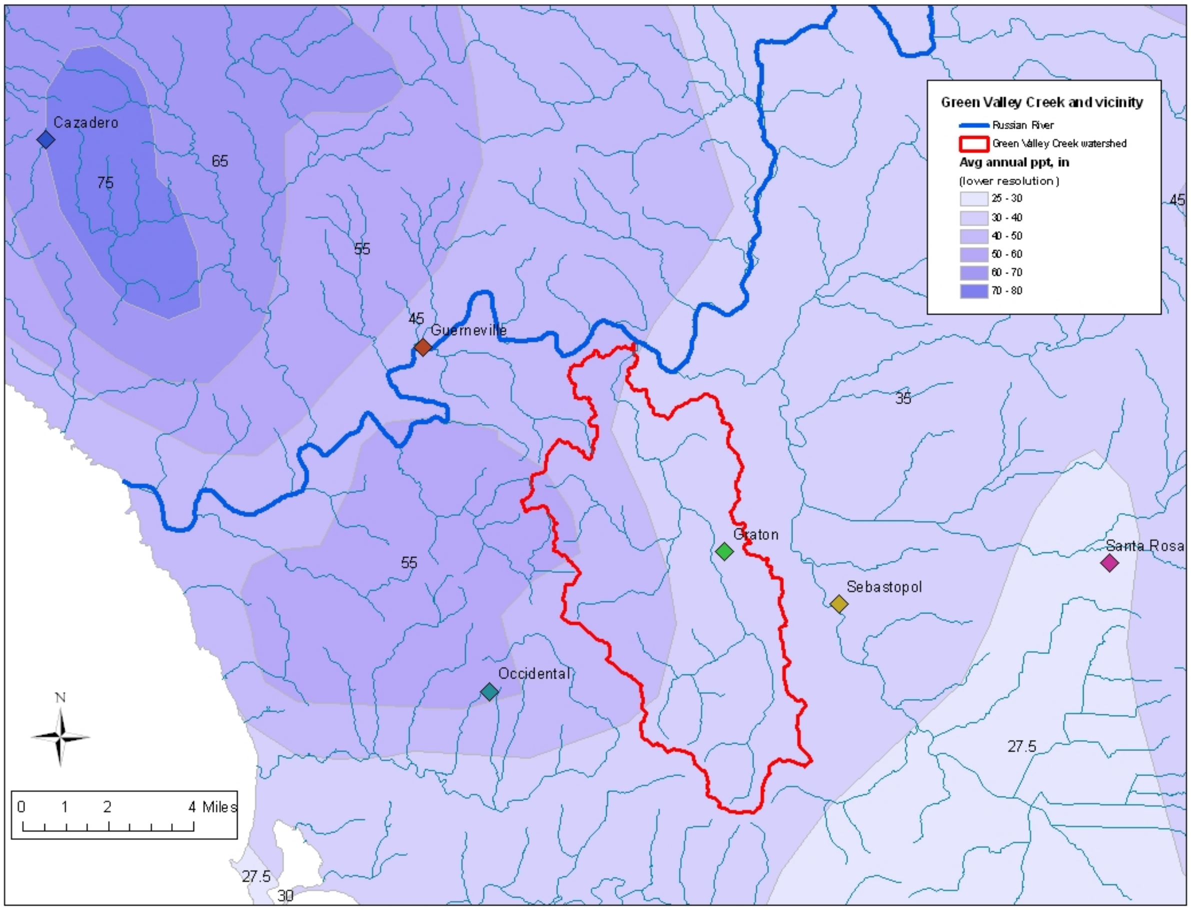


Figure C-1. Mean annual rainfall in the Green Valley Creek watershed and surrounding area, based on long-term records compiled by California Department of Water Resources and US Geological Survey (low-resolution map).

The principle characteristic of Mediterranean-climate regions is the seasonality of precipitation; long-term records of the 6 rainfall gauges listed above illustrate this seasonality (*Table C-1*). Most rainfall occurs during wet winters with little rain falling between May and October. These data also highlight the variation in monthly rainfall among long-term sites: precipitation at Cazadero (northwest of the Green Valley Creek watershed; see *Figures C-1 and C-2*) is approximately double the precipitation at Sebastopol and Santa Rosa on each month through the winter. Despite the large differences in average monthly rainfall among these long-term sites, the *proportion* of rainfall occurring each month relative to the entire year is similar and consistent among all sites (*Figure C-1*). These data also illustrate the extent of precipitation seasonality: the proportion of rainfall occurring during the 6-month period November 1 – April 30 ranges from 88.8 % to 90.3 %.

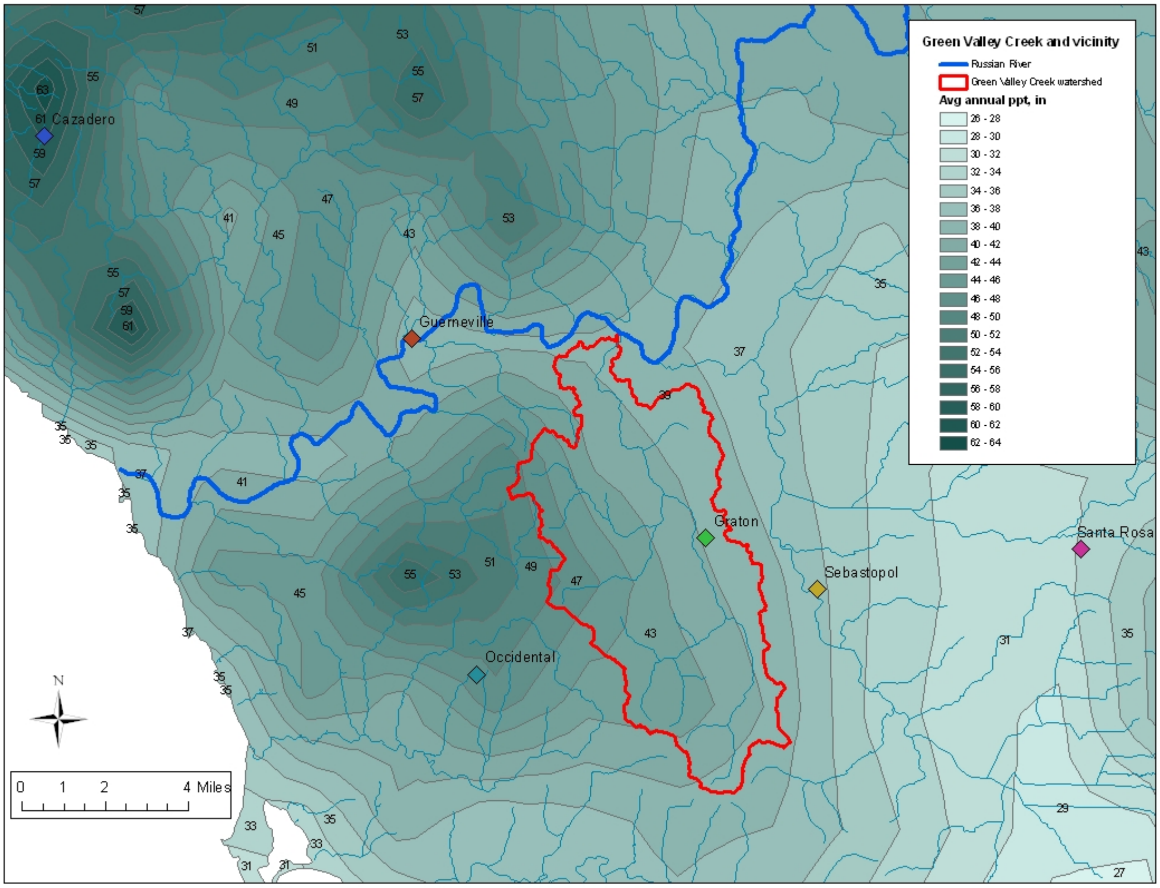


Figure C-2. Mean annual rainfall in the Green Valley Creek watershed and surrounding area, based on PRISM (high-resolution map).

Another characteristic common to the Mediterranean climate is variability of precipitation, which may be most easily described in terms of total annual precipitation over a long-term period. Long-term records from Sebastopol, Graton, and Occidental (mean precipitation 30 inches, 41 inches, and 54 inches, respectively) all illustrate the variability in precipitation from one year to the next (*Figure C-5 a-c*).

Long-term data sets also can provide insights into trends over long timescales. Models predicting effects of climate change in coastal California predict that precipitation will become more variable and more intense than current or recent conditions; long-term data sets can be used to illustrate whether these predicted effects of climate change can be detected in data from recent years, relative to the earlier portion of long-term records. Precipitation data from Graton provide an ideal resource for such an analysis because precipitation records date to 1927.

Table C-1. Average annual precipitation at 6 long-term precipitation gauges in and near the Green Valley Creek watershed.

Location	Period of record	Average annual precipitation, inches
Cazadero	1944-1978; 1996-2009	74.9
Occidental	1944-2009	54.1
Guerneville	1944-1982	48.2
Graton	1926-2009	40.7
Sebastopol	1949-2009	29.9
Santa Rosa	1931-2009	30.3

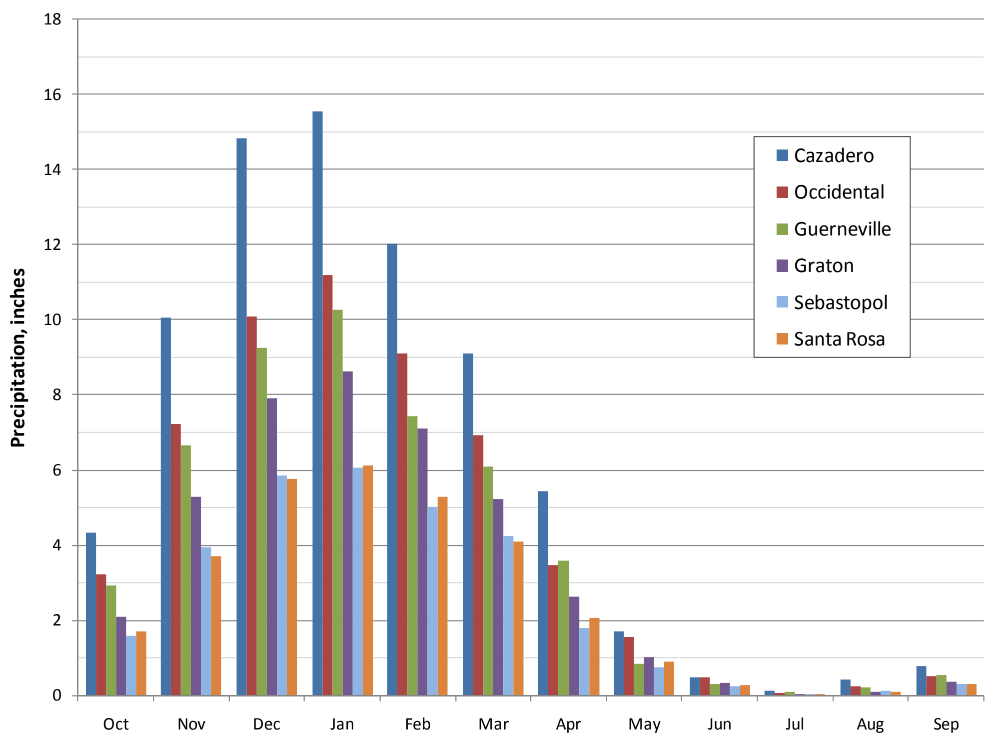


Figure C-3. Average monthly rainfall, in inches, 6 long-term rainfall gauges in and near the UGV watershed.

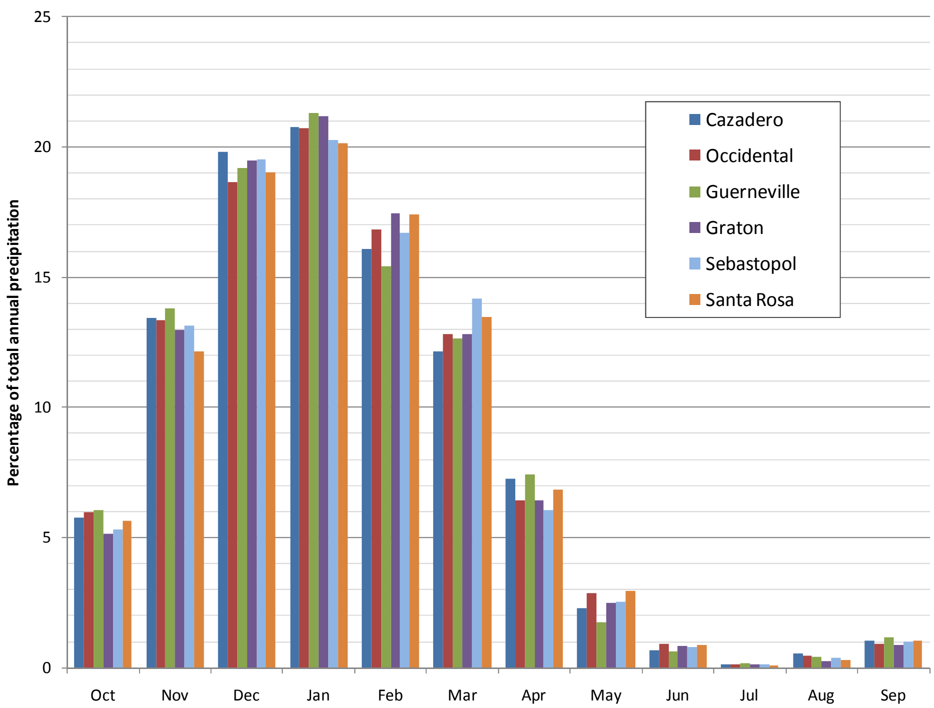


Figure C-4. Percentage of total annual rainfall each month at 6 long-term rainfall gauges in and near the UGV watershed.

To examine whether precipitation variability is greater at an annual scale more recently compared to earlier portions of the record, the average precipitation over (a) the previous 10 years and (b) the previous 5 years was calculated for each year of record. If precipitation is more variable in recent years, it could be expected that the magnitude of 10-year and 5-year averages would be different. 10-year average data beginning in 1936 (encompassing 1927-1936) through 2009 (encompassing 2000-2009) and 5-year average data beginning in 1931 (encompassing 1927-1931) through 2009 (encompassing 2005-2009) suggest that average precipitation is not more variable in recent years compared to earlier in the record. Additionally, the consistency of the pattern in variation among 10-year and 5-year average values over time suggests that the frequency of high- and low-rainfall years is consistent over the more than 80-year period of record as well.

Another trend suggested as likely to occur with climate change is increased magnitude of high-rainfall events. Long-term records can also be used to examine whether rainfall events of high magnitude occur more frequently in recent years compared to earlier in the period or record.

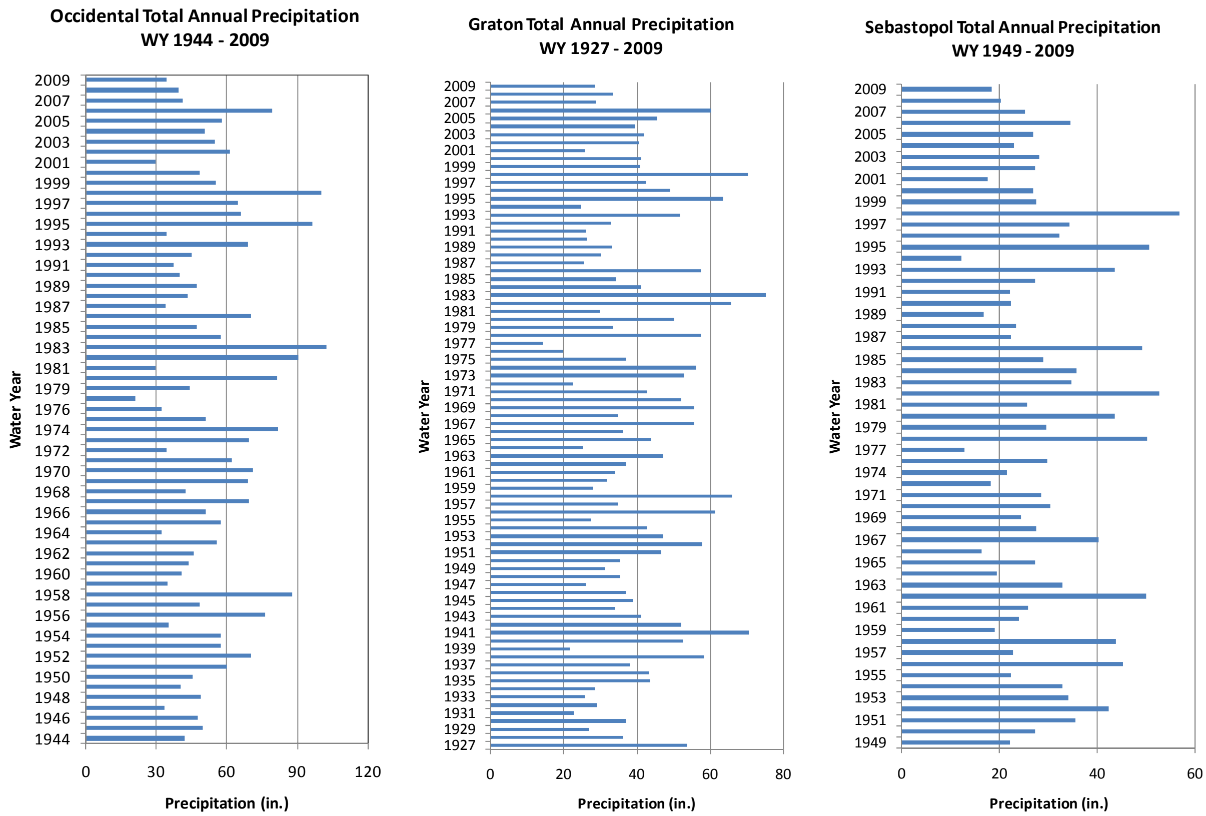
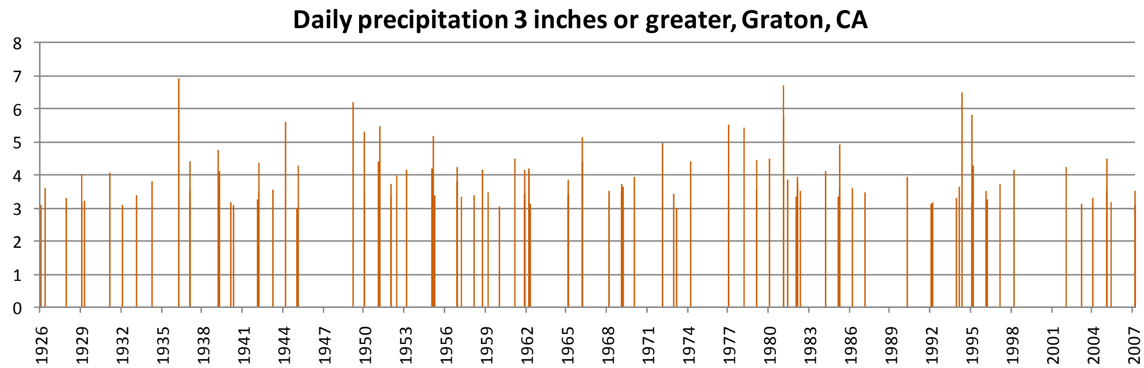


Figure C-5 a-c. Distribution of annual rainfall at Occidental, Graton, and Sebastopol over long-term periods of record.

For this analysis, daily precipitation and cumulative three-day consecutive precipitation data were ranked and sorted by magnitude. Daily precipitation values greater than 3 inches and three-day precipitation values greater than 6 inches, were plotted over time (*Figure C-6 a-b*). Long-term records indicate that the magnitude and frequency of high-rainfall events appear to be no greater in recent years than in earlier years. These data suggest that the watershed is not currently experiencing predicted precipitation consequences of global climate change (see *Section III B, Climate Change*).

Streamflow

If precipitation is the primary input for the hydrologic cycle, streamflow is the most visible means of output. The water that appears in a stream has likely taken a combination of several pathways through shallow and deep groundwater, over lengths of time from hours to years (McDonnell 2003, McGlynn et al. 2004). Understanding the dynamics of streamflow in a watershed is essential for watershed planning because streamflow plays an important role for human development, and because aquatic organisms rely on water in streams for their survival.



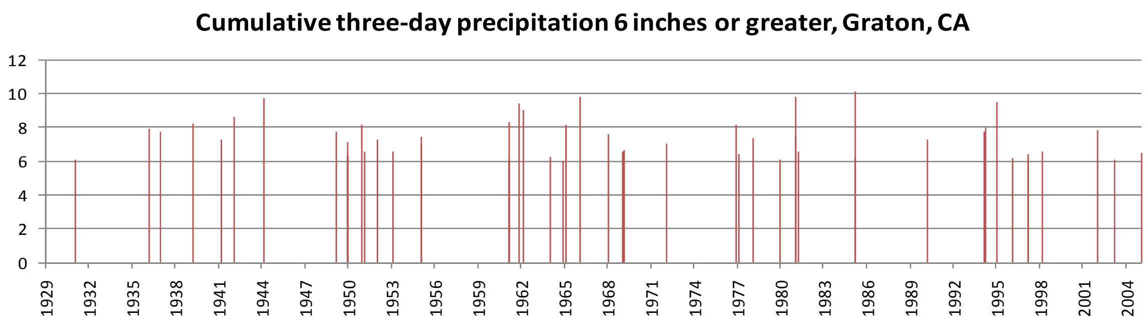


Figure C-6 a-b. Distribution of daily precipitation greater than 3 inches and three-day cumulative precipitation greater than 6 inches at Graton, California.

Unlike rainfall, few long-term records of streamflow records exist in the region: no streams within the Green Valley Creek watershed were gauged by state or federal agencies. The US Geological Survey (USGS) gauged four streams of comparable size to Green Valley Creek near the Green Valley Creek watershed for a period of more than 10 years: Laguna de Santa Rosa from 1999 to 2009; Santa Rosa Creek from 1999 to 2009; Austin Creek from 1960-1966 and 2004-2009; and Salmon Creek from 1963-1975 (*Figure C-7*)[4]. Because of the variations in upstream catchment size among these four gauges, analyses compare discharge in terms of volume per area, thus normalizing by catchment size.

Streamflow records illustrate trends similar to precipitation data. Annual discharge can be expressed as total depth over the watershed in inches to make coarse comparisons to precipitation in inches, calculated using mean daily flow data commonly available through the USGS web site.

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[4] USGS gauge sites and locations used for this analysis are: Laguna de Santa Rosa at Stony Point Rd, gauge number 11465680; Santa Rosa Creek at Willowside Rd, gauge number 11466320; Austin Creek near Cazadero, gauge number 11467200; and Salmon Creek at Bodega, gauge 11460920.

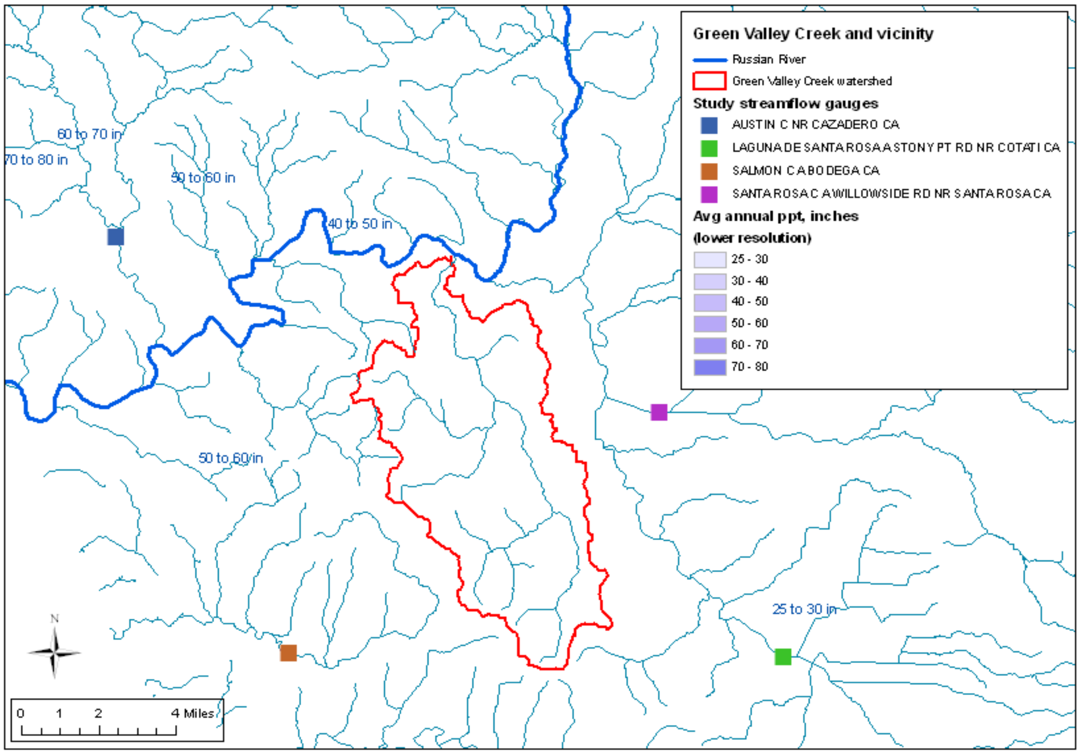


Figure C-7. Streamflow gauges near UGV Creek

The first step listed below converts discharge to acre-ft over the entire year; acre-ft is a unit of volume commonly used in watershed-scale planning, representing the number of acres over which water could be covered to a depth of one foot. Equation 2 then converts this volume in acre-ft to inches over the entire watershed:

1. $$\text{Annual Discharge, acre ft} = \left(\sum \text{mean daily flow, year}, \frac{ft^3}{sec}\right) \times \left(\frac{1\ acre}{43560\ ft^3}\right) \times \left(\frac{86400\ sec}{1\ day}\right)$$

2. $$\text{Annual discharge, inches} = \left(\frac{\text{Annual discharge, acre ft}}{\text{watershed area, } mi^2}\right) \times \left(\frac{1\ mi^2}{640\ ac}\right) \times \left(\frac{12\ in}{1\ ft}\right)$$

Discharge follows similar trends across space as precipitation: discharge is higher to the north and west, and less to the south and east (*Figure C-8*). Discharge converted to inches also illustrates the trend that substantially less water leaves the watershed as discharge than enters as precipitation - Rantz and Thompson (1967) estimate that, in this region, approximately 50-60 % of precipitation falling in a watershed exits as runoff.

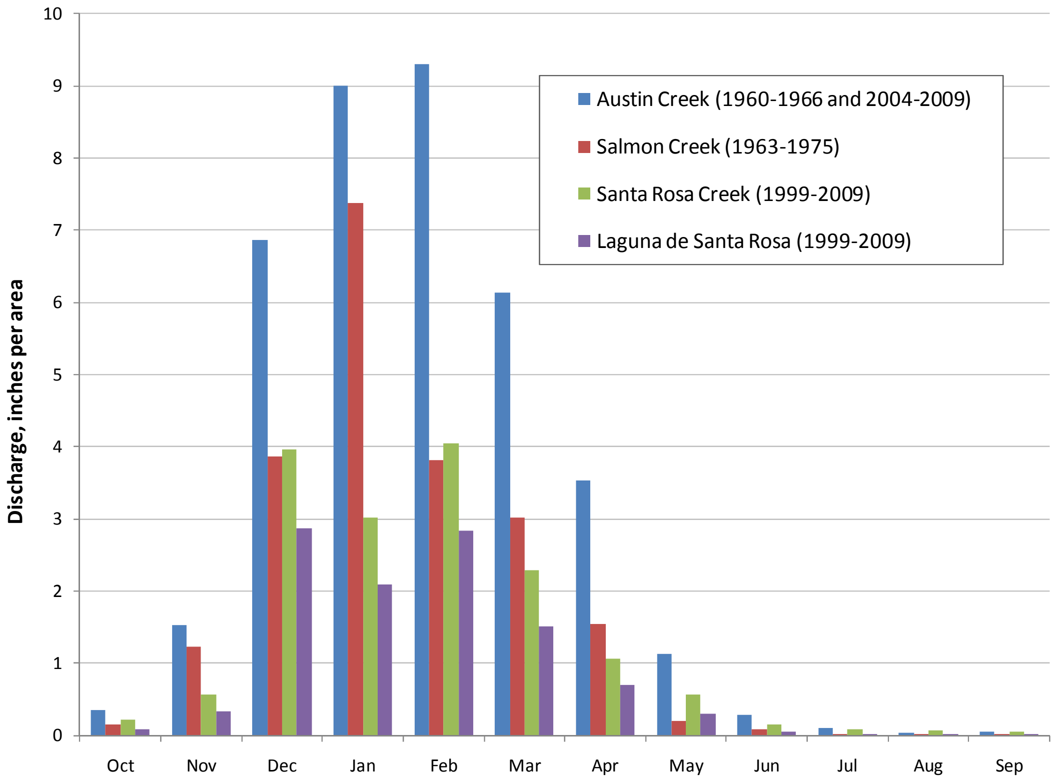


Figure C-8. Average discharge from four streams near the GVC watershed, Sonoma County (as inches of runoff over the entire watershed).

Also like precipitation, the percentage of runoff in each month is similar (*Figure C-9*); and the proportion of discharge occurring during the 6-month period from November through April ranges from 93.0 % (Santa Rosa Creek) to 97.8% (Salmon Creek).

The slightly higher proportion of winter discharge compared to winter precipitation is likely due to the tendency for precipitation occurring early in the water year (October-November) contributing principlely to groundwater recharge rather than streamflow. Hydrologists working in Mediterranean-climate regions attribute this as an effect of the prolonged dry summer, during which shallow groundwater is depleted through soil evaporation and plant transpiration (Gasith and Resh, 1998). A sufficient volume of water must replenish these reservoirs before streams can flow consistently through winter. Historical data reflect this trend – while the proportion of rainfall occurring in October as compared to the entire year is generally near 5%, the proportion of streamflow in October is approximately 1 to 2% of the discharge for the year (*Figure C-9, Table C-2*). Plots of cumulative precipitation at Occidental and discharge at Salmon Creek over four consecutive years (1964-1967) show that between 5 and 10 inches of precipitation falls at Occidental before Salmon Creek carries elevated flows each winter (*Figures C-10 a-d*).

Table C-2. Average annual discharge as measured at four streamflow gauges near the Green Valley Creek watershed.

Site name	Gauge number	Watershed area, mi^2	Period of record	Discharge, ac-ft	Discharge, inches over watershed	Discharge, m3
Santa Rosa Creek at Willowside Rd near Santa Rosa	11466320	77.6	1999-2009	66,580	16.1	82,130,000
Laguna de Santa Rosa at Stony Point Rd near Cotati	11465680	40.8	1999-2009	23,490	10.8	28,970,000
Salmon Creek at Bodega	11460920	15.7	1963-1975	17,870	21.3	22,040,000
Austin Creek near Cazadero	11467200	62.8	1960-1966, 2004-2009	120,500	38.3	148,640,000

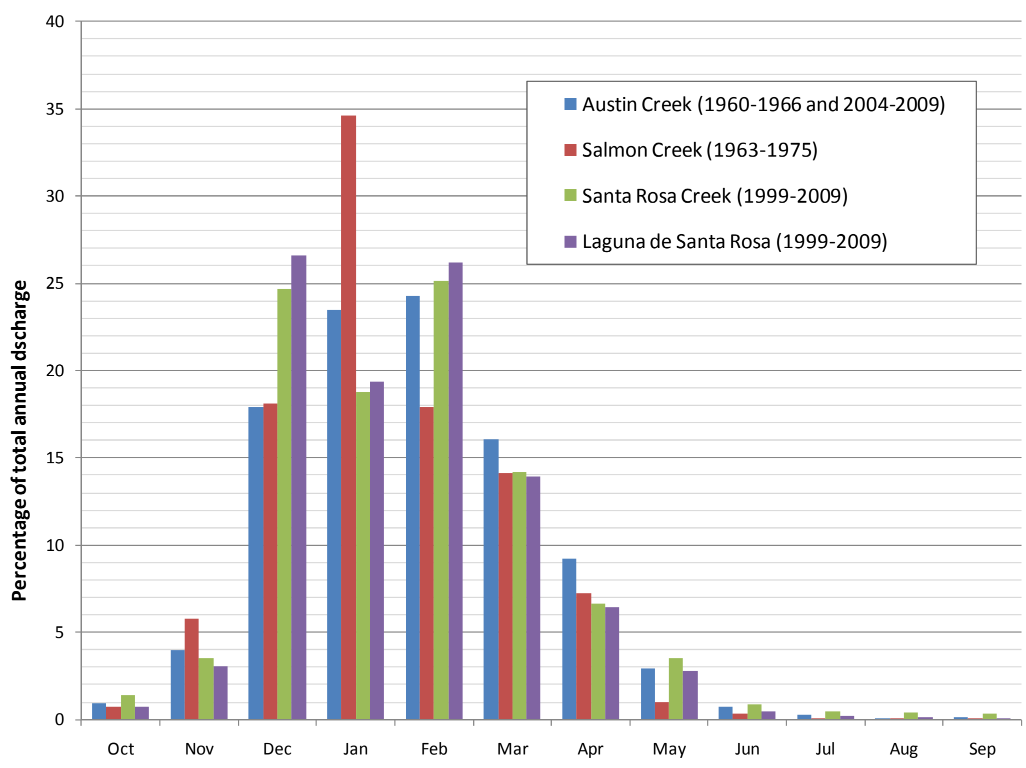


Figure C-9. Average Percentage of Discharge Occurring Each Month.

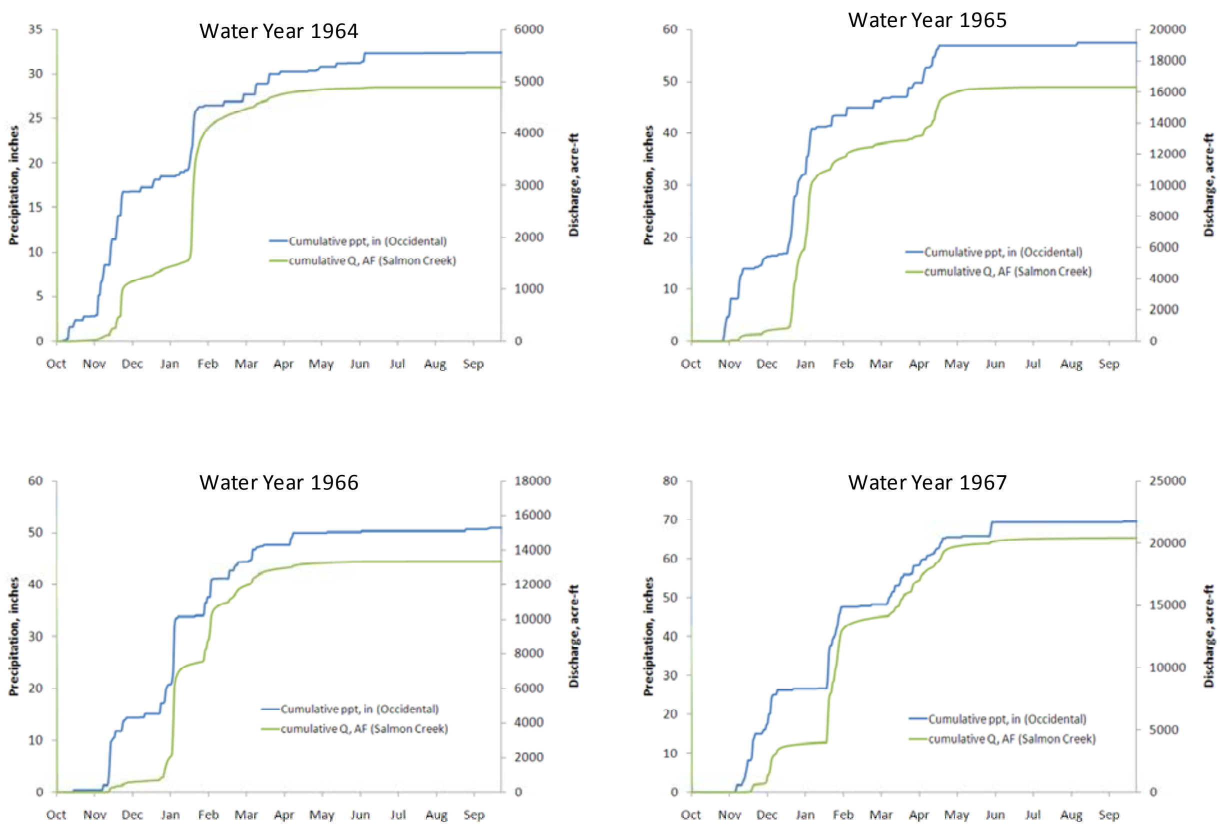


Figure C-10 a-d. Cumulative precipitation (Occidental) and discharge (Salmon Creek) through four consecutive years, 1964-1967.

Extrapolating Discharge to the Upper Green Valley Creek Watershed

As stated above, there are no records describing streamflow in the Green Valley Creek watershed. However, because such data are important for watershed planning, several methods are commonly employed to predict streamflow and discharge in a stream like Green Valley Creek. The following discussion presents two methods by which annual discharge can be calculated for the Upper Green Valley Creek watershed and describes variations among these commonly used methods.

In its worksheet for Water Availability Analysis and Cumulative Flow Impairment Index, the State Water Resources Control Board (SWRCB) outlines two methods for extrapolating annual discharge to ungauged watersheds. The first method described is an adaptation of the Rational Runoff Method that is described by the California Department of Transportation (CalTrans) in its Highway Design Manual. The Rational Runoff Method was designed to predict peak storm flows and ideally is applicable for watersheds of 200 acres or smaller (Dunne and Leopold, 1978), but it is widely applied to larger basins, and is listed by SWRCB as a method for calculating annual discharge. The Rational Method calculates average annual discharge Q as

3. $Q = C \times I \times A$

where *C* represents a Runoff Coefficient, *I* represents the average annual precipitation (in feet), and *A* represents the watershed area in acres. In this equation, the runoff coefficient *C* represents the proportion of rainfall that is converted to discharge.

For the CalTrans method, C is a function of relief, the capacity of soil to store water, vegetal cover, and surface storage; the components of calculating the Runoff Coefficient appear in Figure 819.2A in the Highway Design Manual (CalTrans, 2001). For this comparison, the Green Valley Creek watershed was estimated to have:

a. Generally rolling relief with average slope between 5 and 10%: range 0.14 to 0.2
b. Soil saturation is slow to allow infiltration, imperfectly drained: range 0.08-0.12
c. Vegetal cover fair to good; 50% of the area wooded or grassland: range 0.06-0.08
d. Surface storage is normal, with some ponds and defined channels: range 0.06-0.08.

Based on these estimates, the runoff coefficient is between 0.34 and 0.48. If it is assumed that average annual precipitation is approximately 44.6 inches (3.72 ft) and the size of the Upper Green Valley Creek watershed is 6,560 acres (10.25 mi^2), then the average annual discharge according to the Rational Runoff Method ranges from 8,290 to 11,700 ac-ft (between 15.2 and 21.4 inches per area).

The second method described by SWRCB in its Water Availability Analysis protocols for extrapolating discharge to ungauged streams is a method of scaling streamflow from a nearby gauged stream to the ungauged stream of interest. This scaling method begins with average annual discharge from the gauged stream ($Q_{\text{gauged stream}}$), and then scales that value by a ratio of catchment area and average annual precipitation, according to the equation

4. $Q_{\text{ungauged stream}} = Q_{\text{gauged stream}} \times \left(\frac{\text{Area ungauged wshd}}{\text{Area gauged wshd}}\right) \times \left(\frac{\text{Avg ppt ungauged wshd}}{\text{Avg ppt gauged wshd}}\right)$

Equation 4 accounts for differences in watershed size by assuming that discharge from an ungauged stream will vary from a gauged stream by a linear ratio of watershed area (e.g., a watershed of twice the size should have twice the discharge) and for differences in precipitation by a linear ratio of average annual precipitation (e.g., a watershed receiving twice the rainfall should have twice the discharge). SWRCB recommends using this method only with historically gauged streams without large dams upstream and with more than 10 years of record.

Of the four gauged streams listed above near the Upper Green Valley Creek watershed, Salmon Creek may be the closest and most similar to Upper Green Valley Creek. In addition to Salmon Creek being adjacent to the Upper Green Valley Creek watershed to the southwest, Geographic Information System (GIS) analysis using the high-resolution precipitation data in *Figure C-2* indicates that the average annual precipitation is nearly the same between the two catchments: 44.2 inches in Salmon Creek, and 44.6 inches in Upper Green Valley Creek. Over its period of record (1963 – 1975), the average annual discharge from Salmon Creek was 17,870 ac-ft; when scaled by precipitation and by a ratio of catchment area (Upper Green Valley Creek watershed is 6,560 acres and Salmon Creek watershed above the USGS gauge is 10,060 acres), the average discharge from the Upper Green Valley Creek watershed would be 11,760 ac-ft (or 21.5 inches over the entire watershed area).

(Using discharge and estimated watershed area, it is possible to calculate the Rational Method Runoff Coefficient for Salmon Creek. Given the average annual discharge of 17,870 ac-ft during the 1963-1975 period of record, upstream watershed area of 10,060 acres, and average precipitation of 3.69 ft, the runoff coefficient for the Salmon Creek watershed is 0.48.)

This method of extrapolation from nearby USGS streamflow can have many other uses. Historical data depict actual streamflow that has occurred in the relatively recent past; assuming that the flow regime has not changed substantially between the period of record and the present, historical data can provide a foundation for future scenario planning. Historical data from Salmon Creek scaled to Upper Green Valley Creek can estimate the likely variation in discharge that might occur in Upper Green Valley Creek: the average discharge may be 11,760 ac-ft, but the range based on 13 years of record may be as high as 20,060 ac-ft and as low as 2,930 ac-ft (*Table C-3*).

Table C-3. Estimated discharge from upper Green Valley Creek watershed, based on Salmon Creek data (scaled by watershed area and differences in catchment precipitation), for each year from 1963 to 1975 (ranked by magnitude), along with exccedence probability. Annual discharge with an exceedence probability of 0.50 is likely to be exceeded half of the time.

Year	Annual Discharge, ac-ft	Exceedence probability
1974	20,060	0.07
1973	17,700	0.14
1970	16,580	0.21
1969	16,490	0.29
1967	13,440	0.36
1975	13,220	0.43
1971	11,680	0.50
1965	10,750	0.57
1963	10,510	0.64
1966	8,790	0.71
1968	7,400	0.79
1964	3,220	0.86
1972	2,930	0.93

Though the two methods described above to estimate average annual discharge in the Upper Green Valley Creek watershed are not exactly the same, they both indicate that approximately half the water that falls as precipitation in the watershed is likely to become streamflow. More importantly for planning, records from multiple years show the range of annual discharge likely from the watershed. A very dry year may result in less than one-fourth of the total annual discharge in an average year, which would likely place severe stresses on humans and on aquatic organisms that depend on streamflow for survival.

Despite the lack of long-term gauging stations in the watershed, distributed hydrologic models can provide significant insight into the spatial and temporal variations of discharge. Such a model has been developed for the Purrington Creek watershed, and ongoing work is underway to expand this model to the entire Green Valley/Atascadero Creek watershed. The Purrington Creek model was calibrated against the recently collected CEMAR stream gauging data from the lower watershed. The model was then evaluated for the 20-yr simulation period from 1992 through 2011. Discharge results for the lower watershed are shown in *Figure C-11*.

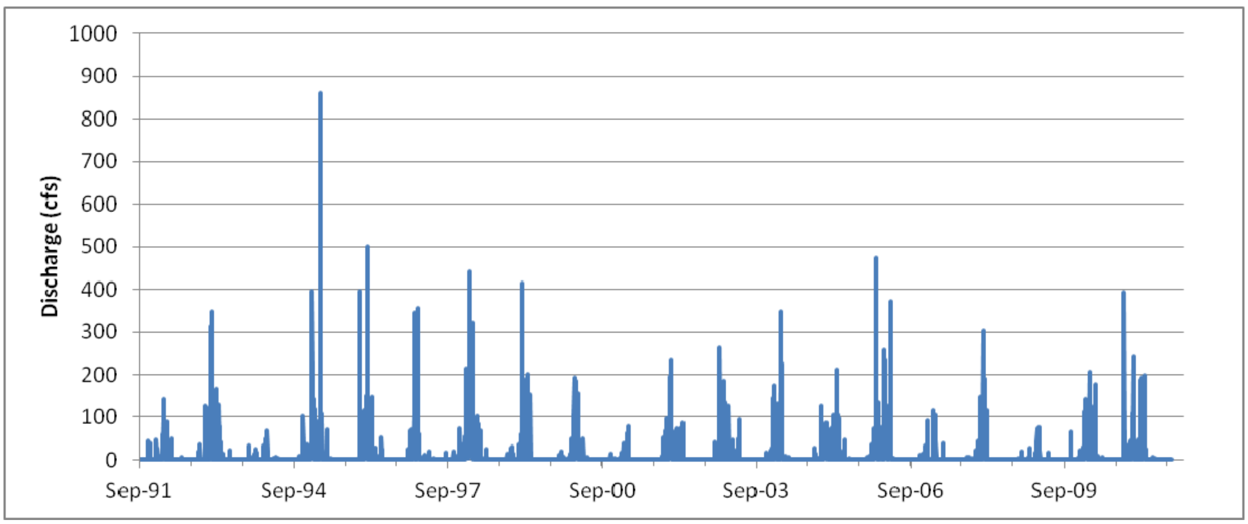


Figure C-11. Representative simulated daily flow, lower Purrington Creek, 1992-2011.

A flow frequency analysis of the simulated discharges reveals that 10% exceedance flows (e.g. flows that are exceeded 10% of time) are on the order of 6.4 cfs in the reach below the Graton Road crossing downstream of Green Hill Road increasing to 8.7 cfs near the confluence with Green Valley Creek. 50% exceedance flows range from approximately 0.3 to 0.7 cfs over this same reach, and 90% exceedance flows range from approximately 0.2 to 0.4 cfs. Based on the long-term modeling results the overall water balance for the watershed can be estimated. These results indicate that on average approximately 52% of the precipitation falling on the watershed is consumed by evapotranspiration processes, 41% becomes runoff, and 7% becomes groundwater recharge.

Calculating Water Needs

Human water need in the Upper Green Valley Creek watershed can be estimated using similar units of volume as discharge analyses above. The discussion that follows provides a method for creating a coarse estimate of *summer* water need based on two components: agricultural water needs and residential water needs. Water needs for each watershed are based on information defined by digital orthorectified aerial photographs in a GIS framework: using these aerial photographs, all land as vineyard and all building structures were identified (*Figure C-12*; orchards were not included in this analysis). Each vineyard was assigned a summer water need value of 0.67 ac-ft per acre and each building structure was assigned a summer water need value of 0.207 ac-ft. From these data, water needs can be accumulated through the watershed to show the cumulative water need through the Upper Green Valley Creek drainage network (*Figure C-13*).

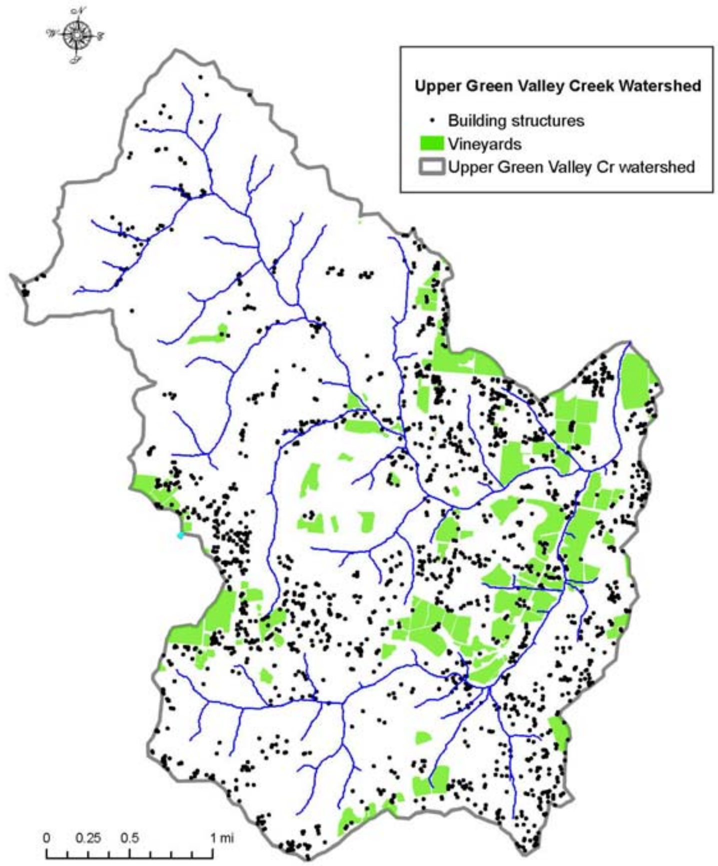


Figure C-12, UGVC Watershed and Drainage Network

In this analysis, summer agricultural and residential water needs are both likely to be overestimated. A volume of 0.67 ac-ft per acre represents a high-end irrigation water need (Smith et al. 2004), and not all buildings identified in the GIS are residences (barns, for example, may not have any summer water needs). These coarse estimates do, however, provide a preliminary foundation for comparing the likely water need in the watershed to its discharge. In this analysis, the total water need for the Upper Green Valley Creek watershed is 816 ac-ft, comprised of 411 ac-ft for agriculture and 405 ac-ft for residential need. This comprises less than 10% of the likely average discharge of the Upper Green Valley Creek watershed (and less than 4% of the average annual precipitation), but more than one quarter of the dry-year discharge.

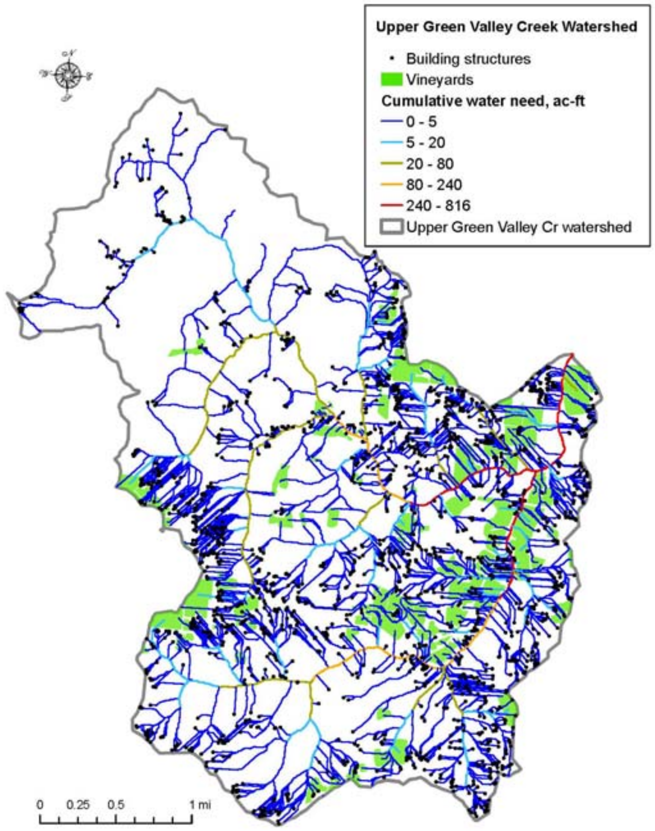


Figure C-13. Upper Green Valley Creek with Cumulative Water Needs

Conclusions and Recommendations

The data and analyses presented here highlight the disparity across time between hydrology and human water needs, and the challenges of planning to meet those needs while maintaining aquatic ecosystems in Mediterranean-climate California. A small fraction of rainfall (and subsequently, streamflow) occurs during the dry half of the year, yet this dry period is when water needs for residential water uses (which may include garden irrigation and recreational uses) and for agriculture tend to be the greatest. If the absence of rainfall during the summer causes grape growers and people living in the watershed to tap streams for water supply, these diversions are likely to place substantial pressures on aquatic organisms that live in these streams.

Despite these challenges, the ample precipitation that typically falls in the Upper Green Valley Creek watershed indicates that it should be possible to maintain a healthy aquatic ecosystem while still providing the water necessary for human uses. However, this may take some careful planning to meet all of these needs. Winter water storage is likely the most significant improvement that can be made to provide for agricultural and residential water needs while providing sufficient resources for aquatic biota.

If the amount of water needed for human use in the Upper Green Valley Creek watershed is approximately 800 acre-ft and the watershed receives approximately 22,000 acre-ft of water through precipitation in an average year, it seems likely that this amount of water needed for human uses (representing less than 4% of the average annual precipitation) can be stored in ways to minimize impacts to aquatic biota. Rainwater catchment off rooftops may provide much of the water needed for residential uses, though some considerations may be necessary to ensure that many structures do not cause unpredicted cumulative effects on streamflow in adjacent streams.

In cases where rooftop catchment is not sufficient, reservoirs may provide ample water storage for larger water uses. Reservoirs could be filled in winter either from streams or groundwater, though appropriate considerations must be implemented and instream flow studies conducted to ensure that surface or groundwater diversions do not adversely affect instream flows for fish. Considering the variability in discharge from one year to the next, it may be necessary to store water for multiple years as well. Winter water storage can likely provide sufficient resources to meet human and ecological water needs, but considerations of cumulative impacts and instream flow studies are also essential to offer appropriate ecological protections.

D. Sediment Sources and Impacts

Prepared by John Green, Gold Ridge Resource Conservation District

Introduction

Human activities over the last century or so have altered the natural erosion and hydrologic regimes of the Green Valley Creek watershed. Through changes in land use and construction of an extensive road network the rate and volume of erosion and the surface hydrology of the watershed have been changed. In addition, some stream channels in the watershed may have been straightened, deepened, or both, to protect farmland from the effects of flooding. The combination of these factors has caused dramatic changes in the mechanisms and rates of erosion in the watershed with consequences for both stream channel form and aquatic habitat quality. These changes in drainage could contribute to changes in runoff patterns, peak flows in streams and groundwater recharge.

The delivery of sediment to streams is controlled by the rate and extent of various erosion processes on the landscape and by the mechanisms through which eroded sediment is transported to streams. Historically, it is likely that smaller streams in the Upper Green Valley watershed delivered sediment derived from upland sources to mainstem stream channels and their broad alluvial floodplains at a slow but steady rate. Mainstem stream channels meandered freely on their floodplains, reworking alluvial sediments and transporting them downstream. This background pattern of steady erosion and transport of sediment was punctuated by larger pulses of sediment derived from landslides and debris flows that occurred in the steeper uplands during infrequent extreme rainfall events.

In the last 100-150 years, significant changes have been made to land cover types, land uses, surface drainage patterns, and stream channels by human activity. Moderate to high intensity logging has taken place in the forested portions of the upper watershed at various times during the past century, increasing storm runoff and sedimentation (CDFG 2004). Formerly undeveloped native grasslands, timberlands and scrub have been converted for a variety of uses including orchards, grazing, rural residential development, and vineyards. This conversion has had the effect of exposing more bare and compacted soil areas to rainfall, further increasing runoff volumes and erosion of fine sediments. Many bare and compacted soil areas, as well as impervious surfaces such as roofs, driveways and roads, drain directly to streams, increasing peak stream discharges during storm events, and very effectively delivering eroded fines.

Accompanying changes in land use has been the development of a fairly dense rural road network. In addition to county roads, many private roads have been constructed for orchard and vineyard access, as well as for accessing rural residential home sites. Many roads have adjacent drainage ditches, some of which accommodate significant flow during periods of storm runoff. These roads interact with erosion processes in a variety of ways, with the net effect of further increasing both peak stream discharge and sedimentation.

Erosion Processes in the Upper Green Valley Watershed

To date, only limited systematic assessment of erosion and sediment delivery to streams has been performed in the Upper Green Valley watershed. However, from this work, as well as other studies, field observations and anecdotal evidence, channel incision and road-related erosion appear to be the most significant anthropogenic sources of sediment in the watershed (LMA 2003).

A CDFG stream inventory conducted in 1994 observed extensive channel incision and bank erosion in Upper Green Valley Creek, as well as reaches where excess fine sediment delivery was causing embeddness of gravels (CDFG 2006a). The CDFG report posited that changes in land use and the extensive road network were contributing fine sediment and causing flashier streamflows in the upper watershed. O'Connor and Rosser (2003) examined 5 reaches of Upper Green Valley Creek, and noted stream entrenchment in all 5, although they did not observe particularly high embeddedness values or fine sediment fractions. CDFG (2006b) noted in 1994 that Purrington Creek was deeply entrenched in its lower, alluvial reach, with moderate to severe gravel embeddeness throughout. Entrenchment in both lower and upper Purrington Creek was also observed by O'Connor (2010).


Incised channel. Photo courtesy of Matt O'Connor.

There may also be a substantial input of fine sediment derived from rainsplash, sheet and rill erosion on agricultural lands and other lands where cover conversion has occurred, but no systematic survey or modeling work on this process has yet been performed. From a review of aerial photography of the watershed, it appears that landslides are not currently major anthropogenic sources of sediment (although they undoubtedly occur), except in areas where they result from stream channel incision.

Channel incision

Stream channel incision (entrenchment) is the process whereby a stream erodes its bed, lowering its level over time. It usually occurs in response to changes in the stream channel and/or watershed that result in the stream having excess energy to spend on its bed and banks, and in locations where the stream cannot spend this energy in other ways, such as by meandering. Changes can include increase in discharge, decrease in sediment load, channel straightening or deepening, decrease in channel boundary roughness (through removal of wood, vegetation, large sediment clasts, etc.), or a combination of some or all of these. Incision can also be initiated by a lowering of the local or absolute base level of the stream, and in these cases incision generally occurs through the upstream migration of a series of knickpoints.

There are many geomorphic and hydrologic consequences that result from channel incision. The most important of these are the hydrologic disconnection of the floodplain from the stream, and streambank instability. Hydrologic disconnection occurs as the floodplain water table lowers in response to the lowering of the streambed. During an episode of stream incision, water table lowering tends to roughly correspond to the level of the stream, and this can cause changes in floodplain vegetation and the dewatering of shallow wells in the floodplain, among other impacts. The deepening of the stream channel also causes larger, higher energy flows to be confined within the channel, instead of spreading out on the floodplain. Confinement of large flows causes accelerated bank erosion, and can contribute to further stream incision. Flow confinement can also increase the size and amount of sediment the stream is competent to transport during a given flow.

Bank Collapse/Erosion. Photo courtesy of Matt O'Connor.

Streambank stability is also decreased in response to incision. As the stream incises, its banks become higher and steeper than before incision, and thus more susceptible to mass failure in the form of sloughing, toppling, undercutting, and slumping. Groundwater sapping on the steep banks can also work to destabilize them, and gullies can form through headcutting as overland stormflow encounters the steep banks. These processes can deliver large amounts of sediment to the stream over time, and all appear to be common throughout incised reaches of both Upper and Lower Green Valley and Purrington Creeks. Active mass failures by slumping and undercutting are more significant in Purrington Creek.

There are several possible causes of channel incision in the Green Valley Creek system, however the two most important are increased stream discharge due to increased storm runoff, and alterations in stream channel form, such as straightening and deepening.

Increased runoff tends to occur after periods of intensive logging, as removal of forest cover and degradation of the organic layer of the soil cause less rainfall to be infiltrated and retained. The conversion of land cover from forest or native grassland to agricultural uses increases the area of bare soil and the level of soil compaction, which also causes rainfall to run off rather than infiltrate the soil. Roads – both dirt and paved – have multiple effects on surface hydrology and shallow groundwater processes; these effects also lead to increased runoff and heightened peak stream flows.

Changes in channel form can also result in channel incision. Channel straightening has historically been used to make more floodplain land suitable for agriculture, and is often accompanied by levee construction for flood control. Straightening a stream channel has the immediate effect of creating higher-energy stream flows, and if the stream cannot spend this excess energy by developing meanders, downcutting and incision will often result. Channel straightening and deepening have also been used in tandem in the past to confine high flows and reduce the risk of flooding. In this case too, flow confinement creates higher-energy flows and prevents the stream from flooding, and channel deepening becomes a self-reinforcing process.

It is unclear from the historical evidence whether stream channel straightening or deepening have been employed in the Upper Green Valley Creek watershed in the past. However, analysis of channel planform (the map view of the channel) in the lower reach of Purrington Creek suggests a much straighter channel than would be expected for a medium-sized stream in an alluvial valley. The same is true of Lower Green Valley Creek.

Significant reaches of Upper and Lower Green Valley Creek and Purrington Creek appear to have incised dramatically in the relatively recent past, and this observation is supported by historical and anecdotal evidence. In his examination of the geomorphology of Purrington Creek, O'Connor (2010) observed that the stream was moderately to deeply incised throughout its low-gradient, alluvial reach, incising into Wilson Grove Formation bedrock in some areas.

Bank heights in incised reaches of lower Purrington Creek now average between 25 and 30 feet, with some locations measured at nearly 35 feet. Although rates of incision are very difficult to estimate, O'Connor documented field evidence that supports a current incision rate of up to 1 foot per decade. Anecdotal evidence suggests that incision in the past 100 years or so may have been even more rapid (Younger, personal communication, 2009).

In areas where Purrington Creek is incising into alluvial material, extensive bank collapse and slumping have occurred, resulting in the formation of lower, inset terraces and locally increasing the supply of sediment (O'Connor 2010). In essence these processes can be viewed as Purrington Creek expending energy to widen its channel and form a new floodplain at its incised elevation.

O'Connor also observed channel incision throughout the steeper upland reach of Purrington Creek, with the channel confined between high and steep streambanks. Bank heights in this reach were measured at 20-30 feet, and landslides and slumps were locally abundant. Because of the steeper stream gradient, sediment delivered to this reach is transported downstream fairly rapidly. Although historic management practices have undoubtedly played a role in the incision of the upper reach of Purrington Creek, relatively rapid tectonic uplift has also very likely influenced incision of this reach.

In an earlier study, O'Connor and Rosser (2003) examined geomorphic characteristics of selected reaches of Upper Green Valley Creek between the Purrington Creek and Harrison Creek confluences. All study sites were observed to be deeply entrenched. Although this study did not specifically examine bank stability, field observations indicate that bank collapse, slumping and gullying are widespread and common.

Channel incision has likely increased the overall sediment load of the entire mainstem of Green Valley Creek. A systematic geomorphic survey of upper Green Valley and Purrington Creeks was completed as part of this project and was integral in shaping the restoration recommendations. Additional work in 2013 on sediment sources in upper Green Valley and Purrington Creeks will quantify the contribution of channel incision relative to other erosion processes. In addition, GRRCD and our partners have conducted assessments of erosion sites on an individual, site-by-site basis, on the properties of cooperating landowners. These assessments support the assertion that channel incision-related erosion is common throughout the watershed, but are insufficient in estimating a total future erosion volume for these processes for the watershed.

Surface Erosion

Rainsplash, sheet and rill erosion are small-scale surface erosion processes that can occur over large areas, depending on land use and cover type. Rainsplash erosion is the physical movement of soil particles that results from raindrop impact. This process makes soil particles available for transport through sheet and rill erosion. Sheet erosion occurs as unconcentrated overland flow (sheet wash) entrains soil particles. Sheetwash coalesces into rills, which are essentially small channels measuring less than 1 ft^2 in cross-sectional area. This concentrated flow of water can be highly erosive, depending on the surface composition and permeability, and is very effective at transporting soil material delivered by sheet wash or rainsplash, and mobilized from the banks and bottom of the rill.

Vineyard drainage. Photo courtesy of Matt O'Connor.

Both rainsplash and sheet erosion generally occur on surfaces with minimal vegetative cover and/or low permeability. In areas of limited vegetative cover, or where vegetation is removed or diminished in extent or density (through physical removal or conversion to a less dense cover), greater soil area is exposed to these processes. Sheet erosion can also occur on surfaces with limited or reduced permeability (soil that has been compacted, for example), where less water can be infiltrated into the soil column.

No systematic assessment or modeling of surface erosion has been conducted for the Upper Green Valley Creek watershed, but it is likely that the process of converting native grasslands and woodlands first for grazing and orchards and later for vineyards has increased surface erosion over historical levels. In vineyards, often in an attempt to design a drainage system that minimizes surface erosion in the vineyard, the problem of increased surface erosion is incidentally compounded at the outlet of drainage systems that typically have been designed to route surface flow rapidly to streams. This potentially results in higher (and more erosive) peak stream discharges, as well as the opportunity for very efficient delivery of surface erosion-derived sediments to stream channels.

Gullying

Gullies occur where surface flow (sheetwash, rills, and other forms of surface runoff) coalesces into channels larger than 1 ft^2 in cross-sectional area. Gullies can be described as newly formed stream channels, but they are located in places where a stream has not existed in the past, such as on hillslopes. Gullies contribute sediment to streams in two ways: through the process of gully expansion, which occurs by headcutting of the gully and bank collapse, and as very efficient conduits for fine sediments eroded through other processes and delivered to the gully.

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

The Impacts of Roads

Roads tend to increase erosion over natural, background levels through a variety of interactions with rainfall, surface flow and shallow groundwater. Because roads (both paved and unsurfaced) have compacted, generally impermeable surfaces, and have historically been built with poor drainage and insloped shapes, they effectively collect and concentrate rainfall, surface flow, and shallow groundwater flow. Along with this flow, roads also collect fine sediment derived on a continuous basis from unpaved road surfaces, cutbanks, and inboard ditches (chronic surface erosion). As with gullies, flow concentrated on a road erodes its own channel, either in the road's inboard ditch or as a gully where the concentrated flow outfalls from the road onto a hillslope, or both. These gullies rapidly deliver both eroded sediment and flow to streams, increasing both sedimentation and peak stream discharge (Weaver and Hagans 1994).

Inboard ditch. Photo courtesy of Matt O'Connor.

In addition, locations where roads cross streams are subject to accelerated and sometimes extreme erosion on an episodic basis. Stream crossings can be constructed in a number of forms, the most common of which utilizes a culvert to convey streamflow across the road. Historically, culverted stream crossings have been poorly built, with culverts that are undersized for peak stream discharge, poorly placed and installed, and prone to plugging. When a culvert plugs or is overwhelmed by streamflow, the crossing can fail, causing immediate delivery of a large volume of sediment directly to the stream. In some cases, the stream can divert down the road, usually resulting in an extreme volume of sediment delivery as the stream finds its way back to its channel.

Road assessments

In the last few years, multiple assessments of road-related erosion and sediment delivery to streams have been conducted in the Upper Green Valley watershed. In 2007-08, Pacific Watershed Associates (PWA) conducted a partial assessment of erosion on private, unpaved roads throughout the greater Green Valley-Atascadero watershed. A total of 25.2 miles of roads were assessed in the Upper Green Valley Creek watershed. Overall, the assessed roads were deemed insufficiently constructed with regard to preventing or controlling erosion, with poorly constructed stream crossings and inadequate road drainage. PWA identified a total of 133 individual road-related erosion sites, each of which was assigned a treatment priority based on the likelihood of erosion, volume of sediment delivery, and other factors. Together, the assessed sites had the potential to deliver nearly 15,000 yds^3 of sediment to streams over the next decade if left untreated. In addition, road segments totaling nearly 11 miles in length were determined hydrologically connected to streams, and PWA estimated that these segments accounted for roughly 1,000 yds^3 of fine sediment delivered to streams in the assessed area per year through chronic surface erosion. PWA recommended treatments for erosion prevention and erosion control for both individual erosion sites and hydrologically connected road segments (PWA 2008).

The 25 miles of road assessed in the PWA project were located on parcels totaling 1,162 acres, about one-fifth of the total area of the Upper Green Valley watershed. If we assume that both the road density and the hydrologically connected proportion of total road length in the entire 6,420 acres of the watershed approximate that of the assessed portion, a fine sediment volume on the order of 5,500 yds^3 per year is currently being delivered to the Upper Green Valley stream system. There is reason to believe that this estimate might be conservative, since the assessment included only roads located on larger parcels with fairly low road densities. Most parcels have at least one driveway or access road, so on smaller parcels road densities tend to be higher. Although an overall sediment budget has not been calculated for the watershed, the estimate of 5,500 yds^3 per year likely represents a significant increase in fine sediment delivery over historic background levels.

Stream crossing in poor condition on upper Green Valley Creek. This crossing is a barrier to coho salmon passage.

Ledwith (2008) conducted an assessment of erosion along 93 miles of county roads throughout the greater Green Valley-Atascadero watershed, including all paved county roads within the Upper Green Valley Creek watershed. This assessment identified a total of 59 road-related erosion sites requiring treatment, with the potential to deliver over 15,000 yds^3 of sediment to the Upper Green Valley stream system, and recommended preventive treatments for each site. Each site was assigned a treatment priority based on the potential for near-term sediment delivery to streams, and opportunity to prevent sediment delivery by implementing the recommended treatment (Ledwith 2008).

Impacts to Aquatic Resources

Because they have evolved with a stream system and within those set of conditions, aquatic resources are very sensitive to changes in both the sediment load and hydrologic regime of a stream. Changes in peak and low-flow discharge, the volume of sediment or the rate at which it enters a stream can degrade water quality and aquatic habitat and result in severe impacts to biotic communities. These impacts are discussed in greater detail in *Chapter II, Section F: Biological Resources.*

Impacts of accelerated erosion can be obvious to the untrained observer, as streams appear muddy during and immediately after rainstorms, excess sediment is stored in channel bed forms, and fine sediment causes gravel embeddedness. Less obvious are both the downstream effects of accelerated erosion and the impacts of changes in surface hydrology, through road construction, land conversion, and increases in impermeable surface area.

Eroded sediment is moved through the system by streamflow, and if the stream is encumbered by a larger sediment load than that which formed it, channel form can change. Specifically, increased sediment load can deposit in low-gradient reaches and cause aggradation. Upper Green Valley Creek has seen dramatic aggradation of the reach immediately upstream of its confluence with Atascadero Creek, particularly in the area upstream of Green Valley Road.

As discussed above, greater compacted and impervious surface area increases runoff, which in turn causes higher peak stream discharge and reduces infiltration as more water is rapidly routed through the stream system. Infiltrated shallow groundwater is a major source of summer baseflow, and in areas where groundwater resources are stressed by water diversions for residential and agricultural uses, further reduction by decreased wet season infiltration can have a drastic effect on summer low flows. In a Mediterranean climate, this can mean that streams run dry earlier in the summer than they normally would.

The combination of increased aggradation with lower summer baseflows and increased water demand can result in extensive reaches where the stream goes dry even earlier in the year, as flows are lower and go subsurface more quickly. This appears to be the case in Upper Green Valley Creek just upstream of its confluence with Atascadero Creek. A sediment source survey of the upper watershed is currently underway to better understand this dynamic. Water scarcity in these areas may prove to be strongly related to anthropogenic changes to the upstream watershed, which have increased both erosion and runoff.

Conclusion

Through field observations and studies completed to date, a picture emerges of anthropogenic changes to the geomorphic regime of the Upper Green Valley watershed, and the impacts of these changes on the streams of the watershed and their suitability as salmonid habitat. Erosion through a variety of processes has accelerated as a result of past and current management practices. Sediment derived from accelerated erosion is routed rapidly through high-gradient reaches (upper Purrington Creek) and confined reaches (lower Purrington and middle Green Valley Creeks), where streamflow has high energy. In confined reaches, gravels may be mobilized by smaller, more frequent flows, decreasing available spawning locations and scouring redds, a hypothesis that will be tested using the modeling resources being compiled by OEI. Eroded sediment is flushed through these reaches and deposited in unconfined, low-gradient and hence lower-energy reaches (Green Valley Creek downstream of Purrington), aggrading the channel. Green Valley Creek has seen dramatic aggradation throughout the reach that includes its confluence with Atascadero Creek, and this aggradation contributes to flooding and potential fish stranding in the Green Valley Road / Korbel Vineyard area. To compound these problems, increased runoff and decreased infiltration are believed to contribute to lower summer baseflows, and the aggraded channel goes dry, with flows going subsurface, earlier in the summer season. This poses a problem for salmonids, as dry stream reaches are neither appropriate as habitat nor conducive to fish passage. Further study is needed, but if this assessment proves accurate, efforts to reintroduce salmon in Upper Green Valley Creek must account for and address the impacts of all of these processes if they are to be successful. A sediment source study is currently being conducted by O'Connor Environmental, Inc. through funding by the State Coastal Conservancy and will be available in late 2013.

Sediment Sources and Impacts Recommendations

Our research of existing information and current geomorphic conditions highlights several issues related to erosion and sediment delivery in the Upper Green Valley Creek watershed, and points toward a course of action designed to limit anthropogenic erosion, normalize surface hydrology, and guide future management decisions.

Now that a geomorphic survey has been completed, as recommended in the first phase of the planning effort, the following recommendations focus on implementation: reducing the anthropogenic sediment load in streams throughout the Upper Green Valley watershed by implementing erosion control and prevention treatment recommendations outlined in this, earlier and future assessments.

1. Expand assessment of erosion and sediment delivery.
   Partial assessments have been conducted for road-related erosion and upland and bank erosion, and these assessments should be continued. The focus should be expanded to include assessment of surface erosion with an emphasis on agricultural lands. All assessment of natural and anthropogenic erosion and sediment delivery should also evaluate hydrologic impacts.

   a. Plan and conduct a second phase assessment of private, unpaved roads

b. Assess the extent, severity and impacts of surface erosion on agricultural lands. This assessment should also address the hydrologic impacts of compacted and impervious surfaces and include recommendations for mitigation of those impacts.
c. Expand and continue assessment of non-road-related bank and upland erosion sites. This assessment should include a systematic watershed-wide evaluation of incision-related bank stability if possible focused on tributary streams.
d. Expand LiDAR resources to cover the entire Green Valley Watershed, including the upper tributaries.

2. Based on the watershed assessment and reach-scale geomorphic processes, including an in-depth hydrologic and geomorphic assessment of the Upper Green Valley watershed, develop a program to arrest channel incision and associated bank erosion through grade control in lower Purrington Creek and upper Green Valley Creek.
   Build on hydrologic modeling and geomorphic assessment work to identify appropriate sites, materials and designs for effective grade control to prevent further channel incision and bank failure, retain gravel, and enhance channel complexity in incised reaches of lower Purrington Creek. See attached design plans for a priority project in Chapter IV.

3. Reduce anthropogenic erosion and sediment delivery.
   Erosion assessment work completed to date includes prioritized recommendations for treating identified erosion sites and issues. Implementation of the recommended treatments should be carried out as funding becomes available.

   a. Implement recommended treatments at priority road-related, bank and upland erosion sites, including both public and private roads. Gold Ridge RCD has secured funding from CDFW for first and second phases of erosion implementation on selected high-priority sites in the Upper

Flooding on Green Valley Road

Green Valley watershed. The Sonoma County Department of Transportation and Public Works is collaborating with conservation organizations to prepare grant proposals addressing high-priority county road stream crossings, with regard to both fish passage and erosion.

b. Implement recommended project designs on Purrington and Upper Green Valley Creeks to use large wood structures to interrupt channel incision processes while stabilizing banks and landslides and enhancing rearing habitat through increasing pool depths via localized scour and enhancing spawning habitat by trapping and sorting gravels.

As geomorphic and erosion assessment work progresses, the results and recommendations of these studies should assist in targeting scarce implementation funding, both toward addressing those processes that pose a greater threat to healthy aquatic systems, and toward high priority sites and stream reaches.

E. Flood Risk

Heavy, episodic rains during winter can result in streambank overflow when stormwater runoff exceeds the capacity of the stream channel to carry it. Flooding along the lower Russian River most frequently occurs in Guerneville, Monte Rio, and Rio Nido; seventeen floods ranging between 32 feet and 49 feet (stage height) have been recorded since 1940 (Russian River Historical Society 2006). Additionally, flooding occurs frequently in the Green Valley Creek watershed, particularly in the lower reach. The Green Valley Road crossing, near the cemetery and Korbel Vineyard in the area of the confluence of Atascadero and Green Valley Creeks has been a frequent flooding concern. Due to channel aggradation in this reach, this crossing floods multiple times annually.

Where streams and human infrastructure meet, flooding can threaten property, roads, and public safety, as well as have biological consequences such as fish stranding.

In Sonoma County, floodplain management has been utilized to limit the type and extent of new construction in FEMA identified flood hazard areas and by raising existing structures above flood levels. The Sonoma County General Plan 2020 (Sonoma County PRMD 2008) identifies flood damage as a major and persistent problem on the Russian River as well as the Petaluma River and Sonoma Creek; Sonoma County has been identified as one of the highest repetitive flood loss communities in the United States.

Flood Risk Recommendations

Flood flows at Ross Station Road, March 2011

1. When considering new development of valuable infrastructure (such as buildings, road or agricultural infrastructure), look at the historical flood footprint. In many reaches of lower Green Valley Creek, the channel width at flood stage extends 200-300’, usually only for a day or two before the flood

waters recede. If you can recognize this entire area as the floodplain or flood zone and develop accordingly, you can avoid flood-related damages.

2. Encourage Low Impact Development and stormwater retention strategies for developed areas to retain stormwater and slow runoff from draining to waterways all at once.
3. Investigate climate change forecasts and models to take into account future flood risk based on changing weather patterns and expected higher intensity rainfall events and associated flooding impacts.

F. Upper Green Valley Creek and Purrington Creek Geomorphic Habitat Restoration Assessment

Prepared by Matt O'Connor, O'Connor Environmental, Inc.

Overview

A study of the geomorphology and associated structural salmonid habitat was conducted by O'Connor Environmental, Inc. in 2011 and 2012. In addition to a systematic survey of stream and bank conditions, the resulting recommendations identify opportunities to improve stream habitat in the Green Valley Creek Watershed and recommend a prioritized plan of action to address bank erosion, stream incision and enhance both spawning and rearing habitat. Surveyed Class I stream channels were categorized based on distinguishing geomorphic characteristics and habitat restoration opportunities and constraints. Classification of stream reaches provides a basis for evaluating existing fish habitat and restoration strategies in terms of the geomorphic processes that create and maintain habitat (Washington Forest Practices Board 1997). Interactions between stream flow, the stream bed (including sediment in transport and sediment stored in bars), stream banks, riparian vegetation and woody debris largely determines the location, extent and character of aquatic habitat. Mass wasting events (landslides and stream bank erosion) can have a strong influence on aquatic habitat by delivering rock, sediment and woody debris to stream channels. Significant channel adjustment and change in channel morphology is often associated with landslides; in the study area, landslides typically occur in the streamside environment, but there are some areas where landslides originating on hillslopes could reach the stream channel.

Stream reaches were classified and grouped into "channel geomorphic units" (CGU's) as shown in *Figure F-1*. The dominant geomorphic features, primary fish habitat attributes and limitations, restoration objectives, and priorities are summarized in Table F-1. The geomorphic assessment has multiple purposes, including analysis of habitat-forming processes, erosion processes, sediment routing, and flood analysis. Consequently, fish habitat restoration recommendations do not necessarily differ significantly in each "channel geomorphic unit" (CGU). It has been assumed that rearing habitat (pools with complex cover, off-channel backwaters and transient floodplain habitats) is the primary limiting factor; although this has not been formally demonstrated in Green Valley Creek, it is generally accepted as a limiting factor for coho populations. Available data on spawning in Green Valley Creek and Purrington Creek suggest that spawning habitat may be another significant limiting factor.

Although streamflow effects on habitat, particularly base flow conditions, are important (and perhaps limiting) in this watershed, streamflow characteristics are not integrated with CGU descriptions and habitat restoration strategies. Anecdotal information on streamflow from past surveys and flow monitoring data were considered in the identification of near term restoration priorities. Ongoing hydrologic monitoring and modeling is intended to address streamflow conditions systematically in Green Valley Creek in the next year. Hydrologic modeling products for Purrington Creek are presented in the following section, including a 20-year simulation of summer base flow and a hydraulic simulation of effects of proposed structures for stream restoration.

CGU summaries for Upper Green Valley Creek are followed by CGU summaries for Purrington Creek. Selected channel survey data for each "channel geomorphic unit" (CGU) are summarized in *Table 3* (Upper Green Valley Creek) and *Table 5* (Purrington Creek). Pools, a critical rearing habitat for coho salmon, were surveyed and their frequency and depth are summarized in *Table 4* (Upper Green Valley Creek) and *Table 6* (Purrington Creek). The following descriptive summaries of CGU's are ordered from downstream to upstream; however, some of the units repeat at intervals in the watershed (*Figure 1*). CGU's found in both are described in the context of each stream and differences are noted. Substantial differences in channel characteristics can occur within CGU's owing to differences in contributing drainage area. For example, channel dimensions (bankfull width and depth) found in the uppermost reach of the High Terrace-Alluvium unit are about half those found in downstream reaches of the same unit. Following is a glossary pertaining to data presented in *Tables F-3,F-4, F-5 and F-6.*

Figure F-1. Upper Green Valley and Purrington Creek Geomorphic Units Map

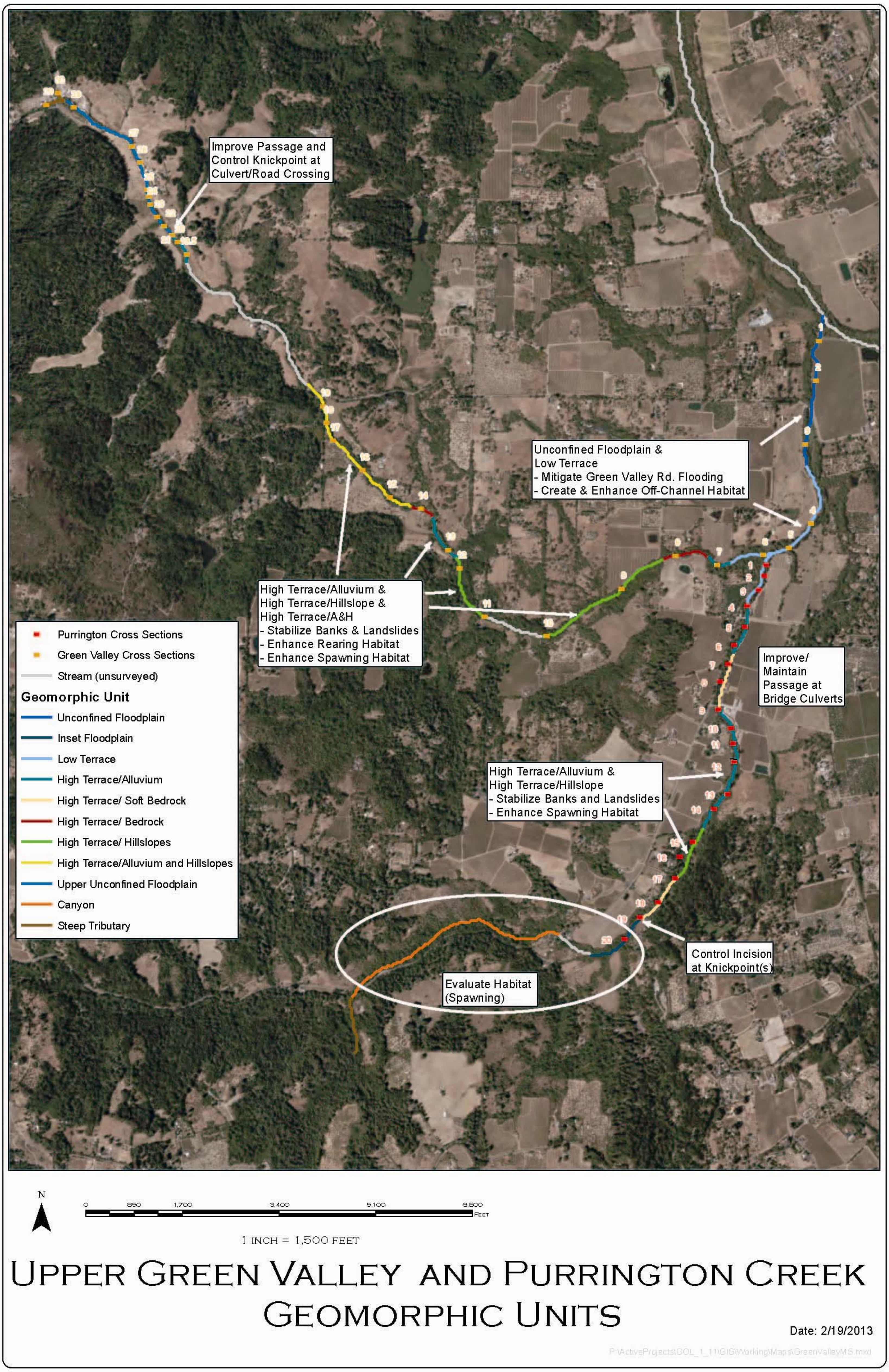


Table F-1. Upper Green Valley and Purrington Creeks Geomorphic Descriptions and Restoration Objective and Prioritization

Upper Green Valley Creek CGU's	Purrington Creek CGU's	Dominant Geomorphic Features	Primary Fish Habitat Attributes	Fish Habitat Limitations	Restoration Objectives	Priority Level
Unconfined Floodplain	**na**	• sedimentation, channel aggradation, avulsion • overbank flooding across Green Valley Road	• steelhead spawning • summer/ winter rearing in backwater slough and pools	• overbank flow across Green Valley Road to vineyard • sedimentation of habitat	• reduce flooding across road • improve floodplain (winter rearing) and off-channel habitat (winter/summer rearing) • reduce sedimentation and watershed erosion	High High Medium
Low Terrace		• sedimentation, channel aggradation	• summer/ winter rearing in pools	• limited abundance of pools/cover • sedimentation of habitat	• increase number of pools and improve cover • reduce sedimentation and watershed erosion	Medium ↓
High Terrace/ Alluvium		• moderate (UGVC) to rapid (Purrington Cr.) channel incision • moderate (UGVC) to extensive (Purrington Cr) bank erosion and bank slumps	• summer/ winter rearing in pools • potential spawning	• limited abundance of pools/cover • under-utilized for spawning	• increase number of pools and improve cover • improve gravel sorting/retention and spawning habitat quality • mitigate rate and extent of bank erosion	High ↓
High Terrace/ Bedrock	**na**	• erosion-resistant bedrock channel	• summer/ winter rearing in deep pools	• limited cover in pools	• improve cover in pools	Medium

Upper Green Valley Creek CGU's	Purrington Creek CGU's	Dominant Geomorphic Features	Primary Fish Habitat Attributes	Fish Habitat Limitations	Restoration Objectives	Priority Level
na	High Terrace/ Soft Bedrock	• weak bedrock vulnerable to ongoing incision	• summer/ winter rearing in deep pools	• limited cover in pools	• improve cover in pools • induce gravel deposition for spawning habitat and to limit channel incision	Medium ↓
High Terrace/Hillslope		• moderate (UGVC) to rapid (Purrington Cr.) channel incision • moderate (UGVC) to extensive (Purrington Cr.) bank erosion and bank slumps • stable bedrock bed and banks locally on one or both banks	• summer/ winter rearing in pools • potential spawning	• limited abundance of pools/cover • pools and pool depth locally limited by bedrock bed • under-utilized for spawning	• increase number of pools and improve cover • improve gravel sorting/retention and spawning habitat quality • mitigate rate and extent of bank erosion	High ↓
High Terrace/ Alluvium & Hillslope	na	• moderate channel incision • moderate bank erosion and bank slumps • stable bedrock bed and banks locally on one or both banks	• summer/ winter rearing in pools • active spawning	• limited abundance of pools/cover • pools and pool depth locally limited by bedrock bed • potential loss of gravel for spawning habitat	• increase number of pools and improve cover • improve gravel sorting/retention and spawning habitat quality • mitigate rate and extent of bank erosion	High ↓

Upper Green Valley Creek CGU's	Purrington Creek CGU's	Dominant Geomorphic Features	Primary Fish Habitat Attributes	Fish Habitat Limitations	Restoration Objectives	Priority Level
na	Inset Floodplain	• moderate channel incision • moderate bank erosion and bank slumps • relict discontinuous floodplain features 4-7 ft above channel bed • alluvial knickpoint at downstream end	• summer/ winter rearing in pools • potential spawning	• limited cover in pools	• stabilize/reinforce alluvial knickpoint • increase number of pools and improve cover • improve gravel sorting/retention and spawning habitat quality • mitigate rate and extent of bank erosion	High Medium ↓
Upper Unconfined Floodplain	na	• knickpoint at road crossing at downstream end • minimal channel incision/active floodplain • dense young riparian vegetation	• summer/ winter rearing in pools • floodplain habitat	• migration impediment at knickpoint • largely unsuitable for spawning	• stabilize/reinforce alluvial knickpoint	High
na	Canyon	• steep valley walls with mass wasting • confined and steep channel with coarser sediment • step-pool and forced pool-riffle morphology	• good potential spawning • summer/ winter rearing in pools	• limited abundance of pools/cover • pools and pool depth locally limited by bedrock bed	• evaluate fish use • preserve forest stands on slopes near channel for future wood recruitment	High Medium

Upper Green Valley Creek CGU's	Purrington Creek CGU's	Dominant Geomorphic Features	Primary Fish Habitat Attributes	Fish Habitat Limitations	Restoration Objectives	Priority Level
na	**Steep Tributary**	• hillslope mass wasting affects channels; narrow terraces • confined and steep channel with coarser sediment • step-pool and forced pool-riffle morphology	• potential spawning • summer/ winter rearing in pools	• limited abundance of pools/cover • pools and pool depth locally limited by bedrock bed	• evaluate fish use • preserve forest stands on slopes near channel for future wood recruitment	High Medium

Definitions – Tables F-3 & F-5

Channel Slope. The channel slope (or gradient) correlates with stream energy and is a major controlling factor in channel morphology (Montgomery and Buffington 1997; see *Table F-2*). Slope is measured from riffle crest to riffle crest.

Table F-2.-Channel morphology and pool spacing as a function of channel slope

Typical Slope (%)	Channel Type	Typical Pool Spacing (bank full widths)
< 1.5	Pool-riffle	5 - 7
1.5-3	Plane-bed	none
< 3	Forced pool-riffle	< 2
3-6.5	Step-pool	1 - 4
> 6.5	Cascade	< 1

Bankfull. The "bankfull" channel width and depth correspond to the width and depth of a peak flow event that has a 50% probability of occurring in any year (also known as 2-year recurrence interval). This magnitude of flow is widely understood to be geomorphically significant because it has sufficient energy to transport stream bed sediment, scour pools, deposit gravel bars and erode stream banks and occurs frequently so that this magnitude of flow is believed to be responsible for the majority of geomorphic work over time. The bankfull width and depth is generally identified by boundaries between the active channel bed and vegetated portions of the channel banks or floodplain.

Width to Depth Ratio. This is a fundamental descriptor of channel form with significant implications for channel hydraulics and geomorphology. Channels are typically considered "wide" when this ratio is > 10 and "narrow" when the ratio is < 10. In wide channels, flow resistance along the banks has a small effect on flow hydraulics across the full width of the channel; in narrow channels, bank effects have a significant effect on flow velocity and bed shear stress (Buffington 1995).

Top of Bank. The upper edge of the stream bank at the point of transition to broad floodplain or terrace surfaces; it describes the approximate flow depth that could be confined within the lateral channel margins. This definition is consistent with, but not identical to, the definition used in Chapter 11 of the Sonoma County Code.

Entrenchment Ratio. This ratio requires a field determination of the channel width at an elevation equivalent to twice the bankfull depth (known as the "flood prone width"; Rosgen and Silvey 1996); the entrenchment ratio is then formed by dividing flood prone width by bankfull width. The entrenchment ratio is an objective measure of channel confinement within defined banks; when the ratio is > 2.2, the channel is considered "slightly" entrenched and is expected to be associated with a substantial floodplain. Successively lower values of the ratio indicate an increasingly incised channel.

d50 and d90. Typical sediment grain diameters of the channel bed surface; d50 is the 50th percentile of the size distribution (the median diameter) and d90 is the 90th percentile of the size distribution (nine of ten sediment grains would be finer than the 90th percentile diameter). The d50 is the most widely used sediment diameter used to describe the size of a mixture of streambed sediment and is also commonly used for analyses of sediment transport. The d90 comprises the coarsest sediment sizes on the streambed; the d90 diameter is often used to quantify the hydraulic resistance of stream bed sediment.

Definitions – Tables F-4 & F-6

Residual Pool Depth. This measure of pool depth is independent of flow depth at time of observation. This metric is the difference between the maximum observed depth of the pool and the depth of flow at the downstream outlet of the pool.

Pool Spacing. The average distance between pools is calculated in units of bankfull width to allow comparison among streams of different size. The calculation is:

(reach length/bankfull channel width)/ # pools in reach = pool spacing.

Higher pool spacing indicates fewer pools; lower spacing indicates a higher pool frequency. Pool spacing in pool-riffle channels is not expected to be greater than about 5 to 7 bankfull widths because pools occur at bends in meandering streams, and the distance between bends in most meandering streams is about 5 to 7 bankfull widths. In low gradient channels (< 3% slope) with obstructions or roughness elements formed by woody debris, bedrock outcrops, live trees on the lower banks, and erosion-resistant banks, pool spacing decreases as pools are scoured adjacent to these roughness elements. Such channels are said to have "forced pool-riffle" morphology (see Table 1); pool spacing is typically < 4, and is not uncommonly < 1 in streams with abundant woody debris (Montgomery et al. 1995).

Table F-3. Summary of Survey Data for Geomorphic Channel Units, Upper Green Valley Creek

Geomorphic Channel Unit	Mean Channel Slope (%)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Bankfull Width-to-Depth Ratio	Mean Height Top of Bank (ft)	Entrenchment Ratio	Typical d50 (mm)	Typical d90 (mm)
Unconfined Floodplain	0.3	34	5.2	6.6	6.5	>>2.2	12	24
Low Terrace	0.4	45	6.5	7.0	11	>>2.2	16	35
High Terrace-Alluvium	0.7	28	5.2	5.1	15	2.0	16	38
High Terrace-Bedrock	3.8	31	6.6	4.5	17	1.8	140	180
High Terrace-	0.3	39	7.3	5.3	15	1.5	14	50

Hillslopes								
High Terrace-Alluvium & Hillslopes	0.3	23	4.8	5.0	18	1.7	39	70
Upper Unconfined Floodplain	0.9	11	2.8	4.2	5.5	2.6	12	32

Table F-4. Summary of Pool Depth and Frequency for Channel Geomorphic Units, Upper Green Valley Cr.

Geomorphic Channel Unit	Average Residual Pool Depth (ft)	Maximum Residual Pool Depth (ft)	Distribution of Pool Depth Class < 2ft	2 - 2.9 ft	≥ 3ft	Pool Count	Total Reach Length (ft)	Pool Spacing (bankfull widths per pool)
Unconfined Floodplain	2.1	4.0	53%	29%	24%	17	2860	4.9
Low Terrace	2.1	3.8	38%	46%	15%	26	2940	2.5
High Terrace/ Alluvium	2.2	4.1	36%	32%	32%	25	1940	2.8
High Terrace/ Bedrock	2.6	5.5	38%	25%	38%	16	1360	2.7
High Terrace/ Hillslope	2.1	3.5	50%	35%	15%	34	4010	3.0
High Terrace/ Alluvium and Hillslopes	2.1	4.0	49%	41%	11%	37	3110	3.7
Upper Unconfined Floodplain	2.5	5.0	31%	54%	15%	13*	3490	NA

Unconfined Floodplain. The lower reach of Upper Green Valley Creek extending from confluence with Atascadero Creek upstream beyond Green Valley Road and the Graton Cemetery; 15% of the length of surveyed channel. This unit has forced pool-riffle channel morphology, with low pool frequency (high pool spacing) and a high proportion of shallow pools. Channel sedimentation appears to be causing bed aggradation; riparian hardwoods on lower channel banks and locally-derived woody debris are principal roughness elements. Riparian hardwood forest provides dense canopy cover below Green Valley Creek Road. Bank heights are low and overbank flow potential is high, and compounded downstream of Green Valley Creek Road by potential backwater flooding at the Atascadero Creek confluence. This is consistent with the high entrenchment ratio (>>2.2; Table F-3). Aggradation of the channel bed is pronounced upstream of Green Valley Creek Road, and overbank flow annually overtops the road along the east bank upstream of the bridge. Permitted gravel removal in the reach upstream of the bridge ended about 10 years ago, and this practice probably helped to limit aggradation, but may also have encouraged development of a new channel that promotes overbank flow across Green Valley Road. The historic channel along the west bank is closed off by gravel deposits at the upper end, but provides backwater habitat over several hundred feet of abandoned channel extending to a point near the Green Valley Road bridge.

A high **habitat restoration priority** for this reach is mitigating flooding at Green Valley Road (which may be considered a risk of "take" of over-wintering coho salmon) and simultaneously enhancing winter rearing and floodplain habitat. This will likely require consideration of effects of long-term watershed erosion and sedimentation processes as well as conveyance limitations associated with the box culvert and causeway of Green Valley Road.

Low Terrace. This unit extends upstream from the Unconfined Floodplain unit to a point several hundred feet beyond the confluence with Purrington Creek; 15% of the length of surveyed channels. The Low Terrace unit has significantly higher banks than the Unconfined Floodplain, however, the entrenchment ratio is similar (>>2.2). Consequently, although the frequency of flooding is expected to be much lower, there remains substantial potential for overbank flow, primarily on the north/west bank. Within the Low Terrace unit, the channel slope is somewhat steeper, and wider, probably resulting from bank erosion associated with flow confinement relative to the downstream reach. Channel morphology is forced pool-riffle. A substantial portion of the east bank abuts a hillslope (where the channel flows in a northerly direction) underlain by bedrock causing greater flow resistance and lateral scour. Streambanks are otherwise comprised of fine-grained alluvium, including consolidated silt and clay, and are potentially vulnerable to erosion where undercut or unprotected by vegetation. Consolidated silt and clay layers are more resistant to erosion and underlie alluvial deposits. Pool frequency is substantially greater (lower pool spacing) than the Unconfined Floodplain, reflecting the effects of confined flow within higher banks that increases the incidence of lateral scour. This reach also appears to be subject to sedimentation and aggradation, and many large mature hardwoods are present on the lower banks. The channel is shaded by a relatively narrow strip of mostly mature riparian hardwoods; there is some woody debris recruitment, but there are few younger trees.

Restoration activities in this reach should include consideration of watershed erosion and sedimentation processes and the effect of habitat improvement (e.g. wood structures) on channel hydraulics, bank erosion and overbank flow potential. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools.

These aquatic habitat goals are somewhat constrained by sedimentation and aggradation, and the addition of wood structures in this reach could add to potential for overbank flow. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration of potential flooding. In addition, substantial modifications to this CGU may be proposed as an element of plans to mitigate flooding at Green Valley Road and to expand off-channel winter rearing habitat for coho salmon.

High Terrace/Alluvium. This unit is comprised of three relatively short channel segments, two of which are bounded on their upstream end by much steeper bedrock channel units (High Terrace/Bedrock); this unit comprises 10% of surveyed channel length. The High Terrace/Alluvium (HT/A) unit has significantly higher banks than the Low Terrace unit and the entrenchment ratio is 2.0 (defined as "moderately entrenched"; Rosgen and Silvey 1996). Potential for overbank flooding is low; adjacent terraces are comprised of relatively flat alluvial valley fills. The channel slope in HT/A varies among separate reaches, but remains < 1% and channel morphology is forced pool-riffle. Bank erosion of alluvial deposits is associated with flow confinement (low width-depth ratio-Table 3) where streambanks are undercut or unprotected by vegetation. Large bank failures are most significant in the HT/A segment in the center of the watershed, but were observed in all HT/A segments. Pool frequency in this unit is relatively high for Upper Green Valley Creek. This reach also appears to be subject to sedimentation (substantial gravel bars and deposits of fine gravel and sand in some pools), however these deposits are probably temporary and channel incision is more likely the dominant process except in the downstream-most HT/A segment where there is evidence of aggradation (large gravel bars and mature hardwoods established at or below present day bed elevation). Riparian hardwoods of mixed age provide canopy cover, and some woody debris.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood structures) on channel hydraulics and bank erosion. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. **The chief habitat restoration priority** for this reach type is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. These objectives are also expected to induce gravel sorting that would improve spawning habitat. These aquatic habitat goals may be somewhat constrained by sedimentation. Addition of wood structures in this reach type would not significantly increase the potential for overbank flow. Bank stabilization efforts should be integrated with habitat improvement efforts.

High Terrace/Bedrock. This unit is comprised of two relatively short, steep channel segments, where erosion resistant Franciscan bedrock dominate channel morphology; this unit comprises 7% of surveyed channel length. The High Terrace/Bedrock (HT/B) units are geomorphically significant because they act as local base levels controlling the slope of upstream channel units. The lower HT/B segment (Figure 1) separates the floodplains and terraces of the lower watershed from the narrow and discontinuous floodplains and terraces of the upper watershed where upland terrain dominates. The upstream-most segment of HT/B experienced significant change in the past decade owing to a catastrophic channel and bank erosion event during a flood event New Year's Eve 2005 (pers. comm., D. Acomb, CDFG); this is consistent with prior channel surveys (O'Connor and Rosser 2003). The flood event caused major erosion because of a short segment of highly confined channel that coincided with a sharp bend and a short bedrock cascade; presumably, flood flows caused water to pool upstream, and a channel avulsion eroded a large segment of stream bank and by-passed the channel constriction, ultimately causing several feet of channel incision.

The banks of HT/B units are high and the entrenchment ratio is 1.8 (defined as "moderately entrenched"; Rosgen and Silvey 1996). Potential for overbank flooding is low; adjacent terraces are comprised of alluvium overlying bedrock. Bedrock comprises much of the channel bottom and most of the lower banks. The channel slope in HT/B varies locally in step-pool morphology, but averages about 4% and is significantly greater than other surveyed reaches in Upper Green Valley Creek. Bank erosion of alluvial deposits on the upper banks is possible, but otherwise banks are stabilized by bedrock outcrops in the lower banks, notwithstanding the catastrophic process described above. Pool frequency is relatively high (spacing is relatively low), and pools are relatively deep owing to bedrock steps in the channel bed. Sedimentation in this unit is limited to deposition of sand and fine gravel in pools. Mature riparian hardwoods provide dense canopy cover in the lower HT/B reach. In the upper reach, recent bank erosion eliminated much canopy cover on the south bank, and a young, dense stand of willow is developing.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood placement) on channel hydraulics and bank erosion. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing cover and complexity in pools. Addition of wood structures in this reach type would not significantly increase pool frequency or depth due to the bedrock channel bed. Bank instability is substantial, and bank failures appear to infrequently generate significant quantities of sediment. Bank stabilization efforts should be integrated with habitat improvement efforts.

High Terrace/Hillslope. This unit consists of one long channel segment near the center of the watershed bounded on its downstream end by a bedrock channel unit (HT/B); this unit comprises 20% of surveyed channel length. An unsurveyed reach about 1,100 ft in length separates the surveyed reaches and would likely be classified as HT/H. The High Terrace/Hillslope (HT/H) unit has high banks, with some local variability, and the entrenchment ratio is 1.5 (the lowest observed here, defined as "moderately entrenched", but near the threshold of 1.4 for "entrenched" channels; Rosgen and Silvey 1996). Potential for overbank flooding is low, with some local variability; adjacent terraces are narrow and sloping from adjacent upland hillslopes, usually on both sides of the stream. The channel slope in HT/H varies, but remains < 1% and channel morphology is forced pool-riffle, although there are local areas where plane bed morphology develops over short reaches where pools are infrequent or absent. Pool frequency and pool depth is lower than average for Upper Green Valley Creek; maximum pool depth may be limited by depth of in-channel alluvial deposits overlying bedrock. Bedrock outcrops intermittently emerge from the stream bed or banks. Bank erosion may occur where streambanks are undercut; trees typically grow only on the upper bank/terrace edge and the lower banks are relatively unprotected by vegetation, in part resulting from dense shade cast by mature trees growing in the riparian zone and extending onto hillslopes. In addition, stream bank failures tend to be more frequent and are relatively large, and in some locations involve portions of adjacent hillslopes. Both riparian species on bank tops and upland hardwoods and conifer provide canopy cover and relatively high potential for woody debris recruitment. This reach also appears to be subject to sedimentation (substantial gravel bars and deposits of fine gravel and sand in some pools), however these deposits are probably temporary and channel incision with sediment transport is more likely the dominant process.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood structures) on channel hydraulics and bank erosion. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. These objectives are also expected to induce gravel sorting that would improve spawning habitat. Addition of wood structures in this reach type would not significantly increase the potential for overbank flow. Bank instability is substantial, and bank failures appear to generate significant quantities of sediment. Bank stabilization efforts should be integrated with habitat improvement efforts.

High Terrace/Alluvium & Hillslope. This unit consists of one long channel segment in the upper third of the watershed bounded on its downstream end by a bedrock channel unit (HT/B); this unit comprises 16% of surveyed channel length. An unsurveyed reach about 3,500 ft in length extends upstream from the surveyed reach and would likely be classified as HT/A&H. The High Terrace/Alluvium & Hillslope (HT/A&H) shares characteristics of the

HT/A and HT/H units and has high banks, with some local variability, and the entrenchment ratio is 1.7 (intermediate between HT/H and HT/A). The hillslopes adjacent to this unit (where surveyed) occur primarily in its lower half, and the bedrock in that area is the Wilson Grove sandstone, which is rarely exposed in the bed or banks of Upper Green Valley Creek. There is historical evidence from past surveys that this reach sustains summer base flows relative to downstream reaches above the confluence of Purrington Creek that are prone to loss of surface flow. High base flow may be caused by relatively high water table associated with the intersecting Wilson Grove sandstone and the shallow alluvium on the valley floor upstream.

Potential for overbank flooding is low, with some local variability; adjacent terraces range from narrow and sloping from adjacent upland hillslopes to relatively wide where alluvial valley fill is present. The channel slope remains < 1% and channel morphology is forced pool-riffle, however, the sediment size distribution becomes coarser in this unit relative to other units downstream. Pool frequency is low (high pool spacing) relative other Upper Green Valley Creek units. Bedrock outcrops intermittently emerge from the stream bed or banks. Bank erosion may occur where streambanks are undercut; trees typically grow only on the upper bank/terrace edge and the lower banks are typically unprotected by vegetation, in part resulting from dense shade cast by mature trees growing in the riparian zone and extending onto hillslopes. Stream bank failures are not uncommon, and in some locations involve portions of adjacent hillslopes. Riparian species on bank tops as well as upland hardwoods and conifer provide canopy cover and some potential for woody debris recruitment. Sedimentation in this reach is less evident than in downstream reaches, presumably owing to reduced upstream drainage area and sediment sources; tributaries upstream of this reach must cross low-gradient valley deposits before entering the mainstem of Upper Green Valley Creek, which probably reduces the efficiency of sediment delivery.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood structures) on channel hydraulics and bank erosion potential. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. These objectives are also expected to induce gravel sorting that would improve spawning habitat. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. Addition of wood structures in this reach type would not significantly increase the potential for overbank flow. There is potential bank instability, and past bank failures generated substantial sediment inputs to the channel. Bank stabilization efforts should be integrated with habitat improvement efforts. The upper portion of this unit has unusually high density of use by coho salmon relative to other tributaries in the Russian River watershed.

Upper Unconfined Floodplain. The upper reach of Upper Green Valley Creek comprises 18% of the length of surveyed channel. This unit has forced pool-riffle channel morphology with channel slopes < 1%; pool frequency data are unavailable because extremely dense riparian vegetation prevented collection of continuous channel data. Pools were observed where access to the channel could be found, and were deep relative to the size of the channel, with abundant shade and overhead cover. Pool frequency is probably at least average in this unit relative to others in Upper Green Valley Creek, and most habitat units are flatwater units such as pools, glides and runs. A relatively young, dense stand of riparian hardwoods, primarily willows, occupy the stream banks and terrace tops and are the dominant feature of channel morphology. Riparian vegetation is the principal element of flow resistance. Bank heights are low and overbank flow potential is high, consistent with the high entrenchment ratio (2.6; see *Table 3*). The frequency of overbank flow is likely to be high, and the valley floor is better described as floodplain than terrace. Wetland meadows border the channel in many areas. This unit is relatively unaffected by recent channel incision that characterizes downstream areas, and represents a remnant of channel and valley morphology undisturbed by channel incision. Since the alluvial valley fill is not significantly incised, it is capable of maintaining a higher water table elevation, and this might be a significant factor maintaining summer base flows.

This reach is bounded on its downstream end by an older road crossing with a 6 ft diameter culvert and a rip-rap outfall with a slope of about 10% over a distance of about 50 ft. This road crossing is probably an impediment to upstream fish migration. Moreover, the crossing and rip-rap outfall form a significant grade control for the Upper Unconfined Floodplain unit. If the culvert plugged during a storm event, the road crossing could fail and a catastrophic channel avulsion could occur that might bypass the rip-rap grade control. If this occurred, this unit would be vulnerable to rapid incision and widening, would produce a significant quantity of sediment that would likely be detrimental to downstream habitat, would interrupt the on-going recovery of habitat in this unit, and would potentially diminish summer base flow generated by the alluvial aquifer that could affect critical summer rearing habitat downstream.

A low concrete ramp forms a low dam (< 3 ft high) a few hundred feet upstream of the aforementioned culvert, a short distance downstream of a tributary entering from the southwest. This low dam forms a long deep pool upstream, but probably is an impediment to migration. There are an additional six road crossings upstream from this point; these do not appear to be migration barriers. There is also a concrete basin that had been used for a flashboard dam about 4 ft high that is now left open to flow; this basin has been partially filled with sediment and has been colonized by cattails.

A high **habitat restoration priority** for this reach is mitigating risks associated with potential culvert failure at the downstream end of the unit; this road crossing is the upstream limit of active channel incision processes. Habitat in this unit for salmonid rearing is good, and would be expected to improve for a period of 10 to 20 years as the young seral stand of riparian vegetation matures, maintaining shade and cover and gradually increasing channel complexity with additions of woody debris and growth of larger diameter stems within the bankfull channel. Spawning habitat in this reach appears to be limited, however, areas upstream are likely to provide spawning habitat. The potential migration barrier formed by the 3 ft concrete dams should also be evaluated for potential removal, taking into account upstream channel and bank stability.

Overview-Purrington Creek Geomorphic Habitat Assessment

A preliminary survey and geomorphic analysis of Purrington Creek was conducted in 2010 by OEI for Gold Ridge RCD. The lower reaches of Purrington Creek were re-surveyed in 2011 in greater detail; this assessment focuses on the reaches downstream of the Graton Road bridge near the intersection of Green Hill Road. A longitudinal thalweg profile and 20 cross-sections were surveyed to support development of a hydraulic model to supplement the hydrologic model developed in 2010. The hydraulic model was also used to evaluate restoration design concepts with respect to potential impacts on water depth, velocity, shear stress and bank erosion (see summary in following section). Model analysis of summer base flow and flow depth are described in a following section. The more detailed survey also produced an inventory of pools (critical rearing habitat for coho salmon) and a map of bank conditions. With this new data, some modifications were made to the geomorphic classification of stream reaches based on better information and informed by surveys and geomorphic assessment of Upper Green Valley Creek. The geomorphic classification of stream reaches for Purrington Creek was unified with that for Upper Green Valley Creek; nevertheless, there are some unique channel types in Purrington Creek.

Selected channel survey data for each CGU are summarized in *Table F-5*. Pool frequency and depth are summarized in *Table 6*. The following descriptions of CGU's are ordered from downstream to upstream, however, some of the units repeat at intervals in the watershed (Figure 1).

The upper reaches of Purrington Creek surveyed and assessed in 2010 were classified into preliminary CGU's: Lower Canyon, Canyon and Steep Tributary (*Figure F-1*). These units were not revisited in subsequent surveys. Nevertheless, these units, along with a short unsurveyed reach downstream of the Lower Canyon unit, are believed to provide better-quality spawning habitat for coho salmon and steelhead, primarily because of steeper channel gradient, coarser sediment, and less erosion and sedimentation on the stream bed. UCCE will be conducting surveys in these areas to evaluate fish use and habitat in the coming year.

Table F-5. Summary of Survey Data for Channel Geomorphic Units, Purrington Creek

Geomorphic Channel Unit	Mean Channel Slope[1] (%)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Bankfull Width-to-Depth Ratio	Mean Height-Top of Bank (ft)	Entrench-ment Ratio	Typical d50 (mm)	Typical d90 (mm)
Low Terrace	0.4	36	5.8	6.1	11	>2.2	14	32
High Terrace-Alluvium	0.6	33	6.8	5.0	18	2.3	16	30
High Terrace-	1.0	27	8.4	3.2	22	2.0	na	na

Soft Bedrock								
High Terrace-Hillslopes	0.7	29	6.6	4.4	31	1.8	na	na
Inset Floodplain	0.2	56	7.5	7.4	24	1.6	17	33

Notes: 1. Mean channel slope determined from thalweg profile data.

Table F-6. Summary of Pool Depth and Frequency for Channel Geomorphic Units, Purrington Cr.

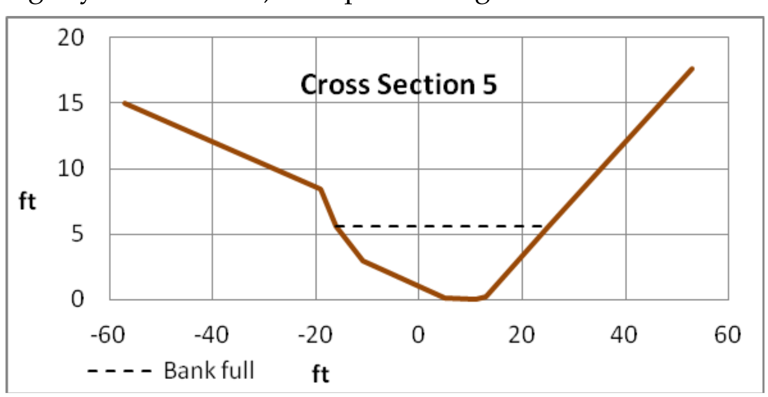
			Distribution of Pool Depth Class					
Geomorphic Channel Unit	**Average Residual Pool Depth (ft)**	**Maximum Residual Pool Depth (ft)**	**< 2ft**	**2 - 2.9 ft**	**≥ 3ft**	**Pool Count**	**Total Reach Length (ft)**	**Pool Spacing (bankfull widths per pool)**
Low Terrace	1.5	3.0	83%	17%	0%	12	960	2.2
High Terrace/ Alluvium	1.7	4.2	79%	18%	3%	34	3200	2.9
High Terrace/ Soft Bedrock	2.3	4.9	44%	36%	20%	25	3330	4.8
High Terrace/ Hillslope	2.0	5.3	77%	8%	15%	13	1190	3.2
Inset Floodplain	2.2	4.0	33%	56%	11%	9	630	1.3

<u>**Low Terrace**</u>. This unit extends upstream from the confluence with Upper Green Valley Creek to a point about 200 ft downstream of the lower Graton Road bridge; 10% of the length of channel surveyed in 2011. The Low Terrace unit has the lowest banks in the lower portion of the Purrington Creek watershed, and the entrenchment ratio is >2.2. It is the only unit in lower Purrington Creek in which there is potential for overbank flooding, however, it would not be expected to flood except under extreme conditions. Within the Low Terrace unit, the channel slope is lower, and the channel wider, than in the incised units upstream. Channel morphology is forced pool-riffle. Streambanks are comprised of fine-grained alluvium and are potentially vulnerable to erosion where undercut or unprotected by vegetation; bank revetments have been built in several locations. Pool frequency is relatively high (lower pool spacing) compared to

other Purrington Creek units, however, pools are relatively shallow. This reach appears to be subject to sedimentation (substantial gravel bars and deposits of fine gravel and sand in some pools), and there is evidence of aggradation (large gravel bars and mature hardwoods established at or below present day bed elevation). Riparian hardwoods of mixed age provide canopy cover, and some woody debris; the riparian forest vegetation is more extensive on the west bank and narrower on the east bank adjacent to a vineyard.

Restoration activities in this reach should include consideration of watershed erosion and sedimentation processes and the effect of habitat improvement (e.g. wood structures) on channel hydraulics, bank erosion and overbank flow potential. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. These objectives are also expected to induce gravel sorting that would improve spawning habitat. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. These aquatic habitat goals are somewhat constrained by sedimentation and aggradation, and the addition of wood structures in this reach could add to potential for overbank flow.

High Terrace/Alluvium. This unit is comprised of two separate channel segments, a short segment straddling the lower Graton Road bridge, and a longer segment beginning a short distance above the bridge at the Dutton Ranch vineyard. The upper segment of HT/A terminates at a bridge/box culvert that has formed a knickpoint with a drop of nearly 5 ft; deposition of alluvium upstream controls bed elevations and limits channel incision. The two HT/A segments are separated by a lengthy segment of bedrock-dominated channel (High Terrace-Soft Bedrock). This unit comprises 34% of surveyed (2011) channel length. The High Terrace/Alluvium (HT/A) unit has significantly higher banks than the Low Terrace unit and the entrenchment ratio is 2.3 (defined as "slightly entrenched"). Despite the high entrenchment ratio, potential for overbank flooding is low—bank heights average 18 ft. The high entrenchment ratio is in this unit is not associated with a broad, active floodplain as is found in the Unconfined Floodplain unit in Lower Green Valley Creek. The relatively high entrenchment ratio in this unit arises because the upper banks are less steeply-sloped than the lower banks (see inset diagram for Cross Section 5); this likely resulted from channel incision, which initially



creates steeply sloping or near-vertical banks. The less-steeply-sloping upper banks originated prior to the most recent era of channel incision and/or deposits from stream bank slumps (rotational mass wasting of the alluvial terrace) induced by bank erosion and channel incision. There is abundant field evidence of instability of stream banks, including areas of active erosion, existing bank revetments, and areas of high potential instability where alluvial terrace deposits overlie compacted clay/weathered bedrock. The channel slope in HT/A varies among separate reaches, but remains < 1% and channel morphology is forced pool-riffle. Adjacent terraces are comprised of alluvial valley fill. Bank erosion of alluvial deposits is associated with flow confinement (low width-depth ratio-*Table 2*) where streambanks are undercut or unprotected by vegetation. Large bank failures and slumps extending high on the stream banks are most significant in the HT/A segment in the center of the watershed, but were observed in all HT/A segments. Pool frequency in this unit is relatively high for Purrington Creek, but pool depths are relatively low. This reach is also subject to sedimentation (substantial gravel bars and deposits of fine gravel and sand in some pools), however these deposits are probably temporary and channel incision with sediment transport is more likely the dominant process except where controlled by bridge culverts. Riparian hardwoods of mixed age provide canopy cover, and some woody debris.

Restoration activities in this reach should include consideration of watershed erosion and sedimentation processes and the potential effect of habitat improvement (e.g. wood structures) on channel hydraulics, bank erosion and overbank flow potential. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. These objectives are also expected to induce gravel sorting that would improve spawning habitat. **The chief habitat restoration priority** for this reach type is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. Addition of wood structures in this reach type would not significantly increase the potential for overbank flow. Active bank erosion and bank slumping are significant in this unit and it is important that restoration projects be carefully planned to reduce erosion and slumping, or at least not aggravate erosion processes. Restoration work could protect the toe of existing slumps and promote gravel retention to gradually raise bed elevations.

High Terrace/Soft Bedrock. This unit is comprised of two relatively long channel segments, where easily-eroded/incised Wilson Grove sandstone governs channel morphology; this unit comprises 10% of channel length surveyed in 2011. The channel has incised the sandstone of the Wilson Grove Formation that underlies the valley alluvium; typical slope is about 1%, which is substantially steeper than other units. Bank heights average about 22 ft indicating a degree of channel incision sufficient to prevent overbank flow under current conditions. Channel banks are steep, often vertical where bedrock forms the bank, and relatively stable. Nevertheless, sandstone of the Wilson Grove Formation is relatively soft, and stream flow is capable of gradually eroding it. Evidence of active erosion processes indicates ongoing channel incision of the sandstone. The upper HT/SB segment (Figure 1) terminates at a natural knickpoint in the channel controlled by woody debris and separates various "high terrace" units from the Inset Floodplain unit at the south end of the alluvial valley segment of Purrington Creek. The lower segment of HT/SB terminates at a bridge/box culvert that has formed a knickpoint with a drop of nearly 5 ft.

The HT/SB unit has an entrenchment ratio is 2.0 (defined as "slightly entrenched"). Channel width varies, but is typically narrower in a trench-like lower channel (width < 20 ft), widening substantially above. In some locations, a bedrock strath terrace (formed by channel incision) is present. Although the overall slope gradient along these reaches was steeper than adjacent reaches, the drop occurs at knickpoints that create longer flatwater units and deep bedrock pools. The dominant channel morphology is forced pool riffle and plane bed. Deep and long pools are common in trench-like rectangular sections of bedrock channel. These pools tend to be characterized by low complexity and poor cover. The stream bed surface in these deeper water bedrock-dominated channel reaches is typically sand. The confined channel geometry and locally steep gradients promotes sediment transport and permits only transient sediment storage in pools and in gravel bars formed where the channel expands or in the lee bank irregularities. Woody debris is sparse and its function is limited owing to bedrock morphology. Riparian forest trees are hardwoods, but are typically found rooted above the contact between bedrock and overlying alluvium, and are therefore rarely affect channel morphology.

The banks of HT/SB units typically are formed of bedrock on one or both banks extending from 2 ft to over 10 ft above the channel bed. Alluvial deposits overlying the bedrock may be vulnerable to erosion and slumping in some locations, but are now mostly perched above the water surface during all but the largest flows. Seeps form at this contact in some locations.

Restoration activities in this reach should include consideration of the potential effect of habitat improvement (e.g. wood placement) on channel hydraulics and bank erosion. Bank stabilization efforts should be integrated with habitat improvement efforts. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing cover and complexity in pools. Addition of wood structures in this reach type would not significantly increase pool frequency or depth due to the bedrock channel bed, but could provide cover. Bank instability is substantial, but many sheer bedrock valley walls appear stable. Bank failures appear to have contributed significant quantities of sediment in the past.

<u>High Terrace/Hillslope</u>. This unit consists of one channel segment near the center of the watershed bounded on its downstream end by an alluvial channel unit (HT/A); this unit comprises 13% of surveyed channel length. The High Terrace/Hillslope (HT/H) unit has very high banks (typically > 30 ft) , with some local variability, and the entrenchment ratio is 1.8 (the lowest observed here, defined as "moderately entrenched". The HT/H unit in Upper Green Valley Creek has an entrenchment ratio of 1.5, which is more entrenched by definition; however, the difference is caused by the greater depth of incision in Purrington Creek and the subsequent mass wasting and channel widening. Potential for overbank flooding is low, adjacent terraces along the west side (left bank) are formed by the valley alluvium. Adjacent upland hillslopes on the east side (right bank) are separated from the channel by a discontinuous, narrow terrace. The channel slope in HT/H varies, but remains < 1% and channel morphology is forced pool-riffle, although there are local areas where plane bed morphology develops over short reaches where pools are infrequent or absent. Bedrock of the Wilson Grove, weathered bedrock, and consolidated clayey alluvium is frequently exposed in the stream bed or banks. Pool frequency is lower and pool depth is greater than average for Purrington Creek; maximum pool depth is associated with local deep scour in clay and soft bedrock. Bank erosion may occur where streambanks are undercut; trees typically grow only on the upper bank/terrace edge and the lower banks are relatively unprotected by vegetation, in part resulting from dense shade cast by mature trees growing in the riparian zone and extending onto hillslopes. In addition, stream bank failures tend to be more frequent and are relatively large, and in some locations involve portions of adjacent hillslopes. Both riparian species on bank tops and upland hardwoods and conifer provide canopy cover and relatively high potential for woody debris recruitment. This reach also appears to be subject to sedimentation (substantial gravel bars and deposits of fine gravel and sand in some pools), however these deposits are probably temporary and channel incision with sediment transport is more likely the dominant process.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood structures) on channel hydraulics and bank erosion. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by increasing the frequency and depth of pools, and providing for enhanced cover and complexity in pools. These objectives are also expected to induce gravel sorting that would improve spawning habitat. Addition of wood structures in this reach type would not significantly increase the potential for overbank flow. Bank instability is substantial, and bank failures appear to generate significant quantities of sediment. Bank stabilization efforts should be integrated with habitat improvement efforts.

Inset Floodplain. The upper-most CGU in Purrington Creek surveyed in 2011 comprises 7% of the length of surveyed channel. This unit was reclassified relative to the assessment completed in 2010 because it was recognized that this reach has a lower gradient and greater bankfull width than downstream units and higher pool frequency (*Table 4 and Table 5*). The unit as shown in Figure 1 extends about twice the surveyed length; the upper section is presumed to have characteristics similar to that of the surveyed lower segment. This unit is bounded upstream by another unsurveyed reach to which access was not available that extends to the Graton Road bridge near Green Hill Road. This unit has forced pool-riffle channel morphology with lower channel slope than the "high terrace" units downstream, about 0.2% in the surveyed reach. Pool frequency is substantially higher and pool depth is greater than average for Purrington Creek.

This unit has high banks (typically > 24 ft) and the entrenchment ratio is 1.6 (the lowest observed in Purrington Creek in the 2011 survey), defined as "moderately entrenched". The lower entrenchment ratio relative to downstream units is interpreted to reflect a lesser degree of bank slumping and accompanying increase in flood prone width, and would be consistent with more recent and less advanced channel incision in this unit. The alluvial knickpoint defining the downstream extent of this unit is believed to indicate the headward extent of recent incision. Potential for overbank flooding is low, adjacent terraces are formed by the valley alluvium. Substantial tributaries join this reach from the south (right) bank, and the right bank terrace is a few feet lower than the left bank terrace. Pebbly conglomerate presumably derived from the Wilson Grove sandstone, and consolidated clayey alluvium is frequently exposed in the stream bed or banks, with overlying alluvium comprising the remainder of the banks. Bank erosion and slumps may occur where streambanks are undercut. Larger diameter alders (2 ft and larger) are found within the bankfull channel, indicating that this portion of Purrington Creek has not been as severely impacted by recent incision as some areas downstream. Nevertheless, vertical eroded banks and slumps are common. Riparian species on the bank provide canopy cover and relatively high potential for woody debris recruitment. This reach also appears to be subject to substantial sedimentation (large gravel bars and deposits of fine gravel and sand in some pools), and although these deposits are transient, they are more extensive than those downstream providing continuous cover of the channel bed and suggest lower rates of channel incision. This unit appears to be somewhat less impacted by the channel incision that characterizes downstream areas, and may represent less disturbed channel and valley morphology. Since the alluvial valley fill is significantly incised, it has eroded and slumped in several locations. Nevertheless, a remnant floodplain about 4 to 6 ft above the channel bed is discontinuously distributed through this unit.

Restoration activities in this reach should include consideration of the effect of habitat improvement (e.g. wood structures) on channel hydraulics and bank erosion. The hydrologic model under development will be capable of evaluating potential impacts of proposed restoration. **The chief habitat restoration priority** for this reach is improving the quality of rearing habitat, primarily by providing for enhanced cover and complexity in pools and increasing the frequency of pools if feasible. These objectives are also expected to induce gravel sorting that would improve spawning habitat. Addition of wood structures in this reach type could increase the potential for more frequent flow on the remnant floodplain, potentially creating off-channel or floodplain winter rearing habitat. Bank instability is substantial, and bank failures appear to generate significant quantities of sediment. Bank stabilization efforts should be integrated with habitat improvement efforts.

The alluvial knickpoint defining the downstream extent of this unit is maintained by relatively-stable LWD wedged across the channel. This knickpoint should be reinforced with additional LWD and/or boulders to maintain channel grade and prevent or delay incision of the alluvial deposits forming the channel floor.

Hydrologic Modeling for Habitat Restoration Planning

As noted above, a sophisticated hydrologic model has been implemented for Purrington Creek. To date, the model has been used for a preliminary assessment of the spatial variation of summer base flow in lower Purrington Creek. The model was also used to support a two-dimensional hydraulic model simulation for a portion of Purrington Creek to evaluate alternative designs for proposed wood structures. Each of these modeling efforts is briefly summarized below.

Purrington Creek Base Flow Classification

A spatially distributed hydrologic model of Purrington Creek was constructed for the Gold Ridge Resource Conservation District in 2010 using MIKE SHE (OEI, 2010). The model represents one component of the Upper Green Valley Creek Watershed Management Plan and is intended to support ongoing habitat restoration efforts in the watershed by providing a tool for characterizing stream flow conditions *throughout* the watershed, quantifying available aquatic habitat volumes, identifying flow-limited reaches, and prioritizing restoration efforts in the watershed. The model is well-suited for examining low flow conditions due to its physically-based simulation of groundwater and surface water processes and the interactions between them.

The model developed in 2010 was calibrated in 2012 using streamflow data collected by CEMAR gauge GV02 located in lower Purrington Creek about 0.5 miles upstream of the confluence with Green Valley Creek. The calibrated model reproduces observed patterns of runoff and baseflow with reasonable accuracy. The calibrated model was then used to simulate watershed conditions based on daily rainfall records for a 20-yr period covering Water Years 1992 through 2011.

This summary discusses how results from this long-term simulation were utilized in conjunction with stream habitat data for pools and riffles collected during surveys in October 2011 to generate maps classifying habitat conditions on a reach by reach basis as a function of streamflow. These datasets represent an incremental step towards developing restoration prioritization maps. Ongoing efforts are underway to expand and calibrate the model to include the entire Green Valley Creek and Dutch Bill Creek watersheds, refine the water availability mapping methodology, and ultimately, to integrate the water availability mapping with additional habitat characterization metrics and species requirement information to generate restoration prioritization maps. The models will also be applied to investigate the effects of expected and hypothetical future or past conditions (e.g. changes in climate, land- and water-use/management) on water and habitat availability.

Development of Hydrologic Habitat Maps

A flow frequency analysis was performed using the modeling results at the stream gauge site (GV02) for the 20-yr MIKE SHE simulation to determine flows for various exceedance intervals. A series of maps were then generated for 50% and 90% exceedance flows (i.e. flows that were exceeded 50% of the time and 90% of the time during the 20-yr simulation period). Discharge and water depth values were extracted at each of the 20 surveyed cross sections in the model. For mapping purposes each cross section was assumed to represent a reach extending from the mid-point of the reach between adjacent cross-section upstream and downstream. Each reach was then assigned a corresponding discharge and water depth value for the 50% and 90% exceedance flows. Additional model parameters that may prove helpful (e.g. velocity, shear stress, and wetted perimeter) are also available but have not been compiled to date.

Pools were located and residual pool depths were measured in the field during autumn of 2011. These values were within the 20 reaches delineated on the basis of the surveyed cross section locations as described above. The cross sections used in the model were taken at riffle crests and as such the model simulated depths represent riffle depths. Discharge and riffle depth maps were generated on the basis of the modeling results alone, and pool depths were generated by adding the residual pool depths measured in the field to the model simulated depths (riffle depths). Results were compiled in Geographic Information System (GIS) and displayed to assist in visualizing the results.

Results

The 90% exceedance discharges are on the order of 0.20 cfs at the upper end of the study reach (~1,200 feet below the upper Graton Road crossing near Green Hill Road) and increase gradually in the downstream direction to approximately 0.35 cfs at the lower end of the study reach above the confluence with Green Valley Creek (*Figure F-2*). The 50% exceedance discharges are on the order of 0.30 cfs at the upper end of the study reach and increase gradually to approximately 0.70 at the lower end of the study reach (*Figure F-3*).

The 90% exceedance riffle depths are on the order of 0.1 to 0.2 feet throughout much of the study reach but are significantly higher locally including reaches centered on cross sections 2, 4, and 8 where they range from 0.3 to 0.6 (*Figure F-4).* The 50% exceedance riffle depth results show a similar pattern as the 90% results but with most depths approximately 0.1 feet higher (*Figure F-5*).

The 90% exceedance pool depth results exhibit significant longitudinal variation, with average depths ranging from 1.5 to 3.0 feet. Pool depths are relatively high throughout the upper reach (cross sections 16 to 20), generally shallow to intermediate throughout the central portion of the study reach (sections 10 to 15), and then vary between shallow and deep over the lower reach with deeper sections of pools in the reach between sections 7 and 9 and centered on section 4 (*Figure F-6*). The 50% exceedance pool depth results reveal a similar pattern but with slightly higher depths (*Figure F-7*).

Discussion

The maps presented here represent an incremental step towards the goal of utilizing a distributed hydrologic model in conjunction with field assessments to characterize water availability and habitat quality and quantity on a reach by reach basis, relate these metrics to target species requirements, and develop restoration prioritization maps and recommendations. As a stand-alone simulation product, they provide a detailed characterization of water availability in Purrington Creek. The discharge maps provide an overall picture of how much water is available in different reaches of the creek and help to underscore the low magnitude of flows (0.2 to 0.35 cfs) in the creek during the dry-season. We expect that they may be particularly useful in delineating the extent of potential habitat areas and how changes in water-use or flow augmentation efforts may alter the extent of potential habitat.

The riffle depth maps are likely most useful for investigating the connectivity of pool habitat by identifying potential passage barriers arising from insufficient water depths. The pool depth maps indicate that pools are deepest (2 to 3 feet) in the upper portions of the study reach, relatively shallow (1.5 to 2 feet) in the central portion of the study reach, and alternate between relatively deep and relatively shallow throughout the lower reach. These results suggest that restoration efforts aimed at enhancing pool habitat may be most beneficial in the central portion of the study reach (between cross sections 10 and 15) and the reaches between cross sections 1 and 2, and 5 and 6. By combining model results with more detailed measurements of habitat dimensions, it is possible to quantify and map the total available habitat volume on a reach by reach basis which may prove to be the most useful water availability metric for characterizing fish habitat. We intend to collaborate with Gold Ridge RCD and its cooperators to further develop hydrologic model applications to support habitat restoration efforts in Green Valley Creek as we enter the next phase of modeling. This will expand the modeling to cover the entire Green Valley Creek watershed from its confluence with the Russian River upstream throughout Atascadero and Upper Green Valley Creeks.

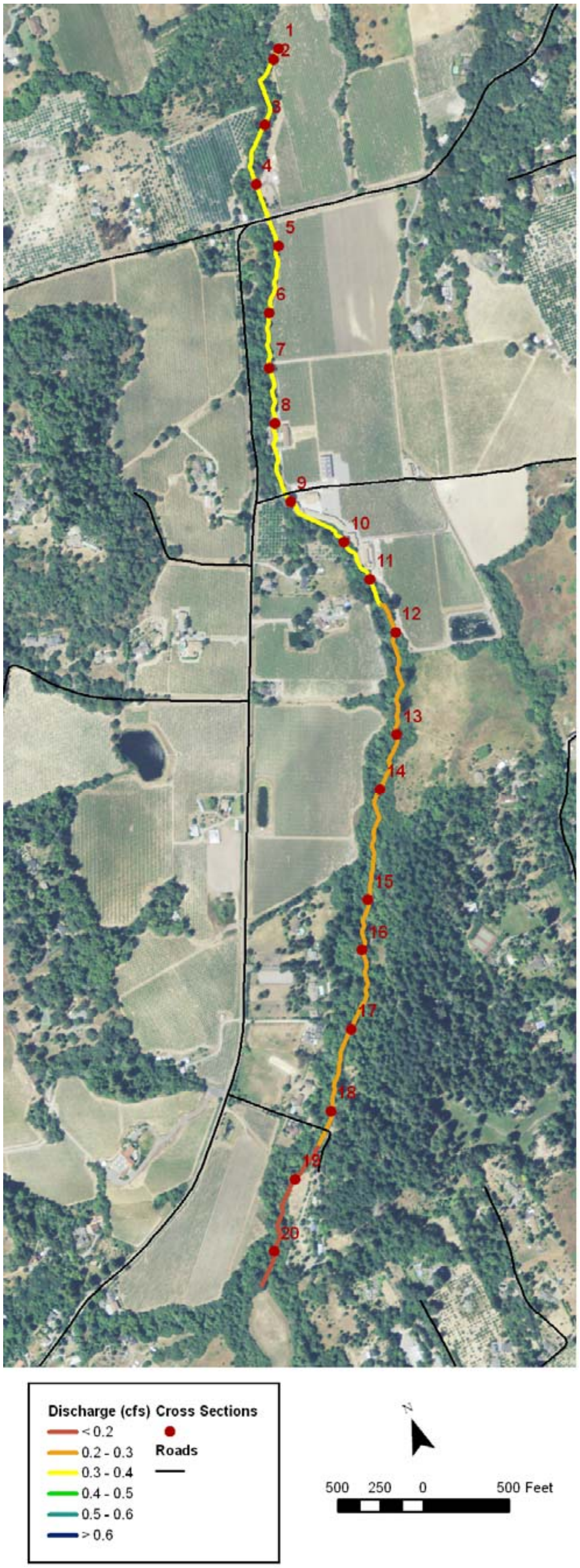


Figure F-2. Discharge classification for 90% exceedance flows.

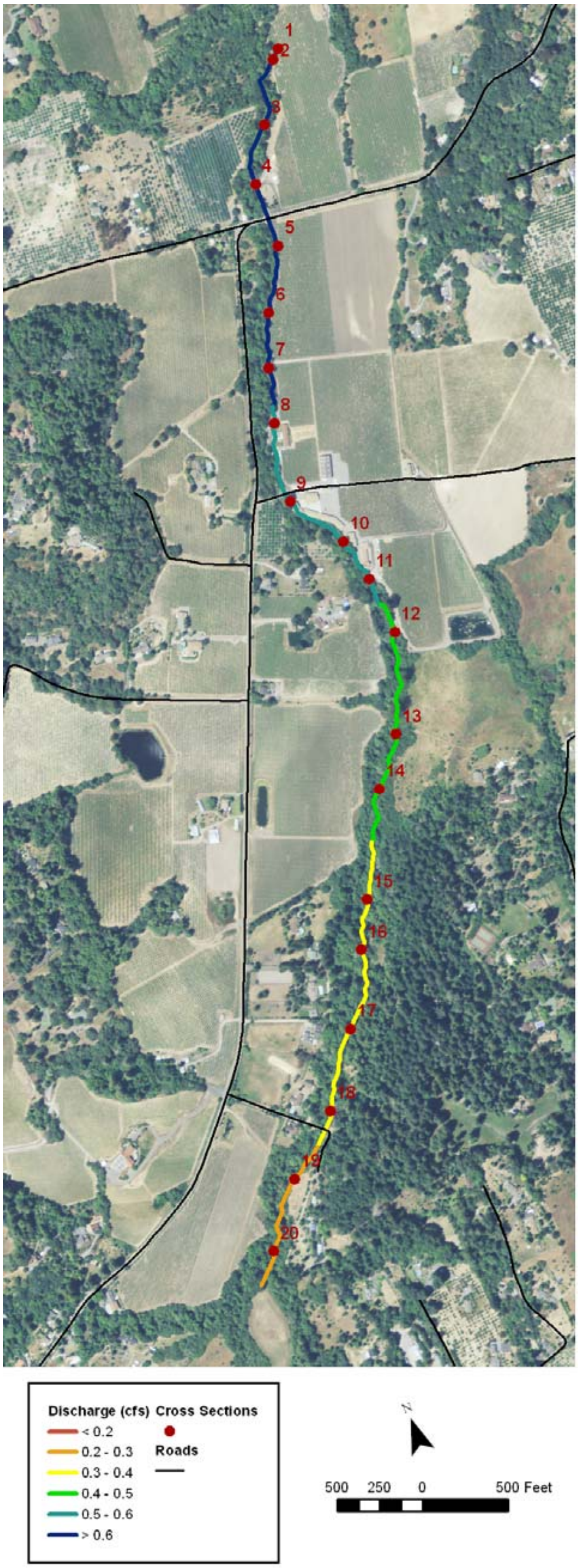


Figure F-3. Discharge classification for 50% exceedance flows.

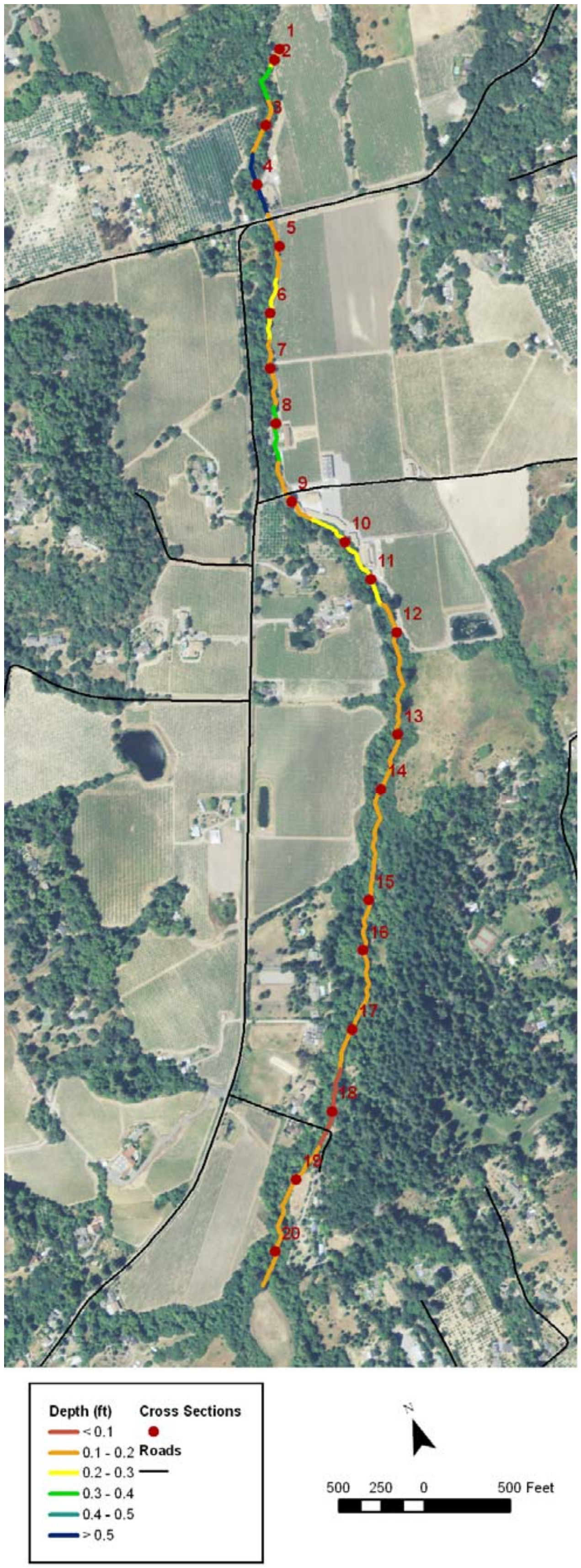


Figure F-4. Riffle depth classification for 90% exceedance flows.

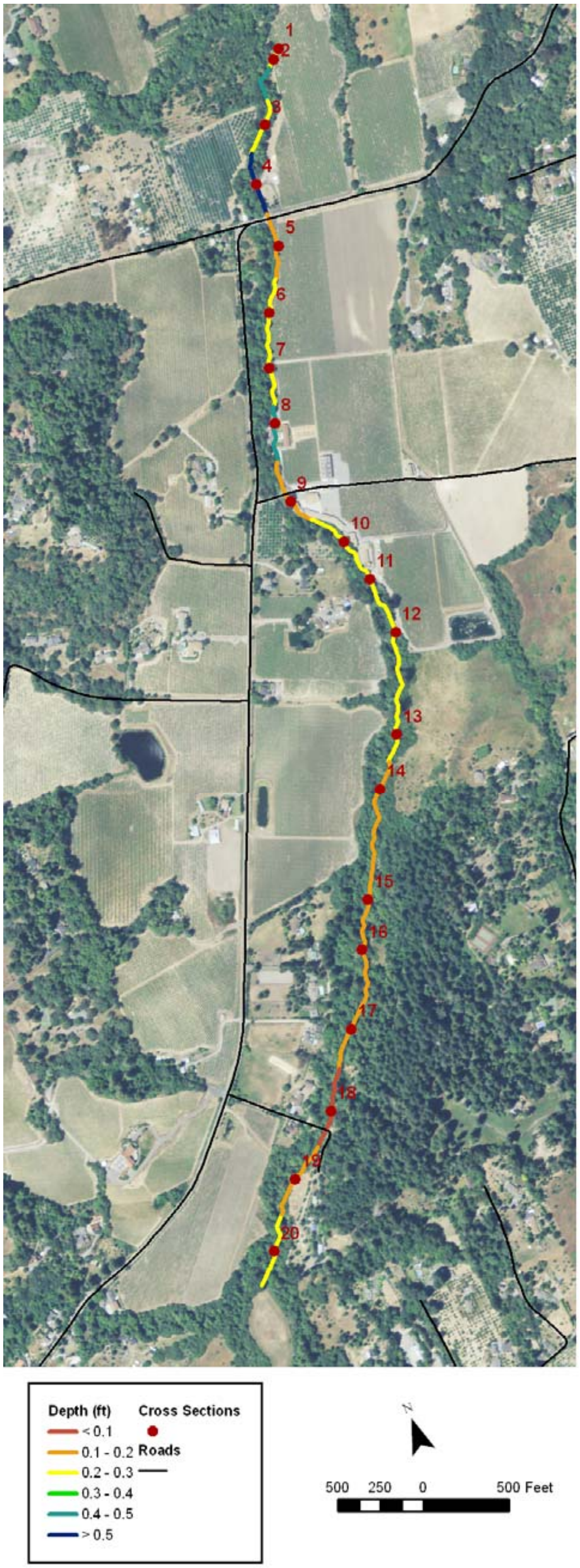


Figure F-5. Riffle depth classification for 50% exceedance flows.

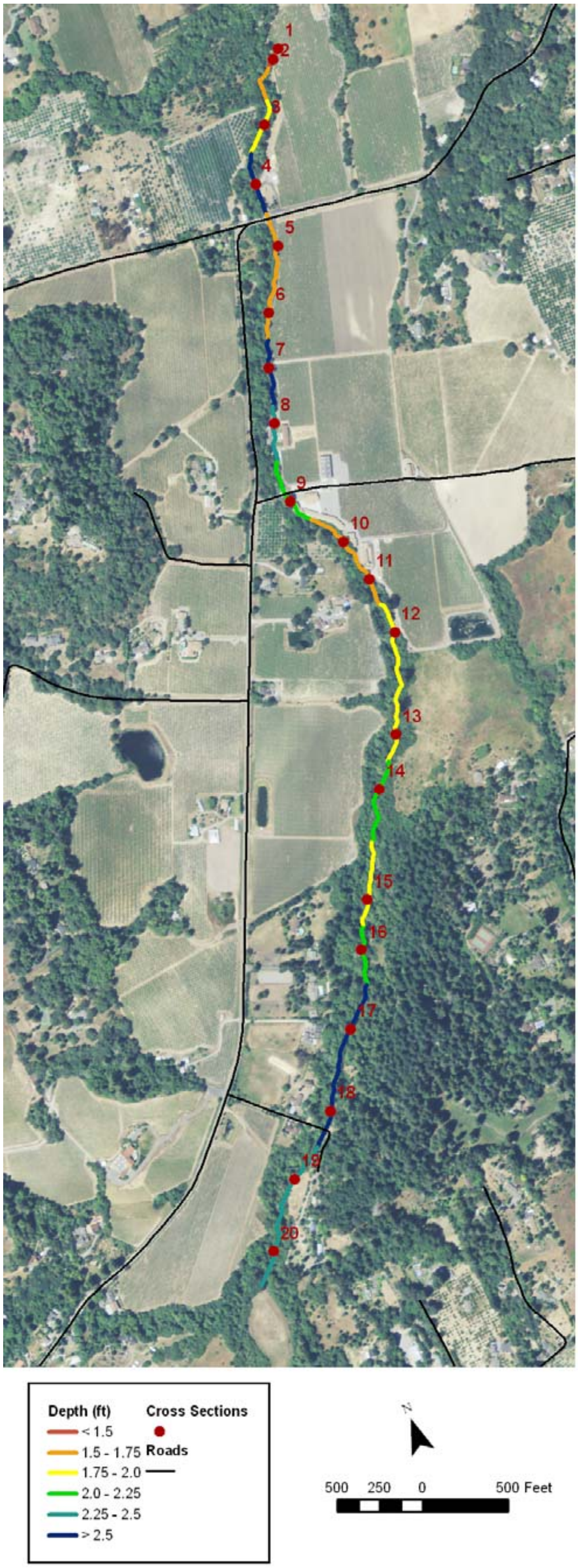


Figure F-6. Pool depth classification for 90% exceedance flows.

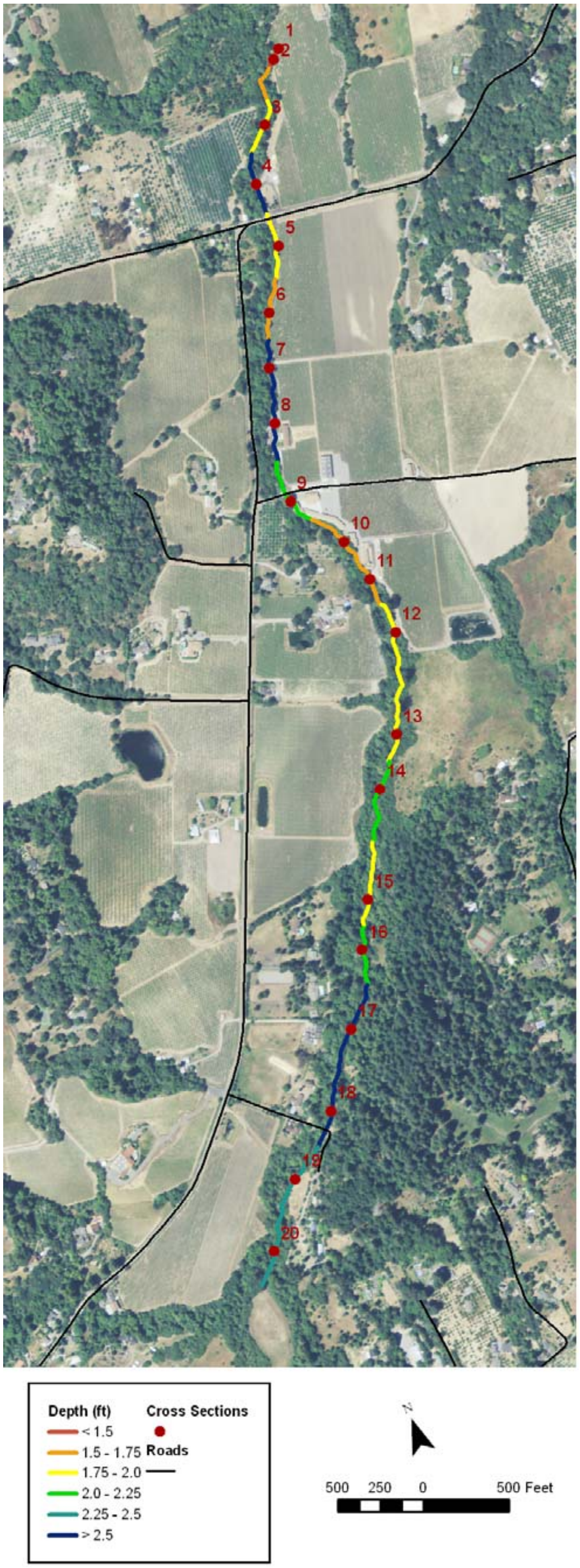


Figure F-7. Pool depth classification for 50% exceedance flows.

Hydraulic Modeling for Restoration Design

Introduction

A 2-dimensional hydraulic model was developed for a test reach of Purrington Creek in order to investigate the hydraulic effects of placing a series of log barbs along the margins of the creek. These structures are designed to serve a variety of purposes including increasing channel complexity, creating pools, promoting bar deposition and protecting streambanks that are susceptible to erosion. The model was used to evaluate various design configurations with respect to restoration objectives and to assess potential for increasing erosion on opposing banks.

Model Development

A 0.5-meter resolution topographic surface was interpolated from survey data at cross sections 11, 12, and 13 (a High Terrace/Alluvium reach-Figure F-1) to provide the basis for developing a 2-dimensional hydraulic model of a ~900-foot long reach of Purrington Creek using the MIKE 21 model code. The model was evaluated using constant inflow discharges of 100 cfs and 400 cfs. Downstream water-level boundary conditions were established based on the simulated water levels associated with these flows in the regional MIKE SHE model developed previously for the watershed. The model was first evaluated for existing conditions in order to quantify water depth, velocity, and shear-stress distributions associated with existing conditions and provide a baseline from which to compare the effects of the restoration design scenarios.

A total of 11 large woody barb structures were added to the model by modifying the existing condition model topography. Structures were first placed at the outside of meander bends and additional structures were then added in order to maintain a relatively uniform spacing. Structure spacing ranged from 45 to 85-ft (about two- to four-times the "bankfull" width). Structures were added to the model topography by placing the base of the structures at a height of 0.5-feet above the channel bottom based on guidance for design of barbs is provided in the National Engineering Handbook(USDA, 2010). *Table F-7* provides a comparison between the key design elements of the three design scenarios.

For Design Scenario A, the base of the structures were placed in the center of the channel bottom (equivalent to effective length of half the channel width see *Table F-7* for definition of effective length) and oriented at a 45 degree angle relative to the bank orientation pointing upstream. Design guidance recommends against effective length greater than a quarter of the channel width owing to high likelihood of bank erosion on the opposing bank; we implemented Scenario A to evaluate this guidance. The structures were then extended towards the channel banks at a slope of 1:4 until the structure elevations projected into the existing topography. This resulted in a variable structure length ranging from 10- to 50-ft depending on the existing bank topography.

For Design Scenario B, the base of the structures were placed one quarter of the distance across the channel (effective length of 0.25) between the bottom of the bank and the center of the channel bottom. The same 45 degree orientation was applied however the slope was increased to 1:2 in order to permit the structures to extend farther up the channel banks. Design criteria for barbs, traditionally built with rocks, recommend that the weir section of the barb be relatively flat (~ 1V:5H; referring to slope of vertical to horizontal), and steepen at the bank to ~1V:2H. This compound shape would be difficult to achieve using logs, so it has been modified to accommodate the use wood. This resulted in a variable structure length ranging from 8- to 60-ft depending on the existing bank topography.

For Design Scenario C, the structures had effective length 0.25 as in B, but were oriented at an 80 degree angle relative to the bank orientation and pointing upstream. They were projected towards the bank at a 1V:2H angle which resulted in a variable structure length ranging from 6- to 48-ft depending on the existing bank topography.

Table F-7. Barb design parameter for three design alternatives evaluated with the hydraulic model.

	Height Above Channel Bottom (ft)	Effective Length*	Orientation Relative to Bank (degrees)	Slope (rise/run)	Length (ft)
Design A	0.5	0.5	45	1:4	10 - 50
Design B	0.5	0.25	45	1:2	8 - 60
Design C	0.5	0.25	80	1:2	6 - 48

*proportion of channel width perpendicular to bank occupied by barb

Results and Conclusions

Water depth, velocity, and shear-stress distributions were compiled for each of the three design scenarios and compared to the existing conditions results in order to quantify the effects of the designs. Design scenario A resulted in significant increases in velocity and shear-stress on some opposing banks. For this reason as well as the fact that it violated design recommendations concerning the distance that the structure projects across the channel bottom, we removed this design from further consideration.

A comparison between existing condition velocities and velocities under Design B reveals that the structures result in decreases in velocity on the order of 0.5 to 1.5 ft/s immediately downstream (and typically upstream) of the structures and increases in velocity on the order of 0.25 to 1.0 ft/s adjacent to the structures (*Figure F-8*). This is consistent with the restoration design goals as the structures are effective at directing flow away from the banks where they are anchored and the changes in velocity are likely to promote scour and pool development adjacent to the structures and bar deposition downstream of the structures. Although modest increases in velocity occur on the opposing banks, the velocity values are not elevated above existing condition velocities at the banks where the structures are anchored and the velocity values are not high enough to cause concern.

The effects of the structures are similar though much more subtle under Design C (*Figure F-9*). Given the relatively small changes that occur under this scenario, Scenario B is the preferred alternative. A comparison between *Figures F-1 and F-3* serves to illustrate the effect of the structure orientation. Specifically, orienting the structures at a high angle relative to the flow direction greatly diminishes their effect on the flow and velocity field relative to orienting them at an angle closer to 45 degrees.

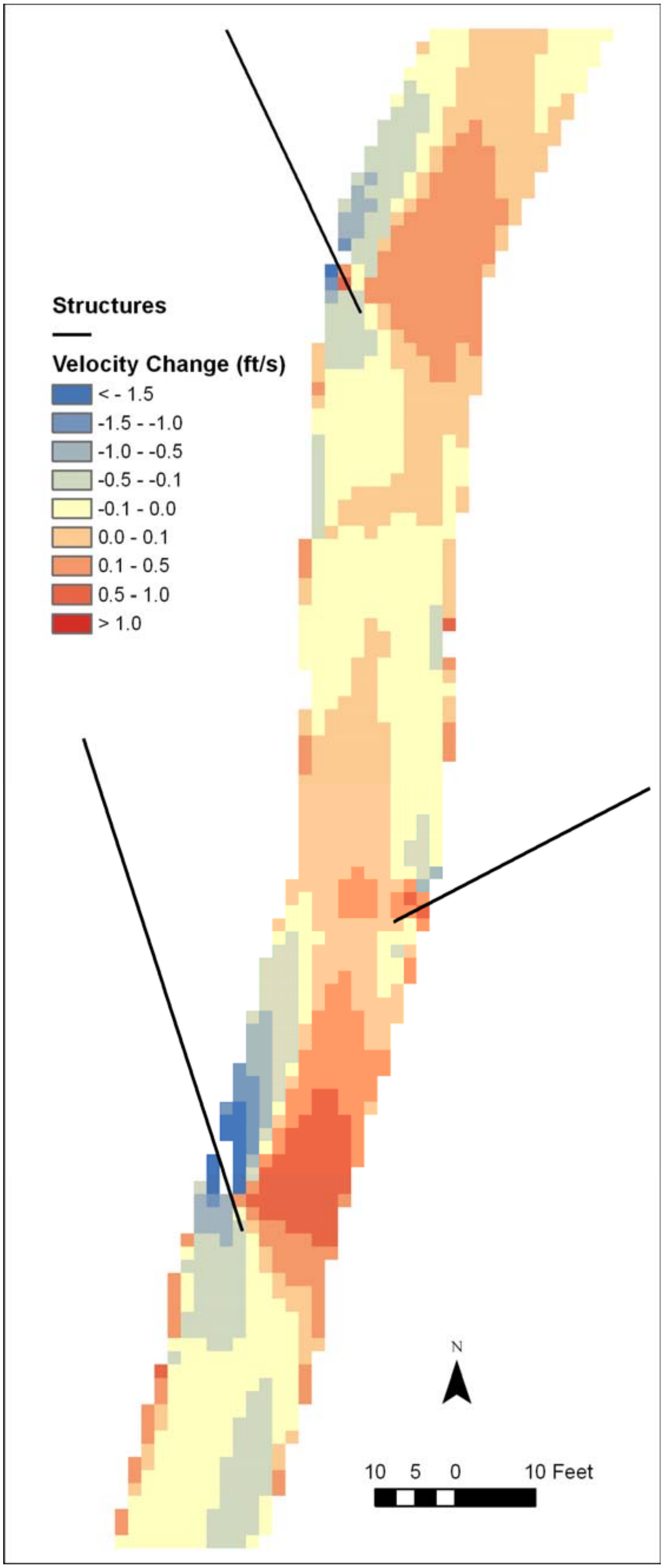


Figure F-8. Change in velocity under Design Scenario B for a sub-reach of the analysis.

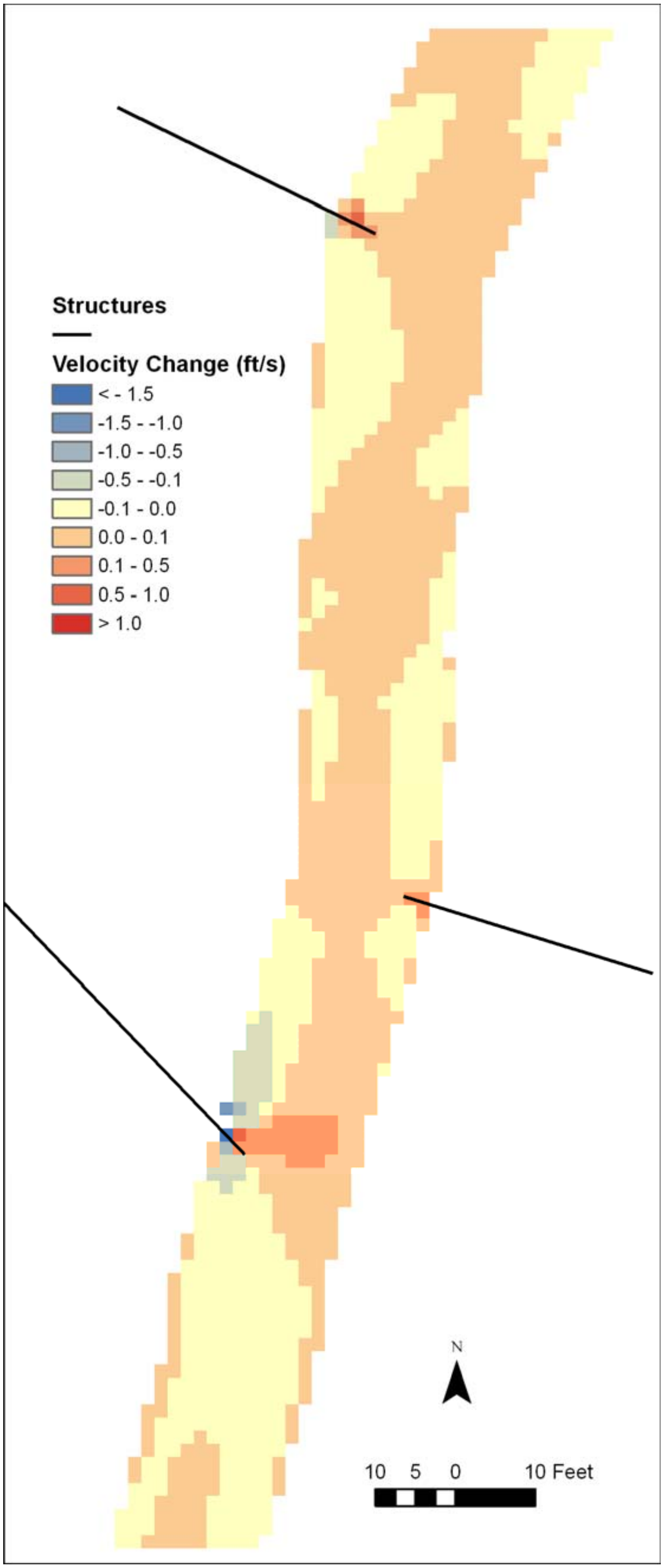


Figure F-9. Change in velocity under Design Scenario C for a sub-reach of the analysis.

G. Biological Resources of the Upper Green Valley Creek Watershed

Prepared by Jennifer Michaud and Joan Schwan, Prunuske Chatham, Inc.

Introduction

The Green Valley watershed supports a diverse assemblage of biological resources (*Figure G-1*). The watershed supports a number of native vegetation communities including coniferous forests, oak woodlands, and annual grassland, which in turn provide habitat for a numerous fish and wildlife species. Of particular importance within the watershed are instream and riparian habitats, which support the endangered coho salmon (*Oncorhynchus kisutch*) and California freshwater shrimp (*Syncaris pacifica*) and threatened steelhead trout (*O. mykiss*), as well as special-status northwestern pond turtle (*Actinemys marmorata marmorata*), California-red legged and foothill yellow-legged frogs (*Rana aurora* and *R. boylii*).

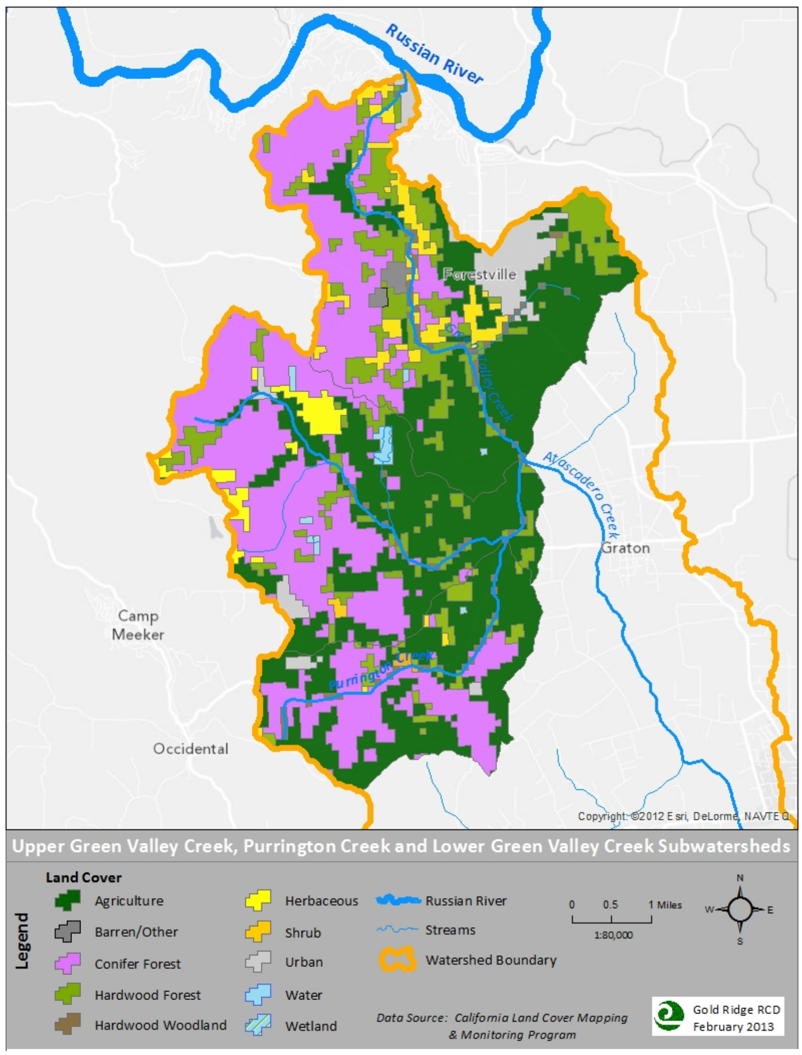


Figure G-1. Green Valley Watershed Land Cover and Vegetation Types

Habitat Changes in Green Valley Creek Watershed

Vegetation communities in Green Valley Creek have been altered over time due to land use practices such as logging, grazing, agriculture, and rural development. Logging was prevalent from the 1920s through the 1950s followed by extensive grazing (CDFG 2006a). Logging occurred in the upper watershed while grazing likely occurred in the lower watershed in grassland habitat. By the early 1900s, many of the natural grasslands and meadows had been converted to apple orchards; more recently, many of these orchards have since been converted to vineyards, particularly over the past 20 years (PWA 2008). Native oak woodlands and coniferous forests have also been converted to vineyard. Agricultural (vineyards and apple orchards) and rural residential development are the primary land uses within the study area (see *Figure A-4, Land Use in the Upper Green Valley and Purrington Subwatersheds*).

In addition to altering native vegetation communities, land use changes within the watershed have had a profound effect on instream habitat. Over the last few decades, land uses changes and various forms of development have caused accelerated erosion and sediment delivery to creeks. A detailed discussion of erosion and sediment and their effects is provided in Chapter II, Section D.

Existing Communities

Existing communities of the Upper and Lower Green Valley Creek and Purrington Creek subwatersheds include forests, woodlands, riparian and aquatic habitats, grasslands, and agricultural lands. The relatively steep western hills support coast redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) forest. Lower in these hills, forest composition changes and oaks (*Quercus spp)*, California bay (*Umbellularia californica*), and madrones (*Arbutus sp*.) become more dominant. Patches of endemic chaparral and Sargent cypress (*Cupressus sargentii*) are found in association with outcroppings of serpentine rock. Most of the gentler terrain of the eastern Upper Green Valley Creek watershed is used for agricultural and residential purposes. Occasional mature oaks dot these landscapes, remnants of what was probably extensive oak woodland and native grassland in historic times. Threats to the remaining upland habitat include habitat loss and fragmentation due to development, spread of invasive species, and Sudden Oak Death (SOD)[5] infestations.

[5] Sudden Oak Death – a tree disease caused by the pathogen *Phytophthora ramorum*

Coast redwood trees. Photo courtesy of Joan Schwan.

As noted above, the existing vegetation communities support a number of special-status species, including both plants and animals. Special-status species occurrences are noted below under the appropriate community discussion. Further life history and listing status information is provided in the *Special-status Species* section that follows. Although the characteristic assemblages of species occur predictably within certain vegetation types, it should be recognized that relatively few species are restricted to a single habitat, and indeed some species may require more than one habitat type.

Coniferous Forest

Coast redwood and Douglas-fir forest occur in the upper reaches of the watershed. Redwoods are found in moister areas, while Douglas-fir dominates drier sites. Many of these lands have been logged or cleared for other purposes in the past, and now support younger forests. In mature stands, these large conifers create a dense canopy and the understory is often sparse. Common understory species include shade-tolerant plants including sword fern (*Polystichum munitum*) and false Solomon's seal (*Smilacina racemosa*). In younger, more open stands with a history of disturbance such as logging, other woody species can also be abundant. These include coast live oak (*Quercus agrifolia*), California bay, tanoak (*Lithocarpus densiflorus*), poison oak (*Toxicodendron diversilobum*), and wood rose (*Rosa gymnocarpa*). No special-status plant species have been documented in the coniferous forests of the watershed (CDFG 2010).

Several invasive species occur in the watershed's redwood and Douglas-fir forests, particularly at forest edges where human activities have disturbed the ground or where landscape plants have escaped from cultivation. Periwinkle (*Vinca major*) and Himalayan blackberry (*Rubus discolor*) are examples of two aggressive species that can inhibit native plant regeneration. Redwood and Douglas-fir forest supports a high abundance of wildlife species. Representative bird species found in this habitat include chestnut-backed chickadee, band-tailed pigeon, northern spotted owl, pileated woodpecker, hairy woodpecker, Steller's jay, brown creeper, winter wren, golden crowned kinglet, hermit thrush, dark-eyed junco, and purple finch. Typical mammals include deer mouse, dusky-footed woodrat, Douglas's squirrel, and Trowbridge's shrew. Large trees and snags provide prime habitat for a number of local bat species. A number of common amphibians also inhabit the coniferous forests of the watershed. Ensatina, California giant salamander, and California slender salamander can be found in moist, protected places under logs or forest litter. Special-status animals documented in the coniferous forests of the western portion of the watershed include northern spotted owl (*Strix occidentalis caurina*) and Sonoma tree vole *(Arborimus pomo)* (CDFW 2013).

Hardwood Forest/Woodland

At lower elevations, redwood and Douglas-fir forests give way to mixed woodlands of oaks (coast live oak; black oak, *Q. kelloggii*; and Oregon oak, *Q. garryana*), California bay, tanoak, and madrone (*Arbutus menziesii*). Like the coniferous forests of the watershed, these woodlands have undergone many changes due to historic land use practices. Clearing for agricultural and residential development and firewood harvesting has fragmented and reduced the extent of oak and bay forests in the watershed. SOD has infected bays and killed tanoaks and live oaks in the watershed (UC Berkeley 2010).

The understory of the watershed's hardwood forests and woodlands include a variety of shrubs and vines, including poison oak, snowberry (*Symphoricarpos albus*), California rose (*Rosa californica*), toyon (*Heteromeles arbutifolia*), coffeeberry (*Rhamnus californica*), and honeysuckle (*Lonicera hispidula*). Annual grasses and forbs, as described in the grasslands section below, are also abundant. In places protected from disturbance, native herbaceous species including California fescue (*Festuca californica*), blue wildrye (*Elymus glaucus*), miner's lettuce (*Claytonia perfoliata*), and Douglas iris (*Iris douglasiana*) can be found. No special-status plant or animal species have been documented in the hardwood forests and woodlands of the watershed (CDFG 2010).

Invasive species that occur in the mixed woodlands of the watershed include Himalayan blackberry, Scotch broom (*Cytisus scoparius*), and French broom (*Genista monspessulana*). In some locations, English ivy (*Hedera helix*) both carpets the ground and grows up the trunks of many native trees, suppressing their growth and preventing regeneration.

Forest and woodland habitats provide nesting opportunities, food, and shelter and may serve as corridors or islands during migration for a variety of wildlife species. Common bird species include chestnut-backed chickadee, ruby and golden-crowned kinglets, Steller's and western-scrub jays, American robin, acorn woodpeckers, and common bushtit. The understory also provides foraging and nesting habitat for ground-dwelling species such as the California towhee, California quail, dark-eyed junco, and spotted towhee. Large trees and snags (i.e., dead or dying trees) provide nesting opportunities for cavity-nesting birds and serve as acorn granaries for acorn woodpeckers and provide potential roosting sites for various bat species in the crevices and tree hollows found throughout the watershed.

Mixed woodlands of the watershed support a number of mammalian species. The understory and tree cavities provide escape, cover, and nesting sites. Some of the most commonly observed mammals include western gray squirrel, dusky-footed woodrat, northern raccoon, and black-tailed deer. Woody debris piles and layers of duff provide habitat for amphibians such as California slender salamander and Ensatina. Additional amphibians, including arboreal salamanders, newts, and western toad, use forested and woodland habitats during the non-breeding season. Common reptiles of these communities include western fence lizard, alligator lizard, and gopher and garter snakes.

Serpentine Chaparral and Cypress Forest

Sargent cypress © Christopher L. Christie.

Chaparral and other shrub-dominated plant communities are not abundant in this area, but chaparral does occur on one region of serpentine-derived soils in the western part of the watershed. Serpentine soils have unusual levels of some minerals important to plant survival and growth; as a result, serpentine plant communities are often unusually rich in native and endemic species. A serpentine area spanning Harrison Grade Road supports a unique suite of native plant species (McCarten 1987). Part of the area is dominated by a stand of Sargent cypress, a closed-cone conifer which depends on fire to release seeds from cones and to prepare the soil surface for germination (Esser 1994). The other dominant vegetation is serpentine-adapted chaparral, including Jepson ceanothus (*Ceanothus jepsonii*) and two special-status plant species, Baker's manzanita (*Arctostaphylos bakeri* ssp. *bakeri*) and Pennell's bird's-beak (*Cordylanthus tenuis* ssp. *capillaris*).

Both Baker's manzanita and Pennell's bird's-beak occur only in Sonoma County; Baker's manzanita is known from only eight occurrences, and Pennell's bird's-beak is known from only four. Both are considered threatened by road maintenance, non-native plants, dumping of trash, and development of private parcels (CNPS 2010). A portion of this unique serpentine habitat is owned and protected by the California Department of Fish and Wildlife (CDFW 2013). One additional special-status plant species, Greene's narrow-leaved daisy (*Erigeron greenei*), was documented historically in serpentine or volcanic chaparral of the watershed, but has not recently been observed.

Chaparral provides habitat for a wide variety of wildlife adapted to shrub-dominated communities. Numerous rodent species inhabit chaparral, and deer and other herbivores make extensive use of it for browse and protective cover. Some small herbivores use chaparral species in fall and winter when grasses are not abundant. Brush rabbits eat twigs, evergreen leaves, and bark from chaparral plants. Shrubs are important to many other mammals (e.g., bobcat, gray fox) as shade during hot weather. Reptiles frequently observed in chaparral include western fence lizard, alligator lizard, and gopher snake. Chaparral provides for a variety of habitat needs for birds in the form of seeds, fruits, insects, and protection from predators and climate, as well as singing, roosting, and nesting sites. Typical birds found in chaparral include California quail, Anna's hummingbird, Bewick's wren, spotted towhee, western scrub-jay, common bushtit, and California thrasher.

Grassland and Agriculture

Most lower elevations in the Green Valley Watershed have been developed for agricultural and rural residential uses. Vineyards, orchards, livestock pasture, and other agricultural lands are common. Historically, this part of the watershed probably supported oak woodland interspersed with native grassland. Today, mature native trees including coast live oak, black oak, and Oregon oak occur in undisturbed locations, but little native grassland remains in this agriculturally-productive area. Where grassland remains, it is dominated by non-native annual species. Many of these species were introduced from the Mediterranean during the Mexican and American expansion into California. Historic disturbances, including livestock grazing and clearing for agriculture, facilitated the conversion of native perennial grassland and savanna to annual grassland.

California poppy. Photo courtesy of Jennifer Michaud.

Typical non-native grass species include wild oats (*Avena* spp.), ripgut brome (*Bromus diandrus*), ryegrass (*Lolium multiflorum*), and velvetgrass (*Holcus lanatus*). Common forbs found in these grasslands include non-native filaree (*Erodium* spp.), cut-leaf geranium (*Geranium dissectum*), bur-clover (*Medicago polymorpha*), vetch (*Vicia* spp.), and clovers (*Trifolium* spp.). A few hardy native grasses and forbs remain in less-disturbed locations, including California oatgrass (*Danthonia californica*), purple needlegrass (*Nassella pulchra*), California poppy (*Eschscholzia californica*), soaproot (*Chlorogalum pomeridianum*), and California buttercup (*Ranunculus californicus*). Occasional native shrubs including coyote brush (*Baccharis pilularis*) and California rose can be found in the grasslands. No special-status plant or animal species have been documented in the grasslands of the watershed (CDFG 2010).

Invasive species of particular concern in the watershed's grasslands include Himalayan black berry and velvetgrass. Historic plantings of eucalyptus (*Eucalyptus* spp.) and acacia (*Acacia dealbata*) are common and often spread into wildlands. Pampas grass (*Cortaderia jubata*), Scotch broom, and French broom are common along roadsides.

Annual grasslands and edges of agricultural fields provide habitat and foraging opportunities for a range of common wildlife species. Grasses, low-growing shrubs, and associated invertebrates provide foraging opportunities for a variety of ground-foraging birds, such as American robin, sparrows (e.g., white-crowned, golden-crowned, song), dark-eyed junco, western bluebird, western meadowlark, and numerous other resident and migratory birds. Predatory hawks, including northern harrier, American kestrel, and white-tailed kite, frequent these areas as well. Small vertebrates and invertebrates within the habitat serve as a food source for these birds and other predatory vertebrates. Subterranean foragers, such as Botta's pocket gopher and California mole, commonly occur in grasslands of the watershed. In addition, small mice (e.g., deer and harvest), California vole, black-tailed jackrabbit, coyote, and black-tailed deer are frequently observed. Reptiles of this community include western fence lizard, alligator lizard, California king snakes, gopher snakes and common garter snakes. Bat species also forage over grasslands.

Rural Residential Areas

The upper watershed contains significant rural residential development. While these areas have been moderately developed, vegetation remains an important component of the landscape and wildlife continues to use some areas. The lower watersheds does as well, with the exception of the more densely developed urban areas of Graton and Forestville. Occasional mature oaks and disturbance-adapted shrubs such as coyote brush occur naturally in places. Landscaping typically consists of a mixture of native and nonnative trees, shrubs, and groundcovers. Ornamental landscaping includes a wide range of introduced species that provide shade and contribute to the aesthetics of the landscape.

Several highly invasive plant species occur in developed areas. Of particular concern in this watershed are Himalayan blackberry, acacia, periwinkle and English ivy, all of which can spread into nearby undeveloped lands.

The wildlife habitat values of the rural residential and urbanized parts of the watershed are generally lower than those of surrounding natural habitats. Roads, turf, and routine landscape maintenance limit protective cover and opportunities for movement and foraging. Wildlife in these developed areas are more acclimated to human activity, and include species such as western scrub-jay, mourning dove, house sparrow, American robin, northern mockingbird, American crow, Norway rat, house mouse, northern raccoon, and Virginia opossum. Mature trees do provide roosting and potential nesting substrate for many species of birds, particularly where they occur in close proximity to open space, riparian corridors, and native woodlands. Fruit trees provide supplemental food for wildlife, and landscape shrubs can provide nesting habitat for generalist bird species, including the house finch and Anna's hummingbird.

Riparian Woodlands and Wetlands

Riparian woodlands are an important component of a healthy watershed. This community includes those plants species occurring along a narrow corridor adjacent to a stream channel. Healthy and intact riparian habitat provides streambank protection, erosion control, and improved water quality. Within the Green Valley Creek watershed, much of the overstory vegetation in the riparian zone consists of alders (*Alnus* spp.) and willows (*Salix* spp.). Other trees present include California bay, Douglas-fir, boxelder (*Acer negundo*), and big-leaf maple (*Acer macrophyllum*). Shrubs and herbaceous plants found in the understory include dogwood (*Cornus sericea*) and poison oak. While many trees line the creek, the riparian corridor has been encroached upon by residential and agricultural development, leaving only a thin strip in most locations and none in others. In addition, in many reaches the ability for riparian trees to regenerate has been impacted by stream incision and the resulting disconnection of the stream from its floodplain

Patches of seasonal wetland occur in low-lying areas along the stream corridors and within shallow upland depressions and seeps. Plants typically found in these areas include common rush (*Juncus patens*), meadow barley (*Hordeum brachyantherum*), and spikerush (*Eleocharis macrostachya*). Historically, wetland habitat within the watershed supported a number of rare plant species, including federally endangered Sonoma alopecurus *(Alopecurus aequalis* var. *sonomensis)*, as well as saline clover *(Trifolium depauperatum* var. *hydrophilum)*. With agricultural and residential development, marsh habitat has declined, and none of these species has been documented in recent times.

The following includes a general discussion of the wildlife communities associated with riparian woodlands and instream habitat; further discussion of the physical properties is provided below. In general, riparian woodlands and stream channels such as those occurring within the watershed provide nesting opportunities, food, and shelter and may serve as corridors or islands during migration for a variety of wildlife species. Birds represent the most abundant and prominent wildlife species. Common bird species found in the riparian habitat of the watershed include red-tailed hawk, American kestrel, acorn woodpecker, Nuttal's woodpecker, common bushtit, winter wren, American robin, yellow-rumped warbler, spotted towhee, California towhee, western scrub-jay, fox sparrow, song sparrow, white-crowned sparrow, golden-crowned sparrow, California quail, hooded merganser, and turkey vulture (Madrone Audubon Society 1999).

Riparian woodland and instream habitats support a number of mammalian species. The understory and tree cavities provide escape, cover, and nesting sites. The presence of a large number of vertebrate species may serve as a significant food source for larger predatory mammals (e.g., bobcat and gray fox). Some of the most commonly observed mammals include western gray squirrel, dusky-footed woodrat, northern raccoon, and black-tailed deer. In addition, common bat species may forage over this habitat.


Riparian area. Photo courtesy of Diana Hines.

Woody debris piles and layers of duff provide habitat for amphibians such as California slender salamander and Ensatina. Additional amphibians, including arboreal salamanders, newts, and western toad, may utilize uplands during the nonbreeding season. Common reptiles of these communities include western fence lizard, alligator lizard, and snakes (e.g., gopher and garter snakes).

The creeks are an important community for a variety of aquatic organisms. Aquatic salamanders (e.g., rough-skinned and California newts, California giant salamander) utilize channels seasonally. Macroinvertebrates (e.g., waterstrider ,*Gerris sp*., water boatman, *Corisella sp.)* serve as the food base for terrestrial and other aquatic species. Fish are abundant, and the creeks support several species of state and federally protected anadromous salmonids (i.e., coho salmon and steelhead). Special-status northwestern pond turtles, foothill yellow-legged frogs, and California freshwater shrimp are also known to occur within the watershed.

Special-status Species

In California, special-status plants and animals include those species that are afforded legal protection under the federal and California Endangered Species Acts (ESA and CESA, respectively) and other regulations. Consideration of these species must be included during project evaluation in order to comply with the California Environmental Quality Act[6] (CEQA), in consultation with State and federal resources agencies, and in the development of specific management guidelines for resource protection.

Special-status plants and animals of California include, but may not be limited to:

- Species listed or proposed for listing as threatened or endangered under the federal ESA.
- Species listed or proposed for listing as threatened or endangered under the California ESA.
- Species that are recognized as candidates for future listing by agencies with resource management responsibilities such as U.S. Fish and Wildlife Service, NOAA's National Marine Fisheries Service (NMFS), and California Department of Fish and Wildlife (CDFW).
- Species defined by CDFW as California Special Concern species.
- Species classified as Fully Protected by CDFW.
- Plant species, subspecies, and varieties defined as rare or threatened by the California Native Plant Protection Act (California Fish and Game Code Section 1900 et seq.).
- Plant species listed by the California Native Plant Society as List 1 and 2 and some List 3 plants under CEQA (CEQA Guidelines, Section 15380).
- Species that otherwise meet the definition of rare, threatened, or endangered pursuant to Section 15380 of the CEQA Guidelines.

[6] Projects undertaken, funded, or requiring a permit by public agency must comply with the California Environmental Quality Act (CEQA). The primary purpose of CEQA is to inform decision makers and the public about the potential environmental impacts of the proposed activities.

Background Research

A background literature and database search was conducted to provide a comprehensive list of all special-status species with documented occurrences in the watershed. The review focused on California Natural Diversity Data Base (CNDDB) maintained by the California Department of Fish and Game (CDFG) for reported occurrences of sensitive plants, animals, and communities; however, additional relevant studies and reference materials were also consulted. The background literature review identified the potential presence of 5 special-status plants within these watersheds (*Table G-9. Special-status Plants of the Green Valley Creek Watershed*). A number of special-status animals were also identified based on reported occurrences within the watershed and/or high probability of occurrence based on the presence of suitable habitat and known occurrences within the region. Special-status animals of the watershed are described in the text below including listing status and general habitat/life history descriptions (Zeiner et al. 1990).

Special-status Plants

Table G-9. Special-status Plants of the Green Valley Creek Watershed

Common Name *Scientific Name*	**Listing Status FEDERAL/ STATE/ CNPS**	**Life Form, Blooming Period, and General Habitat**
Sonoma alopecurus *Alopecurus aequalis var. sonomensis*	FE/--/List 1B.1 (Seriously endangered in California)	Perennial herb. Blooms May-July. Freshwater marshes and swamps, riparian scrub. 5-365 m.
Baker's manzanita *Arctostaphylos bakeri ssp. bakeri*	--/SR/List 1B.1 (Seriously endangered in California)	Perennial evergreen shrub. Blooms February-April. Chaparral, often serpentinite. 75-300 m.
Pennell's bird's-beak *Cordylanthus tenuis ssp. capillaris*	FE/SR/List 1B.2 (Fairly endangered in California)	Annual herb, hemiparasitic. Blooms June-September. Closed-cone coniferous forest, chaparral (serpentinite). 45-305 m.
Greene's narrow-leaved daisy *Erigeron greenei*	--/--/List 1B.2 (Fairly endangered in California)	Perennial herb. Blooms May-September. Chaparral, often serpentinite or volcanic. 80-1005 m.
saline clover *Trifolium depauperatum* var. *hydrophilum*	--/--/List 1B.2 (Fairly endangered in California)	Annual herb. Blooms April-June. Marshes and swamps, valley and foothill grassland (mesic, alkaline), vernal pools. 0-300 m.

STATUS CODES:

FEDERAL:
FE = Listed as endangered (in danger of extinction) by the federal government
FT = Listed as threatened (likely to become endangered within the foreseeable future) by the federal government

STATE OF CALIFORNIA:
SE = Listed as endangered by the State of California
ST = Listed as threatened by the State of California
SR = Listed as rare by the State of California

Special-status Animals

Northern spotted owl. The northern spotted owl (*Strix occidentalis caurina*) is federally listed as threatened and State listed as a California Species of Special Concern. It is an uncommon permanent resident of dense forest habitats in northern California and oak and oak-conifer habitats in southern California. This nocturnal species requires dense, multi-layered canopy cover for roosting sites. Spotted owls feed upon a variety of small mammals, birds, and large arthropods. Nest sites include tree or snag cavities or broken tops of large trees. The breeding period lasts from early March through June with two offspring typically produced each season. A pair of owls may utilize the same breeding site for 5 to 10 years; however, they may not breed every year. Individual territories are typically several hundred acres. The spotted owl has experienced a population decline due to the loss and degradation of existing mature and old growth forests. They are a fairly common permanent resident in Sonoma County where they occupy "old-growth coniferous forests of redwood, Douglas-fir or pines blended with smaller evergreen hardwoods" (Burridge 1995).

Northern spotted owl. Photo courtesy of Gerald and Buff Corsi, California Academy of Sciences.

Occurrence within the watershed. According to the CNDDB, there is documented occurrence of a spotted owl territory within the Purrington Creek subwatershed (CDFW 2013; see *Map 8, Special-status Species Locations*). There are also reported occurrences within the surrounding watersheds in dense forested habitats. Spotted owls may occupy the denser, multi-story habitats of the watershed beyond what is currently reported.

Sonoma tree vole. The Sonoma tree vole (*Arborimus pomo*) is a California Species of Special Concern. It occurs in coniferous forest in humid areas where it is reported to be rare or uncommon. They are largely nocturnal and active year-round. Their home range generally consists of one to several fir trees. Within California, they primarily feed on the needles of Douglas-fir. Needle resin ducts are removed before eating and often used to line the nest cup.

Nests are typically constructed from 6 to 150 feet above ground preferably in tall trees and located on outer branches or on whorl of limbs against the trunk. Breeding occurs year-round, with peak activity from February to September. The primary predators of voles are spotted owls, saw-whet owls, and possibly raccoons.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of Sonoma tree vole within forested habitats at the boundary of the Purrington Creek and Dutch Bill Creek watersheds. They are also known to occur within the lower Green Valley Watershed in the vicinity of the Canyon Rock Quarry in Forestville (J. Michaud personal observation) and within the surrounding watersheds (i.e., Dutch Bill and Salmon Creeks). Sonoma tree vole may occur throughout the older Douglas-fir forests of the watershed.

Northwestern pond turtle. The northwestern pond turtle *(Actinemys marmorata marmorata)* is listed as a California Species of Special Concern by CDFG and one of two distinct subspecies of the western pond turtle (*A. marmorata*). The western pond turtle occurs from Washington south to Baja, Mexico. The northwestern subspecies occurs from the San Francisco Bay north, and the southwestern pond turtle (*A. m. pallida*) occurs from the San Francisco Bay south. There is a zone of intergradation between the two subspecies throughout San Francisco Bay and the San Joaquin Valley. It is the only native turtle in the North Bay region.

Pond turtles are most commonly found in or near permanent or semi-permanent water sources in a variety of suitable habitats throughout their range. Western pond turtles can be observed basking in the sun on the banks of ponds or on logs floating on the surface of the water. They appear to be sensitive to sound and will dive underwater when approached too closely. In water, they prefer wood structures that provide underwater refugia from predators. During winter, they often burrow under logs and other suitable structures for extended periods.

Male northwestern pond turtle. Photos courtesy of Jennifer Michaud.

The size of pond turtle varies from 3.5 to 7 inches length. The upper shell is olive, dark brown, or blackish in color, occasionally without pattern but usually with a network of spots, lines, or dashes of brown or black. The underside is yellowish tan. Pond turtles nest from May to August with peek activity occurring from June to July (Bash 1999). The nests are usually located in full sunlight in dry, well-drained soils, with grass, herbaceous vegetation, shrubs, and trees nearby (Hays et al. 1999). The young hatch the following spring. Western pond turtle populations have decreased due to a combination of overharvesting for food (from the late 1800s to the 1930s), habitat loss, and predation by non-native species (Bash 1999). Juvenile pond turtles are susceptible to predation by non-native species such as bullfrogs and largemouth bass (Bash 1999). Habitat loss due to urbanization, the drainage of wetlands for agriculture or development, and the alteration of watercourses has also contributed to the decline of this species. Fire suppression, water diversion projects and grazing may have altered riparian vegetation, creating habitat less suitable for turtles.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of northwestern pond turtles in the upper portion of Atascadero Creek (CDFG 2010; see *Map 8 Special-status Species Locations*). They are also known to occur in the surrounding watersheds and are relatively abundant along the mainstem Russian River. While there are limited reported observations within the general area, pond turtles are likely abundant in off-channel reservoirs, ponds, and along stream channels throughout the watershed.

Foothill yellow-legged frog. The foothill-yellow legged frog (*Rana boylii*) is a California Species of Special Concern with CDFG. They occur from southern Oregon south to the Salinas River in Monterey County, California, and in isolated patches in the Cascade and Sierra Nevada foothills. These frogs are moderately sized with adults ranging from 1 ½ to 3 inches in length (Jennings and Hayes 1994). Coloration is highly variable ranging from dark to light gray, brown, green, or yellow with a somewhat mottled appearance (Jennings and Hayes 1994). The lower belly and undersurfaces of the legs are yellow or orange/yellow. They are found in or near partly shaded rocky streams from near sea level to 6,300 feet in a

Foothill yellow-legged frog. Photo courtesy of Jennifer Michaud.

variety of habitats. Breeding generally occurs from mid-March to early June after high winter flows have subsided. Egg masses are attached to the downstream side of rock and gravel in shallow, slow, or moderate-sized streams. Tadpoles require three to four months to attain metamorphosis. Adults feed on aquatic and terrestrial invertebrates, and tadpoles graze along rocky stream bottoms on algae and diatoms. During all seasons, this species is generally found in or within close proximity to streams. Garter snakes are the principle predators of tadpoles, juvenile, and adults. Eggs are eaten by non-native centrachid fish such as bass and sunfish.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of foothill yellow-legged frogs along Upper Green Valley Creek, above the confluence with Atascadero Creek (CDFG 2010; see *Map 8, Special-status Species Locations*). While there are limited reported observations outside of this area, foothill yellow-legged frogs are likely abundant along stream channels throughout the watershed where suitable habitat exists.

California red-legged frog. The California red-legged frog (*Rana draytonii*) is federally listed as threatened and a California Species of Special Concern with CDFG. They were federally listed as threatened in 1996 due to a significant decline or extirpation throughout most of their range primarily due to habitat loss and introduced predators [i.e., nonnative American bullfrog (*Rana catesbeiana*) and predatory fish (i.e., sunfish (*Lepomis sp*.)]. Historically, they occurred throughout the foothills of the Central Valley and coastal drainages from Marin County to Baja Mexico (Cook 1997). Most remaining populations are restricted to coastal watersheds from the San Francisco Bay area south to Ventura County (Jennings and Hayes 1994).

California red-legged frog. Photos courtesy of Jennifer Michaud.

The red-legged frog is the largest frog native to California, reaching up to 5 inches in length. They have brown or reddish brown to dark brown on the dorsal side of their body and red on the underside of their hind limbs and on the lower abdomen and underside of their hind legs, often overlying yellow ground color. One key characteristic used to identify this species is a skin fold running from the back of the eye to the posterior end called the dorsolateral fold. Red-legged frogs inhabit streams that typically consist of small pools with emergent and overhanging vegetation such as willow (*Salix* spp.) and marshes with emergent vegetation [i.e., cattail (*Thypa* spp.) and bulrush (*Scirpus* spp.)]. They also frequent livestock pond, reservoirs, and other bodies of water with emergent vegetation and free of predatory fish and bullfrogs. Breeding occurs from November through April depending on the location. Egg masses are attached to emergent vegetation near the water's surface. Tadpoles require 3.5 to 7 months to attain metamorphosis. Adults take invertebrates and small vertebrates. Larvae are thought to be algal grazers.

Occurrence within the watershed. California red-legged frogs are known from a small area just outside the watershed boundary, within an approximate one-mile radius (CDFG 2010) and there is anecdotal information of an unconfirmed sighting within the watershed. While there have been few documented occurrences within the watershed or surrounding areas, private ponds and off-channel reservoirs likely support this species and they could be more widely distributed than is currently documented.

California freshwater shrimp. The California freshwater shrimp (*Syncaris pacifica*) is federally and State listed as endangered. The shrimp is endemic to Marin, Sonoma and Napa counties north of San Francisco Bay, California and currently occupies 23 coastal streams in this area including Green Valley Creek (USFWS 2007). These shrimp are typically found in low elevation (less than 380 feet) low gradient streams (generally less than 1%) (USFWS 1998). The habitat usually consists of perennial freshwater or intermittent streams with perennial pools with undercut banks, exposed roots, and overhanging vegetation or woody debris.

California freshwater shrimp. Photo courtesy of Bill Cox.

California freshwater shrimp are small crustaceans and adults are typically about two inches in length from eye orbit to the tip of the tail. Coloration is variable – females have been found with a dark brown to purple color while males are typically translucent to transparent. The shrimp have the unique ability to darken their bodies to create the illusion that they are submerged, decaying vegetation. They accomplish this with small surface and internal color-producing cells clustered in a pattern to help disrupt their body outline (USFWS 1998). Mating occurs around September and by November most females are bearing eggs. The eggs stay attached to the female throughout the winter incubation period. Young are released in May or early June and grow rapidly. California freshwater shrimp live for about three years. Population declines have occurred due to many factors including deterioration or loss of habitat resulting from water diversion, impoundments, agricultural activities and developments, flood control activities, timber harvesting, migration barriers, and water pollution.

Occurrence within the watershed. According to the CNDDB, and direct observations by GRRCD staff, California freshwater shrimp occur at a number of locations along Creek Valley Creek, both above and below the confluence with Atascadero Creek (CDFG 2010; see *MapG-8, Special-status Species Locations*). While there are limited reported observations outside of this area, shrimp are likely abundant along stream channels throughout the watershed where suitable habitat exists.

Salmonids. Historic and ongoing land-use practices, combined with changes in ocean conditions, have had a dramatic effect on salmonid populations within the Green Valley Creek watershed. Steelhead (*Oncorhynchus mykiss)* and coho salmon (*Oncorhynchus kisutch*) were once abundant in Green Valley Creek and its tributaries. A self-sustaining native run of coho salmon is believed to be extirpated and the watershed is now part of a reintroduction program. Populations of steelhead and coho salmon have declined from historic levels due to past land-use practices, including logging, channel modifications, stream diversions, land development, sedimentation, and increasing water use; however, efforts are being made to reverse this trend. The watershed, in particular Upper Green Valley and Purrington Creeks, is identified as one of the core areas for advancing coho salmon recovery in the Russian River watershed (NMFS 2012).

Steelhead and coho salmon are anadromous fish; they spawn in freshwater and mature in the ocean. Steelhead that never enter the ocean and remain in freshwater streams are called rainbow trout. Green Valley Creek steelhead are part of the central California coast Distinct Population Segment (DPS), which is federally listed as threatened by NMFS. Coho salmon, Central California Coast ESU, are both federally and State-listed as endangered.

Adult steelhead migrate upstream from the ocean during the rainy season, anytime from December through April. They enter the stream only when sufficient flow has opened the downstream coastal lagoon. Steelhead spawn (mate and lay eggs) typically at the downstream edge of pools where cover habitat exists nearby for predator protection. Eggs are laid in a

Adult coho salmon. Photo courtesy of Simpson Timber Company

depression dug into cobble or gravel substrate called a redd. Unlike salmon, steelhead can migrate out to the ocean after spawning and return in subsequent years to spawn again. Eggs hatch in 3 to 14 weeks, depending on stream temperatures. The newly hatched fish (alevins) stay in the gravel for a few additional weeks until their yolk sac is absorbed. When they emerge, they seek slow-water areas, often at the stream margins. As they grow bigger, the juvenile fish move into faster water to feed on drifting insects.

Juvenile steelhead remain in freshwater streams from 1 to 3 years, depending on their rate of growth. Rearing juveniles have many habitat requirements. Most important, they need sufficient, cool streamflow to transport drifting insects for feeding and cover habitat, such as undercut banks, woody material, boulders, and deep pools, to hide from predators and areas for refuge during high flows. When juveniles are large enough, they migrate out to the ocean as smolts typically from March through June. During out-migration, steelhead and salmon need adequate streamflow to swim past barriers and cover for predator protection.

Coho salmon have a similar, but more rigid, lifecycle than steelhead. Upstream migration typically occurs as soon as winter rains have commenced and stream flows increase with peak spawning activity around December. Coho spend their first year in freshwater streams, migrate downstream the following spring and spend two years in the ocean to mature. Coho salmon return to their natal streams when they are three years old to spawn; therefore, coho salmon develop three consecutive "year classes" in each stream. Like steelhead, coho salmon are vulnerable to extreme environmental conditions, such as droughts, floods, and the timing of winter storms, which affect when the sandbar opens for upstream migration and influence survival juveniles and viability of redds[7].

[7] Definition of reed: Spawning area or nest of trout or salmon.

History of Salmonid Fish Surveys and Stocking

Salmonid Fish Surveys

The earliest fish survey of Green Valley Creek was conducted by the Division of Water Resources in 1966 (CDFG 2006a). During this survey, steelhead and coho salmon were found throughout the creek. CDFG conducted surveys in 1969 and again in 1991 and observed steelhead, but no coho salmon. Coho were not recorded again until 1993, when several were observed during a City of Santa Rosa survey (Merritt Smith Consulting 2003). CDFG surveys in 1995 found a few juvenile coho salmon. Subsequent monitoring efforts by UC Cooperative Extension (UCCE) found coho salmon in Green Valley Creek each year from 2001 through 2004; although by 2004, less than 10 individuals were found (Conrad et al. 2005). Prior to reintroduction efforts through the Russian River Captive Broodstock Program (RRCSCBP), the last wild coho salmon were documented in Green Valley Creek in 2004.

In the spring of 2005, UCCE staff installed an outmigrant trap, which captures fish as they migrate downstream, in the watershed (Conrad et al. 2005). A total of nine wild coho salmon smolts were captured in the trap. Six hatchery fish were also captured in the trap, as indicated by the lack of an adipose fin which is removed in the hatchery to distinguish them from wild fish; however, no hatchery fish had been planted in Green Valley Creek.

In the spring and summer of 2005, snorkel surveys were conducted by UCCE to locate potential wild broodstock and to document a suspected decline of wild coho populations from Upper Green Valley Creek. A total of 35 pools were snorkeled in the reach that runs from the confluence of Purrington Creek upstream to the confluence of the Bones Road Bridge. There were no coho salmon found in this reach. In the summer of 2006, another snorkeling survey was conducted in Upper Green Valley Creek. No coho juveniles were found. Additional fish surveys results are described below.

Russian River Coho Salmon Captive Broodstock Program

Coho salmon populations were greatly reduced in other tributaries of the Russian River throughout the 2000s; these significant population declines were the impetus for the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP). The program began in 2001 to help return coho salmon to the Russian River Watershed. Green Valley Creek was chosen as a stocking location because it was the last Russian River tributary that has supported all three year classes of coho and was considered to have fairly suitable habitat, cooperative landowners, and high potential for successful monitoring.

During the summer of 2001, CDFG personnel captured coho salmon for the broodstock program in the Upper Green Valley Creek mainstem between the confluences with Purrington and Harrison Creeks. A survey conducted by SCWA two weeks later found 422 juvenile coho salmon in the same reach of creek. In the summer of 2002, 12 juvenile coho salmon were documented. In 2004, seven juvenile coho salmon were captured using hand seines. The oldest and first collected year class was spawned in December 2003. The young from these fish were planted in other Russian River tributaries, but not Green Valley Creek.

In the fall of 2006, the first broodstock coho salmon were planted in Green Valley Creek (*Table 10 Broodstock Coho Stocking in the Upper Green Valley Creek Watershed*). This included 4,278 juveniles with coded wire tags implanted in their snouts. In the spring of 2007, outmigrant traps were installed and 504 hatchery coho smolts were captured, giving an apparent overwinter survival of 33%. This was considered a moderate survival rate and within the range observed for wild coho salmon in streams in west Marin County. In the fall of 2008, juvenile coho salmon (10,023 juveniles) were released again. Only 163 were captured in the outmigrant traps the following spring, indicating a very low survival rate. In the spring of 2009, 2,850 coho smolts were released with only 386 smolts captured in the outmigrant trap a few weeks later – the second year in a row with an apparently poor survival rate. It is not known if these fish failed to outmigrate and stayed in the upper watershed, or if they died due to some other variable such as predation, poor water quality, excessive sediment in the creek (which might be clogging their gills), or stranding due to insufficient water. Local biologists and other stakeholders are currently trying to better understand and resolve this issue.

Table G-10. Broodstock Coho Stocking in the Upper Green Valley Creek Watershed

Year	**2006-07**	**2007-08**	**2008-2009**		**2009-2010**		**2010-2011**			**2011-2012**			**2012-2013**	
	Fall	Fall	Fall	Smolt	Fall	Smolt	Spr	Fall	Smolt	Spr	Fall	Smolt	Spr	Fall
# of coho	4,278	7,883	10,023	2,850	5,200	3,095	508	7,933	4,986	1,018	9,046	5220	896	10,035

Table G-11. Broodstock Coho Stocking Rates in Purrington Creek Watershed

Year	**2010-11**	**2011-12**	**2012-13**
	Spring	Fall	Fall
# of coho	1,018	3,079	3,004

Despite the various impairments effecting instream habitat in Green Valley Creek, one has only to review the distribution of coho in recent years to understand that Green Valley Creek is a critical refuge for endangered coho within the Russian River watershed. Over the past three years (2010-2013), juvenile wild coho observed by through surveys by RRCSCBP monitors in Green Valley Creek comprised 28% (3,160 of 11,281) of all coho observations throughout the entire Russian River watershed (S. Nossaman, personal communication, February 4, 2013). In 2012, wild coho young of the year were found in 12 of 25 Russian River streams sampled, with 29% (1,504 of 5,172) of those fish observed in Green Valley Creek. Adult returns show a similar pattern. Of the 67 adult coho observed returning to the Russian River basin in 2013 as of January 7, 2013, 19 (28%) of those were documented in Green Valley Creek.

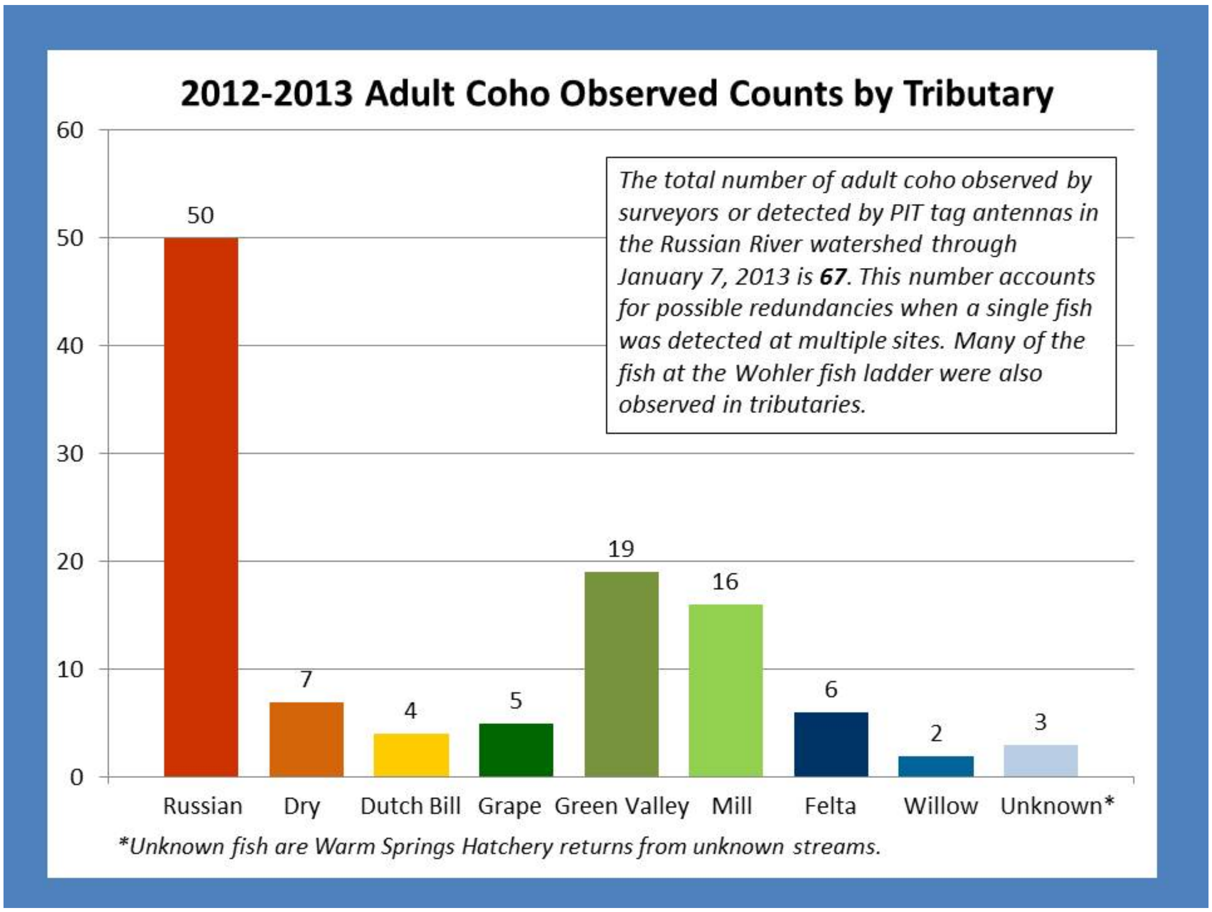


Figure G-2. The most recent Adult Coho observation counts from the Sea Grant Extension Program (http://ca-sgep.ucsd.edu/focus-areas/healthy-coastal-marine-ecosystems/russian-river-coho/captive-broodstock/adult-coho).

*Observed** adult returns to Green Valley Creek during the 2011-2012 spawner season comprised 14% (29 of 205) of the returns to the entire watershed. [1]*(S. Nossaman, personal communication, February 4, 2013).

Instream Habitat

Healthy stream channels are critical for supporting salmonids and other aquatic species. Like most aquatic species, steelhead and salmon require a number of instream habitat elements to support them through their various freshwater life stages. These include access to clean spawning cobble and gravel without fine sediments, year-round supply of cool oxygenated water, diverse habitat with deep, quiet pools and shallow riffles, stable creek banks, dense canopy cover, lots of woody material and other forms of cover, and an adequate food supply. The quality of instream habitat has been shown to have a direct impact on juvenile survival, rates of adult returns, and successful spawning.

Suitable water quality conditions are also critical for the development, growth, and survival of all salmonid life stages. Steelhead and salmon need cool water temperatures, high dissolved oxygen, and low quantities of fine sediment for successful juvenile rearing and adult migration and spawning. They also require sufficient stream flows – both during winter and summer rearing. During winter rearing, they require high flow refuge habitat to reduce their vulnerability during storm events and sufficient stream flows in summer to provide optimal rearing potenial, which can be compromised when pools become isolated or dry up.

Salmonid production within the Green Valley Creek watershed appears to be limited due to the physical structure of the instream habitat, below optimal water quality conditions, and insufficient stream flows. To date, a thorough study of limiting factors – habitat conditions that pose limitations to a species' survival – has not been conducted for the watershed. However, habitat analysis and monitoring conducted by a number of entities suggest several factors are contributing to the poor production of salmonids, specifically coho salmon, within the watershed.

Various deficiencies in channel complexity such as low pool depths and shelter value and a lack of off-channel habitat may play a major role in limiting the success of steelhead and coho salmon within the watershed. A lack of adequate surface flows in the summer to support juvenile rearing is evident in many reaches, and is likely one of the top factors. Reduced flow also likely contributes to low levels of dissolved oxygen which has been shown to limit juvenile rearing, and may reduce smolt survival as well. Finally, high water temperatures during the summer rearing period may also limit the survival of juvenile salmonids. Each factor influences the survival and reproduction of steelhead and coho salmon during various life stages; therefore, it is likely that multiple factors limit salmon production to varying degrees in the watershed.

Watershed Assessments

In 1994, the Green Valley/Atascadero Creek watershed was evaluated by the California Department of Fish and Game as part of their standardized habitat inventories for California streams (CDFG 1998). Inventories were conducted from the confluence with the Russian River to the upper limits of Green Valley Creek, Purrington Creek, and other creeks within the watershed (e.g., Atascadero, Jonive). The goal of the inventories was to assess the quantity and condition of aquatic habitat, with an emphasis on salmonid habitat, and document the presence and distribution of aquatic species (CDFG 2006a and 2006b). The habitat analysis included measurements of specified stream reaches and an evaluation of nine stream components: flow, channel type, temperatures, habitat type, substrate composition, gravel embeddedness, shelter rating, and canopy and bank composition.

The results of the Green Valley Creek and Purrington Creek habitat analyses found a low number of deep pools, low instream shelter values in pools, and gravels/cobbles embedded with fine sediment (CDFG 2006a and 2006b). Canopy cover was noted to be good – above the 80% coverage recommended for salmonid streams. During both inventories, steelhead and coho salmon were noted; however, further biological inventory results are not described here. Results of the habitat analysis component are described in detail below.

Recently, more detailed assessments were completed on Green Valley Creek between the confluences of Harrison and Purrington Creeks (O'Connor and Rosser 2003) and mainstem Purrington Creek (O'Connor 2010). The Green Valley Creek assessment included a habitat inventory based on CDFG guidelines, detailed substrate sampling and channel surveys, flow estimates, and woody material survey at 5 sites in Upper Green Valley Creek in 2002. Habitat inventory findings were consistent with the conditions documented by CDFG in 1994, including a low number of deep pools. The most common type of pool present was scour pools associated with large woody debris. Detailed substrate sampling found high quality spawning habitat within the reach surveyed based on the appropriate particle size and distribution and low percentages of fine sediment.

In 2010, a study comparing the results from the 1994 CDFG inventory was conducted on Purrington Creek to evaluate whether or not significant changes over the past 16 years had occurred to affect fish habitat quality and abundance (O'Connor 2010). The study found that pool forming processes and conditions have not changed significantly between the two surveys. Overall, pools were found to be relatively abundant but lacking depth and cover complexity. Woody debris abundance was also low; however, when present it is typically associated with greater pool depth, abundance, and cover. Rearing habitat was rated as fair based on current geomorphic conditions. Due to high flows during the study, spawning habitat could not be fully evaluated. However, it was noted that based on pool and riffle configurations, spawning habitat likely occurs in relatively small patches.

Primary Pools and Pool Shelter

Deep pools are a critical component of healthy salmonid habitat as they provide cover and rearing space for juvenile fish and high flow refuge habitat. They also provide cool water refuge during the summer months when water and air temperatures can be high and stream flows diminish. CDFG evaluates pool depth and frequency by determining the number of primary pools according to stream order. In first and second order streams, a primary pool has a maximum depth of at least two feet, occupies at least half the width of the low-flow channel, and is as long as the width of the low-flow channel; primary pools in third and fourth order[8] streams are three feet deep or more. In coastal salmonid streams, more than 50% of the total available habitat should be comprised of adequately deep and complex pools (CDFG 1999).

Overall, both Green Valley Creek, a third order stream, and Purrington Creek, a first and second order stream, have a low percentage of deep pools. Based on the 1994 Green Valley Creek CDFG inventory, only 30% of the pools were found to have a maximum depth of three feet or more, comprising 34% of the habitat by length (CDFG 2006a). Similar results were found in O'Connor and Rosser (2003) with only two pools out of 12 identified being greater in depth than three feet. Results are similar for Purrington Creek, with only 38% of its pools found to have a maximum depth of two feet or more. Thus 28% of the habitat, by length, is comprised of primary pools (CDFG 2006b), this being consistent with the more recent study by O'Connor (2010). Contributing factors in the low number of deep pools are the high level of streambank erosion, which results in excessive sedimentation, and lack of large woody debris to form deeper pools (O'Connor and Rosser 2003). In an eight-year study, Merritt Smith Consulting (2003) noted that sediment was filling pools, making them shallower.

Sufficient shelter is another important component of instream habitat, and is a useful indicator of pool complexity. Shelter in the form of large and small woody debris, undercut banks, root wads, aquatic vegetation and boulders provides fish with areas to hide from predators. These habitat features also provide territorial niches and can help reduce density-related competition. Deeper water habitats provide velocity refuge from high flow events. A pool shelter rating of 80% is desirable. Mean shelter values in pools in Green Valley and Purrington Creeks were

[8] A first order stream is an unbranched or unforked stream. Two first order streams joining together form a second order stream, two second order streams joining together form a third order stream, and so on.

found to be 20 and 18, respectively (CDFG 2006a and 2006b). These low shelter values are largely due to the lack of log and root wad cover structures.

Spawning Habitat and Cobble Embeddedness

Salmonids need clean, adequately aerated gravels for successful spawning. Typically, steelhead and coho salmon construct their redd, a salmon nest dug in the streambed where eggs are deposited, at the head of riffles near pool-tail outs. This is where sufficient oxygen circulation for developing eggs, interstitial flow to remove metabolic waste, and water temperature regulation are maximized (CDFG 2004). When gravels contain excess sediment, the eggs and alevin become enveloped by sediment and suffocate. The depth of cobble embeddedness, the degree to which materials are buried in fine materials, at pool-tail outs is a key element in determining the success of spawning salmon. Embeddedness ratings of 25% or less are considered desirable.

During the CDFG inventories, cobble embeddedness ratings of less than 25% were noted in two reaches in Green Valley Creek above the confluence with Purrington Creek; however, they also noted low percentages of gravels within the riffle habitats, which is considered fair for spawning salmonids (CDFG 2006a). O'Connor and Rosser (2003) noted ideal spawning conditions in GreenValley Creek based on low embeddedness (or fine sediment deposition) and appropriate particle size distribution. Cobble embeddedness in Purrington Creek was above the desired rating throughout much of the survey area. However, CDFG noted a high percentage of low gradient riffles with gravels in Purrington Creek, which is generally considered good for spawning (CDFG 2006b). In 2010, spawning habitat within Purrington Creek was noted to be present in relatively small patches with less than ideal substrate conditions (O'Connor 2010).

Riparian Cover and Buffers

Healthy, mature riparian vegetation is critical for maintaining ecosystem function. Intact riparian corridors keep water cool and clean, protect streambanks from excessive erosion, slow flows by increasing stormwater retention and infiltration, and provide roots and wood that are vital to create the complex instream habitat that salmonids and other aquatic species need. Riparian vegetation is also important for the production of salmonid food sources – terrestrial insects and leaf litter on which aquatic insects feed. Canopy cover of 80% is considered desirable for salmonid bearing streams. During the CDFG inventories, canopy cover on both Green Valley and Purrington Creeks was above the desired 80% (CDFG 2006a and 2006b).

Canopy cover conditions in Green Valley Creek were noted to be the same in 2002 (O'Connor and Rosser 2003).

In addition to adequate cover, buffers[9] are critical for maintaining riparian functions (i.e., filtering sediment and pollutants, providing shade, bank stabilization, and instream wood production). Buffers of at least 100 feet or more are recommended to support natural regeneration and woody debris (Ledwith 1996, Chris10sen 2000, Beschta et al. 1987). The CDFG inventory noted a thin riparian buffer in Purrington Creek, with similar values likely occurring in Green Valley as well.

Macroinvertebrates

Macroinvertebrates are animals lacking backbones (invertebrates) that are large enough to be seen with the naked eye (i.e., insects and worms). In 2006, a study was conducted by UCCE to evaluate the relationship between macroinvertebrate biomass in Green Valley Creek and the availability of food for salmonids, particularly coho salmon stocked as part of the Russian River Captive Broodstock Program (Obedzinski et al. 2008), as macroinvertebrates are their primary food source. The study found a high density of macroinvertebrates in Green Valley Creek. During the same year (spring 2006), smolts captured in outmigrant traps were found to be larger than other streams. Through the RRCBP monitoring effort, it has been consistently observed that smolts in Green Valley Creek were notably larger than those in other Russian River streams (Obedzinski et al. 2012). The high density of macroinvertebrates in Green Valley Creek likely contributed to the large smolt size, as there is a strong relationship between growth rates and food availability. The high density of macroinvertebrates within the watershed is important because smolts have a higher chance of survival if they are larger when entering the ocean, which likely leads to higher adult return rates (Holtby et al. 1990).

Floodplain Connectivity

Seasonal connectivity of the stream to floodplains and off-channel habitat is another form of channel complexity that is important to juvenile rearing, overwintering, and outmigration. Land development has tended to simplify the channel form, isolating it from adjacent

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[9] Riparian buffer - "a complex assemblage of plants and other organisms in an environment adjacent to water. Without definitive boundaries, it may include stream banks, floodplain, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic habitat. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season." (Lowrance, Leonard, and Sherida 1985)

floodplains, which in turn results in channel incision. According to watershed landowners and long-time residents, Green Valley Creek has become very incised over the last few decades – in some locations, the creek bottom has dropped over twenty feet. This has created a channel that is completely disconnected from its floodplain. The loss of channel complexity along with reduced pool and shelter components, has likely reduced the carrying capacity[10] of coho salmon in the watersheds. *Channel incision is discussed in more detail in Chapter 2 Section D: Sediment Sources and Impacts.*

Water Quality and Quantity

Temperature. Salmonids need adequately cool water temperatures to thrive, with coho salmon being more restrictive in their tolerances than steelhead or other species (Sullivan 2000). Water temperatures for optimal survival and growth of juvenile coho salmon range from 10 to 15°C (McMahon 1983). Growth ceases at temperatures above 20.3°C and swimming speeds are reduced above 20°C (McMahon 1983). Based on a limited data set collected at four monitoring site by Gold Ridge RCD within the Upper Green Valley Creek watershed, water temperatures appear to be within acceptable ranges during the winter spawning and incubation stages. However, in the summer months, water temperatures are above the optimal level for juvenile rearing (see *Chapter II, Section B*). Additional water quality monitoring by UCCE indicates a similar summer time trend (Obedzinski et al. 2008). Based on this small data set, water temperatures during the summer months appear to be below optimal levels for coho salmon; however, further data collection is needed (and results from volunteer monitoring efforts by the Community Clean Water Institute need to be analyzed) to make more robust conclusions about temperature conditions within the watershed.

Dissolved Oxygen. Salmon and steelhead need an adequate level of dissolved oxygen (DO) at all life stages to support respiration. DO is affected by water temperature, stream flow, and amount of instream organic matter. Water Quality Objectives from the North Coast Regional Water Quality Control Plan set minimum DO levels at 7.0 mg/l for the Russian River HU (NCRWQCB 2007). The suitable range for migrating adult coho is greater than 4.0 mg/l, while the optimum range for rearing juveniles as well as eggs and fry is 6.0 mg/l (see *Chapter II, Section B*). Low DO can occur in streams when flows are low and nutrient levels are high. Low DO levels can affect juvenile rearing salmonids by causing rapidly declining growth at concentrations below 5 mg/l and mortality at levels below 2.3 mg/l (Deas and Orlob 1999).

[10] The carrying capacity of a biological species in an environment is the species population size that can be sustained by the environment indefinitely given adequate food, shelter ,water and other habitat needs available in the environment.

Based on data collected by Gold Ridge RCD within the Upper Green Valley Creek watershed, DO levels appear to be sufficient during the winter and early summer, but fall below acceptable levels when flows become low during late summer and early fall. However, as noted above, further data collection is needed and data collected in volunteer monitoring efforts by the Community Clean Water Institute should be analyzed to make more robust conclusions about instream water quality conditions.

Turbidity. Turbidity is a measure of the transmissivity of light through water. This attribute is defined as levels of suspended sediment (resulting from both natural and anthropogenic origin) which may cause acute, sub-lethal, or chronic effects on salmonids or their habitat. Coho are particularly sensitive to excessive turbidity (Bjornn and Reiser 1991). Elevated levels of turbidity can disrupt normal feeding behavior and efficiency, reduce growth rates, increase stress, and reduce instream dissolved oxygen, respiratory functions and tolerance to diseases, and can also cause mortality (Bjornn et al. 1977, Crouse et al. 1981, Sigler et al. 1984, Velagic 1995,). Displacement of coho can occur in waters with turbidities greater than 70 Nephelometric Turbidity Units (NTU) (Bash et al. 2001). The length of time that fish experience increased turbidity is important. Newcombe and Jensen (1996) found that 148 milligrams per Liter per Day (mg /L/Day) is lethal to spawning salmonids. Adults will stray from turbid tributaries into those with clear water, if they are available (Sigler et al. 1984).

Based on data collected by Gold Ridge RCD within the Upper Green Valley Creek watershed, measurements of turbidity during storm events at various sites within the watershed indicate extended periods of "significantly impaired" conditions for salmonids in both the mainstem and tributaries. During the last year of water quality monitoring, turbidity readings have oftenbeen above the 25 NTU threshold for physiological effects; however, duration of these levels was not measured (see *Chapter II*, *Section B*).

Summer Flow. Summer flows are critical for the survival of rearing juvenile fish and maintenance of high quality habitat. Flows provide rearing space, allow for movement between habitats, maintain water quality and temperature, and facilitate delivery of food for juvenile salmonids. Within the Green Valley Creek watershed, pools typically become disconnected during the summer and fall. In the late summer of 2001, a survey conducted by the Sonoma County Water Agency noted that many pools in the creek were either isolated or received very little inflow (Cook and Manning 2002). More recently, staff at GRRCD has observed dry sections of the creek throughout the watershed during the summer months while conducting water quality monitoring (see *Chapter II*, *Section B*). In 2009, the mouth of Harrison Creek went dry in the beginning of the summer. By fall, parts of Green Valley creek just above the confluence with Atascadero Creek were also dry. A single monitoring site on Purrington Creek was the only location to retain water throughout the summer. However, by October of 2009, flow had returned to all monitoring sites.

Summer flows have likely been reduced due to increased water consumption in the watershed from groundwater and direct stream withdrawals. Over an 8-year study, it was noted that summer juvenile salmonid rearing habitat in Green Valley Creek was likely limited by diminished flow due to water diversions (Merritt Smith Consulting 2003). As described above, this trend has continued, leaving many sections of the stream dry during the summer and limiting the amount of suitable habitat available for rearing juveniles.

Instream Barriers

Instream barriers are obstacles that prevent or inhibit the natural movement of fish and other aquatic species from fully utilizing their habitat. These barriers typically include man-made features such as culverts, dams, weirs, and floodgates, but they can also include natural features such as log jams. Barriers can restrict the upstream movement of spawning adults and multi-directional movements of juvenile fish as they seek cool water, food, and cover throughout their rearing period and downstream migration to the ocean.

Within the Russian River watershed, an assessment of all man-made instream barriers was conducted by Ross Taylor and Associates in 2001 through 2003 (Taylor et al. 2003). A number of barriers were noted within the Atascadero/Green Valley Creek watershed including several within the Upper Green Valley Creek watershed. Two barriers were identified on the mainstem of Purrington Creek. These included a culvert at the upper Graton Road crossing (upstream of the intersection with Green Hill Road) that restricts passage for all life stages of salmonids (i.e., adults, residents, and juveniles) under all flow conditions. The second barrier, just upstream of a private driveway, provides 0% passage of juveniles; however, it does provide passage for adult salmonids and resident trout under most flow conditions. A third barrier was noted on Green Valley Creek at the upper Green Valley Road crossing, near the confluence with Harrison Creek. This barrier provides some passage for adults but restricts passage of juvenile salmonids and resident trout under all flow conditions. The upper Graton Road culvert has been identified as a high restoration priority by the County of Sonoma and is slated for retrofitting in 2010 or 2011.

Conclusion

The Green Valley Creek watershed supports a wide variety and abundance of fish and wildlife species due in part to the diverse upland vegetation communities and riparian and instream habitats. Despite the recent decline and subsequent reintroduction of coho salmon in the watershed, it still supports key habitat elements and a number of special-status species including steelhead, California freshwater shrimp, northwestern pond turtle, northern spotted owl, and foothill yellow-legged frog. With immediate management actions including habitat restoration and changes in land use practices, conservation and enhancement of existing fish, wildlife, and plant communities is possible.

Biological Resources Recommendations

1. Protect and enhance the riparian corridor. Planting native vegetation will improve forested riparian buffer function by increasing buffer width, vegetation density, species complexity, and functional diversity in areas that have minimal cover and/or lack a multi-age, diverse canopy.
   a. Install riparian fencing along stream reaches accessed by livestock. Although currently there is limited livestock in the watershed, if land uses should change to grazing based agriculture, then landowners should be encouraged to adopt conservation plans which follow rotational grazing paterns.
   b. Identify stream reaches with inadequate riparian cover and promote regeneration.
   c. Increase the width of the riparian corridor by increasing native plant diversity and providing shade to protect coldwater habitat and promote long term large wood recruitment.
   d. Utilize biotechnical techniques for stream bank stabilization projects.
   e. Educate landowners on the benefits and components of a healthy riparian corridor.
   f. Manage invasive species (see below).

2. Improve instream habitat.
   a. Install large wood structures in order to allow for habitat feature development and increased channel complexity and cover
   b. Educate landowners on the importance of leaving woody debris accumulations and downed trees.
   c. Remove or modify instream barriers.

3. Improve historical floodplains and off-channel habitats

    a. Increase over-winter and summer survival by increasing and enhancing velocity refuge through floodplain connection and/or enhancing off-channel habitat in reaches where high winter flow velocities are a barrier to successful winter rearing

    b. Identify areas where floodplain connectivity can be re-established in low gradient response reaches (NMFS, 2012), particularly in Lower Green Valley Creek.

    c. Identify and target habitat restoration and enhancement that will function between summer base flows and flood stage (NMFS, 2012).

    d. Support landowners to improve conditions to recreate and restore alcove, backwater or perennial pond habitats where channel modification has resulted in decreased shelter, LWD frequency, and habitat complexity.

4. Manage sediment delivery.
    a. Identify instream and upland sources of sediment.
    b. Treat potential sources including from streambank and upland gully erosion, and vineyard and road runoff.

5. Increase summer base flows.
    a. Reduce water withdrawals and increase spring flow during summer rearing season while ensuring water security by developing alternative sources of water.
    b. Improve riparian cover over the stream channel to reduce evaporation.
    c. Monitor streamflows.

    d. Educate landowners on water rights, water conservation, and conservation strategies designed to effectively use water

    e. Develop and implement a long-term water conservation program for agricultural and residential landowners within the watershed to improve summer base flows.

6. Monitor and improve water quality.
    a. See Water Quality recommendations section.

7. Protect and enhance upland habitats.
    a. Identify priority areas for protection including habitats that support special-status species (i.e., northern spotted owl, Sonoma tree vole) and habitat connectivity.

    b. Map Sudden Oak Death infestations within the watershed and educate landowners on forest management and spread prevention practices.
    c. Develop a fuel-load management plan with resource agencies to protect residents and natural ecosystem function.
    d. Work with Sonoma County Agricultural Preservation and Open Space District to promote easements and habitat enhancement projects on trusted lands.

8. Monitor and enhance habitat for salmonids.
    a. Support on-going monitoring efforts of salmonids populations within the watershed.
    b. Support continued coho salmon captive broodstock reintroductions.
    c. Implement instream and riparian habitat enhancement recommendations (see above).

9. Monitor and enhance habitat for wildlife.
    a. Collect baseline information on foothill yellow-legged frog, California freshwater shrimp, and northwestern pond turtle abundance and distribution within the watershed.
    b. Identify habitat protection and enhancement actions for special-status wildlife species.

10. Work with the agricultural community to promote on-farm habitat enhancement projects.
    a. Develop Pollinator Farm Plans.
    b. Develop Habitat Enhancement Program, including workshops and educational materials.

III. Management Considerations

Management Actions for Watershed Improvement

Land use cover and associated activities have been described in *Chapter II, Section A, Regional Setting* and impacts to water supply, fisheries, and aquatic habitat were explained in detail in *Chapter II, Section C, Hydrology and Instream Flow*, *Chapter II, Section D, Sediment Sources and Impacts*, and *Chapter II, Section G, Biological Setting*. This chapter will present management context, issues and actions associated with the two largest land uses in the Upper Green Valley Creek watershed – agriculture and rural residential.

Since the goal of this plan is to propose a prioritized plan of action for the recovery watershed function and ultimately a self-sustaining coho population, emphasis is being placed on feasible solutions that can be implemented under the current conditions and landownership. While potential restoration approaches such as establishing 100 foot wide riparian buffers on either side of the stream throughout the watershed through conservation easements have been proposed during this planning process, outreach to landowners and conservation organizations alike have proven this approach as unfeasible at this time. While there is biological merit to this approach, there are too many financial and political barriers. Therefore, efforts have focused on identifying restoration priorities that work within the context of current watershed conditions and demographics. The goal being to recover coho salmon in partnership with the existing residential and agricultural communities.

Agricultural Sustainability

A little over 40% of the of the area of the Purrington Creek watershed and 22% of the Upper Green Valley Creek watershed is in agricultural land use (see *Map A-4, Land Use and Land Cover in the Upper Green Valley and Purrington Creek Subwatersheds*) (CDFFPand USDA Forest Service 2002). Vineyards and orchards are the primary agricultural pursuits in this sub-watershed; these activities occur primarily at lower elevations, with vineyards and some livestock grazing along creeks (LMA 2003). Throughout the county, smaller farms on parcels from two to 10 acres are increasingly important economically. Grape production is one of a few crops that provide enough revenue to support small-scale farming operations (Sonoma County PRMD 2008).

Sonoma County ranks 6th in the state and 34th in the nation in agricultural productivity; the county recognizes that agriculture is an important economic, social, and historic resource and has taken measures to protect it (Sonoma County PRMD 2008a). The Sonoma County General Plan 2020 (Sonoma County PRMD 2008b) contains an Agricultural Resources Element (Element) that provides "policies, programs and measures that promote and protect the current and future needs of the agricultural industry." These provide guidelines for land use and other decisions in agricultural areas to protect existing agricultural practices. The Element also provides policies to assist in marketing and promotion of agricultural products and provide fair conditions for farm laborers. Policies AR-1e and AR-1g (*Table III-1, Sonoma County General Plan 2020 Agricultural Resource Element: Policies that Promote Sustainability*) encourage and support sustainable agriculture, economic sustainability, and equitable treatment of farm workers.

The concept of sustainability is based upon the principle that management activities should meet the needs of the present without compromising future generations' ability to meet their needs. Agricultural sustainability incorporates three main goals: preservation of environmental systems and processes, economic profitability, and social and economic equity. Stewardship of both natural and human resources is important. Stewardship of natural resources includes preservation and rehabilitation of ecological processes such as groundwater recharge, pollutant sequestration, pollination services, and nutrient sequestration. Stewardship of human resources includes social issues such as health and housing conditions for laborers, the needs of rural communities, and long-term consumer health and safety. Many agricultural enterprises throughout the county practice stewardship of natural and human resources; such activities include unpaved roads maintenance and repair, riparian revegetation, and provision of agricultural employee housing.

Table III-1. Sonoma County General Plan 2020 Agricultural Resources Element: Policies that Promote Sustainability

Policy AR-1e: Encourage and support farms and ranches, both large and small, that are seeking to implement programs that increase the sustainability of resources, conserve energy, and protect water and soil in order to bolster the local food economy, increase the viability of diverse family farms and improve the opportunities for farm workers.

Policy AR-1g: Support the activities of the Sonoma County Agricultural Commissioner's Office and the Farm Advisors Office in promoting sustainable and organic agricultural production and encourage the exploration of possibilities for production of other diverse agricultural products.

Conservation easements are a form of sustainability involving natural and human resources – they preserve ecological processes while supporting the area's agricultural heritage. Private conservation easements are identified in the Sonoma County General Plan 2020 as a mechanism for natural resource and agricultural lands preservation and enhancement in several General Plan policies (Sonoma County PRMD 2008b). Conservation easements can be acquired through Williamson Act contracts or through purchase. Williamson Act contracts involve the landowner agreeing to maintain land in agricultural or open space condition in exchange for reductions in tax obligations. About 300,000 acres of agricultural land are under Williamson Act contracts with almost 300,000 acres in fee title easements (Sonoma County PRMD 2008a). Much of the Upper Green Valley Creek watershed and some parcels along Purrington Creek have land under Williamson Act Land Contracts[11] (*see FigureA-5: Land in Williamson Act Land Contracts,* Section II-A).

Efforts to increase economic sustainability include local farmers' markets and development of specialty and niche products, such as organic crops and processed products. Organic farming increased in Sonoma County from 2007 to 2008; commodities produced included fruits, vegetables, winegrapes, meats, grain, and eggs (Sonoma County Office of the Agricultural Commissioner 2008). Sustainability practices such as organic growing can provide financial gain. A sustainable agriculture certification was recently developed by two industry trade groups. The Certified California Sustainable Winegrowing Program is based upon an existing Sustainable Winegrowing Program developed in 2001 (Broome and Warner 2008). Certification requires winegrape growers to implement farming practices contained within the *Code of Sustainable Winegrowing Practices: Self-assessment Workbook (2nd ed.)*. The workbook allows farmers to rank operations based on ecological, economic, and social-equity practices through an integrated set of 16 chapters and 227 criteria with metrics to evaluate performance. Two Sonoma County wineries were among the first seventeen certified sustainable in January 2010 (California SWA 2010). Other socially conscious certifications include USDA and California organic certification and Fish Friendly Farming® Certification. Fish Friendly Farming® is a certification program for agricultural properties managed to restore fish and wildlife habitat and improve water quality.

Not only do sustainable agricultural practices reap long-term local benefit, they also contribute toward implementation of statewide goals and programs. Implementation of sediment-control, water conservation, and other BMPs contributes toward attainment of Total Maximum Daily Load (TMDLs) allocations for sedimentation, temperature, indicator bacteria, low dissolved oxygen and nutrients. Sustainable agricultural practices also contribute toward achievement of goals in the North Coast Regional Water Quality Control Board Watershed Management Initiative Chapter, the California Water Plan, the California Department of Fish and Game Coho

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

Recovery Plan, the North Coast Integrated Regional Water Management Plan, and the Sonoma County Climate Action Plan.

Agricultural Best Management Practices

All Agricultural BMPs support one or more aspect of agricultural sustainability. BMPs for vineyard and ranching operations such as those in the Upper Green Valley and Purrington Creek subwatersheds include irrigation water management, spring frost protection, development and implementation of nutrient management plans, cover cropping, prescribed grazing, riparian fencing, and riparian re-vegetation. Resources for BMP planning and implementation are abundant at the federal, state, and local levels. The table below describes several sources for BMPs that have widespread acceptance and local applicability (*Table III-2, Resources for Agricultural Management Measures*). Many of these management activities are supported through funding assistance from agencies such as the Natural Resources Conservation Service (NCRS), California Department of Fish and Game (CDFG), State Water Resources Control Board (SWRCB), Department of Water Resources (DWR) and the Sonoma County Energy Independence Program.

Table III-2. Resources for Agricultural Management Measures

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. Section III contains information on Conservation Management Systems, which establish standards for sustained use. Detailed information about conservation practices is available in Section IV.	All aspects of agricultural operations – extensive list of irrigation water management measures.	http://efotg.nrcs.usda.gov/treemenuFS.aspx
US EPA National Management Measures to Control Nonpoint Source Pollution from Agriculture	This technical guidance document contains information on the best available, economically achievable means of reducing agricultural sources of pollution to surface and ground water.	All aspects of agricultural operations – nutrient, pesticide, grazing, and irrigation water management, erosion and sediment control, and animal feeding operations.	http://www.epa.gov/owow/nps/agmm/index.html
US Forest Service Pacific Southwest Region Water Quality Management for National Forest System Lands in California	This technical guidance document provides BMPs for timber management, road and building construction, mining, recreation, vegetation, fuels management, watershed management, and range management. Writtenfrom an agency perspective.	BMPs that address all aspects of USFS activities in California.	http://www.fs.fed.us/r5/publications/water_resources/waterquality/

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

Rural Residential

Rural residential is the primary land use in the Upper Green Valley Creek watershed; the Upper Green Valley Creek watershed is 36% rural residential while the Purrington Creek watershed is 54% rural residential (LMA 2003). Rural residential development is associated with watershed impacts including sedimentation, nutrient and pesticide runoff, spread of invasive species, and water supply issues, but management practices specific to the category "rural residential land use" have not been developed for Sonoma County. In Upper Green Valley Creek, rural residential development is likely contributing to reductions in summer water supply and increased sedimentation (see *Chapter II, Sections A and F*).

Many of the issues resulting from rural residential development are experienced in a more concentrated manner by urban areas – runoff, flood control, groundskeeping/chemical control, and onsite wastewater treatment systems. Therefore, much of the information about management measures to ameliorate conditions resulting from urbanization is applicable to rural residential land use, including water conservation measures.

An aspect of rural residential development not commonly found in urban areas is the construction, use, and maintenance of unpaved access roads. Roads are widely recognized as a significant source of sedimentation (see *Chapter II, Section D*). Management practices to reduce sedimentation from roads are available from many sources. The table below lists several sources for BMPs that have widespread acceptance and relevance to local rural residential issues (see *Table III-3, Resources for Rural Residential Management Measures*).

Table III-3. Resources for Rural Residential Management Measures

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. The information is mostly intended for large landowners.	Natural resources conservation. Road and trail closure, habitat restoration.	http://efotg.nrcs.usda.gov/treemenuFS.aspx
USEPA National Management Measures to Control Nonpoint Source Pollution from Urban Areas	This document provides guidance regarding management measures to reduce nonpoint source pollution from urban activities.	This document provides implementation actions at the municipal scale.	http://www.epa.gov/owow/nps/urbanmm/index.html#06
USEPA Protecting Water Quality from Urban Runoff	This web page gives an overview of how individual dwellings impact a watershed and provides actions individuals can take to reduce NPS pollution.	Reducing NPS pollution through individual, municipal, and planning implementation activities.	http://www.epa.gov/owow/nps/urban_facts.html#runoff

Resource	Description	Focus	URL
California State Water Resources Control Board Nonpoint Source (NPS) Pollution Control Program	Multi-tool website that contains a Management Practices Miner Tool, a Management Measures Encyclopedia, and NPS Guidance in Specific Interest Areas. The Miner Tool is a compendium of documented NPS pollution management practices collected from scientific texts, journals, web sites, grant projects, and presentations. The Encyclopedia is a free online reference guide designed to facilitate understanding of NPS pollution control and provide quick access to resources available on the internet.	*Urban areas* – most information is agency level, however individual homeowners will find useful information for landscaping and water management. *Forestry* –homeowners may find useful information regarding road construction, reconstruction, and management. *Education and Outreach* – describes specific practices on the individual household scale.	http://www.swrcb.ca.gov/water_issues/programs/nps/tools.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/2_forest.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/3_3_edu.shtml
FishNet 4C Roads Manual	This document provides guidelines for county road maintenance to protect aquatic habitat and fisheries.	County road maintenance, some information applicable to homeowners.	http://www.fishnet4c.org/projects_roads_manual.html
Energy Independence A Sonoma County Program	This website rovides suggestions for residential and commercial improvements to conserve water and energy.	Financial incentives for individual homeowners to implement water and energy saving measures.	http://www.sonomacountyenergy.org/
Marin County Stormwater Pollution Prevention Program Resources About Pesticides and Alternatives Web Page	This web page contains several publications that provide homeowner – level information about less-toxic pesticides, gardening, and water quality.	Reducing toxins in the environment, providing least-toxic pest management to homeowners and schools.	http://www.mcstoppp.org/pesticides.htm
House and Garden Audit: Protecting Your Family's Health and Improving the Environment, A Guidebook to Reducing Your Impacts on the Environment	"The House and Garden Audit is for all people interested in learning how to protect their health while improving the environment."	Reducing toxins in the environment through individual homeowner effort.	http://www.laurelmarcusassociates.com/housegarden.html
Less-Toxic Pest Management: Pesticides and Water Pollution.	This is an informative brochure about homeowner contributions to water quality impairments.	Provides tips for homeowner reduction of pesticide use.	http://ourwaterourworld.org/Portals/0/documents/pdf/PesticidesWQ.pdf

Resource	Description	Focus	URL
Stewardship Guide for the Russian River	The purpose of this guide is to provide practical creek care information, and to offer a host of resources to help with the maintenance and upkeep of creek-side properties throughout the Russian River Watershed.	Provides tips for creekside landowners in onsite creek care and property management.	http://sotoyomercd.org/Stewardship-Guide.pdf
Slow it. Spread it. Sink it!	This purpose of this guidebook is to help landowners and homeowners make the most of the many potential benefits of innovative stormwater management.	Provides tips for homeowners on managing stormwater resources on their properties.	http://www.sscrcd.org/pdf/Slowit.Spreadit.Sinkit.vfinal.pdf

Climate Change

Climate change is becoming an increasingly important concern for governments, businesses, NGOs, and individuals. The state of California and the county of Sonoma are recognized leaders in climate change research and adaptation strategies. Although many impacts of climate change are unknown, models have been developed based on past weather patterns that extrapolate current conditions into projections for the future. Most model simulations provide similar projections for conditions in Northern California; the region is expected to become warmer with only a slight, if any, decrease in precipitation with storms and other weather events likely to become more extreme.

A simple climate change analysis was performed with the calibrated hydrologic model of Purrington Creek considering only changes in temperature (which are relatively well-understood compared to predictions of precipitation changes which vary widely between climate models). These results suggest that based on projected increases in temperature alone, evapotranspiration rates may increase by approximately 8% by the 2080s resulting in declines in groundwater recharge and baseflow on the order of a few percent. (O'Connor 2013).

Weather Predictions

The most current predictive simulations indicate that California will retain a Mediterranean weather pattern with cool wet winters and hot dry summers. Climate model simulations project warming by about 0.5- 2.0 °C during the first thirty years of this century; warming during the last thirty years is expected to increase by 1.5- 5.8 °C (Cayan et al. 2006). With this warming, models predict that heat waves will increase in frequency, magnitude, and duration from the historical period. Where they now occur mainly in July and August, they are likely to occur any time from June through September. Conversely, freezing spells are projected to become less frequent, even in locations such as the Russian River watershed, where they are currently nearly a yearly event (Mastrandrea et al. 2009).

Variable annual precipitation and continued vulnerability to drought are predicted throughout the next century. Six model-driven climate simulations indicate only slight if any precipitation decreases for Northern California, but even if precipitation levels remain at current levels, increased temperatures are likely to lead to evaporative water loss and contribute toward drier conditions overall. In addition to increased variability in weather events from storms to heat waves, weather events are expected to become more intense – for example, heat waves will last for increasingly long blocks of time and rainfall events, though less frequent, are likely to be more intense. These changing patterns will have impacts from increased runoff and flooding during storms to increased wildfires, to increased heat-related deaths.

Potential Vegetation and Crop Changes

Climate change will affect natural ecosystems and the distribution of native plant species. Of the more than 5,500 native plant species endemic to California, about two-thirds are projected to experience range reductions of over 80% by the end of the century (Loarie et al. 2008). The rate at which climate change is expected to affect different ecosystems – that is, the rate that the biological components of these systems can migrate to remain within a preferred temperature zone – varies with topography. Mountainous habitats are expected to adjust to climate change with a gradual migration, since a small move up or down slope can result in a large temperature change. Change will be slowest in mountainous biomes such as tropical, subtropical, and temperate coniferous forests and montane grasslands. Montane landscapes are likely to shelter both plant and animal species into the next century. Additionally, complex topography is likely to provide a spatial buffer for climate change. Because much of the Upper Green Valley subwatershed is mountainous, effects of climate change on remaining natural habitat are likely to occur slightly more slowly than within the Atascadero-Lower Green Valley floodplain.

Increased temperatures and precipitation changes associated with climate change may have important effects on agricultural crops. Changes in water availability, temperature averages and maxima and minima, pest and weed ranges, and growing season length are all likely to impact crop productivity and thus, distribution. Some crop yields are expected to increase while other yields may decrease (CAT 2009). Changes in weather patterns associated with climate change may also alter the phenology of crop plants – the timing of flowering, fruit set, and senescence. These changes may disrupt pollination processes if crop phenology becomes unsynchronized with pollinator life cycles. Pathogens and parasite populations are expected to proliferate in the warmer winters and higher overall temperatures.

On a physiologic basis, elevated increased CO_2 availability gives plants a growth spurt, but this growth is not sustained. Increased CO_2 availability causes stomata – small pores on the leaf surface – to close, which can save water by reducing transpiration at the leaf scale. On the field scale, however, more water will be used by larger plants growing in a warmer climate. Indirect effects of increased CO2 include lengthening of the growing (and transpiration) seasons, stimulation of weed growth, and an increase in insect pest populations. Many crops, including wine grapes, have minimum chill requirements – the number of hours below a certain temperature that will result in plant dormancy and fruit set the subsequent season. With warmer winters, the minimum number of hours at chilling temperature may not be reached. Long-term climate records across California show a negative trend in winter chill accumulation; models show that by 2100, the occurrence of adequate winter chill may be lost for many fruit species unless cultivars requiring less winter chill are developed (Baldocchi and Wong 2006). California losses are estimated up to 40 % for wine, table grapes, and similar commodities with significant regional variation in losses (Karl et al. 2009).

Salmonid Habitat

Salmonid habitat will also be impacted by climate change. Summer instream flows are projected to decline with the greatest drop during June and July (Shaw et al. 2009). Winter flows are expected to increase by 20- 60% for short periods due to increases in extreme precipitation events, which could result in increased scouring of redds and increase the runoff to infiltration rates (an increased net loss of rainwater). This coupled with expected drier climatic conditions will likely mean and increased need for irrigation earlier in the season, thereby placing more pressure on surface and groundwater resources and leaving less water resources to sustain surface flow throughout the dry season. Warmer water temperatures may cause egg hatching earlier in the year, leading to smaller young that are vulnerable to predators. Additionally, earlier hatching dates may cause the fry to become unsynchronized with insect prey life cycles. Warmer waters also increase metabolic function, increasing the need for foraging, and diseases and parasites tend to thrive with higher temperature (Karl et al. 2009).

Ocean conditions will also experience changes. Coastal ocean waters will warm more quickly than deep ocean waters; coastal estuaries and other ecosystems will experience effects of increased temperature including reduced dissolved oxygen levels, shifts in the geographic range of species, and unforeseeable changes to the food web. Nutrient cycling is affected by large weather patterns such as El Niño, Santa Ana winds, ocean temperatures, and ocean currents. Warmer water temperatures combined with changes to nutrient availability could lead to geographic range shifts and changes to fish population numbers. Sea level rise is likely to affect estuarine habitat, which could potentially impact vulnerable life stages of outmigrating coho and steelhead. Ocean acidification, which increases with increasing atmospheric CO_2 concentrations, limits growth and survival of organisms that serve as a basis for marine food chains, potentially affecting the ocean phase of the salmonid life cycle. Acidification can also impact fertilization, development, and metabolic function of marine species and change the toxicity of chemicals and other substances and the biological availability of nutrients and other compounds (CNRA 2009).

Other Potential Impacts

Additional impacts of the changing climate include increased electricity demand, reduced water quality, increased air pollution and airborne allergens, climate-sensitive infectious diseases, illness and death due to extreme weather events such as heat waves, storms, floods, or wildfires. Groups including children, the elderly, and poor are most vulnerable to the range of climate-related health effects. Native American populations are among the most vulnerable because they are often closely linked to a specific piece of land due to the established reservation system. While many of these impacts will occur on a larger scale than this watershed plan, some, such as impacts to agriculture and salmonid habitat, are likely to be relevant to resource management in the Upper Green Valley watershed.

For more information and landowner tools for managing property for climate adaptation, visit the North Bay Climate Adaptation Initiative at www.nbcai.org.

IV. Habitat Restoration Recommendations and Priorities

Restoration Recommendations and Prioritization

The first step in compiling a prioritized list of restoration recommendations was to conduct a literature search and review the various restoration prioritization data that had been published for the Green Valley Creek Watershed. That initial review is summarized in the Green Valley Watershed and Habitat Restoration Recommendations Matrix (the entire matrix including all source summaries and data citations can be found in Appendix A). This data helped orient the Technical Work Group, but no clear consensus on restoration priorities emerged from these various sources.

The next step was to identify and fill as many data gaps as possible. Building on the first phase of the GVCWMP, additional studies and a limiting factor analysis were conducted. Since the goal of this planning effort is to create a prioritized plan of action to restore watershed function and create and enhance the freshwater resources of Green Valley Creek to aid in the recovery of a self-sustaining coho salmon population in the Russian River, the emphasis of the work was to identify the factors limiting coho salmon habitat and identify and design restoration projects that directly address these limiting factors. GRRCD staff worked with O'Connor Environmental, Inc. (OEI) and Prunuske Chatham, Inc. (PCI), all overseen by the Technical Work Group, to conceptualize and design restoration projects. These projects were selected based on the best-available science provided by the project team and the Technical Work Group members. Three projects were designed over the course of this process:

1. Purrington Creek Salmonid Habitat Restoration Project

2. Upper Green Valley Creek Salmonid Habitat Restoration Project

3. Green Valley Creek Off-Channel Winter Refugia Habitat Enhancement Project at Thomas Creek Ranch.

The first two projects were identified and designed by O'Connor Environmental, Inc. based on the Geomorphic Study results, combined with data provided by our technical partners, including:

- Hydrology and streamflow gauge data provided by CEMAR through the Russian River Coho Water Resources Partnership.
- Multi-year salmonid survey data, both spawning and juvenile surveys, and habitat availability data provided by University of California Cooperative Extension, Sea Grant Program.

- Stream habitat inventory data collected by the California Department of Fish and Wildlife.
- Water quality data collected by the Gold Ridge RCD.

The various data sets were overlaid in Google Earth, then analyzed by the Technical Work Group(see *Figures IV-1 to IV-3* below). The upper Green Valley and Purrington Creek reaches correspond to the Geomorphic Units identified by OEI in the Geomorphic study (*Figure F-1. Upper Green Valley and Purrington Creek Geomorphic Units Map* and *Figure IV-4*, below).

The restoration recommendations described in the Geomorphic Study (Chapter II, Section F) are captured in the *Table F-1. Upper Green Valley and Purrington Creeks Geomorphic Descriptions and Restoration Objective and Prioritization* and are combined with watershed-wide recommendations and priorities in Table IV-1, below.

Figure IV-1 . Geomorphic Unit Map of Upper Green Valley and Purrington Creeks

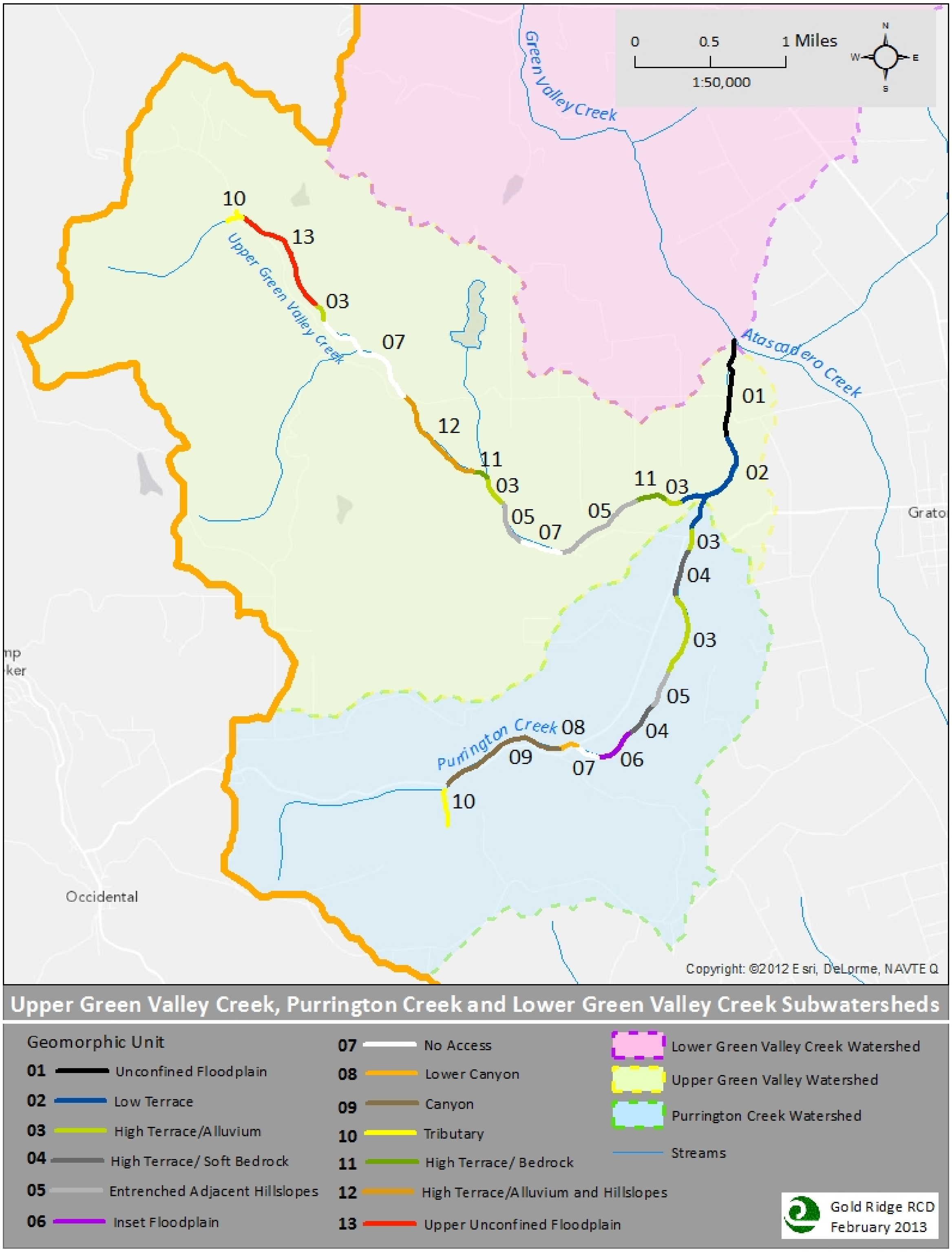


Figure IV-2. Low flow condition habitat summary from 1994 survey

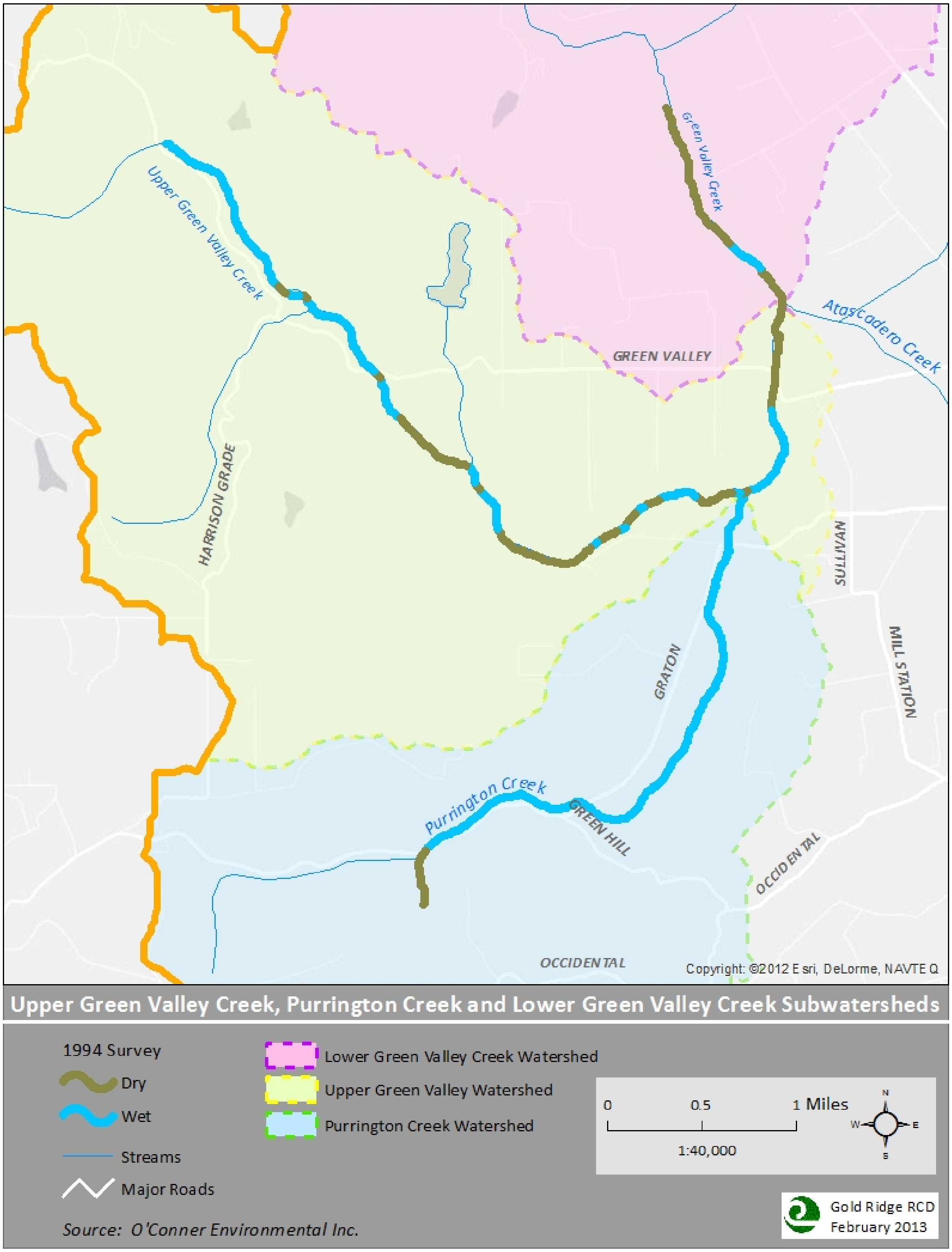


Figure IV-3. Low flow condition habitat summary from 2012 survey

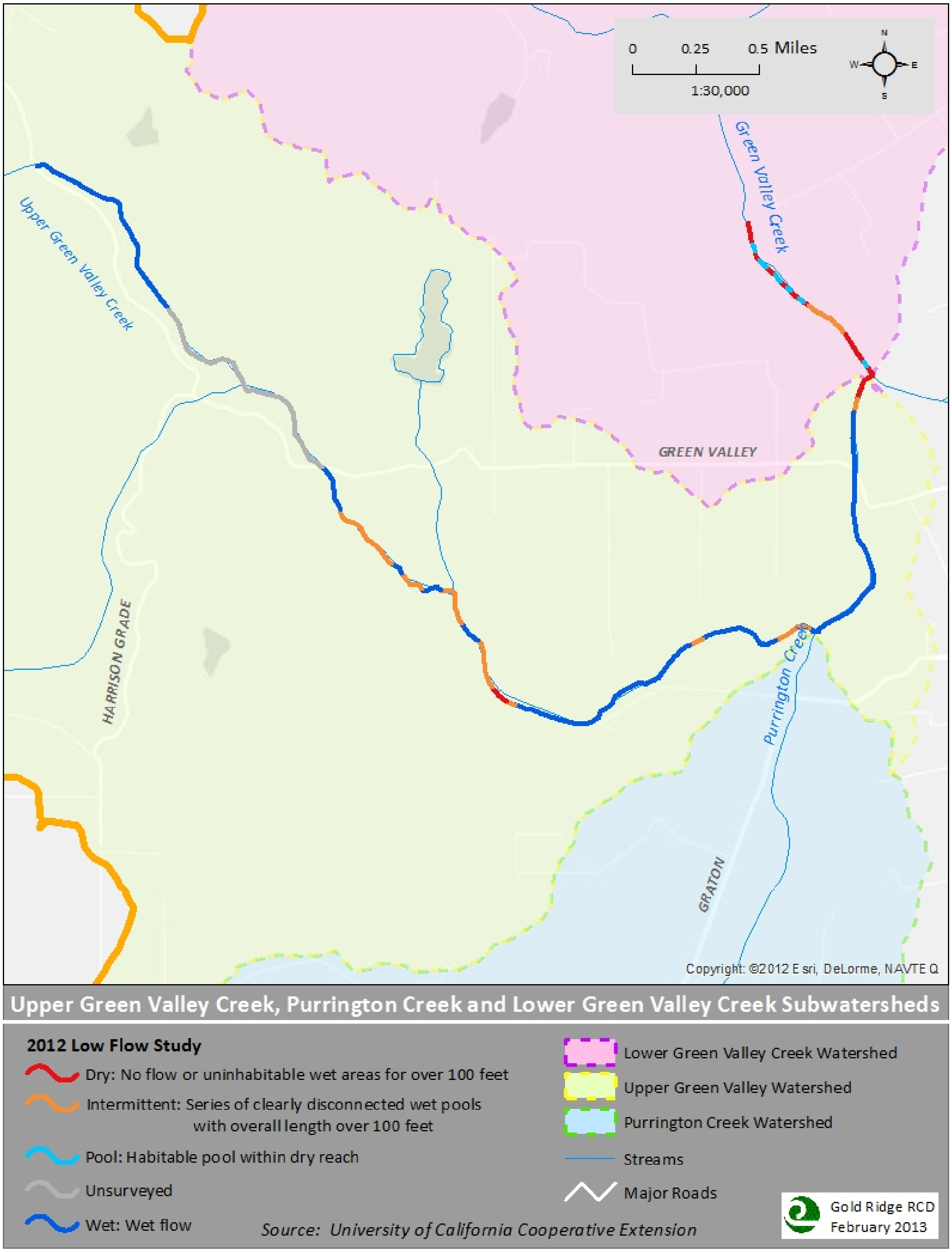


Figure IV-4. Upper Green Valley and Purrington Creek Geomorphic Study Restoration Recommendation by Geomorphic Unit

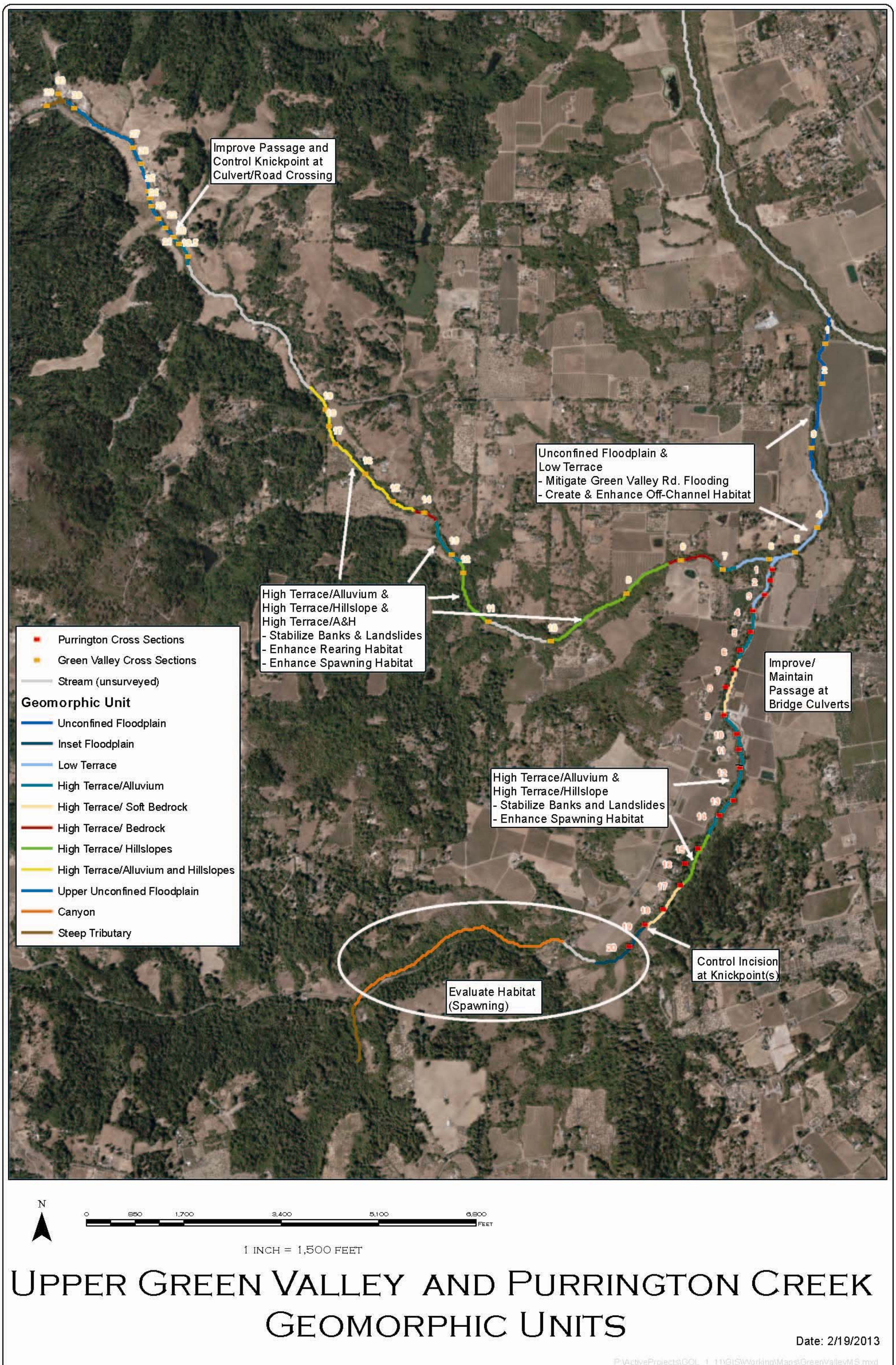


Table IV-1. 2012 Habitat Restoration Recommendations Matrix: H=high priority; M=moderate priority; L=low priority; NA=not applicable for reach: ID=insufficient data to make a recommendation for reach

Habitat Restoration Priorities Upper Green Valley Creek (u/s of Atascadero Creek confluence) Purrington Creek Lower Green Valley Creek (d/s of Atascadero Creek confluence) Geomorphic Channel Unit	Mitigate overbank flooding to avoid "take" of over-wintering coho	Improve the quality of rearing habitat, primarily by increasing the frequency and depth of pools, & providing for enhanced cover and complexity in pools via large wood structures	Improve the quality of rearing habitat, primarily by increasing the cover and complexity in pools	Reduce bank instability and associated sedimentation (bank stabilization efforts should be integrated w/ habitat improvement efforts)	Improve fish passage/ remove or modify migration barriers while mitigating risks associated w/ potential culvert failure	Increase availability of spawning sites; install structures to decrease channel incision & recruit or sort spawning gravel	Create/ augment off-channel habitat to provide winter rearing & refugia habitat, and increased floodplain interaction	Water conservation* and alternative storage projects to reduce impacts associated w/ instream and spring diversions, groundwater extraction	Fine sediment source reduction**	Improve dissolved oxygen levels	Promote riparian corridor protection and/or expansion, demonstrate the value of well-vegetated riparian areas (floodplain connection, function)
Upper Green Valley Creek											
Unconfined Floodplain	H	H	M	L	NA	L	H	H	L	M	M
Low Terrace	NA	H	M	M	L	L	M	H	L	ID	M
High Terrace/Alluvium	NA	H	M	M	NA	H	NA	H	M	ID	M
High Terrace/Bedrock	NA	L	H	M	NA	L	NA	M	M	ID	M
High Terrace/Hillslope	NA	H	H	M	NA	H	NA	M	M	ID	M
High Terrace/Alluvium and Hillslopes	NA	H	H	M	NA	H	NA	M	M	M	M
Upper Unconfined Floodplain	NA	M	M	L	H	M	L	H	L	ID	M
Upslope Habitats	NA	NA	NA	NA	NA	NA	NA	H	H	NA	NA
Purrington Creek											
Low Terrace	NA	H	M	M	NA	L	M	M	L	ID	M
High Terrace/Alluvium	NA	H	M	M	M	H	L	M	M	ID	M
High Terrace/Soft Bedrock	NA	ID	H	M	M	M	L	M	M	ID	M
High Terrace/Hillslope	NA	H	M	M	L	H	L	M	M	ID	ID
Inset Floodplain	NA	M	M	M	H	H	L	M	M	ID	ID
Upslope Habitats	NA	NA	NA	NA	NA	NA	NA	H	H	NA	NA
Lower Green Valley Creek											
Unconfined Floodplain	ID	M	H	L	NA	M	H	M	L	H	M
Upslope Habitats	NA	NA	NA	NA	NA	NA	NA	H	M	NA	NA

* Water conservation and alternative storage projects: All priority levels should be considered tentative and are based mostly on CDFG habitat inventory data and a little from flow and model data to date

** Fine sediment source reduction projects: Priority levels considered tentative pending finding of sediment source assessment

Identified High Priority Restoration Projects

Purrington Creek Salmonid Habitat Restoration Project Description, O'Connor Environmental Inc.

Overview

This conceptual plan (30% complete design) proposes reach-scale salmonid habitat restoration in a 1,000 ft reach of Purrington Creek near Peaks Pike Road. The location and objectives of reach-scale restoration are supported by watershed-scale geomorphic assessment of salmonid habitat conditions and habitat-forming processes.

The project consists of a series of structures designed to enhance instream habitat features while protecting banks from further erosion. The large wood structures are designed to ameliorate the impacts of the deeply incised and the associated loss of in-channel habitat, particularly the lack of winter refugia and spawning habitat. The structures are designed to be placed along both banks of Purrington Creek to create localized scour and promote pool formation while sorting and building gravel bars to combat chronic channel incision. The structures would also provide instream complexity and cover while protecting banks from further erosion and fine sediment contribution. A 2-d hydraulic model was used to evaluate the effect of alternative structure orientation of flow direction of flow velocity. Field reconnaissance and mapping was conducted to determine the proposed structure locations, taking into consideration potential for pool development and condition of stream banks.

Upper Green Valley Creek Salmonid Habitat Restoration Project, O'Connor Environmental Inc.

Overview

This conceptual plan (30% complete design) proposes reach-scale salmonid habitat restoration in a 1,000 ft reach of Green Valley Creek, in upper Green Valley Creek near Green Valley School Road. The location and objectives of reach-scale restoration are supported by watershed-scale geomorphic assessment of salmonid habitat conditions and habitat-forming processes.

The project consists of a series of large wood structures placed along the banks of Green Valley Creek. The large wood structures are designed to enhance salmonid habitat and combat incision at channel reaches that have been simplified by incision by installing structures that will build and sort gravels and provide complex shelter and cover. A 2-d hydraulic model was used to evaluate the effect of alternative structure orientation of flow direction of flow velocity. Field reconnaissance and mapping was conducted to determine the proposed structure locations, taking into consideration potential for pool development and condition of stream banks. Details of the conceptual plan are outlined below, and address restoration objectives, design concepts, design specifications and implementation.

Green Valley Creek Off-Channel Winter Refugia Habitat Enhancement Project, Prunuske Chatham Inc.

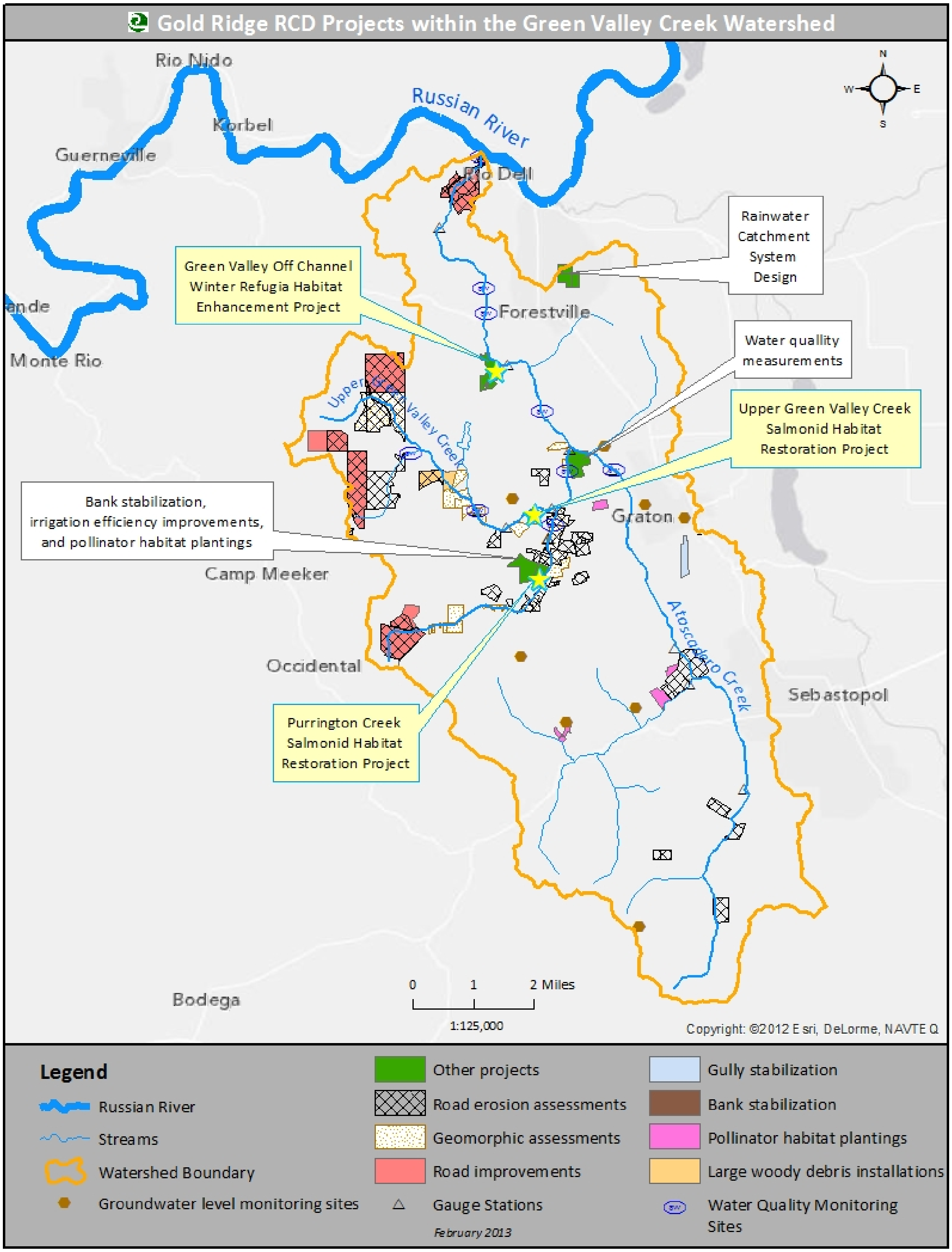
Overview

The third project had been identified at the beginning of this planning process and went through a collaborative process of design, led by PCI. While it was acknowledged that the project was needed based on the lack of high flow refugia habitat through the lower Green Valley stream reach and, in fact, throughout the lower five miles of Green Valley Creek, the design approach was informed by a limiting factor analysis and associated monitoring program of the stream reach. The focused monitoring that was conducted at this site included continuous water quality monitoring, bioassessment (both macroinvertebrate sampling and snorkeling surveys), and geomorphic surveys. This data was presented to the Technical Work Group and a several restoration approaches were explored.

Led by the willingness of the Thomas Creek Ranch community to host a project that will showcase off-channel habitat creation, several design approaches were explored that varied significantly in size and scope. One of the larger scale projects that aimed to create a complex of anastomosed channels that ran several hundred feet throughout the left bank floodplain and could capture the channel at various streamflows was ideal for restoring floodplain connection, but ended up being unfeasible. While the project was designed on a single property, it would have repercussions beyond their property boundaries. Without the active engagement and support of landowners on both sides of the stream, a project that would move the location of the stream channel could result in a redistribution of property, since the centerline of the creek generally functions as a property boundary, and potentially interfere with the riparian water rights associated with streamside parcels. Due to these concerns, a smaller, more localized project was designed.

The Technical Memo prepared by PCI staff describing the project need and design approach is included in Appendix B.

Figure IV-5. Gold Ridge RCD projects in the Green Valley Creek Watershed



Implementation Actions

Targeted actions for the Green Valley Watershed Management Plan were developed to contribute toward coho recovery and agricultural sustainability in the Upper Green Valley watershed. Recommendations specific to archaeology, sediment, water quality, hydrology, and biology are contained within *Section II, Watershed Description*. The recommendations are as specific as possible given the abbreviated planning time-frame and are summarized in the table below.

Table IV-2. Upper Green Valley Watershed Management Plan Actions

Technical Assessment	
Recommendation	**Actions**
Streamflow and Water Needs	
SWN1: Develop an Upper Green Valley Watershed water conservation program and task force	SWN1a: Build upon existing water conservation education efforts
	SWN1b: Assist agricultural producers in acquiring support through NRCS and RCD programs to develop water conservation measures.
	SWN1c: Conduct watershed-wide workshops and encourage water conservation practices
SWN2: Develop alternative water storage systems to reduce the dependency on diversions	SWN2a: Rainwater catchment systems
	SWN2b: Review timing of diversions
	SWN2c: Develop off-channel ponds and distribution systems for agricultural producers
SWN3: Groundwater study	SWN3a: Funding for recharge and groundwater study
SWN4: Graton CSD tertiary water re-use for ag	SWN4a: Feasibility analysis
SWN5: Monitor effectiveness of water supply enhancement projects	SWN5a: Continue the streamflow monitoring program

	SWN5b: Install staff plates on private property monitored by landowners
Water Quality	
WQ1: Surface water quality monitoring should continue with enhanced equipment at an increased number of sites	WQ1a: Parameters measured to include continuous stream discharge, temperature, DO, TSS, indicator bacteria and nutrients
WQ2: Develop goals and monitoring/analysis framework	WQ2a: Develop an SWRCB approved Monitoring and Assessment Plan and Quality Assurance Project Plan to guide monitoring activities
	WQ2b: Incorporate other data sources (ie NCRWQCB, CCWI and UCCE)
	WQ2c: Obtain repeat TSS measurements during periods of high turbidity (storm sampling) to determine duration of high turbidity
	WQ2d: Conduct bioassessment using benthic macroinvertebrate assemblages as an indicator of aquatic habitat quality
	WQ2e: Conduct bioassessment using algal communities as an indicator of nutrient impacts to aquatic habitat quality in stream reaches where algae are consistently present.
	WQ2f: Conduct first flush and subsequent storm sampling to measure pollutant levels entering Green Valley Creek and its tributaries.
WQ3: Implementation of management measures to decrease sediment loads	WQ3a: Work with landowners to implement sediment reduction measures
	WQ3b: Implement priority road related sediment reduction measures
WQ4: Implementation of BMPs to decrease summer water temperatures, increase flow, and improve DO	WQ4a: Maintain and enhance summer season flows

	WQ4b: Increase riparian cover WQ4c: Work with NCRWQCB staff to design a continuous temperature and dissolved oxygen monitoring program throughout the summer months with a level of effort sufficient to assess de-listing the upper Green Valley and Purrington Creeks from low DO impairment
WQ5: Assess and manage pollutant delivery	WQ5a: Conduct testing for high likelihood pollutants (i.e. pesticide, sewage, fertilizer, oil/gas, pharmaceuticals) to establish presence or absence WQ5b: Educate community on pollutants of concern and how to prevent water contamination WQ5c: Support AGVCWC in creek clean-ups (KeepSonomaClean.org) WQ5d: Work with landowners and appropriate agencies to ensure proper disposal of toxics
WQ6: Manage stormwater	WQ6a: Disconnect impervious surfaces WQ6b: Keep stormwater on-site
Sediment and Erosion	
Sed1: Assess watershed and reach-scale geomorphic processes	Sed 1a: Identify extent, causes, and impacts of channel incision Sed1b: Identify extent, causes, and impacts of aggradation in the Korbel Reach of Upper Green Valley Creek (include reach downstream of Atascadero confluence)
Sed2: Expand assessment of erosion and sediment delivery	Sed2a: Plan and conduct a second phase assessment of private, unpaved roads Sed2b: Assess the extent, severity and impacts of surface erosion on ag lands Sed2c: Expand and continue assessment of non-road-related bank and upland erosion sites

Sed3: Implement private roads erosion reduction program	Sed3a: Implement prioritized road related erosion sites
Sed4: Reduce or prevent streambank and gully erosion	Sed 4a: Stabilize streambanks using bioengineering techniques Sed 4b: Implement restoration treatments at selected bank and upland erosion sites
Sed5: Implement agricultural BMPs	Sed5a: If there is active grazing, then resources should be made available to the operator to install riparian pasture fencing, develop off-channel water sources, and revegetate the riparian corridor. Sed5b: Improve soil and irrigation practices to prevent erosion, build soil fertility, and increase water-holding capacity through use of conservation tillage, crop rotations, fallowing, cover crops, and increasing fertilizer use efficiency.
Biological Resources	
Bio1: Protect and enhance riparian and instream habitat	Bio1a: Enhance instream habitat complexity; more shelter, large woody structures (LWS); Outreach and education effort on benefit of LWS Bio1b: Develop a plan to identify and remove or modify fish passage barriers Bio 1c: Support an outreach effort to protect riparian corridors from development Bio1d: Implement riparian habitat restoration projects
Bio2: Uplands habitat	Bio2a: Increase and improve off channel habitat Bio2b:Mapping vegetation
Bio3: Work with the agricultural community to promote on-farm habitat enhancement projects	Bio3a: Develop pollinator farm plans

	Bio 3b: Develop On-Farm Habitat Enhancement Program, including workshops and educational materials
Bio 4: Biological resources monitoring	Bio 4a: Distribution, abundance and limiting factors of non fish species Bio4b: Monitor % vegetative cover along stream corridors Bio4c: Conduct bird surveys as part of project effectiveness evaluations
Bio5: Work with Sonoma County Agricultural Preservation and Open Space District to promote easements and habitat enhancement projects on land trusted properties	Bio5a: Assist producers in participating in programs that provide additional capital to support agricultural land values, such as conservation easements through the Williamson Act. Bio5b: Coordinate with NRCS staff to assist producers in developing Farm Bill program contracts
Bio 6: Develop an invasive species eradication program	Bio6a: Work with MSWMA and BAEDN to map the extent of invasive plant populations Bio6b: Develop an invasive species management strategy Bio6c: Support the agricultural community in adopting grazing management plans that promote grassland biodiveristy
Archaeological Resources	
Arch1: Take steps to ensure the preservation of all archaeological resources in the watershed.	Arch1a: Known resources assessment by a professional archaeologist Arch1b: Specific project area sites should be assessed by a professional archaeologist to avoid disturbance of previously unidentified cultural resources

	Arch1c: If archaeological resources are encountered during construction, work should be temporarily halted near the discovered materials and workers should avoid altering the materials and their context until a qualified professional archaeologist has been consulted. Any identified cultural resources should be recorded on DPR 523 historic resource recordation forms

Implementation Actions

The following section provides a framework to bring the Plan recommendations into existence. It identifies who would implement actions by when and addresses the value of partnerships to engage watershed residents and support Gold Ridge RCD in meeting watershed goals. This chapter presents an overall strategy for keeping watershed residents and other stakeholders current with new information and management practices.

Project selection criteria and process

Gold Ridge RCD is taking the lead for implementing many of the Plan actions. The RCD has been working for nearly 70 years to help coordinate funding resources with landowner needs and will use this plan to solicit and distribute additional funding for the Upper Green Valley Watershed. The following process describes how the RCD will assess and select projects. It recognizes that different funding sources have varying requirements and that additional selection criteria may be needed to fit specific funding programs as well as fulfill resource protection and enhancement goals.

Proposed project selection criteria could include:

1. Improvement to water quality
2. Enhancement of summer streamflow
3. Protection, restoration, or enhancement of one or more natural processes [Examples include restoration of riparian vegetation that will provide shade, LWD, and bank stability over many years; modification of stream crossings to allow sediment transport and movement of aquatic species; and removal of non-native invasive plants.]
4. Improvement of habitat connectivity
5. Support of habitat for a diversity of plant/animal species or protection of vital habitat features for special status watershed wildlife species
6. Addressing causes as well as or instead of symptoms

7. Strong landowner commitment
8. "Pioneer" project that will promote additional projects
9. Technically sound and effective design solution is feasible
10. Cost is reasonable for benefits

Additional on-the-ground restoration projects that are funded and currently underway in the Green Valley watershed:

- California Department of Fish and Wildlife funded "Green Valley Rural Road Improvement Project" to reduce fine sediment loads into Green Valley Creek and its tributaries; Phase I is complete, Phase II in progress

- California Department of Fish and Wildlife funded "Green Valley Creek Channel Stabilization and Coho Habitat Enhancement Project" to improve spawning and rearing habitat by increasing habitat diversity through the placement of large wood structures for coho salmon and steelhead trout in a selected section of upper Green Valley Creek; completed 2012.

- The Pacific States Marine Fisheries Commission funded "Upper Green Valley Fish Passage Design Project" to design a project to modify a partial barrier.

- Pacific States Marine Fisheries Commission and Natural Resources Conservation Service funded "Upper Green Valley Gully Stabilization for Sediment Load Reduction Project".

- National Fish and Wildlife Foundation and Natural Resources Conservation Service funded "Green Valley Ranch Vineyard Irrigation Efficiency Project" to restore salmonid habitat by reducing the amount of water withdrawn from tributaries to the Russian River, including Purrington Creek, during critical low-flow periods, while providing adequate water for beneficial uses such as irrigation and frost protection.

- National Fish and Wildlife Foundation funded "El Molino High School Rainwater Catchment Design".

- California Department of Fish and Wildlife funded "Purrington Creek Bank Stabilization Project," which improved salmonid spawning and rearing habitat by reducing fine sediment and improving riparian canopy on a selected reach of Purrington Creek. Completed 2010.

Future project concepts, not yet designed:

- A project similar to Green Valley Salmonid Habitat Restoration Project at the reach of GVC upstream of Bones Road.

- Investigation of a floodplain reconnection project just downstream of the Green Valley-Atascadero confluence (access on both sides).
- Initiate a discussion with Purrington Creek streamside landowners, agricultural organizations (Sonoma County Farm Bureau, Sonoma County Wine Grape Commission), conservation organizations (Sonoma Land Trust, Sonoma County Ag Preservation and Open Space District) to discuss the landowner interest and feasibility of establishing limited riparian easements, the acquisition of which would create a riparian buffer for streambank adjustment to re-establish floodplain interaction.

Funding

Although some projects are already underway in the Upper Green Valley Creek with other non-profit organizations, additional funding is needed to fully implement the Plan. GRRCD will actively seek funding on behalf of interested landowners. Non-profit project partners are also eligible to receive funding from many state and federal agencies, as well as from foundations. In addition to help from GRRCD and other project partners, eligible private landowners have direct access to federal cost share programs through NRCS and USFWS, state cost-share assistance from CDF, and low-interest loans through the Sonoma County Energy Independence Program (SCEIP). Funding sources for Plan implementation can be found in Appendix C.

Next Steps

GRRCD is committed to watershed planning in the Green Valley watershed and has secured funding from the California Department of Fish and Wildlife and the California State Coastal Conservancy for continuation of this planning effort through additional elements. This funding will provide for greater stakeholder outreach, an analysis of stream flow availability for restoration planning , as well as a sediment source study, feasibility study and project design to alleviate flooding at the Green Valley Road over Green Valley Creek crossing, and implementation funding strategizing for completion of prioritized sediment reduction and habitat improvement projects.

Additionally, GRRCD continues to participate in the Russian River Coho Water Resources Partnership, which identified Green Valley Creek as one of 5 first priority streams important for salmonid recovery in the Russian River basin. The hydrology analysis that was started in the first phase of the Upper Green Valley watershed planning process will continue through the

Coho Partnership. Water quality monitoring will continue with continuous water quality monitoring of temperature, dissolved oxygen, conductivity, and flow.

This Green Valley Watershed Management Plan is intended to serve as a guiding document for future planning efforts in the Green Valley watershed. The Green Valley Watershed planning approach involved an open, inclusive process, identification and recruitment of technical experts, voluntary landowner participation, and a commitment to cooperative problem-solving. The main themes in this watershed management plan are the preservation and restoration of watershed function, protection of key coho habitat and creation of agricultural sustainability through education and implementation of site-specific projects and BMPs. As a "living document," this plan is expected to change, but the process utilized in plan development and the themes that guided plan development are expected to remain relevant for future iterations.

V. Plan Limitations

This plan represents the most current data available regarding the Green Valley watershed; it has been developed using existing literature and data from field investigations conducted during the four years. In spite of every effort to develop a comprehensive, accurate plan, however, there are funding, time, and data constraints. With greater funding, more field assessments would have been possible, allowing for more detailed roads and geomorphologic assessments and an archaeologic assessment. These assessments would provide a greater understanding of riparian processes and impacts from past and present human activities. Additional field data would provide a more thorough understanding of the watershed and greater certainty when prioritizing projects for implementation.

While recognizing these constraints, it is important to recognize that this plan is intended as a "living document." This plan is the first iteration of a plan intended to enable all willing landowners to improve land use practices, ameliorate legacy impacts, restore riparian function, and restore watershed function to improve salmonid and other wildlife habitat.

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VII. Appendices

A: Green Valley Watershed and Habitat Restoration Recommendations Matrix and Source Summary

B: Prunuske Chatham Inc. Technical Memo: Basis of Design –Thomas Creek Ranch Winter Habitat Enhancement Project, Green Valley Creek

C. Local, State, Federal, and Foundation Funding Sources

Green Valley Creek Watershed and Habitat Restoration Recommendations Matrix

The matrix is comprised of habitat restoration or enhancement recommendations made for the Green Valley watershed by a variety of agencies and organizations (see List of Works Cited at the end of this document). If the guidance document mentioned, but did not numerically prioritize, their recommendations then they are signified in the matrix with a √ mark.

Threats/Recommendation Priorities Green Valley Purrington Atascadero Jonive Sexton Redwood Source	Inventory and reduce sediment sources; road and stream bank erosion sites	Protect & Enhance Riparian Habitat (includes Livestock management & exclusion from riparian areas and biotechnical vegetative techniques)	Enhance instream cover and pool number and depth	Maintain and increase LWD	Instream flow management/ water conservation to reduce diversion related impacts	Improve fish passage/ remove or modify migration barriers	Land conservation/easements to protect sensitive habitats	Increase quantity of spawning gravel; install structures to decrease channel incision & recruit spawning gravel
Gold Ridge Resource Conservation District (2010), Upper Green Valley Creek	√	√	√	√	√		√	
California Department of Fish & Game, Guerneville HSA (2004)	1					3		
California Department of Fish & Game, Green Valley Creek (1994-95)	5 (Harrison Creek)	4	3	1		6		2
National Marine Fisheries Service (2008), Green Valley Creek	4		2	2	5	3 (off stream over-wintering habitat)	1	
Merritt Smith Consulting (2003), mid-Green Valley Creek, upstream of Atascadero Creek confl.	√		√		√			√

Threats/Recommendation Priorities Green Valley Purrington Atascadero Jonive Sexton Redwood Source	Inventory and reduce sediment sources	Protect & Enhance Riparian Habitat (includes Livestock management and exclusion from riparian areas and biotechnical vegetative techniques)	Enhance instream cover and pool number and depth	Maintain and increase LWD	Instream flow management/ water conservation to reduce diversion related impacts	Improve fish passage/ remove or modify migration barriers	Land conservation / easements to protect sensitive habitats	Increase quantity of spawning gravel; install structures to decrease channel incision and recruit spawning gravel
Gold Ridge Resource Conservation District (2010), Purrington Creek	√	√	√	√	√		√	
O'Connor Environmental, Inc. (2010), Purrington Creek	√		√ (through LWD structures)	√				√ (stabilize bank erosion & channel incision)
National Marine Fisheries Service (2008), Purrington Creek	4		2	2	5	3 (off stream over-wintering habitat)	1	
California Department of Fish & Game, Purrington Creek (1994)		2	4	1				3
California Department of Fish & Game, Atascadero Creek (1995)		2	3	4		1		
National Marine Fisheries Service (2008), upper Atascadero Creek		3	1			2		

Threats/Recommendation Priorities Green Valley Purrington Atascadero Jonive Sexton Redwood Source	Inventory and reduce sediment sources	Protect & Enhance Riparian Habitat (includes Livestock management and exclusion from riparian areas and biotechnical vegetative techniques)	Enhance instream cover and pool number and depth	Maintain and increase LWD	Instream flow management/ water conservation to reduce diversion related impacts	Improve fish passage/ remove or modify migration barriers	Land conservation /easements to protect sensitive habitats	Increase quantity of spawning gravel; install structures to decrease channel incision and recruit spawning gravel
California Department of Fish & Game, Jonive Creek (2001)	3; 4			2		1		
National Marine Fisheries Service (2008), Jonive Creek		3	1			2		
California Department of Fish & Game, Sexton Creek (2001)	3	4	1	2				
National Marine Fisheries Service (2008), Sexton Creek		3	1			2		
California Department of Fish & Game, Redwood Creek (2001)			2	3		1 (baffles installed in culverts)		
National Marine Fisheries Service (2008), Redwood Creek		3	1			2		

Sources of Information regarding limiting factors to aquatic habitat health and associated enhancement priorities or recommendations

The Upper Green Valley Creek Watershed Management Plan DRAFT Phase 1 (Gold Ridge Resource Conservation District, 2010)

The Upper Green Valley Watershed Management Plan (Plan) provides a description of existing watershed conditions, identifies data gaps, identifies and prioritizes sediment reduction and other projects for immediate implementation and provides recommendations for management practices to support agricultural and environmental sustainability. The Plan is intended to serve as a guiding document for future planning efforts in the Upper Green Valley watershed.

While assessment and enhancement recommendations were made in this Plan, they were not ranked or prioritized. This will be a goal of this second phase of planning.

California Department of Fish and Game Green Valley, Purrington, Atascadero, Jonive, Sexton and Redwood Creek Stream Inventory Reports (California Department of Fish & Game, 1994, revised 2006)

CDFG conducted stream inventories on Green Valley Creek (which included Harrison Creek) and associated tributaries (Purrington, Atascadero, Jonive, Sexton and Redwood Creeks) in the summers of 1994-5 (Green Valley, Purrington, Atascadero) or 2001 (Jonive, Sexton, Redwood). The objective of the habitat inventories was to document the amount and condition of available habitat to fish and other aquatic species with an emphasis on anadromous salmonids. The objective of the biological inventory was to document the salmonids and other aquatic species present and their distribution. Stream inventory reports from sub-basins summarize habitat conditions, biological resources and recommendations specific to that tributary.

The inventory found that, Steelhead were documented consistently during each past survey year (1966, 1969, 1975, 1991, 1993, 1994, 1995) and coho only intermittently. This is likely because physiological and environmental requirements for coho are more stringent than for steelhead, or coho were absent or present only in small numbers in some years. Overall, habitat conditions for both steelhead and coho have declined over time.

In general, Reaches 1-3 of Green Valley Creek (downstream of the confluence with Atascadero Creek) are marginal for salmon and steelhead habitat. Some long, deep sections of the stream occur which may be used as rearing habitat, however, shelter is lacking and stream temperatures are high. Portions of these reaches have been channelized and levied, thus stream velocity has increased resulting in streambank erosion and loss of mature riparian. Little riffle habitat exists for spawning, and what does exist is unsuitable for spawning due to high gravel embeddedness. The unstable banks and effects of channelization in these reaches limits instream habitat improvement alternatives, although some opportunity exists. Any work considered in these reaches will require careful design, placement, and construction that must include protection for the unstable banks and high stream velocities. In Reach 1 bank protection, riparian planting and exclusionary fencing for livestock is recommended. Reaches 2 and 3 are good for bank-placed boulders and single and opposing wing-deflectors. They are fair for low-stage (low profile) weirs, boulder clusters and channel constrictors. Log cover structures can be used to increase instream shelter.

Upstream of the Atascadero Creek confluence conditions are better. In reaches 4 and 5, spawning and rearing habitat exists, canopy shading is higher, although instream shelter is still lacking and stream bank erosion is prevalent due to channel downcutting. However, many opportunities and alternatives exist for habitat improvement due to the more stable channel type. Reaches 4 and 5 are excellent for many types of low and medium stage instream enhancement structures. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and shelter.

The best spawning gravel and habitat in the watershed exists within the lower portion of Harrison Creek, and below its confluence on Green Valley Creek. Unfortunately upper Harrison Creek will not provide year-round rearing habitat for salmonids as it dries up in the summer. In Reach 6 (upstream of the confluence of Harrison Creek) spawning and rearing habitat quality diminishes due to the effects of eroding stream banks, lack of riparian habitat, and increased temperatures and nutrient runoff from agriculture and livestock. Additionally, these upstream effects seriously impact resources downstream (in reaches 4 and 5) especially during the warmer months when stream temperature rises, algae blooms and demand for oxygen and other resources increases. Sediment transported downstream from Reach 6 in the winter also impacts the source of high quality spawning gravel from Harrison Creek. Stream bank protection, riparian planting and exclusionary fencing for livestock is recommended, as well as structures to offset channel downcutting and recruit gravel for spawning.

Specific recommendations for each tributary report are not summarized in the section, but are listed in the matrix.

Recovery Strategy for California Coho Salmon (California Department of Fish & Game, 2004)

In the CDFG "Recovery Strategy for California Coho Salmon", the Green Valley Creek watershed is classified in the Guerneville HSA (hydrologic subarea) of the Russian River hydrologic unit in the Central Coastal California ESU (evolutionarily significant unit). The Guerneville HSA extends from the mouth of the Russian River at the Pacific Ocean upstream to Healdsburg and east to the outskirts of Sebastopol and includes the major tributaries: Green Valley Creek, Fife Creek, Hulbert Creek, Dutchbill Creek, and Willow Creek. During recent surveys (2000 – 2002), coho salmon were found only in three Russian River tributaries: Green Valley Creek, Dutch Bill Creek, and Mark West Creek. Coho salmon have been found in each of the last ten years, except 2001. They were found in Dutch Bill Creek in 2002 but not in 2001, and in Mark West Creek in 2001 but not in 2002.

The Guerneville HSA is the only HSA in the Russian River watershed that received a high priority ranking for restoration and management potential.

The three restoration recommendations made for the Guerneville HSA are:

- RR-GU-02: Assess, prioritize and treat sources of excess sediment;
- RR-GU-03: Supplement first priority barren streams as part of the coho salmon broodstock program. Within the Guerneville HSA, these streams include Willow, Sheephouse, Freezeout, Dutchbill and Green Valley creeks.
- RR-GU-07: Assess, prioritize, and develop plans to treat barriers to migration and improve fish passage.

Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon (National Marine Fisheries Service, 2008)

The Central California Coast ESU population of coho salmon was classified as endangered in 2005. NMFS, as the agency responsible for listing CCC Coho Salmon as federally endangered, is responsible for developing and implementing a plan for species recovery. The foundation of this recovery plan rests upon two Technical Memoranda prepared by the Technical Recovery Team which was comprised of fisheries scientists. The recovery strategy is based on the NOAA Memoranda of historical population structure and biological viability (Bjorkstedt et al, 2005; Spence et al, 2008) which provided a rigorous scientific framework, with numeric population viability goals and scenarios. "The recovery team assessed current conditions and conducted a threats assessment for future threats for the freshwater and marine environments. Conditions and threats were assessed using The Nature Conservancy's Conservation Action Planning (CAP)…"

The highest priority threats to coho salmon recovery as stated by the plan are 1) Agricultural Practices; 2) Droughts; 3) Roads and Railroads; 4) Residential and Commercial Development; 5) Water Diversion and Impoundment. Threats assessment and restoration recommendations are made on the Russian River watershed basin level and do not specify restoration recommendations on a tributary basis, although some recommendations list tributary focus areas.

The Green Valley and Purrington Creeks sub-basins are classified in the Recovery Plan as Core areas (the highest priority status), slated for implementation of protection and restoration plans immediately. "The goal of restoration in the Core Areas is to improve and protect occupied habitats as soon as possible to ensure survival and long-term persistence. Project types will likely include (a) protecting intact habitat through regulatory actions, conservation easements, and other means; (b) installing large woody debris for cover and stream scour (leading to pool formation); (c) creating/providing additional access to off channel over-wintering habitat for juveniles; (d) controlling sediment input from roads; (e) addressing instream flows. High-cost intensive efforts are appropriate in these areas. Watershed assessments to focus restoration actions, water quality monitoring, and fish population trend monitoring are necessary to provide feedback on the effectiveness of restoration actions."

Upper Atascadero Creek sub-basin (including Jonive, Sexton and Redwood Creeks) is classified as a Phase 1 Expansion Area (second highest priority status), slated for implementation of protection and restoration plans in 2009 to 2019. The rest of the Green Valley/Atascadero watershed is classified as a Phase II Expansion (or third priority status) and slated for implementation of protection and restoration plans in 2009 to 2024.

“Phase 1 areas are watersheds adjacent to, or near, Core Areas that (a) recently supported coho salmon populations; (b) currently support coho salmon in low numbers relative to other occupied sub-watersheds; (c) maintain most of the instream habitat conditions necessary for successful completion of all freshwater life stages; and/or (d) may receive strays from Core Areas. Careful analysis of limiting factors and connectivity of project sites is needed to ensure restoration activities address the highest priority limiting factors in the correct sequence. Project types will likely include (a) improving habitat and channel complexity; (b) removing barriers to suitable habitat; (c) improving riparian corridors. In addition to presence/absence monitoring of habitat usage by coho salmon, monitoring water and habitat quality and quantity is also important to track restoration success, in space and time, within Phase 1 areas.”

Under the “Strategies for Restoring Habitats” section/identification and removal of existing passage barriers, the recommendation is made to “Improve passage on Redwood Creek (tributary to Maacama Creek) by constructing passage structure at impassable concrete road crossing.”

Purrington Creek Geomorphic Assessment (O'Connor Environmental Inc., 2010)
As a component of the “Upper Green Valley Creek Watershed Management Plan DRAFT Phase 1”, O’Connor Environmental Inc. prepared a geomorphic assessment any hyrdrologic modeling of Purrington Creek. “The geomorphic assessment focused on evaluating fluvial processes affecting habitat conditions for anadromous fish, (e.g. coho salmon) in order to provide guidance regarding future management of Purrington Creek and its watershed. The assessment emphasizes specific geomorphic processes of importance to these species as identified by the GRRRCD including channel incision, bank erosion/stability, and associated hydraulic conditions. These processes were evaluated with respect to their potential impacts on cridical habitat elements for anadromous fish (e.g. abundance and quality of pools and spawning sites). A comparison was made between present habitat conditions as determined by this study and historical conditions in a 1994 survey by CDFG.”

Salmonid Juvenile Density Monitoring in Sonoma County Streams, Synthesis of a Ten-Year Study (Merritt Smith Consulting, 2003)
Juvenile abundance monitoring was conducted to evaluate spawning success, fry or fingerling production, and juvenile survivorship as part of a larger study examining the potential effects of reclaimed water discharged to Santa Rosa Creek by the Santa Rosa Subregional Reclamation System. Four Russian River tributaries were monitored over eight rearing seasons (1994-2001). Several reaches in Maacama Creek watershed were monitored for juvenile abundance within "index zones". Index zones (a particular reach or portion of stream that is periodically surveyed to track seasonal, year-to-year, or other types of habitat and fish population change) were established in each creek and representative habitat units in each index zone have been sampled with seines twice each summer from 1993 through 2002. The ten-year sampling program has included wet, dry and normal rainfall years. Qualitative field observations in sampled units showed a net deposition of sand and gravel (particularly in 1997) in many cases such that pools became shallower and provided less habitat for larger juveniles.

Fish were sampled in selected units within each index zone by repeated passes through the unit with a beach seine. All fish and other species (invertebrates, amphibians, reptiles, mammals) captured were identified to species, and the salmonids (steelhead, coho) were measured (fork length). Monitoring was conducted at the beginning (July) and end (October-November) of the summer dry period to enable estimation of percent retention within the sampling area over this critical time period, as well as inferences regarding spawning success and juvenile growth rate.

The report makes the general observation that throughout the study area, “The two factors in addition to spring rainfall which appear to have been most prominent in adversely affecting survivorship of juvenile steelhead and coho in the rearing areas are: 1) decreasing pool depth from sediment deposition, and 2) loss of summer habitat due to water diversions.”

The report summarizes the general instream habitat conditions and their suitability to support salmonids in Green Valley Creek as, “The lower reach of Green Valley Creek, downstream from the confluence of Atascadero Creek, is heavily laden with silt, to the extent that whatever rock and gravel comprised the original streambed is completely buried. Although some shelter for salmonids is provided by overhanging blackberries and other vegetation and by rootwads and woody debris in the water, the habitat is generally very poor and different from the other study streams, so it was decided not to do any surveys in this reach. “

“The upper reach of Green Valley Creek, i.e., everything above about 300-foot elevation, appears to be too small and ephemeral to support salmonids (the upper reach was dry when first examined in Fall 1993), and so was also not surveyed. However, habitat in the main portion of the creek lying within Green Valley (this portion is the equivalent of the middle reaches of the other study streams) is suitable for salmonids and was surveyed in the vicinity of the Fred Allen property. Green Valley Creek in its middle reach flows through a narrow, steep-sided channel that is heavily populated with riparian trees and shrubs, which form a nearly complete canopy over most of the reach. Parts of the reach include large bedrock formations through which the stream plunges in a series of cataracts and pools. The bedrock ledges, rootwads of large trees, and woody debris provide instream shelter for fish, partially offsetting the paucity of boulders, cobble, or gravel on the surface of the streambed. The streambed contains a lot of silt, although not as much as in the lower reach. Excessive silt probably limits the production of invertebrate prey for fish, and may thereby limit the stream's carrying capacity for salmonids. A shortage of suitable spawning areas could also limit fish production in this stream.”

“In Green Valley Creek, some coho have been captured in every year of the study, but a trend of declining numbers is apparent, especially for the fall surveys. Nevertheless, our qualitative observations indicate a net increase in sediment over the ten years of study in most reaches of Santa Rosa, Mark West, Maacama, and Green Valley Creeks, the result being decreased depth of pools and glides, and decreased habitat diversity.”

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PRUNUSKE CHATHAM, INC.

TECHNICAL MEMO

Date: February 22, 2013

To: Gold Ridge RCD and Green Valley Creek TWG

From: Lauren Hammack, Senior Geomorphologist, PCI

Subject: Basis of Design –Thomas Creek Ranch Winter Habitat Enhancement Project, Green Valley Creek

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Prunuske Chatham, Inc. (PCI) has developed conceptual and 90% construction plans for a winter habitat enhancement project at the Thomas Creek Ranch on lower Green Valley Creek. The objective of the project, as conceived with the Technical Working Group (TWG), is to provide winter rearing and refugia habitat for juvenile salmonids. A side channel and tributary-confluence alcove complex has been designed to provide a low velocity environment with considerable fixed shelter elements and dense vegetative cover; see 90% Plans for details. Upon maturity, the project will provide the structurally complex, vegetated edge habitat needed by juvenile salmon to survive and thrive during winter high flows – habitat once provided by seasonally inundated, floodplain wetlands. This memo briefly summarizes the basis for and the design features of the project.

Setting

Lower Green Valley Creek is characterized as an entrenched channel, with nearly vertical high banks and homogenous bed form. Long pools are punctuated by short, low elevation gravel riffles. Average channel bottom width hovers around 20 feet. In-channel habitat complexity is minimal, with only an occasional downed tree or dense willow thicket providing spatially limited, discontinuous shelter elements for velocity refuge and cover. The majority of winter flows are confined within the entrenched channel. Velocities are likely above optimal ranges for juvenile salmon rearing conditions. Heavy rainfall-driven flood events do overtop the 7 to 9 foot high banks annually, and floodwaters flow across the floodplains during the flood peak hours. However, the floodplains have little topographic relief to them, as most were, or still are, graded agricultural fields. The riparian forest buffer provides scarce flood habitat for salmonids, with few old downed trees or dense, native understory thickets to provide connected low-velocity zones. Given these channel and riparian corridor characteristics, lower Green Valley Creek appears to have a distinct shortage of high-quality winter rearing habitat for coho and steelhead.

The residents of Thomas Creek Ranch (TCR) have offered to host a habitat enhancement project along their stretch of lower Green Valley Creek. The site is approximately 3 miles upstream of Green Valley Creek's confluence with the Russian River. An unmanaged, 80-

foot wide, forested riparian corridor abuts a gently used grassland pasture immediately downstream of Thomas Creek at its confluence with Green Valley Creek.

Channel Geometry and Habitat Features

A 206-foot long side channel was designed and aligned through the floodplain and riparian corridor on TCR property to maximize usable channel space while minimizing mature tree removal. The side channel inlet is placed at the confluence of Thomas Creek and Green Valley Creek, which will create a low-velocity eddy zone during high flows. Tributary confluences are often cited as critical velocity refugia habitat for salmonids in incised streams such as Green Valley Creek. To maximize the confluence habitat area, the lower 100 feet of Thomas Creek has also been realigned slightly, deepened, and widened to create a backwater. A rock channel has been included at the upstream end of the Thomas Creek redesign to ensure grade stability.

The side channel bottom width is set at 5 feet along the entire length and corresponds to ¼ the main channel bed width. Side slopes range from 1.5:1 to 2.5:1, with the steeper slopes located at the side channel inlet and outlet. Low elevation benches are spaced along the side channel and in lower Thomas Creek. The top of the benches are set 2 feet above the bed with gradual slopes for high-quality, inundated edge habitat at varying flows above winter baseflow. A large ponded area/ seasonal wetland adjacent and connected to the side channel is designed to create additional backwater area and rich feeding opportunities during higher storm flows.

Large wood will be installed throughout the side channel, lower Thomas Creek, and the inlet alcove area to slow flood velocities, provide structural complexity, and support channel stability. Logs and rootwads will be anchored by fastening to existing mature trees where possible, burying a portion of the log in the bank, or attaching to imported and buried boulders. Given that the site is completely submerged multiple times each winter, it is imperative that logs be stabilized in place to keep them from floating away. Once the site has fully matured vegetation and is producing downed wood, it will function and adjust in a dynamic manner.

Figure 1. A naturally occurring high-flow side channel augmented with large wood structures in Salmon Creek (photo by GRRCD).

Vegetation is a crucial component of the habitat design. A primary objective of this project is to provide a productive winter rearing environment for juvenile salmonids. This includes not only a well-sheltered, low-velocity zone, but also a food-rich zone. Abundant edge habitat with wetland plants, such as sedge and rushes, interspersed with native inundation-tolerant grasses, trees, and shrubs will provide feeding opportunities not found in the barren, high-velocity main channel. See Figure 1 for an example of a vegetated side channel.

Maintaining a reach of the side channel that is not densely forested, but rather grassland and shrub complexes, will support a diverse array of vegetation and associated rearing habitat components. As riparian shade and its water cooling properties are not a critical component for high-quality winter water quality, we have focused our revegetation plan largely on wetland, grassland, and shrub plantings. The existing riparian forest appears to be self-maintaining; however, additional tree species can be planted at the top of bank to supplement the existing canopy. Alders and willows will be planted on the side channel and Thomas Creek banks to provide additional stability, complexity, and wood recruitment. We expect natural establishment of alders and ash to occur on the inset benches.

The side channel and lower Thomas Creek will provide habitat for salmonids throughout the winter and early spring. Other wildlife, such as amphibians and beneficial insects, will benefit from the project, as the side channel will be a seasonally inundated, slow-water wetland. This essential habitat is now rare in the region due to historic channel modifications and floodplain grading. Concerns regarding mosquito breeding habitat are often voiced regarding off channel habitat. We have dealt with this concern by setting the side channel above summer low-flow water elevations, and thus it will not be ponded during heavy mosquito periods.

Hydrologic Design

Data from the Martinelli gage, located approximately 2 miles downstream of TCR and operated by the State Water Resources Control Board, was used to set the side channel thalweg and inset bench elevations, as well as to evaluate inundation duration for the revegetation plan. Cross sections and low-flow elevation control (riffle) were surveyed at the Martinelli gage site. These were used to develop a single cross section hydraulic model (WinXSPro). The model was calibrated to measured streamflow stages and discharges per Edwards and Cluer (Data Report: Stream Flow Monitoring in Tributaries to the Russian River 2010 and 2011, NOAA Fisheries, December 7, 2011) using PCI surveyed water surface slopes and estimated roughness values ($n = 0.045$ to 0.055). A single cross section hydraulic model was also developed for a representative section at TCR using site-specific surveyed water surface slopes and the calibrated n values from the Martinelli gage site.

Winter hydrographs from the Martinelli gage were used to evaluate winter streamflow patterns and inform side channel elevations at TCR (Figure 2). To maximize winter habitat and utilization of the feature, the side channel's outlet elevation was set at 0.2 feet above the summer low flow pool elevation. The bed slope of the side channel is set at 0.25 percent. At low winter baseflows, depths in the backwatered side channel range from 0.5 to 1 foot. During high winter baseflow, side channel depths are up to 1.5 feet deep. Inset benches are fully inundated with every storm event at depths of 2 feet in the side channel, which corresponds to a discharge of approximately 50 cfs. Typical storm event peaks range from 2 feet to 8 feet above winter base flow. The elevation at the back of the seasonal wetland (94.0’) is set at ½ the average bank height of Green Valley Creek. The project is designed to backwater and frequently inundate the seasonal wetland and channel features multiple times during the winter months with durations of several days to a couple of weeks at a time.

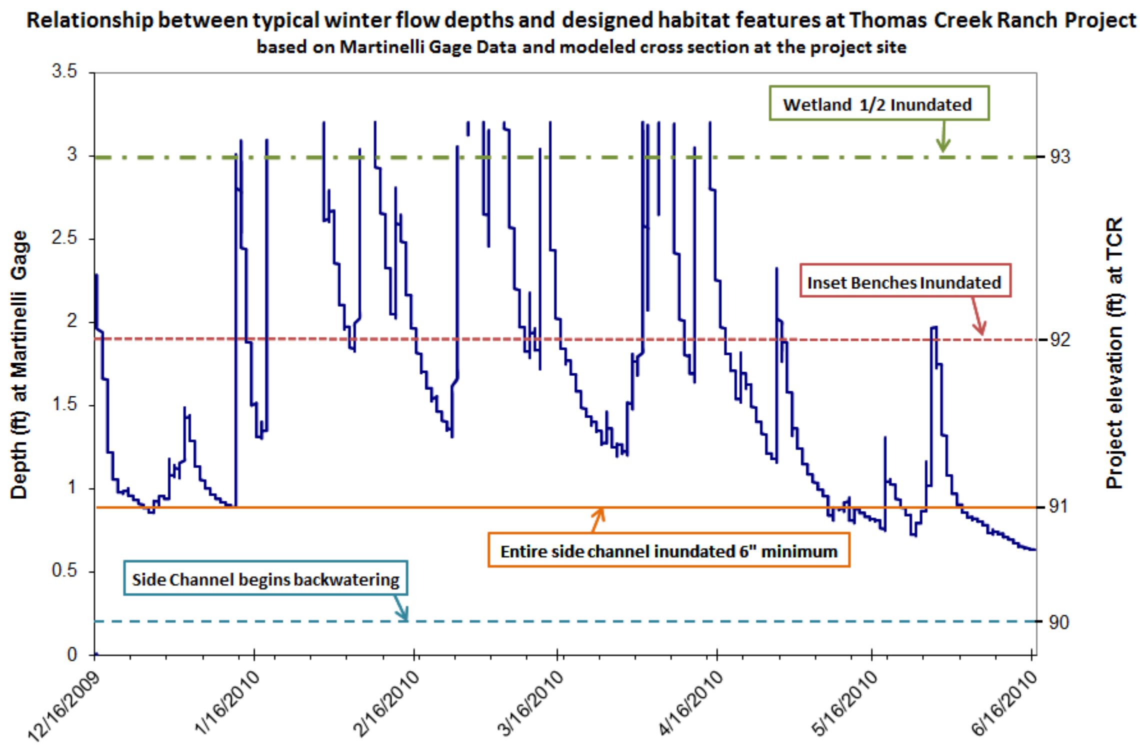

Figure 2. Winter hydrograph showing elevations of side channel features at TCR relative to depths and inundation duration. Note: the Martinelli gage only records depths up to 3.2 feet, thus peak flood depths are not documented.

The upstream inlet to the secondary channel is raised approximately 2.5 feet above the side channel thalweg elevation with a log weir. The inlet elevation is set to begin to overtop at a flow of approximately 60 cfs. At approximately 100 cfs water is flowing freely over the inlet log weir, creating a hydraulic drop into the backwatered channel. Thus, the side channel has been designed to have slow, backwater conditions throughout winter baseflows and only have through-flows during higher storm events. As inlet flows increase during large storm events, the hydraulic gradient and velocities will help flush fine sediments from the channel. Some accumulation of fine sediments is expected in the secondary channel and seasonal wetland. We expect the side channel configuration to reach a dynamic equilibrium based on mature vegetation density, flood velocities, and inundation durations.

The following is a summary of the total off-channel, low velocity habitat created by the project:

- **Winter base flow = 1,200 cubic feet**.
- **Typical storm event = 16,000 cubic feet** (This is when Thomas Creek and the created seasonal wetland are backwatered at elev. 94.0’ or ½ the height of bank.).
- **Annual peak flow = 77,500 cubic feet** (This is estimated from the project’s top of bank and adjacent active floodplain that has been observed to over top annually in the riparian zone).

Local, State, Federal, and Foundation Funding Sources for Habitat Restoration Projects.[1]

Funding Entity	Program
Local Sources	
Sonoma County	Energy Independence Program (SCEIP). Provides low-interest loans to private and commercial property owners for water and energy conservation measures. Loans are repaid through voluntary property tax assessments.
Sonoma County Open Space and Agricultural Preservation District	Protects land through purchasing development rights and acquiring easements. Project selection is based on consistency with the current Acquisition Plan and available funding.
State Agencies	
State Water Resources Control Board with North Coast Regional Water Quality Control Board (Regional Board)	319(h) Nonpoint Source. Funding is through the Environmental Protection Agency (EPA) and is intended for improving water quality through projects that address TMDL implementation or problems to streams, bays, rivers, and lakes that have been listed as impaired. Small Community Wastewater Grant Program. The program provides assistance for planning, design, and construction of publicly-owned wastewater treatment and collection. Clean Water Revolving Loan Fund. Provides low-interest loans for stormwater and wastewater treatment, and implementation of projects to reduce nonpoint source pollution. Integrated Regional Water Management Grant Program. The intention is to integrate sustainable and reliable water supply, better water quality, stormwater management, environmental stewardship, and a strong economy.

[1] This table was created by Liza Prunuske, (Prunuske Chatham, Inc,) for the Salmon Creek Integrated Coastal Watershed Management Plan, 2010

California Department of Fish and Game (CDFG)	Fisheries Restoration Grant Program. This is a long-standing competitive grant program funded by both state and federal sources. Funding can be used for planning, barrier removal, habitat restoration, monitoring, public involvement, maintenance, and education for projects consistent with current CDFG priorities.
State Coastal Conservancy	Funding is primarily through voter-approved bond funds. Provides funding for projects to purchase, protect, restore, and enhance coastal resources.
Department of Water Resources (DWR)	Groundwater program. Includes a range of grants for groundwater monitoring and management.
	Integrated Regional Water Management Grant Program. DWR administers IRWM grants through Proposition 84. DWR also manages many other grant and loan programs.
California Department of Forestry (CDF)	Fire Prevention Program. Firesafe landscaping for homeowners and communities.
	California Forest Improvement Program (CFIP). Provides cost-share assistance to private landowners, RCDs, and non-profit groups for planning, planting, fish and wildlife habitat improvement, and land conservation practices.
California Department of Public Health	Safe Drinking Water State Revolving Fund. Provides funding to correct public water system deficiencies. Selection is based upon a prioritized funding approach that addresses public health risks, compliance with requirements of the Safe Drinking Water Act, and need on a per household affordability basis.

Federal Agencies	
Environmental Protection Agency (EPA)	The Environmental Protection Agency website features an extensive catalog, sorted by keyword (e.g., invasive species, monitoring, land acquisition, watershed management), of federal funding sources for watershed protection (http://cfpub.epa.gov/fedfund/keyword_list.cfm).
US Fish and Wildlife Service	Cooperative Conservation Initiative. Provides cost-share assistance to private landowners to restore natural resources and establish or expand wildlife habitat.
National Marine Fisheries Service (NMFS)	Open Rivers Initiative provides funding and technical expertise for community-driven, small dam and river barrier removals. NMFS provide funding for multi-year regional habitat restoration partnerships including watershed-scale projects that yield significant ecological and socioeconomic benefits.
	National Association of Counties and NMFS are partners in the Coastal Counties Restoration Initiative (CCRI). CCRI encourages innovative, county led or supported projects that restore important marine and coastal habitats and living resources. These projects also develop the capacity of county governments, citizens groups and other organizations to conduct community-based restoration that will enhance local watershed-based resource management and promote stewardship.
Natural Resource Conservation Service (NRCS)	NRCS manages a suite of programs to provide technical and cost-share assistance to implement conservation practices, primarily for owners of land in agricultural production.
	The Healthy Forest Reserve Program is a voluntary program established

	for the purpose of restoring and enhancing forest ecosystems. It can provide cost-share for conservation practices, a conservation easement in exchange for market value, and Safe Harbor from future regulatory restrictions under the Endangered Species Act.
Other Sources:	
National Fish and Wildlife Foundation (NFWF)	NFWF has a number of programs that could apply including:
	Native Plant Conservation Initiative supports projects that protect, enhance, and/or restore native plant communities.
	Marine and Coastal Conservation Initiative includes a priority to build "the capacity of local communities and watershed associations to participate in local stewardship projects that contribute to and build public support for broader restoration goals".
Private foundations	Many private foundations support conservation and restoration efforts. Some foundations limit their funding to non-profit organizations, but others also fund special districts such as public schools and RCDs.