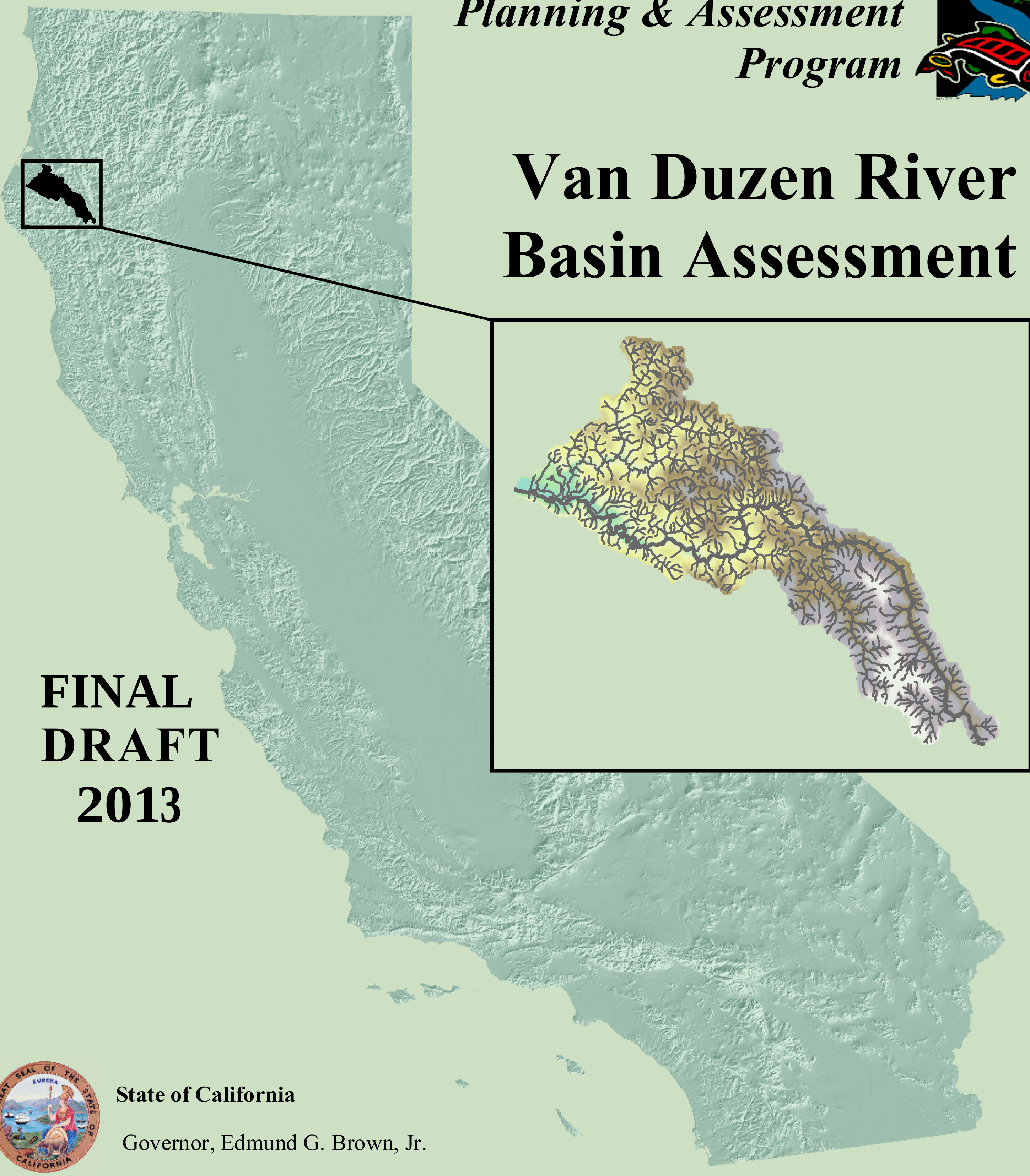
Coastal Watershed
Planning & Assessment
Program

Van Duzen River Basin Assessment



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Van Duzen River Watershed Assessment

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California Department of Fish and Game
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California Coastal Watershed Planning and Assessment Program Introduction and Overview

The Coastal Watershed Planning and Assessment Program (CWPAP) is a program of the California Department of Fish and Game (CDFG) based in Fortuna, CA. CDFG's large scale assessment efforts began in 2001 as a component of the North Coast Watershed Assessment Program (NCWAP), an interagency effort between the California Resources Agency and the Environmental Protection Agency. Due to budget constraints, the NCWAP was discontinued in 2003, but CDFG decided to continue large scale watershed assessments along California's coast to facilitate fishery improvement and recovery efforts.

The 430 square mile Van Duzen River Basin is located in the lower Eel River watershed within Humboldt and Trinity counties (Figure 1). This watershed was selected as a CWPAP assessment area because of its high fishery value to anadromous salmonids, including coho salmon that are listed as threatened by both state and federal agencies. This report was guided by following the outlines, methods, and protocols detailed in the NCWAP Methods Manual (Bleier et al., 2003). The program's assessment is intended to provide answers to six guiding assessment questions at the basin, subbasin, and tributary scales.

Program Guiding Questions

- What are the history and trends of the size, distribution, and relative health and diversity of salmonid coastal populations?
- What are the current salmonid habitat conditions; how do these conditions compare to desired conditions?
- What are the effects of geologic, vegetative, fluvial, and other endemic watershed attributes on natural processes and watershed and stream conditions?
- How has land use affected or disturbed these natural attributes, processes, and/or conditions?
- As a result of those attributes, natural processes, and land use disturbances, are there stream and habitat elements that could be considered to be factors currently limiting salmon and steelhead production?
- If so, what watershed management and habitat improvement activities would most likely lead toward more desirable conditions for salmon and steelhead in a timely, reasonable, and cost effective manner?

These questions systematically focus the assessment procedures, data gathering and provide direction for syntheses, including the analysis of factors affecting anadromous salmonid production. The questions progress from the relative status of the salmon and steelhead resource, to an assessment of the watershed context by looking at processes and disturbances, and lastly to the resultant conditions encountered directly by the fish–flow, water quality, nutrients, and instream habitat elements, including free passage at all life stages. The watershed products delivered to streams shape the stream and create habitat conditions. Thus, watershed processes and human influences determine salmonid health and production and help identify what improvements could be made in the watershed and its streams.

CWPAP assessments do not address marine influences on the ocean life cycle phase of anadromous salmonid populations. While these important influences are outside of the scope of this program, we recognize their critical role upon sustainable salmonid populations and acknowledge that good quality fresh water habitat alone is not adequate to ensure sustainability. However, freshwater habitat improvements benefit their well being and survival during their two freshwater life cycle phases and thus can create stronger year classes to the ocean.

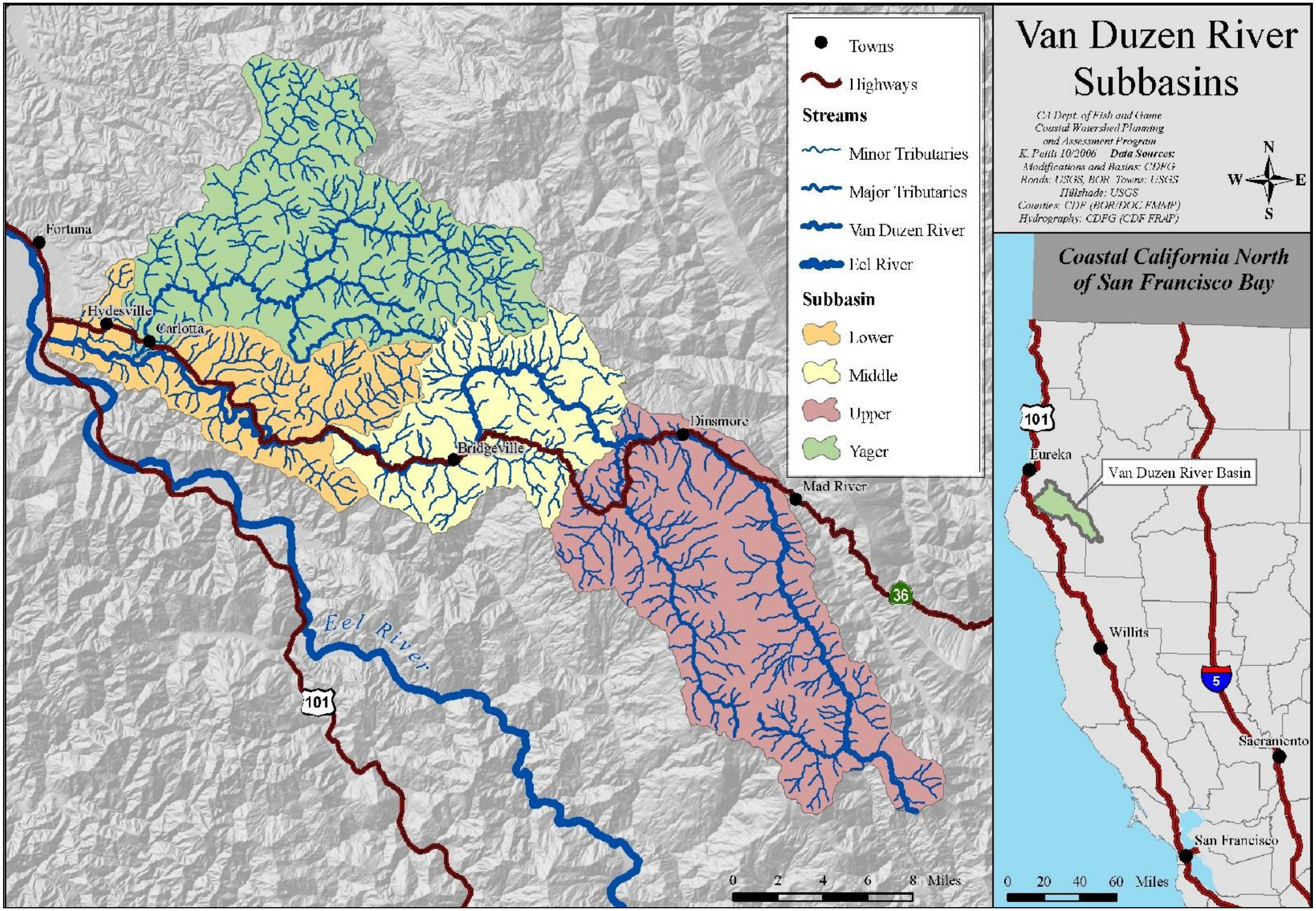

Figure 1. Location of the Van Duzen River Basin and subbasins.

Goals

- Organize and provide existing information and develop limited baseline data to help evaluate the effectiveness of various resource protection programs over time;
- Provide assessment information to help focus watershed improvement programs, and to assist landowners, local watershed groups, and individuals in developing successful projects. This will help guide support programs, such as the CDFG Fishery Restoration Grants Program (FRGP), toward those watersheds and project types that can efficiently and effectively improve freshwater habitat and lead to improved salmonid populations;
- Provide assessment information to help focus cooperative interagency, nonprofit, and private sector approaches to protect watersheds and streams through watershed stewardship, conservation easements, and other incentive programs;
- Provide assessment information to help landowners and agencies better implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

North Coast Salmon, Stream, and Watershed Issues

Pacific coast anadromous salmonids hatch in freshwater, migrate to the ocean as juveniles where they grow and mature, and then return as adults to freshwater streams to spawn. This general anadromous salmonid life history pattern is dependent upon a high quality freshwater environment at the beginning and end of the cycle. Different salmonid species and stocks utilize diverse inter-specific and intra-specific life history strategies to reduce competition between species and increase the odds for survival of species encountering a wide range of environmental conditions in both the freshwater and marine environments. These strategies include the timing and locations for spawning, length of freshwater rearing, juvenile habitat partitioning, a variable estuarine rearing period, and different physiologic tolerances for water temperature and other water quality parameters.

Salmonids thrive or perish during their freshwater phases depending upon the availability of cool, clean water, free access to migrate up and down their natal streams, clean gravel suitable for successful spawning, adequate food supply, and protective cover to escape predators and ambush prey. These life requirements must be provided by diverse and complex instream habitats as the fish move through their life cycles. If any life requirements are missing or in poor condition at the time a fish or stock requires it, fish survival can be impacted. These life requirement conditions can be identified and evaluated on a spatial and temporal basis at the stream reach and watershed levels. They comprise the factors that support or limit salmonid stock production.

The specific combination of these factors in each stream sets the carrying capacity for salmonids of that stream. The carrying capacity can thus be changed if one or more of the factors are altered. The importance of individual factors in setting the carrying capacity differs with the life stage of the fish and time of year. All of the important factors for salmonid health must be present in a suitable, though not always optimal, range in streams where fish live and reproduce (Bjorrn and Reiser 1991).

Within the range of anadromous salmonid distribution, historic stream conditions varied at the regional, basin and watershed scales. Wild anadromous salmonids evolved with their streams shaped in accordance with the inherent, biophysical characteristics of their parental watersheds, and stochastic pulses of fires, landslides, and climatic events. In forested streams, large trees grew along the stream banks contributing shade, adding to bank stability, and moderating air and stream temperatures during hot summers and cold winter seasons. The streams contained fallen trees and boulders, which created instream habitat diversity and complexity. The large mass of wood in streams provided important nutrients to fuel the aquatic food web. During winter flows, sediments were scoured, routed, sorted, and stored around solitary pieces and accumulations of large wood, bedrock, and boulders forming pools riffles and flatwater habitats.

Two important watershed goals are the protection and maintenance of high quality fish habitats. In addition to preservation of high quality habitat, reparation of streams damaged by poor resource management practices of the past is important for anadromous salmonids. Science-based management has progressed significantly and “enough now is known about the habitat requirements of salmonids and about good management practices that further habitat degradation can be prevented, and habitat rehabilitation and enhancement programs can go forward successfully” (Meehan 1991).

Through the course of natural climatic events, hydrologic responses and erosion processes interact to shape freshwater salmonid habitats. These processes influence the kind and extent of a watershed’s vegetative cover as well, and act to supply nutrients to the stream system. When there are no large disturbances, these natural processes continuously make small changes in a watershed. Managers must constantly judge these small natural changes as well as changes made by human activity. Habitat conditions can be drastically altered when major disruptions of these small interactions occur (Swanston 1991).

Major watershed disruptions can be caused by catastrophic events, such as the 1955 and 1964 north coast floods, which were system reset events. They can also be created over time by multiple small natural or human disturbances. These disruptions can drastically alter instream habitat conditions and the aquatic communities that depend upon them. Thus, it is important to understand the critical, interdependent relationships of salmon and steelhead with their natal streams during their freshwater life phases, and their streams’ dependency upon the watersheds within which they are nested, and the energy of the watershed processes that binds them together.

In general, natural disturbance regimes like landslides and wildfires do not impact larger basins like the 430 square-mile Van Duzen River in their entirety at any given time. Rather, they normally rotate episodically across the entire basin as a mosaic composed of the smaller subbasin, watershed, or sub-watershed units over long periods. This creates a dynamic variety of habitat conditions and quality over the larger basin (Reice 1994).

The rotating nature of these relatively large, isolated events at the regional or basin scale assures that at least some streams in the area will be in suitable condition for salmonid stocks. A dramatic, large-scale example occurred in May 1980 in the Toutle River, Washington, which was inundated in slurry when Mt. St. Helens erupted. The river rapidly became unsuitable for fish. In response, returning salmon runs avoided the river that year and used other nearby suitable streams on an opportunistic basis, but returned to the Toutle two years later as conditions improved. This return occurred much sooner than had been initially expected (Quinn et al. 1991; Leider 1989).

Human disturbance sites, although individually small in comparison to natural disturbance events, usually are spatially distributed widely across basin level watersheds (Reeves et al. 1995). For example, a rural road or building site is an extremely small land disturbance compared to a forty-acre landslide or wildfire covering several square miles. However, when all the roads in a basin the size of the Van Duzen River are looked at collectively, their disturbance effects are much more widely distributed than a single large, isolated landslide that has a high, but relatively localized impact to a single sub-watershed.

Human disturbance regimes collectively extend across basins and even regional scales and have lingering effects. Examples include water diversions, conversion of near stream areas to urban usage, removal of large mature vegetation, widespread soil disturbance leading to increased erosion rates, construction of levees or armored banks that can disconnect the stream from its floodplain, and the installation of dams and reservoirs that disrupt normal flow regimes and prevent free movement of salmonids and other fish. These disruptions often develop in concert and in an extremely short period of time on the natural, geologic scale.

Human disturbances are often concentrated in time because of newly developed technology or market forces such as the California Gold Rush or the post-WWII logging boom in Northern California. The intense human land use of the last century, combined with the transport energy of two mid-century record floods on the North Coast, created stream habitat impacts at the basin and regional scales. The result of these recent combined disruptions has overlain the pre-European disturbance regime process and conditions.

Consequently, stream habitat quality and quantity are generally depressed across most of the North Coast region. It is within this widely impacted environment that both human and natural disturbances continue to occur, but with vastly fewer habitat refugia lifeboats than were historically available to salmon and steelhead. Thus, a general reduction in salmonid stocks can at least partially be attributed to this impacted freshwater environment.

Factors Affecting Anadromous Salmonid Production

A main component of the program is the analyses of the freshwater factors in order to identify whether any of these factors are at a level that limits production of anadromous salmonids in North Coast basins. This limiting factors analysis (LFA) provides a means to evaluate the status of a suite of key environmental factors that affect anadromous salmonid life history.[1] These analyses are based on comparing measures of habitat components such as water temperature and pool complexity to a range of reference conditions determined from empirical studies and/or peer reviewed literature. If a component's condition does not fit within the range of reference values, it may be viewed as a limiting factor. This information will be useful to identify underlying causes of stream habitat deficiencies and help reveal if there is a linkage to watershed processes and land use activities.

Chinook salmon, coho salmon, and steelhead trout all utilize headwater streams, larger rivers, estuaries, and the ocean for parts of their life history cycles. In the freshwater phase in salmonid life history, adequate flow, free passage, suitable stream conditions, suitable water quality (such as stream water temperatures), and functioning riparian areas are essential for successful completion of their anadromous lifecycle.

Water Quantity

Stream flow can be a significant limiting factor for salmonids, affecting fish passage, and quantity and quality of spawning, rearing, and refugia areas. For successful salmonid production, stream flows should follow the natural hydrologic regime of the basin. A natural regime minimizes the frequency and magnitude of storm flows and promotes better flows during dry periods of the water year. Salmonids evolved with the natural hydrograph of coastal watersheds, and changes to the timing, magnitude, and duration of low flows and storm flows can disrupt the ability of fish to follow life history cues.

Adequate instream flow during low flow periods is essential for fish passage in the summer time, and is necessary to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries.

Water Quality

Important aspects of water quality for anadromous salmonids are water temperature, turbidity, water chemistry, and sediment load. In general, suitable water temperatures for salmonids are between 48-56°F for successful spawning and incubation, and between 50-52°F and 60-64°F, depending on species, for growth and rearing. Additionally, cool water holds more oxygen, and salmonids require high levels of dissolved oxygen in all stages of their life cycle.

A second important aspect of water quality is turbidity. Fine suspended sediments (turbidity) affect nutrient levels in streams that in turn affect primary productivity of aquatic vegetation and insect life. This eventually reverberates through the food chain and affects salmonid food availability. Additionally, high levels of turbidity interfere with a juvenile salmonids' ability to feed and can lead to reduced growth rates and survival (Bill Trush, Trush & Associates; personal communication).

A third important aspect of water quality is stream sediment load. Salmonids cannot successfully reproduce when forced to spawn in streambeds with excessive silt, clays, and other fine sediment. Eggs and embryos suffocate under excessive fine sediment conditions because oxygenated water is prevented from passing through the egg nest, or redd. Additionally, high sediment loads can cap the redd and prevent emergent fry from escaping the gravel into the stream at the end of incubation. High sediment loads can also cause abrasions on fish gills, which may increase susceptibility to infection. At extreme levels, sediment can clog the gills causing death. Additionally, materials toxic to salmonids can cling to sediment and be transported through downstream areas.

Fish Passage

Free passage describes the absence of barriers to the free instream movement of adult and juvenile salmonids. Free movement in streams allows salmonids to find food, escape from high water temperatures, escape from predation, and migrate to and from their stream of origin as juveniles and adults. Temporary or permanent dams, poorly constructed

[1] The concept that fish production is limited by a single factor or by interactions between discrete factors is fundamental to stream habitat management (Meehan 1991). A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population.

road crossings, landslides, debris jams, or other natural and/or man-caused channel disturbances can lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn.

Instream Habitat Conditions

Complex instream habitat is important for all lifecycle stages of salmonids. Habitat diversity for salmonids is created by a combination of deep pools, riffles, and flatwater habitat types. Pools, and to some degree flatwater habitats, provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas, particularly for young coho salmon. They are also necessary for adult resting areas. A high level of fine sediment fills pools and flatwater habitats. This reduces depths and can bury complex niches created by large substrate and woody debris. Riffles provide clean spawning gravels and oxygenate water as it tumbles across them. Steelhead fry use riffles during rearing. Flatwater areas often provide spatially divided pocket water units (Flosi et al. 1998) that separate individual juveniles, which helps promote reduced competition and successful foraging.

Riparian Zone

A functional riparian zone helps to control the amount of sunlight reaching the stream, provides vegetative litter, and contributes invertebrates to the local salmonid diet. These contribute to the production of food for the aquatic community, including salmonids. Tree roots and other vegetative cover provide stream bank cohesion and buffer impacts from adjacent uplands. Near-stream vegetation eventually provides large woody debris and complexity to the stream (Flosi et al. 1998).

Riparian zone functions are important to anadromous salmonids for numerous reasons. Riparian vegetation helps keep stream temperatures in the range that is suitable for salmonids by maintaining cool stream temperatures in the summer and insulating streams from heat loss in the winter. Larval and adult macro-invertebrates are important to the salmonid diet and are dependent upon nutrient contributions from the riparian zone. Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintain diverse salmonid habitat, and help reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel morphology, helps retain organic matter and provides essential cover for salmonids (Murphy and Meehan 1991).

Therefore, excessive natural or man-caused disturbances to the riparian zone, as well as directly to the stream and/or the basin itself can have serious impacts to the aquatic community, including anadromous salmonids. Generally, this seems to be the case in streams and watersheds in the North Coast of California. This is borne out by the recent decision to list many North Coast Chinook and coho salmon, and steelhead trout stocks under the Endangered Species Act.

Disturbance and Recovery of Stream and Watershed Conditions

Natural and Human Disturbances

The forces shaping streams and watersheds are numerous and complex. Streams and watersheds change through dynamic processes of disturbance and recovery (Madej 1999). In general, disturbance events alter streams away from their equilibrium or average conditions, while recovery occurs as stream conditions return towards equilibrium after disturbance events. Given the program’s focus on anadromous salmonids, an important goal is to determine the degree to which current stream and watershed conditions in the region are providing salmonid habitat capable of supporting sustainable populations of anadromous salmonids. To do this, we must consider the habitat requirements for all life stages of salmonids. We must look at the disturbance history and recovery of stream systems, including riparian and upslope areas, which affect the streams through multiple biophysical processes.

Disturbance and recovery processes can be influenced by both natural and human events. A disturbance event such as sediment from a natural landslide can fill instream pools providing salmon habitat just as readily as sediment from a road failure. On the recovery side, natural processes (such as small stream-side landslides) that replace instream large woody debris washed out by a flood flow help to restore salmonid habitat, as does large woody debris placed in a stream by a landowner as a part of a restoration project.

Natural disturbance and recovery processes, at scales from small to very large, have been at work on north coast watersheds since their formation millions of years ago. Recent major natural disturbance events have included large flood events such as occurred in 1955 and 1964 (Lisle 1981a) and 1974 (GMA 2001a) ground shaking and related tectonic uplift associated with the 1992 Cape Mendocino earthquake (Carver et al. 1994).

Major human disturbances (e.g., post-European development, dam construction, agricultural and residential conversions, and the methods of timber harvesting practices used particularly before the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act) have occurred over the past 150 years (Ice 2000). Salmonid habitat also was degraded during parts of the last century by well-intentioned but misguided restoration actions such as removing large woody debris from streams (Ice 1990). More recently, efforts at watershed restoration have been made, generally at the local level. For example, in California and the Pacific Northwest, minor dams from some streams have been removed to clear barriers to spawning and juvenile anadromous fish. For a thorough treatment of stream and watershed recovery processes, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Defining Recovered

There is general agreement that improvements in a condition or set of conditions constitute recovery. In that context, recovery is a process. One can determine a simple rate of recovery by the degree of improvement over some time period, and from only two points in time. One can also discuss recovery and rates of recovery in a general sense. However, a simple rate of recovery is not very useful until put into the context of its position on a scale to the endpoint of recovered.

In general, recovered fish habitat supports a suitable and stable fish population. Recovered not only implies, but necessitates, knowledge of an endpoint. In the case of a recovered watershed, the endpoint is a set of conditions deemed appropriate for a watershed with its processes in balance and able to withstand perturbations without large fluctuations in those processes and conditions. However, the endpoint of recovered for one condition or function may be on a different time and geographic scale than for another condition or function.

Some types and locations of stream recovery for salmonids can occur more readily than others can. For example, in headwater areas where steeper source reaches predominate, suspended sediment such as that generated by a streamside landslide or a road fill failure may start clearing immediately, while coarser sediments carried as bedload tend to flush after a few years (Lisle 1981a; Madej and Ozaki 1996). Broadleaf riparian vegetation can return to create shading, stabilize banks, and improve fish habitat within a decade or so. In contrast, in areas lower in the watershed where lower-gradient response reaches predominate, it can take several decades for deposited sediment to be transported out (Madej 1982; Koehler et al. 2001), for widened stream channels to narrow, for aggraded streambeds to return to pre-disturbance level, and for streambanks to fully re-vegetate and stabilize (Lisle 1981b). Lower reach streams will require a similar period for the near-stream trees to attain the girth needed for recruitment into the stream as large woody debris to help create adequate habitat complexity and shelter for fish, or for deep pools to be re-scoured in the larger mainstems (Lisle and Napolitano 1998).

Factors and Rates of Recovery

Over the past quarter-century, several changes have allowed the streams and aquatic ecosystems to move generally towards recovery. The rate of timber harvest on California's north coast has slowed during this period, with declining submissions of timber harvesting plans (THPs) and smaller average THPs (T. Spittler, pers. comm. in Downie 2003). However, in the Van Duzen River Basin, the amount of acreage harvested has increased since 1990 as timber stands matured into merchantable second-growth timber and as selection and other partial harvest silvicultural prescriptions are widely implemented.

Timber-harvesting practices have greatly improved over those of the post-war era, due to increased knowledge of forest ecosystem functions, changing public values, advances in road building and yarding techniques, and regulation changes such as mandated streamside buffers that limit equipment operations and removal of timber. Cafferata and Spittler (1998) found that almost all recent landslides occurring in an area logged in the early 1970s were related to legacy logging roads. In contrast, in a neighboring watershed logged in the late 1980s to early 1990s, landslides to date have occurred with about equal frequency in the logged areas as in unlogged areas.

Further, most north coast streams have not recently experienced another large event on the scale of the 1964 flood. Therefore, we would expect most north coast streams to show signs of recovery (i.e., passive restoration [FISRWG 1998]). However, the rates and degrees of stream and watershed recovery will likely vary across a given watershed and among different north coast drainages.

In addition to the contributions made to recovery through better land management practices and natural recovery processes, increasing levels of stream and watershed restoration efforts are also contributing to recovery. Examples of these efforts include road upgrades and decommissioning, removal of road-related fish passage barriers, installation of instream fish habitat structures, etc. While little formal evaluation or quantification of the contributions of these efforts to recovery has been made, there is a general consensus that many of these efforts have made important contributions.

Continuing Challenges to Recovery

Given improvements in timber harvesting practices in the last 30 years, the time elapsed since the last major flood event, and the implementation of stream and watershed restoration projects, it is not surprising that many north coast streams show indications of trends towards recovery (Madej and Ozaki 1996). Ongoing challenges associated with past activities that are slowing this trend include:

- Chronic sediment delivery from legacy (pre-1975) roads due to inadequate crossing design, construction and maintenance (BOF 1999);
- Skid trails and landings (Cafferata and Spittler 1998);
- A lack of improvements in stream habitat complexity, largely from a dearth of large woody debris for successful fish rearing;
- The continuing aggradation of sediments in low-gradient reaches that were deposited as the result of activities and flooding in past decades (Koehler et al. 2001).

Increasing subdivision on several north coast watersheds raises concerns about new stream and watershed disturbances. Private road systems associated with rural development have historically been built and maintained in a fashion that does little to mitigate risks of chronic and catastrophic sediment inputs to streams. While more north coast counties are adopting grading ordinances that will help with this problem, there is a significant legacy of older residential roads that pose an ongoing risk for sediment inputs to streams. Other issues appropriate to north coast streams include potential failures of roads during catastrophic events, erosion from house pads and impermeable surfaces, removal of water from streams for domestic uses, effluent leakages, and the potential for deliberate dumping of toxic chemicals used in illicit drug labs.

Some areas of the north coast have seen rapidly increasing agricultural activity, particularly conversion of grasslands or woodlands to grapes. Marijuana cultivation has also become locally abundant in some north coast watersheds, including the Van Duzen River. These agricultural activities have typically been subject to little agency review or regulation and can pose significant risk of chronic sediment, chemical, and nutrient inputs to streams.

Associated with development and increased agriculture, some north coast river systems are seeing increasing withdrawal of water, both directly from streams and groundwater sources connected to streams, for human uses. Water withdrawals pose a chronic disturbance to streams and aquatic habitat. Such withdrawals can result in lowered summer stream flows that impede the movement of salmonids and reduce important habitat elements such as pools. Further, the withdrawals can contribute to elevated stream water temperatures that are harmful to salmonids.

Key questions for landowners, agencies, and other stakeholders revolve around whether the trends toward stream recovery will continue at their current rates, and whether those rates will be adequate to allow salmonids to recover their populations in an acceptable time frame. Clearly, the potential exists for new impacts from both human activities and natural disturbance processes to compromise recovery rates to a degree that threatens future salmonid recovery. To predict those cumulative effects will likely require additional site-specific information on sediment generation and delivery rates and additional risk analyses of other major disturbances. Also, our discussion here does not address marine influences on anadromous salmonid populations. While these important influences are outside of the scope of this program, we recognize their importance for sustainable salmonid populations and acknowledge that good quality freshwater habitat alone is not adequate to ensure sustainability.

Policies, Acts, and Listings

Several federal and state statutes have significant implications for watersheds, streams, fisheries, and their management. Here, we present only a brief listing and description of some of the laws.

Federal Statutes

One of the most fundamental of federal environmental statutes is the National Environmental Policy Act (NEPA). NEPA is essentially an environmental impact assessment and disclosure law. Projects contemplated or plans prepared by federal agencies or funded by them must have an environmental assessment completed and released for public review and comment, including the consideration of more than one alternative. The law does not require that the least impacting alternative be chosen, only that the impacts be disclosed.

The federal Clean Water Act has a number of sections relevant for watersheds and water quality. Section 208 deals with non-point source pollutants arising from silvicultural activities, including cumulative impacts. Section 303 deals with water bodies that are impaired to the extent that their water quality is not suitable for the beneficial uses identified for those waters. For water bodies identified as impaired, the US Environmental Protection Agency (US EPA) or its state counterpart (locally, the North Coast Regional Water Quality Control Board and the State Water Resources Control Board) must set targets for Total Maximum Daily Loads (TMDLs) of the pollutants that are causing the impairment. Section 404 deals with the alterations of wetlands and streams through filling or other modifications, and requires the issuance of federal permits for most such activities.

The federal Endangered Species Act (ESA) addresses the protection of animal species whose populations are dwindling to critical levels. Two levels of species risk are defined. A threatened species is any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. An endangered species is any species that is in danger of extinction throughout all or a significant portion of its range. In general, the law forbids the take of listed species. Taking is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting a species or attempting to engage in any such conduct.

Many of California's salmon runs are listed under the ESA, including the Chinook and coho salmon and steelhead trout found in the Van Duzen River Basin (NMFS 2001). The Southern Oregon Northern California Coast (SONCC) Coho Evolutionary Significant Unit (ESU) and California Coastal Chinook ESU were listed as a threatened species in 1997 and 1999, respectively. Steelhead trout were subsequently listed as threatened in 2000.

A take of a species listed as threatened may be allowed where specially permitted through the completion and approval of a Habitat Conservation Plan (HCP). An HCP is a document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. An HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the take of species that are covered by the plan.

State Statutes

The state analogue of NEPA is the California Environmental Quality Act (CEQA). CEQA goes beyond NEPA in that it requires the project or plan proponent to select for implementation the least environmentally impacting alternative considered. When the least impacting alternative would still cause significant adverse environmental impacts, a statement of overriding considerations must be prepared.

The Porter-Cologne Water Quality Control Act establishes state water quality law and defines how the state will implement the federal authorities that have been delegated to it by the US EPA under the federal Clean Water Act. For example, the US EPA has delegated to the state certain authorities and responsibilities to implement TMDLs for impaired water bodies and NPDES (national pollution discharge elimination system) permits to point-source dischargers to water bodies.

Sections 1600 et seq. of the Fish and Game Code are implemented by the Department of Fish and Game. These agreements are required for any activities that alter the beds or banks of streams or lakes. A 1600 agreement typically would be involved in a road project where a stream crossing was constructed. While treated as ministerial in the past, the courts have more recently indicated that these agreements constitute discretionary permits and thus must be accompanied by an environmental impact review per CEQA.

The California Endangered Species Act (CESA) (Fish & Game Code §§ 2050, et seq.) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the California Department of Fish and Game. Coho salmon in the Van Duzen River Basin are listed as endangered under CESA.

The Z'Berg-Nejedly Forest Practice Act (FPA) and associated Forest Practice Rules establish extensive permitting, review, and management practice requirements for commercial timber harvesting. Evolving in part in response to water quality protection requirements established by the 1972 amendments to the federal Clean Water Act, the FPA and Rules provide for significant measures to protect watersheds, watershed function, water quality, and fishery habitat.

Assessment Strategy and General Methods

The NCWAP developed a Methods Manual (Bleier et al. 2003) that identified a general approach to conducting a watershed assessment, described or referenced methods for collecting and developing new watershed data, and provided a preliminary explanation of analytical methods for integrating interdisciplinary data to assess watershed conditions.

This chapter provides brief descriptions of data collection and analysis methods used. The reader is referred to the Methods Manual for more detail on methods, data used in the assessment, and assessments of the data.

Watershed Assessment Approach in the Van Duzen River Basin

The steps in large-scale assessment include:

- Conduct scoping and outreach workshops. One public meeting was held to identify issues and promote cooperation;
- Determine logical assessment scales. The Van Duzen Basin assessment delineated the basin into four subbasins (Yager, Lower, Middle, and Upper) for assessment and analyses purposes;
- Discover and organize existing data and information;
- Identify data gaps needed to develop the assessment;
- Collect field data. Stream survey data collection occurred on over 119 miles of stream for this assessment (in addition to previous spawning surveys on streams in the Lower, Middle, and Yager subbasins). Additional data were provided by private and agency cooperators;
- Conduct limiting factors analysis (LFA). The Ecological Management Decision Support system (EMDS) was used to evaluate factors at the tributary scale. These factors were rated to be either beneficial or restrictive to the well being of fisheries;
- Conduct refugia rating analysis. Watershed, stream, habitat, and fishery information were combined and evaluated in terms of value to salmon and steelhead;
- Develop conclusions and recommendations;
- Facilitate monitoring of conditions.

CWPAP Products and Utility

CWPAP assessment reports and their appendices are intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, watershed, and salmonid management decisions. The assessments operate on multiple scales ranging from the detailed and specific stream reach level to the very general basin level. Therefore, findings and recommendations also vary in specificity from being particular at the finer scales, and general at the basin scale.

<u>Assessment products include:</u>

- A basin level Report that includes:
  - A collection of the Van Duzen Basin's historical information;
  - A description of historic and current hydrology, geology, land use, and water quality, salmonid distribution, and instream habitat conditions;
  - An evaluation of watershed processes and conditions affecting salmonid habitat;
  - A list of issues developed by landowners, agency staff, and the public;
  - An analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
  - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid health and productivity;
  - Monitoring recommendations to improve the adaptive management efforts;
- Ecological Management Decision Support system (EMDS) models to help analyze instream conditions;

- Databases of information used and collected;
- A data catalog and bibliography;
- Web based access to the Program's products: http://www.coastalwatersheds.ca.gov/, http://www.calfish.org, http://bios.dfg.ca.gov, http://www.dfg.ca.gov/biogeodata/gis/imaps.asp

Assessment Report Conventions

CalWater 2.2.1 Planning Watersheds and CWPAP Subbasins

The California Watershed Map (CalWater Version 2.2.1) is used to delineate planning watershed units (Figure 2). This hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region, Hydrologic Unit, Hydrologic Area, Hydrologic Sub-Area, Super Planning Watershed, and Planning Watershed (PW). PWs are used by CWPAP to delineate basins, subbasins, and drainages.

CalWater 2.2.1 PWs may not represent true watersheds. Because PWs were created using elevation data, rather than flow models, PWs may cut across streams and ridgelines, especially in less mountainous areas. Streams, such as the mainstem SLR River, can flow through multiple PWs. In addition, a stream, or administrative boundary, such as the California state border, may serve as a division between two PWs. For these and other reasons, PWs may not depict the true catchment of a stream or stream system. However, despite these potential drawbacks, the use of a common watershed map has proven helpful in the delineation of basins and subbasins.

The assessment team subdivided the Lower Eel Basin into four subbasins for assessment and analyses purposes (Figure 2). These are the Estuary, Salt River, Middle, and Upper subbasins. In general, these subbasins have distinguishing attributes common to the CalWater 2.2.1 Planning Watersheds (PWs) contained within them.

Variation among subbasins is a product of natural and human disturbances. Characteristics that can distinguish subbasins within larger basins include differences in elevation, geology, soil types, aspect, climate, vegetation, fauna, human population, land use and other social-economic considerations. Demarcation in this logical manner provides a uniform methodology for conducting large scale assessment. It provides a framework for the reporting of specific findings as well as assisting in developing recommendations for watershed improvement activities that are generally applicable across the relatively homogeneous subbasin area.

Hydrologic Hierarchy

Watershed terminology often becomes confusing when discussing different scales of watersheds involved in planning and assessment activities. The conventions used in the Van Duzen River Basin assessment follow guidelines established by the Pacific Rivers Council. The descending order of scale is from basin level (e.g., Van Duzen River Basin)–subbasin level (e.g., Lower Subbasin)–watershed level (e.g., Grizzly Creek) (Figure).

The subbasin is the assessment and planning scale used in this report as a summary framework; subbasin findings and recommendations are based upon the more specific watershed and sub-watershed level findings. Therefore, there are usually exceptions at the finer scales to subbasin findings and recommendations. Thus, findings and recommendations at the subbasin level are somewhat more generalized than at the watershed and sub-watershed scales. In like manner, subbasin findings and recommendations are somewhat more specific than the even more generalized, broader scale basin level findings and recommendations that are based upon a group of subbasins.

Terminology

The term watershed is used in both the generic sense, as to describe watershed conditions at any scale and as a particular term to describe the watershed scale introduced above, which contains, and is made up from multiple, smaller sub-watersheds. The watershed scale is often approximately 20–40 square miles in area; its sub-watersheds can be much smaller in area, but for our purposes contain at least one perennial, un-branched stream. Please be aware of this multiple usage of the term watershed, and consider the context of the term's usage to reduce confusion.

Another important watershed term is "river mile," indicated as RM. RM is used to assign a specific, measured distance upstream from the mouth of a river or stream to a point or feature on the stream. In this report, RM is used to locate points along the Van Duzen River and/or its tributaries (e.g. Dinsmore Bridge is at RM 45).

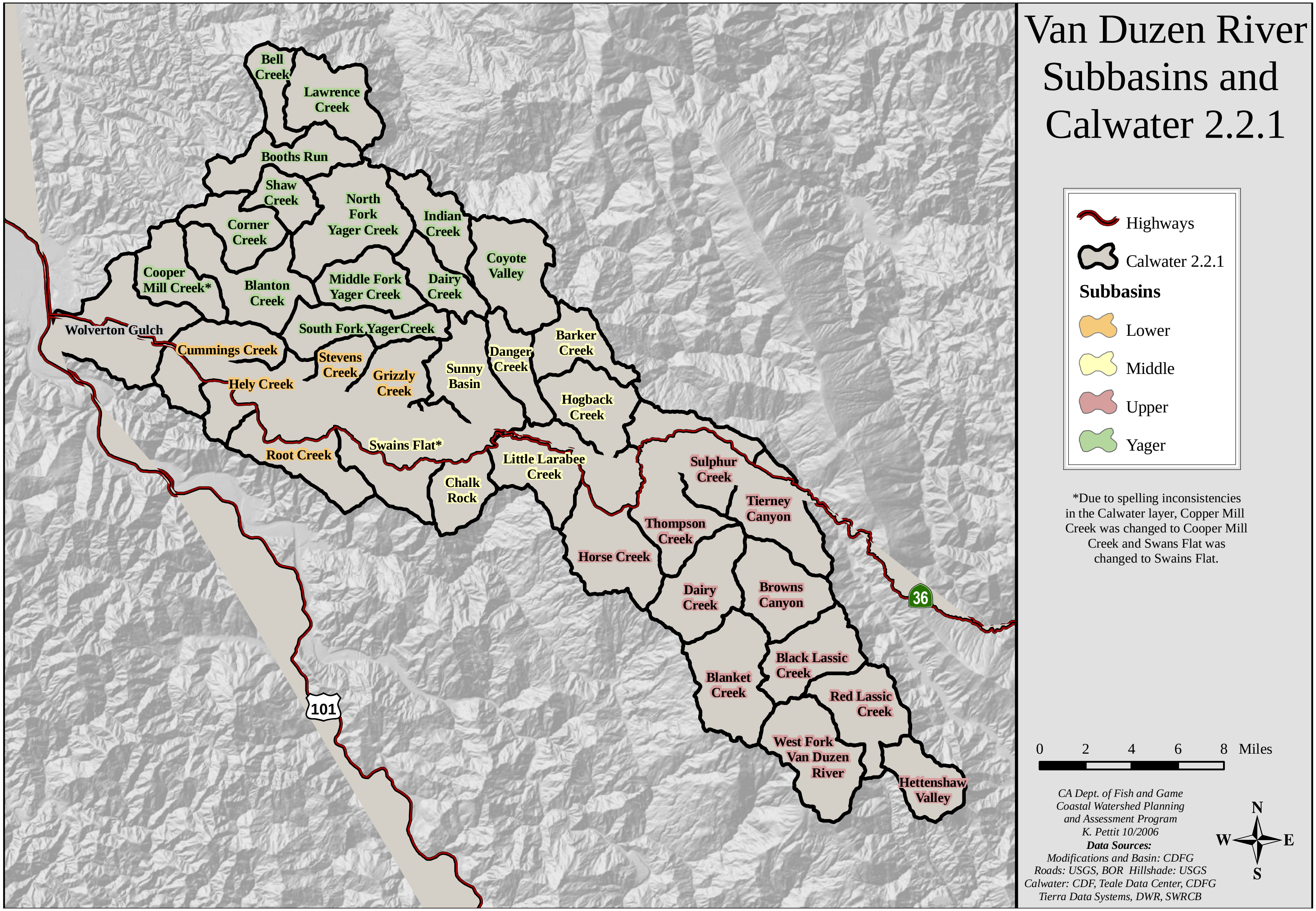

Figure 2. Van Duzen River Basin subbasins and CalWater 2.2.1 planning watersheds.

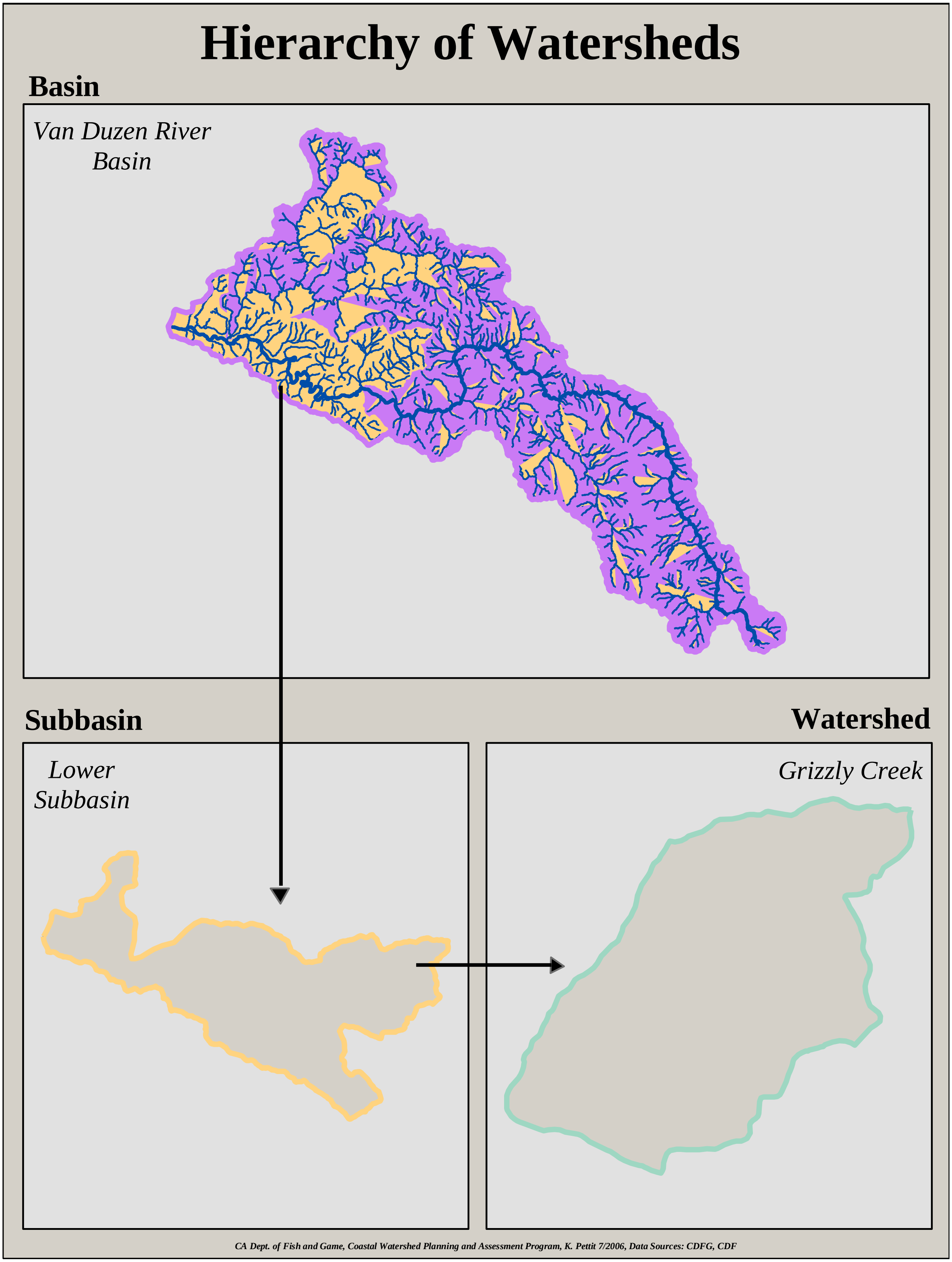

Figure 3. Hydrography hierarchy.

Electronic Data Conventions

The program collected or created hundreds of data records for synthesis and analysis purposes and most of these data were either created in a spatial context or converted to a spatial format. Effective use of these data between the four remaining partner departments required establishing standards for data format, storage, management, and dissemination. Early in the assessment process, we held a series of meetings designed to gain consensus on a common format for the often widely disparate data systems within each department. Our objective was to establish standards which could be used easily by each department, that were most useful and powerful for selected analysis, and would be most compatible with standards used by potential private and public sector stakeholders.

As a result, we agreed that spatial data used in the program and base information disseminated to the public through the program would be in the following format (see the data catalog at the end of this report for a complete description of data sources and scale):

Data form: standard database format usually associated with a Geographic Information System (GIS) shapefile or personal geodatabase (Environmental System Research Institute, Inc. © [ESRI]). Data were organized by watershed. Electronic images were retained in their current format.

Spatial Data Projection: spatial data were projected from their native format to Teale Albers, North American Datum (NAD) 1983.

Scale: most data were created and analyzed at 1:24,000 scale to (1) match the minimum analysis scale for planning watersheds, and (2) coincide with base information (e.g., stream networks) on USGS quadrangle maps (used as Digital Raster Graphics [DRG]).

Data Sources: data were obtained from a variety of sources including spatial data libraries with partner departments or were created by manually digitizing from 1:24,000 DRG.

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in the program. Spatial data sets that formed the foundation of most analysis included the 1:24,000 hydrography and the 10-meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing from a series of 1:24,000 DRG then attributing with direction, routing, and distance information using a dynamic segmentation process (for more information, please see http://downloads2.esri.com/support/whitepapers/ao/ArcGIS8.1.pdf

The resulting routed hydrography allowed for precise alignment and display of stream habitat data and other information along the stream network. The DEM was created by USGS from base contour data for the entire study region.

Source spatial data were often clipped to watershed, planning watershed, and subbasin units prior to use in analysis. Analysis often included creation of summary tables, tabulating areas, intersecting data based on selected attributes, or creation of derivative data based on analytical criteria.

Assessment Methods

Hydrology

In order to help evaluate and categorize streams and rivers, streams are assigned a stream order classification based on the branching pattern of river systems (Strahler 1957). A first order stream is defined as the smallest un-branched tributary to appear on a 7.5-minute USGS quadrangle (1:24,000 scale) (Leopold et al. 1964). This system includes only perennial streams (i.e. those with sufficient flow to develop biota). When two first order streams join, they form a second order stream. When two second order streams join, they result in a third order stream; and as streams of equal order meet they result in a stream of the next higher order (Flosi et al. 1998). Accordingly, the Van Duzer River is classified as a fifth orders stream. Most tributaries in this basin are intermittent or first or second order.

Within the basin there is currently one operating United States Geological Survey (USGS) river gage (USGS ID 11478500). Located near Bridgeville at RM 24, this gage has measured gage height and discharge since 1940. Data recorded from this gage is utilized in this assessment to access seasonal runoff patterns and evaluate linkages between historical flooding and ongoing climatic conditions.

Geology and Fluvial Geomorphology

A general geologic map was compiled for use in this report using published USGS maps and limited, geologic reconnaissance mapping. This map was then simplified combining rock types of similar age, composition, and geologic history (i.e. the Rohnerville and Hookton formations were combined and generalized to "Quaternary river terraces"). Landslides depicted on the map are derived from McLaughlin et al (2000) and represent only large landslide features as of 2000. Calculations of area occupied by each rock type were based on GIS interpretation.

A limited field reconnaissance as well as a review of aerial photos from years 1948, 1988, and 1996 was conducted to gather specific geologic information relevant to the report.

A review of the available literature, published and non-published, pertinent to the geology of the local area was used to gather information presented in this report.

Vegetation and Land Use

The USDA Forest Service (USFS) CALVEG vegetation data were used to describe basin-wide vegetation. This classification breaks down vegetation into major "vegetation cover types." These are further broken down into a number of "vegetation types."

A literature search was conducted to obtain all available historic landuse data. More recent landuse data was obtained from Humboldt County Planning Department. Additionally, more detailed records of logging activity from 1991 to present were obtained from California Department of Forestry (CDF) in digital format.

Year 2000 census data were analyzed to provide population estimates for each Van Duzen subbasin. The 2000 data were available from the CDF's Fire and Resource Assessment Program (FRAP). The Census Bureau statistics are organized at several levels including: State, County, Census County Division (CCD), Census Tract, Block Group, and Block. The Van Duzen Basin contains sections of census tracts. Census Tracts are made up of blocks. Block population totals were compiled to determine the estimated population of each Van Duzen subbasin. Blocks that crossed the basin boundary or subbasin boundaries were examined more closely and population values were allocated by estimated fraction of area.

Fish Habitat and Populations

Data Compilation and Collection

CDFG compiled existing available data and gathered anecdotal information pertaining to salmonids and the instream habitat on the Van Duzen River and its tributaries. Anecdotal and historic information was cross-referenced with other existing data whenever possible. Where data gaps were identified, access was sought from landowners to conduct habitat inventory and fisheries surveys. Habitat inventories and biological data were collected following the protocol presented in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). Twenty-one tributaries were surveyed between the years of 1991 and 2004.

Fish Passage Barriers

During their freshwater life phases, salmonids need free access to a variety of stream habitats from the headwaters to the mouth, as both migratory corridors and habitat for rearing and spawning. Barriers lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn. Barriers may include dams, culverts, diversions, flood control channels, flow dynamics, water quality, and natural features such as waterfalls and bedrock chutes. The assessment utilized the CalFish Passage Assessment Database (PAD) to discuss known barrier locations, and field crews identified and evaluated any additional potential fish passage barriers during stream habitat inventory surveys. Barrier types are categorized as temporary, partial, and total and have varying potential to impact fish passage (Table 1).

Table 1. Definitions of barrier types and their potential impacts to salmonids.

Barrier Category	Definition	Potential Impact
Temporary	Impassable to all fish some of the time.	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish at all times.	Exclusion of certain species and life stages from portions of a watershed.
Total	Impassable to all fish at all times.	Exclusion of all species from portions of a watershed.
Unknown	Fish passage status is unclear	Due to landowner access issues or inadequate funding for sufficient staffing some potential barriers were not examined.

Amended from Taylor 2000

Target Values from Habitat Inventory Surveys

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. In the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) target values were given for each of the individual habitat elements measured (Table 2). When habitat conditions fall below the target values, restoration projects may be proposed in an attempt to meet critical habitat needs for salmonids.

Table 2. Habitat inventory target values.

Habitat Element	Canopy Density	Embeddedness	Primary Pool* Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-100%	0-300 Rating
Target Values	>80%	>50% of the pool tails surveyed with category 1 & 2 embeddedness values	>40% of stream length	>100

*Primary pools are pools >2 feet deep in 1st and 2nd order streams, >3 feet deep in 3rd order streams, or >4 feet deep in 4th order streams. From the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998).

Canopy Density—Eighty Percent or Greater of the Stream is Covered by Canopy

Near-stream forest density and composition contribute to microclimate conditions. These conditions help regulate air temperature and humidity, which are important factors in determining stream water temperature. Along with the insulating capacity of the stream and riparian areas during winter and summer, canopy levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel. Re-vegetation projects should be considered when canopy density is less than the target value of 80%.

Good Spawning Substrate- Fifty Percent or Greater of the Pool Tails Sampled are Fifty Percent or Less Embedded

Cobble embeddedness is the percentage of an average sized cobble piece, embedded in fine substrate at the pool tail. The best coho salmon and steelhead trout spawning substrate is classified as Category 1 cobble embeddedness or 0-25% embedded. Category 2 is defined by the substrate being 26-50% embedded. Cobble embedded deeper than 51% is not within the range for successful spawning. The target value is for 50% or greater of the pool tails sampled to be 50% or less embedded. Streams with less than 50% of their length greater than 51% embedded do not meet the target value. They do not provide adequate spawning substrate conditions.

Pool Depth/Frequency- Forty Percent or More of the Stream Provides Pool Habitat

During their life history, salmonids require access to pools, flatwater, and riffles. Pool enhancement projects are considered when pools comprise less than 40% of the length of total stream habitat. The target values for pool depth are related to the stream order. First and second order streams are required to have 40% or more of the pools 2 feet or deeper to meet the target values. Third and fourth order streams are required to have 40% or more of the pools 3 feet or deeper or 4 feet or deeper, respectively, to meet the target values. A frequency of less than 40% or inadequate depth related to stream order indicates that the stream provides insufficient pool habitat.

Shelter/Cover- Scores of One Hundred or Better Means that the Stream Provides Sufficient Shelter/Cover

Pool shelter/cover provides protection from predation and rest areas from high velocity flows for salmonids. Shelter/cover elements include undercut bank, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain (whitewater), boulders and bedrock ledges. All elements present are measured and scored. Shelter/cover values of 100 or less indicate that shelter/cover enhancement should be considered.

Water Temperatures

The maximum weekly average temperature (MWAT) is the maximum value of the seven day moving average temperatures. The MWAT range for "fully suitable conditions" of 50-60°F was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout

Table 3). As such, it may not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho). Temperatures between 61-62°F are considered "moderately suitable," while a temperature of 63°F is considered "somewhat suitable." The suitability of a 64°F temperature is considered "undetermined." Temperatures of 65°F and above are within the ranges considered "unsuitable" for salmonids.

Table 3. Water temperature criteria.

MWAT Range	Description
50-60°F	Fully Suitable
61-62°F	Moderately Suitable
63°F	Somewhat Suitable
64°F	Undetermined
65°F	Somewhat Unsuitable
66-67°F	Moderately Unsuitable
≥ 68°F	Fully Unsuitable

Ecological Management Decision Support System

The assessment program selected the Ecological Management Decision Support system software to help synthesize information on stream conditions. The EMDS system was developed at the USDA-Forest Service, Pacific Northwest Research Station (Reynolds 1999). It employs a linked set of software that includes MS Excel, NetWeaver, the Ecological Management Decision Support (EMDS) ArcView Extension, and ArcGIS™. The NetWeaver software, developed at Pennsylvania State University, helps scientists model linked frameworks of various environmental factors called knowledge base networks (Reynolds et al. 1996).

These networks specify how various environmental factors will be incorporated into an overall stream or watershed assessment. The networks resemble branching tree-like flow charts, graphically show the assessment's logic and assumptions, and are used in conjunction with spatial data stored in a Geographic Information System (GIS) to perform assessments and render the results into maps.

Development of the North Coast California EMDS Model.

Staff began development of EMDS knowledge base models with a three-day workshop in June of 2001 organized by the University of California, Berkeley. In addition to the assessment program staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, analysts used an EMDS knowledge base model developed by the Northwest Forest Plan for use in coastal Oregon. Based upon the workshop, subsequent discussions among staff and other scientists, examination of the literature, and consideration of localized California conditions, the assessment team scientists then developed preliminary versions of the EMDS models.

The Knowledge Base Network

For California's north coast watersheds, the assessment team constructed a knowledge base network, the Stream Reach Condition Model. The model was reviewed in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to their suggestions, the team revised the original model.

The Stream Reach Condition model addresses conditions for salmonids on individual stream reaches and is largely based on data collected using CDFG stream survey protocols found in the *California Salmonid Stream Habitat Restoration Manual*, (Flosi et al. 1998).

In creating these EMDS models, the team used what is termed a tiered, top-down approach. For example, the Stream Reach Condition model tested the truth of the proposition: The overall condition of the stream reach is suitable for maintaining healthy populations of native Chinook, coho, and steelhead trout. A knowledge base network was then designed to evaluate the truth of that proposition, based upon existing data from each stream reach. The model design and contents reflected the specific data and information analysts believed were needed, and the manner in which they should be combined, to test the proposition.

In evaluating stream reach conditions for salmonids, the model uses data from several environmental factors. The first branching tier of the knowledge base network shows the data based summary nodes on: 1) in-channel condition; 2) stream flow; 3) riparian vegetation and: 4) water temperature (Figure 3). These nodes are combined into a single value to test the validity of the stream reach condition suitability proposition. In turn, each of the four summary branch node's values is formed from the combination of its more basic data components. The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation (Figure).

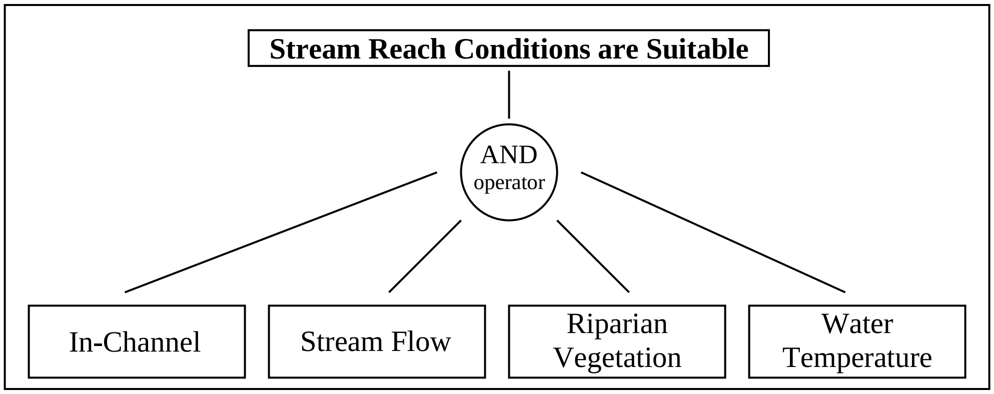

Figure 4: Tier one of the EMDS stream reach knowledge base network.

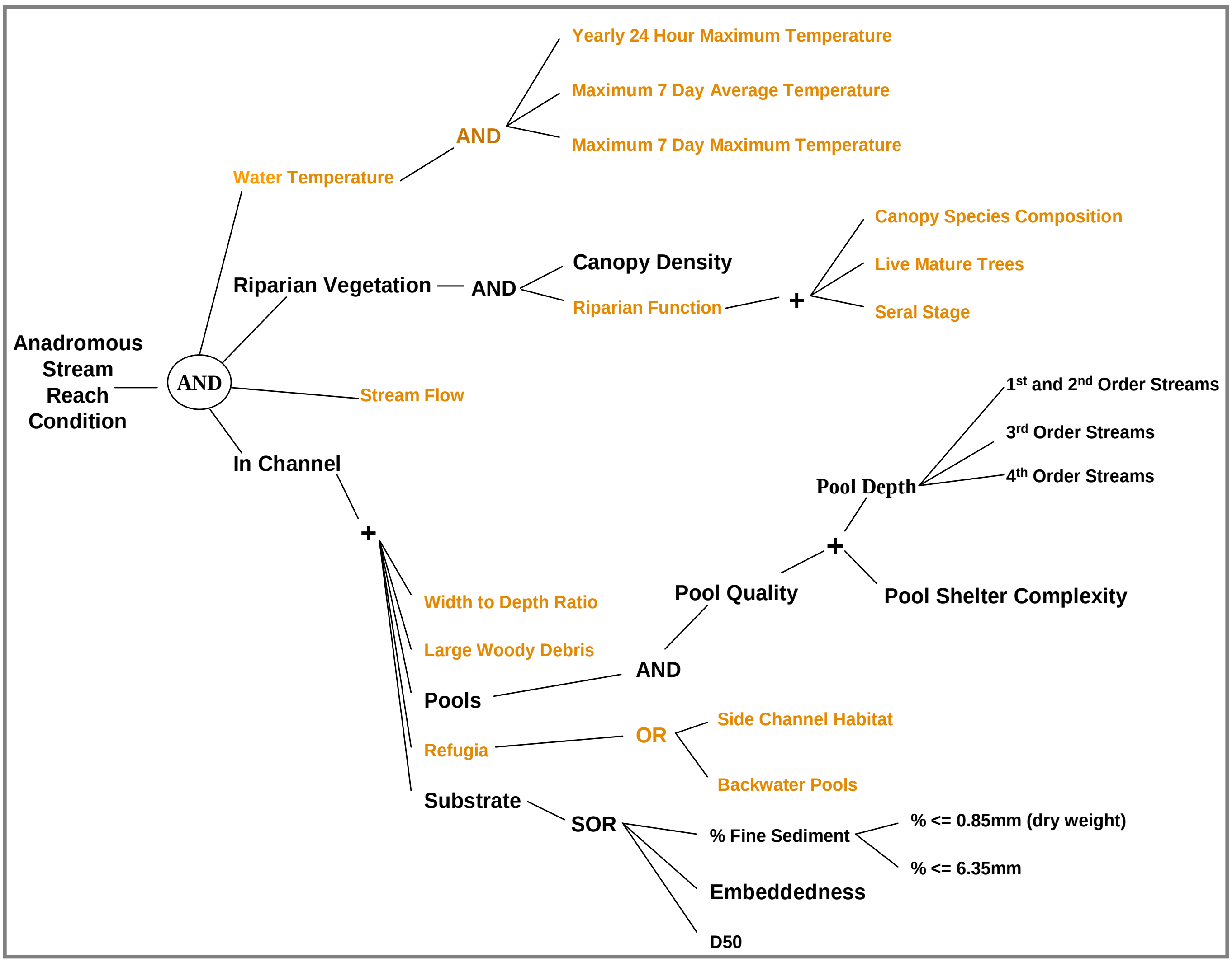

Figure 5. Graphic representation of the Stream Reach Condition model.

Habitat factors populated with data in the Van Duzen River assessment model are shown in black. Other habitat factors considered important for stream habitat condition evaluation, but data limited in the Van Duzen River assessment, are included in orange.

In Figure 3, the *AND operator* indicates a decision node that means that the lowest, most limiting value of the four general factors determined by the model will be passed on to indicate the potential of the stream reach to sustain salmonid populations. In that sense, the model mimics nature. For example, if summertime low flow is reduced to a level deleterious to fish survival or well being, regardless of a favorable temperature regime, instream habitat, and/or riparian conditions, the overall stream condition is not suitable to support salmonids.

Although model construction is typically done top-down, models are run in EMDS from the bottom up. That is, stream reach data are usually entered at the lowest and most detailed level of the several branches of the network tree (the leaves). The data from the leaves are combined progressively with other related attribute information as the analysis proceeds up the network. Decision nodes are intersections in the model networks where two or more factors are combined before passing the resultant information on up the network (Figure).

EMDS models assess the degree of truth (or falsehood) of each model proposition. Each proposition is evaluated in reference to simple graphs called reference curves that determine its degree of truth/falsehood, according to the data's implications for salmon. Figure shows an example reference curve for the proposition stream temperature is suitable for salmon. The horizontal axis shows temperature in degrees Fahrenheit ranging from 30-80° F, while the vertical axis is labeled Truth Value and ranges from values of +1 to -1. The upper horizontal line arrays the fully suitable temperatures from 50-60°F (+1). The fully unsuitable temperatures are arrayed at the bottom (-1). Those in between are ramped between the fully suitable and fully unsuitable ranges and are rated accordingly. A similar numeric relation is determined for all attributes evaluated with reference curves in the EMDS models.

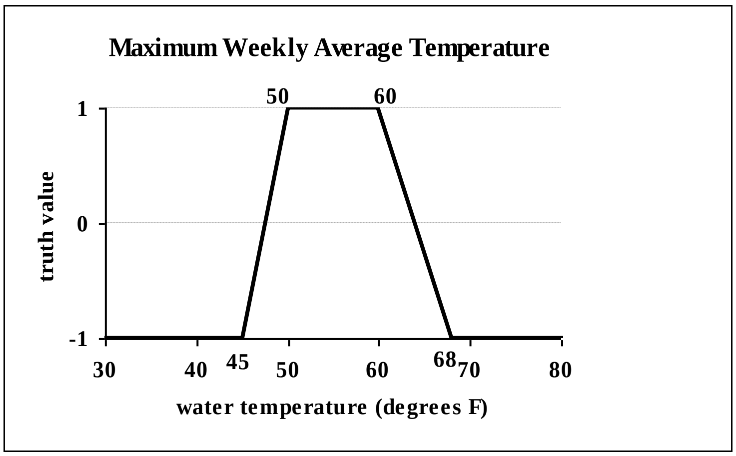

Figure 6. EMDS reference curve for stream temperature.

EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example reference curve evaluates the proposition that the stream's water temperature is suitable for salmonids. Break points on the curve can be set for specific species, life stage, or season of the year. Curves are dependent on the availability of data to be included in an analysis.

For each evaluated proposition in the EMDS model network, the result is a number between –1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is completely true, and –1 implies that it is completely false, while in-between values indicate degrees of truth (i.e. values approaching +1 being closer to true and those approaching –1 converging on completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints occur where the slope of the reference curve changes. For example, in Figure breakpoints occur at 45, 50, 60, and 68°F.

EMDS map legends use a seven-class system for depicting the truth-values. Values of +1 are classed as the highest suitability; values of –1 are classed as the lowest suitability; and values of 0 are undetermined. Between 0 and 1 are two classes which, although unlabeled in the legend, indicate intermediate values of better suitability (0 to 0.5, and 0.5 to 1). Symmetrically, between 0 and –1 are two similar classes which are intermediate values of worse suitability (0 to –0.5, and –0.5 to –1). These ranking values are assigned based upon condition findings in relationship to the criteria in the reference curves. The following table summarizes important EMDS Stream Reach Condition model information (Table 4).

Table 4. Reference curve metrics for EMDS stream reach condition model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Aquatic / Riparian Conditions	
Summer MWAT	Maximum 7-day average summer water temperature < 45°°F fully unsuitable, 50-60°°F fully suitable, > 68°F fully unsuitable. Water temperature was not included in current EMDS evaluation.
Riparian Function	Under development.
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. < 50% fully unsuitable, ≥ 85% fully suitable.
Seral Stage	Seral stage composition of near stream forest. Under development.
Vegetation Type	Forest composition Under development.
Stream Flow	Under development.
In-Channel Conditions	
Pool Depth	Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. ≤ 20% fully unsuitable, 30 – 55% fully suitable, ≥ 90% fully unsuitable.
Pool Shelter Complexity	Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. ≤ 30 fully unsuitable, ≥ 100 - 300 fully suitable.
Pool Frequency	Percent of pools by length in a stream reach. Under development.
Substrate Embeddedness	Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. EMDS calculates categorical embeddedness data to produce evaluation scores between –1 and +1. The proposition is fully true if evaluation scores are 0.8 or greater and -0.8 evaluate to fully false.
Percent Fines in Substrate <0.85mm (dry weight)	Percent of fine sized particles <0.85 mm collected from McNeil type samples. < 10% fully suitable, > 15% fully unsuitable. There was not enough of percent fines data to use percent fines in EMDS evaluations
Percent Fines in Substrate <6.4 mm	Percent of fine sized particles < 6.4 mm collected from McNeil type samples. <15% fully suitable, >30% fully unsuitable. There was not enough of percent fines data to use percent fines in EMDS evaluations.
Large Woody Debris (LWD)	The reference values for frequency and volume are derived from Bilby and Ward (1989) and are dependent on channel size. See EMDS Appendix for details. Most watersheds do not have sufficient LWD survey data for use in EMDS.
Winter Refugia Habitat	Winter refugia is composed of backwater pools and side channel habitats and deep pools (> 4 feet deep). Under development.
Pool to Riffle Ratio	Ratio of pools to riffle habitat units. Under development.
Width to Depth Ratio	Ratio of bankfull width to maximum depth at velocity crossovers. Under development.

Advantages Offered by EMDS

EMDS offers a number of advantages for use in watershed assessments. Instead of being a hidden black box, each EMDS model has an open and intuitively understandable structure. The explicit nature of the model networks facilitates open communication among agency personnel and with the general public through simple graphics and easily understood flow diagrams. The models can be easily modified to incorporate alternative assumptions about the conditions of specific environmental factors (e.g., stream water temperature) required for suitable salmonid habitat.

Using Geographic Information System (GIS) software, EMDS maps the factors affecting fish habitat and shows how they vary across a basin. EMDS models also provide a consistent and repeatable approach to evaluating watershed conditions for fish. In addition, the maps from supporting levels of the model show the specific factors that, taken together, determine overall watershed conditions. This latter feature can help to identify what is most limiting to salmonids, and thus assist to prioritize restoration projects or modify land use practices.

Limitations of the EMDS Model and Data Input

While EMDS-based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. EMDS results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the EMDS model constructed, the dates and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. External validation of the

EMDS model using fish population data and other information should be done.

One disadvantage of linguistically based models such as EMDS is that they do not provide results with readily quantifiable levels of error. Therefore, EMDS should only be used as an indicative model, one that indicates the quality of watershed or instream conditions based on available data and the model structure. It is not intended to provide highly definitive answers, such as from a statistically based process model. It does provide a reasonable first approximation of conditions through a robust information synthesis approach; however, its outputs need to be considered and interpreted in the light of other information sources and the inherent limitations of the model and its data inputs. It also should be clearly noted that EMDS does not assess the marine phase of the salmonid life cycle, nor does it consider fishing pressures.

Program staff has identified some model or data elements needing attention and improvement in future iterations of EMDS. These currently include:

- Completion of quality control evaluation procedures;
- Adjust the model to better reflect differences between stream mainstems and tributaries, for example, the modification of canopy density standards for wide streams;
- Develop a suite of Stream Reach Model reference curves to better reflect the differences in expected conditions based upon various geographic watershed locations considering geology, vegetation, precipitation, and runoff patterns.

At this time, all of the recommendations made by our peer reviewers have not been implemented into the models. Additionally, EMDS results should be used as valuable but not necessarily definitive products, and their validation with other observations is necessary. The EMDS Appendix provides added detail concerning the system's structure and operations.

Adaptive Application for EMDS and CDFG Stream Habitat Evaluations

CDFG has developed habitat evaluation standards, or target values, to help assess the condition of anadromous salmonid habitat in California streams (Flosi et al. 1998). These standards are based upon data analyses of over 1,500 tributary surveys, and considerable review of pertinent literature. The EMDS reference curves have similar standards. These have been adapted from CDFG, but following peer review and professional discussion, they have been modified slightly due to more detailed application in EMDS. As such, slight differences occur between values found in Flosi et al. (1998) and those used by EMDS. The reference curves developed for the EMDS are provided in the EMDS Appendix of this report.

Both habitat evaluation systems have similar but slightly different functions. Stream habitat standards developed by CDFG are used to identify habitat conditions and establish priorities among streams considered for improvement projects based upon standard CDFG tributary reports. The EMDS compares select components of the stream habitat survey data to reference curve values and expresses degrees of habitat suitability for fish on a sliding scale. In addition, the EMDS produces a combined estimate of overall stream condition by combining the results from several stream habitat components. In the fish habitat relationship section of this report, we utilize target values found in Flosi et al. (1998), field observations, and results from EMDS reference curve evaluations to help describe and evaluate stream habitat conditions.

Due to the wide range of geology, topography and diverse stream channel characteristics which occur within the North Coast region, there are streams that require more detailed interpretation and explanation of results than can be simply generated by EMDS suitability criteria or tributary survey target values.

For example, pools are an important habitat component and a useful stream attribute to measure. However, some small fish-bearing stream channels may not have the stream power to scour pools of the depth and frequency considered to be high value "primary" pools by CDFG target values, or to be fully suitable according to EMDS. Often, these shallow pool conditions are found in low gradient stream reaches in small watersheds that lack sufficient discharge to deeply scour the channel. They also can exist in moderate to steep gradient reaches with bedrock/boulder dominated substrate highly resistant to scour, which also can result in few deep pools.

Therefore, some streams may not have the inherent ability to attain conditions that meet the suitability criteria or target values for pool depth. These scenarios result in pool habitat conditions that are not considered highly suitable by either assessment standard. However, these streams may still be very important because of other desirable features that support valuable fishery resources. As such, they receive additional evaluation with our refugia rating system and expert professional judgment. Field validation of any modeling system's results is a necessary component of watershed assessment and reporting.

Limiting Factors Analysis

A main objective of CDFG watershed assessment is to identify factors that limit production of anadromous salmonid populations in North Coast watersheds. This process is known as a limiting factors analysis (LFA). The limiting factors concept is based upon the assumption that eventually every population must be limited by the availability of necessary support resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an overabundance, deficiency, or absence of a watershed ecosystem component. Identifying stream habitat factors that limit or constrain anadromous salmonids is an important step towards setting priorities for habitat improvement projects and management strategies aimed at the recovery of declining fish stocks and protection of viable fish populations.

Although several factors have contributed to the decline of anadromous salmonid populations, habitat loss and modification are major determinants of their current status (FEMAT 1993). Our approach to a LFA integrates two habitat based methods to evaluate the status of key aspects of stream habitat that affect anadromous salmonid production- species life history diversity and the stream's ability to support viable populations.

The first method uses priority ranking of habitat categories based on a CDFG team assessment of data collected during stream habitat inventories. The second method uses the EMDS to evaluate the suitability of key stream habitat components to support anadromous fish populations. These habitat-based methods assume that stream habitat quality and quantity play important roles in a watershed's ability to produce viable salmonid populations.

The LFA assumes that poor habitat quality and reduced quantities of favorable habitat impairs fish production. Limiting factors analysis is focused mainly on those physical habitat factors within freshwater and estuarine ecosystems that affect spawning and subsequent juvenile life history requirements during low flow seasons.

Two general categories of factors or mechanisms limit salmonid populations:

- Density independent and
- Density dependent mechanisms.

Density independent mechanisms generally operate without regard to population density. These include factors related to habitat quality such as stream flow and water temperature or chemistry. In general, fish will die regardless of the population density if flow is inadequate, or water temperatures or chemistry reach lethal levels. Density dependant mechanisms generally operate according to population density and habitat carrying capacity. Competition for food, space, and shelter are examples of density dependant factors that affect growth and survival when populations reach or exceed the habitat carrying capacity.

The program's approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. Priority steps are given to preserving and increasing the amount of high quality (density independent) habitat in a cost effective manner.

Restoration Needs/Tributary Recommendations Analysis

CDFG inventoried 36 tributaries and portions of the mainstem Van Duzen River using protocols in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). The stream surveys were divided into stream reaches, defined as Rosgen (1994) channel types. The stream inventories are a combination of several stream reach surveys: habitat typing, channel typing, biological assessments, and in some reaches LWD and riparian zone recruitment assessments. An experienced Biologist and/or Habitat Specialist conducted quality assurance/quality control (QA/QC) on field crews and collected data, performed data analysis, and determined general areas of habitat deficiency based upon the analysis and synthesis of information.

CDFG biologists selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFG habitat inventories, and updated the recommendations with the results of the stream reach condition EMDS and the refugia analysis (Table 5). It is important to understand that these selections are made from stream reach conditions that were observed at the times of the surveys and do not include upslope watershed observations other than those that could be made from the streambed. They reflect a single point in time and do not anticipate future conditions. However, these general recommendation categories have proven to be useful as the basis for specific project development, and provide focus for on-the-ground project design and implementation. Bear in mind that stream and watershed conditions change over time and periodic survey updates and field verification are necessary if watershed improvement projects are being considered.

In general, the recommendations that involve erosion and sediment reduction by treating roads and failing stream banks, and riparian and near stream vegetation improvements precede the instream recommendations in reaches that demonstrate disturbance levels associated with watersheds in current stress. Instream improvement recommendations are usually a high priority in streams that reflect watersheds in recovery or good health. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant.

Table 5. List of tributary recommendations in stream tributary reports.

Recommendation	Explanation
Temp	Summer water temperatures were measured to be above optimum for salmon and steelhead
Pool	Pools are below CDFG target values in quantity and/or quality
Cover	Escape cover is below CDFG target values
Bank	Stream banks are failing and yielding fine sediment into the stream
Roads	Fine sediment is entering the stream from the road system
Canopy	Shade canopy is below CDFG target values
Spawning Gravel	Spawning gravel is deficient in quality and/or quantity
LDA	Large debris accumulations are retaining large amounts of gravel and could need modification
Livestock	There is evidence that stock is impacting the stream or riparian area and exclusion should be considered
Fish Passage	There are barriers to fish migration in the stream

Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), are usually a treatment priority. Good examples of these are the recent and dramatically successful Humboldt County/CDFG culvert replacement projects in tributaries to Humboldt Bay. In these regards, the program's more general watershed scale upslope assessments can go a long way in helping determine the suitability of conducting instream improvements based upon watershed health. As such, there is an important relationship between the instream and upslope assessments.

Additional considerations must enter into the decision process before these general recommendations are further developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistic considerations that enter into a recommendation's subsequent ranking for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of the candidate work sites. Biological considerations are made based upon the propensity for benefit to multiple or single fishery stocks or species. Cost benefit and project feasibility are also factors in project selection for design and development.

Potential Salmonid Refugia

Establishment and maintenance of salmonid refugia areas containing high quality habitat and sustaining fish populations are activities vital to the conservation of our anadromous salmonid resources (Moyle and Yoshiyama 1992; Li et al. 1995; Reeves et al. 1995). Protecting these areas will prevent the loss of the remaining high quality salmon habitat and salmonid populations. Therefore, a refugia investigation project should focus on identifying areas found to have high salmonid productivity and diversity.

Identified areas should then be carefully managed for the following benefits:

- Protection of refugia areas to avoid loss of the last best salmon habitat and populations. The focus should be on protection for areas with high productivity and diversity;

- Refugia area populations which may provide a source for re-colonization of salmonids in nearby watersheds that have experienced local extinctions, or are at risk of local extinction due to small populations;
- Refugia areas provide a hedge against the difficulty in restoring extensive, degraded habitat and recovering imperiled populations in a timely manner (Kaufmann et al. 1997).

The concept of refugia is based on the premise that patches of aquatic habitat provide habitat that retains the natural capacity and ecologic functions to support wild anadromous salmonids in such vital activities as spawning and rearing. Anadromous salmonids exhibit typical features of patchy populations; they exist in dynamic environments and have developed various dispersal strategies including juvenile movements, adult straying, and relative high fecundity for an animal that exhibits some degree of parental care through nest building (Reeves et al. 1995). Conservation of patchy populations requires conservation of several suitable habitat patches and maintaining passage corridors between them.

Potential refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams. If altered streams or watersheds recover their historic natural productivity, through either restoration efforts or natural processes, the abundant source populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat. Protection of refugia areas is noted as an essential component of conservation efforts to ensure long-term survival of viable stocks, and a critical element towards recovery of depressed populations (Sedell 1990; Moyle and Yoshiyama 1992; Frissell 1993, 2000).

Refugia habitat elements include the following:

- Areas that provide shelter or protection during times of danger or distress;
- Locations and areas of high quality habitat that support populations limited to fragments of their former geographic range, and;
- A center from which dispersion may take place to re-colonize areas after a watershed and/or sub-watershed level disturbance event and readjustment.

Spatial and Temporal Scales of Refugia

These refugia concepts become more complex in the context of the wide range of spatial and temporal habitat required for viable salmonid populations. Habitat can provide refuge at many scales from a single fish to groups of them, and finally to breeding populations. For example, refugia habitat may range from a piece of wood that provides instream shelter for a single fish, or individual pools that provide cool water for several rearing juveniles during hot summer months, to watersheds where conditions support sustaining populations of salmonid species. Refugia also include areas where critical life stage functions such as migrations and spawning occur. Although fragmented areas of suitable habitat are important, their connectivity is necessary to sustain the fisheries. Today, watershed scale refugia are needed to recover and sustain aquatic species (Moyle and Sato 1991). For the purpose of this discussion, refugia are considered at the fish bearing tributary and subbasin scales. These scales of refugia are generally more resilient to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities than the smaller, habitat unit level scale (Sedell et al. 1990).

Standards for refugia conditions are based on reference curves from the literature and CDFG data collection at the regional scale. The program uses these values in its EMDS models and stream inventory, improvement recommendation process.

Li et al. (1995) suggested three prioritized steps to use the refugia concept to conserve salmonid resources:

- Identify salmonid refugia and ensure they are protected;
- Identify potential habitats that can be rehabilitated quickly;
- Determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Meta-population Concept

The concept of anadromous salmonid meta-populations is important when discussing refugia. The classic metapopulation model proposed by Levins (1969) assumes the environment is divided into discrete patches of suitable habitat. These patches include streams or stream reaches that are inhabited by different breeding populations or sub-populations (Barnhart 1994; McElhany et al. 2000). A metapopulation consists of a group of sub-populations which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994). Metapopulations are characterized by 1) relatively isolated, segregated breeding populations in a patchy environment that are connected to some degree by migration between them, and 2) a dynamic relationship between extinction and re-colonization of habitat patches.

Anadromous salmonids fit nicely into the sub-population and metapopulation concept because they exhibit a strong homing behavior to natal streams forming sub-populations, and have a tendency to stray into new areas. The straying or movement into nearby areas results in genetic exchange between sub-populations or seeding of other areas where populations are at low levels. This seeding comes from abundant or source populations supported by high quality habitat patches which may be considered as refugia.

Habitat patches differ in suitability and population strength. In addition to the classic metapopulation model, other theoretical types of spatially structured populations have been proposed (Li et al. 1995; McElhany et al. 2000). For example, the core and satellite (Li et al. 1995) or island-mainland population (McElhany et al. 2000) model depicts a core or mainland population from which dispersal to satellites or islands results in smaller surrounding populations. Most straying occurs from the core or mainland to the satellites or islands. Satellite or island populations are more prone to extinction than the core or mainland populations (Li et al. 1995; McElhany et al. 2000). Another model termed source-sink populations is similar to the core-satellite or mainland-island models, but straying is one way, only from the highly productive source towards the sink subpopulations. Sink populations are not self-sustaining and are highly dependent on migrants from the source population to survive (McElhany et al. 2000). Sink populations may inhabit typically marginal or unsuitable habitat, but when environmental conditions strongly favor salmonid production, sink population areas may serve as important sites to buffer populations from disturbance events (Li et al. 1995) and increase basin population strength. In addition to testing new areas for potential suitable habitat, the source-sink strategy adds to the diversity of behavior patterns salmonids have adapted to maintain or expand into a dynamic aquatic environment.

The metapopulation and other spatially structured population models are important to consider when identifying refugia because in dynamic habitats, the location of suitable habitat changes (McElhany et al. 2000) over the long term from natural disturbance regimes (Reeves et al. 1995) and over the short term by human activities. Satellite, island, and sink populations need to be considered in the refugia selection process because they are an integral component of the metapopulation concept. They also may become the source population or refugia areas of the future.

Methods to Identify Refugia

Currently there is no established methodology to designate refugia habitat for California's anadromous salmonids. This is mainly due to a lack of sufficient data describing fish populations, meta-populations and habitat conditions and productivity across large areas. This lack of information holds true for all study basins especially in terms of meta-population dynamics. Studies are needed to determine population growth rates and straying rates of salmonid populations and sub-populations to better utilize spatial population structure to identify refugia habitat.

Classification systems, sets of criteria and rating systems have been proposed to help identify refugia type habitat in north coast streams, particularly in Oregon and Washington (Moyle and Yoshiyama 1992; FEMAT 1993; Li et al. 1995; Frissell et al. 2000; Kitsap County 2000). Upon review of these works, several common themes emerge. A main theme is that refugia are not limited to areas of pristine habitat. While ecologically intact areas serve as dispersal centers for stock maintenance and potential recovery of depressed sub-populations, lower quality habitat areas also play important roles in long-term salmonid metapopulation maintenance. These areas may be considered the islands, satellites, or sinks in the metapopulation concept. With implementation of ecosystem management strategies aimed at maintaining or restoring natural processes, some of these areas may improve in habitat quality, show an increase in fish numbers, and add to the metapopulation strength.

A second common theme is that over time within the landscape mosaic of habitat patches, good habitat areas will suffer impacts and become less productive, and wink out and other areas will recover and wink in. These processes can occur through either human caused or natural disturbances or succession to new ecological states. Regardless, it is important that a balance be maintained in this alternating, patchwork dynamic to ensure that adequate good quality habitat is available for viable anadromous salmonid populations (Reeves et al. 1995).

Approach to Identifying Refugia

The program's interdisciplinary refugia identification team identified and characterized refugia habitat by using expert professional judgment and criteria developed for North Coast watersheds. The criteria used considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, water quality, and other factors that may affect refugia productivity. The expert refugia team encouraged other specialists with local knowledge to participate in the refugia identification and categorization process.

The team also used results from information processed by the program's EMDS at the stream reach and planning watershed/subbasin scales. Stream reach and watershed parameter evaluation scores were used to rank stream and watershed conditions based on collected field data. Stream reach scale parameters included pool shelter rating, pool depth, embeddedness, and canopy cover. Water temperature data were also used when available. The individual parameter scores identified which habitat factors currently support or limit fish production (see EMDS and limiting factors sections).

Professional judgment, analyzing field notes, local expert opinion, habitat inventory survey results, water quality data results, and EMDS scores determined potential locations of refugia. If a habitat component received a suitable ranking from the EMDS model, it was cross-referenced to the survey results from that particular stream and to field notes taken during that survey. The components identified as potential refugia were then ranked according to their suitability to encourage and support salmonid health.

When identifying anadromous salmonid refugia, the program team took into account that anadromous salmon have several non-substitutable habitat needs for their life cycle.

A minimal list (NMFS 2001) includes:

- Adult migration pathways;
- Spawning and incubation habitat;
- Stream rearing habitat;
- Forage and migration pathways;
- Estuarine habitat.

The best refugia areas are large, meet all of these life history needs, and therefore provide complete functionality to salmonid populations. These large, intact systems are scarce today and smaller refugia areas that provide for only some of the requirements have become very important areas, but cannot sustain large numbers of fish. These must operate in concert with other fragmented habitat areas for life history support and refugia connectivity becomes very important for success. Therefore, the refugia team considered relatively small, tributary areas in terms of their ability to provide at least partial refuge values, yet contribute to the aggregated refugia of larger scale areas. Therefore, the team's analyses used the tributary scale as the fundamental refugia unit.

CDFG created a tributary scale refugia-rating worksheet. The worksheet has 21 condition factors that were rated on a sliding scale from high quality to low quality.

Twenty-one factors were grouped into five categories:

- Stream condition;
- Riparian condition;
- Native salmonid status;
- Present salmonid abundance;
- Management impacts (disturbance impacts to terrain, vegetation, and the biologic community).

Additionally, NCRWQCB created a worksheet specifically for rating water quality refugia. The worksheet has 13 condition factors that were rated on a sliding scale from high quality to low quality.

Thirteen factors were grouped into three categories:

- In-stream sediment related;
- Stream temperature;
- Water chemistry

Tributary ratings were determined by combining the results of NCRQCB water quality results, EMDS results, and data in CDFG tributary reports by a multi-disciplinary, expert team of analysts. The various factors' ratings were combined to determine an overall tributary rating on a scale from high to low quality refugia. Tributary ratings were subsequently aggregated at the subbasin scale and expressed a general estimate of subbasin refugia conditions. Factors with limited or missing data were noted. In most cases there were data limitations on 1–3 factors.

These were identified for further investigation and inclusion in future analysis.

The program has created a hierarchy of refugia categories that contain several general habitat conditions. This descriptive system is used to rank areas by applying results of the analyses of stream and watershed conditions described above and are used to determine the ecological integrity of the study area. A basic definition of biotic integrity is "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

The Report of the Panel on the Ecological Integrity of Canada's National Parks (2000) submitted this definition:

A Definition of Ecological Integrity

The Panel proposes the following definition of ecological integrity: "An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes. In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact."

Salmonid Refugia Categories and Criteria:

High Quality Habitat, High Quality Refugia:

- Maintains a high level of watershed ecological integrity (Frissell 2000);
- Contains the range and variability of environmental conditions necessary to maintain community and species diversity and supports natural salmonid production (Moyle and Yoshiyama 1992; Frissell 2000);
- Contains relatively undisturbed and intact riparian corridor;
- All age classes of historically native salmonids present in good numbers, and a viable population of an ESA listed salmonid species is supported (Li et al. 1995);
- Provides population seed sources for dispersion, gene flow and re-colonization of nearby habitats from straying local salmonids;
- Contains a high degree of protection from degradation of its native components.

High Potential Refugia

- Watershed ecological integrity is diminished but remains good (Frissell 2000);
- Instream habitat quality remains suitable for salmonid production and is in the early stages of recovery from past disturbance;
- Riparian corridor is disturbed, but remains in fair to good condition;
- All age classes of historically native salmonids are present including ESA listed species, although in diminished numbers;
- Salmonid populations are reduced from historic levels, but still are likely to provide straying individuals to neighboring streams;
- Currently is managed to protect natural resources and has resilience to degradation, which demonstrates a strong potential to become high quality refugia (Moyle and Yoshiyama 1992; Frissell 2000).

Medium Potential Refugia

- Watershed ecological integrity is degraded or fragmented (Frissell 2000);

- Components of instream habitat are degraded, but support some salmonid production;
- Riparian corridor components are somewhat disturbed and in degraded condition;
- Native anadromous salmonids are present, but in low densities; some life stages or year classes are missing or only occasionally represented;
- Relative low numbers of salmonids make significant straying unlikely;
- Current management or recent natural events have caused impacts, but if positive change in either or both occurs, responsive habitat improvements should occur.

Low Quality Habitat, Low Potential Refugia

- Watershed ecological integrity is impaired (Frissell 2000);
- Most components of instream habitat are highly impaired;
- Riparian corridor components are degraded;
- Salmonids are poorly represented at all life stages and year classes, but especially in older year classes;
- Low numbers of salmonids make significant straying very unlikely;
- Current management and/or natural events have significantly altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions.

Other Related Refugia Component Categories:

- Potential Future Refugia (Non-Anadromous);
- Areas where habitat quality remains high but does not currently support anadromous salmonid populations;
- An area of high habitat quality, but anadromous fish passage is blocked by man-made obstructions such as dams or poorly designed culverts at stream crossings etc.

Critical Contributing Areas

- Area contributes a critical ecological function needed by salmonids such as providing a migration corridor, conveying spawning gravels, or supplying high quality water (Li et al. 1995);
- Riparian areas, floodplains, and wetlands that are directly linked to streams (Huntington and Frissell 1997).

Data Limited

- Areas with insufficient data describing fish populations, habitat conditions, watershed conditions, or management practices.

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Basin Profile and Synthesis

Introduction

The Van Duzen River basin assessment examines relationships between physical and biological factors that operate on anadromous salmonid freshwater habitats. A key goal of the assessment is to identify relationships among stream conditions, watershed features, and land management activities that influence anadromous salmonid populations. The assessment of present stream habitat conditions and investigations into the causes of historical channel changes are presented at the basin, subbasin and watershed context. Recommendations are intended to guide restoration efforts and land management by addressing root causes that contribute to declines in salmonid populations and impairments to their essential habitats. We also utilize knowledge gained from analyses of past impacts to minimize future impediments to recovery of stream ecosystems associated with land and water management.

Assessments must begin with an understanding of the dominant processes that are operating in the channel, on the floodplain, and throughout the watershed. The assessment should consider the likely temporal variability in these processes, develop hypotheses on how these processes might be altered by management activities and natural events, and then make the initial field observations to support, dismiss, or modify these hypotheses. A diagnostic approach, while not foolproof, is important because it provides a logical and minimally biased framework for assessing channel condition (Montgomery and MacDonald 2002). A process-based understanding of spatial and temporal linkages within a watershed is essential for assessment of channel condition, prediction of channel response to disturbance, and interpretation of the causes of historical channel changes (Montgomery and Buffington 1997).

Assessments can be translated into improving or preserving stream conditions by two distinct strategies (Montgomery and Buffington 1993). The first identifies areas that have been impacted by past management and then use strategies to promote recovery or minimize further degradation. A second approach is to identify areas likely to be impacted in the future and apply strategies to modify management to minimize disturbance to streams. In the Van Duzen River Basin, both strategies are necessary to achieve watershed management goals to protect or increase production of salmonid fishery resources.

Individual compliance or effectiveness cannot be assessed using indicators influenced by a variety of conditions and activities over a wide area. In-channel characteristics at a particular location reflect the full distribution of conditions throughout the upstream watershed.

Several studies, reports and assessments have been conducted at the stream or watershed scale. These studies have identified problems with anadromous stream habitat in the Van Duzen River Basin (CDFG 1974, 1981, and 2006; DWR 1966 and 1976; HRC 2010, Kelsey, Tetra Tech 1997; 2002; USEPA 1999, USCOE 1980). Watershed factors that adversely impact salmonids such as high water temperature, lack of quality pool habitats, loss of shade, excessive fine sediments in spawning grounds and fish passage barriers have been noted.

The streams of the Van Duzen River Basin that once supported abundant coho salmon (*Oncorhynchus kisutch*) populations now support few returning adult fish according to recent spawning surveys. The cumulative impacts from land use, floods, droughts and over harvest have manifested in the possible extirpation of coho salmon and critical reductions of Van Duzen River Basin Chinook salmon (*O. tshawytscha*) and steelhead trout (*O. mykiss*) populations as well. Further challenges to recovery of coho salmon and preserving extant populations of all salmonids in the Van Duzen River Basin may be complicated by uncertain effects from climate change.

The Van Duzen River Basin drains approximately 430 square miles of mountainous terrain in California's North Coast Range (Figure 1). Eighty-four percent of the basin is within Humboldt County and the remaining portion (16%) is within Trinity County. The Van Duzen River is a major tributary to the Eel River which flows into the Pacific Ocean approximately 15 miles south of Eureka, in Humboldt County. The basin terrain is extremely mountainous, with the only flatland occurring on river terraces along the lower basin, or in the relatively small Larabee, Hettenshaw, and Dinsmore valleys. Elevations in the Van Duzen River Basin range from approximately 5,900 feet at the upper basin headwater peaks (Mount Lassic, Black Lassic, and Red Lassic) to a low elevation of 60 feet where the Van Duzen joins the Eel River near the town of Fortuna, approximately 13 miles from the Pacific Ocean.

The Van Duzen River is one of the few remaining un-dammed rivers in California. In addition to its free flowing quality, the Van Duzen River is recognized for its extraordinary scenic, recreational, and fish and wildlife values. To help protect these values, sections of the river were added to the State Wild and Scenic River system in 1972. These include a designated recreational reach that extends from the confluence with the Eel River upstream to the power lines crossing above Little Larabee Creek (RM 32) and a designated scenic reach from Little Larabee Creek upstream to the Dinsmore Bridge (RM 49). The State Wild and Scenic Rivers Act mandates that state and local agencies protect the free flowing character and extraordinary values of the designated reaches of Van Duzen River. In 1981, those river reaches also received National Wild and Scenic River designation. However, due to cumulative impacts effects from land use on geologically unstable terrain and large floods of 1955 and 1964, the Van Duzen River was listed by the U.S. Environmental Protection Agency (USEPA) under the Total Daily Maximum Load (TMDL) program as sediment impaired and water quality limited. The TMDL listing is due to impacts of sedimentation/siltation on beneficial uses including maintenance of critical aquatic habitat which supports anadromous salmonids.

Many of the people that work, recreate, and enjoy the scenic beauty of the Van Duzen River also live in the basin or reside close by (Figure 2). With a cumulative population of less than 4,000 residents, the small towns of Hydesville, Neeland, Carlotta, Bridgeville, and Dinsmore provide services for rural, mountain community residents dispersed throughout the basin. In addition, visitors are attracted to the area to enjoy the river, forests, fish and wildlife, parks, campgrounds, and public lands. Stands of old growth redwoods viewed along Highway 36 are of particular interest.

Land owners, stakeholders, and interested parties have formed watershed groups and land conservancies to maintain and /or improve the status of the basin's aesthetic values, and economic and natural resources. These include the Yager/Van Duzen Environmental Stewards (YES), Friends of the Eel River, the Buckeye Conservancy, Friends of the Van Duzen River, and the Eel River Watershed Improvement Group (ERWIG). These groups and stakeholders along with California Department of Fish and Game (CDFG) and other state and federal agencies have worked to promote sustainability and improve values of the Van Duzen River Basin's natural resources.

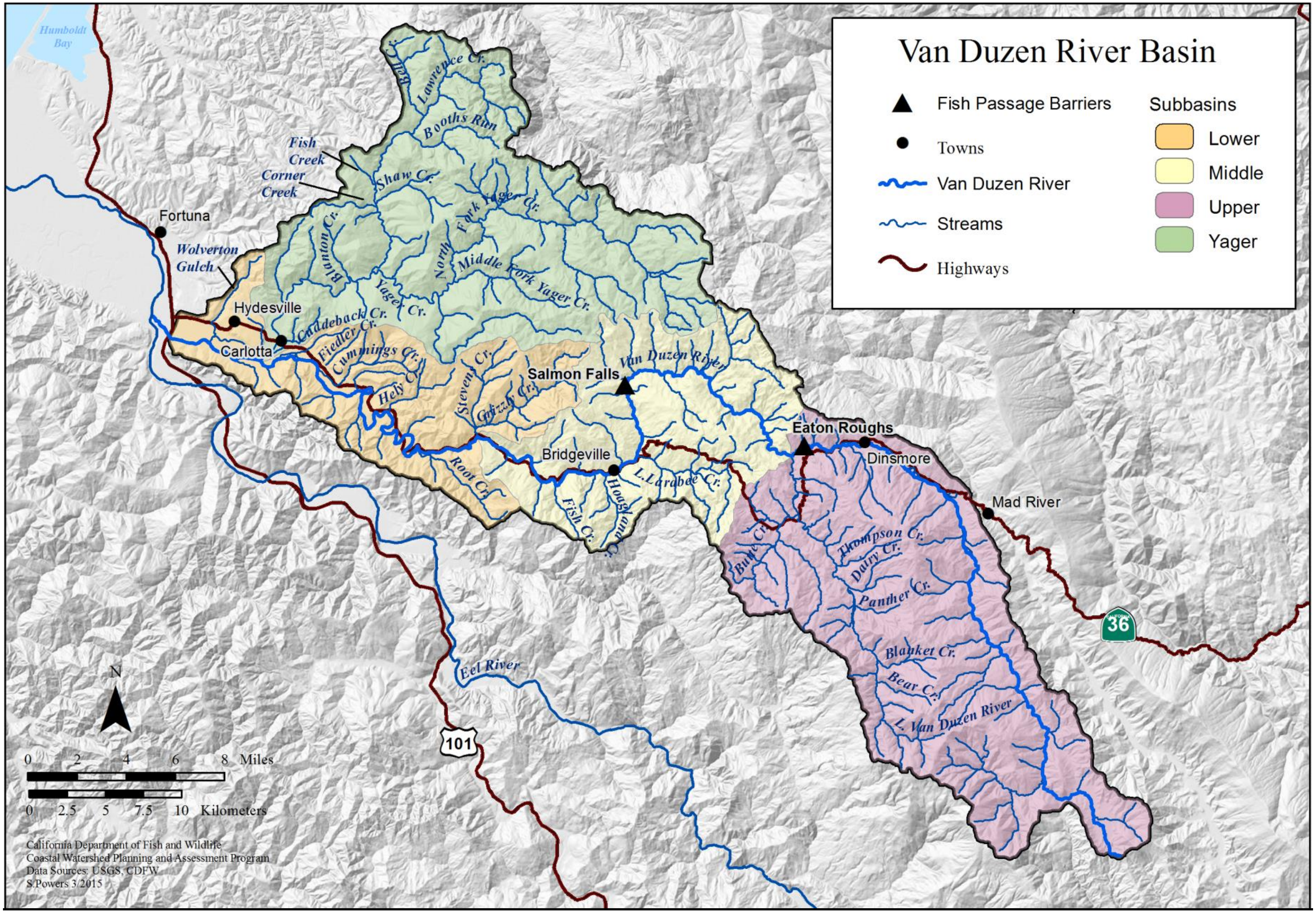


Figure 1. Location of the Van Duzen River Basin and subbasins in Northern California.

Watershed improvement projects have focused on reducing erosion and sediment delivery to streams by improving road conditions and watercourse crossings, and improving instream habitat conditions with instream enhancements.

Subbasin Scale

The complexity of large basins such as the Van Duzen River makes it difficult to address watershed assessment and recommendations except in very general terms. In order to be more specific and of value to planners, managers, and landowners, it is useful to subdivide the larger basin into smaller subbasin units whose size is determined by the commonality of many geographic attributes (Figure 1). Attributes that can distinguish subbasins include differences in elevation, geology, soil types, climate, vegetation, human population, and land use (Table 1). The subbasins conform to CalWater 2.2 Planning Watershed boundaries (Figure 3), except for a small modification to include the lower reach of Yager Creek in the Yager Subbasin.

The Yager Creek Subbasin includes all the land and waterways in the Yager Creek watershed. The Carlotta Post Office is located in the Yager Creek Subbasin. Principle land use is industrial and non-industrial timber production and livestock grazing (Figure 3, Table 1).

The Lower Subbasin includes all the land and waterways from the confluence of the Van Duzen and Eel rivers upstream to Grizzly Creek. The communities of Hydesville and Carlotta are located in the Lower Subbasin (Figure 3). Principle land use includes industrial and non- industrial timber production, livestock grazing, and rural developments.

The Middle Subbasin includes the land and waterways upstream of Grizzly Creek to the eastern limits of the Hogback and Little Larabee Creek Planning watersheds. The communities of Swains Flat and Bridgeville are located in the Middle Subbasin (Figure 3). Principle land use includes non-industrial timber production, livestock grazing and rural developments.

The Upper Subbasin includes the Van Duzen drainage area above (east) the confluence of the Little Van Duzen River (Figure 3). The upper half of the subbasin is within Trinity County where the majority of land is part of Six Rivers National Forest and managed by U.S. Forest Service, Mad River Ranger District. Timber harvest is a dominant land use. Several small rural developments and a few large private land ownerships are near the towns of Dinsmore and Mad River.

Figure 2. River kayaking and fishing for salmon and steelhead are popular activities on the Van Duzen River. Photographs courtesy of Trevor Tollinson.

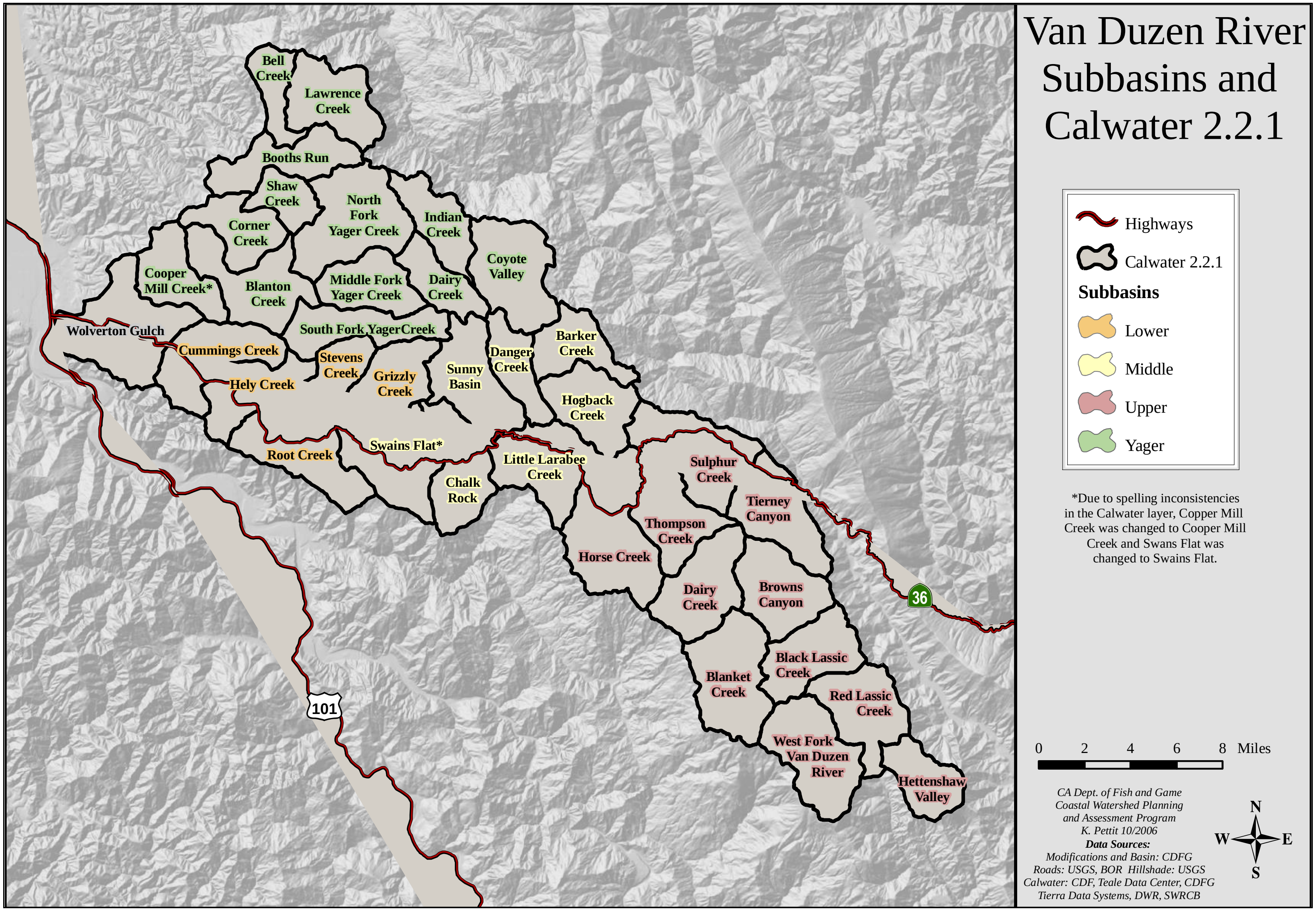


Figure 3. Van Duzen River subbasins and planning watersheds based on Calwater 2.2.1.

Table 1. Summary of Van Duzen River subbasin attributes.

Attribute	Yager	Lower	Middle	Upper	Basin Total
Area (Square Miles)	137.5	69	78.4	143.5	428
Total Acres	87,975	44,151	50,182	91,814	274,121
Private Acres	85,862	43,142	49,435	43,795	222,234
Federal Acres	947	0	579	48,005	49,531
State Acres	1166	1009	167	14	2,356
Principal Communities	Carlotta	Hydesville/Carlotta	Bridgeville	Dinsmore	
Dominant Land Uses	Industrial and non-industrial timber production and livestock grazing	Industrial and non- industrial timber production and rural developments	Non-industrial timber production/ Livestock grazing	Timber production, rural developments	
Dominant Vegetation Type	Redwood/Douglas fir	Redwood	Douglas fir	Douglas fir	
Anadromous Fish Access (stream miles)	53	45	27	28	153
Lowest Elevation (ft)	89	60	380	1,540	60
Highest Elevation (ft)	3,565	3,440	4,200	5,900	5,900

Climate

The climate of the Van Duzen Basin is characterized as Mediterranean, typified by cool, wet winters and warm to hot, dry summers. Fall and spring weather patterns are relatively shorter transitions between the longer wet and dry seasons. The climate varies according to the distance from the coast, elevation, and the slope and aspect of the mountainous terrain. At the subbasin scale, the climate of the Lower Subbasin and westerly portions of the Yager Creek Subbasin is moderated by marine air masses and cooled in summer by coastal fog. The coastal fog belt extends eastward approximately 30 miles from the coast (approximately three miles west of Bridgeville). The Middle and Upper subbasins are less influenced by the marine climate and experience greater extremes of air temperature between the seasons. During summer months, the middle and upper portions of the basin reach or exceed 100° F, but often cool substantially at night. A resident near Bridgeville stated “there are really two seasons here; muddy and dusty” (Anonymous communication).

Approximately 90 percent of the seasonal precipitation occurs between October and April. Annual average precipitation varies from 40 inches in the lower Van Duzen River basin, in the area of Hydesville and Carlotta, to over 70 inches in the headwater area of Yager Creek and McAlvey Ridge along the northern drainage divide (Figure 4). Average rainfall at Bridgeville is 67 inches per year and to over 80 inches around Buck Mountain east of Larabee Valley with higher amounts occurring along ridge tops and prominent south and west facing slopes (Rantz 1968). Winter storms often last for several days or longer and may produce bouts of intense rainfall. Flooding can occur by either rainfall delivered by large and persistent winter storms or by intense rains of only a few days. Snow levels are usually above 2,000 feet in elevation, but occasionally it snows at lower elevations. The floods of 1955 and 1964 were rain on snow events and produced the largest river flows on record. These rain and associated floods were major climatic events that contributed to long term changes to streams in the basin.

Climate is important to the production of anadromous salmonids because they are instinctively tied to rain events that provide water for passage to and from spawning grounds. The stream flows from winter rains are also necessary for the incubation and hatching of eggs and for sustaining juveniles over the dry season. A relatively stable climate surrounding salmonid streams and within the streams is also important to maintain productive conditions for juvenile salmonids over the summer rearing season. That is water temperature and stream flows should stay in a range that will sustain viable populations. Productive salmonid streams often flow through forest areas that form cool microclimates and retain cool water temperatures during summer months. Microclimates formed by forest shade canopy, hillslope and aspect of stream channels helps to maintain cool water (generally between 54-64ºF) over the warm summer season. Factors such as species composition and seral stage of forests, proximity to streams, and slope aspect (northern exposure) can act as buffers against high summer air temperatures and moderate cold temperatures of winter. Microclimates in mature riparian areas are often much cooler and more humid than the upland forests due to extensive understory and overstory shade canopy that insulates against warming from high air temperature and direct sunlight. Tall conifers block sunlight well above the ground level which helps keep riparian air masses and stream water cool.

However, most watersheds have undergone timber harvests that have removed or altered the near stream forest's role to provide shade and insulation from high air temperatures. The loss of cool microclimates can lead to high summer water temperatures, a limiting factor to salmonid production.

Climate Change

In addition to land use factors affecting the climate surrounding salmonid streams, climate change is affecting California. As stated in the Climate Action Team Report to Governor Schwarzenegger and the California Legislature (2010):

> Average temperatures have increased, leading to more extreme hot days and fewer cold nights. Shifts in the water cycle have been observed, with less winter precipitation falling as snow, and both snowmelt and rainwater running off earlier in the year. Sea levels have risen. Wildland fires are becoming more frequent and intense due to dry seasons that start earlier and end later. These climate driven changes affect resources critical to the health and prosperity of California.

These changes are having and will continue to have an impact on salmonids. Drought conditions may become more severe and more common as the climate continues to shift and seasonal changes become more pronounced, thus reducing the amount of water available at the various salmonid lifecycle stages. Precipitation patterns may very more dramatically with potentially stronger winter storms that could increase sediment loads and impact spawning habitat and successful egg to fry production. Changes could also occur when looking at small scale regional weather characteristics, like the frequency of fog on the California coast. Data from 1901 to 2008 indicate that coastal temperatures have increased more than inland temperatures, accompanied by a reduced number of hours of coastal fog (in some areas as much as 33%) (Johnstone and Dawson 2010). If coastal fog continues to diminish there will be increased drought stress and potentially a reduction in the range of coast redwoods and associated fish and wildlife communities. In the coming years climate change will affect the ability to influence the recovery of some salmon species in most or all of their watersheds (NMFS 2012).

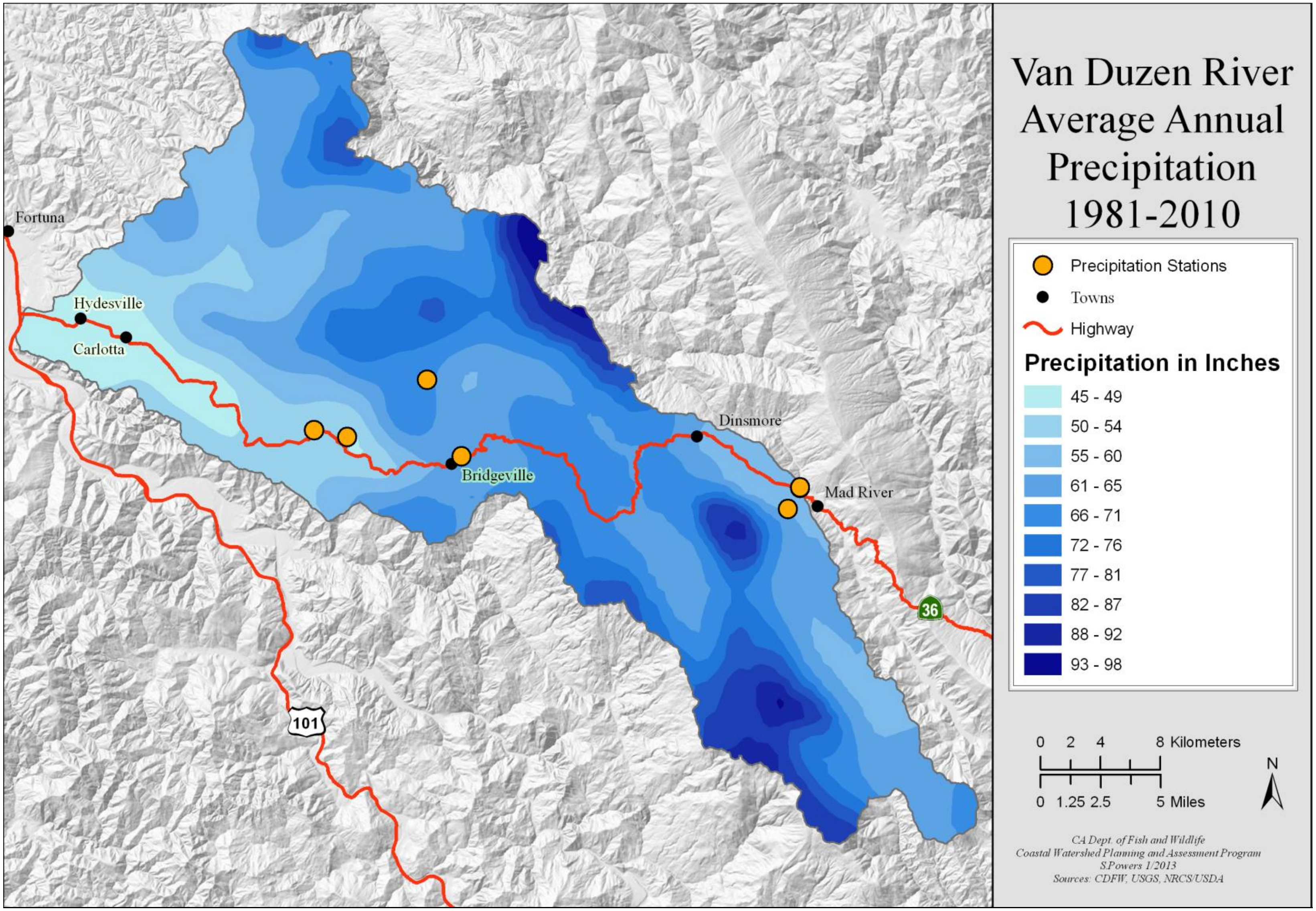


Figure 4. Average annual precipitation from 1961-1990 in the Van Duzen River Basin.

Geology

The Van Duzen River Basin is located in one of the most geologically complex and tectonically active regions of the United States. The landscape was created by the accretion of oceanic crustal material with its associated overlying sediments, island arcs, and continental sediments resulting from subduction of the Farallon/Gorda plate beneath the North American Plate during the last 200 million years. Tectonic uplift is occurring in this area due to the encroachment of the Mendocino Triple Junction where the North American, Pacific, and Gorda plates meet. Immense tectonic interaction of these three plates also creates large compressional and translational forces that shape the underlying landscape of this region. This tectonic regime has folded and faulted the geology of this area and created a rugged landscape of Northwest trending mountains and river systems.

The Van Duzen River Basin is physically located within the Coastal, Central Belts, and Eastern belts of the Franciscan Complex of the Coast Ranges geomorphic province.

The Franciscan Complex is made of complexly deformed continental margin deposits of mostly sandstone and shale that have been uplifted as part of the accretionary process resulting from collision and subduction of the Farallon/Gorda Plate (Baily et al. 1964). Bedrock underlying this basin has gone through a complex process of tectonic deformation, as part of the accretionary process which has left it relatively incompetent and prone to erosion. High rates of tectonic uplift have further faulted, tilted and weakened the bedrock further decreasing bedrock stability. Uplift has also effectively raised the potential energy of the local streams allowing them to better erode the landscape and incise at higher rates. These geologic factors combined with abundant winter rains and anthropogenic land disturbances have contributed to excessive levels of erosion and large sediment inputs to the basin’s streams. Excessive amounts of sediment inputs to streams has filled pools and buried spawning gravels needed to sustain salmonids. In addition, prolonged periods of high turbidity levels caused by chronic hillslope erosion and associated inputs of fine sediments to streams impairs beneficial ecological functions of aquatic habitats needed by salmonids.

Relevant Geologic Concepts
Subduction – The process in which one tectonic plate (usually oceanic) under-rides another (usually continental) in a convergent plate boundary.
Accretion – The process through which material from the subducting oceanic plate accumulates onto the edge of the continental plate.
Terrane – A fault bounded area with a geologic history which is distinct from the surrounding area originating as part of the accretionary process.

Major bedrock units within the Van Duzen River watershed include; alluvium, river terrace deposits and large landslide deposits, marine deposits of the Wildcat Group, Yager terrane, Central Belt mélange, sandstone, and incorporated Yolla Bolly terrane (Figure 5). A more detailed description of major bedrock units is presented in the subbasin sections of this report.

GEOLOGIC RELATION AND DESCRIPTION OF MAJOR UNITS WITHIN THE VAN DUZEN RIVER BASIN						
Unit	**Belt/Rock type**	**Formation/ terrane**	**Composition**	**Age**	**Years ma**	**%**
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Holocene	0-0.01	4
	River terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.	Holocene-Quaternary	0.01-2	2
		Rohnerville formation	Unconsolidated, gently folded, older Eel/Van Duzen River gravel, sand, silt and clay	Upper Pleistocene	0.01-0.13	
		Hookton formation	Poorly consolidated-unconsolidated marine-nonmarine sand, gravel, and silt.	Mid-upper Pleistocene	0.13-0.78	
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Holocene-Quaternary	0.01-2	5
	Wildcat group undifferentiated	Carlotta formation	Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay.	Early Pleistocene	0.78-1.8	10
		Scotia Bluffs sandstone	Shallow marine sandstone and conglomerate	Late Pliocene	1.8-3.6	
		Rio dell formation	Marine mudstone, siltstone, and sandstone	Late Pliocene	1.8-3.6	
		Eel River formation	Marine mudstone, siltstone, and sandstone	Early Pliocene	3.6-5.3	
		Pullen formation	Marine mudstone, siltstone, and sandstone	Upper Miocene - Lower Pliocene	5.3-11.6	
Franciscan Complex	Coastal belt	Coastal terrane	Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, limestone lenses, and exotic blocks of rock.	Pliocene-late Cretaceous	1.8-99.6	0
		Yager terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Eocene-Paleocene	33.9-65.5	13
	Central belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Late Cretaceous-late Jurassic	65.5-161.2	11
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert,	Early tertiary-late Cretaceous	1.8-65.5	40
	Eastern belt	Pickett Peak terrane	Schistose metasedimentary and metavolcanic rocks.	Early Tertiary-late Cretaceous	1.8-65.5	0.1
		Yolla Bolly terrane	Semi-schistose metagraywacke with minor metachert and metavolcanic rocks.	Early Cretaceous-Mid Jurassic	99.6-199.6	14
Great Valley Sequence/Coast Range Ophiolite	Mudstone		Thin-bedded mudstone, arkosic siltstone and sandstone.	Mesozoic	65.5-251	0.02
	Mélange		Sheared matrix of serpentinized dunite containing blocks of basalt, diabase, gabbro, and ophiolitic breccia.			1
Sources: Kilbourne, 1985, Ogle, 1953, McLaughlin, 2000.						

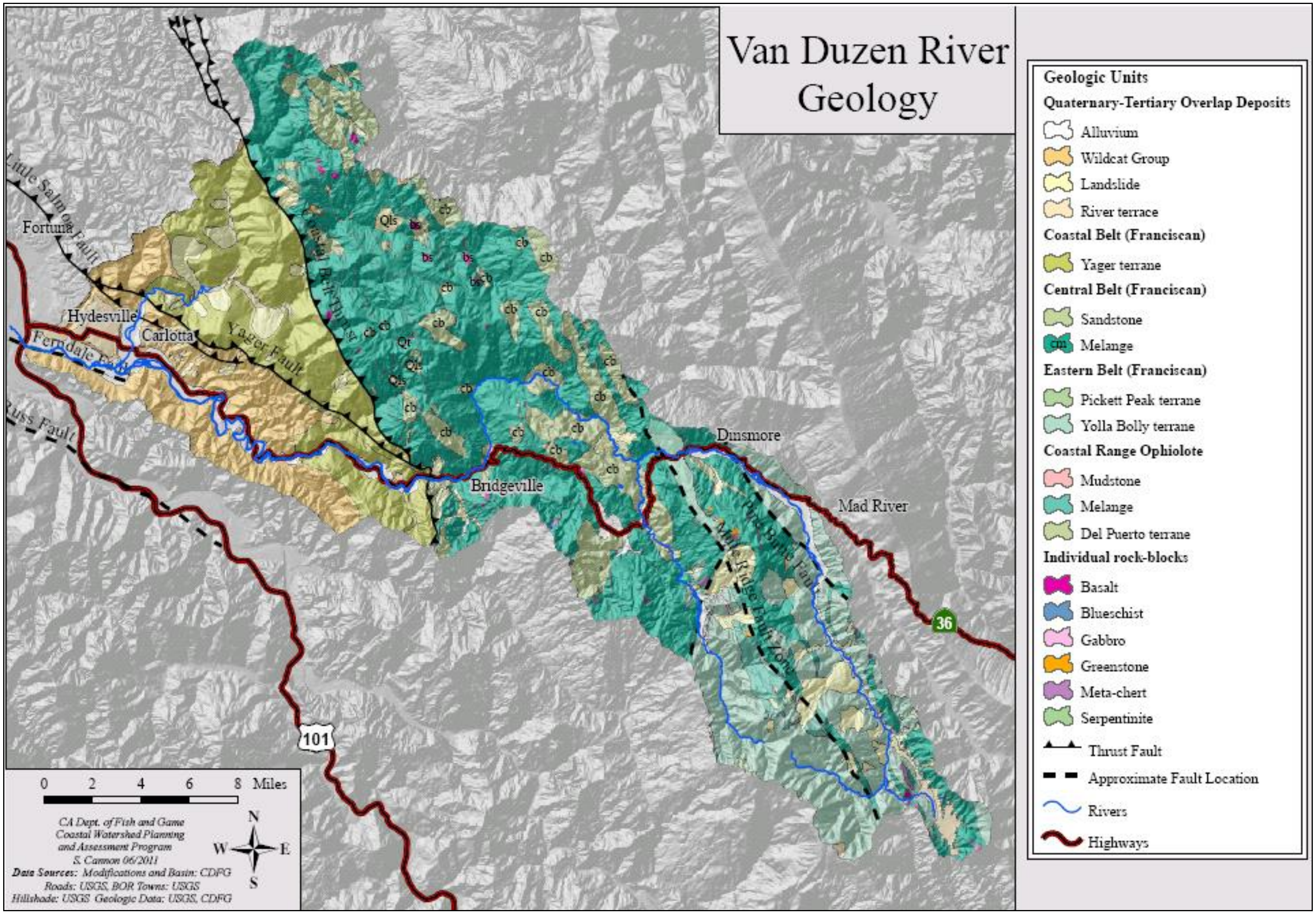


Figure 5. Simplified geologic map of the Van Duzen Basin. Modified from McLaughlin et al.2000.

Table 2. Estimated square acre and percentage make-up of Lithologic units of the Van Duzen River subbasins and Basin.

Lithologic Unit	Yager	Lower	Middle	Upper	Basin Total
Quaternary Alluvium	1365 (2%)	5074 (11%)	1046 (2%)	4073 (4%)	11559 (4%)
Quaternary river terraces	1012 (1%)	2427 (6%)	142 (<1%)	1862 (2%)	5442 (2%)
Quaternary Landslides	4993 (5%)	766 (2%)	1381(3%)	6859 (7%)	13999 (5%)
Wildcat Group	5356 (6%)	22049 (50%)	175 (<1%)	0	27580 (10%)
Yager terrane	20818 (24%)	8457(19%)	6103 (12%)	0	35377 (13%)
Central Belt Sandstone	10856 (12%)	568 (1%)	12127 (24%)	5508 (6%)	29060 (11%)
Central Belt Mélange	43576 (50%)	4817 (11%)	29195 (58%)	32270(35%)	109857 (40%)
Picket Peak terrane	0	0	0	214 (<1%)	214 (0.1%)
Yolla Bolly terrane	0	0	0	37998 (41%)	37998 (14%)
Great Valley/Coastal Range Ophiolite mudstone	0	0	0	56 (<1%)	56 (0.02%)
Great Valley/Coastal Range Ophiolite mélange	0	0	13(%)	2974 (3%)	2988 (1%)
Data are in square acres and percent of subbasin and represent a rough approximation based on GIS mapping.					

Faults and Earthquakes

The Van Duzen River Basin is located in one of the most seismically active regions in North America. Transpression (translation and compression) generated by tectonics of the Mendocino Triple Junction has caused intense deformation of this region evidenced by a myriad of folds and faults within this landscape. Tectonic stresses inherent to the Mendocino Triple Junction drive periodic movement on faults (earthquakes) within and within proximity to the basin.

Earthquakes can trigger rockfalls, landslides, and earth/debris flows as well as increasing erosional processes in the area of surface rupture or liquefaction (Figure 8). Fault movement can result in uplift of the local landscape increasing the potential for erosion or cause the local landscape to subside increasing the potential for deposition. Faults may deform, break, or weaken rock leaving the immediate area unstable and more prone to erosion.

Major, mapped faults with significant influence on the Van Duzen River Basin are as follows:

Mendocino Triple Junction

The Mendocino Triple Junction located just off shore between Cape Mendocino and Petrolia. It juxtaposes the Gorda, Pacific, and North American plate in a complex tectonic regime. The Mendocino triple Junction has been migrating northward relative to the North American plate over geologic time increasing the seismicity of this region.

Cascadia Megathrust
The Cascadia Megathrust allows subductive movement of the Gorda plate beneath the North American plate. This fault is capable of generating very large earthquakes (~M9) and usually produces uplift or subsidence of the coastal area adjacent to the Van Duzen River Basin. Several prehistoric seismic events that produced significant tsunamis and sudden uplift or subsidence along this area of the coast have been documented. In 1992 an earthquake of magnitude 7.1 (Richter) occurred that uplifted the coast at Cape Mendocino by about five feet.

The San Andreas fault (Northern segment) is and active dextral fault that runs just off shore, southwest of the Van Duzen River Basin. It is capable of large earthquakes (~M7) that can significantly affect the basin by seismic shaking, deformation, and their associated mass wasting/erosion effects. Although not well documented within the Van Duzen River basin, the 1906 northern San Andreas fault seismic event (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments.

The Little Salmon fault is an active, northeast-dipping thrust fault that trends northwest coming onshore near Eureka and terminating approximately at Cummings Creek. It is about 50 miles in length and is the dominant active fault within the Van Duzen river basin. This fault is capable of generating large earthquakes (~M 7).

The Yager fault is a low-dipping thrust fault that trends northwest through the basin. The Yager fault may be an active offshoot of the Little Salmon fault.

Goose Lake fault is a northwest trending thrust fault associated with the Little Salmon and Yager faults. It is mapped within the lower subbasin in the vicinity of Hydesville.

The Ferndale fault is a steeply dipping reverse fault that trends west by northwest and bounds the southern edge of the Van Duzen River valley floor within the lower subbasin in the area from Alton to Carlotta.

The Coastal Belt Thrust fault is the major fault that juxtaposes the Coastal belt and the Central belt. It trends north by northwest through the Van Duzen River Basin. It is most likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal belt when the active subduction moved west to its present location along the Cascadia Megathrust.

The Mule Ridge fault is another steeply dipping to nearly vertical fault that runs northwest through the eastern portion of the upper subbasin. It is believed to be similar to the Grogan-Red Mountain fault zone.

The Pine Ridge fault is considered part of the Grogan-Red Mountain fault zone which is a steeply dipping fault zone that runs northwest within the Upper subbasin. This fault zone separates the Central belt from the Eastern Belt of the Franciscan Complex. It probably marks the zone of active subduction before the Coastal Belt Thrust.

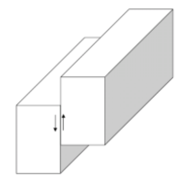
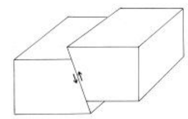
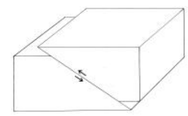
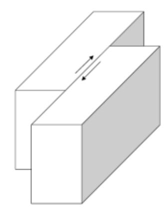
Fault Type	Description	Diagram
Vertical	A fault in which relative movement between the hanging wall and the foot wall occurs along a vertical plain.	
Reverse	A fault in which the hanging wall moves upward relative to the footwall along a plain who's dip is between 46° - 89°	
Thrust	A fault in which the hanging wall moves upward relative to the foot wall along a plain that has a dip of 45° or less.	
Dextral	A fault where relative movement viewed across the fault is to the right. Also known as a right-lateral fault.	

Figure 6. Fault types present in the Van Duzen River Basin.

Table 3. Faults of the Van Duzen River Basin.

FAULTS WITHIN AND WITH INFLUENCE TO THE VAN DUZEN RIVER BASIN				
Active Faults:	**Fault Type**	**Possible Magnitude**	**Recurrence Interval**	**Subbasin**
Cascadia Megathrust	Thrust	9	500-600	West of basin
Little Salmon fault	Thrust	7.2	400-800	Lower, Yager
Yager fault	Thrust	Unknown	Unknown	Lower, Yager, Middle
Goose Lake fault	Thrust	Unknown	Unknown	Lower
San Andreas fault (Northern segment)	Dextral	7.3	200-300	Southwest of basin
Faults:				
Coastal Belt Thrust	Thrust			Lower, Yager, Middle
Mule Ridge fault	Vertical/Dextral			Upper
Ferndale fault	Reverse			Lower
Pine Butte fault (Grogan-Red Mountain fault zone)	Vertical/Dextral			Upper
Sources: U.S.G.S. 2011, McLauglin 2000				

Landslides

The majority of sediments entering the Van Duzen River system are introduced by various types of landsliding. The term "landsliding" or "landslide" is used in a general sense to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock within this basin.

During the early spring of 2006 a series of landslides occurred on Cummings Creek. They were most likely triggered by an earthquake which destabilized the rain saturated slope.

Subduction of the Gorda plate and compressional tectonics contribute to the high rate of uplift of this area. Encroachment of the Mendocino Triple Junction has accelerated the rate of tectonic uplift during the last 500 thousand years. Both of these processes have combined to raise this area by 1-3 millimeters per year. The increased elevation of the region increases the erosion potential. That coupled with the high precipitation rates effectively erode the landscape at a rate of about 0.79 millimeters per year (Gendaszek et al. 2006).

The following discussion is a general description of the natural propensity for movement of the most susceptible bedrock types. It does not take in to account land use issues.

Quaternary river terraces are subject to debris sliding. The Hookton formation is subject to gully erosion, debris slides and earthflows (Kilbourne 1985). In the Rio Dell formation landsliding is common in zones between mudstone and sandstone beds during super saturation. The Yager terrane is susceptible to debris sliding, especially in areas of shear and along stream banks. Mélange material, due to the weak nature of its sheared matrix, tends to slowly flow over time creating a hummocky landscape with boulders of various lithology weathering out as "Franciscan Knockers". It is highly susceptible to large deep-seated earthflows that contribute a significant amount of sediment to the drainages. On average they move at a rate of 2.4 to 4.0 m/yr. (Kelsey, 1978). Landslides, debris slides, and earthflows are common features of the Van Duzen River Basin and some examples are presented in Figure 9.

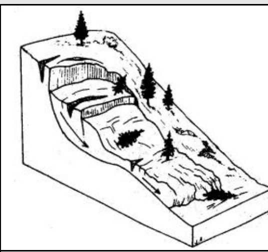
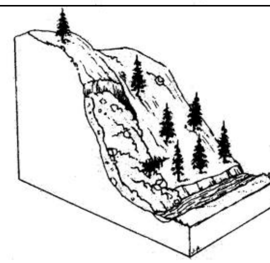
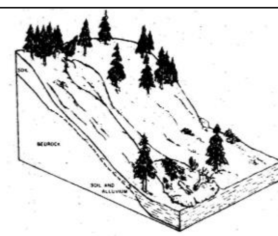
Fault zones are also extremely prone to landsliding and earthflow movement due to their weakened lithology or tectonic movement.

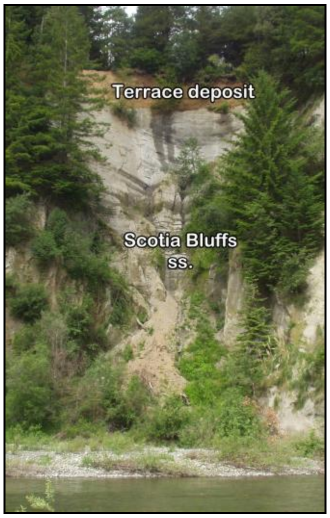
Slope Inclination

The percent slope (rise in feet per horizontal distance) is a slope inclination measurement of distance perpendicular to the contour of the slope. For example a ten percent slope is a one-foot rise over a 10-foot horizontal run. A three foot rise over a ten foot horizontal run constitutes a thirty percent slope. Steep slopes (>30%) comprise 51 percent of the subbasin's terrain (Figure 10).

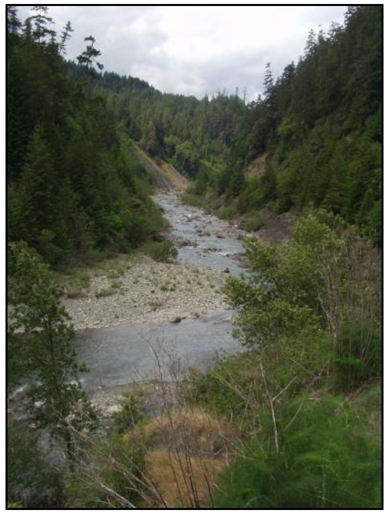
Disturbance of steep slopes often results in accelerated erosion processes and sedimentation of streams, degradation of water quality and impairment of aquatic habitats needed by salmonids. When excessive erosion occurs, pool habitats decrease by aggradation (filling in) and spawning gravels become embedded (Madej 1984). Related effects include soil loss, changes in natural topography and drainage patterns, increased flooding potential, and compromised aesthetic values. It has become widely recognized that disturbance of steep slopes should be avoided or regulated based on the impact disturbance of steep slopes can have on water quality and quantity, and the environmental integrity of landscapes.

Figure 7. Common landslide types present in the Van Duzen River Basin.

General Landslide Types Within The Van Duzen River Basin	
TRANSLATIONAL/ROTATIONAL SLIDE: A landslide in which the bedrock that moves remains mainly intact. Rock slides can range in size from small and thin to very large and thick. The sliding occurs at the base of the rock mass along zones of weakness. The sliding surface may be curved or planar in shape. Rock slides with curved sliding surfaces are commonly called “slumps” or “rotational slides,” while those with planar failure surfaces are commonly called “translational slides,” “block slides,” or “block glides.” Rock slides commonly occur on relatively steep slopes in competent rocks. Slope gradients are commonly from 35% to as steep as 70 %.	
EARTH FLOW: A Soil Flow landslide where the majority of the soil materials are fine-grained (silt and clay) and cohesive. The material strength is and movement occurs on many discontinuous shear surfaces throughout the landslide mass. This movement along numerous internal slide planes disrupts the landslide mass leading to cumulative movement that resembles the flow of a viscous liquid characterized by a lumpy, or “hummocky” slope morphology. Earth flows commonly occur on moderately steep slopes from 10% to as steep as 30%. Earth flows typically are initiated by periods of prolonged rainfall and sometimes don’t initiate until well after a storm or the rainy season has passed.	
DEBRIS SLIDE: A slide of coarse-grained soil. Its overall strength is generally higher than earth flows, but there may be a very low strength zone at its base. Debris slides typically move initially as shallow intact slabs of soil and vegetation, but break up after a short distance. The debris is deposited at the base as a loose hummocky mass, and may be rapidly removed by erosion. Debris slides commonly occur on very steep slopes, as steep as 60% to 70%, usually in an area where the base of a slope is undercut by erosion. Debris slides form steep, un-vegetated scars which are likely to remain un-vegetated for years. A single heavy rainstorm or series of storms may deliver enough rain to trigger debris slides. Debris slide scars are extremely steep and therefore are very sensitive to renewed disturbance. Erosion at the base of debris slide scars may trigger additional slides. Cutting into the base of a debris slide scar may also trigger renewed slides. Even without additional disturbance, debris slide scars tend to ravel and erode, leading to small rock falls and debris slides.	
DEBRIS FLOW: A non-cohesive, coarse-grained (fine sand to boulder size particles) Soil Flow. Debris flows are most often triggered by intense rainfall following a period of less intense precipitation, or by rapid snow melt. High pore water pressures cause the soil and weathered rock to rapidly lose strength and flow downslope. Debris flows can move very rapidly, at rates ranging from meters per hour to meters per second and travel relatively long distances. Individual debris flows typically are small in areal extent and their deposits are relatively thin.	
ROCK FALL: A landslide where a mass of rock detaches from a steep slope by sliding, spreading or toppling and descends mainly through the air by falling, bouncing or rolling. Intense rain, earthquakes or freeze-thaw wedging may trigger this type of movement. Rockfalls occur on steep slopes of hard, fractured rock. Rockfall deposits are loose piles of rubble that may be easily removed by erosion.	
Source: CGS 2011	



Van Duzen County Park. Colluvial fan that has built up from raveling of a Quaternary terrace and slaking of the Scotia Bluffs fm. Sediment from fan will wash into the river during high flows.



Chalk Mountain landslide (left bank) on the Van Duzen River just west of Grizzly Creek. Continuous secondary slides eroding the toe fill the inner gorge area for at least 1 mile downstream. This slide complex is located within Yager Terrane.

Debris flow at Goat Rock on the Van Duzen River with erosion of the toe located on the Coastal Belt Thrust.

Debris slide/Rotational slide complex in Wildcat undifferentiated into the mainstem of the Van Duzen R (river mile 9).

Debris slide in Wildcat undifferentiated near "Blue Slide Creek" into the mainstem of the Van Duzen.

Donaker Creek earthflow in Central belt mélange. This is the largest earthflow within the Van Duzen River basin. Located just west of Bridgeville.

Figure 8. Examples of sedimentary material entering the Van Duzen River from landslides, debris flow and earthflows.

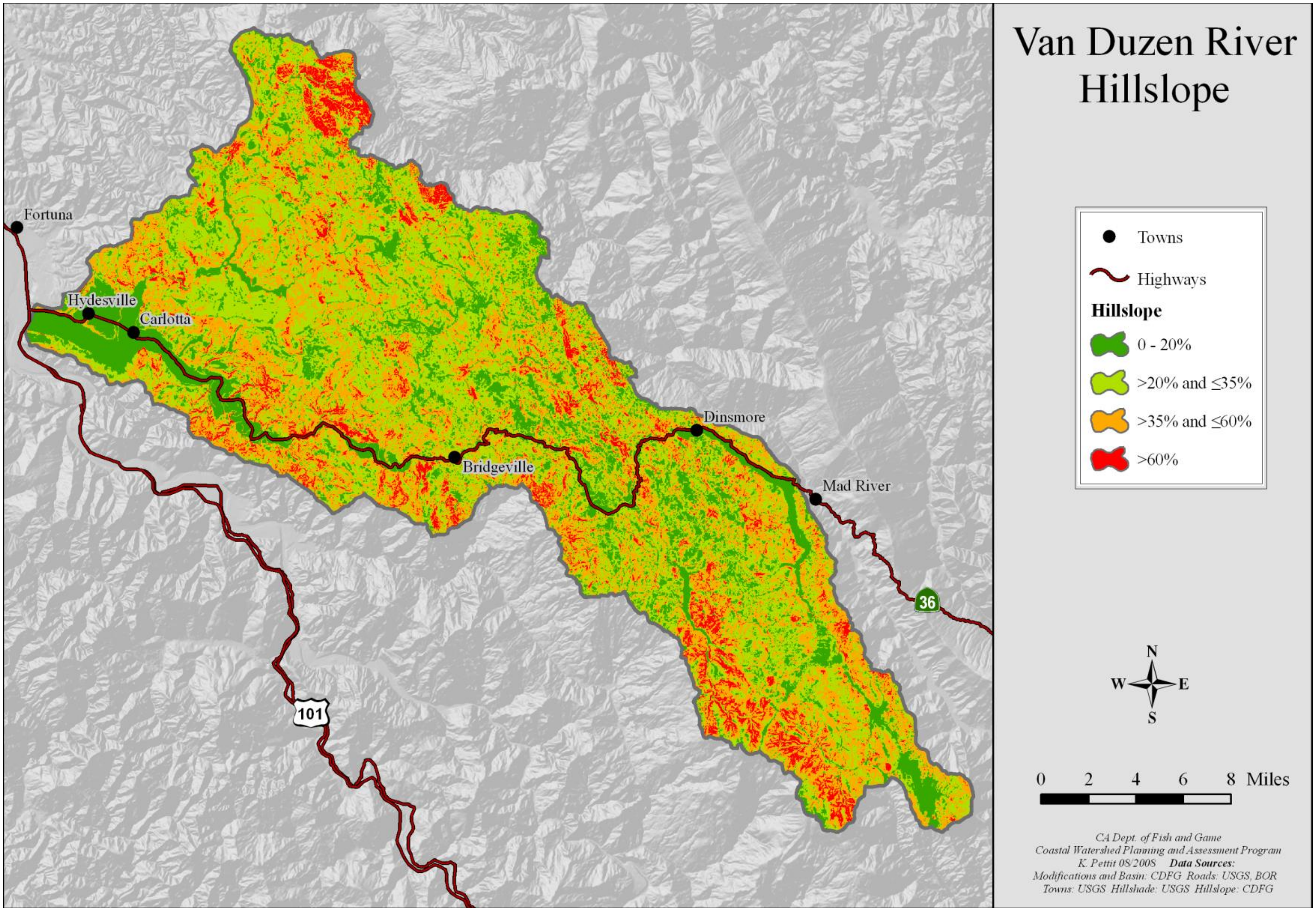


Figure 9. Slope inclination classes of the Van Duzen River Basin.

Definitions:
Flood Plain: the level area near a river channel constructed by the river in the present climate and overflowed during moderate flow events.
River Terrace: an abandoned floodplain as the climate becomes drier. Terrace deposits are often a source of sediment delivery to streams as peak flows erode terraces that laterally constrain channel widths.

Hydrology

According to USGS 1:24,000 topographic maps, there are approximately 455 miles of perennial (solid blue line) streams and 480 miles of intermittent streams within the Van Duzen River Basin (Figures 11 and 12). The mainstem Van Duzen River flows approximately 75 miles from its headwaters to the confluence with the Eel River. The basin's headwaters are located in a rugged area of the Six Rivers National Forest near Hettenshaw Peak. The Van Duzen River flows into the lower Eel River (about 13 miles from its entrance into the Pacific Ocean) just a few miles south of Fortuna. The Van Duzen River's two largest tributaries are Yager Creek and the Little Van Duzen River (South Fork Van Duzen River). The Little Van Duzen River flows north-west, drains the south-eastern portion of the basin, and joins the main stem at RM 45 near Dinsmore. The mainstem Van Duzen River becomes a fifth order stream at the confluence with the Little Van Duzen (Strahler 1952). Yager Creek drains approximately one third (138 square miles) of the Van Duzen River Basin. Yager Creek joins the mainstem Van Duzen at RM 5 near Carlotta and drains the lower north-western portion of the basin. In addition to Yager Creek and Little Van Duzen River, there are 63 named perennial and intermittent tributaries with the basin.

Along the mainstem reach of the Middle and Upper subbasins, zones of geologic weakness propagate a trellis network of smaller tributary drainages. Many of these small tributaries have intermittent stream flows (Figure 12). Overall, the basin has a high drainage density of 2.2 miles of stream channel per square mile of basin (range = 2.1 mi/m^2 in the Middle and Upper subbasins to 2.3 mi/m^2 in the Lower Subbasin). Drainage density is defined as the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. Drainage density is related to a number of factors including geology, topography, vegetative cover, anthropogenic erosion, and seasonal rain intensity. Drainage channel density can affect the shape of a river's hydrograph during a rain storm. Rivers like the Van Duzen that have a high drainage density will often have a more "flashy hydrograph" with a steep falling limb. That is, during large storm events, river flows may rise and fall rapidly. High densities can also indicate greater flood risk and high levels of soil erosion into tributaries and into the mainstem, especially when gullies or channels form on deforested areas.

The first headwater mile of mainstem Van Duzen River drops 825 feet to Hettenshaw Valley (Figure 11). The river then passes through a narrow valley which gradually widens until the river reaches Dinsmore (RM 45). In this 22-mile stretch, the river maintains a very low, smooth gradient and meanders gently through alluvial deposits. The side slopes are generally stable, but there is localized bank erosion and a few active slides reach the river.

Downstream of the community of Dinsmore, the streambed becomes steep and irregular, and it is strewn with boulders. At Eaton Rough Falls (RM 46), the river drops greater than 20 feet. These falls are considered the end of anadromy as they prevent salmon and steelhead from accessing the upper river. About ½ mile downstream of Eaton Falls, the Little Van Duzen joins the main river and nearly doubles the river's discharge. The terrain in this section is very unstable as the river flows through a narrow canyon where erosive hillslopes exhibit considerable stream side landsliding and sediment inputs.

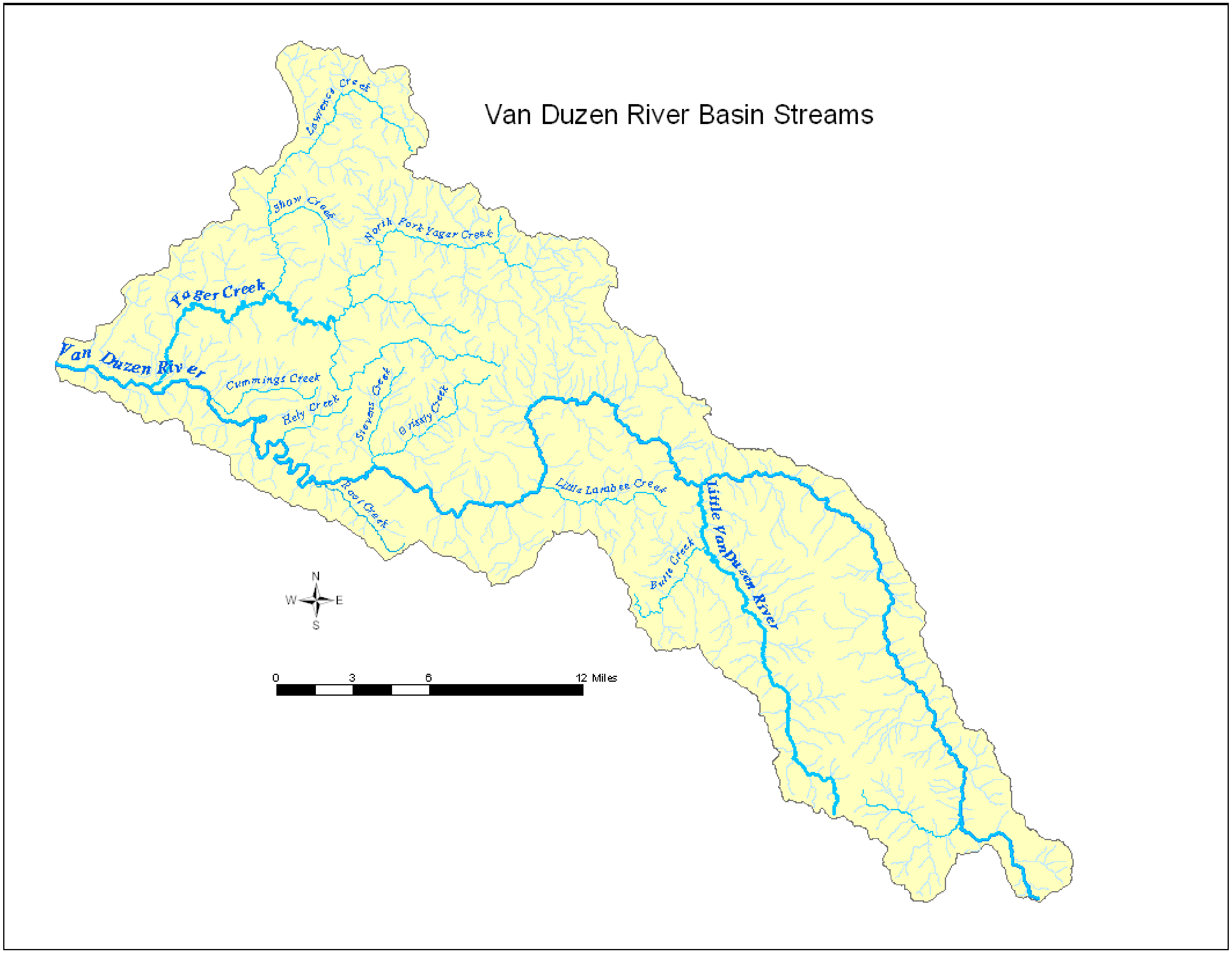


Figure 10. Major streams of the Van Duzen River Basin.

The streambed gradient begins to decrease downstream from Bridgeville (RM 29.5) and eventually becomes a very low gradient, meandering stream channel just downstream the confluence of Grizzly Creek (RM 23). In the 10 miles between Root Creek (RM 20) and Fox Creek (RM 10) the river flows through entrenched meanders confined by bedrock banks.

Downstream of the confluence of Cummings Creek the channel is situated in a broad floodplain dominated by large expanses of gravel. This reach and surrounding land contains the greatest human population, commercial and industrial activity and the only area of intensive agricultural land use. Yager Creek joins the Van Duzen near river RM 5 adding considerable flow and sediments to the river. The confluence of the Van Duzen River with the Eel River occurs one mile west of the community of Alton and Highway 101.

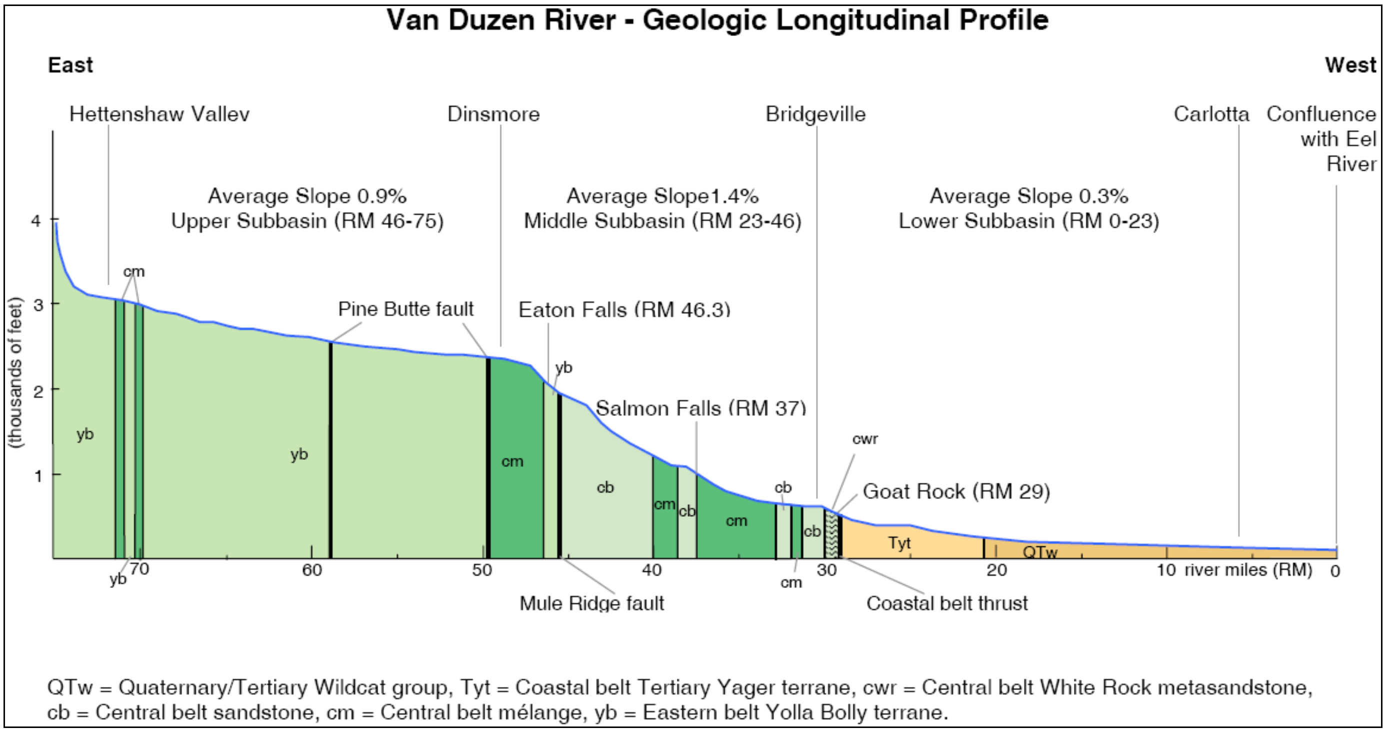


Figure 11. Geologic Longitudinal Profile of the Van Duzen River Basin

Streamflow

Streamflow data are an important component in determining the existing conditions and assisting watershed assessment, restoration, and management activities. Streamflow is a primary factor influencing channel characteristics and seasonal conditions of fish habitat. Channel modifications, such as bank erosion and excessive sediment loadings or channel scour often occur during peak flows of winter storms (Nolan et al. 1987). Flood flows can scour eggs from spawning beds or initiate damaging landslides that bury developing eggs. Conversely, low stream flow can be a limiting factor for anadromous fisheries, affecting passage and the quantity and quality of spawning, rearing, and refugia areas. Stream flow also has a direct effect on other factors such as water temperature, dissolved oxygen, and sediment and chemical transport.

The quantity, movement and distribution of water within streams of the Van Duzen River Basin are closely tied to annual precipitation cycles. The highest stream flows occur with high rainfall events of winter and the low flows occur towards the end of the dry summer season (Table 4). While precipitation is received in the form of snow at mid and upper elevations of the basin during winter storms, the accumulation does not generally become great enough to result in long term moisture storage which would affect the hydrology of the Van Duzen River (Draft Van Duzen River Waterway Management Plan, 1981). Rantz (1968) noted that stream flow for October through March is greater than 65% of the total annual streamflow indicating the streamflow is dominated by rainstorm runoff. April through July streamflow is usually less than 30% of the total annual flow; further suggesting snowmelt is not a dominant factor. The extremely low streamflow of August and September, less than 1.5% percent of the total annual streamflow, indicates that baseflow is poorly sustained by groundwater and soil moisture (Rantz 1968).

Table 4. Mean monthly discharge (CFS) in the Van Duzen River Basin from 1950-2007.

YEAR	**Monthly mean discharge in cfs (Calculation Period: Oct. 1950 to Oct. 2007)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean of monthly Discharge	2,240	2,020	1,610	943	454	143	36	16	18	131	828	1,960

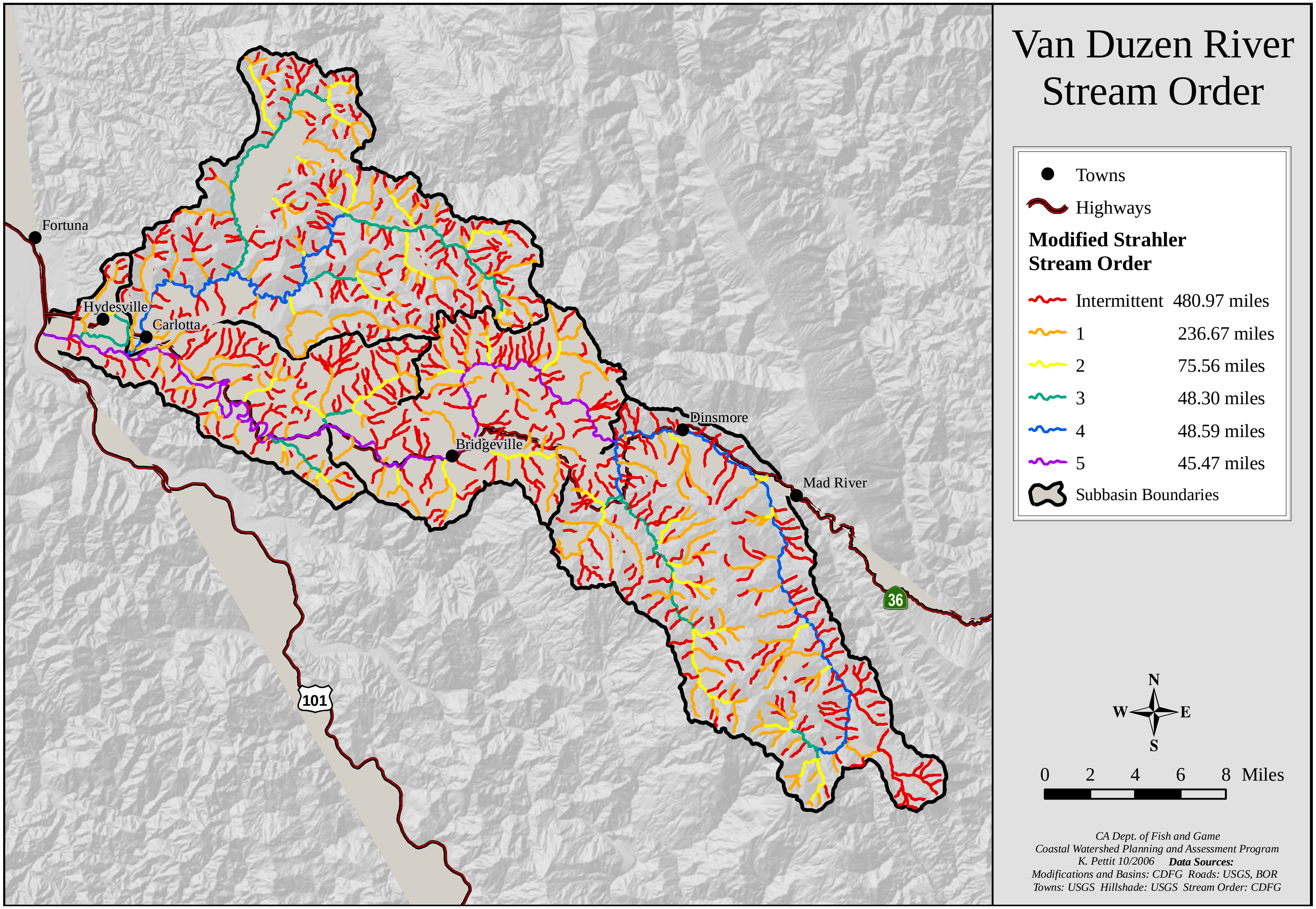


Figure 12. Stream order and subbasin boundaries of the Van Duzen River Basin.

Streamflow records for the Van Duzen River are collected at a USGS gauging station located at RM 24, approximately one mile upstream of Grizzly Creek State Park near Bridgeville (Table 5, 6 and 7). The stream gauge measures discharge from the upper half (222 sq. mi.) of the 430 square mile Van Duzen River Basin. Mean annual peak flow from the Bridgeville gauging station is estimated at 22,300 cfs, which is about a two year event or a re-occurrence interval of every two years (Steppen 2002). The highest peak flow on record reached 48,700 cfs on December 22, 1964 (Table 6). This peak flow was estimated as a 90 year event and effected other watersheds in California. Other high peaks of 43,700 cfs and 43,500 cfs were recorded for water years 1955 and 1995 respectively and are approximately 50 year events. Both the 1955 and 1964 floods were generated by intense rains and melting snow, while the 1995 peak was due to persistent intense rainfall that fell over several days. These floods caused the greatest magnitude of damage to structures and changes to streambed channels in the watershed. Other large magnitude floods occurred prior to the construction of the Grizzly Creek gauging station (e.g. 1867, 1871, 1878, 1890 and 1907), including a flood in 1861-1862 that was approximately equal to the 1964 event (CDFG 1981). Historical peak flow events have been recorded annually beginning in 1940. Five of the top ten highest peak flow events since 1940 occurred during a recent 10-year period from 1993 to 2003 (1993, 1995, 1996, 1997, and 2003) (Table 6). Four of these top rain years occurred during El Niño events.

While extreme peak flows may only last a few hours they can cause damage to manmade structures and have long term impacts to stream channels and fish habitats, such as flatten channel profiles, reduced pool frequencies, forced removal of large woody debris (LWD), increased scouring of redds and cause bank erosion and inner gorge failure (Spence et al. 1996). The magnitude of peak flows is affected by intensity and duration of rainfall, soil saturation, and runoff rates. Peak flows may be more extreme in the Van Duzen River Basin today compared to the past as timber harvests and other land alterations may have accelerated the rainfall runoff rates. For example, the large scale removal of trees that intercept and hold rain water, and the large amount of disturbed and exposed hillslopes, may have contributed to the magnitude of the damaged associated with the 1964 flood. Such timber harvest impacts expose soils and accelerate runoff during winter storms often resulting in increased hillslope erosion rates, increased peak flows, and attenuated descending limbs of the hydrograph. Prior to land disturbances rain water had more time to percolate into ground water for a slower release to stream channels by lateral movements of subsurface flows.

Extensive flooding has occurred in the Van Duzen River Basin in the past and similar and/or potentially larger floods may be expected to occur in the future, particularly in the lower river reach where the majority of the population and infrastructure is located. Heavy rainfalls coupled with an aggrading riverbed contribute to the increasing potential for damage from major floods. Property damage from flooding can be reduced or prevented by minimizing development within the river flood plain, reducing excessive hillslope erosion and associated sediment loading that further aggrade stream beds, and promoting restoration of forest and flood plain functions.

Table 5. Annual low flow (CFS) from 1951-2007 from USGS gauging station near Grizzly Creek.

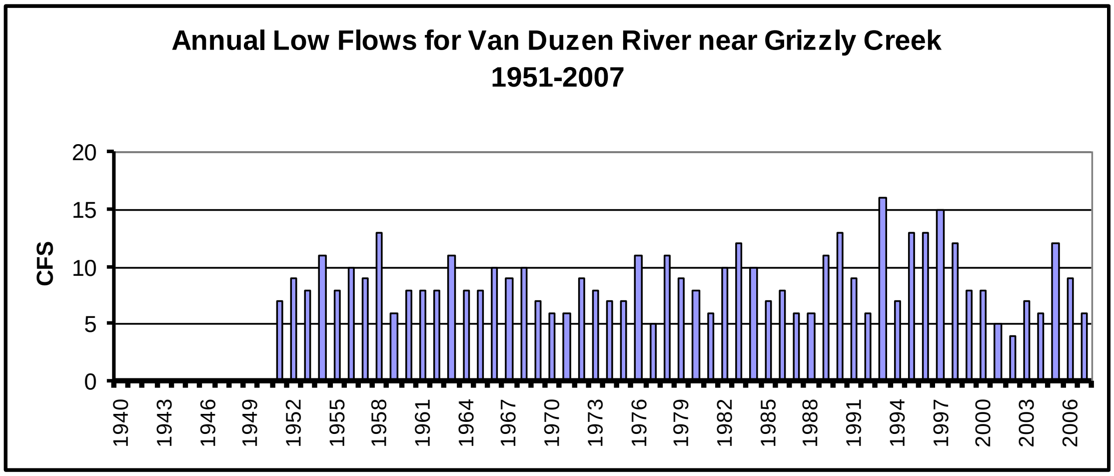


Table 6. Annual peak flow (CFS) from 1940-2006 from USGS gauging station near Grizzly Creek.

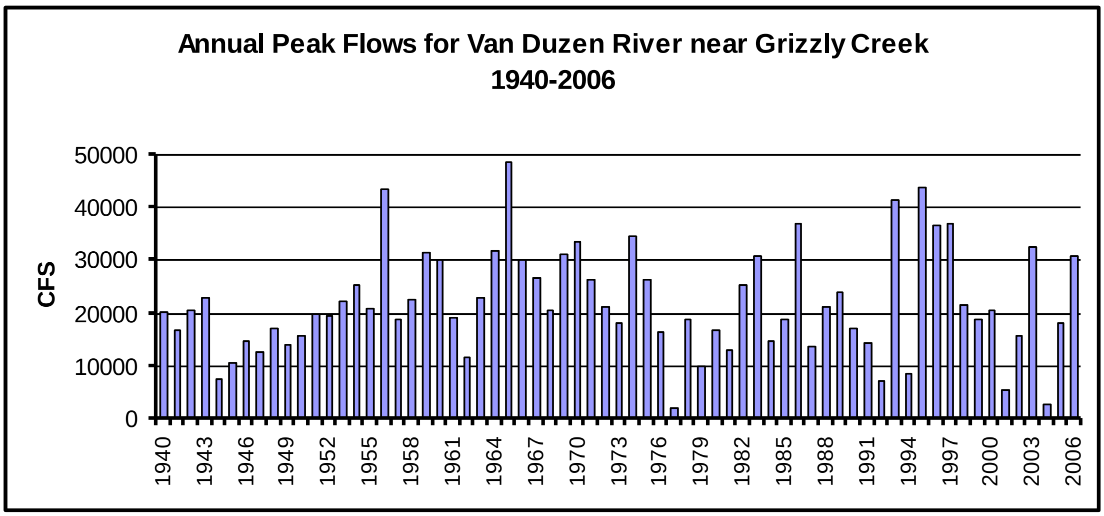
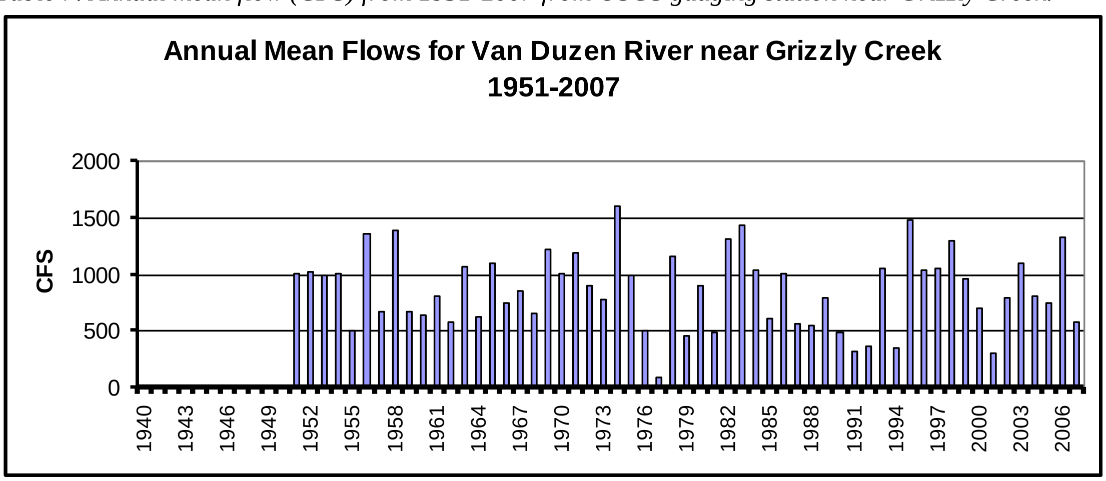


Table 7. Annual mean flow (CFS) from 1951-2007 from USGS gauging station near Grizzly Creek.



Sediment Yields and Turbidity

Sediment yields, sediment transport and turbidity are key factors that influence stream habitat conditions and production of anadromous salmonids. Sediment inputs to streams in the form of clean gravels and cobbles provide substrate for salmon spawning sites and support insect production needed as a food source for juvenile fish. Also, sediment in the form of large cobbles and boulders provide escape cover for fish from predators and resting areas from high stream flows. However, too much sediment in a stream can fill pool habitat, aggrade channels and adversely alter stream and riparian processes that impair fishery resources. Excessive fine sediment accumulations can smother developing salmonid eggs and bury substrate used by aquatic insects. Fine sediments suspended for extended periods of time are known to impair juvenile fish feeding ability (Berg and Northcote 1985). The prolonged, highly turbid flows limit a fish's ability to find food and can reduce growth rates. The reduction in growth and size obtained by juvenile salmonids in freshwater can reduce survival rates upon entering the ocean. Several studies show that survival during the first year of ocean life is generally better for larger salmonids compared to those of a lesser size (Riemers 1976; Nicholas and Hankin 1988).

The historically large storms and subsequent floods of 1955 and 1964 caused excessive erosion and excessive sediment inputs in the Van Duzen River system. These storms hit while much of the basin's forests and hillslopes were especially vulnerable to erosion from large scale timber harvests, poorly constructed roads and numerous skid trails. The storms generated landslides on exposed slopes left vulnerable by clear cut timber harvest. Attesting to the severity of the 1964 storm, the flood triggered widespread avalanching even in the unmodified, virgin timber lands on headwater slopes. However, much of the debris sliding in lower watershed areas may not have occurred without timber harvest activities prior to the storm (Kelsey 1977).

Kelsey (1977) estimated that during the 1964 flood the vast majority of sediment inputs to streams came from erosion of grassland mélange (including earthflows) and debris slides in forested sandstone that had undergone timber harvests. Even though these areas comprised only a little over a third (35%) of the basin area, they contributed 93% of the sediment inputs. While the undisturbed forested sandstone slopes comprised over half (54%) of the basin area, they contributed only 2.5% of the sediment input (exclusive of debris slides and avalanches). Landslide areas (including earthflows, debris slides and debris avalanches) comprised only 1% of the basin area, but accounted for 27% of sediment input to streams (Kelsey 1977).

The legacy sediment sources of the 1955 and 1964 floods combined with newly disturbed sites and naturally eroding areas continue to yield sediment, including excessive amounts at times. The excessive erosion and sediment inputs led to the listing of the Van Duzen River as sediment-impaired under Section 303(d) of the Federal Clean Water Act (see http://www.swrcb.ca.gov/rwqcb1/programs/tmdl/tmdlprogram.html). Public trust responsibilities and concerns over the status of anadromous salmonids and their freshwater habitat has been a leading cause for the development of the TMDL program.

It is difficult to determine how much sediment is delivered to streams naturally because much of the basin has been altered by timber harvests, roads construction, or other land use that exacerbates erosion. The USEPA in their report of Van Duzen River and Yager Creek TMDL (1999) found that land use in the basin has increased sediment delivery to streams. While the TMDL report designated subbasins slightly differently than the CDFG assessment (see Figure 13), it is apparent that sediment delivery from land use, particularly in the Yager Creek and

Lower subbasins resulted in extremely high sediment yields (Table 8). Timber harvests made the largest land use contribution to sediment yields, nearly doubling the contribution from road and skid trail use. Collectively, these two land uses combined to yield 21% of all sediment loads for the basin (USEPA 1999). Even though natural erosion rates in the Van Duzen River are extremely high, especially in the Middle Subbasin, land use activities undoubtedly contribute a substantial amount of sediment to the basin streams as well. The importance of these data are to show that in contrast to natural erosion, a significant amount of anthropogenic sediment sources can be treated by improvement projects or reduced through best management practices. This thought was conveyed in the USEPA TMDL report: "Based on the new methodologies available as well as considering what is feasible in Northcoastal watersheds, resource managers can control approximately 90% of the historic road-related sediment delivery by implementing proper road design and maintenance practices, particularly regarding stream crossings and drainage techniques (personal communication with D. Hagans, PWA, September 1999; Weaver and Hagans 1994)."

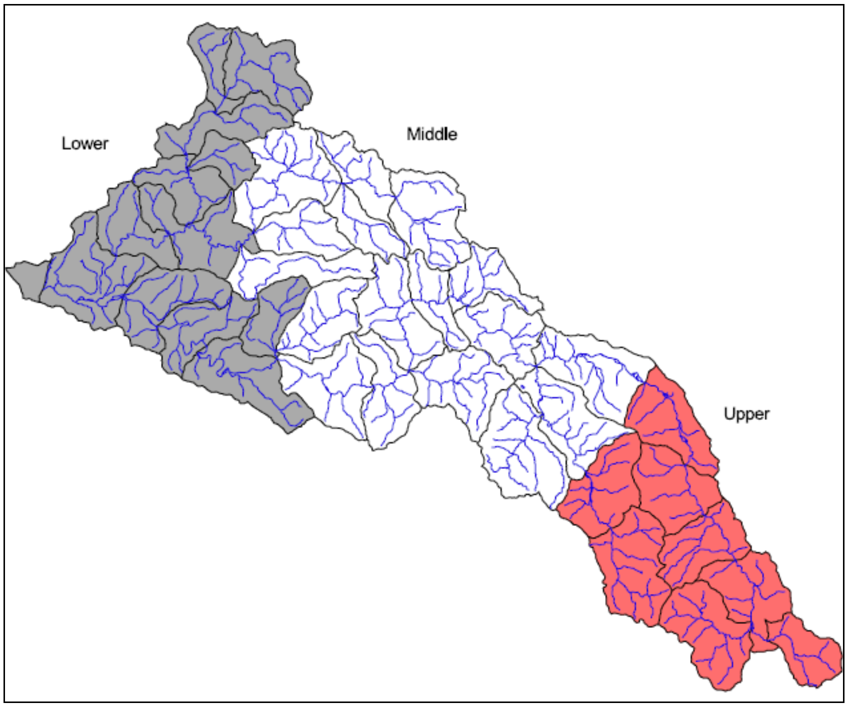


Figure 13. EPA designated subbasins of the Van Duzen River Basin.

Table 8. Sediment load (yards^3 / Mile^2 / year) and percent of subbasin load for each EPA Subbasin (EPA 1999).

EPA Subbasin & area (mi^2)	Natural Process	Road and Skid Trails	Timber Harvests*	Total
Lower 129 mi^2	815 (64%)	202 (16%)	240 (20%)	1257
Middle 202 mi^2	1593 (84%)	110 (6%)	183 (10%)	1886
Upper 98 mi^2	1162 (80%)	33 (3%)	238 (17%)	1433
Basin Totals	**540,797 (79%)**	**51,512 (7.5%)**	**91,250 (13.5)**	

* *Included timber harvesting impacts, such as landslides, debris torrents, gullies, and stream bank erosion.*

Land use on US Forest Service (USFS) lands in the Upper Subbasin mainstem was considered a minimal source of erosion by Tetra Tech (1997). Tetra Tech also noted that the USFS has been actively engaged in addressing sediment related management concerns on their lands. Personal observations made in 2006 and 2007 by S. Cannata (CDFG) and others noted that a few days after intense rains, the water flowing in the mainstem near Dinsmore (upper basin) was clear while highly turbid flows were present in the river downstream (mid-basin) below Bridgeville, a distance of approximately 20 miles. These observations support the Tetra Tech (1997) findings and suggest that much of the sediment delivery and associated turbidity comes from hillslopes downstream of Dinsmore. How much of this turbidity was sourced in the Little Van Duzen was not discerned. However, there has been considerable erosion and stream bank widening in the Little Van Duzen that occurred during the 1955 and 1964 floods (Kelsey 1977).

USEPA (1999) found the Middle portion of the basin had the least percent of land use derived sediments relative to background (natural processes) levels in the basin. Total sediment yield for the middle region was reported as 1886 cubic yards/square mile/year. However the large amount of sediment loading considered background makes the land use related sources appear relatively and disproportionately small. In addition, the USEPA (1999) noted that they did not consider cumulative effects from land use derived sediments in the basin as an anthropogenic contribution to stream bank erosion as a sediment source.

Stream Gradient and Reach Classification

Stream gradients determine patterns of sediment transport and accumulation in the stream network. Stream classification is more compatible with the stream classification of Rosgen (1996). Montgomery and Buffington (1993) described several types of stream reaches as follows:

- Source Reaches are "transport-limited, sediment storage sites subject to intermittent debris flow scour;
- Transport Reaches are morphologically resilient, high-gradient, supply-limited channels that rapidly convey increased sediment inputs;
- Response Reaches are low-gradient, transport-limited channels *in which significant morphologic adjustment occurs in response to increased sediment supply* (emphasis added).

Montgomery and Buffington (1993) stated that the "…cumulative effects of upstream increases in sediment supply are magnified in a response reach where longer time and/or significant morphological change is required to transport the additional sediment." They further stated that response reaches "are of fundamental concern for aquatic resource management because of the associated habitat values".

Sediments can enter a channel of any gradient. Once sediments enter the river network, streams either transport or store these sediments within their channels and flood prone zones. To help explain how sediment moves through the river system, three major stream categories are used in this report. The source, transport, and response reaches shown below are generalized to fit in stream gradient categories, but there may be overlap between the gradients that bound each category (Figure 14, Table 9).

- **Source Reaches** drain steep landscapes, such as basin headwaters, are high gradient (>20%), supply limited channels that receive sediment from on-stream storage sites or debris flows from adjacent hill slopes.
- **Transport Reaches** are morphologically resilient, high gradient (4 to 20%), tributary valley,

supply limited channels. They rapidly convey sediment inputs downstream.

- **Response Reaches** or depositional reaches are low gradient (0-4%), transport-limited channels that occupy alluviated valleys in which significant aggradation occurs in response to increased sediment supply.

The storage and transport of sediments helps to maintain a relatively stable bed elevation and a balance between pools, runs and riffles. Important habitat components such as pools fill or scour occur as a result of the balance of sediment supply and sediment transport capacity of the stream channel. Large inputs of coarse material can lead to structural changes of the channel, such as channel widening, braiding, and aggradation, accompanied by substantial reductions in pool volume and frequency. However, deposition of coarse material may enhance obstruction-related turbulence that initiate or enhance pool scour.

Generally, sediment transport capacity, in gravel bed channels like the Van Duzen River, exceeds sediment supplies (Lisle 1982) or else the channel would fill with sediment. However, channel beds may build up progressively (aggrade) or erode (degrade) in response to changes in sediment supplies and flow regimes.

The flow that transports the most sediment over the long term and is a main channel forming flow is called the effective discharge (Nolan et. al 1987). Bankfull discharge can be described as theoretical (conceptual) or actual (effective) (calculated) discharge for alluvial streams in equilibrium. Both conceptual and effective discharge have been used in stream restoration strategies in recent years (Leopold 1997), however other researchers note significant differences between the two terms (Nolan et al. 1987, Knighton 1998).

The effective discharge for the Van Duzen River near Grizzly Creek was estimated at 13,490 cfs by Nolan et al. (1987) and has an average recurrence interval of 1.6 years. Varying slightly, Tetra Tech (2002) estimated flow of 14,500 cfs with a recurrence interval of 1.25 years. They also estimated a flow of 29,800 cfs to be a 5 year recurrence interval for the Van Duzen River. The differences between the estimates may be attributed to Tetra Tech using a different and more recent set of stream flow data for their analysis.

Large flow events such as those associated with the floods of 1955, 1964, 1993, and 1995 move more sediments per unit time often resulting in long term alterations to stream channels. However these flows theoretically occur less frequently (25 to 50 year recurrences) and result in less net sediment transport over time than do bankfull or effective discharge flows.

The condition of response reaches and some transport reaches has a large influence on salmonid survival and productivity because they are generally found in streams with gradients less than 10%, (generally less than 5% for Chinook and coho salmon). Moreover, since sediment moves downstream from source and transport reaches, salmonid habitat quality is linked to watershed conditions upstream. For example, if upstream hillslopes experience excessive erosion and high levels of sediments are delivered to steep gradient streams, sediment accumulations in the low gradient reaches can affect salmonid habitats for decades or longer. Montgomery and Buffington (1993) stated that the "cumulative effects of upstream increases in sediment supply are magnified in a response reach where longer time and/or significant morphological change is required to transport the additional sediment". Channel widening, which has significant impacts to salmonid habitat quality, is also a consistent indicator of increased sediment inputs (Lisle1982). Channel widening has been

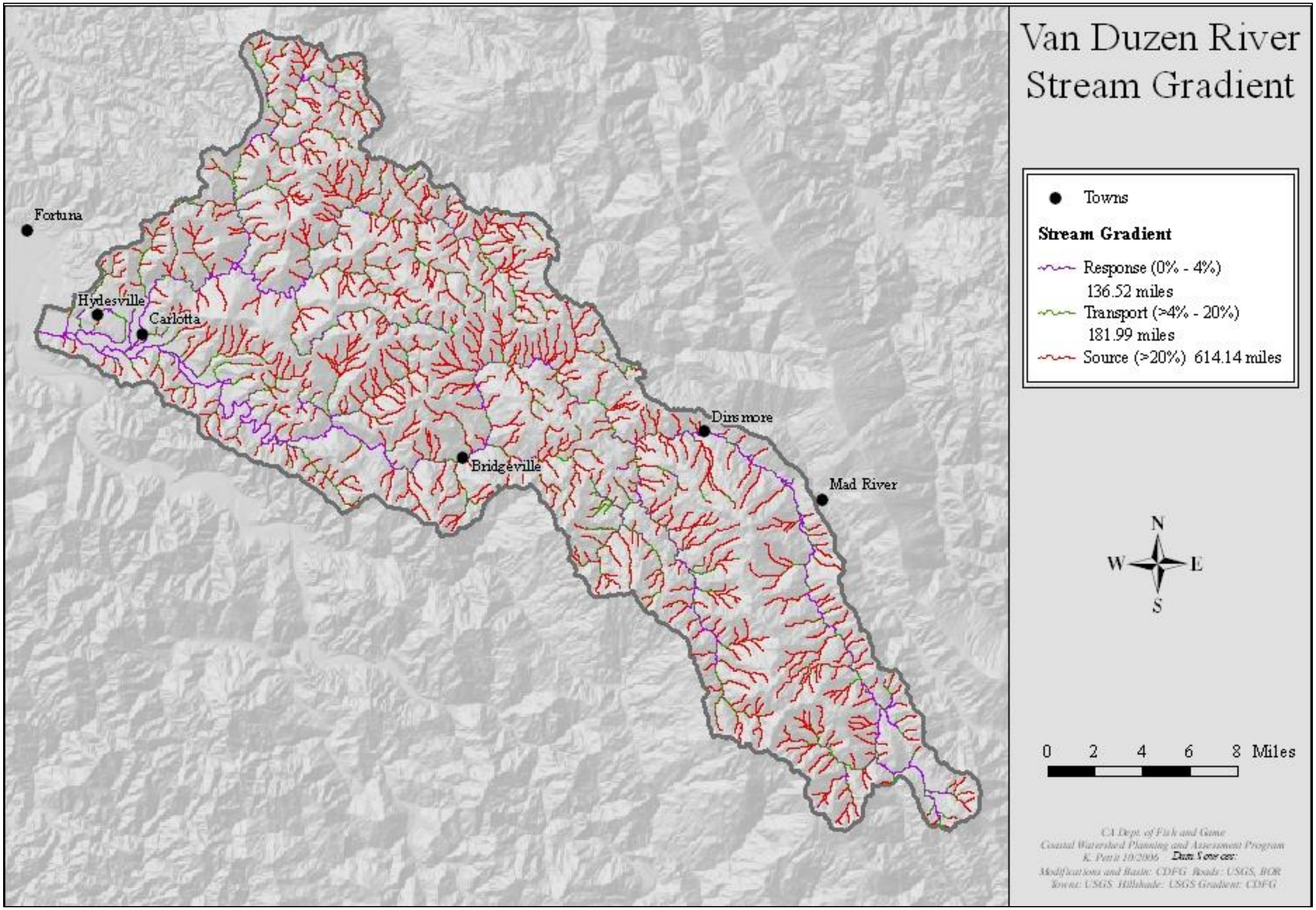


Figure 14. Stream gradient classes based on slope and characterized by process for the Van Duzen River.

Table 9. Miles of Van Duzen River Basin subbasins in response, transport and source reaches for each subbasin.

Subbasin	Total Miles	Response (0-4%)	Transport (>4-20%)	Source (>20)
Yager Creek	314	38 (12%)	67 (21%)	209 (67%)
Lower	161	38 (24%)	32 (20%)	91 (56%)
Middle	137	16 (12%)	27 (20%)	119 (87%)
Upper	296	44 (15%)	57 (19%)	195 (66%)

noted to occur in the Van Duzen Basin. For example, channel widths of the wide alluvial reach of the Little Van Duzen have greatly increased from the 30 to 45 feet measured in 1872 to 40 to 130 feet in 1963 and finally to 100 to 600 feet in 1974 (Tetra Tech 1997, Kelsey 1977). These significantly widened alluvial channel sections are very unlikely to return to their pre disturbance bottom profiles, especially in large channels like the mainstem Van Duzen River (Lisle 1982). In widened tributary streams alder trees may begin to grow in terrace deposits and re-establish stream banks by recruiting sediments, but in larger streams the gravel terraces can be too large to allow growth of trees as their roots cannot reach moist soils needed to sustain them over dry summer seasons. Flood flows and shifting channel beds can also impair growth of trees and bank building along the margins of the mainstem Van Duzen River.

The tendency to resist the return to pre disturbance conditions in alluvial response reaches is observed in the Van Duzen River and other North Coast streams. For example, the large scale disturbances to California's North Coast salmon streams including the Van Duzen River, were noted to occur during floods of 1955 and 1964 (Fisk et al. 1966, Kelsey 1977). The excessive amount of sediments that entered streams during floods, the associated widening of stream channels, and large gravel terraces deposits are still presently impairing much of the salmonid habitat in the low gradient response reaches. Some of these legacy impacts from the flood events will likely remain for an unknown time, and their persistence is further exacerbated by delivery and transport of excessive sediment loads.

Vegetation

The vegetation of the Van Duzen River Basin is composed of redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudotsuga menziesii*) dominated coniferous forests, mixed hardwood forests, and grasslands (Figure 15). Redwood and Douglas fir dominated forests generally include a mix of other conifer and broad-leafed trees. The redwood dominated forest grows almost exclusively within the coastal fog belt which extends inland approximately 30 miles from the coast to near Swain's Flat on State Route 36. The majority of redwoods are found in the Yager Creek and Lower Subbasin (Table 10).

A few virgin stands of giant redwoods still grow in the public lands of Humboldt County Parks, Cheatham Grove and at Grizzly Creek State Park and on private lands. Among these giants, unique assemblages of understory herbaceous plants depend on the shaded and moist conditions that exist under the redwood canopy. An estimated 122,000 acres of the basin are in redwood dominated forests. Other commonly found tree species in redwood dominated forests include Douglas fir, big-leaf maple (*Acer macrophyllum*), California bay (*Umbellularia californica*), madrone (*Arbutus menziesii*), dogwood (*Cornus stolonifera*), western hemlock (*Tsuga occidentalis*), and California hazelnut (*Corylus cornuta*). Inland from Swain's Flat, Douglas fir dominated forests, mixed hardwood forests and grasslands predominate. A list of plant species found in the Van Duzen Basin and a detailed description of forest types is presented in the Appendix to DWR (1976).

Functions provided by late seral stage redwoods to stream ecosystems have also been disrupted by logging activities. Most of the giant old growth redwoods on private lands have been harvested by commercial timber operations. In recently logged areas, the old growth characteristics of redwood forests are suppressed to early seral stages of forest succession. Continuous harvesting will likely preclude re-establishment of late seral ecosystems and their benefits to stream channels. Disturbance to the dense litter and humus layer, exposure to direct sunlight and soil desiccation temporarily accelerates runoff rates and removes the favorable conditions needed to support the unique understory of shrubs and herbaceous plants found in the old growth forest community. Many of these understory plants have been temporarily extirpated by the change in growing conditions or displaced by an increase in invasive species (DWR 1976 Appendix and T. LaBanca, CDFG, personal cmmunication). However, the redwood forest and its plant communities can re-colonize relatively quickly and re-establishment of ecological processes can occur provided adequate management strategies are used (T. LaBanca, CDFG, Personal communication).

Douglas fir is the most abundant and widely distributed conifer in the basin. Douglas fir dominated forests contain most of the same additional tree species as noted for redwood forests in addition to tan oak (*Lithocarpus densiflora*), white oak (*Quercus garryana*), black oak (*Q. kelloggii*), and buckeye (*Aesculus californicus*). Douglas fir forests are found in dense stands in the cooler, western portion of the basin, on north facing slopes, or near gullies and stream canyons where soil moisture is favorable. The shrub and herbaceous understory of Douglas fir dominated forest are adapted to grow in cool and moist conditions associated with the trees. A few native orchids and other rare oruncommon wildflowers also occur in this understory (DWR 1976 Appendix T).

Much of the Douglas fir forests in the basin have been logged and some areas were cleared and seeded with forage grasses for livestock grazing. Areas of Douglas fir forests disturbed by logging or clearing can change to hot and dry microclimates and result in the death of sensitive understory plant species. Heat sensitive understory plants of the Douglas fir forests have

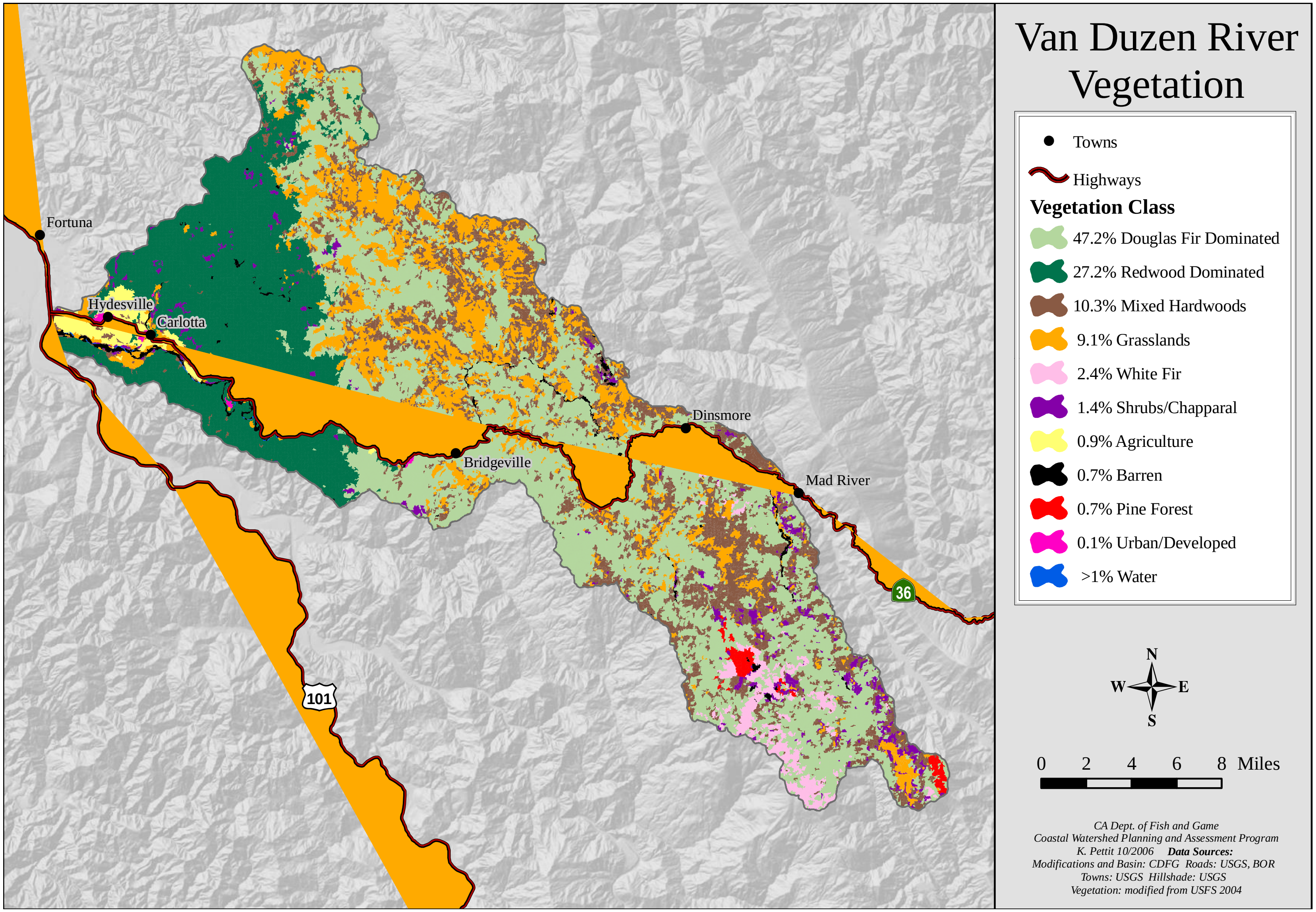


Figure 15. Vegetation categories for the Van Duzen River Basin.

difficulty recovering to their former status or may not re-establish at all after such disturbance events (DWR 1976 Appendix, T.)

Other conifers growing in the basin are white fir (*Abies concolor*), ponderosa pine (*Pinus ponderosa*), Jeffery pine (*Pinus jeffreyi*) and incense cedar (*Calocedrus decurrens*). Common trees of mixed hardwood forests include white oak, blackoak, tan oak, madrone, buckeye, big leaf maple, and California bay.

Approximately 9% of the Van Duzen River Basin is vegetated by grasslands (Table 10). Most of this area was originally composed of north coastal prairie grassland which typically occurs in discontinuous patches on ridge tops and their upper slopes (DWR 1966). Deep rooted native perennial bunch grasses dominated the prairies until the affects of livestock grazing and non-native grasses were introduced which displaced the native grasses over much of their range (DWR 1976).

Grasslands are most abundant in the Yager Creek and Middle subbasins and are often found on south or south-west facing slopes where soil moisture is too dry to support trees. Grasslands are also found in areas of unstable soils or areas that have been cleared of forest vegetation and converted to livestock grazing pastures. Wildfires and managed burning has helped maintain grasslands by preventing trees from growing in some areas. With the recent suppression of fires, trees may be invading into traditional grasslands and/or reclaiming historic forestlands.

Table 10. Acres of generalized vegetation classes by subbasin in the Van Duzen River Basin.

Vegetation Type	Entire Basin	Yager Creek Subbasin	Lower Subbasin	Middle Subbasin	Upper Subbasin
Conifer Total					
Douglas-Fir Dominated	211,275	48,881	10,175	55,630	96,588
Redwood Dominated	121,852	64,098	55,724	2,031	0
Mixed Hardwoods	45,992	12650	1,660	7,748	23,934
Grasslands	2,958	16,324	4,174	12,245	7,793
White Fir	10,762	0	0	0	10,762
Shrubs/Chaparral	6,251	1,111	811	374	3,955
Agriculture	4,053	1,034	2,934	84	0
Pine Forest	351	0	0	0	2,932
Barren	319	276	1,064	794	946

Role of Riparian and Nearstream Forests in Stream Ecosystems

Coniferous forests play a crucial role in watershed processes needed to maintain productive salmonid streams. For example, in a mature redwood forest, the top soil is several feet deep, incredibly porous, and able to hold and regulate the flow of immense quantities of water. This, in combination with the redwood's root system, has the stability and resilience to hold a mountainside intact throughout the normal processes of rain, flooding and erosion.

Riparian forests are defined as the area of forested land located immediately adjacent to streams, lakes, or other surface waters, and extending into floodplain and terraces. This environment can support a unique assemblage of plants because of high levels of soil moisture and frequent flooding that delivers deposits of silt and organic sediments rich in nutrients that enhance plant growth. However, determining distinct boundaries of the often dynamic riparian zone can be difficult, especially in forested streams.

Riparian vegetation along many stream corridors in the Van Duzen River is typically composed of a mix of hardwood (alder, willow, and maple), coniferous trees (often redwood and fir) and herbaceous plants. Many of the largest redwoods and Douglas fir are found in this fertile environment. While representing only a fraction of the total basin, riparian forests typically support a broader array of plant and animal species than upland areas. This diversity is evident in the range of ecosystem functions that riparian areas provide. Riparian and nearstream forests play important roles in shaping stream channel morphology, influencing water quality and providing critical habitat components for anadromous salmonids. Riparian forests provide shade over streams, help stabilize stream banks, regulate runnoff, supply habitat for insects, and provide an input source of LWD to stream channels. Riparian communities also include numerous terrestrial insects that are food for fish and the leaf litter and wood inputs are important supplies of nutrients to fuel the aquatic food web and as channel forming elements. Many of the same benefits from riparian forests are provided by or enhanced by the nearstream forest.

The term nearstream forest is used in this report to describe the transition zone that includes upland forests within close proximity to streams and those forests that contribute to riparian processes. While the boundary (i.e., ecotone) of the riparian area, the mergence of nearstream forests and adjoining upland forests is not always well defined, strong differences in microclimate conditions can occur (Brosofoske et al. 1997). Microclimates in mature riparian areas are often much cooler and more humid than the upland forests due to the cumulative effect of cool stream water, higher soil moisture, high humidity, and extensive understory and overstory shade canopy that insulates against warming from high air temperature and direct sunlight. Tall conifers block sunlight well above the ground level which helps keep riparian air masses and stream water cool. In addition, root masses from the trees increase soil cohesion that helps stabilize stream banks. Trees are a source of LWD loading into stream channels needed for channel forming processes and sediment routing. Therefore, disruptions of riparian and nearstream forest functions can have serious impacts to the aquatic habitat. Nearstream forests include transitional areas between upland forests and riparian areas adjacent water bodies. Harvesting of redwoods and fir along riparian zones has resulted in an increase of alder and the overall loss of overstory canopy needed to maintain cool microclimates that help moderate air and stream temperatures. The loss of mature root structure after harvesting conifers also contributes to soil instability and erosion.

Riparian forests are dynamic environments that develop in response to disturbance cycles. Flooding, fire, mass wasting, windfall, and disease are all natural disturbance processes that affect riparian vegetation through succession (Naiman 1998). The spatial extent of riparian areas varies laterally throughout the channel network and is strongly influenced by channel morphology such as flood plain width (Naiman 1998).

Suggested regulations from scientific studies may vary as to how wide and dense nearstream buffers should be to maintain functions that benefit anadromous salmonid habitat depending on the geographical location of the stream and species present. A common approach bases nearstream forest protection zones as one to three potential tree heights. However, studies in Caspar Creek (Mendocino County) suggest a larger area may be needed (Reid and Hilton 1998).

Roles of Large Woody Debris

Wood pieces measuring 12 inches or more in diameter and at least six feet in length are considered LWD (Flosi et al. 1998). Once common in redwood and Douglas fir forests, pieces six feet in diameter or more and over 100 feet in length have generally become rare throughout Northern California streams, including the Van Duzen River watershed.

The importance of LWD in the development of a stream's morphology and biological productivity has been well documented with respect to strong influences on stream habitat characteristics and biotic composition. Bilby (1984) and Rainville et al. (1985) found that in nearly 80% of the pools surveyed in small streams, LWD are the structural element forming the pool. The influence LWD has on the diversity of juvenile salmonid populations, with particular emphasis on the adverse impact of timber harvest activities, has been documented by Reeves et al. (1993). Inputs of LWD come from windfall, debris torrents, landslides, bank failure, and by other means. Land use activities that remove large trees from near stream forests have changed the amount and reduced the size of LWD that is potentially available for input to stream channels, thereby altering present and near future channel processes, morphology and aquatic habitat. The loss of LWD and riparian forests reduces channel roughness and can result in increases to the rate of sediment transport and increased bank erosion (Buffington et al. 2002). The retention of high quality salmonid spawning gravels is often associated with LWD in the channel. If not for LWD, gravels may be flushed out of streams. The wood is also an important source of nutrient inputs to the stream ecosystem. Fish populations benefit by both the cover and habitat diversity created by LWD and by the substrate environment for benthic invertebrates that serve as fish food (Sedell et al. 1984, Bisson et al. 1987, Sedell et al. 1988).

Relatively large pieces of woody debris are needed in streams to influence the physical form of the channel, movement of sediment, retention of gravel, and composition of the biological community (Bilby and Ward, 1989, Buffington et al. 2002). The relationship between size of individual LWD and its effects on channel morphology are influenced by a number of variables such as stream-flow energy, sinuosity, bank composition, and channel width. Bilby and Ward (1989) and Likens and Bilby (1982) describe LWD and its relationship to pool formation, gravel retention, channel orientation, and channel width. Once LWD enters the stream, their orientation and spacing may be more significant than their volume in influencing channel morphology and aquatic habitats (Platts et al. 1987).

Land and Resource Use

Pre-European Settlement

Prior to Euro-American settlement, the Van Duzen River Basin was home to Native American people of the Wiyot, Kittel or Nongatl, Wailaki, and Lassics tribes. These people lived in villages or in groups of smaller satellite settlements located around central village sites. The people utilized acorns as a staple food, and also ate other vegetable foods, wild game, and depended on harvests of salmon and steelhead along the main river channels and tributaries. In winter and spring the villages were situated near the river where the people could cooperatively harvest salmon and lampreys. During the summer they moved to meadows located in higher grounds, but not far from the rivers. Their way of life required freedom to move throughout their territory with the seasonal changes in abundance of natural resources (CDPR 1981). Tribal members shared a language, culture, and history. They acknowledged the leadership of a chief who usually resided in the largest and most important village. The chief, controlled economic resources and activity, and was generally wealthy and greatly respected. Many of these small tribal groups failed to survive the impact of Euro-American settlers of the mid 19th century.

European Settlement

The Van Duzen River was named in 1850 after James Van Duzen who was one of the eight members of the Gregg-Wood party that were the first Euro-Americans to reach the Humboldt Bay coast by traveling overland from the gold mining areas of the upper Trinity River. Continuing their journey, the Gregg-Wood party left Humboldt Bay and traveling south and were soon in need of food. The group came upon a river and nearby found two Wiyot tribesmen that shared baskets full of lampreys with the hungry travelers. The members of the Greg-Wood Party then camped along the river just below the Van Duzen confluence and feasted on "eels" (lamprey), for two days. The group named that river the Eel River for its abundance of "eels".

As Euro-Americans moved into the Van Duzen Basin in the 1850s, they established year-round settlements on the same sites that native tribes had used for decades as seasonal village sites or hunting and gathering grounds (CDPR 1981). When native people returned to their long-established seasonal sites conflicts over this land soon lead to bloodshed and the eventual demise of the native people's way of life. The changes brought about by permanent farms and grazing of domesticated livestock depleted many of the wild food sources needed by native people. A few Native Americans were welcomed into early settler homes but most were sent to Fort Baker located approximately 14 miles east of Bridgeville prior to permanent delivery to a reservation created in Round Valley. Others were hunted down and killed while some were sold into slavery. Their historic homeland was quickly claimed by the Euro-American settlers.

Historic Timber Harvest and Livestock Grazing

Shortly after arriving in the mid 1800s, Euro-American settlers began timber cutting in the Van Duzen Basin with the intent of clearing the land for farming, livestock grazing, and utilization of wood products. The first saw mill was built by George and John Cooper along Yager Creek near Hydesville in 1854. The Cooper's mill was powered by a water wheel that received water delivered from over a mile of ditches. The water source was likely Cooper Mill Creek. The mill operated for only a few years and was abandoned soon after the death of George Cooper who was shot in a territorial battle with native tribesmen. By 1865 a second mill, a steam powered saw mill, began its operation located near Rohnerville (Eureka Times 1943).

The timber industry continued to grow and soon became the major land use in the Van Duzen Basin. The first logging company to harvest timber was the Pacific Lumber Company (PALCO). PALCO made its first land purchase of 5,000 acres in the Yager Creek watershed in 1882. Early logging was done by axe and hand saws, steam donkeys, cable systems, and railroads. The axe and cross cut saw harvests were relatively slow moving projects compared to the speed of mechanized systems that evolved in the 1900's. Like harvests that were occurring all along the northern California coast, most trees were cut without regard or knowledge of best management practices. The adverse impacts to streams and salmon from logging were obvious to some, but no timber harvest regulations were in place to protect or reduce the ensuing damage.

Logging activity accelerated with the increase in demand for timber products during World War II and the following construction boom of the 1950s and 60s. Saw mills sprang up throughout the basin and were operated by gypo-loggers (a term used to describe a logger with his own equipment, and who mostly acquired small timber sales). Moreover, the ad-valorum timber tax instituted in 1946 added to the timber harvest rush. The tax was based on the value of standing timber on an individual's private land holdings. In response to the tax, land owners cut trees to reduce their tax liability. Some harvests had the mutual benefit to ranchers of converting forests to livestock grazing lands. The use of modern tractors to move fallen trees to landing sites and a dense road network for trucks to carry logs to mills further accelerated harvests rates. There were still no rules or regulations for logging. Clear cuts, the use of tractor yarding, and haul roads to offsite mills was a common method to harvest and transport timber. Along with the rush to harvest timber from the Van Duzen River's forests came a tremendous disturbance to the basin's soils from clear cuts, building and use of an extensive network of logging roads, and the use of tractors that made skid trails over the landscape to move cut logs to trucks. A review of air photos (1950- 1965) showed that a large amount of the basin's forests were cut by the 1960s and an extensive road and skid trail network was cut into the fragile landscape.

The logging activity removed trees that were an integral part for maintaining riparian, stream and upslope forest ecosystems. The trees that stabilized soils with intricate root systems on hill slopes, moderated rain runoff, and provided shade, cool microclimates and LWD inputs to streams were removed. In addition, miles of tractor skid trials and haul roads caused significant ground disturbance that contributed to hillslope instability and soil erosion. The large winter storms of 1955 and 1964 collided with the disturbed watersheds with a vengeance causing large scale erosion. Much of the eroded soils and logging debris were washed into the network of stream channels and caused large scale changes in the river and tributaries that are viewed as legacy impacts to this day. It is generally accepted that cumulative effects from past harvest activities were widespread, contributed to large scale disturbance to watersheds all over the basin and contributed to significant long term, adverse impacts to salmonid streams.

The timber industry proceeded without timber harvest rules until the Forest Practices Act of 1973. The Z'berg-Warren-Keene-Collier Forest Taxation Reform Act, changed the method of taxing timber in California by replacing the ad valorem tax on standing timber with a yield tax on harvested timber. The timber yield tax is imposed on every timber owner who harvests timber or causes it to be harvested on or after April 1, 1977.

Historic livestock grazing utilized the native prairies, grasslands and meadows where native, perennial prairie bunch grasses grew year round. To develop more livestock grazing lands, trees surrounding grasslands were often "ringed" (a deep, circular cut) and left to die. Thousands of sheep that grazed from the late 1800s to the 1930's were likely more destructive to the range than the cattle that were introduced later. One large ranch had 20,000 to 30,000 sheep (Moore 1999). As sheep and cattle consumed or overgrazed much of the deep rooted bunch grasses, unstable soil was exposed, allowing weaker, short rooted non- native, annual grasses to become established. Present gullies and slumping landscape appear to be recent features related to livestock grazing and the associated loss of deep rooted prairie grasses that helped to stabilize top soils (Kelsey 1977).

Present Land Use

Land use in the Van Duzen watershed includes timber production, ranching, farming, industrial marijuana agriculture, rural residential development, instream gravel mining, tourism, and recreation (Figure 16). The basin is sparsely inhabited with approximately 3,000 people. The population is located mostly within or near the few small towns found along Highway 36. These towns include Hydesville, Carlotta, Bridgeville, Dinsmore and Mad River.

Approximately 357 square miles (82%) of the basin are held in private ownership. The private ownership is primarily divided into fifteen large private ranchlands (30%), industrial timberlands (27%), and small private rural developments (25%). About 67 square miles (16%) of the basin is under the jurisdiction of Six Rivers National Forest, while the remaining 5 square miles (1%) are under the control of the Bureau of Land Management and the State of California. Humboldt County also maintains small holdings in County Parks.

Cumulative effects from intensive land use over a relatively short time, has contributed to adverse changes to stream habitat conditions. Soil disturbance from removal of timber and roads built across hill slopes and along water courses has increased erosion rates and accelerated sediment inputs to stream channels to excessive levels. The cutting of mature forests has also reduced the amount of shade over streams and reduced potential inputs of LWD needed to maintain channel diversity, sediment routing and shelter for fish. Gravel mining, particularly near the confluence of the Van Duzen River and Eel River, has increased erosion, affected channel alignment and may block fish migration. Moreover, the recent conversions of rural private property lands to industrial marijuana agriculture operations in areas throughout the basin have had negative impacts to the quantity and quality of the water resources and their associated aquatic ecosystems.

Timber Harvest

The industrial timberlands are mostly located in the Yager Creek and Lower Subbasin. A little over half (51%) of the Upper Subbasin is composed of the Six Rivers National Forest, which is managed by U.S. Forest Service for timber production and other multiple purposes including recreation, camping and livestock grazing. Timber harvests are also conducted by private land owners within all of the Van Duzen subbasins. Some are relatively large holdings (>3500 acres), and in addition to timber production they also raise livestock, primarily cattle. Records of logging activity from 1991 to present are available in digital format for all subbasins in the Van Duzen River (Figure 17 and Table 11). Earlier logging information is available in paper records from CDF, but at this time, remains largely unanalyzed.

The Pacific Lumber Company (PALCO) was the largest landowner in the Lower Subbasin. However, due its tremendous debt PALCO filed for bankruptcy in January, 2007, and in July, 2008, PALCO was officially transferred over to Mendocino Redwood Company (MRC) and Marathon Structured Finance Fund LP (The Forestry Source 2008). The MRC shortly thereafter renamed PALCO holdings as Humboldt Redwood Company (HRC). Prior to this transfer, PALCO developed a habitat conservation plan (HCP) to help manage and regulate timber harvest activities on their lands. With the intent to further review management rules devoloped in the HCP PALCO completed a watershed analysis (WA) in the Lower Subbasin in 2002. The HRC inherited the HCP and WA that guides timber harvest activities on lands in the Van Duzen River Basin. It should be noted that recent HCR timber harvest rates have been significantly less than PALCO rates of harvest during the past decade. Under PALCO management, an average of 150 to 160 million board feet was cut from 2000 to 2005 on their 220,000 acres of land in Humboldt County. That figure dropped to 99 million board ft. in 2006, and fell to 77 million board ft. last year. Under the new management of the HRC annual harvesting will be limited to 55 million board ft. per year for the next decade and a no-cut policy for old growth will be observed (http://www. building-products.com).

Sierra Pacific and Green Diamond Resource Company also manage timber lands in the basin. Green Diamond has a HCP that helps regulate timber harvest activities on their lands.

Table 11. Timber harvest activity 1991-2005 by subbasin in the Van Duzen River Basin.

Subbasin	Subbasin Acres	Conifer Acres	% Subbasin in Conifers	Conifer Harvest Acres	% Conifers Harvested	% Subbasin Harvested
Lower	44150.18	32940.66	75	19380.17	59	44
Middle	44752.2	26919.42	60	10274.86	38	23
Upper	50084.62	27144.37	54	8903.951	33	18
Yager	37956.55	22672.86	60	7156.086	32	19

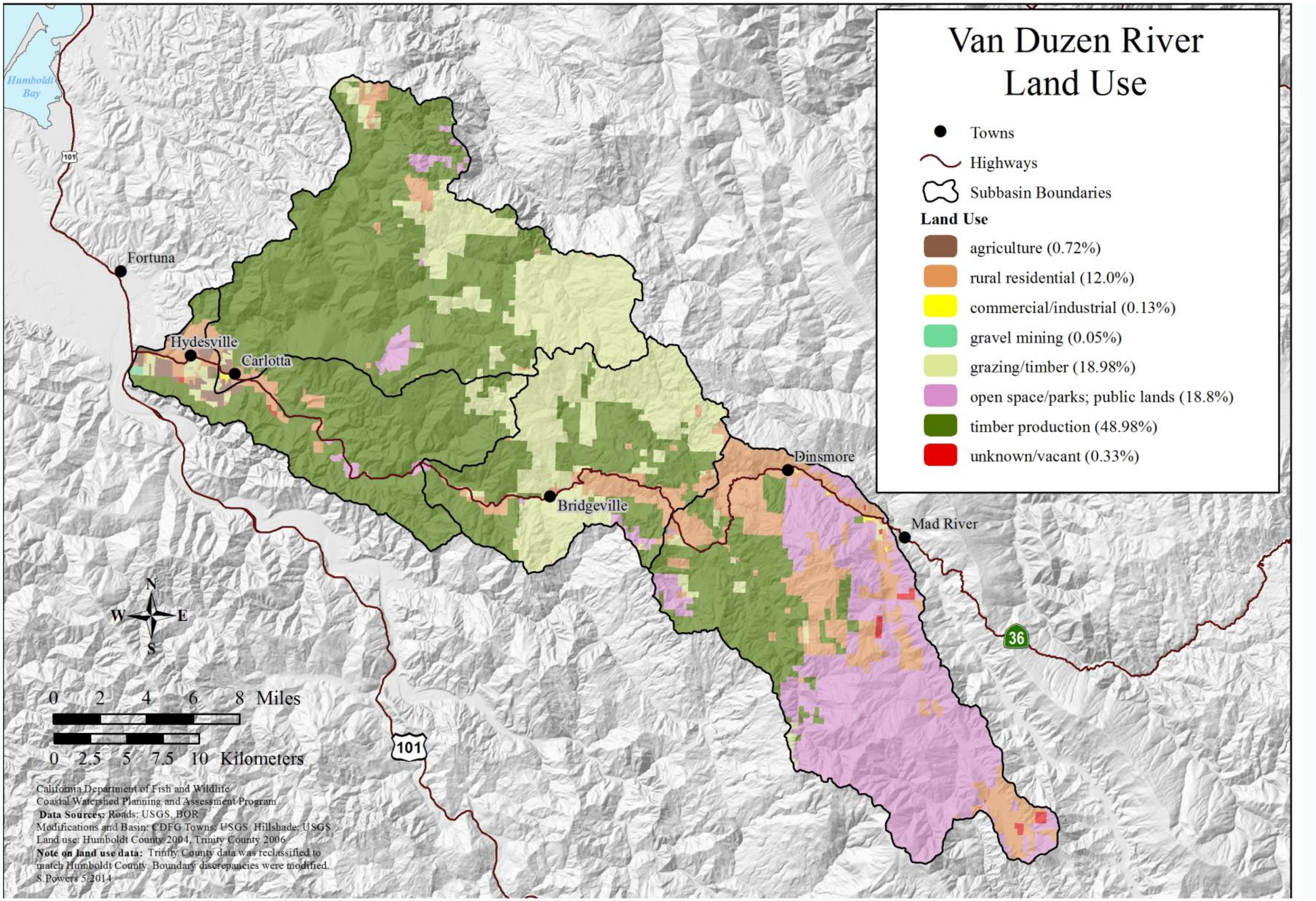


Figure 16. *Land use classification in the Van Duzen River Basin.*

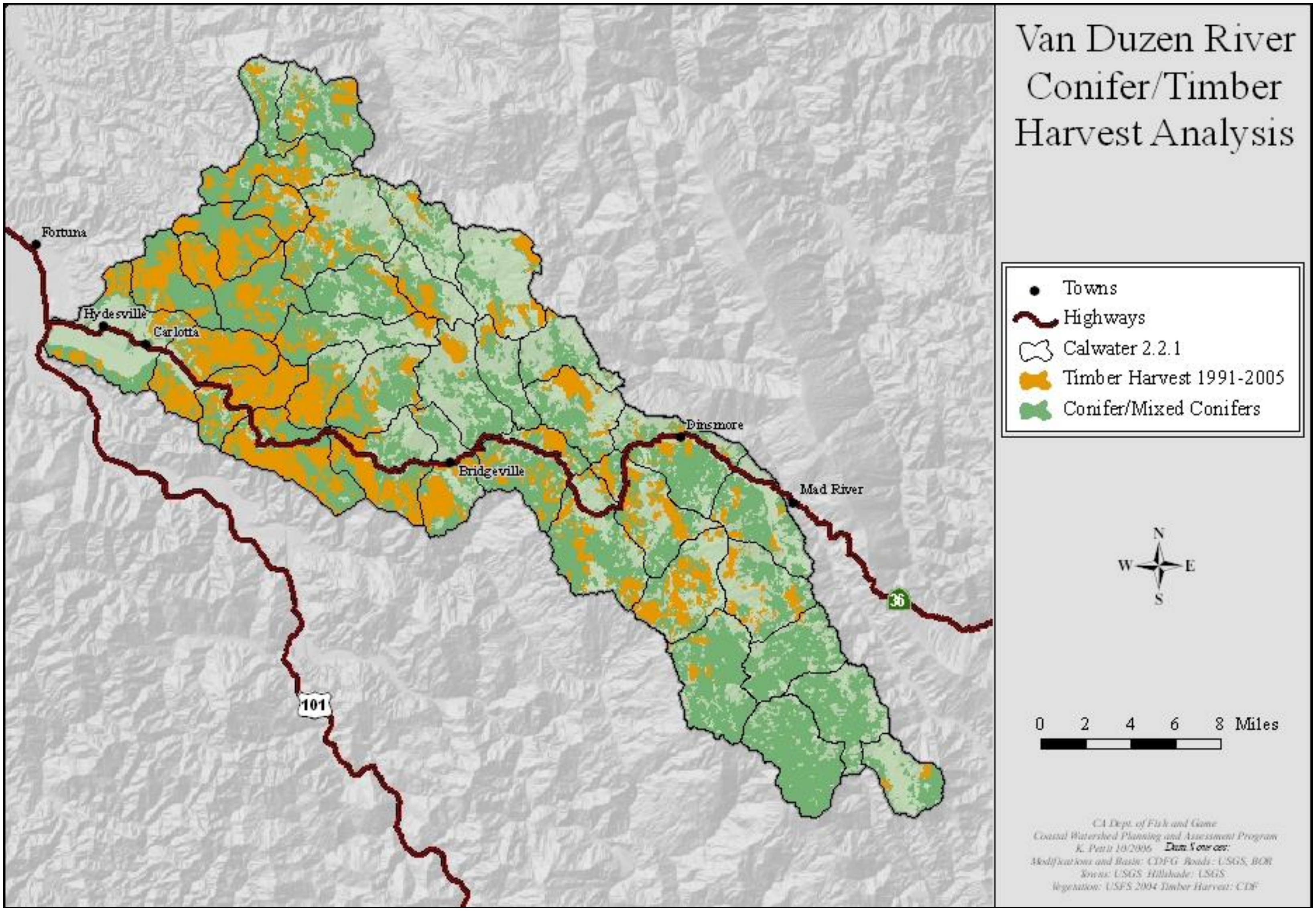


Figure 17. Van Duzen River Basin timber harvest activites from 1991-2005.

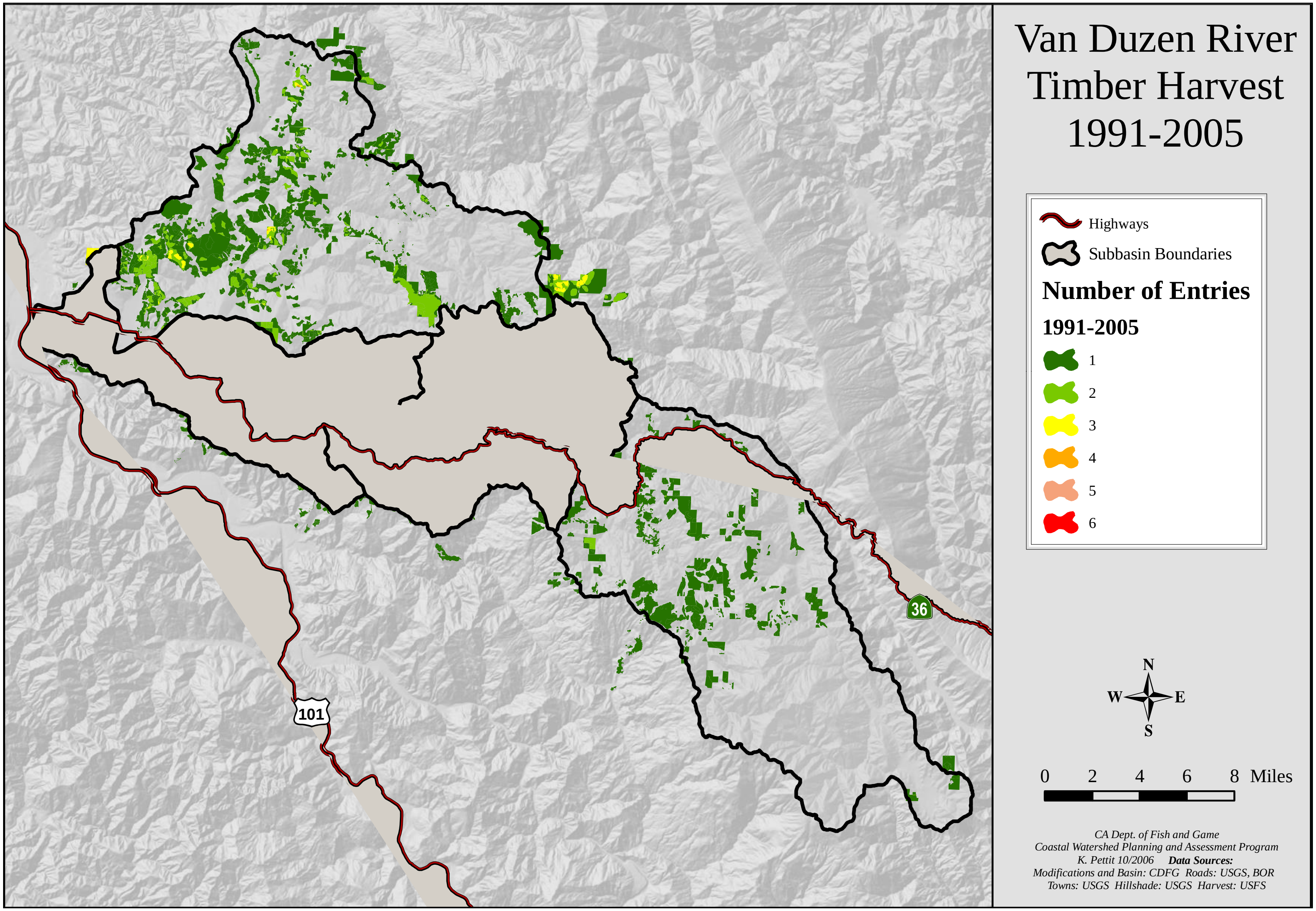


Figure 18. Timber harvest activities in the Van Duzen River Basin from 1991-2005.

Roads

Roads are widespread features across the Van Duzen River Basin (Figure 18). The roads layer data source estimates that there are 1,900 miles of roads within the basin. However, this source data does not cover the full extent of the subbasin, and therefore underestimates the actual miles of roads on the landscape (ftp.fire.ca.gov/forest).

Using the best available data, the Van Duzen Basin has an average of 4.4 miles of roads per square mile for the entire basin. The highest road density of 6.0 mi/sq. mi. is found in the Lower Subbasin, followed by 4.3 mi/sq. mi. in Yager Creek, and 3.9 mi./sq. mi and 3.6 mi/sq. mi. in the Middle and Upper Subbasins respectively. The highest density of roads is generally in forested areas where an extensive road network was built to help move logs to timber mills. Many of these roads were built using poor design plans on unstable slopes which caused undue hillslope erosion, stream diversions, gully erosion and other sources sediment inputs to the streams (Weaver et al. 1995). There are also an undetermined number of timber harvest related tractor skid trails in the Van Duzen Basin.

Forest roads affect basin hydrology and mass wasting through interception and redirection of subsurface flow, and they are another source of surface sediment in these environments. Roads tend to increase hillslope erosion potential and are identified as primary and persistent sources of sediment input to stream channels (FEMAT 1993). The construction of roads increases the potential for surface erosion and slope instability by increasing the area of bare soil exposed to rainfall and runoff, obstructing stream channels and by altering subsurface flow pathways. Poorly designed roads can alter physical processes, leading to changes in stream flow regimes, sediment transport and storage, channel bank and bed configurations, substrate composition, and stability of slopes adjacent to streams (Furniss et al. 1991). Moreover, road ditches concentrate storm runoff, and increase its erosive power to form rills and gullies, as well as pathways of sediment delivery to streams.

Important components of roads are the stream crossings that are utilized throughout the overall road system. One type of widely used stream crossing is metal culverts. Undersized or improperly placed culvert stream crossings often fail during storm events causing massive fill wash outs and stream diversions. These failures occur when the hydraulic capacity of the culvert is exceeded either because of obstruction of the inlet or inadequate culvert sizing. Stream crossing fill material is often washed into watercourses when water accumulates behind the road fill prism until it flows over and erodes the road fill, or the fill becomes saturated and catastrophically fails (Furniss et al. 1998). In some instances, stream crossing failures divert streams out of their channels and down the roadway, which often leads to gullies, landslides and other stream crossing failures (Furniss et al. 1998; Weaver, et al. 1995).

Erosion is especially problematic from older, un-maintained or poorly designed roads. The majority of the un-paved roads in the basin were constructed during the initial timber harvest period prior to the 1970's and dating back to the early 1900's. These older roads were generally built well below current construction standards. The logging practices of the time had little consideration for water quality and fisheries, as evidenced by the common practice of using stream channels as roads and landings. In some cases, roads have created a 'legacy' of potential instability across the northwest including the Van Duzen River Basin. Many recent landslides have occurred as the result of road construction practices of many decades ago (NMFS 1998). These physical impacts can have significant consequences to health and survival of salmon populations.

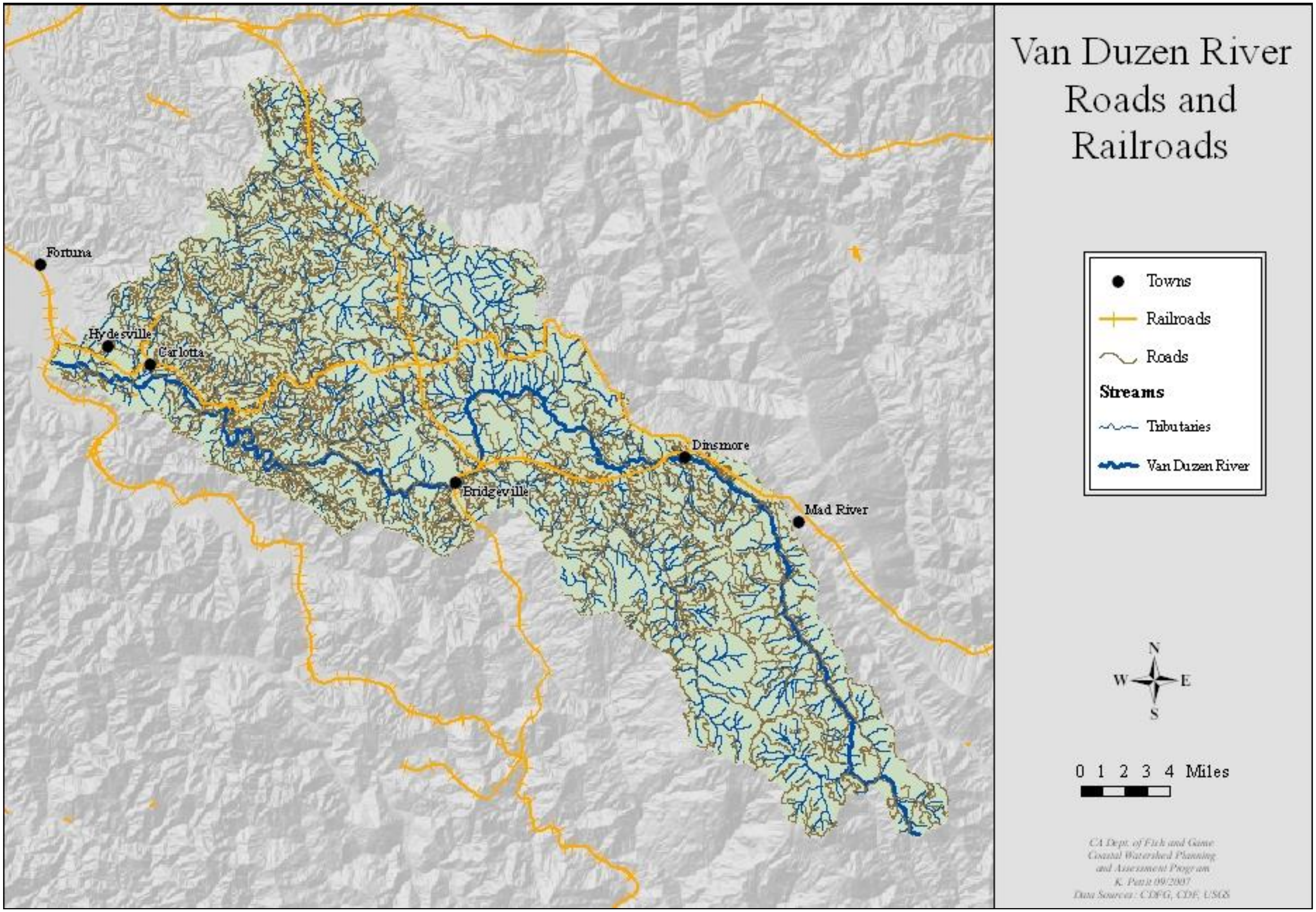


Figure 19. Roads within the Van Duzen Basin. Railroads shown are historic routes and no longer support rail traffic.

A standard for road density related to erosion was established by Cederholm et al. (1981). They noted that the amount of fine sediment delivered from road surface erosion to stream channels was elevated in basins with more than 3 miles of road per square mile of area. They also recommend that road density not exceed 2.5 miles/sq. mi. of landscape to reduce sediment impacts to streams from road surface erosion. All of the subbasins in the Van Duzen Basin exceed this critical target value. To protect salmonids of the Columbia River Basin, National Marine Fisheries Service (NMFS) recommended road miles be reduced to a maximum of 2 miles/sq. mi. of landscape (NMFS 1995).

Because road-related erosion has been shown to be a major source of sediments to streams, it is the focus of ongoing restoration efforts in the basin. Roads built on relatively steep slopes and in close proximity to stream channels are high priority sites for restoration work (Figure 19 and Table 12). Several miles of roads in the basin have been surveyed and improved, but many road miles (active and inactive) are still in need of improvements to reduce erosion and sediment delivery to streams and prevent or mitigate blocking fish passage. With evolving changes in Forest Practice Regulations, new harvest-related road construction is held to higher standards aimed to minimize hillslope erosion. These regulations cover construction activities such as operations on steep slopes, road alignment, road grades, erosion control, watercourse crossings, culvert instillation, winter period operations, and road maintenance. A guide for rural road construction can be found in Weaver, W.E., and D.K. Hagans (1994) *Handbook for Forest and Ranch Roads.*

Table 12. Number of road miles on hillslope greater than 30% and within 100 feet of blue line stream channels for each subbasin.

Subbasin	Total Road Miles	Miles on Slope 30-60%	Miles on Slope >60%	Percent of Road Miles on >30 % slope
Yager	639	232	16	39
Lower	417	158	19	42
Middle	312	100	11	36
Upper	514	173	16	37

Gravel Mining

Gravel mining occurs on the lower Van Duzen River from the confluence with Eel River to approximately a mile above the confluence with Yager Creek (RM 6). The County of Humboldt Extraction Review Team (CHERT) monitors and makes recommendations on sites that extract over 5,000 cubic yards annually. For each harvest site, CHERT estimates the mean annual recruitment (MAR) of bedload in relation to the surrounding instream mining operations. Based on the MAR, the CHERT sets limits on the maximum volume of aggregate available for harvest each year, recommending extraction should not exceed 75% of MAR in salmonid-bearing rivers and streams; and only after analysis has determined the MAR for a particular mining reach (Laird et al. 2000). From 1997 through 2007, 111,347 cubic yards was the average volume extracted from the Van Duzen River’s lower reach, about 70% of the maximum volume permitted by CHERT. Gravel mining operations are explained in more detail in the Lower Subbasin in the Land Use section (pgs. 25-27).

Mineral extraction also occurs at various scales, targeting multiple types of minerals (e.g. nickel, gold) within the Van Duzen River Basin.

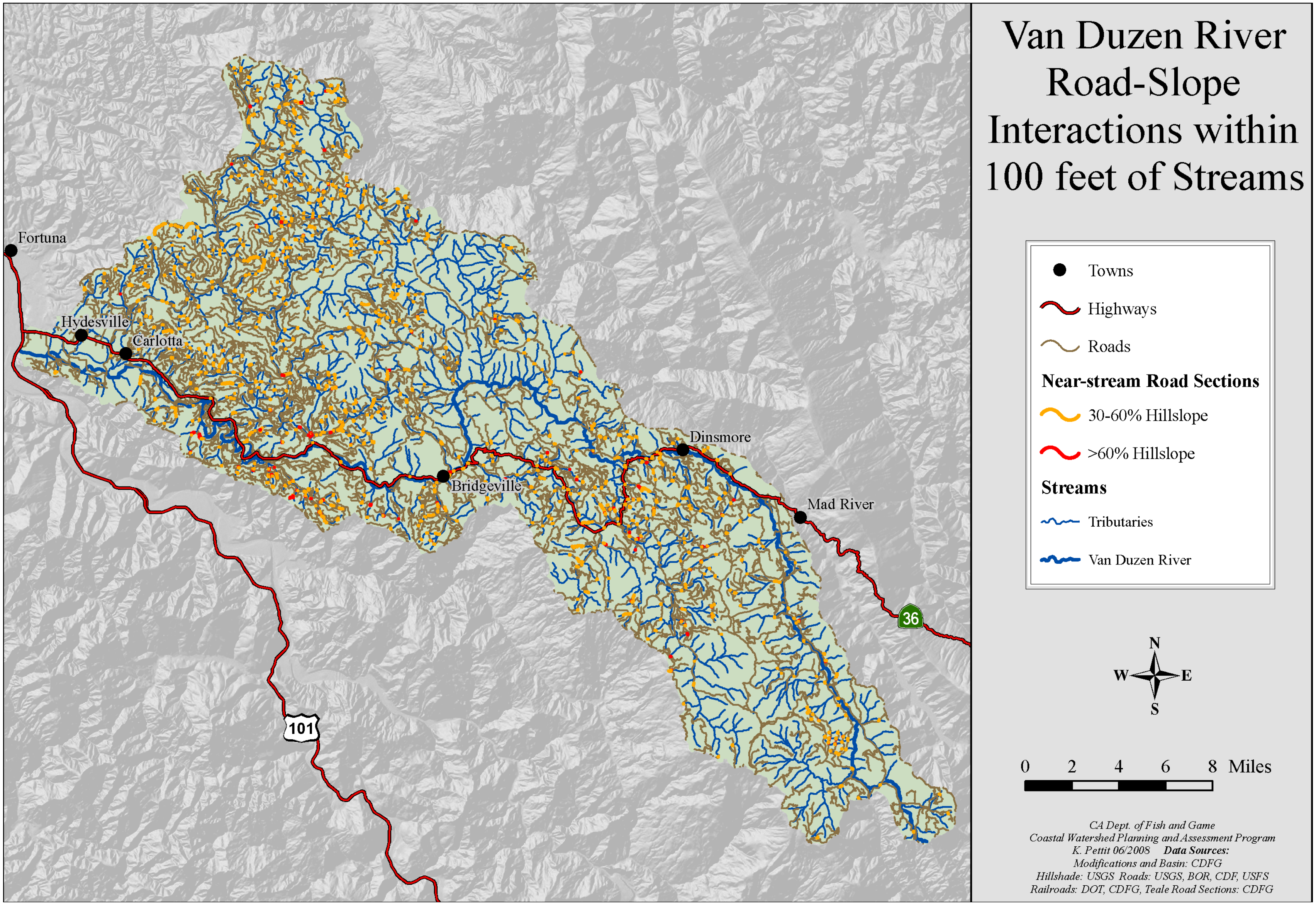


Figure 20. Interactions between roads, hillslope and streams are depicted. Locations with steep slopes near streams are considered high priority areas for restoration

Water Diversions and Hydroelectric

California law recognizes various types of water rights to surface water flow. Their proof of existence and exercise can often be a complicated and controversial issue. Surface water diversions can have a major impact on stream flow and consequently fisheries habitat. Ground water extractions, with a few exceptions (for example, underground water extractions from "subterranean streams flowing through known and definite channels") are not subject to California law and can also affect stream flow. A description of the different types of surface water rights can be found at the State Water Resources Control Board (SWRCB) web site (waterrights.ca.gov).

Three types of water rights that apply within the Van Duzen River Basin are small domestic, riparian and appropriative. Small domestic water rights apply for the diversion and storage of up to ten acre feet of water per year for domestic use only. Riparian water rights generally concern the diversion and use of surface water from a natural watercourse on land parcels that the watercourse passes through or borders. Appropriative water rights generally apply to the diversion and use of water on lands that do not border the watercourse, or are for water stored for more than 30 days.

A search of the SWRCBs Electronic Water Right Information System (eWRIMS) was performed to determine the number and types of water rights within the Van Duzen River Basin. A total of approximately 540 acre-feet per year is licensed and 40,000 acre-feet are permitted in the basin. The Middle and Upper subbasins show 22,000 and 18,000 acre-feet respectively. The Lower and Yager Creek subbasins list 72 and 360 acre-feet respectively. Some pre-1914 and riparian water rights are also contained in the WRIMS database for those water rights whose users have filed a "Statement of Water Diversion and Use". Since water flow is paramount to production of salmonids, the diversion and use of water for domestic, agricultural and other purposes should be done in a manner that considers impacts to stream and riparian ecosystems and fishery resources.

There are two small hydro electric power generating facilities (1 and 2 megawatt) located in the Middle Subbasin and likely several other small projects to supply power to off grid households in the basin.

Industrial Marijuana Agriculture

Not included in these permitted water diversions are the illegal diversions from the recent proliferation of industrial marijuana agricultural operations in the Van Duzen River Basin. Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFG field staff has discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes.

During an August 29th, 2012 flight over several watersheds including the Van Duzen River. Third District Supervisor stated:

> Without trying too hard, we were able to count 125 grows in the Van Duzen… Some appeared to be no different than a small farm, but far too many showed evidence of illegal and unpermitted clearcutting, grading, road building and water diversion. Regardless of their size and other difference, they all use precious water from these impoverished creeks and rivers, some of which no run dry in places." (www.arcataeye.com).

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.) a 10,000 square foot outdoor marijuana grow, moderate size operation, uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFG, personnel communication 2012). Considering the number of outdoor and indoor operations within the watershed, this industry is having an affect on water flows in the Van Duzen River and its tributaries. A recent trend has emerged in that even during wet water years atypical low flows are occurring during the late summer to early fall (T. LaBanca, CDFG, personnel communication 2012). Figure 21 displays this potential trend using flow data from the USGS Van Duzen River gauging station near Bridgeville. Daily mean discharge (in cfs) for the 2011 water year, which was considered a wet year with above average rainfall, was plotted along with the median daily statistic (60-year flow average). The graph shows a distinctive decrease in low flows in September/October in 2011 (7cfs) when compared to the 60 year average during this same time frame (10cfs).

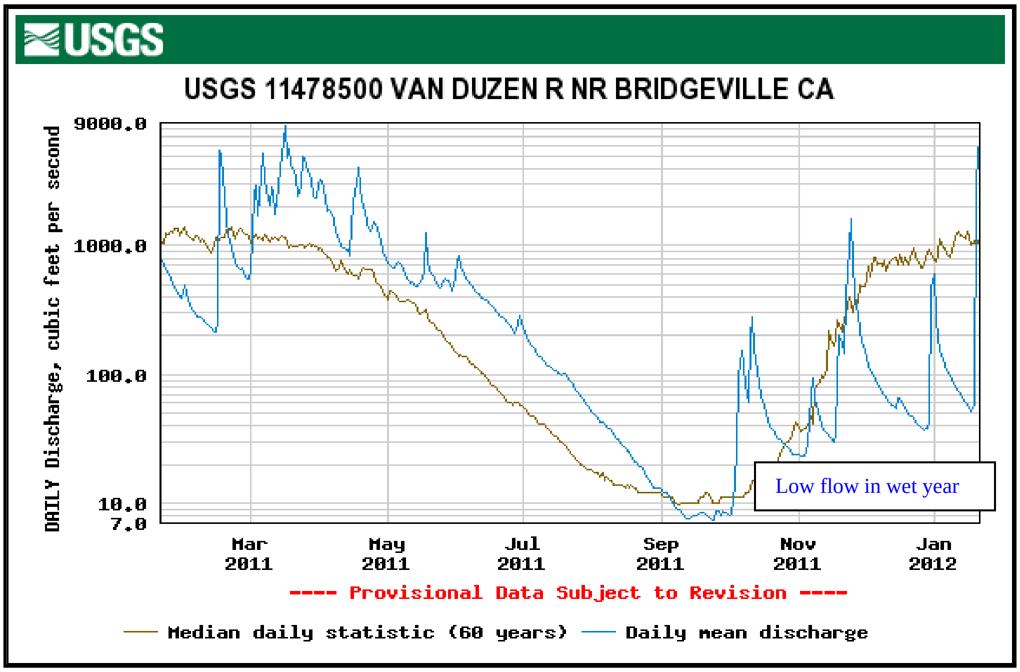


Figure 21. USGS gauging station near Bridgeville showing 2011 daily mean discharge (in cfs) and the mean daily statistic (60-year average in cfs).

Unlike permitted/licensed water diversions and other regulated land use activities such as legal timber harvesting and/or mining operations, there are no standards for "best practices management" or any review by agencies like CDFG and the state Water Quality Control Board; therefore, a wide range of impacts to watercourses and their aquatic resources can be associated with these industrial marijuana agricultural operations. These impacts may include the following (T. LaBanca, CDFG, personnel communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decrease in stream flows due to these water diversions;
- A wide range of pollutants may be used, including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually releasing into the water throughout the year;
- Human wastes from camps that could also directly enter or leach into watercourses;
- Improperly constructed roads and construction around the site that contributed to sediment production

that enters watercourses throughout the rainy season;

- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

Figure 22. View of marijuana cultivation along the Van Duzen River. Note, the entire summer steelhead population (federally listed species) is located just upstream. With 250 plants using approximately 6 gallons of water a day, this operation would use 1, 500 gallons a day (approximately), equaling 225,000 gallons for the 5 month growing season.

Land Management Impacts on Riparian Forests and Aquatic Resources

Timber harvest practices, agriculture (including industrial marijuana), livestock grazing, and urban and rural developments have the potential to adversely affect riparian functions that contribute to stream ecosystem processes. Land use that either reduces benefits from near stream forest functions or initiates excessive sediment delivery to streams are significant disturbance factors to stream ecosystems. The amount of watershed disturbance it takes to impair salmonid growth and survival depends on the temporal, spatial extent and type of disturbance and a watershed's inherent characteristics. Inherent watershed characteristics such as geologic instability, climate and other factors cumulatively contribute to a watershed's sensitivity to land use and potential for stream impairments.

Today, riparian and near stream forests of the Van Duzen River Basin streams are impaired, as they tend to lack mature stands and still reflect the legacy of past forest management practices. In the past there was little or no protection given to riparian or nearstream forests during timber harvests or other land uses. The dense overstory shade canopy provided by tall conifers that helps maintain cool air and high humidity near streams was removed from many of the basin's streams, thus leading to higher stream temperatures during the summer months. Potential for large wood loading needed for channel forming processes, instream shelter complexity, large woody structure (terrestrially and in aquatic communities), and sediment routing also has diminished due to lack of large trees.

In addition to the loss of late seral forest and its associated large trees, the potential effects of timber harvests on stream communities and its native species includes the following: increasing rates of erosion and sedimentation of aquatic habitats; change in soil moisture regimes; increased precipitation runoff rates and thus increasing flooding potentials; increasing temperatures of aquatic habitats which may negatively impact salmonid growth and favor the growth of exotic fish species; increasing the potential for exotic plant invasion; and overall fragmentation of aquatic habitat.

A degree of protection of riparian zones, nearstream forests and aquatic habitat is currently provided through riparian stream buffer requirements of state Forest Practice Rules applied to non-federal lands and Northwest Forest Plan guidelines for federal lands. Moreover, habitat conservation plans that incorporate additional protection measures for stream habitats have been developed for lands in the Van Duzen Basin managed by HRC and Green Diamond Resource Company.

Grazing by livestock animals is prevalent within the Van Duzen Basin and has multiple negative effects on native species including: riparian habitat degradation, competition with native herbivores, inhibiting or depressing regeneration of native plants (e.g. oaks), favoring exotic plant species (e.g. exotic graminoids vs natives), increases human caused mortality for medium and large carnivores, increased erosion, and simplification of vegetative structure. Grazing also degrades the quality of riparian vegetation and increases the potential for erosion and thus sedimentation into aquatic habitats. Finally, grazing can reduce the amount of riparian habitat that can buffer aquatic habitats from flooding and sedimentation.

Two major types of mining occur in the Van Duzen River Basin: gravel and mineral mining. Gravel mining involves the removal of substrate from aquatic habitats generally faster than it can be replaced by natural processes. Mining on the lower Van Duzen River has most likely contributed to braiding and flattening of the river between its confluence with the Eel River upstream to approximately RM 5. This type of shallow and wide channel morphology provides less cover from predation, less food, and higher water temperatures for juvenile fish as the channel is decoupled from riparian vegetation. Historically, the mining activities on the Lower Van Duzen River created migration barriers for adult fish, sometimes leading to stranding on shallows and mortality. In cooperation with the regulatory agencies of the NMFS, USFWS, CDFG, and USACOE, mining operators have since prevented these types of incidents from reoccurring. It is important that gravel mining be managed in a way that does not further decrease salmonid habitat and, ideally, works with riverine dynamics to maintain or improve the quality habitat that still exists.

While the pace of rural development has been slow to moderate in most areas of the basin, it nonetheless includes the loss of natural habitat to a variety of development activities (conversion to homes, agriculture, pasture, etc.) that effect native species by: reducing the amount of habitat available to species (especially in lowlands, valleys, and the coastal plain), increasing fragmentation effects, increasing exotic species introduction, and increased pollution.

Pollution includes many forms of degradation (e.g. chemical runoff, excess sediment loads, thermal) mainly caused by industrial and agricultural activities that affect native species by depositing large amounts of contaminants into aquatic habitats, degrading water quality enough to negatively alter the growth, reproduction, and survival of many species.

Blue-Green Algae Blooms

Blue green algae, or cyanobacteria, can be any number of microscopic bacteria that photosynthetic and occur naturally in surface waters. Some forms of blue green algae produce harmful toxins which may attack the liver (hepatotoxins) or the nervous system (neurotoxins). Toxins are released into the environment when cells rupture or die, and are concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009).

Algal blooms, or rapid accumulations of cyanobacteria cells, occur primarily in warm summer months, under optimal conditions that include elevated stream temperatures, high levels of nutrients (including phosphorous and nitrogen, and the ratio of the two), increased periods of sunlight, and low flows. Human activities such as inadequate sewage treatment, or activities that result in increased agricultural and sediment input from farms and roads, lead to excessive fertilization (eutrophication) in water bodies, creating favorable conditions for blue green algae blooms (WHO 2009).

In recent years the Humboldt County Department of Health and Human Services (HCDHHS) has been notifying recreational users of the Van Duzen River, South Fork Eel River, Big Lagoon, and other fresh water areas to take appropriate precautions to avoid contact with blue-green algae blooms. The blue-green algae blooms have occurred in the Van Duzen River during the late summer months and pose health hazards for those swimming or playing in the river, especially children and pets.

In order to minimize the spread/proliferation of blue-green algae the HCDHHS (Division of Environmental Health, 2011) has provided the following recommendations to homeowners and land managers:

- Minimize the use of water, fertilizers and pesticides on your property. Do not apply more than the recommended amounts of fertilizers or pesticides, and conserve water with drip irrigation, etc.;
- Recycle or dispose of any “spent” pre-fertilized soil that has been used for intensive growing. Runoff from this soil can still contain a lot of nutrients that may stimulate algal blooms;
- Operate and maintain your septic system properly. Overloaded or damaged septic systems can increase nutrients in nearby waters. Have your system pumped every 3-4 years;
- Encourage the growth of native plants around banks and shorelines. Wetland and streamside plants help filter water and do not require fertilizers or pesticides to stay healthy;
- Prevent surface water runoff from agricultural areas and keep livestock out of surface waters;
- Prevent/minimize erosion around construction and logging operations.

Fish Habitat Relationships

Fishery Resources

The Van Duzen River Basin supports populations of fall run Chinook salmon, coho salmon, winter and summer runs of steelhead trout, coastal cutthroat trout, numerous additional native fish species, and other important aquatic resources (Table 13).

There are approximately 150 miles of stream habitat accessible to anadromous salmonid in the Van Duzen Basin. The mainstem provides approximately 47 miles and tributaries provide approximately an additional 105 miles of accessible habitat (Table 15). The number of accessible stream miles may vary from year to year depending on presence of temporary barriers from debris accumulations (in tributary streams) and the timing, duration and magnitude of optimal flows for passage to upstream spawning sites.

Steelhead trout are the most widely distributed salmonid in the basin (Figure 22). They presently utilize approximately 147 miles of stream habitat including 46 miles of mainstem habitat and 101 miles of tributary habitat (Table 14). The tributary habitat includes 16 miles of the Little Van Duzen River and 15 miles of Yager Creek. Chinook presently utilize approximately 90 miles of habitat composed of 55 miles of tributary and 35 miles of mainstem Van Duzen River (Table 15). Historically, coho regularly spawned in low gradient tributaries of the Lower Subbasin and in Yager Creek and (Puckett et al. 1968), however, recent coho sightings have become very limited.

There are two natural barriers that hinder or prevent adult fish passage on the mainstem Van Duzen River: Salmon Falls (RM 37) and Eaton Falls (RM 46). Salmon Falls, located on near the confluence of Bloody Run Creek, is typically a passage barrier to Chinook and coho salmon. However, it was stated in a public review meeting that anadromous salmonids had made passage above Salmon Falls in the past (Annonymous Communication). During most water years steelhead can migrate past Salmon Falls and access the Little Van Duzen River (S.F. Van Duzen River) at RM 45.5. Steelhead are able to ascend the Little Van Duzen and utilize approximately 15 miles of spawning and rearing habitat. Eaton Falls is considered the upstream extent of their spawning run on the mainstem Van Duzen River. CDFG (1965) noted steelhead have been known to migrate up the roughs during some years. Stocks of rainbow trout reside in the upper mainstem and tributaries, and prior to 1964 there was a popular resident trout fishery. Construction of a fishway at the roughs was considered by US Forest Service and CDFG, but the site was deemed too geologically unstable to support any such structure.

Streams in the Lower Subbasin and Yager Creek Subbasin provide the largest amount of Chinook and coho salmon habitat of all the subbasins (Table 14). Even though most of the Middle and Upper Subbasin tributaries are not accessible to salmonids they contribute important water flows into the Van Duzen River and may support resident populations of rainbow trout above barriers to anadromous salmonids.

The numbers of salmon and steelhead that spawned in the Van Duzen River prior to Euro-American settlements are not precisely known. However, it is generally accepted that the runs of the 1800s were much larger than most runs of the twentieth century or the present-day runs. Similar to most salmonid streams, the number of salmonids returning to the Van Duzen varied annually depending on environmental and biological factors.

Table 13. Fishery resources of the Van Duzen River Basin.

Common Name	Scientific Name
Anadromous	
coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
steelhead trout	*Oncorhynchus mykiss*
sea run coastal cutthroat trout	*Oncorhynchus clarki clarki*
Pacific lamprey	*Entosphenus tridentatus*
Freshwater	
rainbow trout	*Oncorhynchus mykiss irideus*
coastal cutthroat trout	*Oncorhynchus clarki clarki*
Coast range sculpin	*Cottus aluticus*
Humboldt sucker	*Catastomus occidentalis humboldtianus*
prickly sculpin	*Cottus asper*
western brook lamprey	*Lampetra richardsoni*
California roach*	*Lavinia symmetricus*
Speckled dace*	*Rynichthys osculus*
Sacramento pikeminnow*	*Ptychocheilus grandis*
three-spine stickleback	*Gasterosteus aculeatus*
Amphibians	
Pacific giant salamander	*Dicamptodon tenebrosus*
tailed Frog	*Ascaphus truei*
red-legged frog	*Rana aurora*
foothill yellow-legged frog	*Rana boylei*

*Table 14. Approximate number of stream miles accessible to anadromous salmonids in each of the Van Duzen River subbasins***.**

Subbasin	Van Duzen River mainstem miles currently utilized by anadromous salmonids				Tributary miles currently utilized by anadromous salmonids			
	Chinook	**Coho**	**Winter Steelhead**	**Summer Steelhead**	**Chinook**	**Coho**	**Winter Steelhead**	**Summer Steelhead**
Yager	na	na	na	na	30	16	43	18
Lower	23	23	23	23	23	9	23	1
Middle	12	12	23	23	1.5	0	4.5	2
Upper	0	0	1	1	0	0	31	12
Total	35	35	47	47	54.5	25	101.5	33

Table 15. Anadromous salmonid distribution in the Van Duzen Basin.

Subbasin and Streams	Steelhead	Cutthroat	Chinook	Coho
Yager Subbasin Streams				
Bell Creek	P			
Blanton Creek	P			
Booths Run Creek				
Cooper Mill	P		P	H
Corner Creek	P			H
Dairy Creek	P			H?
Fish Creek	P		P	P
Grouse Creek				
Lawrence Creek	P		P	P
Lone Star Creek	P			
Shaw Creek	P		P	P
Strawberry Creek	P			
Yager Main stem	P	?	P	P
Yager Middle Fork	P		P	
Yager North Fork	P		P	
Yager South Fork	P		P	
Lower Subbasin Streams				
Barber Creek	P			H?
Cuddeback Creek	P		P	H
Cummings Creek	P		P	P
Fielder Creek			P	H
Fox Creek	RT,	H		
Flanigan Creek				
Grizzly Creek	P		P	P
Heley Creek	P	?	P	P
Jordan Creek	P			
Root Creek	P		P	H
Stevens Creek	P			
Wilson Creek	P		P	H
Wolverton Gulch	?	P		H
Middle Subbasin Streams				
Brown Creek	P			H?
Cashlapooda	No fish			
Fish Creek	P			
Hoagland Creek	P, RT			H
Little Larabee Creek	P		H	
Rutledge Creek	RT			
Van Duzen Mainstem	P		H	P
Upper Subbasin Streams				
Bear Creek	P			
Big Meadow	RT			
Black Lassic Creek	No fish			
Blanket Creek	P			
Brown’s Canyon Creek	RT			
Burr Creek	?			
Butte Creek	P			
Butte Creek trib				
Crook’s Creek	RT			

Subbasin and Streams	Steelhead	Cutthroat	Chinook	Coho
Dolores Creek				
Horse Creek	P, RT			
Lost Canyon Creek				
Mill Creek	RT			
Panther Creek	P			
Swift Creek				
Thompson Creek	RT			
Van Duzen Main Stem	P	P	P	P
Van Duzen South Fork	P, RT			

P = Present; H = Historically observed
Source: Hallock et al. 1952; Moyle 1991and Moyle 2002; CDFG field surveys

The first recorded numerical estimates of anadromous salmonids returning to the Van Duzen Basin were calculated from studies conducted in the 1950s (USFWS 1960) and CDFG records from the period 1932-1962. Tag recoveries from the 1950s at Benbow Dam show that 35-40% of the coho salmon run spawns above Benbow Dam. Spawning ground surveys showed that tributaries of the Van Duzen River and South Fork Eel were the most important spawning areas for coho salmon (USFWS 1960). In 1965, the CDFG estimated that an average of 4,000 Chinook salmon, 4,000 coho salmon and 11,500 steelhead trout adults spawned in the Van Duzen Basin annually during the period from 1932 to 1962 (CDFG 1965). Peak populations for the same time period for the Eel River Basin was estimated at 177,000 Chinook salmon, 78,000 coho salmon and 196,000 steelhead trout (USFWS 1960, CDFG 1965). We would expect relatively proportional (near 10% of the Eel River numbers) similar peaks to have occurred in the Van Duzen River salmon and steelhead populations.

Overall, there is limited current data concerning the salmonid populations in the Van Duzen River Basin, and estimates of the present size of salmonid populations have not been determined. Recent population data such as downstream migrant studies and spawning surveys are available for select streams, however, these data are inconclusive because they lack of consistent effort across the study areas, or have not been ongoing for sufficient time to establish trends, and may require optimal environmental conditions to conduct observations. Nonetheless, a review of past fisheries studies, anecdotal information and data collected for this assessment indicates that present salmonid populations in the Van Duzen River are less abundant and less widely distributed compared to the estimates of 1965 (USFWS 1960; McEwan and Jackson 1996; NMFS 1998; McElhany et al. 2000; CDFG 2002). A similar decline in wild salmon populations has been observed in most of California’s streams, prompting listing of anadromous salmonids as threatened under the Federal Endangered Species Act in 1997.

Steelhead Trout

The Van Duzen River supports two distinct runs of steelhead (*Oncorhynchus mykiss*); a winter run and a summer run. In addition, a juvenile run of “half-pounder” steelhead, return to the river after a short period of ocean rearing. Winter run steelhead are the most abundant and widely distributed anadromous salmonid in the basin (Figure 23). Beginning with the onset of the winter rainy season they make spawning migrations up the mainstem Van Duzen River into most of the perennial streams below Eaton Falls near Dinsmore (Figure 23). Eaton Falls (RM 46.5) is a natural barrier to steelhead passage during most years. Adult steelhead also have access to most of the Little Van Duzen River. In contrast to all anadromous

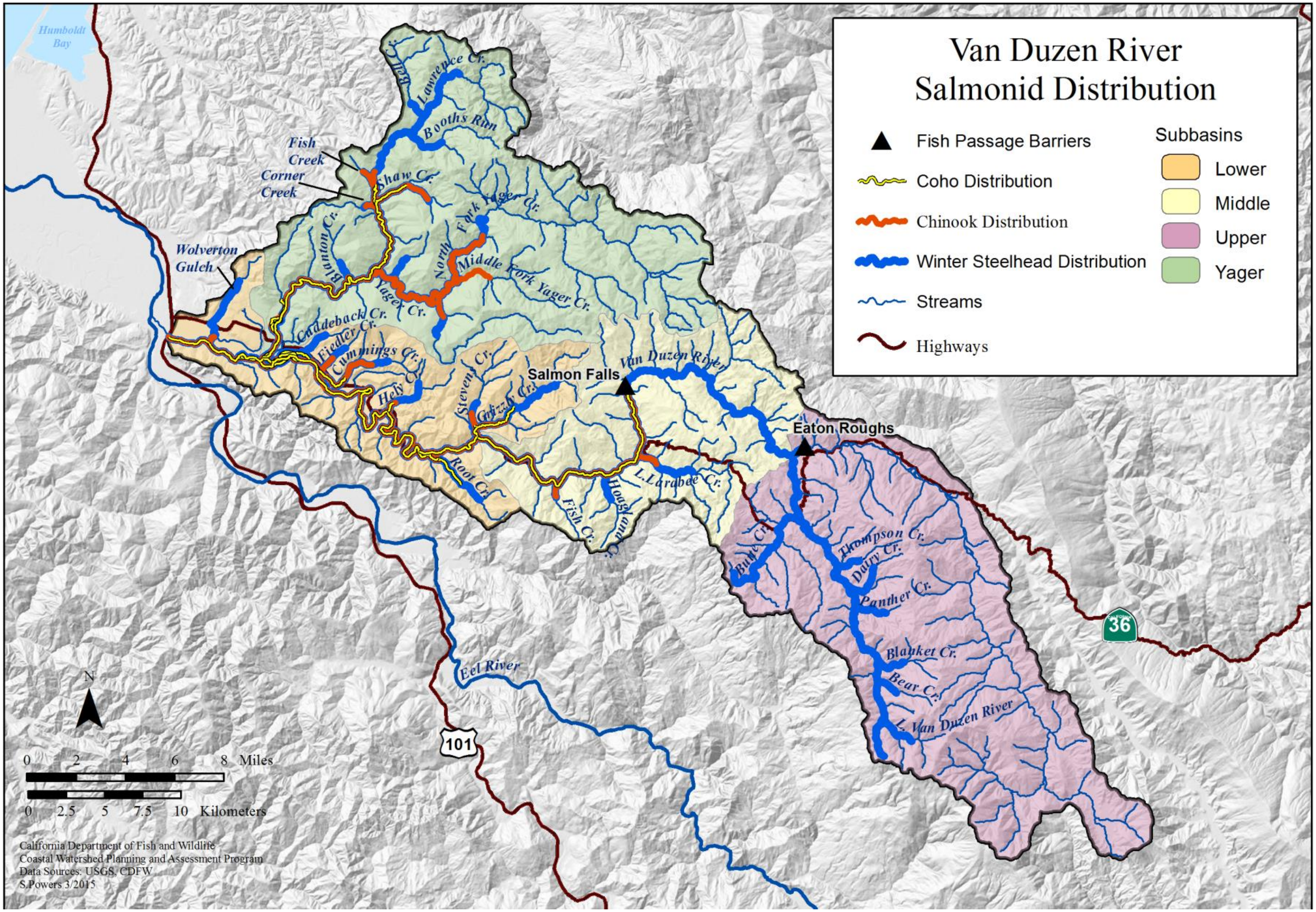


Figure 23. Current range of Coho and Chinook salmon and winter steelhead trout in the Van Duzen River Basin based on California Department of Fish and Game estimates

Pacific salmon, steelhead may not die after spawning. Incidence of repeat spawning by steelhead ranges from about 17.6% for small coastal streams to 63.6% for spring run of the Sacramento River system (Hopelain 1998). Steelhead may repeat spawning migrations as many as four times (Barnhart 1986 and Hopelain 1998). Juvenile winter steelhead typically spend one to three years in inland waters before migrating towards the ocean. Although juvenile steelhead numbers have likely decreased from historic levels, their decline in numbers and distribution is not as significant as coho or Chinook salmon. This difference may be attributed to their ability to tolerate a broader range of stream habitat conditions compared to the juvenile coho salmon. The peak migration to the ocean occurs during December through May. Steelhead typically live in the ocean from one to four years before returning to freshwater streams to spawn.

Summer steelhead migrate from the ocean during the peak spring and early summer flows to a select few of California's north coast streams. Summer steelhead enter fresh water sexually immature and must hold in cool, deep pools over the summer and fall until winter rains provide passage to spawning habitat (Barnhart 1986). Only about 20 streams in Northern California are populated with summer steelhead including the Van Duzen River (Gerstung 2001 draft). Spawning summer steelhead may be somewhat spatially and temporally segregated from winter steelhead. Generally, summer steelhead spawn December through February in smaller tributaries or in the headwaters of larger systems, further upstream than winter steelhead (Barnhart 1986). The majority of adult summer steelhead in the Eel River Basin utilize pools from 10 to 20 feet deep for over summer habitat (Scott Harris, CDFG, Personal Communication). In addition to deep pools, summer steelhead prefer water temperatures less than 66^{o} F (19^{o}C) (Baigun et al. 2000) and ample cover such as large rootwads, large boulders, underwater ledges, caverns, and bubble curtains, which fish seek when disturbed. Cool pool temperatures are often maintained by inputs from cold hyporheic seeps, springs or tributaries that feed pools that are somewhat isolated from mixing with the main river. A level of isolation from mixing with main river flows allows pools to retain cool temperatures or thermally stratify. The deep, stratified, cool pools may be necessary to provide summer refugia for adult summer steelhead (Nielsen et al. 1994, Ozaki et al. 1999). The loss of deep pool habitat in the Van Duzen River as a result of sedimentation and stream flow reductions has reduced rearing and holding habitat for juvenile and adult salmonids.

Anecdotal reports and newspaper articles from the early 1900s to 1950 tell of a productive sport fishery for summer steelhead in the Van Duzen River, Yager Creek and up the Little Van Duzen River (Van Kirk 1998). The CDFG (1966) estimated 2,000 summer steelhead once populated the Little Van Duzen (Gustrung 1991). This number was based on summer steelhead population estimates prior to the flood of December 1964. The flood, landslides and other associated watershed erosion left a large passage barrier about one mile below the Highway 36 Bridge that prevented steelhead passage to the Little Van Duzen from the mainstem for several years. In addition, all deep holding pools in the Little Van Duzen above Highway 36 Bridge were filled with sediment (Gustrung 1991). All of the passage barriers into the Little Van Duzen were reported cleared by August 1979 (McCloud 1979). A similar population decline and loss of summer steelhead habitat is reported from Redwood Creek near Orick (Cannata et al. 2006).

Recent CDFW summer dive counts indicate the Van Duzen supports a population of summer steelhead that ranges from 50 to 250 fish per year in the mainstem Van Duzen River (Table 16). Only a few pools along the Van Duzen are presently known to provide over summer holding habitat for summer steelhead. Personnel communications with CDFG staff and review of PALCO reports indicate no summer steelhead have been recently observed in Yager Creek. However, no specific surveys to detect them have been recently conducted; therefore, the status of Yager Creek summer steelhead needs to be determined. The status of adult holding areas in the Little Van Duzen and over summer populations is also unknown at this time and should be studied.

The summer steelhead population of the Van Duzen River is much more at risk than winter steelhead because of their reduced numbers and special need for adult over summer holding habitat. The cool and deep pools upon which they depend are a rare type of habitat in the Van Duzen River system and the lack of such pools is likely the most limiting factor to summer steelhead production. The known pools that provide over summer holding areas are truly critical habitats and should be protected from any disturbance that could reduce their capacity to support summer steelhead.

Resident rainbow trout are present in the upper mainstem and tributaries. These rainbow trout once provided a productive sport fishery. At present, trout fishing on the Upper Van Duzen is a minor fishery compared to years past. Some of the resident trout may contribute to anadromous populations. They may move downstream and migrate to the ocean and return as steelhead to streams below Salmon Falls.

Table 16. CDFW Van Duzen River summer steelhead dive counts from 2012-1995.

Van Duzen River summer steelhead dive counts from 2012 to 1995	
Year of Survey	**Number of adult steelhead observed**
2012	255
2011	110
2010	NS*
2009	65
2008	130
2007	100
2006	50
2005	16
2004	54
2003	80
2002	30
2001	NS*
2000	14
1999	4
1998	11
1997	6
1996	15
1995	4

*NS = No survey performed

Coho Salmon

Coho salmon (*Oncorhynchus kisutch*), also known as silver salmon, tend to use coastal streams for spawning and juvenile rearing along west coast of North America from Alaska to central California. They historically used tributaries of San Francisco Bay; however, viable populations have not been described from the Sacramento or San Joaquin river systems. Currently, the southernmost stream that supports coho salmon is Aptos Creek in Santa Cruz County, but there are historic reports of coho salmon as far south as the Santa Ynez River in Santa Barbara County (CDFG 2004).

The Van Duzen River and several of its tributaries are noted as an important coho habitat comprising approximately 10% of the Eel River population (USFW 1960; CDFG 1965; Leos and Mills 1983) (Figure 24). Coho salmon share a juvenile rearing strategy with steelhead trout but are more sensitive to high water temperature and exhibit a greater affinity for complex habitat than steelhead (Rosenfeld et al. 2000). Shapovalov and Taft (1954) found that the coho salmon of the Van Duzen River typically have a three-year life cycle, spending one year in freshwater streams and two years in the ocean before returning to spawn. They noted, however, each year 4% to 28% of the spawning run is composed of 2- year old males called jacks or grilles.

Because coho salmon spend a year or more in freshwater streams, they must have habitat available that will provide refuge from seasonal environmental variation such as floods or droughts. Coho salmon depend upon complex channels with woody debris, cool water, good shade canopy, and sufficient food to sustain them through their fry and juvenile stages. In addition to complex mainstem habitat, secondary channel habitats such as alcoves and backwater pools with LWD cover, are highly preferred habitat conditions for juvenile coho salmon (CDFG 1991).

Coho salmon prefer small tributaries for spawning rather than large mainstem reaches of the Van Duzen River used by Chinook salmon. In the past, coho regularly spawned in low gradient tributaries in the Lower Subbasin and in Yager Creek (Puckett et al. 1968). In 1983, juvenile coho salmon were identified in Butte Creek a tributary to the South Fork Van Duzen in the Upper Subbasin (Decker and Fuller field studies 1984). Grizzly Creek is the eastern most Van Duzen tributary stream known to regularly produce coho salmon in this century (CDFG 2004). If coho salmon can navigate past boulder roughs near Goat Rock, the lower reach of Little Lararbee Creek would provide suitable habitat for spawning and juvenile rearing. Chinook salmon have been documented in Little Larabee which increases the likelihood for coho salmon presence there.

Moyle et al. (1995) estimated that in the mid 1990s, 5,000 wild coho salmon (no hatchery influence) spawned in California each year. This is a dramatic decline from the 1940s, when a state wide estimate of anywhere from 200,000 to 1,000,000 adult coho adults returned annually to California (Calif. Advisory Committee on Salmon and Steelhead Trout 1988). In response to declining wild populations in Washington, Oregon and California, wild coho, were listed as “threatened” in 1997 under the Federal Endangered Species Act (FESA). In 2002, the California Fish and Game Commission found that coho salmon of the Van Duzen River and other North Coast streams warranted listing as state threatened, as defined under the California Endangered Species Act (CESA). Coho salmon that reproduce in streams south of Punta Gorda in Mendocino County were listed as state endangered. The decision to list coho under the CESA was based on the results from recent studies (2001-2003) conducted by CDFG and a review of past studies.

Coho populations in the Van Duzen River, like in other California watersheds, have declined in numbers and distribution compared to their historic presence (CDFG 2002). Surveys conducted from 2001 to 2003 failed to detect juvenile coho salmon in many of the Van Duzen River tributaries where coho were found during past surveys conducted in those same streams (CDFG 2004). More recently, an adult coho (about 10-12 lbs) was caught by an experienced sport fisherman approximately one mile downstream of Goat Rock (RM 29), near Bridgeville in 2006; and during 2010 CDFG spawner surveys adult coho were observed in Shaw Creek and Fish Creek (tributaries to Lawrence Creek). This was the first documentation of coho in Fish Creek (10 adults) and the first sightings in Shaw since 2003. The Fish Creek observation was significant since coho had not previously been documented upstream of Shaw Creek in the Lawrence Creek watershed.

The very limited recent observations indicate a high risk of extirpation of coho from the Van Duzen Basin. As part of a strategic recovery plan based on current information, streams of the Van Duzen Basin were identified by CDFG (2004) as supporting key coho populations to maintain or improve include:

- Yager Creek
- Cooper Mill Creek
- Lawrence Creek
- Shaw Creek
- Hely Creek
- Grizzly Creek

Streams of the Van Duzen Basin that once supported coho and were identified by CDFG (2004) as sites to establish coho population include:

- Wolverton Gulch
- Wilson Creek
- Cuddeback Creek
- Fielder Creek
- Cummings Creek
- Root Creek
- Stevens Creek

Chinook Salmon

The Van Duzen River supports a fall run of Chinook salmon *(Oncorhynchus tshawytscha)* (Figure 25). Chinook salmon, also referred to as "king salmon," is the largest of the Pacific salmonid species and has been critical to the commercial and sport fishing community along the California north coast. Due to declining wild populations, Chinook salmon of the Coastal California Evolutionary Significant Unit (ESU) were listed as Threatened under the Federal Endangered Species Act in 1999. The Coastal California ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River to the Russian River.

A spawning reconnaissance study of Chinook salmon conducted by the U.S. Fish and Wildlife Service in 1959 in the Van Duzen watershed indicated that the basin had the capability to support 7,000 adult Chinook and observed 1,500 redds (USFWS 1960). The CDFG (1965c) presented a spawning escapement estimate of 2,500 adult Chinook in the Van Duzen Basin during the early to mid-1960s. However, this number of adult Chinook spawners most likely underestimates the earlier historical abundance of salmon due to the destructive effects of the great floods of 1955 and 1964 (Yoshiyama and Moyle 2010).

Traditionally, the Chinook spawning run began as early as August in the Van Duzen River; however, due to the loss of surface flow in the lower Van Duzen as well as lower flows in the Eel River during this period the run has been delayed. Chinook now typically begin spawning migrations in the fall after sufficient rainfall occurs to allow passage into the Van Duzen River from the Eel River. The majority of spawning occurs from November through January and generally peaks in December. According to anecdotal accounts, Chinook utilized much of the mainstem Van Duzen below Salmon Falls for spawning as well as the mainstem Yager Creek.

Juvenile Chinook may begin seaward migrations soon after emerging from their redds or rear for some time in their natal stream. The peak downstream migration period is generally from mid April to early June. Water temperatures in the mainstem generally become too warm for rearing during the summer months so downstream migrations are usually completed by July. A few juvenile Chinook have been observed rearing in tributary streams during the summer months. The majority of the basin's juvenile Chinook arrive in the Eel River estuary by July where they may rear for weeks to months before entering the sea (Puckett 1977, and Cannata 1995). Rearing in the estuary allows Chinook to achieve important growth that increases survival upon entering the sea.

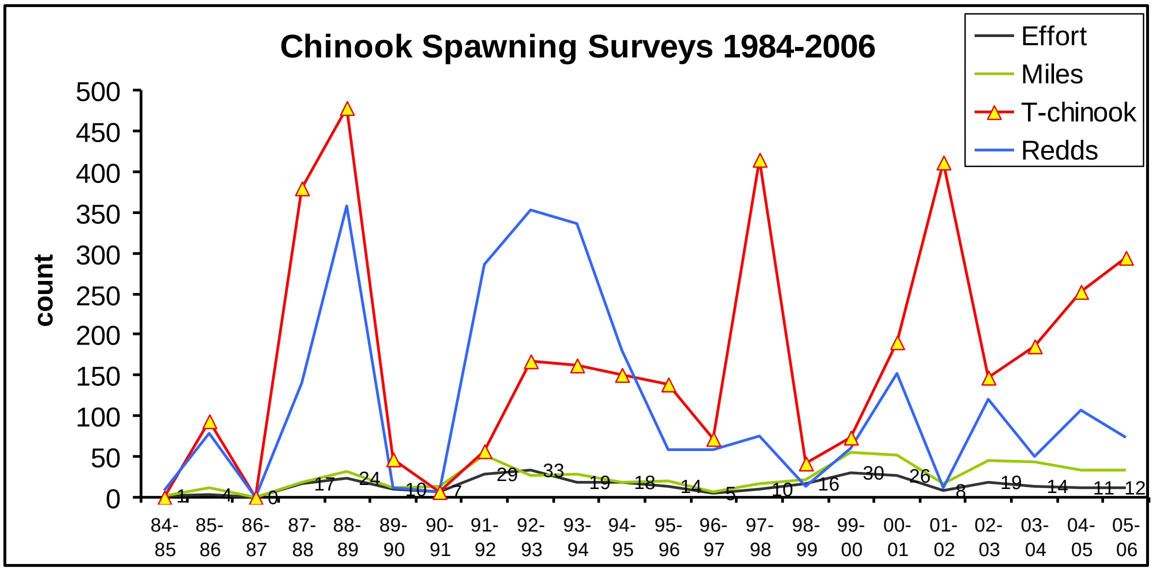


Figure 24. Combined results from CDFG Chinook spawner surveys in Van Duzen Basin streams 1984-2006. Streams surveyed include Lawrence, Shaw, Grizzly, and Root creeks.

Coastal Cutthroat

Coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) have a life history more strongly connected to fresh water than most anadromous fish, especially in California (Moyle 2002). They live mainly in small, low-gradient coastal streams and estuaries that contain cool, well shaded, aquatic habitats with an abundance of instream cover.

The Eel River watershed is the furthest southern extension of the range of coastal cutthroat trout. A few sea run coastal cutthroat reside in the Van Duzen Basin, including Wolverton Gulch and at least historically in Fox Creek. In the late 1800s and into the early 1900s, watershed supported a healthy cutthroat population which attracted sport anglers (Snyder 1908, Dewitt 1954, USDI 1960, Van Kirk 1994).

While populations declined slowly throughout the early 1900s, it was not until the mid to late 1900s that coastal cutthroat populations crashed in response to detrimental habitat changes during the 1950s to 1960s (Gerstrung 1996). There have been very limited recent observations of cutthroat trout and little is known of their current distribution within the Van Duzen River Basin.

Non-Native Fish

Sacramento pikeminnow (*Ptychocheilus grandis)* are the most problematic introduced fish species in the river. Pikeminnow were noted in the Van Duzen River near Grizzly Creek in 1988 and in 1989 young-of-the-year were observed above Goat Rock indicating successful reproduction in the Van Duzen River (Brown and Moyle 1991). Pikeminnow are now abundant in some locations in mainstem Van Duzen River and in Yager Creek. They have not been reported from any of the smaller tributaries. Pikeminnow are known predators of juvenile salmonids, and they compete with salmonids for critical habitats. The salmonid populations of the Van Duzen River have suffered from both predation and competition for habitat from pikeminnow.

Control of pikeminnow has been attempted in the Eel River with little success. Attempts include removing them by electrofishing efforts, beach seine nets and isolating pikeminnow schools and using explosives. Given the large size of the Eel River, these efforts were not considered to be effective at reducing or controlling pikeminnow. A solution to pikeminnow predation on salmonids has yet to be realized.

California roach (*Lavinia symmetricus)* was first seen in the Eel River around 1970, and are now common throughout the system. Speckled dace (*Ptychocheilus grandis)* was discovered in the Van Duzen drainage by Brown and Moyle in 1988, and is believed to have been introduced to the river near Bridgeville. They have not been reported elsewhere in the Eel River to date. There appears to be little impact from California roach and speckled dace on native fish and the overall aquatic ecosystem.

Stocking

The historical record of hatchery plantings in the Eel River system, including the Van Duzen River is mostly incomplete, but sufficient enough to clearly show that salmon and steelhead from various sources (including the upper Sacramento River basin) were extensively planted into the Eel River and Van Duzen River systems (Yoshiyam and Moyle 2010). Records from DFG indicate that the river was stocked initially stocked with steelhead in 1930 to 1938 (DFG 1936a, DFG 1938a). Considering the Eel River was broadly stocked from the early 1900s, Chinook salmon may have been planted as well in the Van Duzen basin during or around this time frame.

PALCO operated a hatchery in the Van Duzen River (located on Copper Mill Gulch) from 1977 until the early 2000s. Again, stocking records were incomplete, but according to a report produced by Berg Associates (2002): “PALCO records dating back to 1990 can be summarized by the total number of steelhead, Chinook salmon, and coho salmon released from the Yager Creek hatchery from the time between 1990 and 2002 as follows: steelhead trout 90,257, chinook salmon 306,927, and coho salmon 6,500.” The steelhead stock had been documented from three Humboldt Beacon articles as originating from the Mad River and Iron Gate hatcheries. A majority of the Chinook salmon most likely came from the Van Arsdale Fishery Station (located on the Eel River below the Cape Horn Dam) as reported in Steiner Environmental Consulting (1998): “Between 1991 and 1995 the South Fork (South Fork Eel) and Van Duzen River were the sites of virtually all Chinook planting activity, receiving 237,000 and 207,000 fish, respectively.”

Habitat Overview

Freshwater and estuarine habitat degradation and loss has been identified as the leading factors in the decline of anadromous salmonids (Ricks 1982; Larson 1982; Hofstra 1983; Anderson 1988; Brown 1988; Madej 1991; and CDFG 2002). Widespread declines of summer steelhead, sea run coastal cutthroat, coho and Chinook salmon is likely linked to their sensitivity to degradation of specific habitat components necessary to complete the freshwater and/or estuarine phase of their life cycle. Because steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the basin and have persisted in streams where other species have declined or are now rarely observed.

In California most of this habitat degradation and loss is related to land use over the last 150 years including, logging, agriculture, urban and rural developments, water diversion, road construction, soil erosion, flood control, dam building, and livestock grazing. In the Van Duzen River Basin, land use activities that accelerate runoff during winter storms or causes excessive erosion and excessive sediment delivery to streams, or alters nearstream forest processes and contributions to stream environments are currently the major factors contributing to salmonid habitat degradation and influencing the diversity of fish communities (Reeves et al. 1993).

Road construction and poor logging practices, particularly historical practices, have increased erosion, leading to excessive sediment buildup in the river and its tributaries. In addition, gravel mining, particularly at the confluence of the Van Duzen River and Eel River, has increased erosion, affected channel alignment and may block fish migration.

CDFG stream surveys from the 1930s to the 1970s and anecdotal reports share a common theme on timber harvest activities: streams declined in habitat quality differences in stream habitat conditions and fish populations before and after logging activity; timber harvest activities had little to no protective rules in place to safeguard riparian zones, stream habitat, or fish populations until the mid 1970s; and declines in fish abundance after logging activities attributed to early rules that were inadequate and not sufficiently enforced to protect fishery resources (Taft 1933, Shapovolov and Vestal 1938, CDFG 1952a, CDFG 1956a, CDFG 1964a, DWR 1966, CDFG 1969a, DWR 1976 and others). Consequently, spawning habitat and pools were often filled with fine sediment and silt, slash decomposed in stream channels causing oxygen depletion, large debris accumulations blocked fish passage to spawning grounds and water temperature increased due to a lack of shade from near stream forest canopy. In addition, two large flood events in 1955 and 1964 exacerbated problems on the landscape by initiating large scale erosion in the subbasin.

By the 1980's, problems with fish habitat related to timber harvests and other land disturbance activities were becoming more widely known and better surveys, studies, and watershed improvement efforts were beginning to gain acceptance. Additional changes occurred in land use activities as a result of the Threatened or Impaired Watershed Rules and Anadromous Salmonid Protection Rules in 2000 and 2009, respectively. These rules were implemented in response to the continued decline of anadromous salmonid populations.

Current Conditions

Within the Van Duzen River Basin, CDFG inventoried 36 tributaries as well as portions of the mainstem VDR between the years of 1991 and 2006 (Table 17; Figs. 24 & 25). The data collected during these inventories are compared to the target values defined in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998) to determine if habitat conditions within the streams are limiting to salmonid production. Data collected during these habitat inventories describe the canopy density, cobble embeddedness of pool tails, length of primary pools, and mean pool shelter coverage along surveyed reaches within the Van Duzen River Basin. Additionally, the CWPAP evaluates these habitat data using the Ecological Management Decision

Support (EMDS) system software. The EMDS system can evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. More details of how the EMDS functions are in CWPAP Methods Manual. Habitat data collected in the Van Duzen Basin that can be used in the EMDS are: canopy, pool quality, pool depth, pool shelter, and embeddedness (Figures 26–34). Calculations and conclusions made in the EMDS are pertinent to surveyed streams and are based on conditions existing at the time of survey. Tributary EMDS results are presented in the subbasin sections.

Three of the four Van Duzen subbasins have had habitat inventories completed by the CDFG over the past fifteen years (Table 17). The large majority of these surveys have occurred in the Yager and Lower subbasin. The Yager Subbasin, which has the longest length of stream miles, has had the most inventories completed; and most of the streams in this subbasin have had repeat surveys.

Table 17. CDFG stream inventories in the Van Duzen River Basin.

Subbasin	Years of survey	Number of streams surveyed	Number of surveys	Total length of survey (miles)
Yager	1991, 1993, 1996, 2000, 2003 & 2006	17	33	76.9
Lower	1991,1996, 1997, 2006 & 2008	8	14	36.3
Middle	1991 & 1996	3	4	6.5
Upper	1992 & 1994	9	9	N/A

Streamside Canopy Density

Significance: Streamside canopy density is an estimate of the percentage of stream channel that is shaded by riparian tree canopy. An effective tree canopy provides shade to reduce direct sun light from warming water. Generally management to increase shade canopy including re-vegetation projects are considered when canopy density is less than 80% (Flosi et al. 1998). A second attribute of streamside canopy data is the percent of coniferous and deciduous tree species providing the shade. The percent coniferous and deciduous component of the stream side canopy influences the potential for LWD loading. Streams flowing through mature conifer stands tend to have larger amounts of wood with larger average piece size than streams with younger riparian stands, which often are dominated by smaller deciduous species (Bilby and Bisson 1998). LWD produced by conifers is generally favored over deciduous wood because it tends to be larger and less likely to move downstream, it decays more slowly, and stays longer in stream systems.

Pool:Riffle:Run Relationships

Significance: Productive anadromous streams are composed of a balance of pool, riffle and run habitat. Each plays an important role as salmonid habitat. The measure of pool habitat characteristics is an important indicator of stream condition. Productive anadromous streams are composed of a balance of pool, riffle and runs. Each plays an important role as salmonid and stream community habitat. There are several factors affecting the relationships of pools, runs and riffles. These factors include channel type, stream gradient, bed materials, width to depth ratios and flow obstructions such as boulders and LWD. A pool to riffle ratio of approximately 1:1 has been suggested to

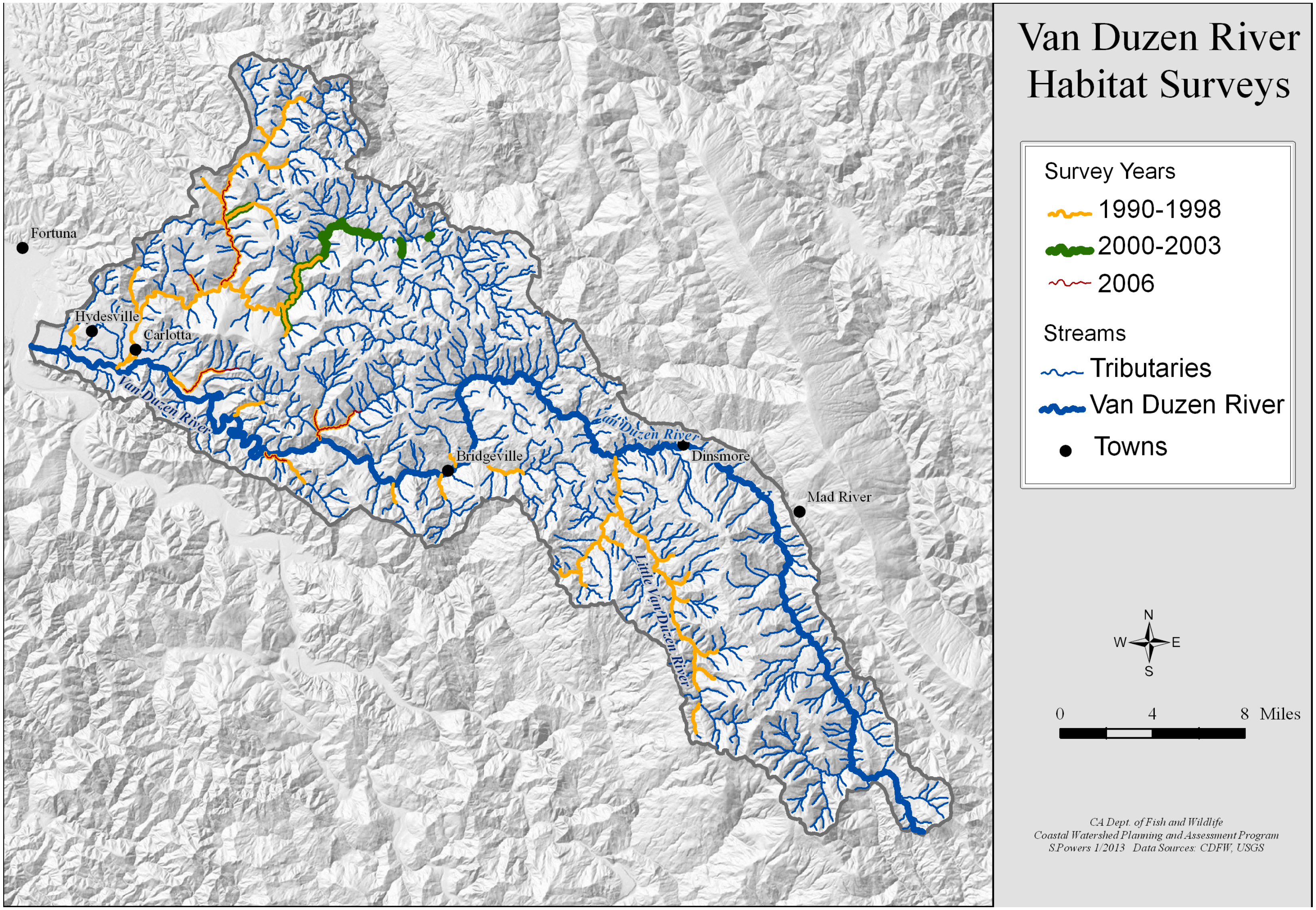


Figure 25. Habitat surveys conducted on the Van Duzen River Basin by California Department of Fish and Game

provide optimum food production and cover conditions for juvenile coho and other salmon (McMahon 1983; Rosgen 1996). Flosi et al. (1998) also notes that the length of anadromous salmonid streams should be composed of 40% pool habitats.

The number of pools or pool frequency can be measured as a ratio of the number of bank full widths (BFWs) per pool in a stream reach. Using this metric, pool to pool spacing in many redwood forest streams ranges from approximately 2 to 5 BFWs and is often controlled by LWD (Keller and MacDonald 1981). In straight and meandering streams, pools are also often spaced more or less regularly at a repeating distance of 5 to 7 BFWs (Leopold 1994).

A potential problem with using this metric is that BFWs may be widened from disturbance associated bank erosion during recent flood events. Since pool spacing is influenced by BFW, pools may be less frequent than pre-disturbance conditions if channels have widened, but appear within desirable ranges relative to present conditions.

Pool Depth

Significance: Deep pools are important for adult salmonid holding areas during spawning migrations and as year round habitat for rearing juvenile salmonids. Quantifying the amount of deep pool habitat in a stream reach is a useful indicator to assess stream conditions. Many factors can influence pool dimensions and frequency including channel type, bed material size, sediment loads, and LWD, boulders and other flow obstructions (Buffington et al 2002). In streams of the Van Duzen Basin a shortage of deep pools commonly indicates elevated levels of stored sediments and/or lack of LWD. Generally, the desirable length of a coastal anadromous stream reach should consist of approximately 30 – 40% pools with moderate maximum depths. Moderate maximum depths for the Van Duzen Basin streams are pools with maximum depths of from 2.0 to 2.5 feet for 1st and 2nd order streams, >3 feet for 3rd order steams and >4 feet deep for 4th order streams. These target values were developed to help assess the pool condition of anadromous salmonid habitat in typical north coast California streams. However, shallow pool conditions are more likely in low gradient reaches within small watersheds that lack sufficient discharge to deeply scour the channel. Therefore, some smaller streams may not meet the general pool target values, but still provide important fish habitat.

Pool Shelter

Significance: Salmonid abundance in streams increases with the abundance and quality of shelter of pools (Meehan 1991). Pool shelter complexity is rated by a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation (Flosi et al. 1998). These elements serve as instream habitat, create areas of diverse velocity, provide protection from predation, and separates territorial units to reduce density related competition. The ratings range from 0-300, with ratings of ≥100 considered good shelter values, however they do not consider factors related to changes in discharge such as water depth.

Most pools in forested mountain streams are associated with boulders and LWD that scour bed materials during channel forming flows (Montgomery et al. 1997). A low measure of pool occurrence, pool area, pool depth, and pool shelter is often found in stream channels that are in low supply of LWD. A common result from land use practices and winter storms over the last 100 years has been the wide spread erosion of the landscape that contributed vast amounts of sediments and logging debris to stream channels. In large supply, sediments tend to accumulate in pools especially when pools lack scour objects. The lack of pool and channel bed form diversity is often related to the oversupply of sediments.

The overall lack of instream LWD has led to a reduction in pool habitat area in many streams when compared to the pre logging era descriptions. Therefore indicators of aggraded channels may be large proportions of run or riffle habitats compared to pools. Most coastal streams with less than 25% of their length in deep, complex pools are considered to be lacking good quality pool habitat. We seldom find pool habitat meeting these conditions in north coastal streams in part due to excessive watershed erosion and a generally low occurrence of LWD needed to help form pools.

Spawning Cobble Embeddedness

Significance: Cobble embeddedness is the percent of an average-sized cobble piece at a pool tail out that is embedded in fine substrate. Percent cobble embeddedness provides a measure of spawning substrate suitability for egg incubation, and fry emergence. Excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds, which may suffocate eggs or developing embryos. Excessive levels of fine sediment accumulations within gravel and cobble substrate may also alter aquatic insect species composition and may also reduce connectivity of flow between surface and subsurface stream flows needed to moderate water temperature.

High embeddedness ratings may indicate elevated levels of erosion occurring somewhere in the watershed due to natural and/or human causes. The potential for high levels of fine sediments is higher in watersheds like Yager Creek where the geology, soils, precipitation, and topography cumulatively exacerbate erosional processes. Fine sediments are typically more abundant where land use activities such as road building or land clearing expose soil to erosion and increase mass wasting (Cederholm et al. 1981, Swanson et al. 1987, Hicks et al. 1991).

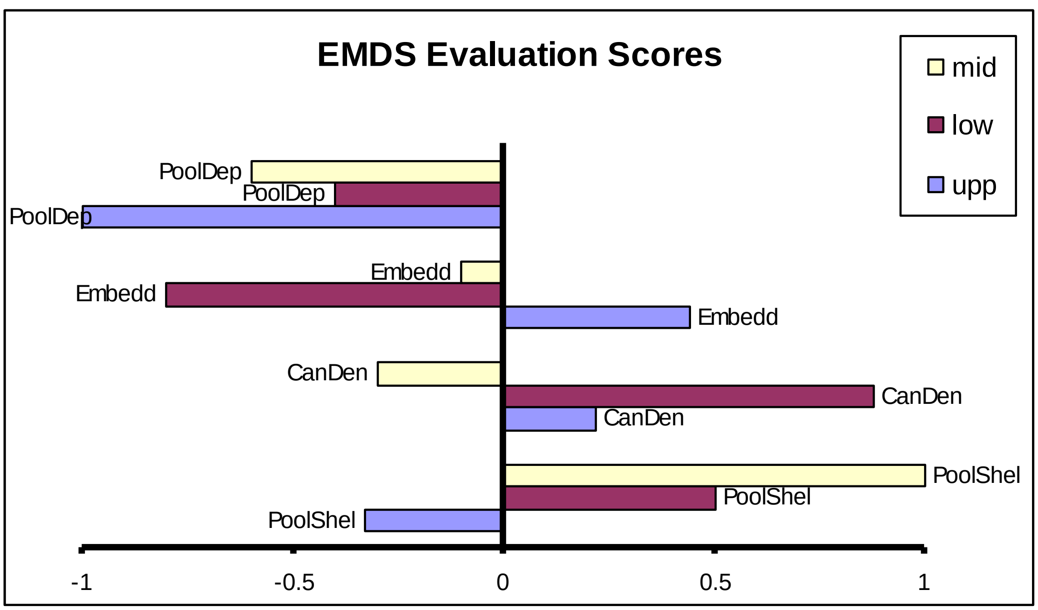


Figure 26. An example of EMDS evaluation utilizing hypothetical stream habitat data.

Habitat Improvement Projects

The CDFG Fisheries Restoration Grant Program (FRGP) was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California. With wild populations of coho and Chinook salmon at critically low levels, restoring anadromous salmonid habitat is a commitment this program and partners have embraced. There are many opportunities in the Van Duzen Basin for restoration projects to increase stream habitat quality. The program goals are to reduce excessive sediment inputs to streams, improve fish passage, and help restore riparian and instream habitat values to benefit anadromous salmonids. Grants also provide fish and watershed management education. Contributing partners include the CDFG, federal and local governments; tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps (CCC), AmeriCorps, and private landowners. This competitive grant program has invested approximately $250 million to support watershed improvement projects throughout coastal California.

As of 2009, approximately three million dollars has been spent on fifty-one watershed improvement projects in the Van Duzen River Basin under the CDFG's FRGP. The projects include instream restoration, monitoring and research, riparian restoration, road upgrade and decommissioning, stream crossing improvements or road removal, and upslope management (Figure 21, Table 18). However, it is important to note that only projects that received funds from CDFG's FRGP are shown in Figure 21. The California Habitat Restoration Project Database (CHRPD) maintains habitat restoration project data from the CALFED Ecosystem Restoration Program, the National Fish and Wildlife Foundation, the State Coastal Conservancy, the NOAA Restoration Center, the U.S. Fish and Wildlife Service, and the CCC. Figure 27 displays these additionally funded restoration projects by category that have occurred in the Van Duzen Basin from 1983 to 2006.

The CDFG, CCC, PALCO, Eel River Watershed Improvement Group (ERWIG), Yager Environmental Stewards (YES), along with other land owners and restoration specialists have completed several upslope and instream habitat improvement projects in the basin. The project goals have been to reduce sediment delivery from roads, promote growth of riparian vegetation, increase stream habitat diversity, and restore fish passage into spawning streams. These habitat improvement projects were in part the result of recommendations from CDFG stream surveys of the 1980-2000s, or were volunteered by land owners or required by timber harvest regulations. A major goal of this assessment report is to provide recommendations, justifications and reference for future habitat improvement projects in the Van Duzen Basin.

Table 18. Amount of FRGP funds spent in Van Duzen Basin by watershed improvement type 1981-2009.

Watershed Improvement Type	Amount of FRGP funds spent
Fish Ladder	$7,482
Instream Barrier Modification	$56,318
Instream Habitat Restoration	$544,282
Riparian Restoration	$179,227
Instream Bank Stabilization	$395,090
Watershed Restoration (Upslope)	$1,778,337
Monitoring	$69,382
Total:	**$3,030,118**

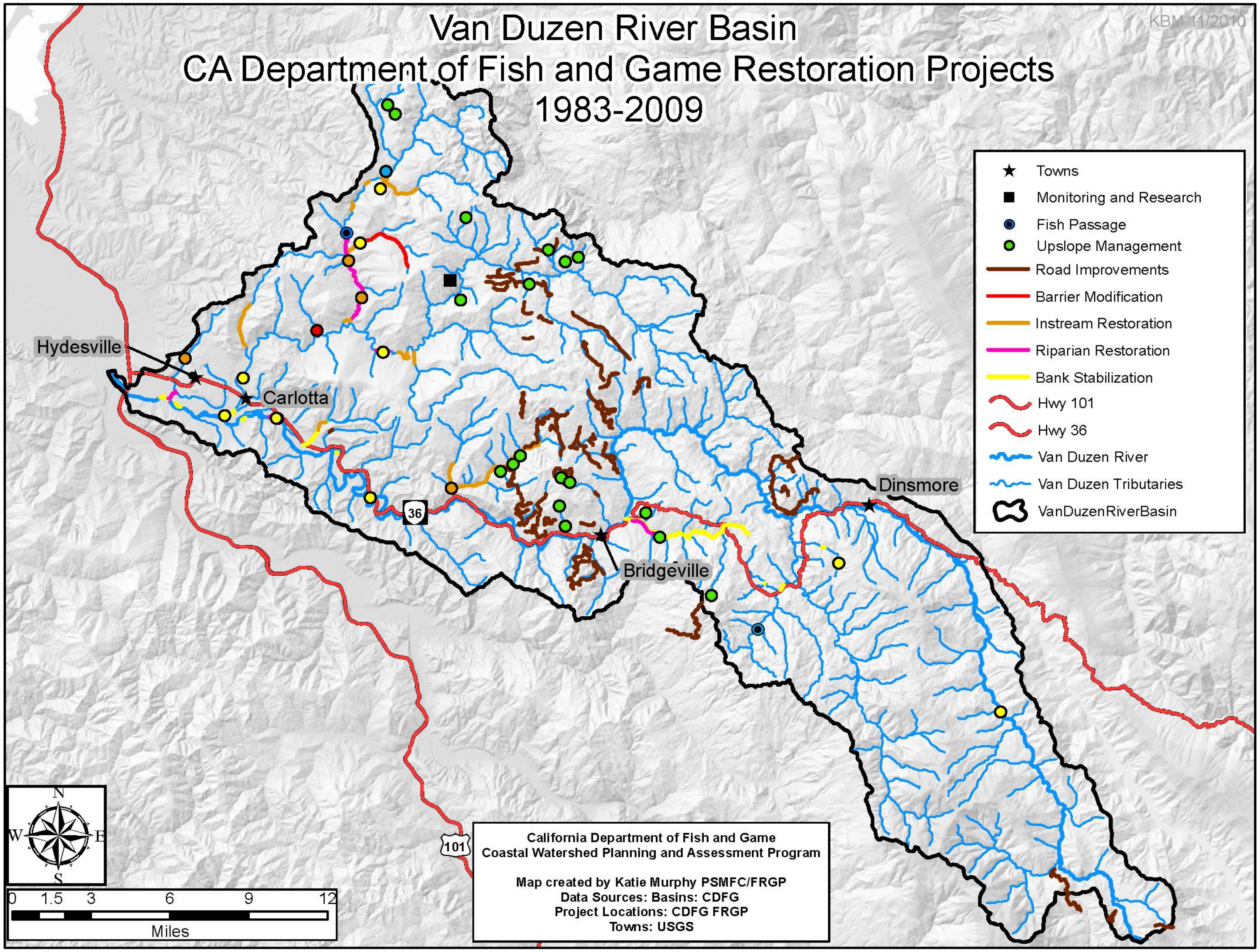


Figure 27. California Department of Fish and Game habitat restoration projects in the Van Duzen River Basin from 1983-2009

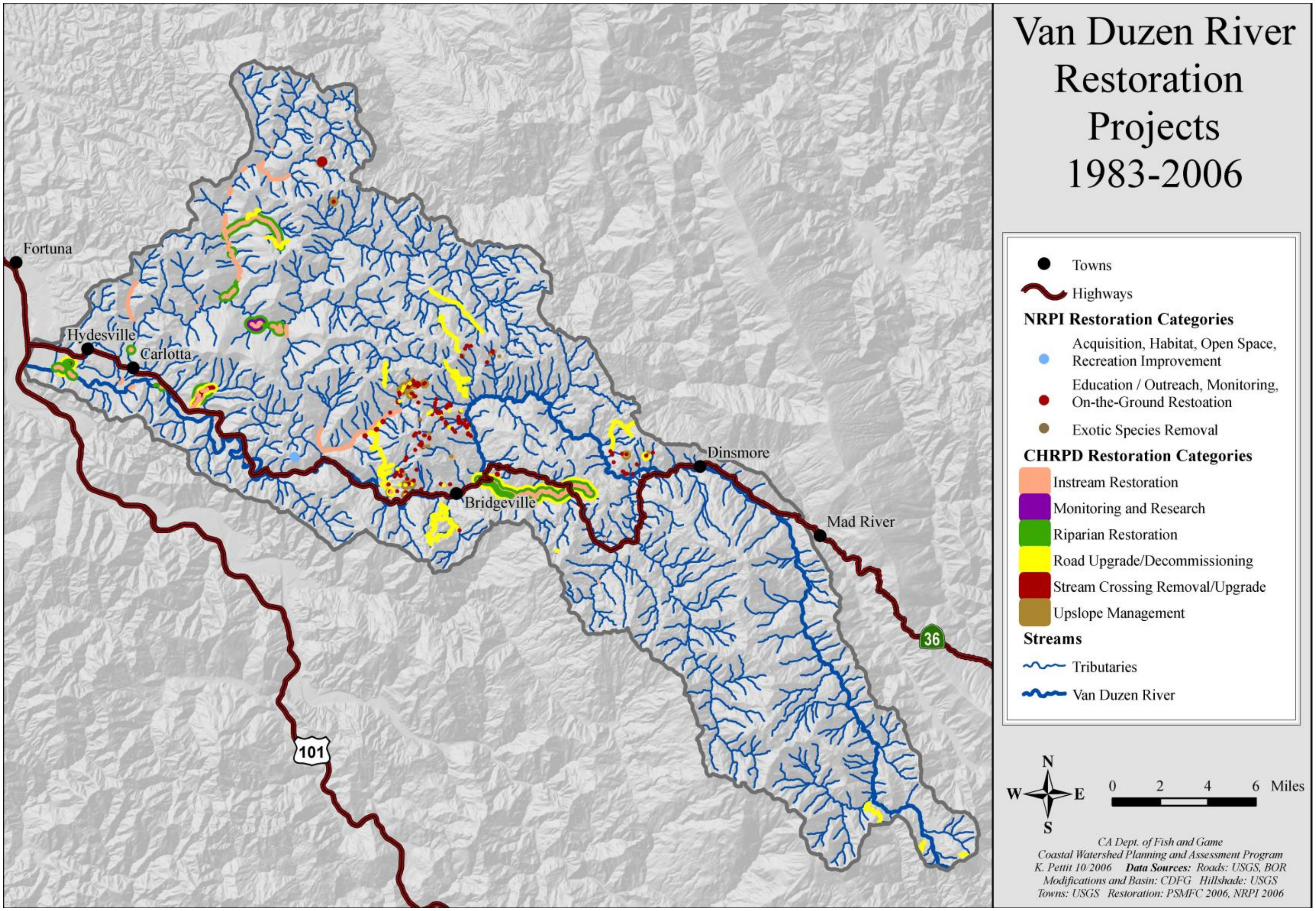


Figure 28. Restoration projects in the Van Duzen River Basin from 1983-2006.

Integrated Analysis

The geologic composition of the Van Duzen River Basin contributes to a great extent to watershed processes that form and maintain stream systems and aquatic habitats needed to sustain anadromous salmonid populations. Major features of the basin's geology are bedrock type, tectonics, faulting and hill slope inclination. Cumulatively, these features along with winter rains contribute to formation of the stream drainage network, and determine erosion potential as well as the amounts and rates of sediment delivered to streams. Sediment inputs are important to maintain stream ecologic processes and to support anadromous salmonids. However, excessive amounts of sediment deliveries have significantly impaired salmonid habitats in the Van Duzen River since the major flood events of 1955 and 1964. These legacy impacts and present day, persistent, excessive sediment deliveries are noted as key factors contributing to declining salmonid populations (Meehan 1991; USEPA 1999). Since most of the bedrock types of the Van Duzen Basin are considered highly prone to erosion, geologic features are major factors for consideration when developing stream, riparian and land use management plans. Geologic characteristics of the Van Duzen River Basin are summarized below and are reviewed in greater detail in each of the subbasin sections that follow.

The combination of tectonic, geologic, basin morphology and climatic factors makes much of the Van Duzen River Basin very susceptible to erosional processes. The amount of erosion that occurs on an annual basis is also related to hydrologic factors such as the duration and intensity of winter storms and soil saturation levels. In addition, because the basin terrain is naturally unstable, any land use that weakens structural integrity of hillslopes can add significantly to landsliding and cause excessive amounts of sediment inputs to stream channels.

CDFG confirmed the status of stream habitat factors (such as water temperature and pool characteristics) that characterize stream condition are a cumulative product of watershed conditions, land use, and dynamic watershed processes and stream conditions and limiting factors may be linked to actions or events that occur at various spatial and temporal scales. These findings illustrate that relatively short term disturbance to watersheds can have long term effects to stream systems and salmonid populations.

To simplify a complex problem of identifying numerous watershed factors that affect stream conditions, the CWPAP identified four primary factors: 1) the unstable geology and relatively weak lithology make lands of the Van Duzen River Basin naturally susceptible to erosional processes; 2) large winter storm events elicit erosional processes on the landscape; 3) land management actions often increase erosion potential, exacerbate land instability, or accelerate runoff that results in excessive sediment input to streams; and 4) land management actions can devalue beneficial qualities of near stream forests, upland forests, and other vegetation characteristics that lead to a reduction in shade canopy, reduces LWD loading potential, and eliminates air cooling microclimate effects.

The present habitat problems observed in most streams of the basin are often related to excessive sediment inputs to stream channels and/or the lack of a large conifer component in nearstream forests. When excessive amounts of sediment is delivered to the stream network, fluvial processes and stream channels respond in ways that can result in several adverse impacts to salmonid habitat. These include channel aggradation, stream bank erosion, widened channels, increased width to depth ratios, filling of pools, loss of riparian shade, increased water temperature, loss of channel diversity, loss of stream connectivity, impediments to spawning migrations and prolonged high turbidity levels. The negative impacts from excessive sediments are in some cases elevated by the general lack of instream LWD needed for pool scour and sediment routing processes.

As a result of timber harvests and stream bank erosion, there is a low potential for near term LWD input to several anadromous reaches in the basin. In the Middle and Upper subbasins, over 75% of the area within a 150 foot buffer width along anadromous salmonid bearing reaches is composed of trees that average less than 24 inches diameter at breast height (DBH) and 35% of the area has trees that average less than 12 inches DBH. Fox (1994) suggested that for streams ranging from 20 to 45 feet channel width, key individual LWD pieces should be 22 to 25 inches in diameter and 32 to 59 feet long. For a channel the size of mainstem Van Duzen River, the size of functional LWD is much larger. Based on these data, near term LWD recruitment to streams is likely less than what is needed for channel maintenance, instream cover for fish, and nutrient inputs.

The lack of large trees and the shade they provide has also contributed to the warming of the mainstem Van Duzen. Salmonid habitat is impaired by warm water for most of its length.

Figure 31. Photo of the lower Van Duzen River.

Basin Scale Responses to Assessment Questions

The following discussion of the assessment questions and recommendations for improvement activities are generalized to the basin scale.

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Van Duzen River Basin?

- The Van Duzen River basin supports populations of Chinook and coho salmon, and steelhead and coastal cutthroat trout;
- Salmonid populations have declined from historic levels, prompting listings under the state and federal ESA;
- Present populations of anadromous salmonids are overall less abundant and less widely distributed compared to their historic presence. It appears that populations declined abruptly during the years following the December 1964 flood;
- Summer steelhead, coho and Chinook salmon and coastal cutthroat trout have likely suffered widespread declines due to their sensitivity to degradation of specific habitat factors necessary to complete the freshwater and /or estuarine phase of their life cycle;
- Because winter steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the basin and have persisted in streams where other species have declined or are now rarely observed;
- Coho salmon is the most prone to extirpation of all the anadromous salmonid species of the Van Duzen River Basin;
- Coho counts at Benbow Dam fish ladder located on the South Fork Eel River provide convincing evidence of the declining trend in coho production;
- The capacity for salmonids to increase in abundance and distribution is in part limited by the reproductive potential of existing stocks;
- Given improving aquatic habitat conditions, it will take several generations before salmonid populations rebound to viable levels;
- Not enough population information is available to determine if the long-term declining stocks trend still predominates over the basin.

What are the current salmonid habitat conditions in the Van Duzen River Basin? How do these conditions compare to desired conditions?

- There are approximately 101.5 miles of tributary streams and 47 miles of Van Duzen mainstem accessible to anadromous salmonids. Approximately two-thirds (66 miles) of the available tributary habitat is located in the Yager Creek and Lower subbasins;
- Patches of good quality salmonid habitat exist within each of the subbasins;
- Stream conditions are generally below desirable standards for salmonid habitat. Cumulative land use and watershed effects have contributed to high stream temperatures and a general lack of stream habitat diversity;
- Presently, high summer water temperatures in the majority of the length of mainstem Van Duzen River is deleterious to summer-rearing juvenile salmonids and adult summer steelhead;

- Juvenile salmonids have been observed concentrated in patches of cool water refugia during warm summer months, when adjacent water is too warm for suitable habitat;
- Many tributaries have cool water temperatures but may lack the combination of structural components that create the habitat diversity and complexity considered desirable for good salmonid habitat;
- The amount of LWD needed for pool formation, shelter elements and spawning gravel recruitment is generally below levels needed to maintain high quality stream channel conditions for salmonid production in the majority of the basin's streams;
- Productivity in streams may be reduced by a general lack of organic matter inputs from instream LWD and the decline in returning salmon whose carcasses are valuable sources of nutrients to fuel the aquatic food web;
- Riparian shade canopy is poor along the mainstem Van Duzen and Little Van Duzen and overstory shade and air temperature moderating benefits provided by large coniferous trees is lacking;
- The riparian shade canopy provided by hardwood trees is generally good along surveyed sections of anadromous fish bearing tributary reaches in all subbasins;
- A general trend towards improved channel conditions measured by declining sediment accumulations and an increase in channel form development has occurred in the mainstem of the Upper Subbasin and portions of the Middle Subbasin and some tributary streams;
- Streams have not recovered in a linear fashion from excessive sediment inputs; rather recovery has reversed at times at various locations.

What are the relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?

The Van Duzen Basin has been described as a highly susceptible to erosion. The combination of naturally unstable terrain and infrequent, severe storms and land disturbance from intensive timber harvesting can trigger major episodes of erosion. Earlier studies showed that the damage caused by the flood of December 1964 was severe, widespread and simultaneous (Kelsey 1977).

- The basin is located in a tectonically active and geologically complex region with recent rapid uplift of the weak bedrock underlying the landscape. Most of the bedrock is relatively weak, easily weathered and naturally susceptible to landsliding and erosion;
- Significant factors affecting stream habitat conditions are excessive hillslope erosion and associated sediment inputs to streams, a reduction of nearstream shade canopy, and a lack of LWD input from large nearstream coniferous trees;
- The unstable geology, dynamic tectonics, steep topography, and high precipitation rates of this region combine to make it one of the most erosion prone in the United States;
- Vegetation plays a crucial role in watershed processes needed to maintain productive salmonid streams;
- Riparian and nearstream forests play important roles in shaping stream channel morphology;
- Root masses from the trees increase soil cohesion that helps stabilize stream banks and hillslopes;

- Riparian and nearstream forest trees are a source of LWD loading into stream channels needed for channel forming processes, sediment routing and shelter elements for fish;
- Large channel forming flows can help improve bed form development (pool riffle run sequences). However if these flows are accompanied by large landslides initiated by winter storm events, then more sediment may enter the channel than is mobilized and transported by flow which can inhibit bed form development;
- Excessive sediment accumulations in stream channels are in part related to the lack of instream LWD needed to create scour objects that move sediment downstream;
- The overall lack of instream LWD has led to a reduction in pool habitat area in many streams when compared to the pre logging era descriptions;
- Stream flows can rise and fall suddenly in the Van Duzen Basin and may cause flooding in response to intense winter rains;
- Lags in response and recovery times of 1 to 100 years or more confound measurements of stream habitat conditions;
- Many of the adverse changes to stream habitat conditions have been exacerbated by winter floods and summer droughts;
- The Van Duzen River and its tributaries respond quickly to precipitation events;
- Stream gradients influence the transport and accumulation of sediments in the river system;
- Historically active landslide features comprise approximately 5% of the basin area;
- The Yager and Upper subbasins are the most geologically unstable parts of the basin. The instability of these subbasins contributes largely to the movement of sediment from the hillslopes into the stream system;
- The Upper Subbasin contains the highest length of stream channels adjacent to landslides;
- Excessive sediment generated from landslides or other erosional processes is often delivered to stream channels where it may impair stream habitat conditions;
- Excessive erosion and associated sediment inputs to stream channels contributes to channel bed aggradation, loss of channel complexity, filling of pools, stream bank erosion, channel widening, undercutting and loss of streamside trees, loss of riparian shade, increased stream temperature, a reduction of surface flow, loss of channel connectivity, and the introduction of fine sediments to streams reduces spawning substrate quality;
- Gully and stream erosion at toes of earthflows can accelerate earthflow movement and sediment inputs to stream channels;
- Recent studies indicate that channel-storage reservoirs are still partially full from the last series of large floods and the potential for large scale sediment delivery exists;
- While sediment is generally transported relatively quickly from source reaches and from steeper transport reaches, it can remain for decades in the lower gradient response reaches of the Lower Subbasin mainstem channel;
- The bulk of the heat input to water of mainstem Van Duzen occurs in the Upper Subbasin where the water warms especially quickly during hot summer days;
- Direct exposure to sunlight due to lack of shade canopy in the Upper and Middle subbasins contributes to higher water temperatures;

- Change in riparian and near stream forest structure and function has also played a role in degrading channel conditions and altering channel maintenance processes. The general lack of LWD in many stream channels impairs pool development, sediment routing, and organic nutrient inputs needed to fuel the aquatic food web;
- A cumulative effect from excessive sediment inputs and lack of shade and lack of other benefits provided nearstream forests in the Upper and Middle subbasins is much of the mainstem Van Duzen salmonid habitat is impaired by warm water temperature;
- The recruitment of LWD to stream channels is limited due to a lack of large, mature conifers growing near the stream zone in much of the basin;
- The riparian and nearstream forest along many of the basins' tributary streams are mainly composed of small sized trees and these trees are not yet capable of providing full benefits of shade, slope stability and LWD to aquatic habitat;
- General trends in the basin are toward the improvement of a number of the factors that currently act on stream conditions. Recovery appears to be occurring in terms of declining sediment in most channels and increasing tree growth in riparian areas.

How has land use affected these natural processes?

- Primary causes for stream habitat deficiencies can often be traced back to land management actions that increase erosion, or activities that alter characteristics of near stream forests;
- High summer water temperatures can be a limiting factor to salmonid production and are often linked to near stream timber harvests or other uses that contribute to the loss of shade quality and microclimate;
- Within the past 10 years increasing conversions on private property of large, industrial marijuana agriculture operations have proliferated from the upper portion of the Lower Subbasin throughout the Middle Subbasin and into the Upper Subbasin. These mostly unregulated operations have decreased summer/early fall stream flows and degraded water quality in Van Duzen River and its tributaries;
- Land use activities that remove large trees from near stream forests have changed the amount and reduced the size of LWD that is potentially available for input to stream channels, thereby altering present and near future channel processes, morphology and aquatic habitat. The overall lack of instream LWD has led to a reduction in pool habitat area in many streams when compared to the pre logging era descriptions;
- A common result from land use practices and winter storms over the last 50-60 years was the wide spread erosion of the landscape that contributed vast amounts of sediments and logging debris to stream channels;
- Any soil disturbance such as road building, logging activities, or other land use that disturb soil can add to erosion potential in the basin;
- Land management on unstable slopes often exacerbates slope instability and the release of sediment. Relatively minor land use actions, such as undercutting the toes of slopes, increasing the duration of ground saturation, or reducing soil shear strength by a relatively small amount, could trigger extensive landslides;
- Roads, skid trails, and gullies can disrupt natural drainage patterns. Runoff is commonly directed to new areas where gullies erode soil which ends up in streams. Redirected flows also may end up in channels that evolved with lower volumes of water and sediment. The

increase in flow causes expansion of the channel and accelerates bank erosion and sediment delivery;

- Road-related erosion is believed to be a major source of sediments to the stream network.
- Several studies have shown that the relatively high road density increases erosion which generates excessive sediment inputs to streams;
- According to USEPA, tractor yarding used in clear cut timber harvests cause the most erosion and generate the highest sediment yields of all land use types in the basin;
- Nearstream forests along mainstem Van Duzen and many tributaries in the basin have undergone timber harvests that removed large conifers from the riparian zone;
- Harvesting of large conifers has removed the beneficial functions of large riparian vegetation (including shade, moderating air temperature, bank stability, potential recruitment of LWD, and nutrient inputs) needed to maintain salmonid habitat;
- Legacy impacts due to logging and widened mainstem channel from excessive sediment inputs have caused a shortage of trees large enough to provide temperature moderating shade over the water;
- Land use in the basin, including road construction, timber harvesting, livestock grazing, slash burning and other human activities increases storm runoff rates and accelerates mass wasting processes and erosion rates. These impacts on the basin's unstable terrain contributes to excessive sediment inputs to streams;
- Many of the effects from land use activities on upland sediment sources and are spatially and temporally displaced from response reaches;
- Kelsey (1978) suggested that earthflow activity was accelerated or initiated during the last century by livestock grazing and subsequent conversion of prairie vegetation from perennial long-rooted native bunch grasses to annual short-rooted exotic grass;

Based upon these conditions, trends, and relationships, are there physical elements that could be considered to be limiting factors for salmon and steelhead production?

- Many of the same factors limiting salmonid production occur within all subbasins;
- High water temperature limit juvenile salmonids from utilizing rearing habitat in much of the mainstem Van Duzen and also the lower reaches of some tributary streams;
- Barriers to fish passage from sediment deltas limit fish access to some tributary spawning grounds;
- The lack of high quality spawning substrate in the Lower, Middle, and Upper subbasins may limit successful salmonid egg incubation and emergence of fry from redds;
- The lack of deep pool habitat in all subbasins is a limiting factor for juvenile salmonids and adult summer steelhead;
- Instream shelter complexity provided by LWD is in short supply across the basin and likely limits salmonid production;
- The reduction of nutrients contributed to streams from decaying wood and decaying carcasses may limit salmonid production levels in the Van Duzen River.

<u>What habitat improvement and other activities would most likely lead toward more desirable conditions in a timely, cost effective manner?</u>

A considerable amount of restoration work has been done on PALCO lands (now Humboldt Redwood Company). Road removal and stabilization and improvement of existing roads and stream crossings, and improving fish passage have been a major focus of this work. Working together, the major landowners recently completed assessment work to identify erosion related problems with the roads throughout the basin. The landowners are now working to implement the road improvement recommendations produced through the road assessments.

<u>Barriers to Fish Passage</u>

- Annual channel maintenance is required to facilitate fish passage into the lower Van Duzen River from Eel River;
- Inspect fish passage into Wolverton Gulch and at culverts located on HWY 36 and Rohnerville Road;
- Fish access into Cummings and Fiedler creeks should be improved by channel reconfiguration in their lowermost reaches;
- Review options for improving salmonid spawner access through sediment deltas into Root and Hely creeks.

<u>Flow and Water Quality Improvement Activities:</u>

- Keep cold springs and seeps cold. Fish depend on these cold water sources to keep streams cool or as cool water refuge sites where they flow into streams.
- Fish habitat requirements and channel maintenance flows should be considered prior to any water development projects including riparian diversions and small domestic water use;
- In order to help reduce water temperature in tributaries and the mainstem, ensure that near stream forest management encourages growth and retention of conifers sufficient for providing shade and cool micro climate benefits to stream and riparian zones;
- Consider using willow baffles, tree planting or other applicable methods to promote effective shading from riparian trees and to reduce the channel width along reaches widened stream reaches.
- Timber harvests or other land use should be conducted in a manner that does not increase peak flows, accelerate runoff rates, or deliver excessive sediment to stream channels.

<u>Erosion and Sediment Delivery Reduction Activities:</u>

- Existing sediment production problem sites that have potential to deliver sediments to streams should be evaluated and mitigated;
- Since timber harvesting and other land use can cause disturbances that may contribute to slope instability, management on slopes with high landslide potential and/or on lands adjacent to streams should first involve a risk assessment or be avoided. Determination of appropriate practices should be made through the use of the CGS landslide and landslide potential maps, in conjunction with site-based geological examinations by licensed and appropriately trained geologists;

- Landowners should continue road erosion hazard surveys throughout the basin and use this information to set priorities for road removals and upgrades, and implement these improvements as rapidly as private and public funding allow. Roads located on unstable slopes and roads near streams should receive high priority for survey and upgrades and decommissioning projects;
- Consider avoidance or mitigation for risks of excessive erosion when planning, building or removing roads in or near deep-seated landslides and earthflows;
- Reduce road density across the basin;
- If new roads need to be constructed, they should be designed to prevent erosion and not be located near the valley bottom where they may pose a high risk of generating sediment delivery to streams. Consider locating roads along ridge tops where feasible;
- The use of fire for site preparation purposes should be minimized on schist soils during warm, dry periods (late summer and fall).

<u>Riparian and Stream Habitat Improvement Activities:</u>

- Promote growth and retention of large conifers in the riparian corridor along mainstem and tributaries;
- Where current near stream forest canopy is strongly dominated by hardwoods and site conditions are appropriate, land managers should consider cautious thinning of hardwoods from below to hasten the development of denser and more extensive coniferous canopy component;
- To address the lack of LWD in many tributary channels and along the mainstem, management should promote growth of near stream conifers and allow natural recruitment of trees to stream channels;
- Where near stream conifers are not large enough to function as naturally occurring scour elements, consider importing LWD from nearby hillslopes for placement in locations and orientations where it will provide beneficial habitat elements and will not accelerate adverse bank erosion;
- Add combinations of boulders and LWD to increase shelter complexity to cool water patches located in Van Duzen River and Little Van Duzen. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from springs, seeps and tributary flows;
- For timber harvest plans in the Lower, Yager, and Middle subbasins, consider additional measures to increase function of watercourse protection zones when justified by lack of large conifers to provide shade and microclimate, lack of instream LWD, and low LWD loading potential;
- Consider the use of conservation easements or other management strategies to maximize potential benefits to aquatic habitats from near stream forest protection along the middle and upper reaches of Redwood Creek;
- Consider limiting cattle access in streams where their presence has caused significant bank erosion and impaired growth of vegetation;
- Regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur.

<u>Monitoring, Education and Research Activities:</u>

- A long-term, concerted monitoring effort among the land owners, interested parties, and responsible agencies is needed to determine the status and trends of anadromous fish populations of Van Duzen Basin. Efforts should include annual spawner surveys, summer steelhead dive counts, and monitoring juvenile populations;
- Utilize CalVeg GIS layers to locate areas where coniferous trees are too small to provide beneficial functions of LWD loading. These areas should be considered for LWD addition to stream channels if needed to retain and promote desirable pool characteristics, sediment routing and other channel maintenance processes;
- Temperature monitoring by land owners and responsible agencies should continue at current and additional sites to extend trend lines and track changes that may impact salmonids or that may indicate a status change. The establishment of trend lines from these data will aid in future studies, validate improvements from forest and stream recovery and will be helpful for habitat improvement project effectiveness monitoring;
- Monitoring suspended and in-channel stored sediments by sampling sediment size distribution, turbidity, V*, photo points, etc. should be continued, and tracking of streambed levels with stream channel cross sections should be continued by responsible agencies and landowners;
- Biological monitoring, particularly for aquatic insects and aquatic food web dynamics, will be an important addition to monitoring efforts;
- Ensure that CEQA-compliant environmental assessment is conducted prior to issuance of the Fish and Game Code 1600 series streambed alteration permits and Corps of Engineers or NOAA Fisheries permitting requirements are complete for significant projects;
- It is unclear whether modern timberland management practices will allow full restoration and recovery of desirable watershed ecosystem function. Conservation easements that provide wider buffers along water courses or additional management measures may be needed to provide the protection needed to promote watershed and aquatic ecosystem recovery;
- Stream habitat surveys have not been performed in the middle to upper Van Duzen River (below Eaton Roughs), Little Larabee Creek, and the Little Van Duzen River since the early 1990s resulting in a lack of current information concerning the habitat available/condition to salmonids within the Middle and Upper Subbasin;
- CDFG stream habitat surveys provide information only for reaches accessible to anadromous salmonids. Additional surveys above the limits to anadromy are necessary to identify upstream conditions that affect anadromous reaches such as riparian canopy status or additional sediment delivery sites that may benefit from erosion control treatments;
- Conduct community based outreach meetings to discuss approaches that could be implemented to help address the problems created by industrial marijuana agriculture practices.

Yager Creek Subbasin




Overview

The Yager Creek Subbasin in the northwest portion of the Van Duzen River Basin is the second largest of the four subbasins, draining approximately 140 square miles (*Figure 1*). The subbasin includes 12 Calwater 2.2 planning watersheds (PW) and the portions of Wolverton Gulch and Cummings Creek PWs that drain the Yager Creek watershed (*Figure 2*). The subbasin is sparsely populated, containing only the small town of Carlotta, located in southernmost portion of the subbasin. Vegetation in the subbasin is mostly composed of coniferous forests (78%) and grasslands (11%). Almost the entire subbasin (98%) is in private ownership and land use is dominated by commercial timber harvesting with cattle ranching occurring on prairie grasslands spread throughout the eastern portion of subbasin. General attributes of this subbasin are listed in *Table 1.*

The subbasin's topograpy is a moderately rugged, with slopes ranging from gentle to steep. Stream elevations range from 100 feet near the confluence of Yager Creek and the Van Duzen River to over 3,600 feet in the headwaters of the North Fork (NF) Yager Creek and its tributaries. The western half of the subbasin is dominated by coastal marine climate, giving the area mild, foggy summers and wet winters. While the eastern half has less fog, warmer summer temperatures and the most precipitation. Average yearly rainfall is generally between 50-60 inches with up to 70 inches per year occurring in the higher elevations. Most of this precipitation is in the form of rain with the exception of higher elevations in the eastern portion of the subbasin where snow may accumulate.

With approximately 53 miles of anadromous stream miles, Yager Creek and its tributaries are among the

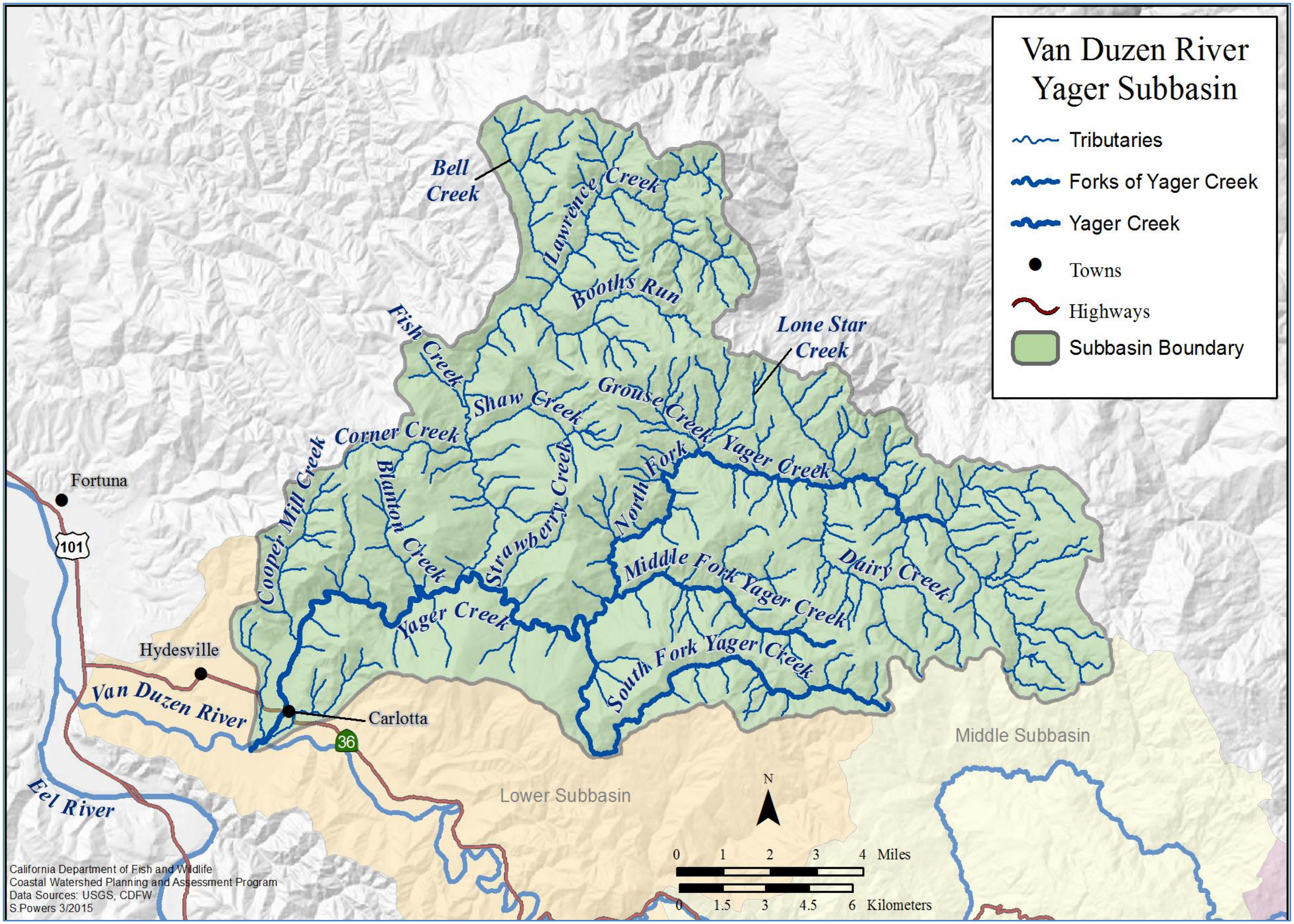


Figure 1. Yager Creek Subbasin map.

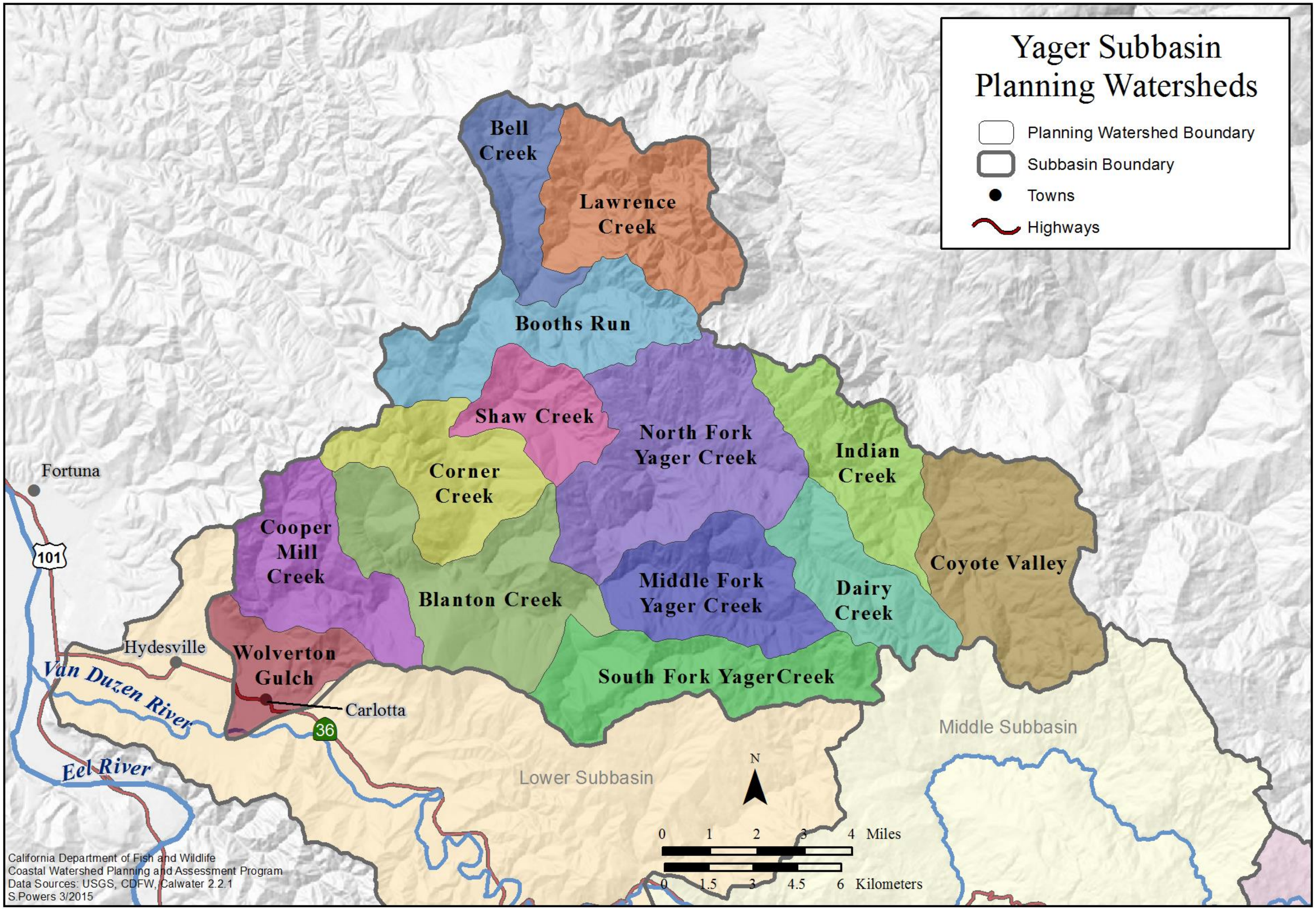


Figure 2. Calwater Planning watersheds of Yager Creek Subbasin.

most important coho and Chinook salmon streams in the Van Duzen River Basin. The streams have received a substantial amount of instream improvement projects over the last twenty years to lessen adverse impacts from past floods and land use issues. A substantial amount of road improvement projects in the subbasin have helped to reduce sediment delivery to streams, however, more road improvement work is needed. Watershed projects and protective measures that improve stream habitat conditions to benefit salmonids in the Yager Creek Subbasin should be considered high priority management objectives.

Yager Creek Subbasin Report Update:

The majority of this subbasin report was completed prior to 2010 (similar to the Van Duzen River Basin Profile and other subbasin sections) and most of the data, graphs, and figures are representative of data collection/analysis up to 2010. However, considering important, recent observations of coho salmon through adult spawner surveys and juvenile snorkel dives, this subbasin report provides some updated fishery resource assessment information.

Table 1. Yager Creek Subbasin geographic summary.

Square Miles	137.5
Total Acreage	87,975
Private Acres	85,865
Federal Acres	935
State Acres	1,166
Predominant Land Use	Timber Harvests/Cattle
Predominant Vegetation Type	Coniferous Forest
Total Stream Miles	313
Stream Miles/Subbasin Miles	2.24
Miles of Anadromous Stream	53
Low Elevation (feet)	100
High Elevation (feet)	4,000

Geology

Bedrock

The Yager Creek Subbasin is composed of 7 different rock types (*Figure 3 and Table 2*) which are described in detail below in order of their abundance within the subbasin.

Melange of the Central Belt of the Franciscan Complex is the most abundant rock type. It makes up approximately 50% of the Yager Subbasin surface lithology. Melange can be described as a completely sheared matrix of argillite and sandstone containing very small (gravel sized) to very large (city block sized), mapable blocks of sandstone, blue schist, greenstone, serpentinite, and chert. Argillite is basically hardened mudstone existing in metamorphic grade between mudstone and shale.

The mélange formed between 65.5 through 199.6 million years ago in the subduction trench between the Farallon and North American plates as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off of the continent (Aalto 1981). This mixture was accreted to the western edge of the continent beginning approximately 88 million years ago (McLaughlin 2000). Because the melange matrix material is internally sheared to such a degree it is very weak and tends to behave more as an extremely viscous liquid than bedrock, slowly "flowing" over time. The "flowing" of melange exposes the more coherent lithologic blocks known as "Franciscan Knockers" and creates a hummocky, rolling landscape. The Central Belt mélange is also considered one of the most unstable rock types in the subbasin and highly prone to erosion especially when saturated with water and/or disturbed by land use. Melange is especially prone to earthflows as well as secondary debris flows.

Yager terrane of the Coastal belt of the Franciscan Complex, named by Burdette Ogle in the early 1950's because its exposure along Yager Creek, makes up 24% of this subbasin. The Yager terrane consists of well consolidated, interbedded sandstone and argillite, and in some places conglomerate.

The geology of this unit is considered a tectonostratigraphic terrane because it has been faulted into its current location by tectonic processes as part of the accretionary wedge and contains a stratigraphic history of deposition, age, and metamorphic grade that set it apart from its neighboring terranes.

For the most part the Yager terrane is relatively stable, however, it has many areas where it is faulted and/or sheared. This typically causes zones of weakness, within the bedrock, that are prone to large-scale landsliding (*Figure 4*). Furthermore argillaceous interbeds of the Yager tend to crumble when exposed to water and air leading to sliding along bedding planes as well as an input of small sediments into streams.

Sediments of the Yager terrane were originally deposited between 65 and 34 million years ago by sediments transported by rivers from as far away as

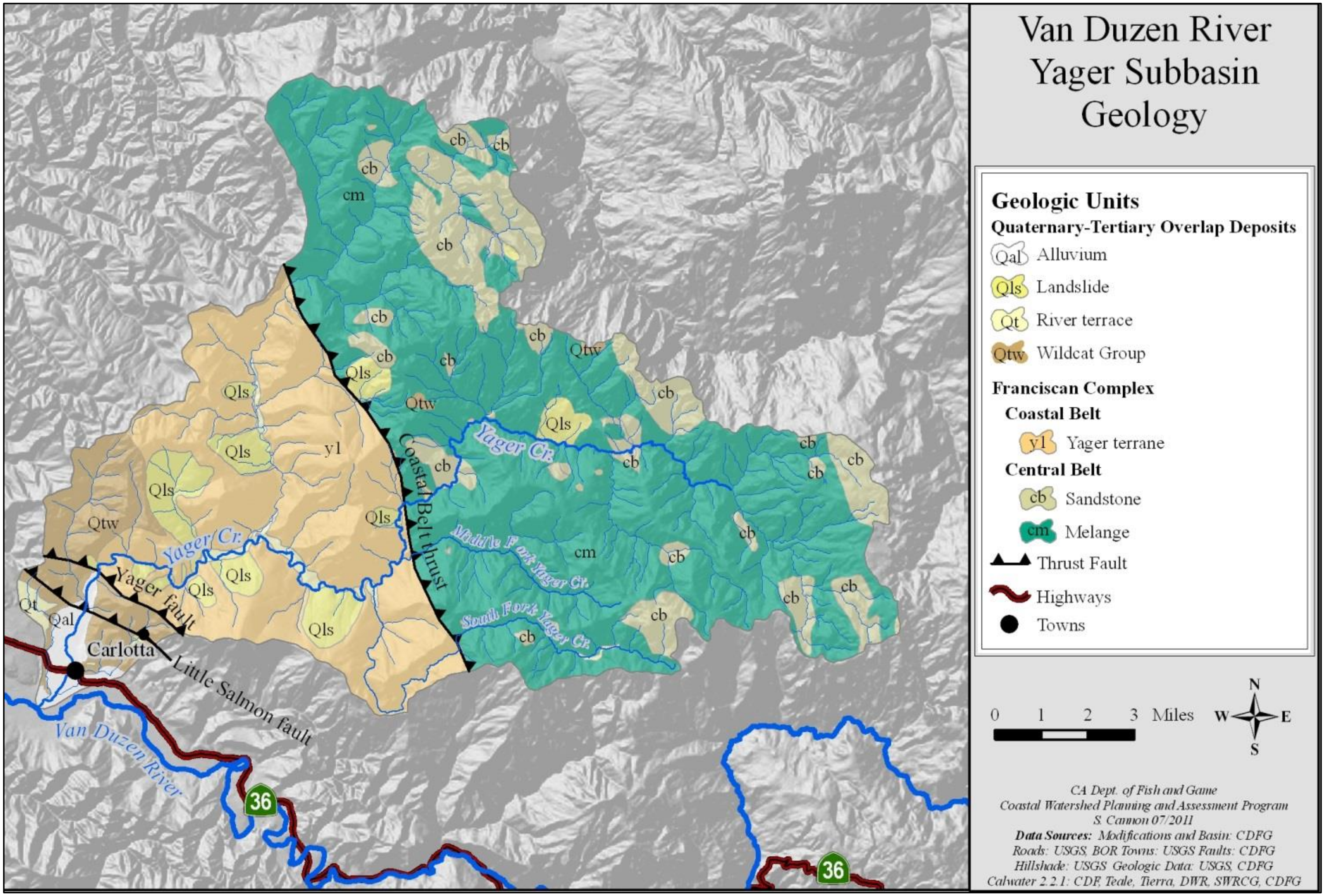


Figure 3. Yager Creek Subbasin geology. Adapted from the U.S. Geological Survey's Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 Minute Quadrangles and Adjacent Offshore Area, Northern California geologic map of California.

Table 2. Surface percentage of lithologic units within Yager Creek Subbasin

GEOLOGIC RELATION AND DESCRIPTION OF MAJOR UNITS WITHIN THE YAGER SUBBASIN						
Unit	**Belt/Rock type**	**Formation/ terrane**	**Composition**	**Erosion**	**Age ma**	**%**
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes.	0-0.01	2
	River terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.		0.01-2	1
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare.	0.01-2	6
	Wildcat group	undifferentiated	Marine mudstone, siltstone, sandstone grading upwards through nonmarine sandstone and conglomerate.	Shallow landslides, debris slides, rotational slides and slumps, and block slides especially along inward dipping bedding planes between sandstone and mudstone layers. Toppling along joints. Some rock falls and slaking of exposed surfaces.	0.78-11.6	6
Franciscan Complex	Coastal belt	Yager terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers.	33.9-65.5	24
	Central belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.	65.5-161.2	12
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert,	Suseptable to mass movement by large earthflows and subsequent debris flows triggered by saturation.	1.8-65.5	50
Sources: Kilbourne, 1985, Ogle, 1953, McLauglin, 2000. % Data represent an approximation based on GIS mapping.						

Idaho (Underwood and Bachman 1986) that accumulated along the continental shelf to the deep marine deposition of sediments punctuated by large underwater landslide events. These subaqueous landslides were likely triggered by large seismic ocean floor. The accumulation of sediment composing the Yager terrane is at least 10 thousand feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents calm, events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003) attesting to the abundance seismic activity in this region coupled with high erosion rates contributing large amounts of sediments during the deposition of the Yager terrane.

Although considered relatively stable compared to other rock types in the subbasin, the Yager terrane of the Yager Creek Subbasin yields the highest percentage of land use generated sediment to stream channels within the Van Duzen River Basin (USEPA 1999). Yager terrane is especially prone to debris sliding on steep stream banks (Kelsey et al. 1075).

Central Belt sandstone makes up roughly 12 percent of the surface of this subbasin. The Central Belt sandstone units are basically described as large blocks of slightly metamorphosed sandstone, graywake ("dirty" sandstone), and argillite (McLaughlin 2000). They most likely formed from 65.5 through 161.2 million years ago as sediment eroded from the continent as far away as Idaho (Underwood and Bachman 1986), and blanketed the subduction trench. These layers of sediment are not as tectonically mixed as sediments within the mélange and have been preserved relatively intact. Although they have been metamorphosed, folded, and sheared to some extent they are more coherent than the mélange. The Central Belt sandstone is generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages (Kelsey et al. 1975).

The Wildcat Group consists of soft marine sedimentary bedrock and occupies approximately 6 percent of the subbasin. The Wildcat consists of marine sandstone, siltstone and claystone deposited within the last 11 million years, representing a time when this area went from a deep to a shallow sea. Capping the Wildcat Group are non-marine conglomerates and sandstones deposited in the last 2 million years, representing a time when this area was uplifted above sea-level and became dominated by river systems.

The Wildcat is highly prone to erosion especially when disturbed by land use. Landsliding is most common in zones between mudstone and sandstone beds with inward dip especially during episodes of saturation.

Quaternary landslides. This subbasin has a relatively large amount of mapped, large Quaternary landslide features. Although they occupy only about 6 percent of the subbasin, they reflect only what has been mapped on a large scale. Many smaller, less obvious landslides most likely exist that have not been mapped or have been mapped as part of landslide inventories at a much more detailed scale. Large mapped landslides that have occurred sometime within the last 2 million years are concentrated in Shaw, Blanton, and Corner Creek Planning Watersheds (mapped as of 2000 – McLaughlin et al). The toes of these landslides are typically eroded by winter stream flows causing prevalent secondary, smaller scale sliding and input of sediments into the river system. Furthermore, if the toes erode far enough or if there is a large, local seismic event these landslides may reactivate. Being mostly older or dormant landslide features (active prior to 1900), many have re-vegetated and to some extent stabilized. However, because the coherency of the bedrock has been disrupted, the deposits are prone to further sliding from reduction of slope stability from even minor land use actions and may increase surface erosion.

Alluvium blankets the stream channels and their associated floodplains occupying nearly 2% of the subbasin. Alluvium includes any actively moving stream channel sediments as well as unconsolidated bank deposits and floodplain deposits.

River terrace deposits including some Hookton formation occupy only 1 percent of this subbasin. These terrace deposits consist of unconsolidated through poorly consolidated cobbles, gravels and fine sediments. These terraces that were once river channel and flood-plane alluvial deposits have been raised during the last 2 million years by regional tectonic uplift above the hundred-year-flood level. Typically river terrace deposits form steep channel banks that are prone to dry ravel and slumping.

Faults and Shear Zones

The Little Salmon fault, Yager fault, and Coastal belt thrust run through this subbasin disrupting the coherency of the bed rock and increasing the erosion potential (*Table 3*). The Little Salmon and Yager faults are active and occasionally generate earthquakes large enough to trigger landsliding.

The Little Salmon fault is an active, northeast-dipping thrust fault that trends northwest coming onshore near Eureka and terminating approximately at Cummings Creek within the Lower Van Duzen River Subbasin. It is about 50 miles in length and is the dominant active fault within the Van Duzen River Basin. This fault is capable of generating large earthquakes (~M 7). The Little Salmon fault has accommodated over four miles of dip-slip offset during the last million years (Carver and Burke 1992).

The Yager fault is a low-dipping thrust fault that trends northwest through the basin. The Yager fault may be an active offshoot of the Little Salmon fault.

The Coastal Belt Thrust fault is the major fault that juxtaposes the Coastal belt and the Central belt. It trends north by northwest through the Van Duzen River basin. It is most likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal belt when the active subduction moved west to its present location along the Cascadia Megathrust.

Table 3. Faults of the Van Duzen River Basin.

FAULTS WITHIN AND WITH INFLUENCE TO THE VAN DUZEN RIVER BASIN			
Active Faults:	**Fault Type**	**Possible Magnitude**	**Recurrence Interval**
Cascadia Megathrust	Thrust	9	500-600
Little Salmon fault	Thrust	7.2	400-800
Yager fault	Thrust	unknown	unknown
Goose Lake fault	Thrust	unknown	unknown
San Andreas fault (Northern segment)	Dextral	7.3	200-300
Faults:			
Coastal Belt Thrust	Thrust		

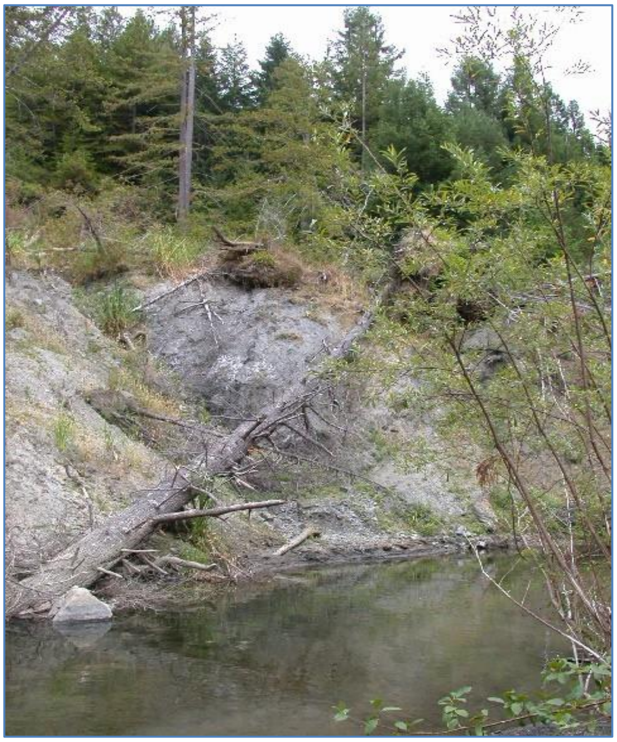


Figure 4. Streamside landslide photos. Left: Re-activated landslide originating along a shear zone related to the Yager fault within the Yager terrane. Right: Bank erosion and sediment source input to lower Lawrence Creek.

Slope Inclination

Steep slopes (>30%) comprise 50 percent of the subbasin's terrain (*Table 4*) and are located throughout the subbasin (*Figure 5*). Studies involving several bedrock types show that most erosion in terms of sediment volume comes from slopes between 30 and 50 percent and from slopes that have experienced timber harvests (Nolan and Janda 1995; Cannata et al. 2006). Since all steep hillslope geology of the Yager Subbasin should be considered as high for erosion potential (USEPA 1999), actions such as road construction, timber harvests, and other land use actions that disturb soils should be mitigated according with Best Management Practices (BMP). The BMPs should meet or exceed all regulatory agency standards of soil conservation to insure protection of critical habitat for State and federally listed salmonids and meet TMDL water quality objectives. BMPs are critically important where inner gorges or other hill slopes can erode sediments directly to any watercourses that contribute to salmonids bearing streams.

Table 4. Slope classes of the Yager Creek Subbasin

Slope class	Acres (% of Subbasin)
0-15% Gentle	10,176 (12%)
>15 -30% Moderate	33,293 (38%)
>30 -65% Steep	39,893 (45%)
>65% Very Steep	4,600 (5%)

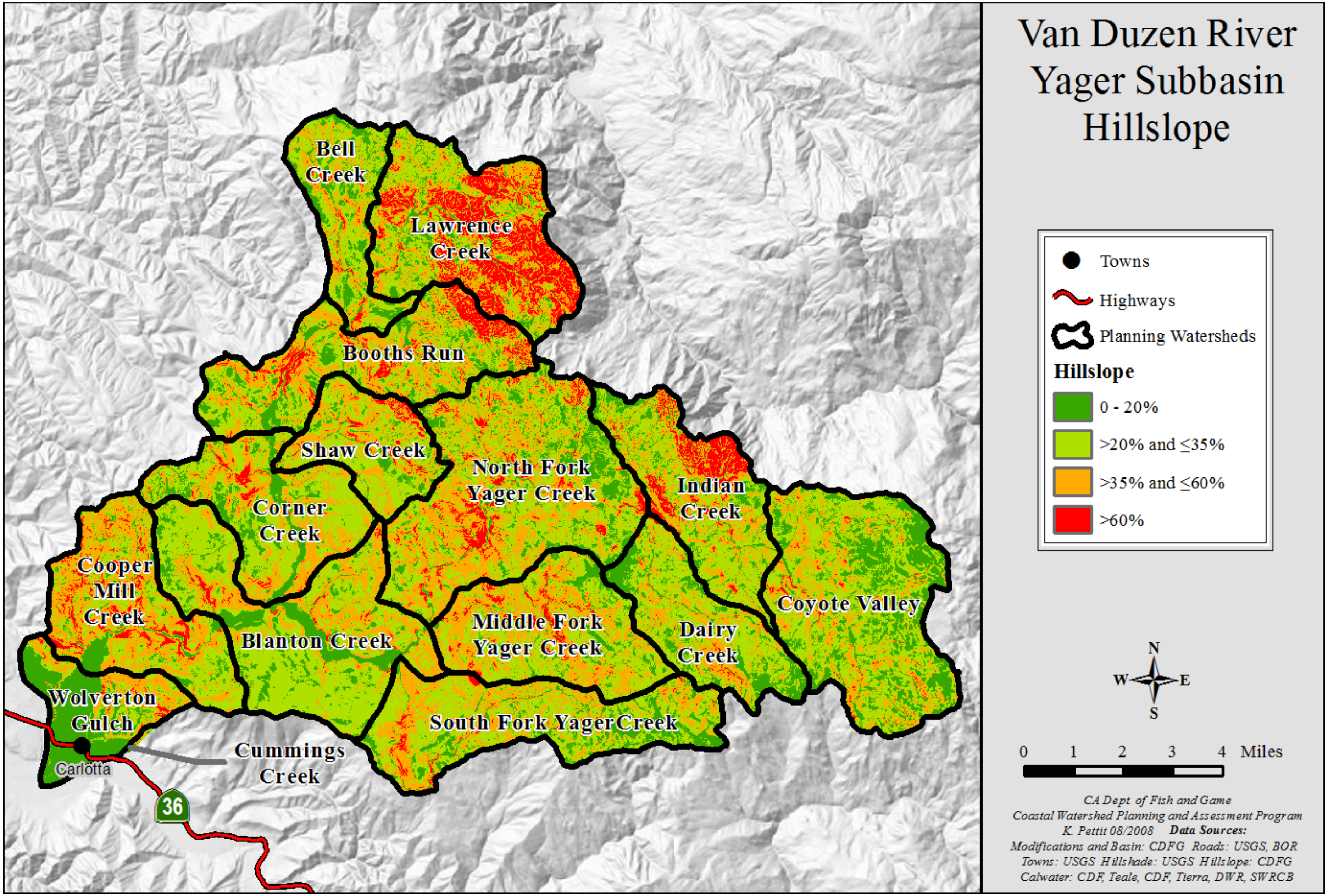


Figure 5. Yager Creek Subbasin hillslope map.

Hydrology and Sediment Transport

There are approximately 150 miles of perennial stream channels and 160 miles of intermittent stream channels shown on 1:100,000 USGS maps in the Yager Creek Subbasin (*Figure 6; Table 5*). Yager Creek, a fourth order stream is the largest stream flowing through the subbasin. Yager Creek divides into three forks: South Fork, Middle Fork, and North Fork. The South Fork confluence is near RM 14, the Middle Fork and North Forks divide the mainstem near RM 15. The South Fork Yager Creek drains the south eastern portion of the subbasin and provides approximately two miles of anadromous salmonid habitat before a boulder roughs and high gradient typically blocks passage of upstream spawning migrations. The North Fork provides approximately nine miles to steelhead and over five miles of Chinook and possibly coho salmon habitat. Lawrence Creek with 12.7 miles of perennial stream is the largest tributary in the subbasin. Lawrence Creek drains the northern and western portion of the subbasin and Yager Creek and its forks drain the middle and eastern portions. Yager and Lawrence creeks (a third order stream) are cumulatively affected by flow, temperature and sediment contributions from the 160 miles of intermittent streams. No USGS stream flow gages are located in the Yager Creek Subbasin; therefore, current and historic stream flow data is unavailable to examine.

Processes of stream sedimentation are controlled by stream power, which is a combination of discharge and slope over which a stream runs (velocity). The Yager Subbasin contains a high percentage (67%) by length of high gradient (>20% gradient), sediment source stream reaches (*Figure 7*). The remaining portion of the subbasin is divided between 21% sediment transport reaches (4-20% gradient) and 12% of the stream miles are response (0-4% gradient) or sediment depositional reaches. These are general stream gradient classes exclusive of stream side landslides, debris flows and LWD that also influence sediment transport along the stream network. Sediment is eroded from steep headwater reaches as well as steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Much of the coho and Chinook salmon habitat is located in the low gradient response reaches.

Table 5. Yager Subbasin stream lengths.

Stream Name	Length (miles)
Yager Mainstem	18
South Fork Yager	11.8
Middle Fork Yager	5.1
North Fork Yager	12.3
Wilson Creek	4.7
Cooper Mill Creek	3.1
Allen Creek	2.2
Blanton Creek	2.4
Lawrence Creek	12.7
Corner Creek	3.3
Shaw Creek	5.7
Booth's Run Creek	6.3
Bell Creek	5.5
Strawberry Creek	2
Owl Creek	1.2
Humphrey Creek	3.1
Grouse Creek	3.1
Lone Star Creek	2.5
Salmon Creek	1.3
Iaqua Creek	0.7
Dairy Creek	5.8
Ellison Creek	2.7
Butte Creek	2
Freese Creek	3.4
Indian Creek	3.3
Olsen Creek	2.9
Owl Creek	1.2

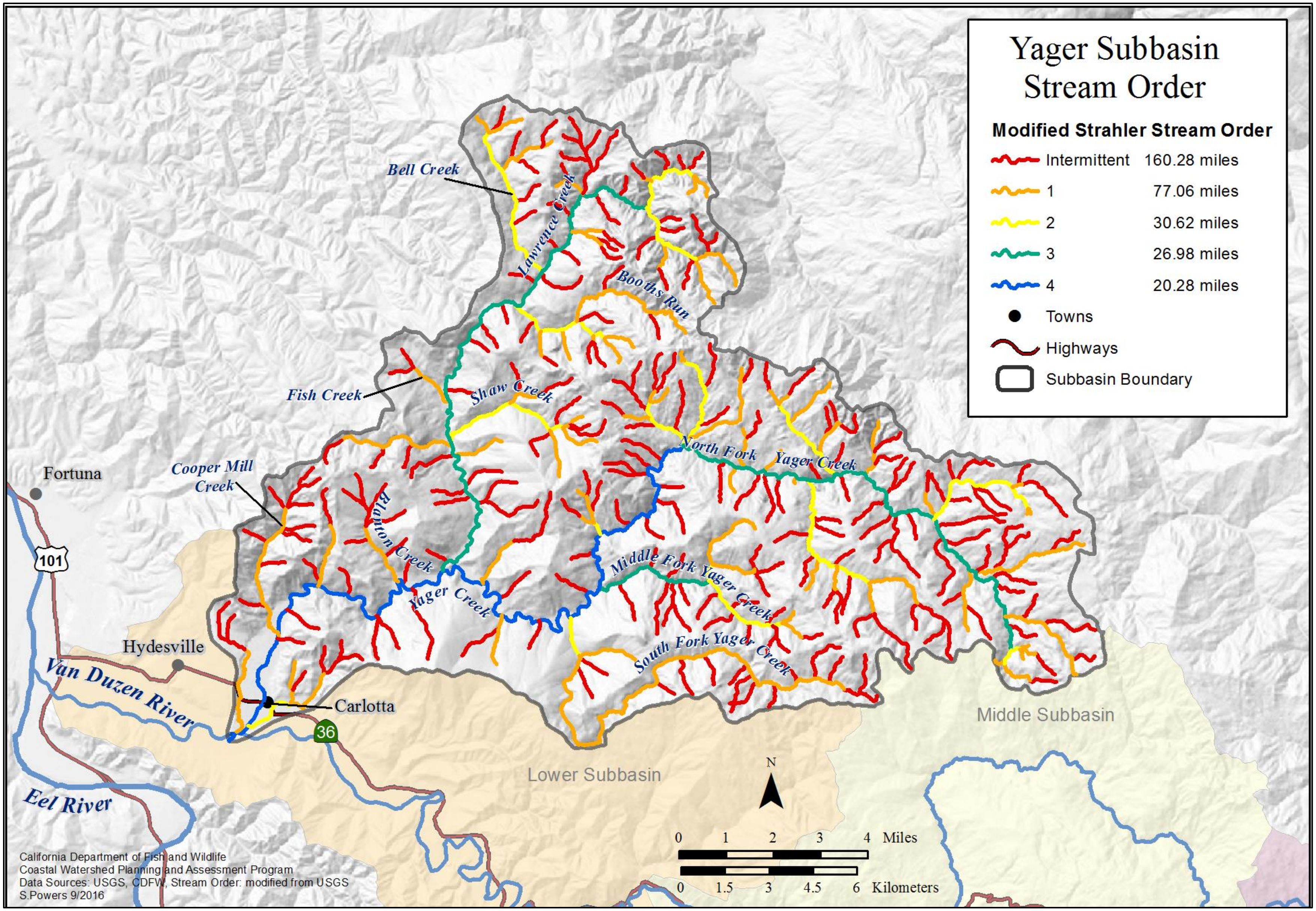


Figure 6. Approximation of Strahler Stream order for Yager Creek Subbasin streams.

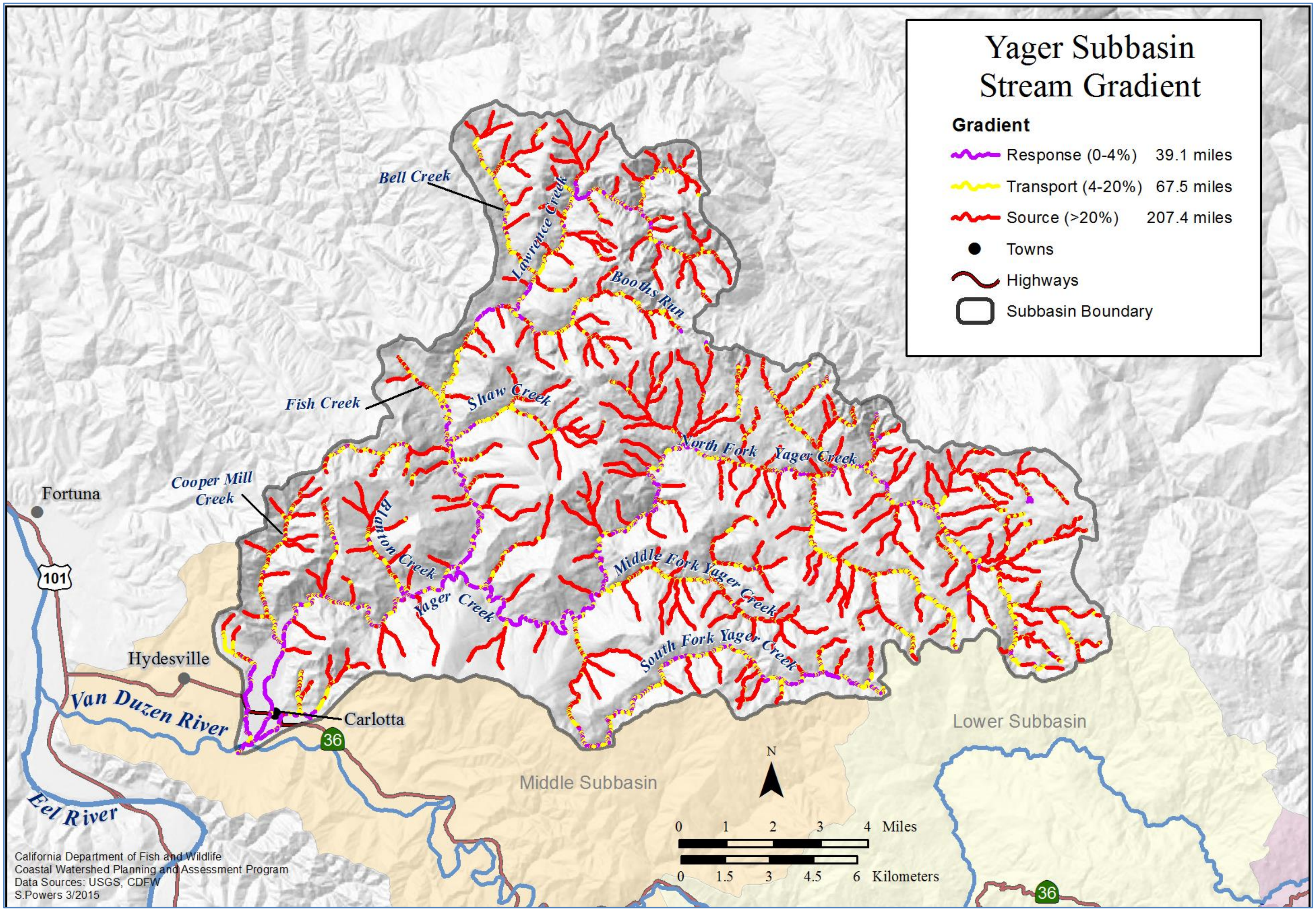


Figure 7. Stream gradient for Yager Creek Subbasin.

Vegetation

Vegetation within the Yager Creek Subbasin consists primarily of redwood dominated and Douglas fir dominated forests (*Figure 8*) and (*Table 6*). Redwood dominated forest occupy the majority of the western portion of the subbasin within the coastal fog belt region. Moving further inland (east) where the climate becomes warmer and the coastal fog influence diminishes, Douglas fir, mixed hardwoods (mostly oaks) and grasslands occupy the landscape.

Vegetation on grasslands and prairies are dominated by non-native annual grasses. Perennial native bunch grasses once covered the prairie grasslands and provided forage for wildlife year round in much of the Yager Creek watershed. The deeply embedded root systems of native bunchgrass also added to soil cohesion providing a degree of stability to prairie slopes. However, impacts from livestock grazing including seeding pastures by ranchers helped establish non-native grasses that have displaced native bunch grasses over much of the grassland areas (HCRCD 2002).

In many areas in the subbasin, the inherent values provided by forest and to some extent grassland vegetation to watersheds and streams are reduced compared to how they functioned prior to European settlements. The majority of coniferous forests of the Yager Creek Subbasin were harvested for timber at least once, most forest have experienced multiple entries. The return of forests towards old-growth characteristics especially near streams should be a main objective to improve stream conditions and to benefit natural salmonid production. More information about the role vegetation plays in stream ecosystems is located in the Basin Profile within the Vegetation section of the Van Duzen Basin assessment report.

Most streams in the Yager Subbasin that support salmonids flow through coniferous forests for much of their length. Some of the most important salmonid streams occur in the redwood dominated forest of the western portion of the subbasin. These include Lower Yager Creek, Cooper Mill Creek, Blanton Creek, and Lawrence Creek and its tributaries.

Table 6. Acres of vegetation cover types and total acres of the Yager Creek Subbasin planning watersheds.

Planning Watershed	Cover Type								
	Redwood Dominated	Douglas Fir Dominated	Grass Lands	Hard wood	Shrubs	Agriculture	Developed	Barren	Total Acres
Bell Creek	934	1,312	944	394	102	0	0	0	**3,691**
Blanton Creek	8,253	23	138	28	181	0	0	80	**8,703**
Booths Run	3,603	1,986	491	599	96	0	0	6	**6,780**
Copper Mill Creek	5,824	0	59	50	79	9	10	16	**6,047**
Corner Creek	5,364	11	9	12	71	0	0	60	**5,526**
Coyote Valley	0	2,569	3,027	3,636	0	0	0	3	**9,235**
Cummings Creek (Yager)[1]	48	0	2	0	0	19	0	0	**70**
Dairy Creek	0	2,099	1,327	1,085	0	0	0	0	**4,511**
Indian Creek	0	1,796	1,870	1,799	0	0	0	0	**5,465**
Lawrence Creek	1,074	4,131	1,130	1,149	1,074	0	0	1	**7,486**
Middle Fork Yager	498	3,593	1,290	599	9	0	0	0	**5,989**
North Fork Yager	977	4,024	3,900	1,840	156	0	0	0	**10,899**
Shaw Creek	2,134	617	497	53	131	0	0	16	**3,449**
South Fork Yager	1,831	2,280	1,323	1,330	55	0	0	0	**6,829**
Wolverton Gulch (Yager)[1]	1,514	0	316	76	231	1,007	72	84	**3,304**

1 Portions of Cummings Creek and Wolverton Gulch Planning Watersheds are included in the Yager Creek Subbasin

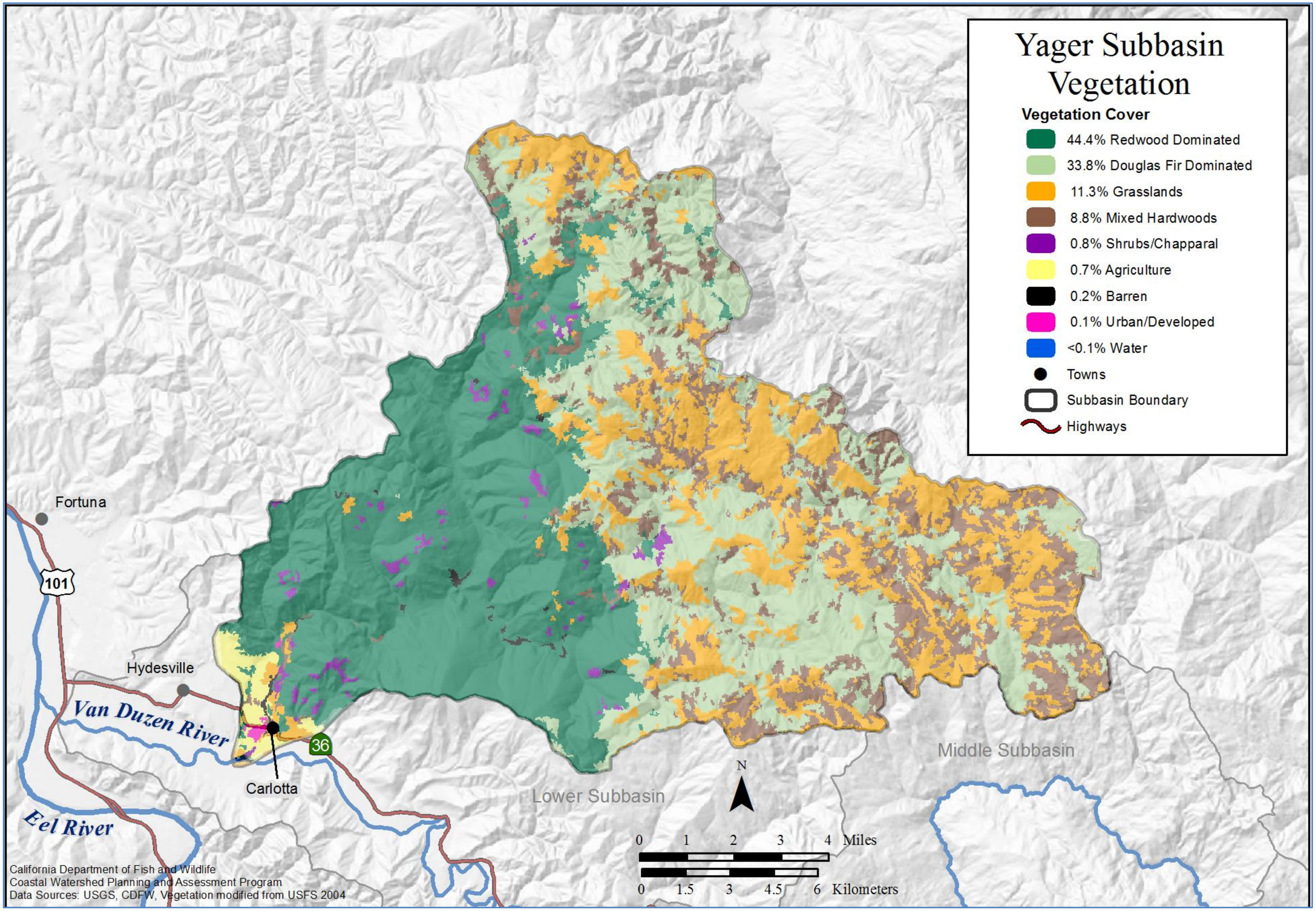


Figure 8. Yager Creek Subbasin vegetation cover types.

Land Use

The majority of land (~60,000 acres) within the Yager Creek Subbasin is managed for timber production/harvests. The largest land holder in the subbasin with approximately 34,179 acres is Humboldt Redwoods Company (HRC) (*Figure 9*). HRC acquired the timber lands formerly owned by PALCO in 2009 and are currently managed under the former PALCO Habitat Conservation Plan (HCP). Sierra Pacific (5,400 acres) and Green Diamond (960 acres) timber companies also own land in the Yager Subbasin. Livestock grazing, the small communities of Hydesville and Carlotta and the roads that link the towns to ranches and timberland roads are also important uses of land (*Table 7 and Figure 10*). There are four, large private ranches totaling 29,400 acres in the subbasin. These multi-generation family owned ranches raise cattle and also harvest timber. Other private holdings including smaller ranches and rural developments cover approximately 16,000 acres of the subbasin.

For a detailed discussion of the pre-European and European settlement see the Land and Resource Use section within the Basin Profile component of the Van Duzen River Assessment report.

Table 7. Land use categories in the Yager Creek Subbasin (in acres).

Total Yager Subbasin Acres	Agriculture	Rural Residential	Commercial/ Industrial	Open Space/ Parks; Public lands	Grazing/ Timber	Timber Production	Unknown/ Vacant
87,975	338	2,715	94	622	22,754	59,876	49

Figure 9. Lower Yager Creek within Humboldt Redwood Company property.

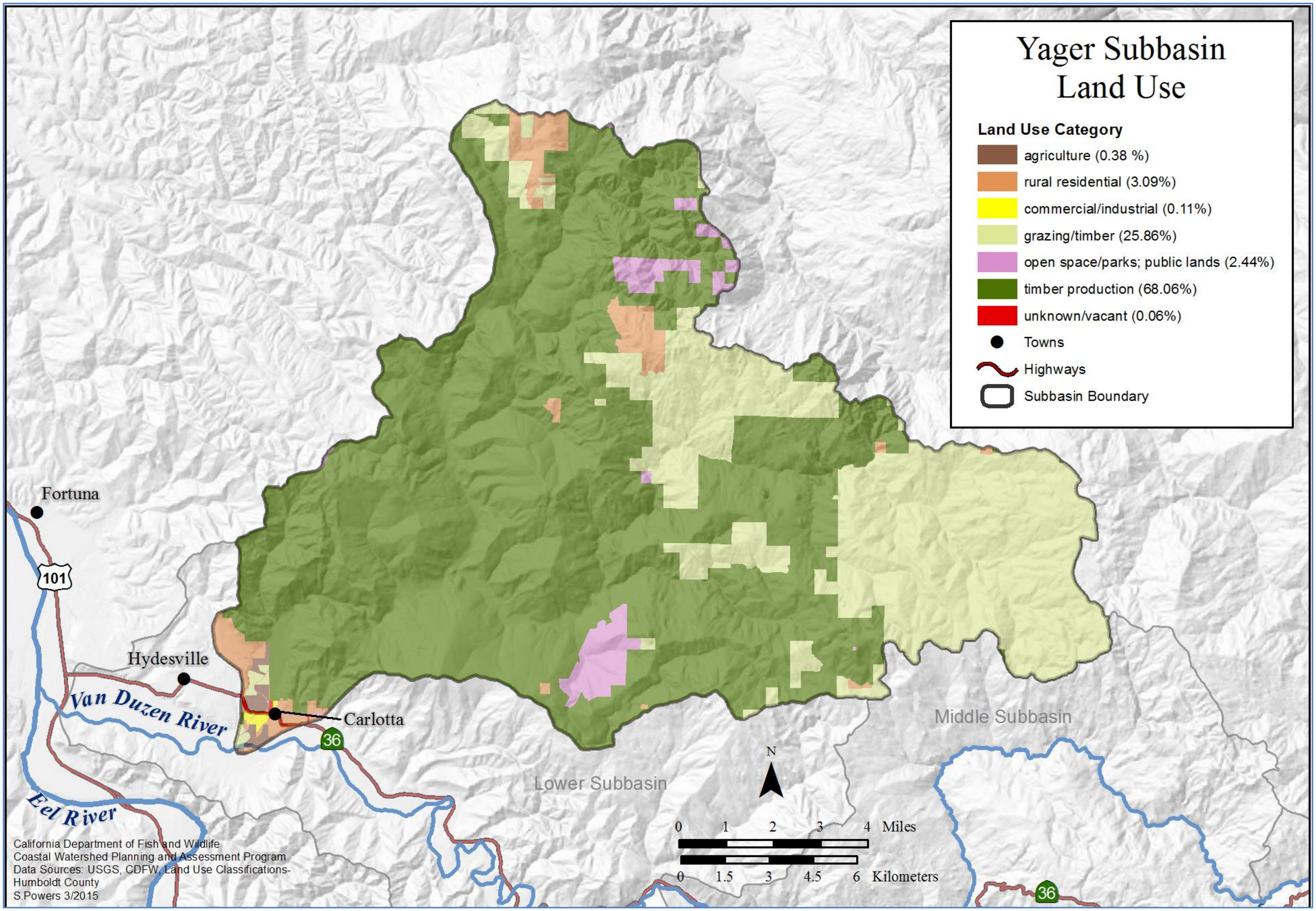


Figure 10. Land use in the Yager Creek Subbasin.

Timber Harvests

Historic

Timber harvests in the Yager Creek Subbasin began soon after the gold rush of the 1850s. The first lumber mill was built in 1854 by the Cooper family near Hydesville (Eureka Times 1943). Called the Cooper Mill, it was powered by a water wheel with water diverted from Cooper Mill Creek. The diverted water flowed through over a mile of ditch to the mill site. The Cooper Mill operated for only a few years and closed after George Cooper was killed in a clash with native tribesmen. By 1865 a second mill, powered by steam, was built near Rohnerville (just west of the subbasin).

One of the first large timber land acquisitions in the Van Duzen Basin was made when the Pacific Lumber Company (PALCO) purchased 5,000 acres in the Yager Creek Watershed in 1882 marking the beginning of the commercial timber industry operations in Van Duzen Basin. Other large tracts of land were acquired by ranchers who first cut or “ringed” trees on the perimeters of grasslands to increase the amount of livestock grazing lands.

Examining historical records, it seems the first significant large-scale commercial timber operation in the Yager Creek watershed began in the early 1940s. Susie Van Kirk (1998) noted a two-page layout in the September 1940 issue of the Timberman logging industry trade paper that described major logging activities within the region. Kirk included an excerpt of the Timberman story written by George F. Cornwall:

> Biggest logging development at the moment in the California redwood region is the opening of the Yager-Lawrence creek area by the Pacific Lumber Company of Scotia, California. This recently consolidated tract comprising 23,000 acres, carries an estimated stand of nearly one and half billion feet of choice redwood timber, averaging about 50,000 feet to the acre. Twenty-three miles of standard gauge railroad will be required to the complete project together with an indeterminate amount of motor truck feeder roads for later consideration. The new railroad on which construction was stared in June begins at Carlotta where a junction is made with the Northwestern Pacific and follows Yager creek for a distance of seven miles to its confluence with Lawrence creek. Here the road branches, one line proceeding to the eastern limits of the tract and the other extending northward along Lawrence creek almost to the divide separating the new theater of operations from the old Freshwater development and terminating at Bell creek.

These logging operations supported the building boom that occurred after World War II; forests were clear cut from the stream banks and up steep slopes as shown in *Figures 11 and 12*. The harvests were conducted without any regulations to protect streams or fish. In addition to causing severe bank erosion and eliminating riparian functions, slash and logging debris clogged stream channels blocking upstream fish migrations, accumulated large stores of sediments and lowered dissolved oxygen in streams to sub-lethal levels as decomposition of organic materials consumed oxygen. For additional historic perspectives on timber harvests, please see the Van Duzen Basin Profile section (p.39) of the assessment report.

Current

Since 1973, with the passage of the Z’Berg-Nejedly Forest Practice Act, environmental regulations have become stricter, resulting in improved timber harvest practices. Timber harvest activities require the development of plans detailing the amount and method of plans based on the area of timberland owned and whether or not the landowner is an individual/family or a corporation. Non-industrial timber management plans (NTMPs) were established by the CA Legislature in 1989 to allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that were not as expensive and time-consuming as THPs (CalFire 2003). NTMP’s are permanent, and once approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP).

From 1991 to 2007 (16 years) approximately 21,000 acres or 37% of the subbasin’s conifer forests have been involved in timber harvests. That equals a conifer forest harvest rate of over 2.3 percent per year. At this rate of harvest, it would take approximately 43 years to harvest all the conifer forests in the Yager Creek Subbasin (*Table 8*). This table does not include multiple harvests on the same acres, which would increase the

Figure 11. Logging in N.F. Yager Creek in 1956.

Figure 12. Logging in N.F. Yager Creek in 1956. Photos by Earl Gibbs.

number of acres harvested. Timber harvest prescriptions were primarily divided between clear cuts (5,800 acres), seed tree removal (5,600 acres), and selection cuts (4,450 acres). Including multiple harvests, over 16,000 acres of harvests used tractor skid yarding with approximately 7,000 acres yarded with tractor cable systems. The majority, but not all of these harvest were conducted by PALCO.

The Regional Water Quality Control Board (2006) developed a system of adjustment factors to assess impacts to watershed processes that occur from different silvilcultural prescriptions. The impacts include excessive hillslope erosion, sediment delivery to streams, prolonged high levels of turbidity and others. According to the system, clear cuts are the most detrimental to the forest landscape. Seed tree removal impacts are considered three-fourths as disruptive as clear cuts and selection cuts are considered half as disturbing relative to clear cuts (NCRWQCB 2006). Yarding methods also vary in their contribution to land disturbance. Tractor yarding is considered to generate the most disturbances to top soils compared to other yarding methods.

Klein et al. (2008) published these adjustment factors for different sivilcultural prescriptions which we used for analysis of timber harvest activities in the subbasin. Klein et al. (2008) also recommended a maximum harvest rate of 1.5% per year (~ 65 year rotation) to mitigate for excessive erosion, associated sediment inputs to streams and prolonged high turbidity levels related to logging activities. Using silvilculture area adjustment factors (Klein et al. 2008) and 1991 to 2007 harvest plan data (noted above) the Yager Creek Subbasin forest has been cut at a rate of 1.95% per year representing a 50-year rotation. For comparison, if not adjusted for silvilcultural methods, approximately 2.6% per year of the forest area was involved in timber harvests, representing a 38 year rotation.

Looking at individual planning watersheds (PW), Shaw Creek PW, one of the last coho bearing watersheds in the Van Duzen River Basin had one of the highest adjusted timber harvest rate of 2.6 percent per year, a 38 year rotation (non-adjusted 3.3% per year 30 year rotation). Other important salmonid habitat areas include Corner Creek, Blanton, and Cooper Mill PWs had harvest rates of over 2.5 percent per year. These rates largely exceed the maximum harvest rate of 1.5% per year suggested to help mitigate for excessive erosion (Klein et. al 2008) and excessive sediment input to streams considered detrimental to salmon production.

Table 8. Yager Creek Subbasin and planning watershed (PW) timber harvest statistics 1991-2007.

Planning Watershed (PW)	PW Acres	THP Acres	% PW Harvested	Conifer Acres	% PW in Conifers	% Conifer Acres in THP	NCRWQCB Adjusted THP Acres	Annual Harvest Rate Adjusted for Sivilculture (%/yr.)
Bell Creek	3,691	487	13	2,251	61	22	367	1.1
Blanton Creek	8,703	4,257	49	8,276	95	51	3,277	2.5
Booths Run	6,780	2,019	26	5,588	82	32	1,492	1.7
Cooper Mill Creek	6,047	2,270	38	5,824	96	39	2,647	2.8
Corner Creek	5,526	2,637	48	5,375	97	49	2,175	2.5
Coyote Creek	9,235	1,412	15	2,569	28	55	1,056	2.6
Cummings Creek	70	38	55	48	69	79	NA	NA
Dairy Creek	4,511	891	20	2,099	47	42	409	1.2
Indian Creek	5,465	336	6	1,796	33	19	233	0.8
Lawrence Creek	7,486	1,100	15	5,205	70	21	790	0.9
MF Yager	5,989	747	12	4,091	68	18	495	0.8
NF Yager	10,899	1,910	18	5,000	46	38	1,452	1.8
Shaw Creek	3,449	1,527	44	2,751	80	56	1,158	2.6
SF Yager	6,829	1,395	20	4,111	60	34	1,331	2.0
Wolverton Gulch	3,304	915	23	1,514	46	49	776	3.2
Subbasin Total	**87,984**	**21,941**	**23.5**	**56,499**	**64**	**37**	**1,768**	**1.95**

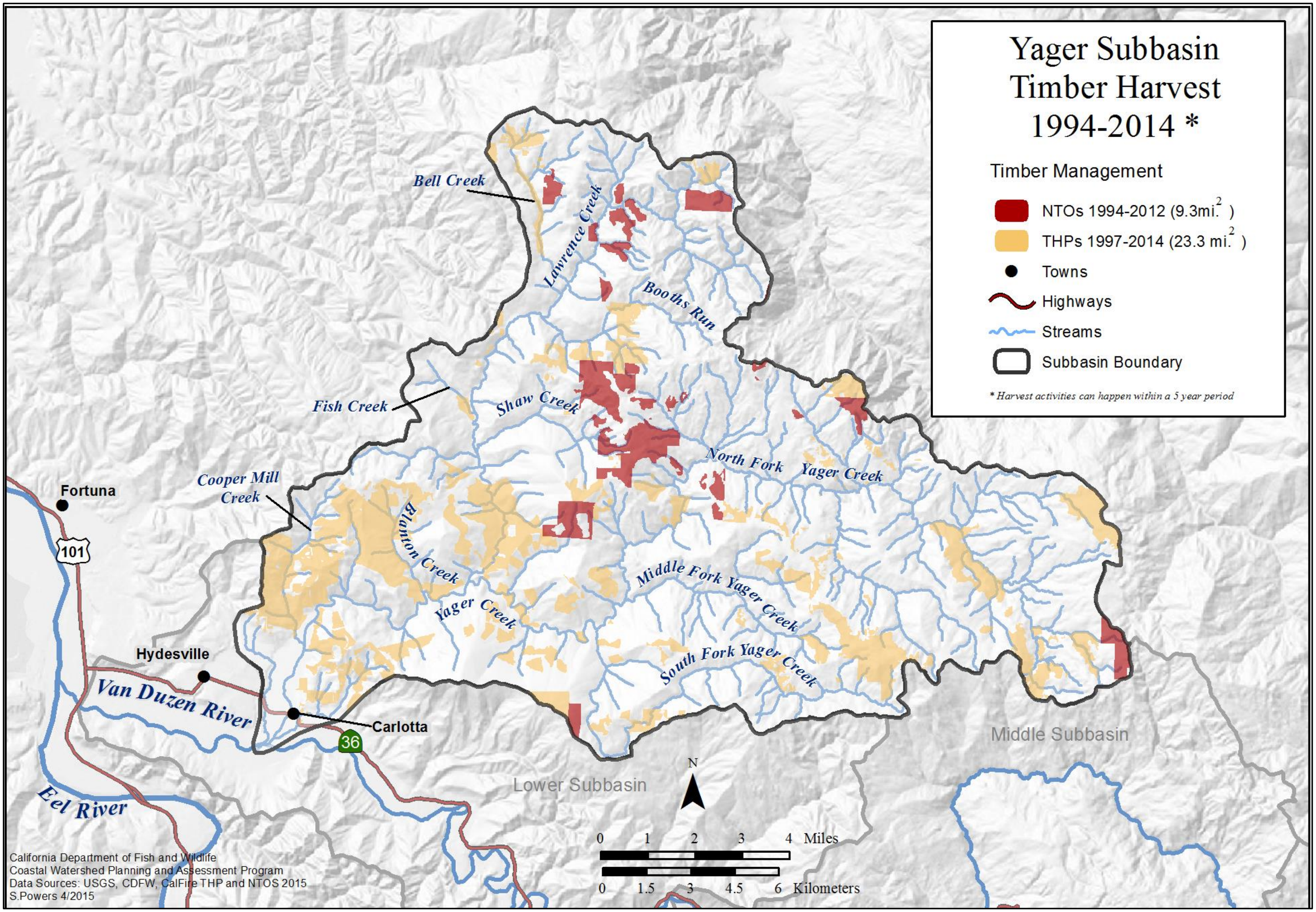


Figure 13. Timber harvest in the Yager Creek Subbasin 1994 – 2014.

Ranching

Ranching activity in the Yager Creek Subbasin often includes a combination of livestock grazing and timber harvesting. Noteworthy, there are four large ranches (>3,500 acres) in the Yager Subbasin and numerous ranches of lesser size. They are mostly located on grasslands in the headwater areas of Lawrence Creek and the North Fork (*Figure 14*) and South Fork Yager creeks. Cattle production is the principle land use on the grasslands. Timber harvests are conducted along forested hillslopes. Cutting trees on ranches was first done to increase rangeland area. Ranchers paid to have trees along the perimeter of the grass lands cut or "ringed". The trees were commonly left on the ground in remote areas because it was difficult to move them. This practice continued until after World War II when fir timber became a valued product.

Livestock grazing began by the 1870s with large numbers of sheep moving into the area. By the 1920s there were tens of thousands of sheep grazing over the grasslands of the Yager Subbasin. Due to the heavy stocking and continuous grazing it was believed that sheep were destructive to native grasslands. California oatgrass, a long lived perennial bunchgrass and a favored feed was grazed out by sheep by 1930 (Moore 1999). The loss of native oatgrass and the sheep themselves helped spread of non-native and less desirable grass species which now predominate in many areas. In addition to the loss of a valuable feed, the loss of oatgrass was also detrimental to grassland soils. Kelsey (1977) noted that the overgrazing of oatgrass that have deep, mesh-like roots that bind soil and the following displacement by non- native grasses has likely contributed to loss of soil stability leading to top soil loss and increased hill slope erosion. The effect of overgrazing by sheep and decreased soil stability from the loss of deep rooted oatgrass likely still contributes to erosion and sediment delivery to streams today.

By the 1940s the large numbers of sheep were replaced with cattle. The shift from sheep to cattle was made with a goal to improve rangeland and to implement grazing management practices. These include rest, set stock, summer/winter range, and rotational grazing (Moore 1999). The change from sheep to cattle and implementing grazing practices may have improved the quality of range land and may reduce impacts to riparian areas and streams. But, streams and riparian areas are still at risk. Livestock grazing, watering and seeking shade in riparian areas can destroy vegetation, cause stream bank erosion and generate sediment inputs to stream channels (WSARE 2003). Cumulatively, these effects can alter fluvial processes and reduce salmonid production in the affected area and in downstream reaches (Meehan 1991). The distance to water often determines grazing range, so if the only water source is the stream, livestock are likely to congregate there (WSARE 2003). Some ranchers have provided off stream watering sources to help minimize cattle related erosion and other impacts to the riparian zones. Reducing cattle density, herding livestock from riparian areas and developing off-site attractants such as water, feed, and minerals has been shown to give impacted riparian areas a chance to recover and increase riparian health and function (WSARE 2003).

Figure 14. Grazing lands and timber lands of the North Fork Yager Creek watershed.

Roads

Even though the Yager Creek Subbasin is located in a rural portion of Humboldt County there are numerous miles of various types of roads spread throughout the subbasin. The majority of roads in the subbasin are private logging roads within the Humboldt Redwoods Company lands (labeled "Improved" and "Unimproved" in *Figure 16*). The rest are either private ranch lands or roads maintained by Humboldt County. County maintained roads Kneeland Road and Shower Pass Road (labeled "Secondary" on *Figure 16*) traverse the upper portion of the Yager Creek Subbasin and provide access to timber and ranch roads. Monitoring road systems in watersheds is important because poorly designed or un-maintained roads can be significant sources of sediments delivered to streams. Sediment sources come from road surface erosion, culvert failures, or gully development. An example of road surface erosion (Showers Pass Road) is shown in Figure 15. The amount of sediment produced is reduced or eliminated by road removal or improvement projects and regular maintenance.

Roads data available from Cal Fire GIS roads layers show an average of 4.6 miles of roads per square mile in the Yager Creek Subbasin (*Table 9*). However, the Cal Fire GIS roads layer source data does not cover the full extent of the subbasin, so it underestimates the actual miles of roads on the landscape (ftp.fire.ca.gov/forest). A long used standard for maximum road density of less than 2.5 miles per square mile is recommended to mitigate against excessive sediment input to streams (Cederholm et al. 1981 and NMFS 1995). Most Yager Creek planning watersheds exceed this recommended maximum density. According to the Cal Fire data, the highest road densities are in the Wolverton Gulch (6.9 mi/m^2), Blanton (6.3 mi/m^2), and Shaw (6.0 mi/m^2) creek Planning Watersheds. The high road density of Wolverton Gulch PW is in part from county residential roads in the area of Carlotta and Hydesville. The Indian Creek PW has the lowest road density of 2.9 road miles per square mile and it also has the lowest amount of timber lands.

Figure 15. Fine sediment from surface erosion on Humboldt County maintained Showers Pass Road near head waters of N.F. Yager Creek. This road is hydrologically connected to Class I, II, and III watercourses and the loose road surface material (up to four inches) will be delivered.

Another example of how roads can contribute sediments to streams is shown in the Pacific Watershed Associate's (PWA) Shaw Creek sediment source inventory (1992). They estimated delivery of 5,100 cubic yards of sediment eroded into stream channels in 1991 and this sediment largely originated from roaded hill slopes and other land uses within Shaw Creek Watershed. PWA (1992) found an additional 34,500 cubic yards of sediment expected to erode mostly from roads built since 1981. Approximately 17,500 cubic yards of this sediment was expected to be delivered to Shaw Creek channels. For perspective, it would take approximately 1,750 dump trucks to carry this load. An erosion prevention project was initiated in 1992 to prevent as much as 8,000 cubic yards of this sediment from eroding into Shaw Creek (PWA 1992). The Shaw Creek watershed should be a

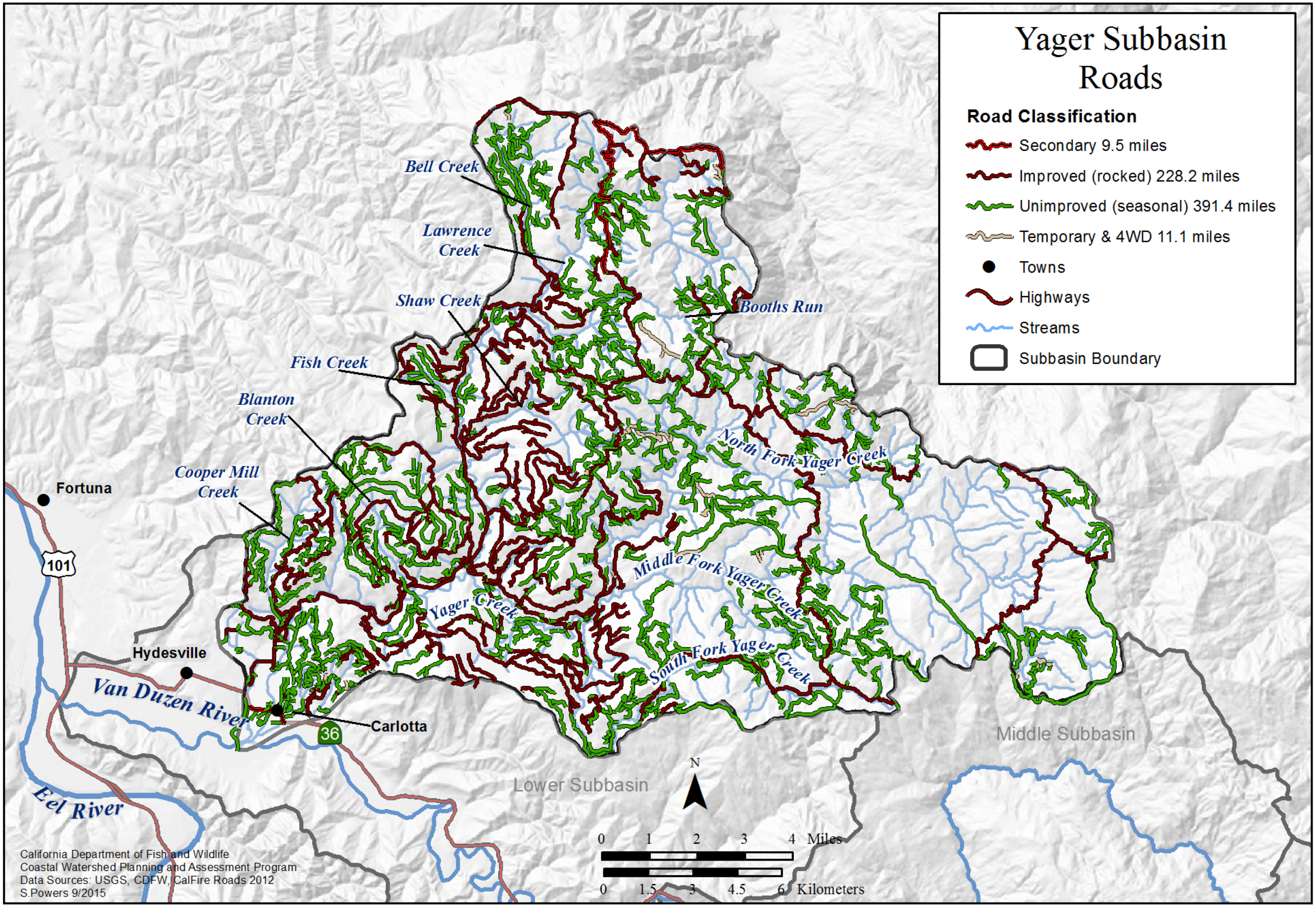


Figure 16. Yager Creek Subbasin roads map. Roads layer source data does not cover the full extent of the subbasin so it underestimates the actual miles.

priority watershed for road related sediment reduction projects because Shaw Creek is one of the only creeks where coho salmon have been observed in recent years. Several other road improvement projects *(Table 9*) have been completed in the Yager Subbasin by PALCO or HRC from 1999 to 2009 (HRC written communication). These road improvement projects are in compliance with the PALCO habitat conservation plan (PALCO 1999).

Roads and timber landings can be sources of excessive sediment inputs to stream systems especially when located on steep slopes or near stream channels. Approximately 39% of the roads in the Yager Creek Subbasin are located on steep slopes (>30% slope). Lawrence, Booths Run and the North Fork Yager Creek PW have the most roads while Cooper Mill, Shaw, Lawrence and Booths Run PW have the highest percentage of roads on steep slopes (*Table 10*).

Table 9. Road miles and road density for planning watersheds in the Yager Creek Subbasin. Miles of roads treated by Humboldt Redwood Company to reduce erosion also are shown.

Panning Watershed	Road Miles	Square Miles	Road Miles per Square Mi	Road Miles Storm proofed	Road Miles up-graded
Bell Creek	32.89	5.77	5.70	1.4	
Blanton Creek	84.93	13.60	6.25	28	9.5
Booths Run	60.15	10.59	5.68	32	0.9
Copper Mill Creek	54.82	9.45	5.80	22	5.5
Corner Creek	48.24	8.63	5.59	15	9
Coyote Valley	30.45	14.43	2.11	na	na
Cummings Creek (Yager)	0.75	0.11	6.92	na	na
Dairy Creek (Yager)	20.56	7.05	2.92	na	na
Indian Creek	24.64	8.54	2.89		
Lawrence Creek	48.75	11.70	4.17		
Middle Fork Yager Creek	26.87	9.36	2.87		
North Fork Yager Creek	84.55	17.03	4.97		
Shaw Creek	32.36	5.39	6.00	13	0.7
South Fork Yager Creek	53.31	10.67	5.00	0.2	0.9
Wolverton Gulch (Yager)	35.36	5.16	6.85	3	4
Subbasin Totals	**638.63**	**137.48**	**4.6**	**114**	**30.5**

Table 10. Amount of roads (feet) on steep slopes in the Yager Subbasin.

Planning Watershed	Total Feet	Roads (ft) on 30-60% slope	Roads (ft) on >60% slope	% Road on steep slope
Bell Creek	173,683	60,682	5,368	38
Blanton Creek	44,8425	133,556	1,639	30
Booths Run	317,593	128,256	17,068	46
Copper Mill Creek	289,466	143,342	7,935	52
Corner Creek	254,700	98,938	1,470	39
Coyote Valley	160,762	28,900	1,303	19
Cummings Creek	3,974	1,255		32
Dairy Creek	108,531	24,248	335	23
Indian Creek	130,123	43,991	5,064	38
Lawrence Creek	257,376	98,050	20,078	46
Middle Fork Yager Creek	141,871	48,273	1,580	35
North Fork Yager Creek	446,437	178,090	12,367	43
Shaw Creek	170,844	7,6355	6,371	48
South Fork Yager Creek	281,497	104,482	3,099	38
Wolverton Gulch (Yager)	186,689	5,8002	1,918	32

Watershed Improvement Projects

The CDFW, California Conservation Corps (CCC), Humboldt Redwood Company (formerly Pacific Lumber Company), Pacific Watershed Associates (PWA), Yager/Van Duzen Environmental Stewards (YES), along with other land owners, watershed groups, and restoration specialists have completed numerous upslope and instream habitat improvement projects in the Yager Creek Subbasin (*Figure 17*). The project goals were to reduce sediment delivery from roads by improving road conditions, promote growth of riparian vegetation, stabilize stream banks, increase stream habitat diversity, and restore fish passage into salmonid spawning streams. Many of these projects were completed with assistance from CDFW's Fisheries Restoration Grants Program and the National Marine Fisheries Service (NMFS).

While upslope restoration has occurred most prominently in the North Fork Yager Creek drainage, a large majority of the stream habitat improvement projects have been completed in the Lawrence Creek drainage. These habitat improvement projects were in part the result of recommendations from CDFG stream surveys beginning in the 1980s, or were volunteered by land owners or required mitigation for timber harvest plans. Most recently (September of 2015), the Humboldt Redwood Company and NMFS collaborated to improve slow water refugia habitat through the creation of an off channel pond on Lawrence Creek. This pond, located a little over a mile upstream of the confluence with Yager Creek, is approximately 150 feet long, 45 feet wide, and has two separate pools from 4 to 6 feet deep. Approximately ¼ acre in size, the pond was designed to contain deep water pools as well as edge water habitat from 1-2 feet deep to provide temperature and food diversity (Pagliuco and Perkins 2016). Habitat structures were added to the pond to create diverse habitat. Beginning in December of 2015, NMFS conducted monthly monitoring of the pond and identified, counted, and measured fork length of each fish captured. Juvenile coho and steelhead trout numbers peaked during the December, January and February survey efforts with a total of 82 fish observed (46 coho/36 steelhead). As expected, very few fish (10 fish total) were captured during the survey months of April through October, 2016.

Mid Van Duzen River Ranch Road Sediment Reduction Project

HCRCD has entered into a cooperative working agreement with a local watershed group – the Yager/Van Duzen Environmental Stewards (YES) to complete on-the-ground treatments on ranch roads to reduce sediment delivery to watercourses. YES formed in 1998 with the mission: "To ensure the environmental integrity of our watershed, while maintaining our heritage and the economic sustainability of our endeavors." The membership of YES is made up of non-industrial private landowners and resource managers, encompassing approximately 78% of the land base in the middle third of the basin, who manage the working landscape in the Van Duzen River Basin.

The Iaqua Ranch Conservation Easement

Another land management event occurred in October of 2006 in the North Fork Yager Creek watershed. After four years of negotiating bureaucratic trails, winning over donors and assembling the paperwork North Coast Regional Land Trust (NRLT) through a conservation easement secured the preservation of the 4,700-acre Iaqua Ranch as a working cattle ranch, in perpetuity (North Coast Journal, 2006). The Iaqua Easement is part of the NRLT's Six Rivers to the Sea effort to conserve working ranch lands and water resources from the Six Rivers National Forest down to the coast in Humboldt, Del Norte and Trinity counties.

An October 12, 2006 North Coast Journal article describes the basic framework of the easement:

> The conservation easement is an agreement between the Carringtons, who bought the ranch in 2002, and the state. The property owners relinquish their and subsequent owners', right to subdivide and develop the property in exchange for some money and lower taxes. The owners will be allowed to continue working the ranch -- hunting, raising cattle (in a way that doesn't degrade streams or soil) and cutting timber (no clear-cutting allowed, nor any streamside logging, and only 25 percent of the timber can be cut each decade). The California Department of Forestry will hold the easement, and the NRLT will keep an eye on the land to make sure its conservation values remain protected, said the trust's Shayne Green. NRLT paid the Carringtons $3.5 million for the easement, using funds

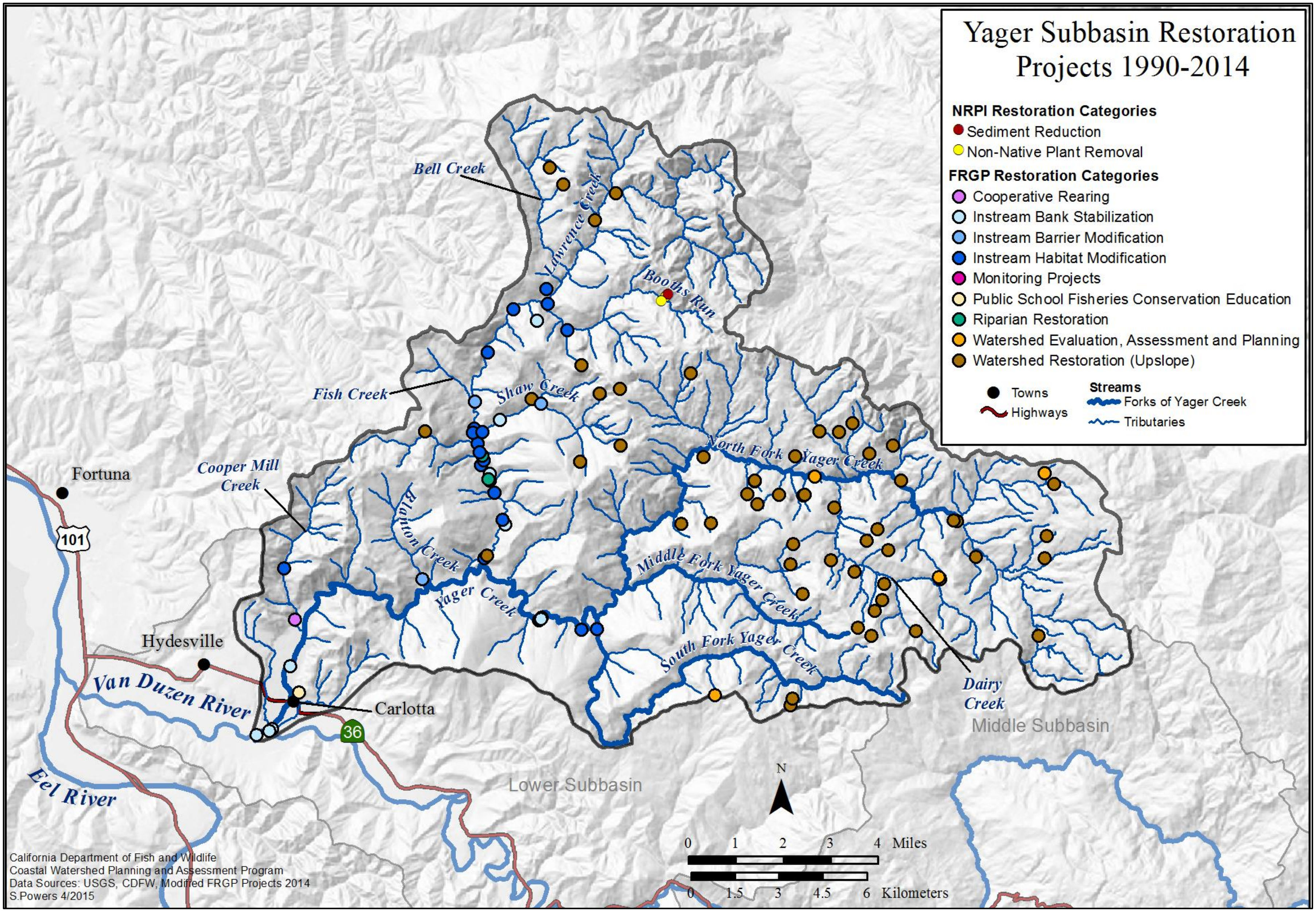


Figure 17. Watershed improvement projects in the Yager Creek Subbasin. Projects displayed are mostly projects that received funds from CDFG's Fisheries Restoration Grants Program. The graphic also does not contain all work done in the 1980s or projects required for mitigation. In addition, projects completed by land owners with other agencies or on their own may not be shown.

from the state Wildlife Conservation Board, the federal Forest Legacy Program and the state's Forest Legacy Program, plus grants from Humboldt County and a few individuals.

Stocking Efforts and Fish Rearing Facilities

The Pacific Lumber Company (PL) operated fish-rearing facilities to augment Yager Creek Subbasin salmonid stocks (Cooperative Rearing category, *Figure 17*). A hatchery and rearing facility was built and operated on Cooper Mill Creek from 1976-2002. Additional facilities on Corner Creek and South Fork Yager Creek were built in 1993 for rearing and acclimating fish for release. Fish were released at various locations throughout the Yager Creek drainage such as Lawrence, Cooper Mill, Shaw, Corner, and Blanton creeks. Records from 1990 to 2002 show that approximately 3,000 to 20,000 juvenile steelhead trout and 3,500 to 100,000 juvenile Chinook salmon were released per year. Prior to 1990, stocking records indicate a wide range of fish release numbers with some years only releasing Chinook juveniles and The Humboldt Beacon and historic CDFW field notes (September 27, 1976) reported the steelhead stock originated from the Mad River Hatchery. A majority of the Chinook salmon most likely came from the Van Arsdale Fishery Station (located on the Eel River below the Cape Horn Dam) as reported in Steiner Environmental Consulting (1998).

It is unclear what the contribution the hatchery made to salmon stocks because no studies were conducted to evaluate effectiveness of the fish rearing project. The fish rearing facility and stocking operations may have temporarily increased populations of salmonids in stocked streams during those stocking years; however, overall it most likely had a limited contribution to sustaining the salmonid fishery in the Yager Subbasin.

Salmonid Fishery Resources and Habitat Assessment

The Yager Creek Subbasin provides critical habitat for Chinook salmon, coho salmon, steelhead trout, and coastal cutthroat trout (*Table 11*). At present, there are approximately 53 miles of stream habitat available to steelhead in the Yager Creek Subbasin (*Table 12*) and an additional unknown number of miles inhabited by resident trout. Steelhead are distributed in the mainstem Yager Creek, all of its forks and in 12 tributaries (*Figure 18*). At least 19 of the available stream miles are potentially used by coho salmon and approximately 30 miles are utilized by Chinook salmon.

A review of CDFG surveys conducted from the 1930s to the present shows that stream and riparian habitat conditions exhibit spatial and temporal variation within the subbasin. Land use, geologic and other watershed factors that influence stream conditions are discussed in the Basin Profile section of this report. Some streams have changed from a condition that favored production of all salmon species to a status that lack critical habitat needed for coho salmon, but still sustains the more robust species of steelhead. Steelhead are the most abundant salmonid species found in the subbasin and they still occupy much of their historic range but likely at a lower abundance than populations of the past.

Table 11. Salmonid distribution in streams of the Yager Creek Subbasin.

Streams	Steelhead	Cutthroat	Chinook	Coho
Bell Creek	X	X		
Blanton Creek	X		X	
Booths Run Creek	X			
Cooper Mill	X		X	X
Corner Creek	X			
Dairy Creek	X ?			
Fish Creek	X		X	X
Grouse Creek	X			
Lawrence Creek	X		X	X
Lone Star Creek	X			
Shaw Creek	X		X	X
Strawberry Creek	X			X
Yager Mainstem	X	X	X	X
Middle Fork Yager	X		X	
North Fork Yager	X		X	
South Fork Yager	X		X	

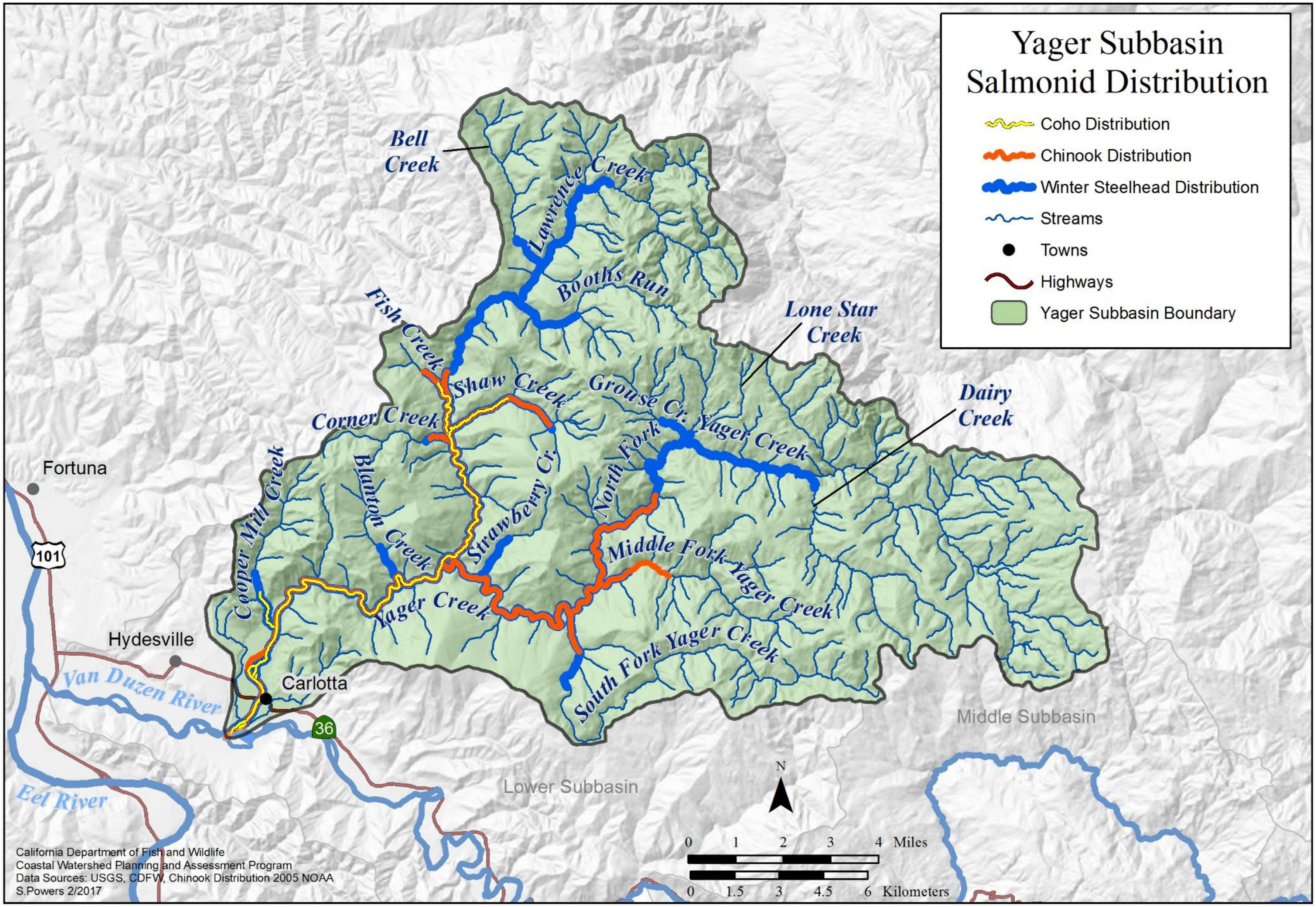


Figure 18. Yager Creek Subbasin salmonid distribution map.

Table 12. Streams of the Yager Subbasin and miles of accessible salmonid habitat.

Stream	Miles of Accessible Salmonid Habitat
Bell Creek	0.8
Blanton Creek	0.85
Booths Run	1.79
Corner Creek	0.62
Cooper Mill Creek	1.6
Fish Creek	0.81
Grouse Creek	0.6
Lawrence Creek	12.14
Lone Star Creek	0.2
Middle Fork Yager Creek	4.37
North Fork Yager Creek	7.8
Shaw Creek	3.1
South Fork Yager Creek	1.2
Strawberry Creek	1.3
Tributary to Yager Creek	1.11
Yager Creek	15.2
Totals	**53.5**

Coho Salmon

Coho salmon (*Oncorhynchus kisutch*) in the Southern Oregon/Northern California Coast (SONCC) Evolutionary Significant Unit (ESU) were listed as threatened under the federal Endangered Species Act in 1997 (62 FR 24588); and their listing was reaffirmed in 2005 (70 FR 37160). The SONNC coho salmon ESU was also listed as threatened under the California Endangered Species Act in 2002 (CDFG 2002). The Yager Creek Subbasin provides about one half of the coho salmon habitat (19 miles) in the Van Duzen River Basin. While once noted as abundant in the subbasin, recent surveys observe very limited numbers of coho salmon. Currently, most of the occupied coho habitat is located in lower Yager Creek, including the Lawrence Creek drainage (*Figure 18*). Lawrence Creek and one of its main tributaries, Shaw Creek, are thought to have the last sustaining runs of coho salmon within the subbasin.

The CDFG *Recovery Strategy for California Coho Salmon* (2004) lists Yager, Lawrence, Shaw, and Cooper Mill creeks as key populations to maintain or improve. Because of the limited numbers of coho salmon from the Yager Creek Subbasin, efforts should be made to protect, preserve and increase quality of stream habitat conditions year-round to benefit spawning and juvenile rearing of coho salmon.

CDFW spawning ground - index reach sampling

Coho have not been considered abundant in the subbasin since at least 1985 when the first annual CDFW spawning surveys were conducted in the subbasin. The survey sites were selected by CDFW biologists based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. Annual surveys also differed in sampling duration and effort, and redds were not assigned to species; however, these data provide a continuous record of spawner survey information in select Yager Subbasin streams. Only a total of 17 live coho and 9 coho carcass were observed during 70 spawner surveys of Lawrence and Shaw creeks conducted from 1985-2002. There was concern that coho were nearly extirpated from the subbasin as no adult coho salmon were positively detected in any Yager Creek Subbasin streams during spawning surveys from 2002 through 2009 (over 60 spawner surveys). Furthermore, only a very few juveniles were observed during snorkel surveys in Shaw Creek during this time frame. However, since 2010 during 50 spawner surveys (*Table 13*) on Lawrence and Shaw creeks collectively, a total of 38 live adult coho and 18 coho carcass were identified. Moreover, on Fish Creek, a tributary to Lawrence Creek, a 2010 summer CDFW reconnaissance-level juvenile fish snorkel survey observed juvenile coho salmon in the lower portion of Fish Creek. This observation was the first documentation of coho salmon in Fish Creek as coho had not previously been documented upstream of Shaw Creek in the Lawrence Creek watershed. Subsequent spawner surveys of Fish Creek from 2010 to 2015 have observed a total of 30 adult live coho and 13 coho carcass (*Table 13*).

California Coastal Salmonid Monitoring Program

Monitoring of juvenile coho salmon population spatial structure was conducted as a component of the of the CDFW's Coastal Salmonid Monitoring Program (CMP) in the Lower Eel River and its tributaries, inclusive of the Van Duzen River. This juvenile coho salmon spatial structure monitoring protocol (Garwood and Ricker 2013) utilized the design based sampling of the CMP to measure occupancy patterns of juvenile salmonids during the summer juvenile rearing period (June to September).

A total of 39 surveys were complete on 28 stream reaches throughout the Yager Creek drainage between 2013 and 2016 (Lam and Powers 2016 *Draft*). Juvenile coho observations occurred each year of the survey; however, these observations were limited to 9 surveys in 7 stream reaches. With the exception of one reach on Yager Creek (downstream of Lawrence Creek), all other coho observations were confined to Lawrence Creek and its tributaries of Shaw and Fish creeks. Overall, no new location detections of coho were made through the survey efforts. More detailed survey information including maps, graphs, and further analysis are presented in the Lower Eel River and Van Duzen River Juvenile Coho Salmon Spatial Structure Survey Summary reports, which are available up request from the CDFW Fortuna office. Upon finalization these reports will also be posted on the CDFW Document Library: (https://nrm.dfg.ca.gov/Documents/Default.aspx).

Table 13. CDFW Index reach spawner surveys in Lawrence, Shaw and Fish creeks from fall of 2005 to spring of 2015

Stream	Year	Live Fish			Carcasses			Redds	Effort*
		Unknown	Chinook	Coho	Chinook	Coho	Unknown		
Lawrence Creek	2014-2015	23	242	0	20	0	4	118	5
	2013-2014	3	5	2	4	1	0	26	6
	2012-2013	1	133	0	9	1	13	45	4
	2011-2012	6	707	2	240	1	12	184	7
	2010-2011	6	317	0	200	0	6	137	5
	2009-2010	88	182	0	2	0	0	78	2
	2008-2009	62	103	0	130	0	12	63	5
	2007-2008	50	41	0	4	0	0	48	3
	2006-2007	38	75	0	60	0	16	25	4
	2005-2006	142	102	0	42	0	4	57	4
Shaw Creek	2014-2015	1	41	0	10	0	0	36	6
	2013-2014	17	0	27	2	8	0	56	4
	2012-2013	3	20	0	15	0	6	48	7
	2011-2012	0	0	7	1	4	0	9	6
	2010-2011	1	128	0	65	3	27	53	6
	2009-2010	0	6	0	4	0	3	11	3
	2008-2009	11	42	0	30	0	13	21	4
	2007-2008	0	0	0	0	0	0	0	2
	2006-2007	17	32	0	9	0	0	38	4
	2005-2006	38	37	0	3	0	8	5	4
Fish Creek [1]	2014-2015	0	0	1	0	1	0	9	5
	2013-2014	1	0	12	0	4	0	12	4
	2012-2013	3	20	0	15	0	6	48	7
	2011-2012	3	0	9	1	8	0	16	6
	2010-2011	3	0	8	0	0	1	8	5

**Effort represents the number of surveys completed during the typical spawner season for Chinook and coho salmon.*
[1] Fish Creek Index reaches were not conducted prior to the 2010-2011 season.

Chinook Salmon

Chinook salmon (*Oncorhynchus tshawytscha*) populations have fared better than coho but are considered to be well below their historic abundance in the subbasin. Chinook salmon have been observed in at least the lower reaches of most fish bearing streams of the Yager Subbasin. Spawning surveys have focused on the significant tributaries in the subbasin and have not been conducted in the mainstem Yager Creek or North Fork Yager Creek. Chinook have been reported to spawn in the North Fork Yager Creek near Grouse Creek (Mark Moore personnel communication) indicating that Chinook likely use spawning habitat in the mid and upper mainstem in addition to the North Fork. Based on review of spawner surveys from the mid 1980's to 2009, Lawrence and Shaw creeks have by far been the best producers of Chinook salmon (*Figures 19 and 20*).

Linear regression analysis and ANOVA test of spawner survey data from Lawrence Creek indicate no significant change or trend in the redd numbers (R^2=0.0000, P value=0.9831) or peak numbers of Chinook salmon (R^2=0.0934,P value=0.1562) observed from 1985 to 2008. In addition, no trend was identified for redd counts (R^2=0.02378, P= 0.6321) or peak abundance (R^2=0.1304, P=0.2488) over the last 12 years 1998-to 2009.

Linear regression analysis and ANOVA tests of Shaw Creek spawner survey data indicate no significant change or trend in the observed redd numbers (R^2=0.0149, P value=0.4865) or observed peak numbers of Chinook salmon (R^2=0.0577, P value=0.2695) observed from 1987 to 2007. In addition, no trend was identified for redd counts (R^2=0.1001, P=0.3162) or peak abundance (R^2=0.0349, P=0.5609) over the last 12 years 1998-to 2009.

Spawner survey efforts were less consistent and more limited in in Cooper Mill Creek, Fish Creek, Blanton Creek, and S.F. Yager Creek (*Figures 21-24*). With the exception of Cooper Mill Creek there were no spawner surveys performed after 2001 in these streams. Besides a few years of surveys in Cooper Mill Creek, only a few adult Chinook were observed during these surveys.

Recent CDFW index reach spawner surveys (2010-2015) have seen a significant increase in number of live adult Chinook and carcasses observed in Lawrence Creek (Table 13). Whether or not this is reversing the downward trend in Chinook salmon numbers within the basin remains to be seen. None the less, it is encouraging to these higher returns of adult Chinook salmon.

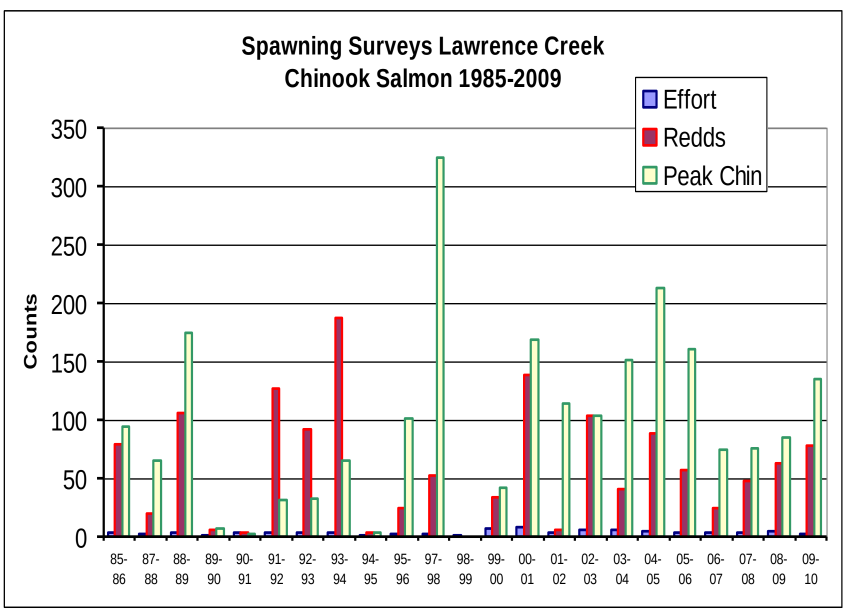


Figure 19. Lawrence Creek Chinook salmon spawner survey results 1985- 2009.

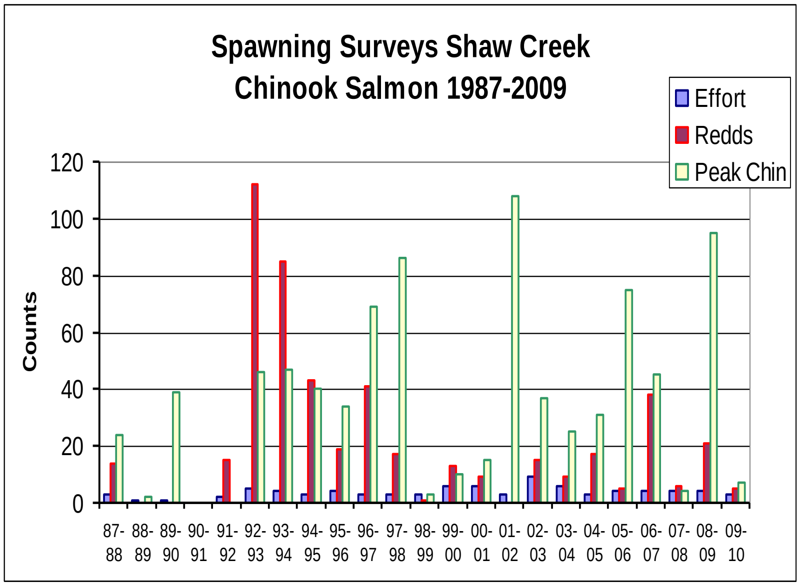


Figure 20. Shaw Creek Chinook salmon spawner surveys 1987-2009 (23 years).

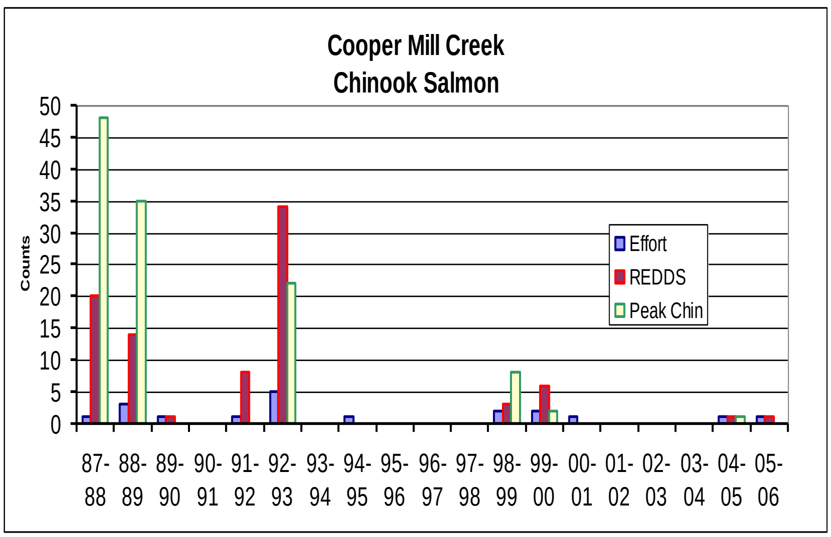


Figure 21. Cooper Mill Creek Chinook salmon spawner surveys 1987-2006.

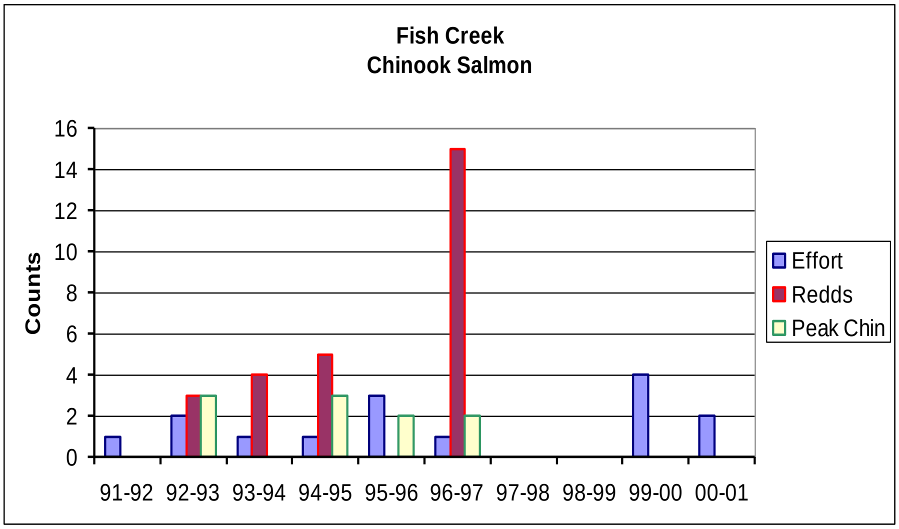


Figure 22. Fish Creek Chinook salmon spawner surveys 1991-2001.

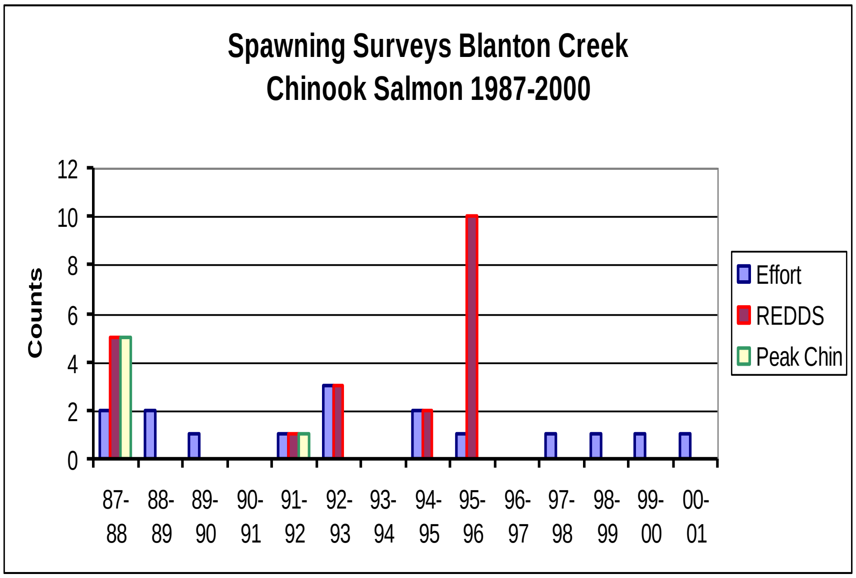


Figure 23. Chinook salmon spawner surveys in Blanton Creek 1987-2000.

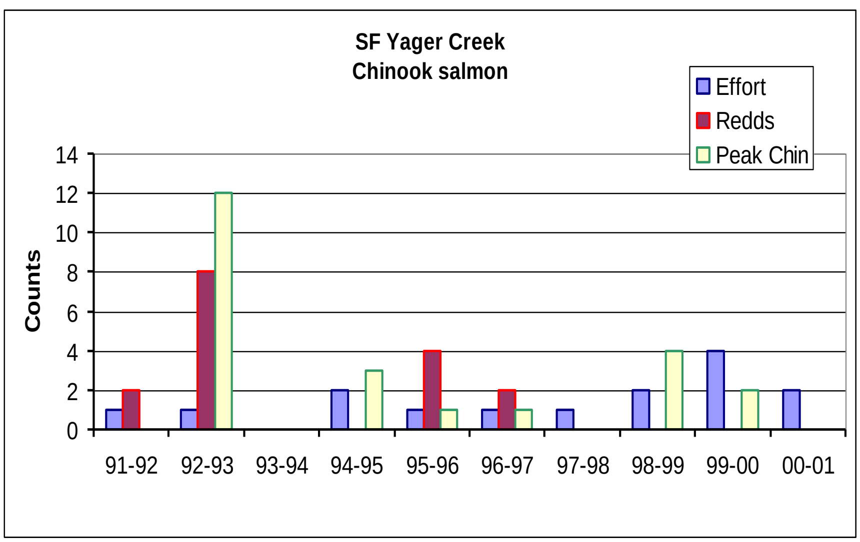


Figure 24. SF Yager Creek Chinook salmon spawner surveys 1991-2001.

Steelhead

Most fish bearing streams of the Yager Creek Subbasin support runs of winter run steelhead (*Oncorhynchus mykiss*) and perhaps some remnant runs of summer steelhead. The winter run steelhead (*Figure 25*) population appears to be in a viable, self-sustaining condition and widely distributed across the subbasin (*Figure 18*). Adult, summer steelhead, once noted as abundant in the Yager Creek Subbasin (Van Kirk 1986) have not been observed in recent surveys. However, no focused surveys have been conducted to detect presence of summer steelhead in the subbasin.

A newspaper article printed in the Ferndale Enterprise April 17, 1917 tells of a run of steelhead into Yager Creek in April of 1917:

> *FE (l7 April l9l7) Steelhead in Yager--A correspondent from Yager writes: "The annual run of steelhead salmon is on in Yager and the same conditions prevail as in the past as in regard to the barrier opposite the Porter place. The fish unable to get over the falls gather in great numbers at the foot of the falls and batter themselves against the rocks in their attempts to get over and will soon become unfit for food. The bones will soon be seen lining the banks of the river. Repeatedly the attention of the Game and Fish Commission has been called to this matter but no investigation has been made. As before stated this condition could be remedied by the expenditure of a small amount of money and by removing the obstruction the salmon could go for several miles further up the river and also enter several of its tributaries."*

Coastal Cutthroat Trout

Coastal cutthroat trout (*Oncorhynchus clarki clarki)* are the least monitored species of salmonids in the Van Duzen River Basin. The Lower Eel River and Van Duzen River are at the southern-most end of coastal cutthroat trout's range. A few known sea run coastal cutthroat trout reside in the Yager Creek drainage. In the late 1800s and into the early 1900s, the Van Duzen River watershed supported a cutthroat population which attracted numerous sport anglers (Snyder 1908, Dewitt 1954, USDI 1960, Van Kirk 1994). While populations continued to decline slowly, it was not until the mid to late 1900's that coastal cutthroat populations crashed in response to detrimental habitat changes during the 1950s to 1960s (Gerstrung 1996). While focused coastal cutthroat trout distribution surveys have not been conducted in recent years, adult coastal cutthroat trout have been identified in Bell Creek and in the Yager Creek mainstem.

Figure 25. Steelhead caught on the Lower Van Duzen River.

Habitat Overview

Historic Conditions

CDFW has collected habitat data in Yager Creek Subbasin streams since the 1930s. For the most part, the first stream observations were originally collected and recorded in memorandum format, with no established methodology. Beginning in the 1950s, CDFG (now CDFW) used a standard stream survey to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (1991) and is outlined in the *California Salmonid Stream Habitat Restoration Manual*.

Historical stream observations and reports described abundant spawning habitat, suitable rearing habitat, and abundant fish numbers. A stream survey of upper Lawrence Creek near the Yager-Kneeland Road crossing on August 8, 1938 noted abundant steelhead from 1.5-5 inches in length and water temperature of 58 F at 12:30 pm. This survey also noted the pools and shelter were in good condition and fishing pressure was heavy (Vestal and Shapovolov 1938). It was described by CDFG that there was extensive spawning habitat in the middle and upper reaches of the Yager Basin (CDFG 1965) and silver salmon were present in lower Yager Creek in August of 1965. A field survey of Lawrence Creek in 1972 noted that "silver salmon and steelhead fingerlings were observed throughout the stream" (on July 17) from its mouth to approximately 7.5 mile upstream (CDFG 1972a). The 1972 survey also noted several log jams. In addition, in response to a substantial recreational fishery presence within the basin, rainbow trout were planted in Dairy, Bell and possibly other tributaries.

CDFG stream surveys from the 1930s to the 1980s and additional anecdotal reports share a common trending theme. Historic flood events and land use activities (particularly extensive timber harvest) have modified natural stream channels and conditions throughout the subbasin. Once abundant fish populations declined in numbers and distribution as stream habitat quality declined. Changes to stream habitat after logging included loss of large riparian tress, large increases in fine sediments in spawning gravels, a general reduction in the numbers and depth of pools numerous log jams impeded upstream spawning migrations and decomposing slash piles left in creeks consumed dissolved oxygen to below minimum levels required to sustain fish (Taft 1933, Shapovolov and Vestal 1938, CDFG 1952a, CDFG 1956a, CDFG 1964a, DWR 1966, CDFG 1969a, DWR 1976 and others).

Problems with fish habitat related to timber harvests and other land disturbance activities were widely known. Stream habitat surveys and watershed management strategies were including recommendations for improving instream and upslope conditions with restoration activities and watershed management efforts. However, protective measures were inadequate or too late to reverse declining trends.

Current Conditions

Stream surveys using methods described in Flosi et al. (1991) were conducted in the Yager Creek Subbasin beginning in 1991 (*Table 15*). The results of the surveys are the basis for this salmonid habitat assessment. These surveys include recommendations for watershed and stream habitat improvement projects. Numerous watershed improvement projects have been implemented in the subbasin based on the recommendations from stream habitat surveys completed in the 1990's. Increasing pool area, depth and shelter was an objective of many instream projects. After project completion, a second or third stream survey was often conducted to re-assess conditions (eg. Fish, Shaw and Strawberry creeks) and to evaluate project effectiveness. It is important to note that the conditions of some streams discussed below reflect the results of these instream projects. Streams marked with an asterisk in Table 15 have received instream habitat improvement work prior to the stream survey. A project map and discussion of watershed improvement projects in the Yager Creek Subbasin are presented above in the Land Use section of the report.

In the following sections we will examine the past and present conditions of stream and riparian habitat within the Yager Creek Subbasin. An analysis will show that in many streams, habitat conditions are below preferred, conditions to sustain viable salmonid populations. Based on these conditions, additional restoration projects are needed in conjunction with suitable land management practices to help increase salmonid populations.

Table 14. Stream Surveys conducted in the Yager Creek Subbasin 1991-2006. Stream surveys generally start near the mouth and proceed upstream.

Stream Reach	Survey Year	Survey Length (feet)
Bell Creek *	1991	4,171
Blanton Creek *	1991	4,195
Blanton Creek *	2006	4,571
Booths Run	1991	9,661
Butte Creek	2003	1,137
Cooper Mill Creek *	1990	7,509
Cooper Mill Creek *	1996	13,152
Corner Creek	1991	2,339
Dairy Creek	2003	3,960
Fish Creek *	1991	4,652
Fish Creek *	1996	8,239
Fish Creek *	1998	3,538
Grouse Creek	2003	4,634
Lawrence Creek, Lower *	1991	32,880
Lawrence Creek, Lower *	2006	31,890
Lawrence Creek, Mid	1991	10,195
Lawrence Creek, Upper	1991	21,514
Lone Star Creek	2003	939
Shaw Creek *	1991	17,365
Shaw Creek *	1993	16,325
Shaw Creek *	1996	6,590
Shaw Creek *	2000	7,840
Strawberry Creek *	1991	3,818
Strawberry Creek *	1996	4,060
Strawberry Creek *	1998	3,128
Yager Creek *	1991	77,297
MF Yager Creek	1991	4,237
NF Yager Creek	1991	20,361
NF Yager Creek	1996	12,743
NF Yager Creek	2003	44,198
SF Yager *	1991	6,631
SF Yager *	1996	7,024
SF Yager *	2000	5,150

* Streams received instream habitat improvement work prior to stream survey.

Stream Habitat Characteristics

Pool:Riffle:Run Relationships

Significance: The measure of pool habitat characteristics is an important indicator of stream condition. Productive anadromous streams are composed of a balance of pool, riffle and runs. Each plays an important role as salmonid and stream community habitat. A pool to riffle ratio of approximately 1:1 has been suggested to provide optimum food production and cover conditions for juvenile coho and other salmon (McMahon 1983; Rosgen 1996) and Flosi et al. (1998) notes that the length of anadromous salmonid streams should be forty percent composed by pool habitats. There are several factors affecting the relationships of pools, runs and riffles. These include channel type, stream gradient, bed materials, width to depth ratios and flow obstructions such as boulders and LWD.

Findings: Pool riffle and run relationships and average maximum residual pool depths for the years 1991 -2006 in Yager subbasin streams are shown in *Table 16*. Using the most recent data available (for stream with multiple surveys), 22 percent (95% CI= ±6%) of the surveyed stream length is composed of pools in 1st and 2nd order streams. Coopermill Creek had the highest percent length in pools (41%) followed by Shaw

Creek (30%). Both of these streams received improvement projects that helped to increase pool area, depth, and shelter from pre project conditions. For 3rd and fourth order streams, 24 percent (95% CI= ±7%) of the stream length is composed of pools. Generally, the percent occurrence of pools and riffles are greater than their corresponding percent length of a stream in the Yager Subbasin streams. This indicates that pools are generally shorter in length than run and riffle habitats. Adding LWD to existing pools could increase the depth and length of the pool habitat in Yager Creek Subbasin streams.

Table 15. Pool, riffle and run relationships from Yager Creek Subbasin streams

Stream Reach	Survey Year	Stream Order	Ave. Max Res Pool Depth	Pool:Riffle:Run % occurrence	Pool:Riffle:Run % length
Bell Creek	1991	2	2.7	41:16:40	27:15:57
Blanton Creek	1991	1	1.8	43:35:22	21:43:36
Blanton Creek	2006	1	2.2	34:34:32	25:30:45
Booths Run	1991	2	2.1	25:37:37	15:30:56
Butte Creek	2003	1	1.5	23:43:33	16:57:27
Cooper Mill Creek	1990	1	1.5	38:29:32	36:25:39
Cooper Mill Creek	1996	1	1.8	44:30:26	41:26:33
Corner Creek	1991	1	1.5	22:38:40	11:39:49
Dairy Creek	2003	1	2.2	32:37:32	20:51:29
Fish Creek	1991	1	1.3	49:28:23	10:8:82
Fish Creek	1996	1	1.2	45:24:30	28:18:54
Fish Creek	1998	1	2.1	37:33:30	28:30:42
Grouse Creek	2003	1	1.8	21:31:47	21:31:47
Lawrence Creek, Lower	1991	3	3.2	16:35:49	13:32:55
Lawrence Creek, Lower	2006	3	3.0	31:34:35	29:34:37
Lawrence Creek, Mid	1991	3	3.3	24:40:36	18:43:39
Lawrence Creek, Upper	1991	3	2.3	42:28:30	38:25:37
Lone Star Creek	2003	1	1.2	33:46:21	25:53:22
Shaw Creek	1991	2	1.8	31:40:29	23:46:31
Shaw Creek	1993	2	1.9	35:40:25	28:45:27
Shaw Creek	1996	2	1.9	47:21:32	41:19:40
Shaw Creek	2000	2	2.3	45:30:24	30:35:49
Strawberry Creek	1991	1	1	49:43:8	23:67:10
Strawberry Creek	1996	1	1.1	39:31:29	25:7:69
Strawberry Creek	1998	1	1.4	41:34:24	28:40:30
Yager Creek	1991	4	3.9	25:28:46	20:21:59

Stream Reach	Survey Year	Stream Order	Ave. Max Res Pool Depth	Pool:Riffle:Run % occurrence	Pool:Riffle:Run % length
MF Yager Creek	1991	3	1.6	51:36:13	35:49:17
NF Yager Creek	1991	3	4.1	21:47:42	16:32:51
NF Yager Creek	1996	3	3.3	29:28:43	21:25:54
NF Yager Creek	2003	3	3.8	30:34:35	30:26:43
SF Yager	1991	2	2.1	27:36:37	16:35:49
SF Yager	1996	2	2.4	29:32:39	25:17:58
SF Yager	2000	2	2.3	35:19:46	20:16:63

Measures of Deep Pool Habitat

Significance: Deep pools are important for adult salmonid holding areas during spawning migrations and as year round habitat for rearing juvenile salmonids. Summer steelhead rely on cool deep pools for over summer holding habitat. Quantifying the amount of deep pool habitat in a stream reach is a useful indicator to assess stream conditions. Lack of deep pools may indicate elevated levels of in channel sediments or a lack of pool forming LWD. Generally, the desirable length of a coastal anadromous stream reach consist of approximately 25 to 45% pools with depths sufficient to serve as protection from predators and high winter flows. A residual pool depth of 3 feet is generally considered sufficient to provide this protection. However, some fish bearing streams are not large enough or lack the scour power to develop many such deep pools. Therefore, some smaller streams may not meet the general target values, but still provide important fish habitat. We consider suitable salmonid steams of the Yager Creek Subbasin to be composed of at least 25 percent pools with residual depths of 2.0 to 2.5 feet for 1st and 2nd order streams, ≥3 feet for 3rd order steams and ≥4 feet deep for 4th order streams. These target values were developed to help assess the pool condition of anadromous salmonid habitat by the EMDS for typical North Coast California streams (*Figure 26*).

Findings: Most Yager Creek Subbasin stream survey reaches were below target values for percent of stream length in deep pools (*Figure 26 and Figure 27*). Based on the most current survey data, the mean maximum residual depth for 1st and 2nd order streams is 1.9 feet, 2.8 feet for 3rd order streams, and 3.9 feet for the fourth order reach of Yager Creek. There are three reaches shown on the 1998-2006 EMDS results maps that rated suitable for amount of deep pools along the North Fork Yager Creek. These pools may offer over summer holding areas for summer steelhead if located near confluence streams, springs or seeps that input cool water.

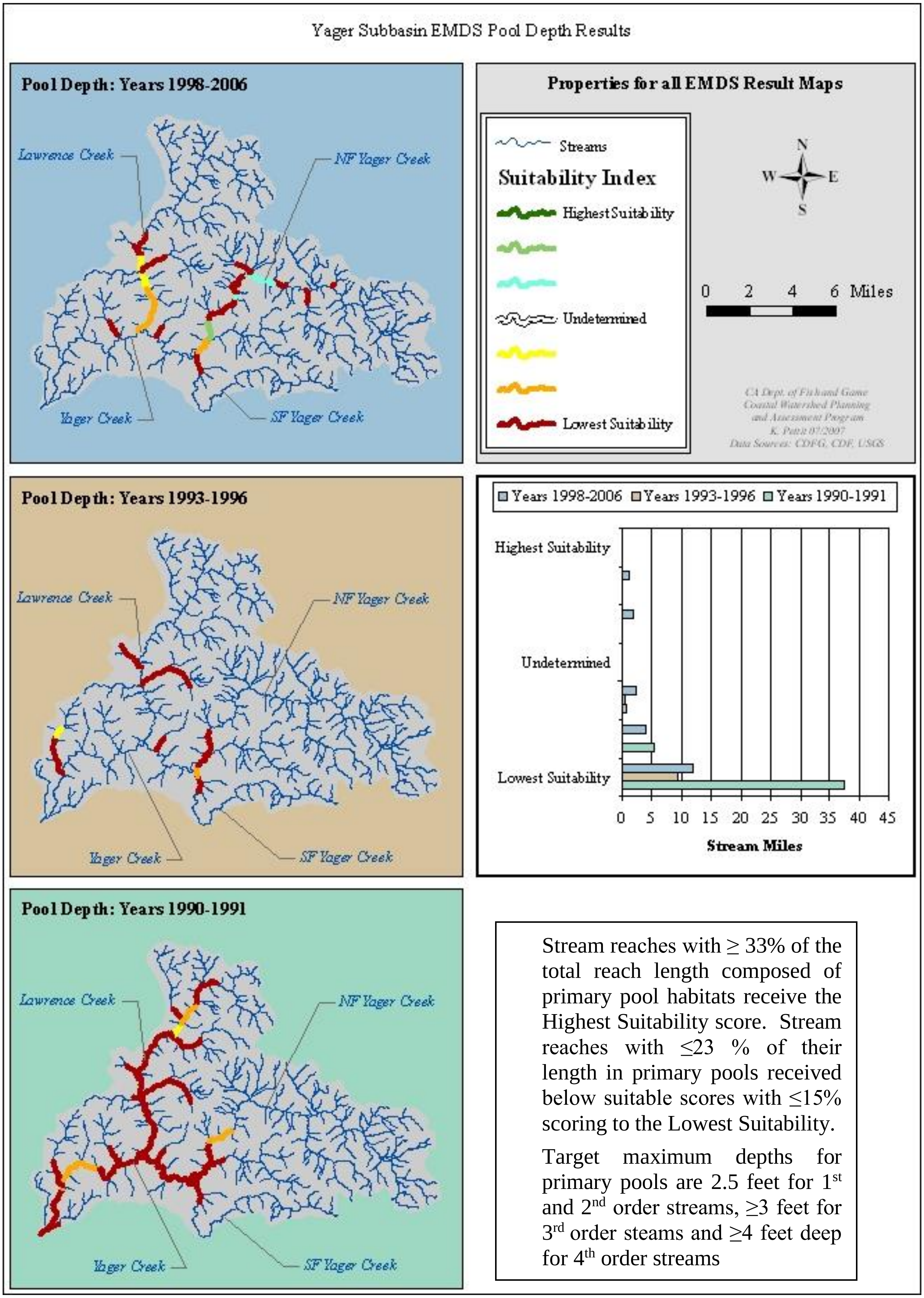


Figure 26. Pool depth suitability in Yager Creek Subbasin streams, using data collected between 1990-1991, 1993-1996, and 1998-2006.

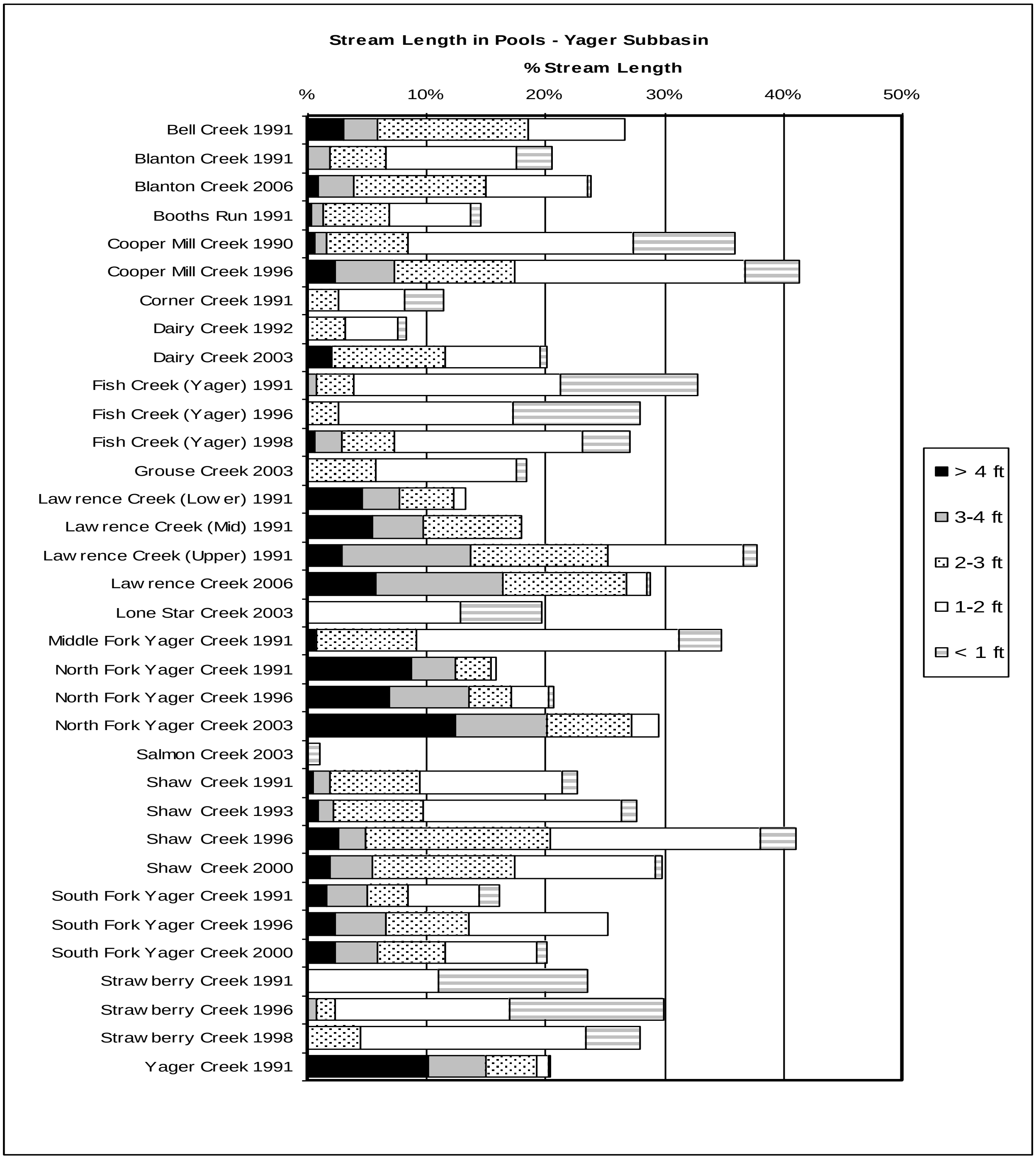


Figure 27. Percent stream length composed of pools. Data grouped by pool depth and year for streams of the Yager Creek Subbasin.

Pool Shelter

Significance: Salmonid abundance in streams increases with the abundance and quality of shelter of pools (Meehan 1991). According to a CDFG survey protocol, pool shelter complexity is rated by a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation (Flosi et al. 1998). These elements serve as instream habitat, create areas of diverse velocity, provide protection from predation, and separates territorial units to reduce density related competition. The ratings range from 0-300, with ratings of ≥100 considered good shelter values. They do not consider factors related to changes in discharge, such as water depth.

Findings: The pool shelter ratings were below the pool shelter rating target value of 100 for all surveyed streams (*Figure 28*). The highest shelter values were from streams where surveys were conducted soon after the streams received shelter improvement treatments during habitat improvement projects. These include Shaw, Blanton, Fish, and Strawberry creeks. Boulders and woody debris comprise most of the shelter in the surveyed pools, which are commonly used for pool enhancement projects (Table 17). Terrestrial vegetation and undercut banks were the least abundant type of shelter element. These two elements often work together as roots from large trees growing near the stream banks provide soil cohesion necessary to maintain undercut banks.

Stream reaches evaluated by EMDS show that Shaw Creek in 2000 and a small reach of Blanton in 2006 had suitable amounts of shelter elements in pools. The remaining reaches on the most recent EMDS maps show low suitability levels of pool shelter (*Figure 29*).

Table 16. Summary of mean percent cover in pools for streams surveyed 2000-2006 in Yager Subbasin

Stream / year	Undercut Banks	Woody Debris	Terrestrial Vegetation	Aquatic Vegetation	White-water	Boulders	Bedrock Ledges
Blanton Creek / 06	11	51	2	0	10	31	0
Dairy Creek / 03	1	8	1	0	12	70	10
Grouse Creek / 03	7	12	1	2	12	63	3
Lawrence Creek /06	5	43	5	0	1	40	6
Lone Star Creek / 03	3	19	0	0	10	65	4
Shaw /00	8	70	0	0	23	5	00
NF Yager / 03	2	17	2	0	1	66	12
SF Yager /00	2	33	6	0	17	41	0
Average Percent	**5**	**32**	**2**	**0.25**	**11**	**48**	**4**

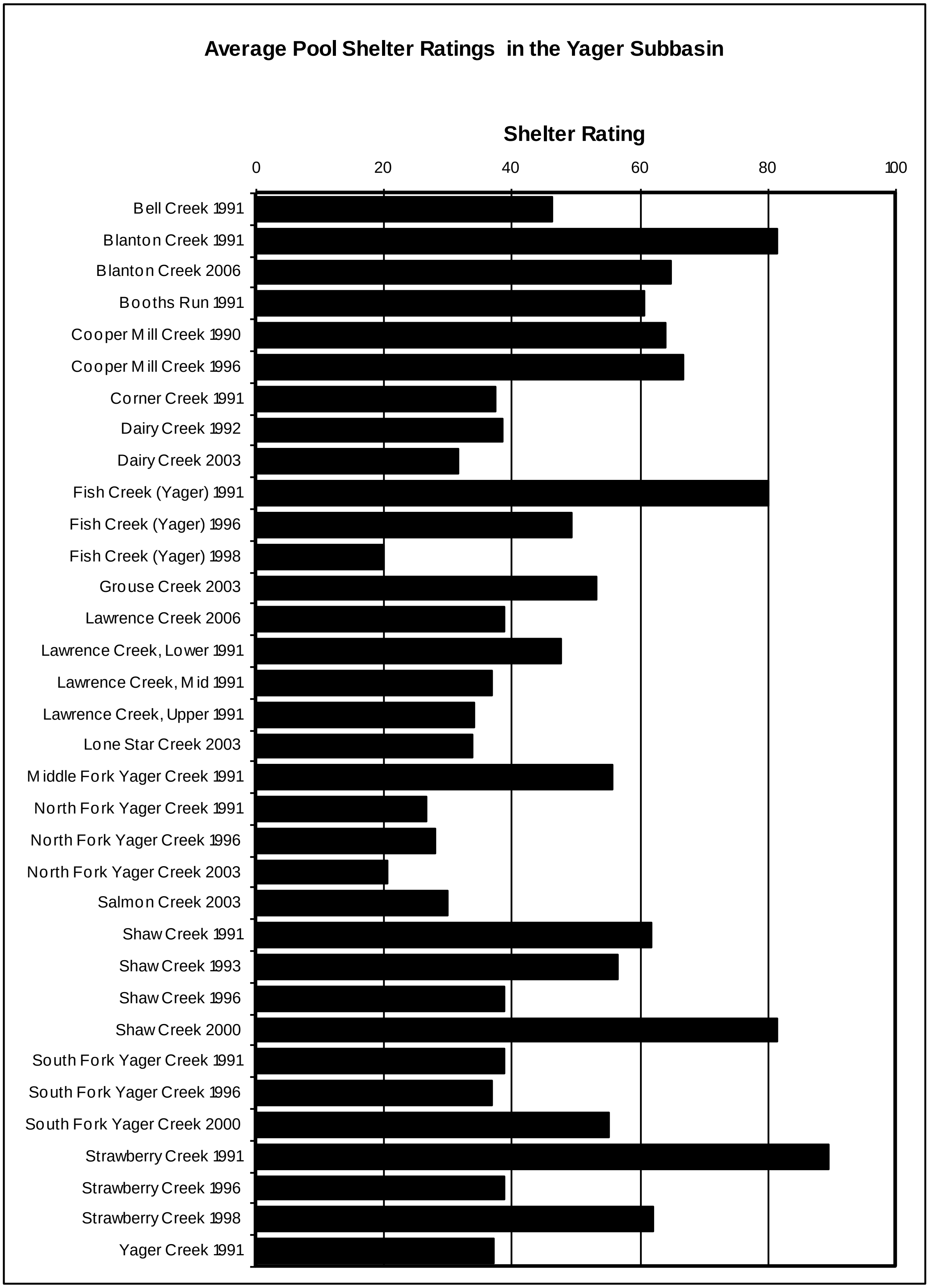


Figure 28. Average pool shelter ratings from CDFG stream surveys, Yager Creek Subbasin. Average pool shelter ratings ≥100 are considered fully suitable and average pool shelter ratings less than 60 indicate poor status of pool shelter elements.

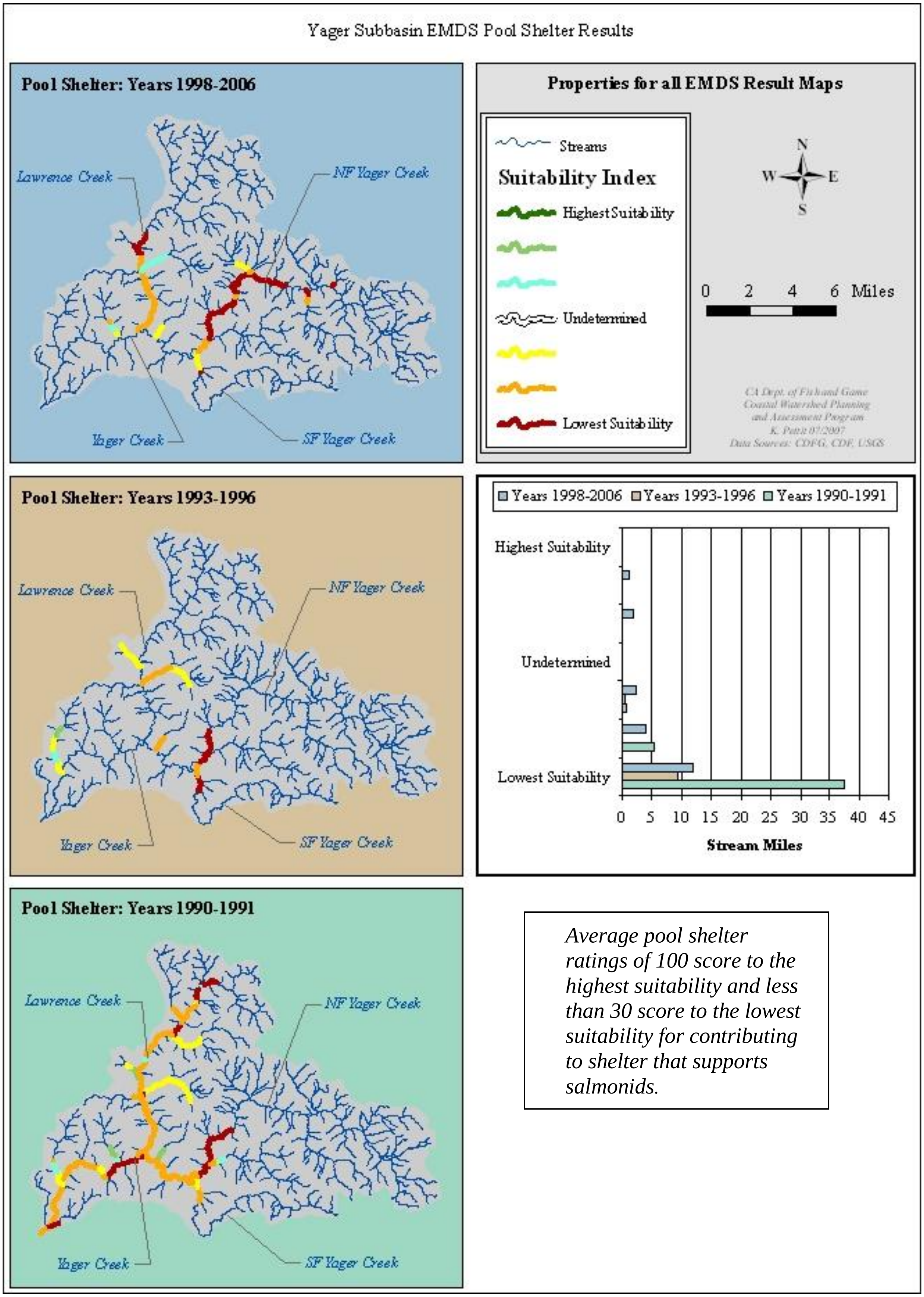


Figure 29. Map results of EMDS scores for shelter rating in pools. The number of stream miles in each category are also shown.

Streamside Canopy Density

Significance: Streamside canopy density estimates the percentage of stream channel shaded by riparian tree canopy. A second attribute of streamside canopy data is the measured percent of coniferous and hardwood tree species providing the shade.

In mixed conifer forests, an effective multistory canopy is often composed of understory and overstory shade provided by a mix of hardwoods (e.g. alder and maple) and conifers (e.g. redwood and fir). The effective canopy provides direct shade to reduce radiant heat from sun light from warming water and reduces convective heat input from air by providing shade far above the water by forming cool microclimates. Streams flowing through conifer forests are expected to have at minimum fifty percent shade provided by conifer trees.

Streams flowing through mature conifer stands tend to have larger amounts of wood with larger average piece size than streams with younger riparian stands, which often are dominated by smaller deciduous species (Bilby and Bisson 1998). LWD produced by conifers is generally favored over deciduous wood because it tends to be larger and less likely to move downstream, it decays more slowly, and stays longer in stream systems

The condition of streamside canopy can degrade relatively rapidly with management that removes trees. Conversely, positive changes associated with re-growth occur slowly. Habitat improvement projects to increase shade canopy including re-vegetation projects are recommended when canopy density is less than 80% (Flosi et al. 1998).

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Based on recent surveys (2006), Blanton, Shaw, Grouse, and small reaches of Dairy, and Butte creeks all show suitable levels of streamside shade canopy (*Figure 30 & 31*). A trend of increasing streamside shade canopy in Shaw, Cooper Mill and Blanton creeks is also apparent. However, most of the shade in the survey reaches is provided by understory vegetation composed of alders or other hardwoods. The amount of overstory shade provided by conifers is small. Lawrence Creek is generally lacking in shade canopy. Lawrence Creek averaged 70 percent shade which is below the target of 80 percent (Flosi et al. 1998). However, Lawrence Creek, like other streams, is showing an increasing trend in streamside shade compared to surveys in 1991 when shade was less than 50 percent in all but the uppermost reach (*Figures 30 and 31*). North Fork Yager Creek had an average streamside shade canopy of about 50% in 2003. This is also a significant increase in shade canopy compared to the 1990s surveys, in which canopy shade levels were only about 20%. This increase may be due to a rapidly growing understory of hardwood species.

Considering these streams flow through coniferous forests, most large coniferous shade trees were cut during past timber harvests and re-growth has not been allowed to or has been slow to occur Inspection of the EMDS maps (*Figure 31*) show how the amount of streamside shade canopy has increased over time.

Recommendation: In order to restore benefits (e.g. cool micro climate and LWD inputs) from a mature riparian forest, managers should promote retention of existing large conifers and encourage methods to accelerate growth of smaller conifers that are within riparian and nearstream forests.

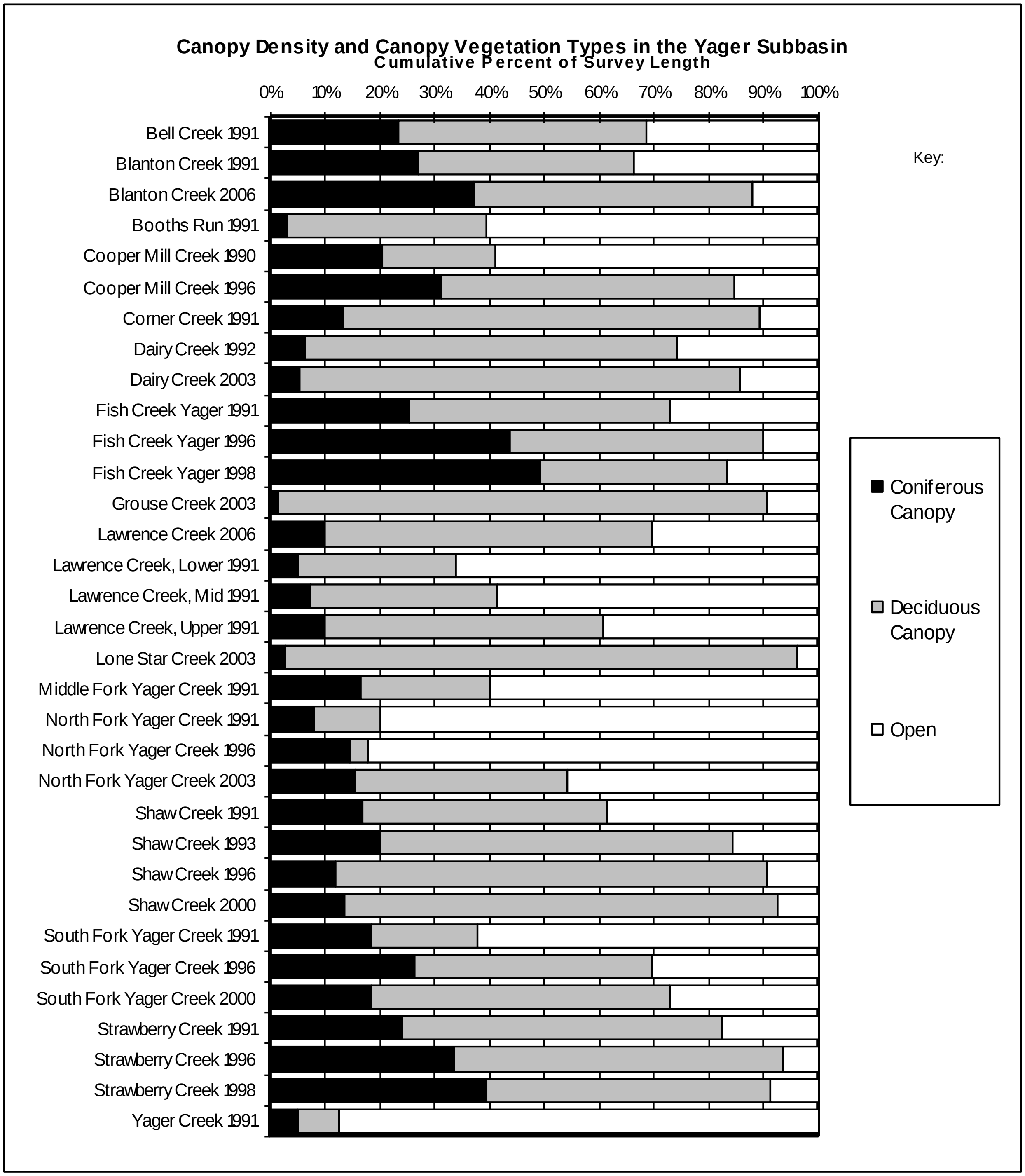

Figure 30. Percent canopy density measurements and the percent vegetation type contributing to shade canopy, Yager Creek Subbasin.

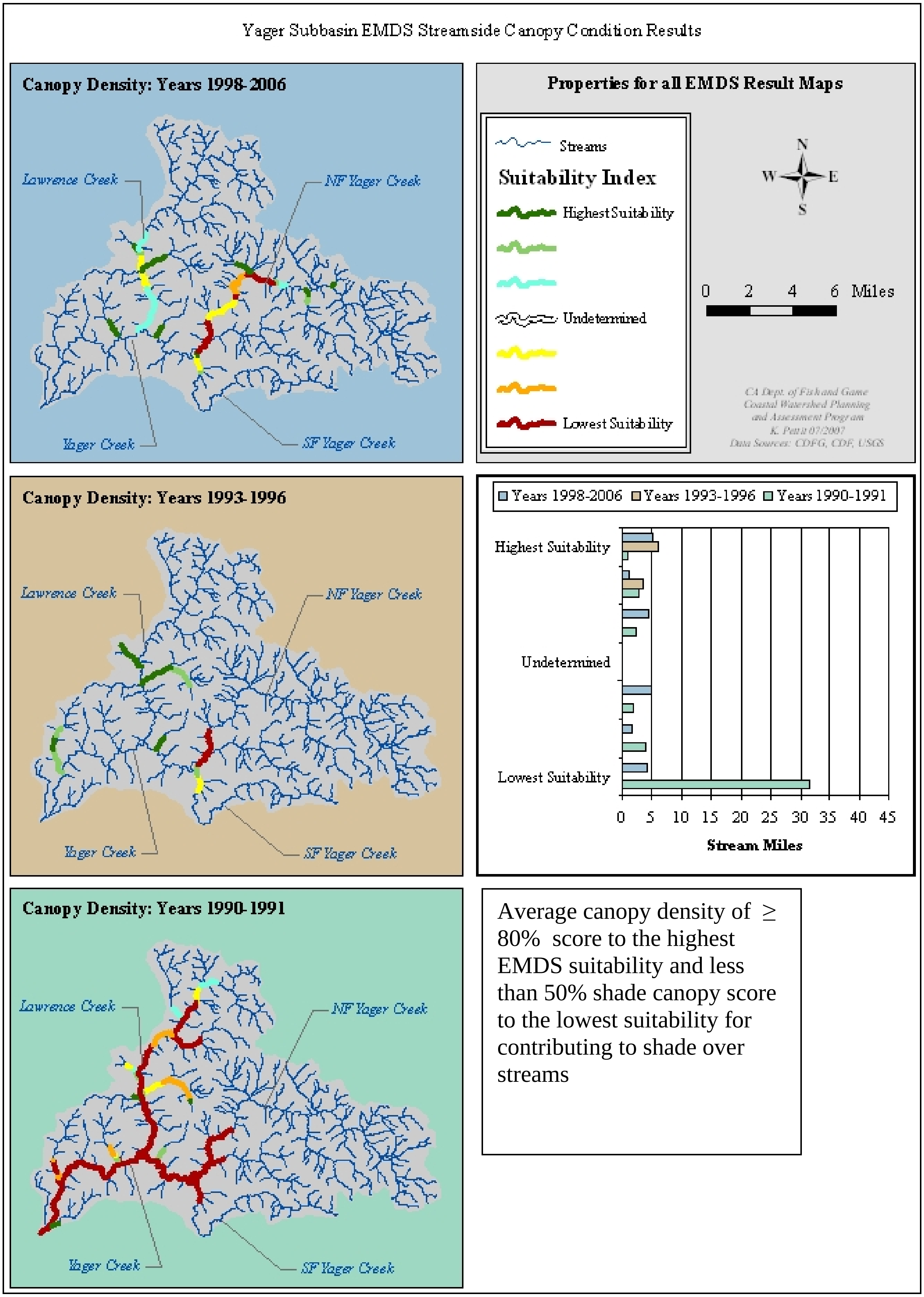

Figure 31. Map results of EMDS scores for streamside canopy density.

Cobble Embeddedness

Significance: Cobble embeddedness is the percent of an average-sized cobble piece embedded in fine substrate observed in a pool tail out. Percent cobble embeddedness provides a subjective measure of spawning substrate suitability for egg incubation, fry emergence and insect production. Embeddedness observations (>50 %) may indicate where excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds, which may suffocate eggs or developing embryos. High levels of embeddedness usually are a response to excessive fine sediment inputs due to erosion. Excessive levels of fine sediment accumulations within gravel and cobble substrate can also alter aquatic insect species composition to less valuable prey species. Excessive sedimentation can also reduce connectivity between surface and subsurface stream flows needed to moderate water temperature. Gravels and cobble that are less than 25 percent embedded with fines sediments are considered good quality substrate for salmonid spawning and production of aquatic insects. A general target is for streams to be with at least fifty percent of pool tail substrate embedded less than 25 percent in fine sediments. Gravels and cobbles over 50 percent embedded are viewed as poor quality for salmonid spawning and insect production that depends on clean gravel and cobble substrate.

High embeddedness ratings may indicate elevated levels of erosion occurring somewhere in the watershed due to natural and/or human causes. The potential for high levels of fine sediments increases in watersheds like Yager Creek where the geology, soils, precipitation, topography, and land use cumulatively exacerbate erosional processes (Duncan and Ward 1985). Fine sediments in salmonid streams are typically more abundant where land use activities such as logging, road building or land clearing expose soil to erosion and increase mass wasting (Cederholm et al. 1981, Swanson et al. 1987, Hicks et al. 1991).

Findings: Blanton Creek in 2006 had the best spawning gravel condition rating with approximately 55 percent of tails measured in the low embeddedness (<25%) category (*Figure 33*). All other stream reaches are considered moderated to highly embedded with fine sediments. Inspection of Figures 32 and 33 suggests an increasing trend in sedimentation of pool tails in many of the streams with multiple survey years. The high embeddedness values seen on other streams likely limit successful salmonid egg incubation, fry emergence and alter aquatic insect species composition needed as prey for salmonids.

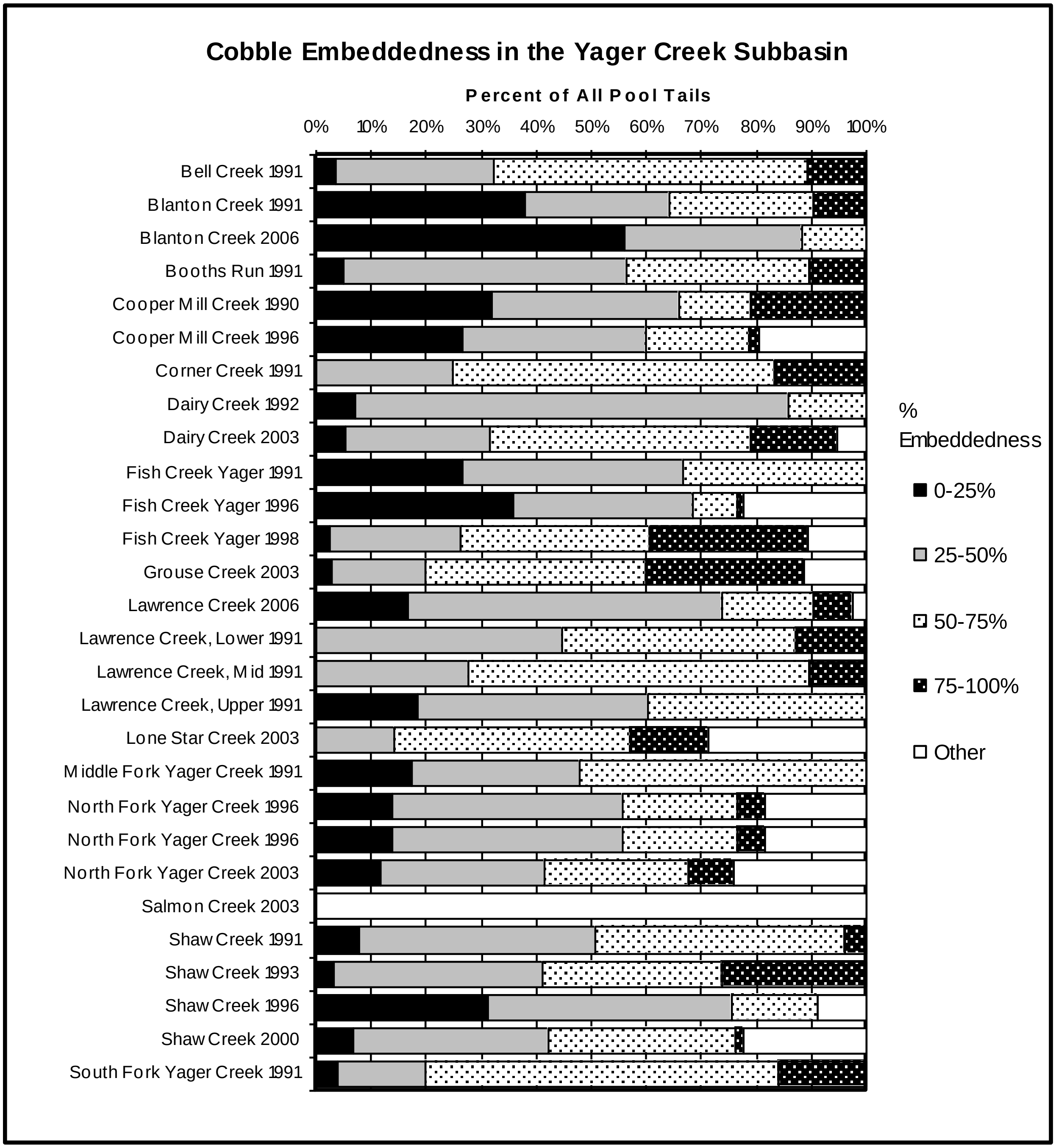

Figure 182. Cobble embeddedness categories and rating in pool tails for surveyed streams in the Yager Subbasin

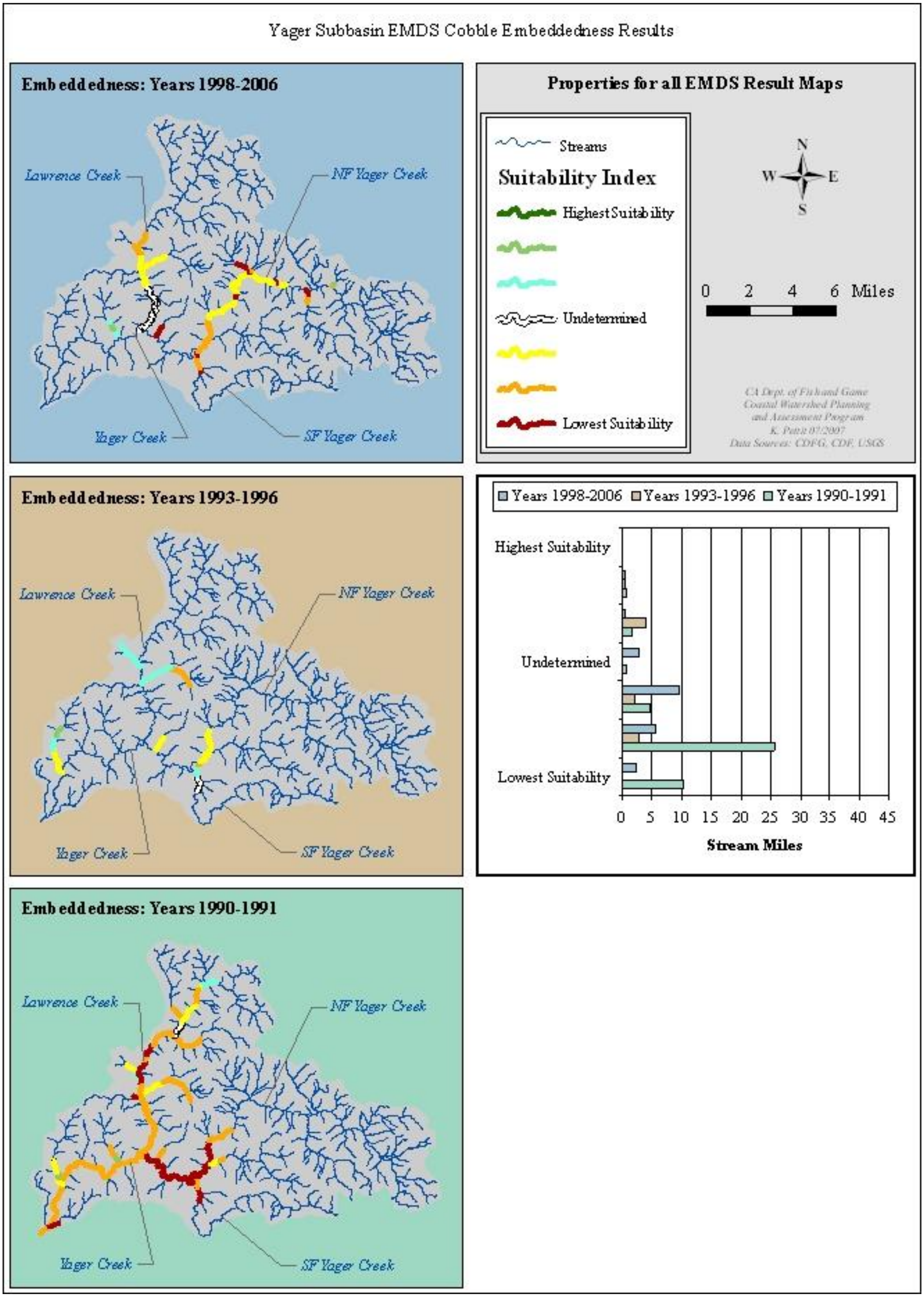

Figure 33. Map results of EMDS scores for embeddedness ratings in pool tails.

Water Temperature

Water temperature is one of the most important environmental influences on salmonids at all life stages, affecting physiological processes and timing of life history events (Spence et al. 1996, Carter 2005). Stressful conditions from high temperatures are cumulative and are positively correlated with both the severity and duration of exposure (Carter 2005). Elevated instream temperatures result from an increase in direct solar radiation due to the removal of riparian vegetation, channels widening and becoming shallower due to increased sedimentation, and the transport of excess heat downstream (USEPA 1999).

Water temperature data was collected in 1997 by the HCRCD and in 1999-2005 by PALCO from streams of the Yager Creek Subbasin (*Table 13 & 14,* respectively, and *Figure 34*). According to these data, the tributaries Bell, Shaw, Corner and Strawberry, SF Yager and upper Lawrence creeks sites show maximum weekly average temperatures (MWATs) considered suitable for salmonids. The sites on mainstem Yager Creek and the North Fork Yager Creek recorded temperatures above desired levels for over summer rearing of juvenile salmonids.

Table 17. 7-day average and maximum average temperature (Fº) recorded 1997 in the Yager Creek Subbasin.
Data source: HCRCD

Site	Location	1997	
		7-day Ave (Fº)	7-day Ave Max (Fº)
1209	Lawrence Creek	66.7	72.1
1211	NF Yager Creek	71.2	83.1
1247	Lawrence Creek	63.0	68.4
1248	Lawrence Creek	65.1	72.0
1249	Lawrence Creek	67.1	72.5
1250	Lawrence Creek	64.8	69.1
1251	Lawrence Creek	65.8	71.2
1252	Lawrence Creek	67.6	74.8
1253	Lawrence Creek	66.7	71.8
1342	Lawrence Creek	66.6	71.4
1344	Lawrence Creek	66.4	70.7
1347	Lawrence Creek	64.2	67.6
1349	Lawrence Creek	61.2	65.1
1351	Lawrence Creek	58.5	60.6
1353	Lawrence Creek	62.1	65.7
1354	Lawrence Creek	61.7	65.1
1355	Lawrence Creek	59.9	68.7
1360	Lawrence Creek	70.3	77.0

Table 18. 7-Day maximum average temperature (ºF) recorded between 1999 and 2005 in the Yager Creek Subbasin.
Data source: PALCO.

Station Location / Year	1999	2000	2001	2002	2003	2004	2005
Bell 117	56.8	56.6	55.0	56.9	58.5	56.6	58.1
Lawrence 47			59.6	59.9		61.1	
Lawrence 49	65.5	65.2	66.3	64.7	65.6	67.0	
Lawrence 9			64.9	65.1	66.5	67.7	65.3
Shaw 40		59.0	58.7	58.1	59.6		59.4
Corner 88	56.9	56.4	56.3	56.2	57.3	57.7	57.5
NF Yager 11			68.8	70.0	71.1	72.7	71.6
SF Yager 68	62.4	62.6	61.9	60.9	69.5	63.9	61.9
Strawberry 163			57.7	57.0	59.1	59.7	57.8
Yager 164		72.2	73.5			75.0	71.2
Yager 5					71.1	72.9	69.7
Air T 68		65.0	63.9	64.2	68.0	67.2	65.2

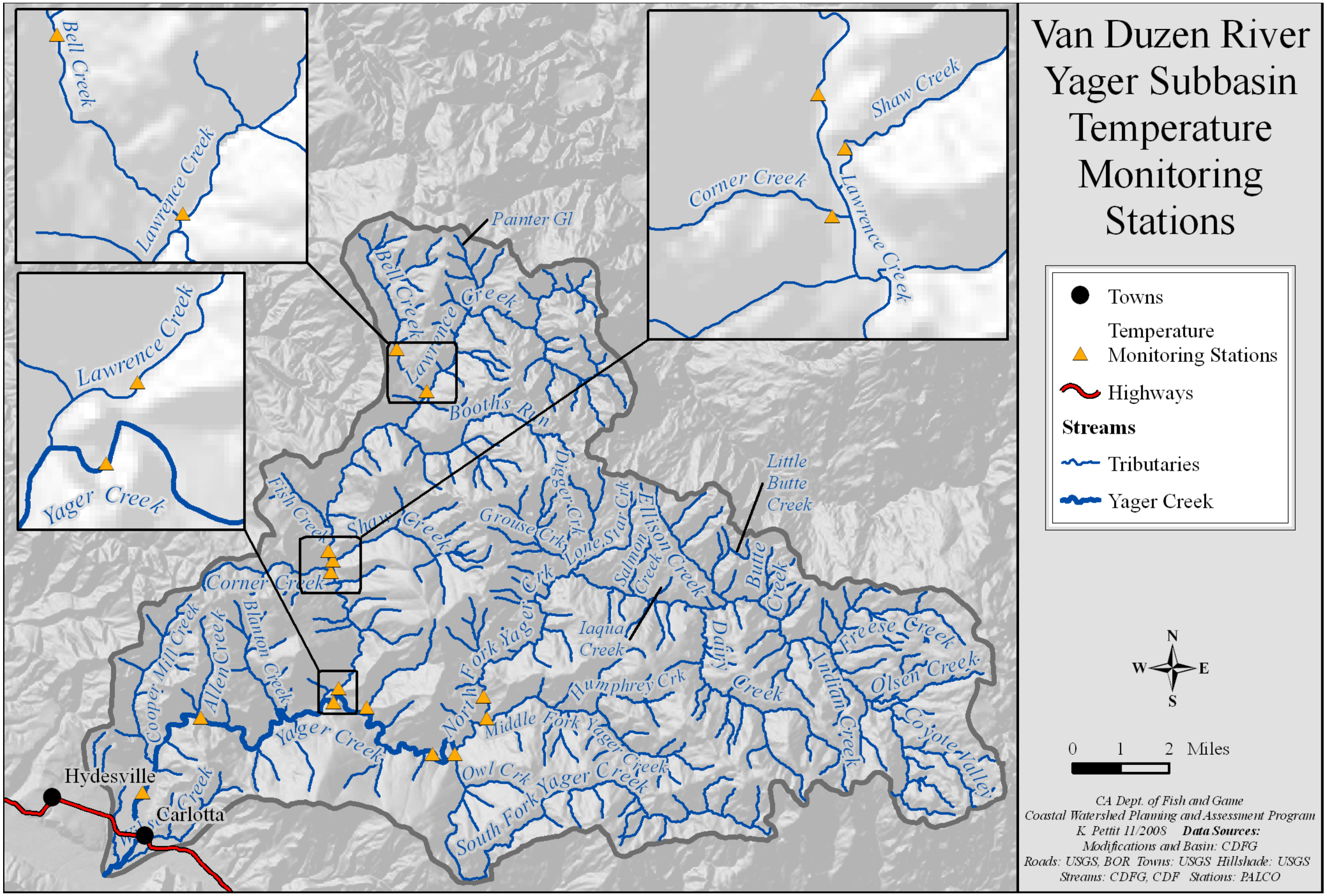

Figure 34. Yager Subbasin temperature monitoring stations1997-2005.

Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Yager Creek Subbasin using professional judgment and criteria developed for North Coast watersheds. The criteria included measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quantity and quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS based analysis at the stream reach scale.

Sixteen Yager Creek Subbasin streams were rated as salmonid refugia areas. Refugia categories were defined as:

- **High Quality** – relatively undisturbed habitat, with the range and variability of conditions necessary to support species diversity and natural salmonid production;
- **High Potential** – diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia;
- **Medium Potential** – degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Habitat may improve with modified management practices and restoration efforts;
- **Low Quality** – highly impaired riparian and instream habitat with few salmonids (species, life stages, and year classes). Current management practices and conditions have significantly altered the natural ecosystem and major changes are required to improve habitat.

Salmonid habitat conditions in the Yager Creek Subbasin on streams surveyed by CDFW are generally rated as medium potential refugia, with 10 of 16 streams surveyed in that category (*Figure 35*). Most of these streams in this category have degraded habitat due to previous land management practices. In addition, the majority of these streams has reduced or lacks any distribution of Chinook and coho salmon and is limited to steelhead trout production.

No stream within the subbasin is currently rated as high quality habitat. However, Lawrence Creek, Shaw Creek, and mainstem Yager Creek provide the best salmonid habitat in this subbasin and are rated in the high potential refugia category. These streams are almost entirely within Humboldt Redwoods Company property and have had numerous restoration projects completed with the goal of improving upslope and stream habitat conditions.

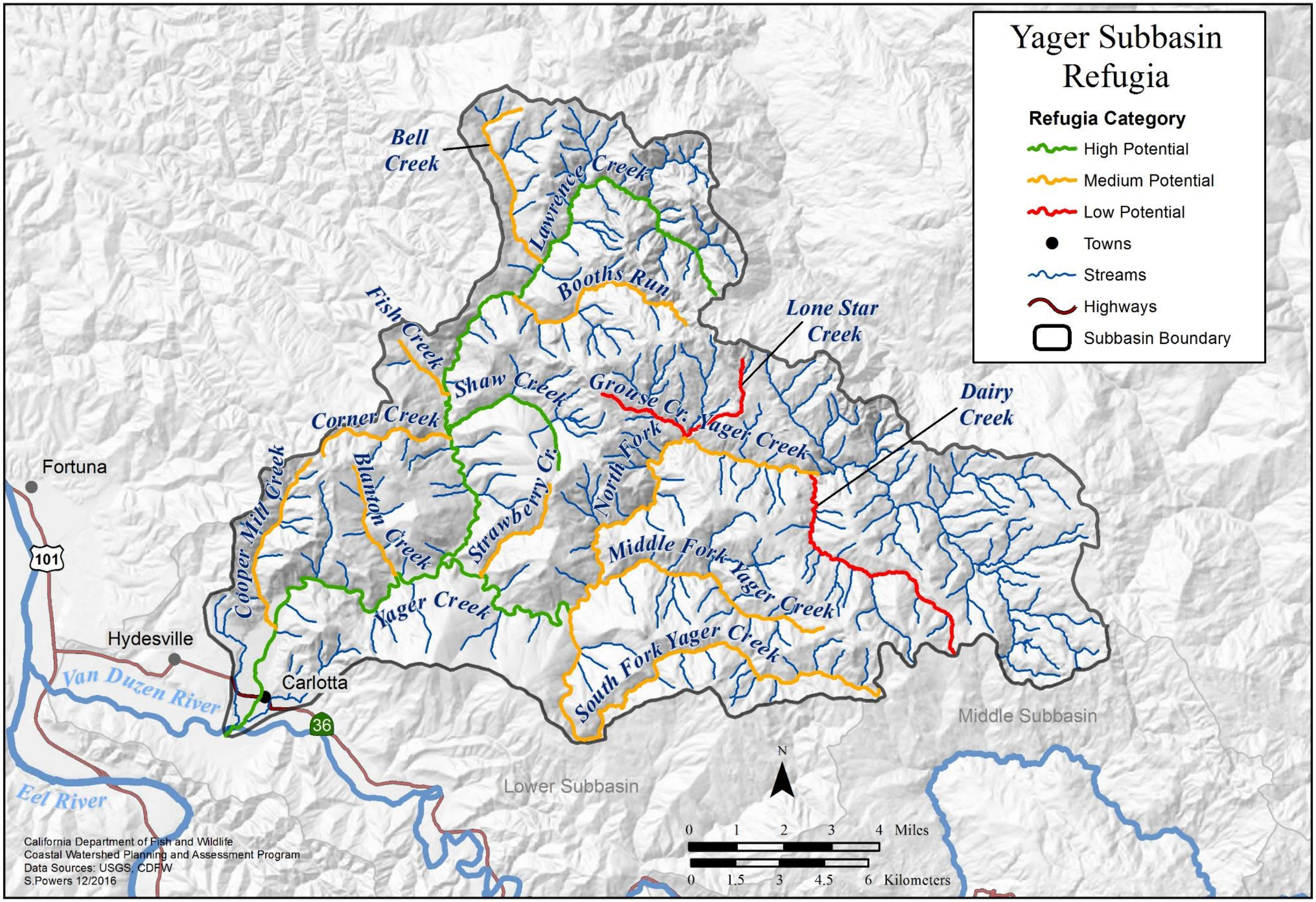

Figure 35. Refugia categories in the Yager Creek Subasin streams.

Responses to Assessment Questions

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Yager Creek Subbasin?

- The Yager Creek Subbasin supports populations of Chinook and coho salmon, and steelhead, resident rainbow trout, and coastal cutthroat trout;
- Chinook and coho salmon, steelhead and coastal cutthroat trout were once considered abundant in the Yager Creek Subbasin;
- Populations of Chinook salmon are now at historically low levels of abundance and they are less widely distributed compared to their past known extent;
- Coho salmon populations are very low and their distribution is limited to the Lawrence Creek and a few of its tributaries within the subbasin. No adult coho were observed during annual CDFW index reach spawner surveys from 2002 through 2009. However, since 2010 low numbers of spawning adults have been observed in Lawrence, Shaw, and Fish creeks. Juvenile coho salmon also have been recently observed in these streams as well as Cooper Mill Creek;
- Viable populations of winter run steelhead are still present and they retain much of their historic distribution in the subbasin, but at lower population densities than reported in the past;
- Anecdotal records suggest that summer steelhead populations were once abundant in the subbasin; however, there are no recent recorded observations of their presence.

What are the current salmonid habitat conditions in the Yager Creek Subbasin? How do these conditions compare to desired conditions?

- Due to its geographic setting, the Yager Creek Subbasin once provided some of the best salmonid habitat in the Van Duzen Basin. The majority of stream miles flow through redwood forests growing on mountainous terrain located within the coastal fog belt;
- There are approximately 53 miles of mainstem and tributary stream habitat accessible to anadromous salmonids in the Yager Creek Subbasin;
- Current conditions for most of the anadromous stream reaches of the Yager Subbasin do not meet desirable status or are below standards for salmonid production. However, the subbasin possesses some of the best potential for high quality salmonid habitat in the Van Duzen River Basin;
- Excessive amounts of sediment inputs have adversely impacted salmonid habitat for decades;
- Spawning substrate is highly embedded with fine sediments causing a shortage of good quality spawning habitat;
- Most of the surveyed stream miles lack deep pool habitats;
- Most of the surveyed stream miles lack a desired distribution of instream LWD and other shelter elements;
- Debris accumulations may impair fish passage and alter sediment transport in Shaw Creek;
- Due to lack of complex shading and the shallow, aggraded channel, the water temperature in the lower reach (~1 mile) of Lawrence Creek exceeds desired levels for salmonid production;

- Recovery of coho salmon in the subbasin depends on immediately protecting, preserving or improving conditions in Shaw and Lawrence creeks.

What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?

- Unstable, erodible bedrock, frequent seismic movement, high regional uplift rates and high (at times intense) seasonal rainfall contribute to natural recruitment of sediment into the Yager Creek stream network;
- The mature forest condition and native hillslope vegetation of the past performed important ecosystem functions. Mature forests helped to ameliorate hillslope erosion, formed cool microclimates surrounding streams that kept water temperatures cool during warm summer months and supplied streams with LWD. Deep rooted, native bunchgrasses also helped to maintain soil stability in prairies and grasslands.
- The continual vegetative changes in forest and hillslope condition combined with the development of an extensive road system over the last hundred years has significantly increased erosion rates and sediment inputs to streams across the subbasin. The large scale ground disturbance coupled with heavy rainfall events contributes to stream channels aggraded with sediments eroded from unstable hillslopes. Excessively aggraded channels can actively erode their stream banks, bury instream scour objects and form an armored layer stream channel bottom embedded with fine sediments.
- Heavily embedded stream reaches usually are poor areas for salmonid spawning success, are deficient in complex habitat diversity and generally lack pool to riffle to run ratios desirable for rearing of juvenile salmonids;
- LWD is an integral component to maintain a stream morphology suited for production of anadromous salmonids.
- The Yager Creek Subbasin is composed bedrock and soils considered naturally unstable, having a high potential for surface erosion;
- Large Quaternary landslide deposits present along stream banks are subject to reactivation and enhanced bank erosion during heavy rains and/or seismic events;
- Geologic uplift and rapid incision rates of portions of Yager Creek and its tributaries have left very steep, high banks which increase the likelihood for rockfalls and landslides;
- Steep slopes, (>30%) are highly prone to landsliding, comprise 50 percent of the subbasin's terrain and are distributed throughout the subbasin;
- Multiple faults and shear zones cut through this area fracturing the bedrock and making it less competent;
- Frequent landslides especially during heavy storm events and/or seismic events contribute a significant amount of sediments to the stream network;
- Large flow events play a major role in aggradation, degradation, as well as other changes in channel morphology;
- Stream flows in excessively aggraded channels generally tend to be shallow and lacking in a sufficient number of deep pools. These areas may lose connectivity with cool ground water and surface flows, and are more susceptible to heating by direct solar radiation or convective heat transfer with air than deeper, non-aggraded streams with deep pools and ground water exchange;

- Aggraded channels with highly embedded spawning substrate are found in reaches of all forks of Yager, Lawrence, Shaw, Fish, Blanton, Corner, and Coopermill creeks and likely others streams in the subbasin;
- Factors that contribute to aggraded channels are excessive sediment inputs and lack of objects such as large boulders, bedrock outcrops and LWD that help scour sediment and form and maintain deep pools. Scour objects also maintain sediment transport processes;
- The early seral condition or removal of nearstream conifer forests has reduced the capacity of multistory shade canopy to maintain cool microclimates surrounding streams;
- Watershed integrity largely depends on the various functions provided by healthy stands of forests and other vegetative attributes.

How has land use affected these natural processes?

- Land and forest management in the subbasin has led to adverse changes in anadromous salmonid habitats;
- Primary causes for stream habitat deficiencies are often related to actions that increase erosion, or activities that alter characteristics of near stream forests;
- The combination of land disturbance from intensive timber harvesting and road construction on naturally unstable terrain combined with severe winter rainstorms and has triggered major episodes of erosion and continuous chronic delivery of sediments to stream channels;
- The naturally high potential for erosion is elevated by land use such as road construction, tractor logging skid trails and timber harvesting;
- According to USEPA (1999), clear-cut timber harvest that use tractor yarding cause the most erosion and generate the highest sediment yields to streams of all land use types in the subbasin;
- A common result from land use practices and strong winter storms over the last 50-60 years has been the wide spread erosion of the landscape that contributed vast amounts of sediments and logging debris to stream channels.

Based upon these conditions, trends, and relationships, are there physical elements that could be considered to be limiting factors for salmon and steelhead production?

Barriers to Fish Passage

- Log debris accumulations may impede anadromous fish passage to upstream spawning areas in Shaw and Cooper Mill creeks;
- Perched sediment deltas may impede anadromous fish passage during varying stream flows to upstream spawning areas in Blanton and Cooper Mill creeks.
- Consider modifying or removing the small check dam located on lower Copper Mill Creek (RM 0.5) to ensure year round passage to all life stages of juvenile salmonids. This seasonal barrier was formerly associated with the PALCO fish rearing facility that is no longer in use.

Flow and Water Quality Improvement Activities:

- Halt, avoid, or mitigate all land use practices that exacerbate prolonged or excessive turbidity in streams;

- Ensure that water diversions used for domestic and/or irrigation purposes bypass sufficient flows to maintain all needs of fishery resources.
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement, and support actions designed to encourage efficient use of water.

Erosion and Sediment Delivery Reduction Activities:

- Halt, avoid, or mitigate all land use practices that exacerbate excessive sediment input to streams;
- Since all the steep (>30% slope) hillslope geology of the Yager Subbasin is considered high for erosion potential, actions such as road construction, intensive timber harvests, and tractor yarding should be mitigated according with Best Management Practices that meet all regulatory agency standards of soil conservation, fish and wildlife values and water quality objectives;
- Perform road assessment surveys on the Kneeland and Shower Pass county roads.

Riparian and Stream Habitat Improvement Activities:

- Promote growth and retention of large conifers in the riparian corridor along mainstem and tributaries;
- Where current near stream forest canopy is strongly dominated by hardwoods and site conditions are appropriate, land managers should consider cautious thinning of hardwoods from below to hasten the development of denser and more extensive coniferous canopy component;
- To address the lack of large woody debris in many tributary channels and along the mainstem, management should promote growth of near stream conifers and allow natural recruitment of trees to stream channels;
- Where near stream conifers are not large enough to function as naturally occurring scour elements, consider importing LWD from nearby hillslopes for placement in locations and orientations where it will provide beneficial habitat elements and will not accelerate adverse bank erosion;
- Consider installing vortex boulder weir structures or opposing wing deflectors keyed into banks in lower Yager Creek to maintain sediment transport and reduce width to depth ratios;
- Improve winter rearing habitat in Lawrence and Yager creeks by creating off-channel ponds.

Monitoring, Education and Research Activities:

- Perform fish surveys in the North Fork Yager Creek designed to detect Chinook and coho salmon presence and distribution;
- Perform salmonid surveys in Lawrence Creek and its tributaries to detect Chinook and coho salmon presence and distribution;
- Consistently collect water quality data, including summer stream temperatures in the Lawrence Creek drainage as well as lower Yager Creek.

Subbasin Conclusion

Within the Van Duzen River Basin, the Yager Creek Subbasin most likely maintains the highest salmonid fisheries value, particularly concerning presence/viability of coho salmon within the Lawrence Creek drainage. The subbasin is mostly contained within the coastal fog belt, which helps provide sufficient summer stream flow and moderate summer stream temperatures. Furthermore, the subbasin is located primarily within private timber company land, which allows for relatively cohesive/regulated land management and resource use and monitoring of salmonid distribution.

Nevertheless, the combination of many factors has contributed to the decline of coho and other salmonids. Impairments to adult spawning grounds and juvenile rearing habitat have likely contributed to the significant reduction of salmonid abundance and distribution in the Yager Creek Subbasin. In particular, juvenile coho rearing habitat is very limited in the subbasin. Due to the changes in stream habitat conditions associated with land use, the critical elements that combine to form coho habitat are rare in the subbasin.

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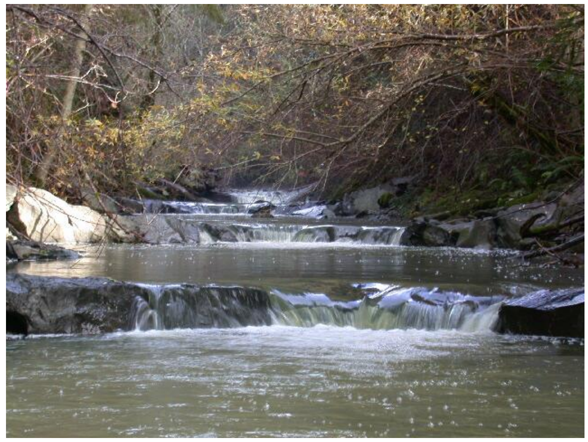
Lower Subbasin

Overview

The Lower Subbasin drains approximately 69 square miles of the southwestern portion of the Van Duzen River Basin, including approximately 23 miles of the mainstem Van Duzen River, 54 miles of perennial tributary channels and 85 miles of intermittent tributary stream channels according to 1:1000 USGS maps (Table 1 and Figure 1). This subbasin consists of six Calwater 2.2 planning watersheds (Fig. 2). Grizzly Creek is the eastern most planning watershed in the subbasin, marked by the approximate eastern extent of the coastal fog zone and distribution of redwood forests. Nearly all the land in this subbasin (97.7%) is privately owned, and the remaining 2.3% is owned by the state. Primary land uses include timber production, dairy and cattle ranching, gravel

Table 1. Attributes of the Van Duzen River Lower Subbasin.

Square Miles	69
Total Acreage	44,159
Private Acres	43,144
Federal Acres	0
State Acres	1,015
Predominant Land Use	Timber Harvests and rural developments
Predominant Vegetation	Redwood Forest
Total Stream Miles	162
Miles of Anadromous Stream	45
Low Elevation (feet)	60
High Elevation (feet)	3,440

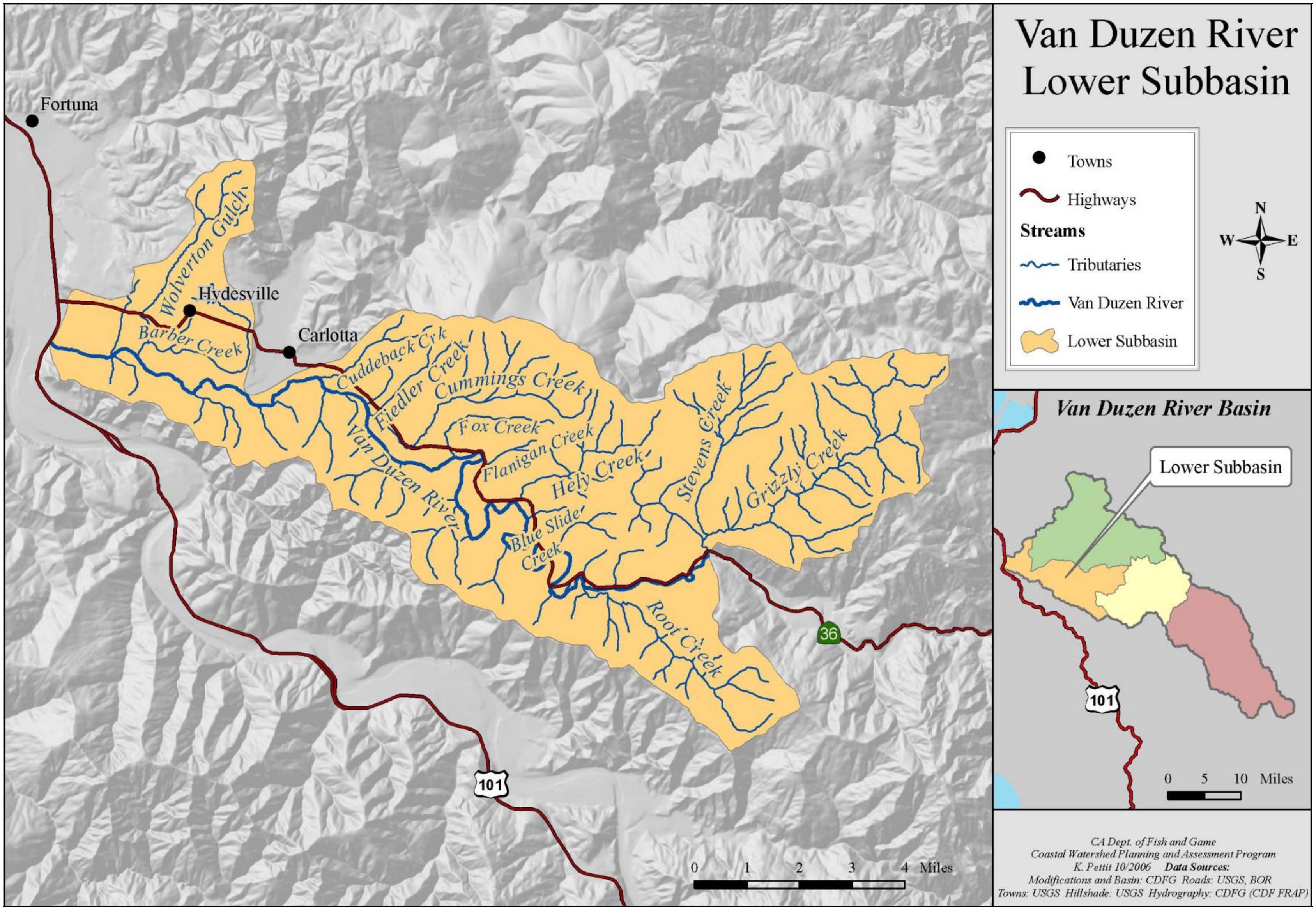


Figure 1. Location and tributaries of the Van Duzen River Lower Subbasin.

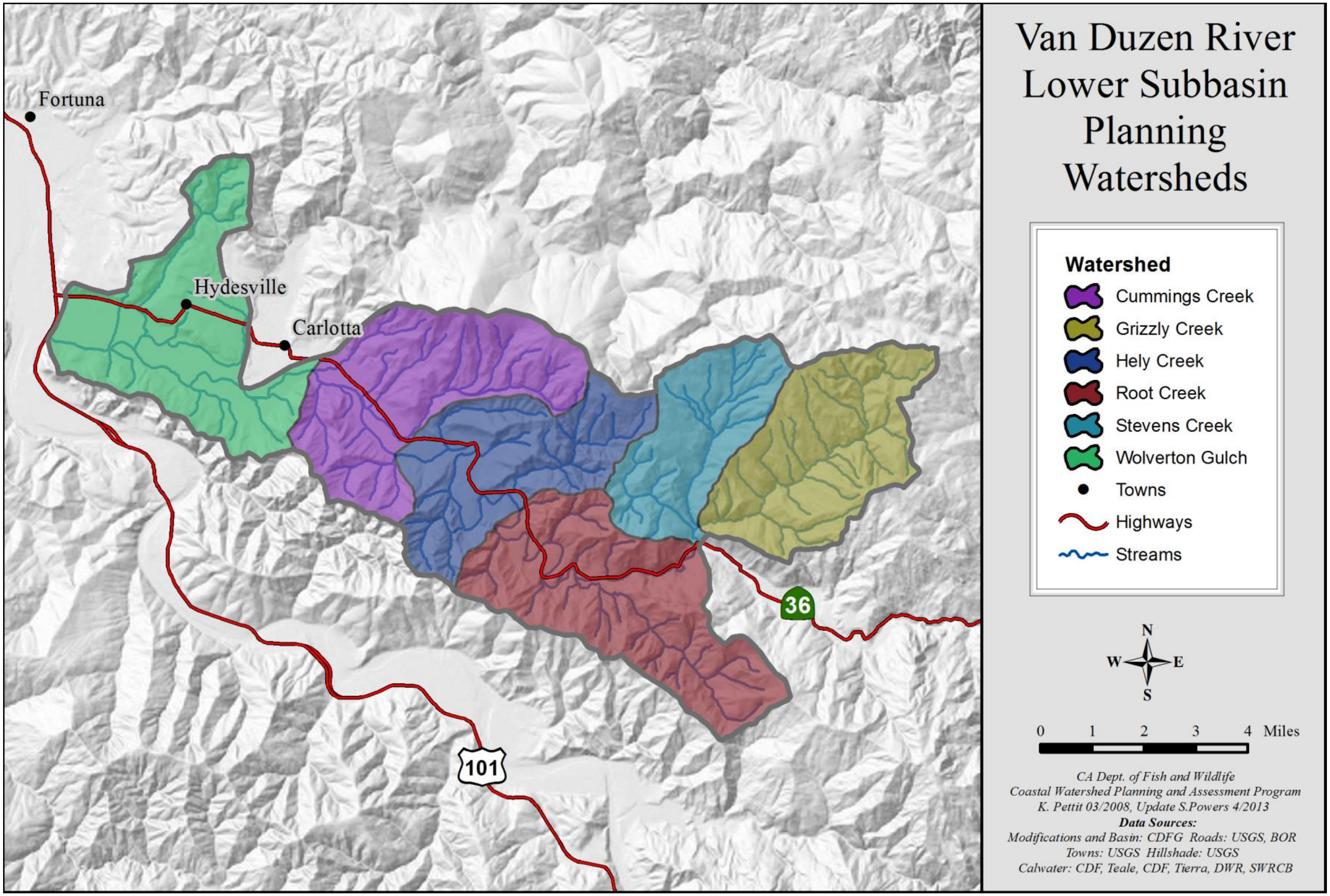


Figure 2. Six Cal 2.2 planning watershed comprise the Van Duzen River Lower Subbasin.

mining and residential developments. The towns of Hydesville and Carlotta are centers for residential developments located in the lower river valley. There are two county parks (Swimmers Delight and Pamplin Grove) and Grizzly Creek State Park in the Lower Subbasin designed to conserve natural resources and provide recreational opportunities to the public.

Streams of the Lower Subbasin support populations of Chinook salmon, coho salmon, steelhead, and coastal cutthroat trout. The largest tributaries in this subbasin are among the most important salmonid producing streams in the Van Duzen River Basin, including Grizzly Creek, Root Creek, Hely Creek, and Cummings Creek (Fig. 1).

Geology

The geology of the Lower Subbasin of the Van Duzen River is complex and characterized by active faults and land movement that have important implications for watershed health, planning, and restoration. The Basin Profile of the Van Duzen provides a review of the important processes, terrain types, and references. In this section, we present the geologic units at the tributary scale within the Lower Subbasin.

Bedrock

The Lower Subbasin is composed of seven different rock types: the Wildcat group (50%), Yager terrain (19%), Central Belt Franciscan Mélange (11%), alluvium deposits (11%), river terrace deposits (6%), landslide deposits (2%), and Central Belt sandstone (1%) (Fig. 3 and Table 2). Lower Subbasin streams have down cut into erodible bedrock during extensive tectonic uplift of this region leaving very steep bank-slopes and terraces, which are susceptible to small-scale, frequent slope failure (Reynolds et al. 1981). The naturally high potential for erosion is elevated on steep slopes (>30%) and dormant landslides where land use has disturbed top soil or reduced slope stability.

The Wildcat Group is the most abundant bedrock type in the subbasin, occupying 50% of the Lower Subbasin. The Wildcat Group consists of moderately to poorly indurated marine – nonmarine sedimentary bedrock. Along the lower Van Duzen River valley, the Wildcat Group is often covered by alluvium and river terrace deposits (Fig. 4).

The bedrock of the Wildcat Group is one of the most unstable in the subbasin. Consequently, very high erosion potential exists where the Wildcat underlies Cummings Creek, Hely Creek, and Root Creek planning watersheds. Erosion of the soft, sedimentary rock types of the Wildcat contributes fine sediments to stream channels (Fig. 5). These properties of the Wildcat bedrock allow it to shed large amounts of fine sediment into the streams causing heavy levels of turbidity that can fill in spawning gravels. The clay content within the bedrock is easily suspended in the water column, and erosion near the surface tends to stabilize as cohesion between grains increases. In areas where Wildcat bedrock goes through repeated wet and dry cycles, the surface tends to crumble and slough off allowing fine sediment input to the streams. Streams within Wildcat bedrock tend to form steep to vertical canyon walls, which are prone to undercutting and rock sliding. The Wildcat bedrock is also prone to sliding in areas where bedding dips inward towards the stream canyon. Slide planes tend to develop along bedding between sandstone and mudstone layers. While the sediments that make up the Wildcat are considered bedrock, they are rather loosely cemented and friable making them susceptible to crumbling under light pressure. The size of the grains within the Wildcat are composed of small, clay-sized fine sand particles.

The Yager terrane consists of well-consolidated marine, interbedded sandstone, argillite (metamorphically hardened mudstone), and conglomerate deposits occupying 19% of the Lower Subbasin. Most of the Yager terrane is exposed in the Steven’s and Grizzly Creek planning watersheds. The sandstone interbeds represent the deposits of large, drawn-out submarine sediment flows collectively termed turbidites that careen down the Continental slope

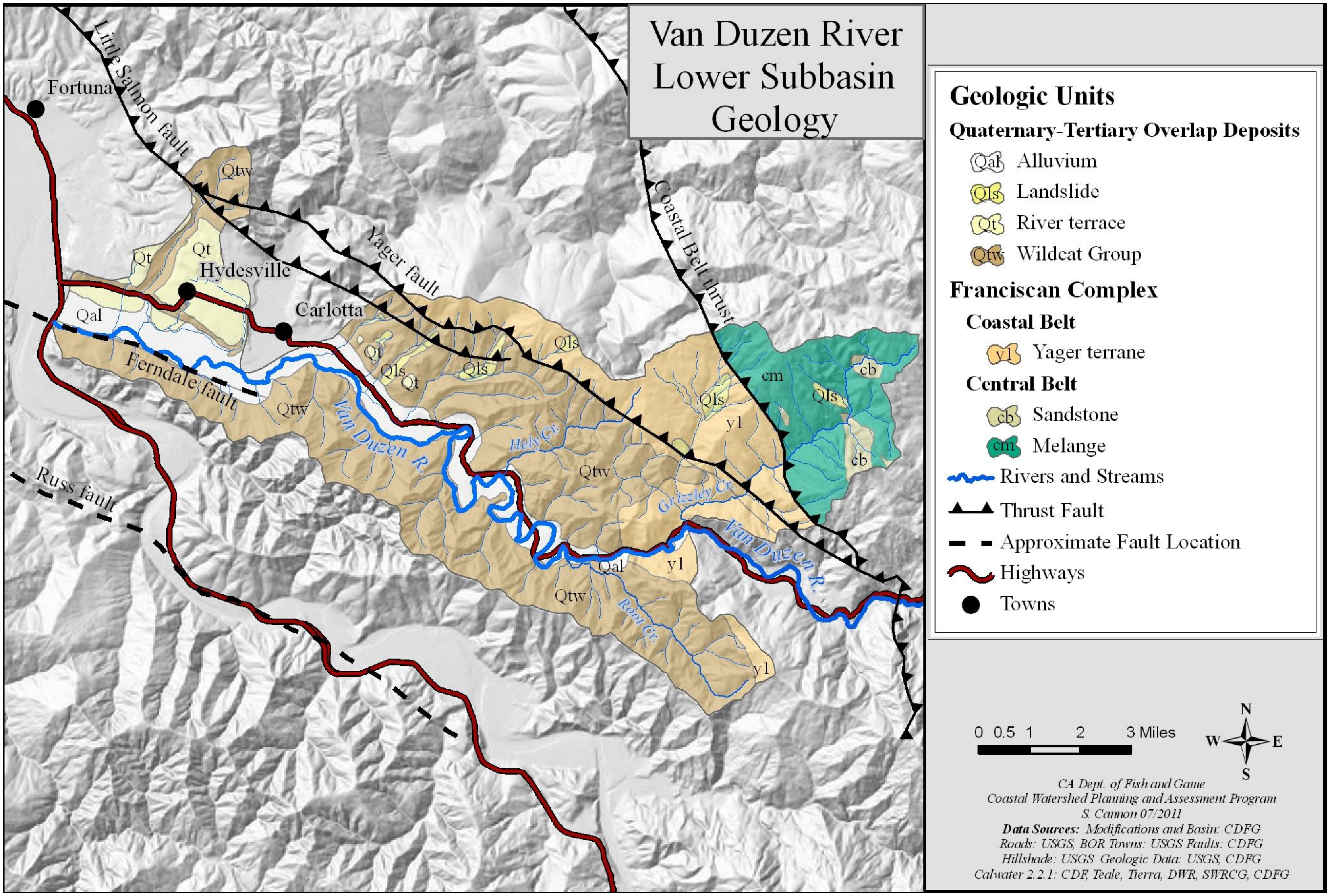
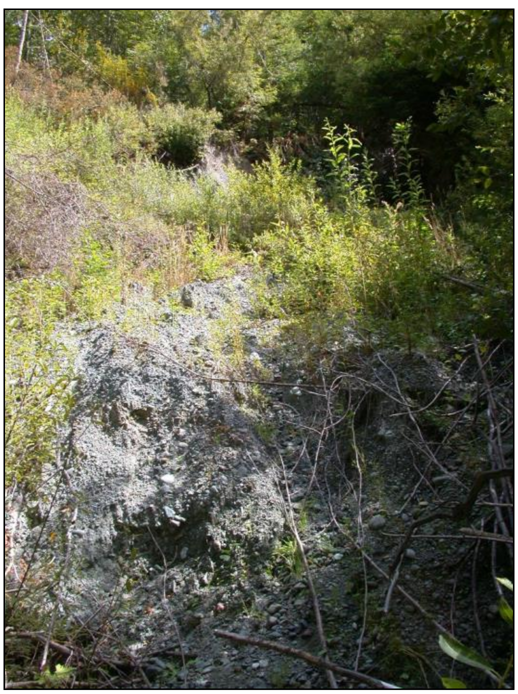


Figure 3. Geologic units of the Van Duzen River Lower Subbasin.

Table 2. Lithologic units of the Van Duzen River Lower Subbasin.

GEOLOGIC RELATION AND DESCRIPTION OF MAJOR UNITS WITHIN THE LOWER SUBBASIN						
Unit	**Belt/Rock type**	**Formation/ terrane**	**Composition**	**Erosion**	**Years ma**	**%**
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes.	0-0.01	11
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare.	0.01-2	2
	River terrace	Hookton Rohnerville	Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel/flood-plane.	Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes, gullying, and debris slides.	0.01-2	6
	Wildcat group (undifferentiated)	Carlotta	Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay.	Shallow landslides, debris slides, and block slides along inward dipping bedding planes. Toppling along joints. Some rock-falls and ravel.	0.78-1.8	50
		Scotia Bluffs	Shallow marine sandstone and conglomerate	Friable, typically fails in numerous small debris slides.	1.8-3.6	
		Rio Dell	Marine mudstone, siltstone, and sandstone	Of the Wildcat group the Rio Dell formation is one of the most susceptible to landsliding. Landsliding is most common in zones between mudstone and sandstone beds with inward dip during saturation.	1.8-3.6	
		Eel River	Marine mudstone, siltstone, and sandstone	Debris slides/flows, slaking.	3.6-5.3	
		Pullen	Marine mudstone, siltstone, and sandstone	Debris slides/flows, rotational slides, slumps, slaking.	5.3-11.6	
Franciscan Complex	Coastal belt	Yager terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers.	33.9-65.5	19
	Central belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.	65.5-161.2	1
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert,	Susceptible to mass movement by large earth flows and subsequent debris flows triggered by saturation.	1.8-65.5	11
Sources: Ogle 1953, Kilbourne 1985, McLaughlin et al. 2000. % Data represent an approximation based on GIS mapping.						

Figure 4. River Terrace deposit overlays wildcat group along bank of the Van Duzen River near Root Creek. Note Large Woody Debris which provides pool and habitat complexity for fish.



a)

b)

Figure 5. a) Fine sediments of the Wildcat formation erode from hill slope to Hely Creek, b) fine sediment from the Wildcat formation accumulate in Hely Creek.

periodically. The argillitic layers represent calm deposition of mud and clay that have settled out of suspension. This sequence of turbidites and argillitic interbeds is up to 5,000 feet thick and was deposited between 34 and 65 million years ago.

Yager terrane is relatively stable if left undisturbed, however many areas where it is faulted and/or sheared are prone to large-scale landsliding. In addition, argillaceous interbeds of the Yager terrane tend to crumble when exposed to water and air leading to some sliding along bedding planes especially if they dip inward towards the stream valley. This erosion contributes small to fine sediments into the stream. Further erosion is linked to land use activities occurring in the Yager terrane such as road construction and timber harvest. These activities constitute over 35% of sediment delivery to streams which is well above natural levels (USEPA 1999).

Mélange of the Central Belt represents 11% of the Lower Subbasin and is found mostly in the Grizzly Creek planning watershed. The Central Belt Mélange can be described as a completely sheared matrix of argillite and sandstone deposits containing very small (pebble sized) to mappable blocks (acres) of sandstone, blue schist, greenstone, basalt, and chert. The mélange matrix material is very weak and tends to slowly flow over time exposing the more coherent rock blocks known as “Franciscan Knockers”. Mélange is often vegetated by grasses that are susceptible to surface erosion, headword erosion, and gullying. The Mélange is easily disturbed by land use activities that may increase the rate of erosion and sediment delivery to streams.

Alluvium in the river floodplain and Van Duzen River valley covers approximately 11% of the subbasin. Alluvium includes active stream channel sediments as well as stored floodplain and low lying terrace deposits.

River terrace deposits, including the Rohnerville and Hookton formations, occupy 6% of this subbasin. River terrace deposits consist of unconsolidated and poorly consolidated cobbles, gravels and fine sediments. River channel and flood plain deposits have been raised during the last 2 million years by regional tectonic uplift above the 100-year flood level and may form steep channel banks that are prone to dry ravel and slumping.

Faults and Shear Zones

Faults and shear zones tend to weaken the bedrock making it more prone to erosion. Active faults may also seismically trigger landslides during earthquakes. The combination of active faults located near dormant landslides adds to the potential for hillslope erosion. In light of the high erosion potential on these sites, avoidance and/or careful planning involving a geologic study should be considered with future land use actions. Table 3 shows the faults within or influencing the Van Duzen River basin.

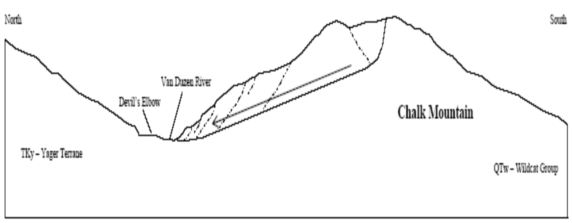
The Little Salmon fault is an active, northeast-dipping thrust fault that trends northwest coming onshore near Eureka and terminating approximately at Cummings Creek. The onshore extent of the Little Salmon fault zone is about 50 miles in length.

Table 3. Faults within or influencing the Van Duzen River Lower Subbasin.

FAULTS WITHIN OR INFLUENCING THE VAN DUZEN RIVER BASIN			
Active Faults:	**Fault Type**	**Possible Magnitude**	**Recurrence Interval**
Cascadia Megathrust	Thrust	9	500-600
Little Salmon fault	Thrust	7.2	400-800
Yager fault	Thrust	unknown	unknown
Goose Lake fault	Thrust	unknown	unknown
San Andreas fault (Northern segment)	Dextral	7.3	200-300
Faults:			
Coastal Belt Thrust	Thrust		
Ferndale fault	Reverse		

A prehistoric seismic event associated with the Little Salmon fault zone likely triggered the Chalk Mountain landslide which was a large (640 acre) deep-seated landslide located just downstream of Grizzly Creek on the left bank of the mainstem of the Van Duzen. This slide likely dammed the mainstem of the Van Duzen for a time until the river was able to rework the sediment (Oswald 2006). The landslide dam may have existed for a period of time sufficient to impede water upstream and initiate widespread sliding of the banks allowing the impounding of massive amounts of sediment upstream of the landslide dam. It is possible that the low-lying terraces from downstream of Grizzly Creek State Park to approximately six miles upstream near “Goat Rock” are a result of this event. The outwash of sediments was flushed downstream when the dam was breached and deposited the terrace on top of the Wildcat bedrock near Root Creek.

Erosion of the toe of this landslide is still supplying sediments into the river in a series of smaller, subsequent stream-bank landslides and ravel. Encroachment of the landslide has narrowed and increased the steepness of the canyon along this stretch.



Depiction of the Chalk Mountain landslide.

The Yager fault is a low-dipping thrust fault that trends northwest through the basin. The Yager fault may be an active offshoot of the Little Salmon fault and share similar characteristics. The Northeastern draining tributaries of the Lower Subbasin cut across the Little Salmon and Yager faults and into the Yager terrane (Box 1).

The Goose Lake fault is an active, northwest trending thrust fault associated with the Little Salmon and Yager faults. It is mapped within the lower subbasin in the vicinity of Hydesville and bounds the southern limb of a synclinal down-warp that historically held “Goose Lake”. This fault disrupts river terraces of Yager Creek and Van Duzen River deposition. The upper portion of Barber Creek runs along this fault and drains this area.

The Ferndale fault runs into the Lower subbasin on its western edge. The Ferndale fault is a steeply dipping reverse fault that trends west by northwest and bounds the southern edge of the Van Duzen River valley floor in the area from Alton to Carlotta.

The Coastal Belt Thrust fault trends north by northwest through the Lower Subbasin near Steven’s Creek and Grizzly Creek, and many of their tributaries cut across this fault.

The Coastal Belt Thrust juxtaposes the Coastal Belt with the Central Belt. It is most likely the zone that accommodated movement between the subducting Farallon slab and the North American plate before accretion of the Coastal belt when the active subduction moved west to its present location along the Cascadia Megathrust.

The Cascadia Megathrust allows subductive movement of the Gorda plate beneath the North American plate. This fault is capable of generating very large earthquakes (~M9) and usually produces associated uplift or subsidence of the coastal area adjacent to the Van Duzen River basin. The last major event on the Cascadia was on January 26, 1700 and was estimated to be between a magnitude of 8.7 and 9.2. Although not within the basin this fault can produce strong ground-shaking and trigger widespread landsliding. It is possible that a large seismic event on the Cascadia Megathrust could trigger movement on faults within the basin.

The San Andreas fault (Northern segment) is an active, right-lateral fault that runs just offshore, southwest of the Van Duzen River basin. It is capable of large earthquakes (~M 7) that can significantly affect the basin by seismic shaking, and wide-spread landsliding. The earthquake of 1906 (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments.

The Mendocino Triple Junction is located just offshore between Cape Mendocino and Petrolia. It juxtaposes the Gorda, Pacific, and North American plate in a complex tectonic regime. The Mendocino triple Junction has been migrating northward, relative to the North American plate, over geologic time increasing the seismic activity and deformation of this region. Tectonic stresses inherent to the complex interactions of the Mendocino Triple Junction are predominately responsible for driving fault movement and land deformation within this basin.

Coseismic Landsliding. Strong ground shaking by local earthquakes tends to trigger landslides in areas of unstable geology especially during the rainy season when the hill slopes are saturated with water.

Landslides

Large Quaternary landslides occupy only ~ 2% of the Lower Subbasin at the scale and limited detail of the geology map used in this report. Large mapped landslides infer features that can readily be seen at a basin-wide scale and are usually on the order of square miles in aerial extent. The designation of Quaternary infers that these landslides moved sometime within the last 2 million years. There are undoubtedly many more landslides than what is reflected within our mapping. Detailed landslide maps covering the areas of Rohnerville, Hydesville, Carlotta, and Chalk Mountain show a much higher density of landslide features. The largest mapped landslides in the Lower Subbasin occur in Steven's Creek, Cumming's Creek, and Fiedler Creek. The local effect of landslides on the stream network include persistent contribution of fine sediments and are particulary prevalent in areas where faults occur (Fig. 6 and 7).

In the headwaters of Steven's Creek (tributary to Grizzly Creek), a large earthflow exists in the geology of the Central belt mélange and the Coastal belt Yager terrane of the Franciscan Complex (Fig. 8). The Coastal Belt Thrust dissects this area juxtaposing these two belts. Cumming's Creek drains a large earthflow within Wildcat Group geology that is situated in an area cut by the Little Salmon and Yager faults. Fiedler Creek drains an earthflow that initiates in the Wildcat Group geology (Eel River, Rio Dell, Scotia Bluffs, and Carlotta formations) in the area of the Little Salmon and Yager Faults.

These landslides may have been initiated by their proximity to nearby faults, either from strong ground shaking during seismic events on the Little Salmon and/or Yager faults or by weakening of the bedrock by fault disruption and shearing.

Figure 6. Toe of streamside landslide on steep slope actively eroded and undercut by Grizzly Creek destabilizing the deposit as well as persistently contributing fine sediments to the creek.

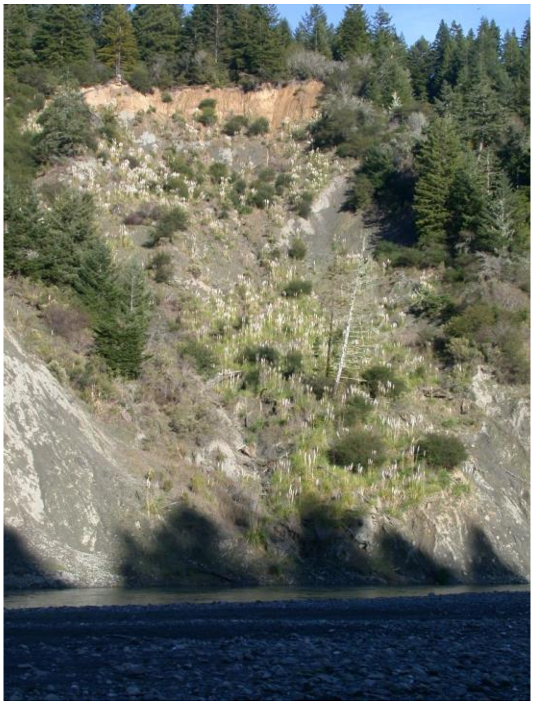


Figure 7. Persistent streamside landslide in undifferentiated Wildcat contributing fine sediments to the Van Duzen River near Cheathum Grove.

Figure 8. Pseudo-aerial view looking northeast of an Earthflow in the headwaters of Steven's Creek.

Slope Inclination

Steep slopes (>30%) comprise 51% of the Lower Subbasin terrain (Table 4 and Fig. 9). The steepest slopes are often located in headwater areas of streams that are not fish bearing, and therefore may receive the least protection from land use regulations. However, these sizeable headwater areas with steep slopes and unstable geology have contributed to excessive and persistent erosion and sediment inputs to fish bearing stream reaches. Since all the steep hillslope geology of the Lower Subbasin is considered high for erosion potential, actions such as road construction, timber harvesting, and yarding should be mitigated according to best management practices that meet or exceed all regulatory agency standards for soil conservation, water quality concerns, and protection of fish and wildlife.

Table 4. Acres of Van Duzen River Lower Subbasin Slope classes.

Slope class	Acres
0-15% Gentle	10, 130 (23%)
>15 -30% Moderate	11, 260 (25%)
>30 -65% Steep	20,500 (46%)
>65% Very Steep	2262 (6%)

Hydrology, Fluvial Processes and Sediment Transport

Streamflow in the Van Duzen River is measured at the USGS Bridgeville stream gauge located approximately one mile upstream of Grizzly Creek at RM 24. However, the highest flows occur downstream the confluence with Yager Creek (RM 5). Yager Creek drains approximately 33% (140 sq. mi.) of the Van Duzen River basin, and therefore adds substantial flow and sediments to the Lower Van Duzen River. Annual streamflow data from the Bridgeville site is shown in the Hydrology section of the Basin Profile (page 23).

The Lower Subbasin has the highest density of streams per square mile (2.3 mi/mi^2) in the Van Duzen River basin. The high stream density produces rapid runoff from the mountainous

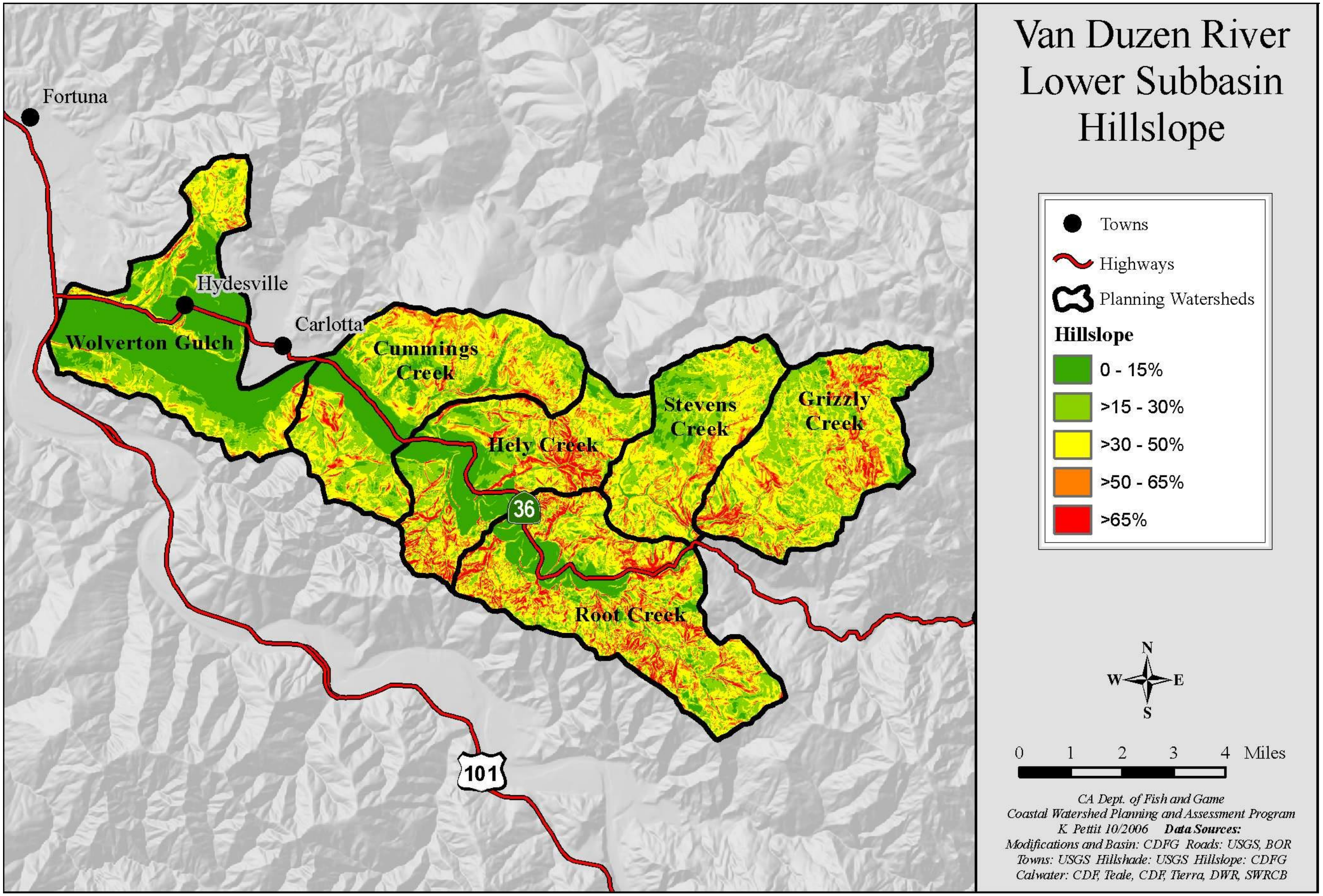


Figure 9. Van Duzen River Lower Subbasin hillslope classes valuable pools and reduce the quality of spawning substrate.

terrain during winter storms, which can lead to flooding on portions of Highway 36 and other areas. Attributed to the relative instability of hillslopes, large amounts of sediments can be eroded and enter streams during strong winter storms. The sediments are transported or stored within the stream channels or floodplain depending on several factors including stream flow, particle size, channel gradient, channel confinement and presence of scour elements. The excessive sediment accumulations tend to aggrade channels, fill valuable pools, and reduce the quality of spawning substrate.

Extended and excessively high turbidity levels occur when fine sediments continually enter the stream and remain suspended in the water column. Many of the Lower Subbasin tributary streams display highly turbid flows during and after rain events. Flow of prolonged, excessive turbid water can impair the ability of juvenile salmonids to feed and grow.

Mainstem Van Duzen River

The mainstem Van Duzen River flows approximately 23 miles (RM 23-0) through the Lower Subbasin from Grizzly Creek to the Eel River. Within this river segment there are three distinct reaches: 1) from the confluence of Grizzly Creek to Root Creek where the river flows at an average 4% gradient for approximately three miles though a narrow boulder laden gorge; 2) the 12 miles between Root Creek to near Cummings Creek (~RM8) where the channel gradient is approximately 1% and the river flows through entrenched meanders confined by bedrock banks; and 3) from RM 8 near Cummings Creek to the Eel River where the channel widens to a largely unconfined, alluvial plain bed channel. Low gradient alluvial channels are characterized as having lower sediment transport capacity to supply ratios and thus tend to accumulate sediments delivered from upstream sources (Montgomery and Buffington 1997). Sediment deposition and storage occurs in the wide and unconfined sections of the lower river. The amount of stored sediments is noticeably larger downstream of the confluence with Yager Creek (Figure 10).

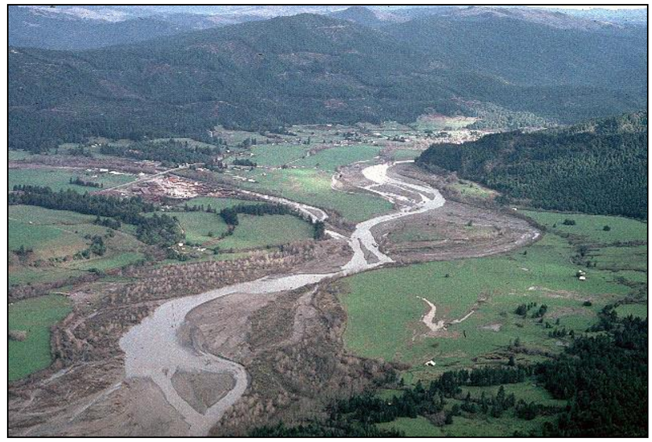


Figure 10. Confluence of Yager Creek with Van Duzen River. Note channel widening and bank erosion in the Van Duzen River linked to sediment inputs and high flows from Yager Creek. Photo courtesy of Kris Coho.

Many of the wide sections along the lower Van Duzen River, such as the area below the Yager Creek confluence, have experienced stream bank erosion in response to flood flows and channel aggradation. The process of channel widening and associated sediment accumulation contribute to detrimental impacts to both land owners and to aquatic habitats. Landowners lose potentially valuable land and may have to invest in bank protection methods to reduce or minimize channel erosion along their property. While in addition to a loss of valuable riparian land from erosion, channel widening and excessive lower sediment accumulations have reduced the quality of fisheries habitat by filling in valuable pool habitats and increasing width to depth ratios resulting in a wide, shallow channel. Wide shallow reaches without a shade canopy allows sunlight to heat the water to stressful or levels lethal to salmonids during warm summer months. These wide, shallow channel reaches and such conditions are common along the Van Duzen River in the Lower Subbasin. An increase in sediment deposition also occurs in the lowest river segment where the current velocity slows as it pushes into the larger Eel River, also known as a “delta effect” (Figure 11). The slowing current reduces the river’s ability to transport sediments along the lowermost reach of the Van Duzen.

The wide, shallow river condition creates a reoccurring problem for fish passage into the

Van Duzen River from the Eel River. After the first rains of fall, this reach forms wide, braided shallows that impede upstream passage of fall migrating Chinook salmon. In the fall of 1996 approximately 20 adult Chinook salmon stranded and died on braided riffles as they attempted to migrate up the Van Duzen River from the Eel River during intermittent flows. A similar stranding event occurred in the fall of 2002 when over 130 adult Chinook salmon were stranded in the shallows and died along the lower mile of river. Every fall season since the incident, the river bed has been modified by local gravel miners excavating a single thread channel, up to one-half mile through the streambed. The passage channel is controlled at the lower end by three exclusion culverts that prevent migrating fish from entering the Van Duzen River from the Eel River during low flows (Fig. 12). When flows in reach 160 cfs, (gauged when the three 36 inch exclusion culverts are at their full capacity) the exclusion culverts are removed allowing salmon to move upstream into the Van Duzen River (Fig. 12). There is a high risk of a repeat stranding of salmon and mortality if the channel modifications are not made on an annual basis. Details regarding the gravel mining extraction methods are included in the section “Gravel Mining” (pgs 26-27).

Figure 11. Van Duzen River plane bed channel caused fish stranding at low flows. Photo taken near dry channel confluence with Eel River.

Figure 12. Excavated channel with exclusion culverts (top) looking upstream and looking downstream with culverts removed (bottom) to allow fish passage into Van Duzen River at flows of ~160 cfs.

Tributary Streams

The Lower Subbasin drains approximately 54 miles of perennial tributary channels and 85 miles of intermittent tributary channels (Fig. 13). Approximately 91 miles of the tributary channels are characterized as steep (gradient >20%) and are considered sources areas for sediment inputs (Fig. 14). Most of these steep stream reaches are also intermittent channels and likely do not support anadromous salmonids, but may provide habitat for resident trout. No stream flow gauging stations exist in the tributaries. Winter flows in the tributaries are generally episodic typified by a rapid rise and fall in flow relative to the intensity and duration of rain events. Observations indicate that summer base flows usually occur by August. Fox, Cummings, Fielder, Wolverton, Root, and Grizzly creeks

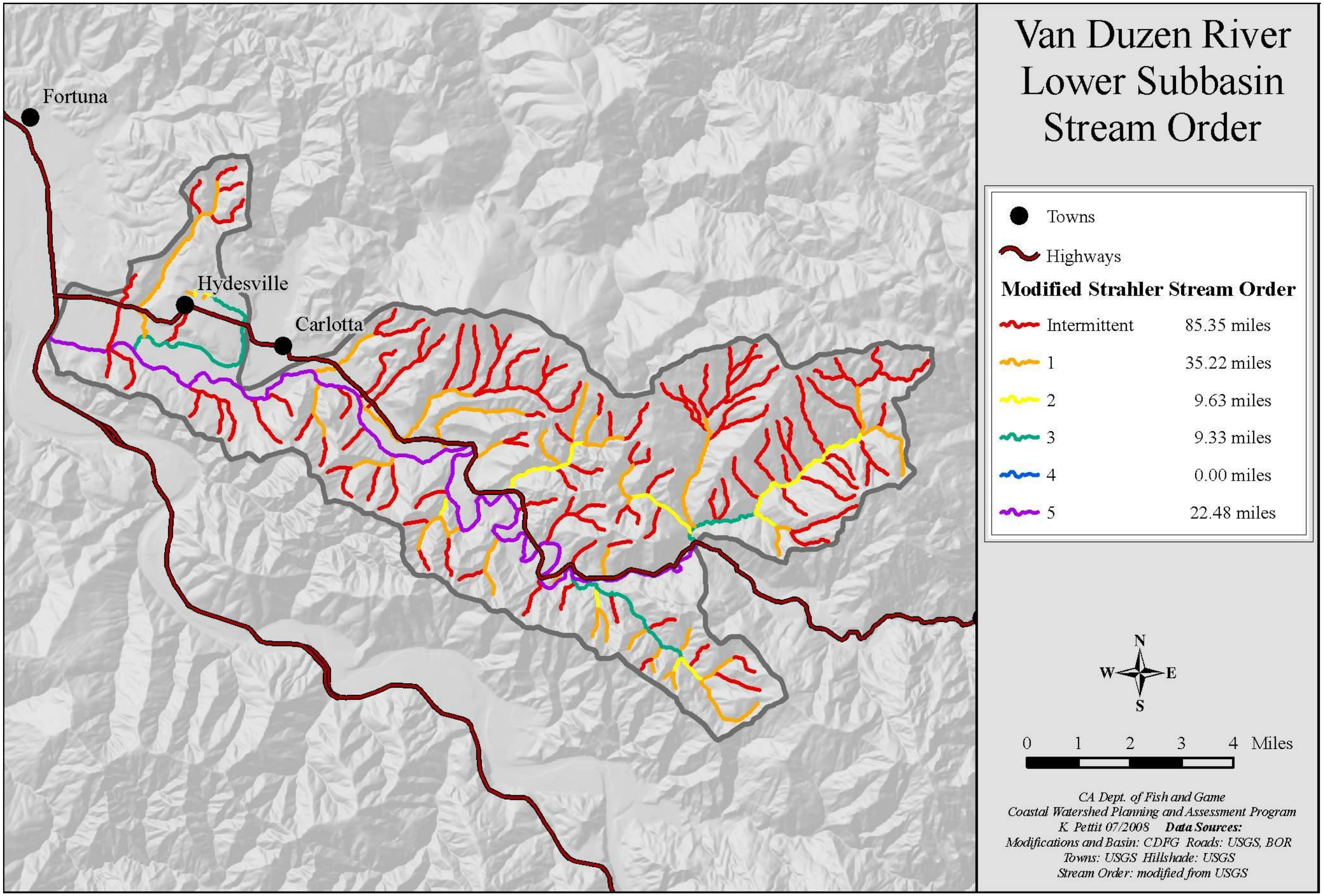


Figure 13. Stream order and intermittent streams in the Van Duzen River Lower Subbasin.

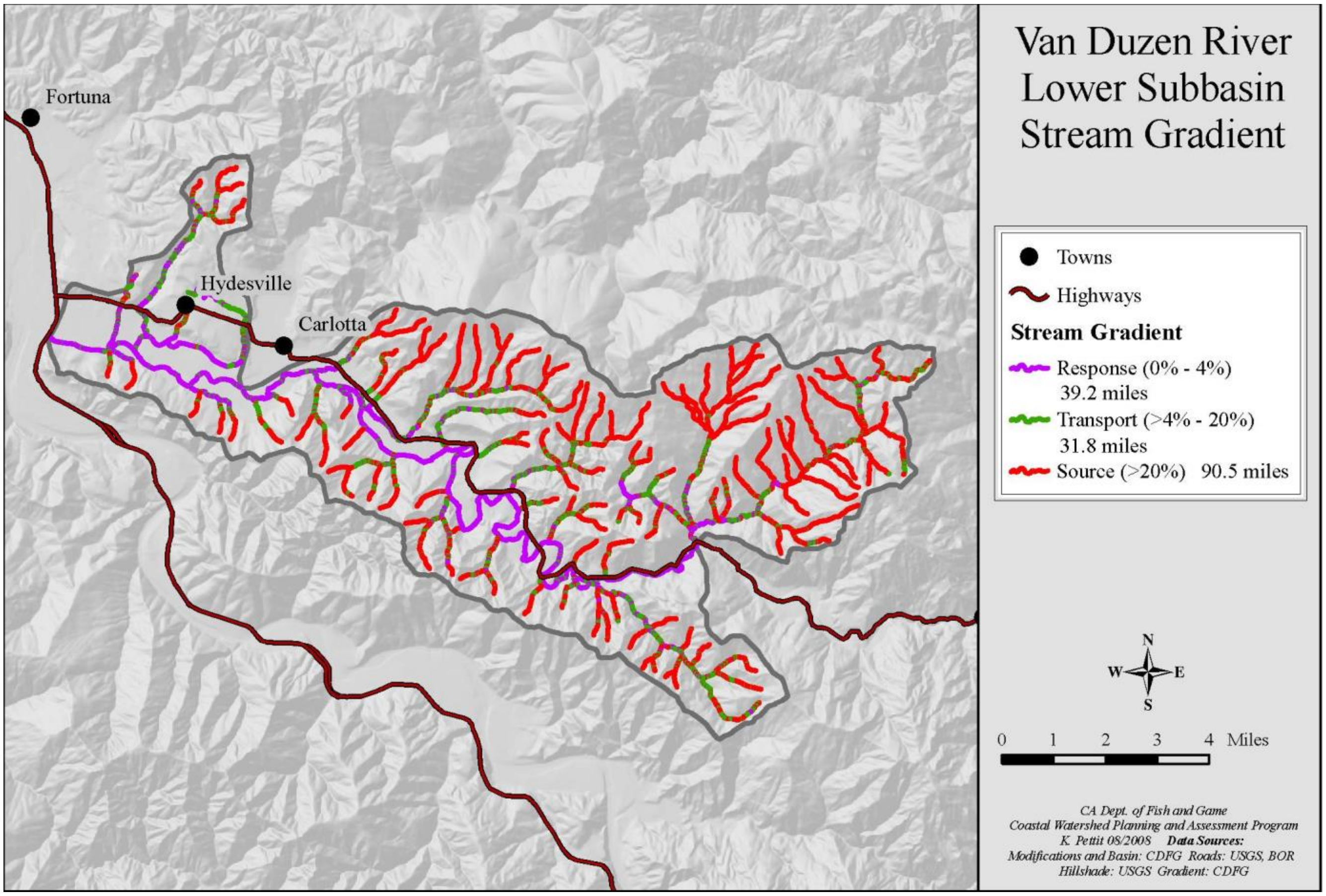


Figure 14. Channel gradient of Van Duzen River Lower Subbasin streams.

typically lose an active surface connection with the mainstem in summer due to intermittent flow and/or from sediment accumulations that raise the channel bed above the mainstem river base flow elevation. During summer the lack of water in stream reaches limits fish movements and likely reduces salmonid production. Any management actions that increase summer flows in the tributaries should receive consideration as they benefit fish habitat.

Vegetation

Coniferous forests cover 85% of the Lower Subbasin terrain. Redwood dominated forest is the most common vegetation class, covering approximately 70% of the terrain (Fig. 15, Table 5). Douglas fir dominates the remainder of conifer forests. Patches of mixed hardwoods (alder, willow, cottonwood, bay laurel) grow in the lower river valley, and patches of oaks grow in the uplands of the eastern most region of the Lower Subbasin.

Grasslands occur in the lower river valley and in patches and prairies spread across the Lower Subbasin. Agricultural vegetation composed of mostly pasture grasses occupies much of the lower river valley and the area around Hydesville. Much of the pasture land used for livestock grazing was converted from hardwood or coniferous forests.

Most of the coniferous forests of the Lower Subbasin have been recently logged, and are subsequently dominated by early stage seral forests stands. The adverse changes to salmonid habitat related to extensive logging of forests and land use that disturbs riparian and near stream forests are discussed in the “Role of Riparian and Nearstream Forests in Stream Ecosystems” section in the Basin Profile.

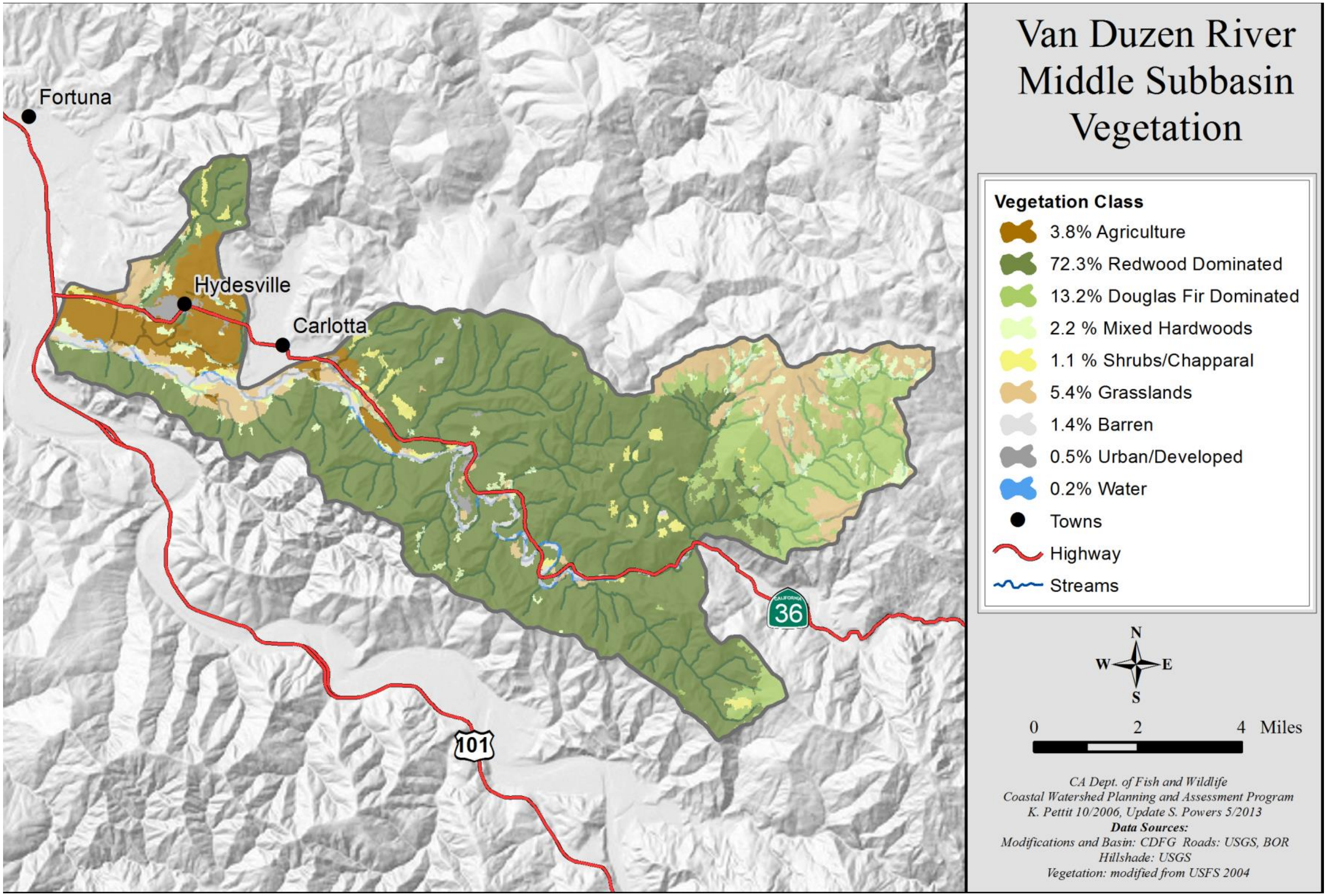


Figure 15. Vegetation classes by percentage in the Van Duzen River Lower Subbasin.

Table 5. Vegetation cover types in Van Duzen River Lower Subbasin planning watershed (shown in acres).

Planning Watershed	Cover Type								
	Redwood Dominated	Douglas Fir Dominated	Grass Lands	Hard wood	Shrubs	Agriculture	Developed	Barren	Total Acres
Cummings Creek	6,937	2	195	117	208	3,020	92	121	7,997
Grizzly Creek	781	3879	1,783	710	21	0	0	6	7,180
Hely Creek	6,035	35	72	115	39	4	94	210	6,613
Root Creek	8,027	402	79	32	87	0	0	230	8,945
Stevens Creek	2,748	769	1,014	237	183	0	0	10	4,963
Wolverton Gulch	3,325	0	1,029	447	271	2,628	227	487	8,451

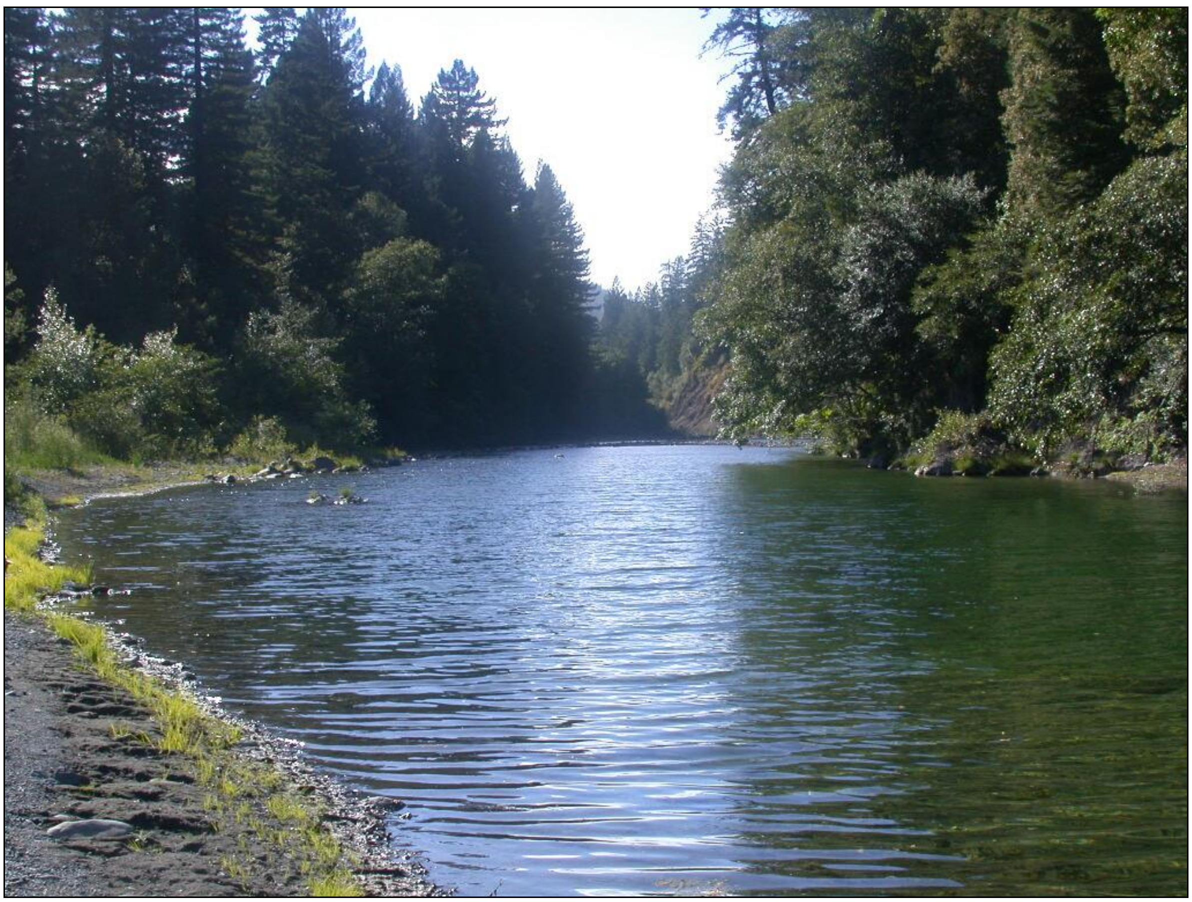


Figure 16. The lower Van Duzen River.

Land and Resource Use

Principle land uses in the Lower Subbasin are industrial and non-industrial timber harvests, livestock grazing, gravel mining, rural residential developments, and roads (Fig. 16). Timber harvesting is the dominant land use, especially upstream of the Carlotta area, involving approximately 79% (35,000 acres) of the land in the Lower Subbasin. Rural residential developments occupy 8% (3,405 acres) of the land use and are mostly located around the town of Hydesville and along Highway 36 east of Carlotta. Other land uses in the Lower Subbasin, most prevalent in the lower river valley area west of Carlotta, include livestock grazing (7%; 3142 acres) and dairy production and growing agricultural crops (4%; 1625 acres). Remaining land uses are classified as public lands such as parks and open space (<2%, 622 acres), gravel mining (<1%, 147 acres), and commercial/industrial (<1%, 72 acres). Gravel mining sites are located in the lower Van Duzen River channel near the confluence with the Eel River.

Timber Harvests

Commercial timber harvest began in the Lower Subbasin shortly after the arrival of first white settlers around the mid 1800s. These early harvests involved both clearing forests to open up rangeland for livestock grazing and cutting and milling trees for wood products (Moore 1999).

Early timber harvest rates were minimal until the late 1800s as harvest methods relied on horses or oxen were used to pull logs over skid trails. Harvest rates experienced a gradual increase with the use of the steam donkey cable yarding and railroad hauling in the late 1800s and early 1900s. However, with the implementation of tractor yarding and truck hauling in the mid-1940s combined with the boom for building products that occurred after World War II timber harvest rates had accelerated rapidly as large tracts of forest were being cut and processed in numerous local mills. By the end of the 1970s, most of the forests had been clear cut harvested at least once and were supported by a dense network of haul roads to truck logs from the forests to mills. Tractors dragged, or “skidded”, the logs to landings where they were loaded on trucks. The tractors carved up skid trail across the landscape and through creek channels. At times, high line cable systems were also utilized to move trees. Between the large expanse of clear cuts, skid trails and logging roads the mountain landscape were exposed to forces of unnatural occurring erosion. The heavy rains and floods of 1955 and 1964 were the first documented large storms to hit the area after these numerous consecutive years of heavy-handed harvests.

The cumulative impacts from these intensive land use activities and severe rain associated with winter storms and snow resulted in widespread flooding, severe erosion from landslides, and debris torrents forming large debris accumulations. Excessive erosion caused aggradation of stream channels and channel widening. Timber harvest activities that occurred during the 20th century were likely the most significant detrimental land use to salmonid stream habitats, and the resulting legacy impacts are still apparent today in some areas. After these two large floods, problems associated with timber logging continued to develop. For example, in 1974 a CDFG field note from Hely Creek states, “during past logging activities it is apparent little regard was given the stream. Much slash and standing timber is sliding into the creek, and many debris jams are silted in and are barriers to fish passage” (CDFG 1974). In 1983, after heavy rains a debris torrent flooded Hely Creek with large cull logs, slash and sediment (Figs. 17 and 18). The probable source of the debris torrent was noted as a tributary that was part of timber harvest activities that occurred shortly before the event. Despite fledgling timber harvest rules instituted in 1973 and further rule development regulating harvest methods, salmonid habitats continued to suffer from loss of shade from large stream side conifers, loss of input of large wood and excessive sediment inputs.

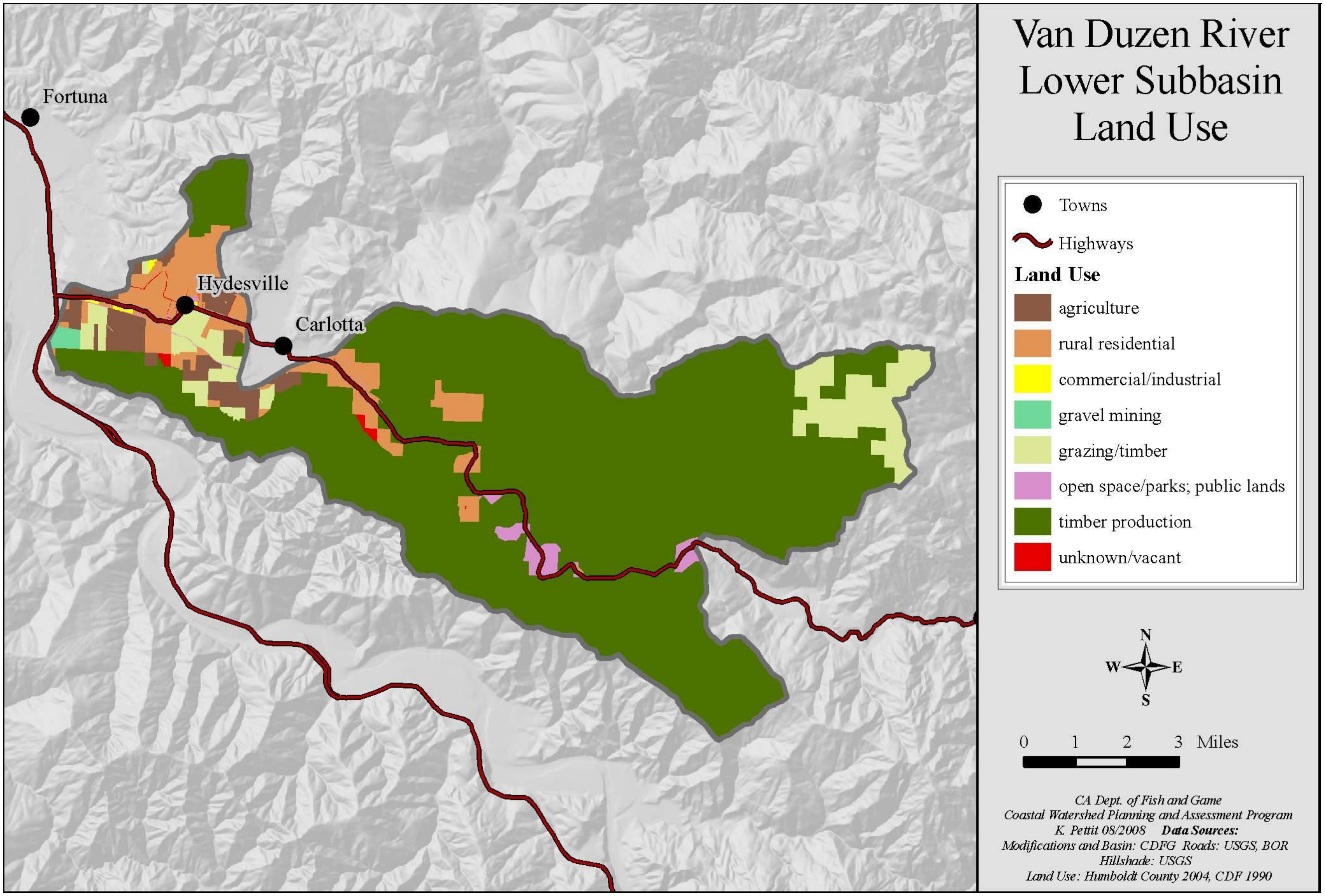


Figure 17. Van Duzen River Lower Subbasin land use classes

Based on analyses of more recent timber harvests impacts, the issue of harvest rates appear to be as important to manage as the harvest methods themselves. Approximately 40% of the Lower Subbasin area (54% of conifer forests) was part of timber harvest plans from 1991-2008 (Table 6, Fig. 20). Timber harvest prescriptions included primarily clear cuts (5,780 acres), selection cuts (5,678 acres), commercial thinning (5,450 acres), seed tree removal (1,550 acres). Over the 17-year period, Cummings Creek, Stevens Creek, and Hely Creek planning watersheds had the most timber harvest related activity in the subbasin with 70%, 66%, and 60%, respectively, of the coniferous forests involved in timber harvest respectively not including multiple harvests on the same acres.

To assess water quality impacts from timber harvests, the Regional Water Quality Control Board developed a series of adjustment factors that rated impacts from various silvilcultural prescriptions (RWQCB 2006). According to the adjustment system, clear cuts are the most detrimental to the forest landscape and water quality parameters. Seed tree removal impacts are considered 75% as disruptive as clear cuts, and selection cuts are considered 50% as disruptive relative to clear cuts. Several other prescriptions are evaluated, including yarding and tractor yarding methods. Yarding methods vary in their contribution to land disturbance. Tractor yarding typically generates the most erosion of top soils compared to other yarding methods.

Klein et al. (2008) suggests using the adjustment factors for a relative measure of timber harvest rates to compare with a maximum watershed harvest rate of 1.5% per year (~ 65 year rotation) to mitigate for erosion and associated sediment inputs to streams. Using silvilculture area adjustment factors and 1991-2008 harvest plan data, the Lower Subbasin forest has been cut at a rate of approximately 2.7% per year representing a 37-year rotation. The recommended harvest rate of 1.5% and 65 year rotation was exceeded in all planning watersheds except for Grizzly Creek. The highest annual adjusted harvest rates were in Stevens Creek (4.1%/yr) Cummings Creek (3.6%/yr), and Hely Creek (3.1%/yr) planning watersheds. For comparison, if not adjusted for silvilcultural methods, 3.2% per year of the forest area was involved in timber harvests, representing a 31-year rotation through the Lower Subbasin forests. The high harvest rates likely contribute to a continuous impairment to stream ecosystem recovery needed to improve status of State and/or Federally listed threatened salmonid populations.

Figure 18. Debris torrent buries Hely Creek with logging debris near Redwood House Road in 1983.

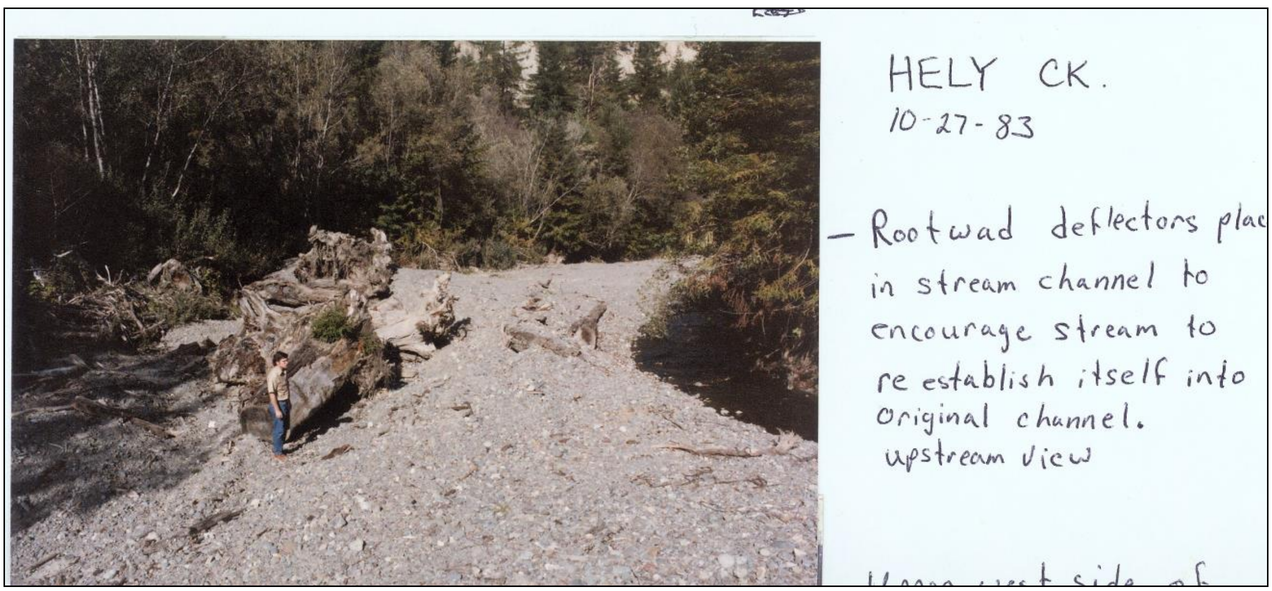


Figure 19. After wood salvage and clean up from debris flow in Hely Creek 1983. Large sediment accumulation remains.

Figure 20. Hely Creek 2006. While large wood occupies the bank and channel providing cover and habitat for salmonids and potential spawning cobble has replaced some fine sediment, the recovery of Hely Creek remains ongoing. A dense growth of young willow resides in the active, braided channel.

Table 6. Lower Subbasin of the Van Duzen River timber harvest plan statistics 1991-2008. This table does not reflect 382 acres of pending THPs in 2008. Harvest rates exceed the recommended 1.5% per year harvest rate (Klein et al. 2008) in all planning watersheds except for Grizzly Creek.

Planning Watershed (PW)	PW Acres	Conifer Forest Acres	THP Harvest Acres	% PW Harvested	% PW in Conifers	% Conifer Acres in THP	Conifer Harvest Rate Adjusted for Prescription
Cummings Creek	7997	6938	4832	60	87	70	3.6%/yr
Grizzly Creek	7180	4660	1797	25	65	39	1.4%/yr
Hely Creek	6613	6070	3645	55	92	60	3.1%/yr
Root Creek	8946	8429	4152	46	94	49	2.1%/yr
Stevens Creek	4963	3517	3191	47	71	90	4.1%/yr
Wolverton Gulch	8451	3325	1131	13	39	34	1.9%/yr
Subbasin Total	44,150	32941	17,875	41	75	57	2.7%/yr

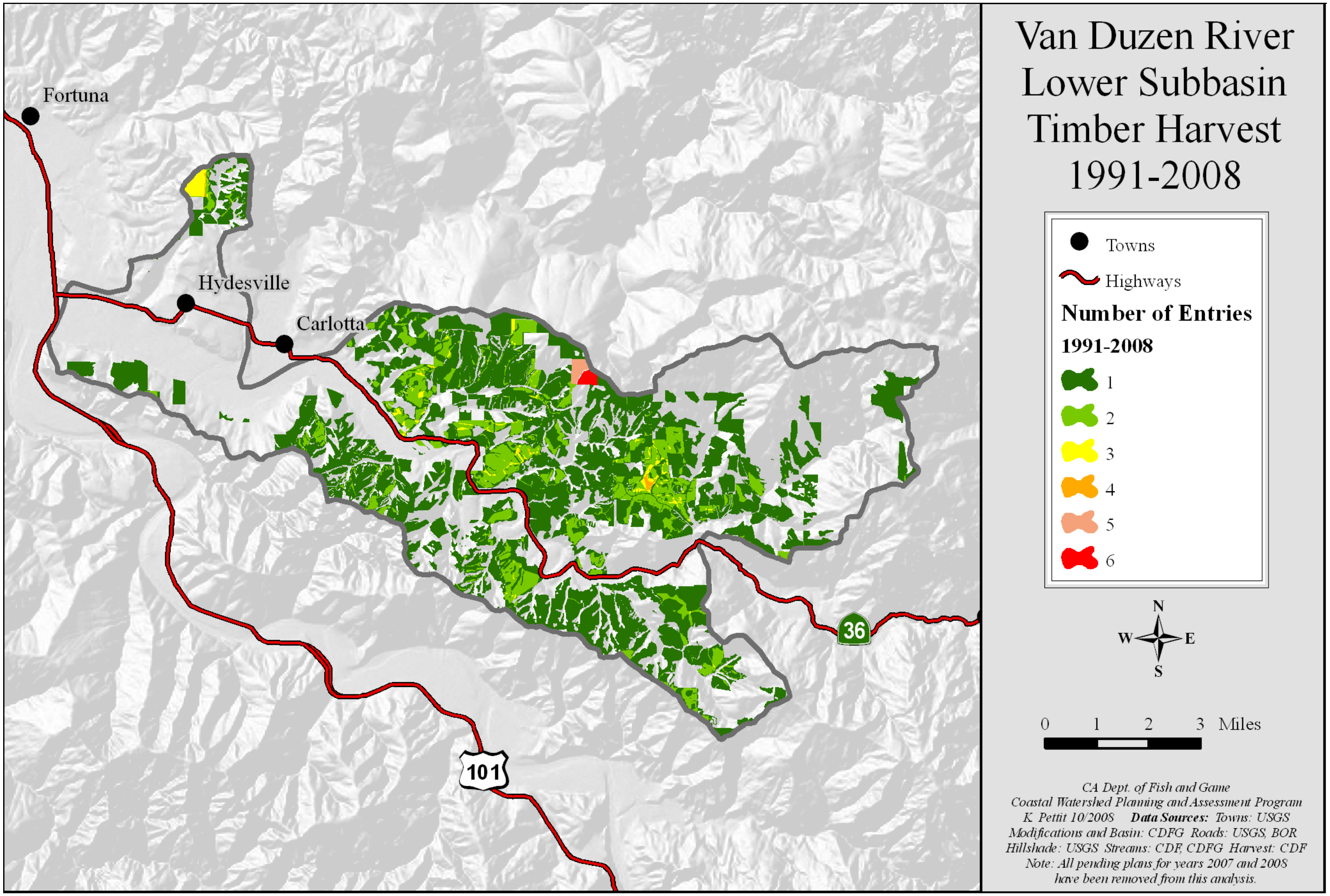


Figure 21. Van Duzen River Lower Subbasin timber harvest activity 1991-2008.

Roads

Roads data available from CDF GIS roads layers show that there is an average of six miles of roads per square mile of area in the Lower Subbasin (Table 7, Fig. 21). This large number is an underestimate because the roads layer source data does not cover the full extent of the subbasin so it underestimates the actual miles of roads on the landscape (ftp.fire.ca.gov/forest) and does not consider skid trails. Using the available data, the highest road densities are in the Cummings Creek, Root Creek, and Hely Creek planning watersheds where road densities exceed 7 mi/sq. mi (Table 7). More than 2.5 miles of roads per square mile of watershed is considered to produce excessive surface erosion and excessive sediment inputs to stream channels (Cederholm 1981, NMFS 1995). The high road density in the Lower Subbasin is well above recommended levels.

In order to reduce the impacts from the high road density, recent efforts in the Lower Subbasin include road decommissioning and road improvement projects. Approximately 118 miles of roads located on Humboldt Redwoods Company lands within the Lower Subbasin have been improved with culvert upgrades, rolling dips, outsloping, or other treatments intended to reduce road related erosion (HRC, written communication). Most of the work on HRC lands is in compliance with their Habitat Conservation Plan (HCP). Other road projects were completed with support funding from CDFG's grants program (see Watershed Restoration section below). With the high density of roads in the Lower Subbasin, more road decommissioning and improvement projects are likely and should be implemented. New road construction should be minimized. Any new road construction plans should be reviewed by a certified geologist, carefully located, designed and built using best management practices.

Table 7. Road miles in planning watersheds of the Van Duzen River Lower Subbasin.

Planning Watershed	Road Miles	Square Miles	Road Miles per Sq Mi	Improved Road Miles
Cummings Creek (Lower)	89.2	12.50	7.14	21.5
Grizzly Creek	53.3	11.22	4.75	9.4
Hely Creek	72.5	10.33	7.01	31
Root Creek	99.9	13.98	7.15	38.1
Stevens Creek	50.0	7.75	6.45	13.5
Wolverton Gulch (Lower)	52.0	13.20	3.94	4.5
Total	417	69	6	118

Gravel Mining

Gravel mining occurs in the lower Van Duzen River from the confluence with the mainstem Eel River to approximately one mile above the confluence with Yager Creek (RM 6). Gravel mining activities may potentially impact salmonid spawning and rearing habitat through alteration of channel morphology, sediment routing processes and impairment of the development and maturation of woody riparian vegetation (Meehan 1991; Brown et al. 1998; ACOE 2003; McBain and Trush 2009). Surface gravel mining should therefore be conducted in a prudent and cautious manner, especially in known salmonid bearing rivers like the Van Duzen River. The United States Army Corps of Engineers (USACOE), State of California and Humboldt County, among others, provide oversight to the surface gravel mining industry through annual collaborative planning sessions.

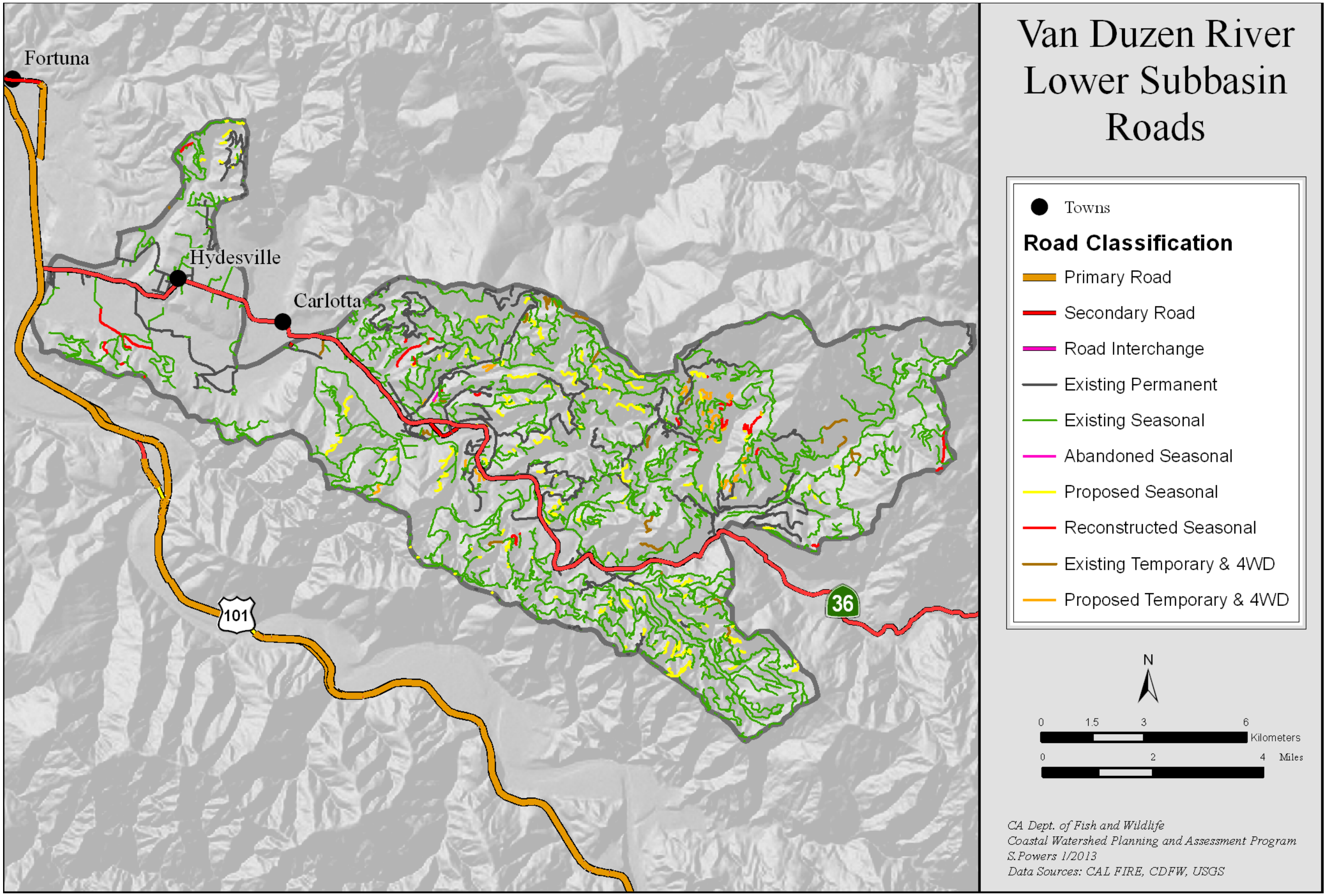


Figure 22. Road network of the Van Duzen River Lower Subbasin.

The County of Humboldt Extraction Review Team (CHERT) monitors and makes recommendations on sites that extract over 5,000 cubic yards annually. For each harvest site, CHERT estimates the mean annual recruitment (MAR) of bedload in relation to the surrounding instream mining operations. Based on the MAR, the CHERT sets limits on the maximum volume of aggregate available for harvest each year, recommending extraction should not exceed 75% of MAR in salmonid-bearing rivers and streams; and only after analysis has determined the MAR for a particular mining reach. Without specific reach analysis, 25% of MAR should be the guideline (Laird et al. 2000). From 1997 through 2007, the average volume extracted from the lower reach of the Van Duzen River was 111,347 cubic yards, or about 70% of the maximum volume permitted by CHERT (Table 8).

Table 8. Van Duzen River Lower Subbasin Extraction 1997-2007 (CHERT 2008).

Year	Max Volume (cy)	Extracted Volume (cy)	Percent Extracted
1997	120,000	81,600	68%
1998	119,100	103,700	87%
1999	159,900	108,800	68%
2000	194,800	121,300	62%
2001	161,700	85,600	53%
2002	202,500	167,400	83%
2003	175,100	123,000	70%
2004	179,045	92,610	52%
2005	159,090	123,170	77%
2006	134,910	104,750	78%
2007	152,773	113,184	74%
Totals	1,758,918	1,225,114	70%
Averages	159,902	111,374	70%

Channel bed elevation changes in the Van Duzen River have been measured in three separate studies. Kesley (1977) found that the upper Van Duzen River had aggraded during the time period from 1941 to the post-1955, and 1964 floods. Given the magnitude of those system reset events, this conclusion was not surprising. Fifteen years later (1992) and in the lower Van Duzen River, Humboldt County determined that a river cross-section near Highway 101 had downgraded 10 feet (Humboldt County 1992). However, the USACOE measured channel aggradations in the lower Van Duzen River from 1968 to 1999, and concluded that these measurements were not evidence of gravel mining impacts (ACOE 1999).

Legacy effects of aggradation in the Van Duzen River due to the large-scale erosion of the basin during major floods, and resultant deposition in the lower reaches have left the lower five miles of the active river channel extremely wide; of which has led to the current shallow, braided, and even sub-surface flows common in late summer and early fall prior to seasonal rains. This condition has posed a significant adverse impact to early fall Chinook spawners in the Van Duzen River and lower Eel River just upstream of the confluence with the Van Duzen River. As described in the “Mainstem Van Duzen River” section (pg.14), stranding events occurred in 1996 and 2002 when adult Chinook salmon died in the wide, shallow, braided channel as they tried to migrate upstream to spawn.

Following the major stranding event in 2002, and annually since, the construction of a single thread, low flow channel has been included in gravel mining operations in the lower one mile of the river. In the USACOE Letter of Permission, bar-skimming as a technique is no longer approved in the lower two miles of the river, and preferred alternative methods are trench, alcove, or wetland pit mining (ACOE 2003). By utilizing these preferred methods, in coordination with CDFG and NMFS personnel, current gravel mining operations have improved the lower Van Duzen River’s channel shape and functionality and curtailed early Chinook salmon migration mortalities.

Industrial Marijuana Agriculture

What is not displayed/categorized in Land Use Fig. 16 (p. 19) is the recent proliferation of industrial marijuana agricultural operations. Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFG field staff has discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes. These operations are having a significant impact on the landscape and natural resources of the Basin (including the Lower Subbasin).

Unlike other regulated land use activities such as legal timber harvesting and/or mining operations, there are no standards for "best practices management" or any review by agencies like CDFG and the state Water Quality Control Board; therefore, a wide range of impacts to watercourses and their aquatic resources can be associated with these industrial marijuana agricultural operations. These impacts may include the following (T. LaBanca, CDFG, personnel communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decrease in stream flows due to these water diversions;
- A wide range of pollutants may be used, including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually releasing into the water throughout the year;
- Human wastes from camps that could also directly enter or leach into watercourses;
- Improperly constructed roads and construction around the site that contributed to sediment production that enters watercourses throughout the rainy season;
- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

Fish Habitat Relationships

Fishery Resources

The Lower Subbasin supports populations of Chinook and coho salmon, steelhead and coastal cutthroat trout (Table 9). Winter steelhead are the most widely distributed and abundant anadromous salmonid in the subbasin utilizing approximately 45 miles of stream habitat in the Van Duzen River and its tributaries (Fig 22). Approximately 30 miles of the available stream miles are used by coho and Chinook salmon with about half of these miles in the tributaries and the other half in the mainstem. Chinook salmon spawn in both the mainstem Van Duzen River and its tributaries (Fig. 23), whereas coho and steelhead typically spawn in the tributaries. Some of the streams not currently displayed as fish bearing streams in Figures 22 and 23 (non-highlighted) may be utilized by juvenile steelhead for rearing or adults for spawning, but due to limited staff and funding these streams were not surveyed during this assessment.

Currently, the most important tributary streams for salmonid spawning and rearing are Cummings Creek, Hely Creek, Root Creek, and Grizzly Creek. These streams (along with several others) in the Lower Subbasin once supported robust populations of Chinook and coho salmon, steelhead and possibly coastal cutthroat trout. A review of recent CDFG spawner survey results (Appendix B) reveals the present number of Chinook and coho salmon returning to spawn in the Lower Subbasin have declined significantly compared to the substantially larger runs reported prior to 1965 (CDFG 1965). Moreover, coho salmon stocks have declined to drastically low numbers and may be functionally extirpated from the subbasin.

CDFG stream field notes are located in Appendix B of the Van Duzen River Assessment report. These field notes describe anecdotal historical stream conditions and presence/

absence observations. Additionally, Appendix B contains results of CDFG spawner surveys conducted in the mid-eighties to 2008 for the following streams: Cummings, Root, and Grizzly creeks.

Table 9. Salmonid streams of the Lower Subbasin Van Duzen River.

Stream	Anadromous Miles	Steelhead	Chinook	Coho	Cutthroat
Barber Creek	**1.0**	**X**			
Wolverton Gulch	**2.4**	**X**		**X**[1]	**X**
Cuddeback Creek	**0.8**	**X**	**X**	**X**[1]	
Fielder Creek	**1.0**	**X**	**X**	**X**[1]	
Cummings Creek	**3.1**	**X**	**X**	**X**[1]	
Fox Creek	**0.4**	**X**[2]			**X**
Flanigan Creek	**0.5**				
Hely Creek	**1.8**	**X**	**X**	**X**	
Root Creek	**2.6**	**X**	**X**	**X**[1]	
Grizzly Creek	**3.0**	**X**	**X**	**X**	
Stevens Creek	**0.9**	**X**	**X**	**X**[1]	

[1] Sites to re-establish coho salmon population; [2]resident rainbow steelhead/trout

Figure 23. Adult steelhead caught on the lower Van Duzen River.

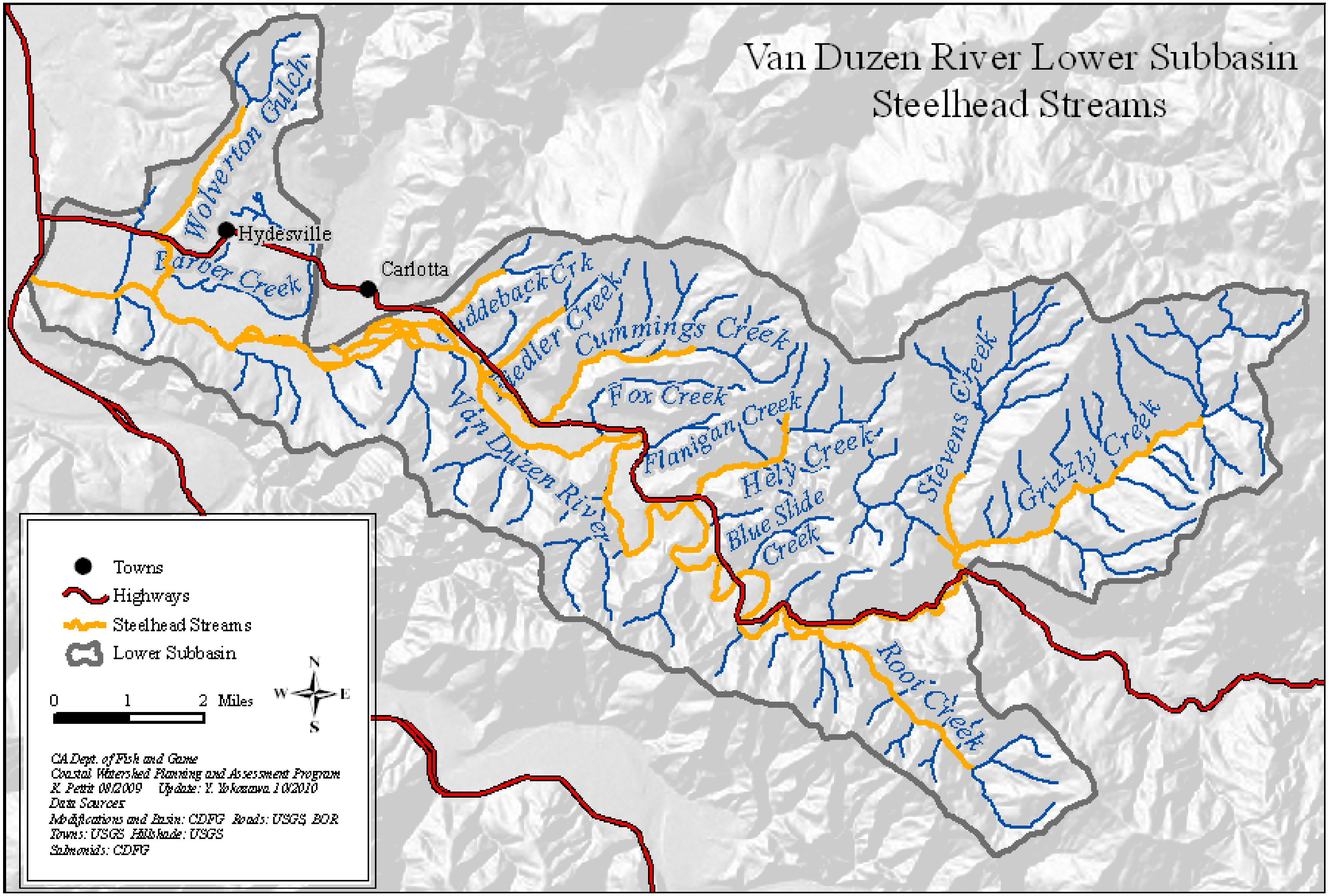


Figure 24. Lower Subbasin winter steelhead distribution

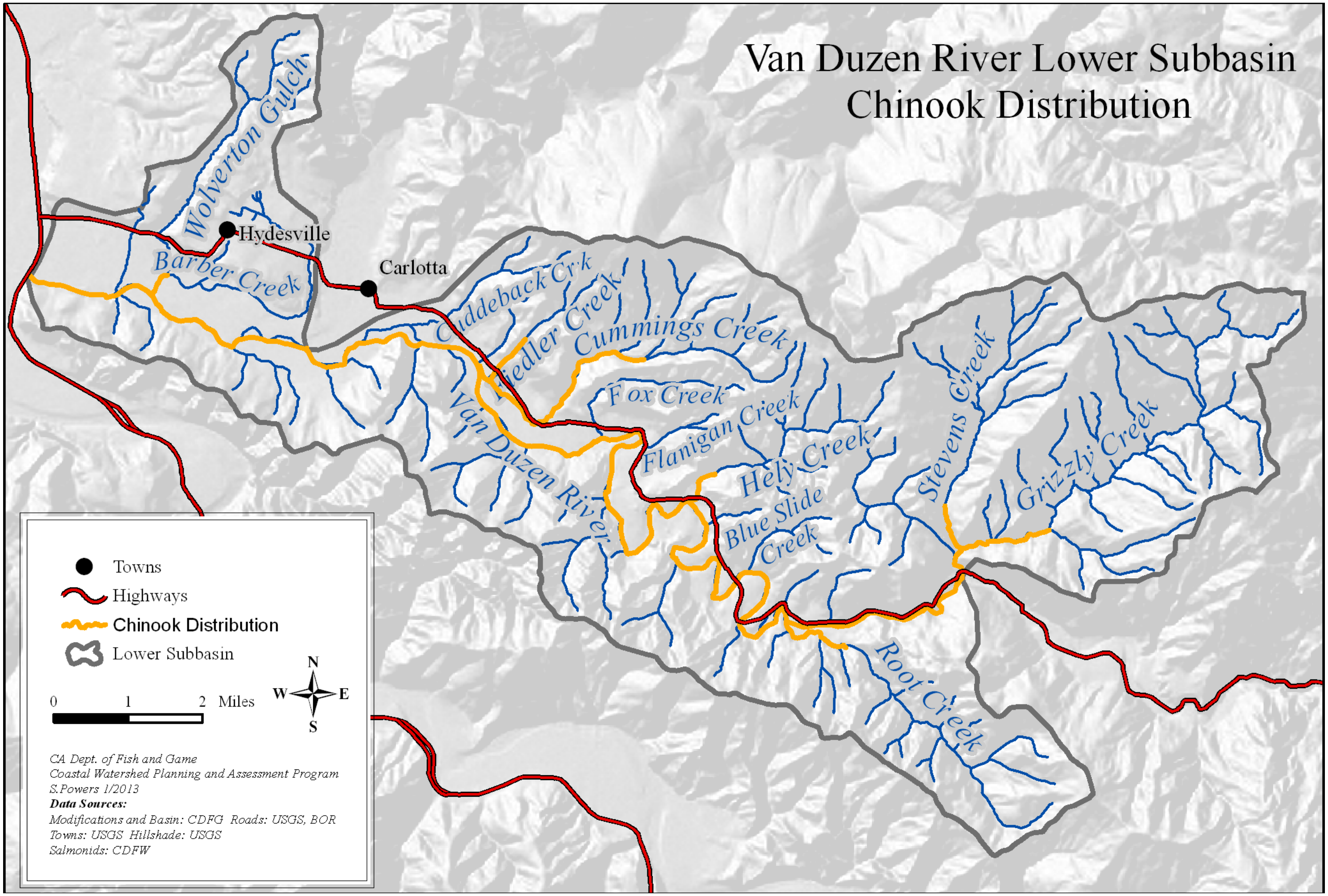


Figure 25. Chinook distribution in the Lower Subbasin.

Habitat Overview

Water Temperature

Water temperature data for streams in the Lower Subbasin are available from the Humboldt County Resource Conservation District (HCRCD) 1996-1998 (Table 10) and from PALCO 1999-2005 (Table 11). Overall, the stream temperature data indicates unsuitable salmonid water temperatures in the mainstem Van Duzen River, but suitable water temperatures in the Lower Subbasin tributaries (except in Grizzly Creek for coho, see below). The 1996-1998 data (Table 10) show that the 7-day average maximum temperature in the Van Duzen River is often above 68ºF (20ºC), for several hours each day, which is well above the average maximum temperature thresholds suggested as an upper limit for coho salmon presence of 63.7ºF (17.6ºC) (Hines and Ambrose 2001). Moreover, the averages above 68ºF (20ºC) is considered to stress all salmonids during the warm summer months of mid-July through early September. The water temperature data also show a general trend of decreasing temperature as the Van Duzen River flows from warmer inland areas (near Root Creek) to the cooler coastal climate (near Alton). Small patches of cool water refugia have also been observed adjacent to Grizzly Creek, Root Creek, Hely Creek and possibly at other locations where tributary seeps bring cool flows to the mainstem river.

Persistently or intermittently flowing tributaries, springs or seeps may add cool water near the confluence with the mainstem Van Duzen River resulting in localized patches of cool salmonid refugia during summer months, especially in side channel pools and alcoves. These cool water habitats may be particularly important for juvenile coho salmon compared to Chinook salmon because Chinook juveniles are more likely to leave their natal streams by early summer and migrate to the estuary before temperatures reach stressful or lethal levels.

Water temperatures recorded in Lower Subbasin tributary streams from 1999-2005 (Table 11) are generally suitable for year round rearing of all salmonids, except for Grizzly Creek where the summer season 7-day average maximum temperature from 2001-2005 averaged 65ºF (18.3ºC). Even though these temperature values exceed suggested coho salmon thresholds and recent detection of coho salmon in Grizzly Creek has been limited to very small numbers, it was historically considered a good coho-bearing stream (CDFG 2004) and still has potential to be so once again. In September 2007 and August 2008, juvenile salmonids were observed holding in small patches of cool water refugia in the mainstem Van Duzen River near the Grizzly Creek confluence, which may be attributed to the importance of patches of cool water refugia during summer months.

Table 10. Seven-day maximum average water temperature (°F) in the Van Duzen River and Lower Subbasin streams 1996-1998. Source: HCRCD.

Year	**1996**	**1997**	**1998**
Site	**7-day Ave Max**	**7-day Ave Max**	**7-day Ave Max**
VDR near Root Cr.		79.7	77.9
VDR near Cummings		78.3	75.7
VDR near Alton	75.6	74.5	73.8
Cuddeback Creek 969			58.8
Cummings 1530	64.0	65.1	64.0
Cummings 1531	62.6		
Cummings 969			58.8
Root Creek 1203	61.3	63.1	61.2
Root Creek 1404	62.1	61.7	61.5

Table 11. Seven-day maximum average water temperature (°F) from Van Duzen River Lower Subbasin streams 1999-2005. Source: PALCO.

Station Location / Year	1999	2000	2001	2002	2003	2004	2005
Grizzly Creek			63.8	64.1	65.3	66.7	65.0
Root Creek	59.4	58.4	59.2	57.7	60.3	61.4	
Hely Creek		58.5	58.4	57.2		60.4	58.5
Cummings Creek			59.9	57.7	60.0	60.7	59.0

Turbidity

Turbidity was monitored in Lower Subbasin streams during the 2007 and 2008 water years by Friends of the Van Duzen River, a local volunteer watershed group. Analysis of collected data showed a strong positive relationship between discharge and turbidity levels for all sample sites. Highest turbidity levels were observed during the highest stream flows, and extended periods of high turbidity occur following rain events indicating prolonged inputs of fine sediment inputs to stream channels. Among the sample sites, Flanigan Creek, Fox Creek, and Wolverton Gulch consistently ranked highest in turbidity levels while Grizzly Creek had the lowest turbidity levels during the study (Friends of the Van Duzen 2010).

Stream Habitat Characteristics

CDFG measures a set of stream habitat characteristics to help assess stream condition in terms of suitability for anadromous salmonid production through the expression of several watershed factors and geomorphic processes acting together on spatial and temporal scales. The resulting channel geomorphology and riparian functions influence overall stream ecosystem conditions.

Within the Lower Subbasin, CDFG inventoried 7 tributaries between the years of 1991 and 2006 (Table 12). The data collected during these inventories are compared to the target values defined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) to determine if habitat conditions within the streams are limiting to salmonid production. Data collected during these habitat inventories describe the canopy density, cobble embeddedness of pool tails, length of primary pools, and mean pool shelter coverage along surveyed reaches within the Lower Subbasin. Additionally, the CWPAP evaluates these habitat data using the Ecological Management Decision Support (EMDS) system software. The EMDS system can evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. More details of how the EMDS functions are in NCWAP Methods Manual (2003), located on the CWPAP website (http://coastalwatersheds.ca.gov/AboutAssessment/AssessmentTools). Habitat data collected in the Lower Subbasin that can be used in the EMDS are: canopy, pool quality, pool depth, pool shelter, and embeddedness (Figures 25, 28, 30, and 31). Calculations and conclusions made in the EMDS are pertinent to surveyed streams and are based on conditions existing at the time of survey.

Pool:Riffle:Run Relationships

Significance: Productive anadromous streams are composed of a balance of pool, riffle and runs; each playing an important functional role in stream habitat ecology. A pool to riffle ratio of approximately 1:1 has been suggested to provide optimum food production and shelter for juvenile coho salmon (McMahon 1983), and the length of anadromous salmonid streams composed of primary pool habitats should be 40% (Flosi et al. 1998).

There are a variety factors affecting the relationships of pools, riffles, and runs, including channel type, channel gradient, bed and bank materials, sediment inputs, width to depth ratios, scour objects such as boulders and LWD, and the condition of the upstream watershed. Pools in forested mountain streams, common in the Lower Subbasin, are often associated with LWD and rock outcrops that help scour sediments during channel forming flows. A low measure of pool area and aggraded channels are often found when LWD is in low supply and/or when sediments are in excess. Large proportions of run or riffle habitats compared to pools may indicate an aggraded channel.

Pool, riffle and run relationships for Lower Subbasin streams are shown in Table 12. Using the most recent data available (for streams with multiple surveys), the mean percent stream length considering all streams of the Lower Subbasin is 30% pools (95% CI ±10%). Root Creek had the highest percent of surveyed stream length in pools in 2006 (45%) followed by Stevens Creek (38%). There are likely some quality pools in Root Creek, however field measurements may be biased because of the following factors: long sections of standing water that went dry soon after the stream survey was conducted; a large fish bearing section of Root Creek that was not surveyed in 2006 due to logging activity that posed a safety hazard to surveyors; and because of the limited survey period. Wilson Creek had the lowest amount of pools at 4% of the surveyed stream length. It should also be noted that Grizzly, Stevens, and Cummings creeks received improvement projects in the 1990s and early 2000s, often resulting in increased pool area.

Generally, the percent occurrence of pools and riffles are greater than their corresponding percent length of a stream in Lower Subbasin streams, indicating pools and riffles are relatively shorter in length than run habitats. In excessively aggraded channels, runs may develop as pools fill. Because pools are generally below desired lengths, habitat improvement projects should consider strategic placement of LWD in existing pools to enhance scouring and result in greater pool depths and increased pool lengths within the tributary streams.

Table 12. Pool, riffle and run relationships from Van Duzen River Lower Subbasin streams.

Stream Reach	Survey Year	Survey length	Pool:Riffle:Run % occurrence	Pool:Riffle:Run % length
Cummings Creek	1991	17,823	35:41:24	11:36:25
Cummings Creek	1996	10,572	33:33:34	18:24:58
Cummings Creek	2006	16,164	44:34:22	35:36:29
Grizzly	1991	12,962	30:36:34	21:31:47
Grizzly	2006	15,849	34:44:21	31:47:22
Hely Creek	1991	8,220	31:39:30	16:55:29
Hely Creek	2006	9,892	32:34:34	23:39:38
Root Creek	1991	13,824	39:23:38	25:21:54
Root Creek	2006	6,830	53:25:22	45:30:25
Stevens Creek	1991	5,063	49:27:24	27:33:40
Stevens Creek	2006	5,131	46:32:20	38:31:31
Wilson Creek	1991	2,481	19:50:31	4:86:10
Wolverton Gulch	1997	6,224	51:6:43	32:2:66

Pool Depth

Significance: Deep pools are important habitats for adult and juvenile salmonids. They are used as holding areas by adult salmonids during spawning activities, and by juveniles for year round rearing and refuge from both predation and high winter flows. During low summer flows or in streams with intermittent flows, deep pools may provide the only suitable salmonid habitat.

The length of deep pool habitat in a stream reach is a geomorphic characteristic commonly used as an indicator of stream conditions. Pool depth and length are easily measured without significant observer bias. We use the term primary pool to indicate pools with relatively deep maximum pool depths. The target primary pool depths are scaled relative to the Strahler stream order of the surveyed stream reach, such that primary pools are considered to have maximum residual depths of at least 2.0-2.5 feet for 1st and 2nd order streams, ≥3 feet for 3rd order steams and ≥4 feet deep for 4th order streams (Flosi et al. 1998, NCWAP 2003). We consider streams with approximately 25-60% of their length consisting of primary pools suitable for salmonids in terms of deep pools. These indicator values are then used to assess the pool condition of anadromous salmonid habitat with the EMDS and by inspection of maximum pool depth histograms. However, shallow pool conditions can occur in low gradient reaches within small watersheds that lack sufficient discharge to deeply scour the channel. Therefore, some of the smaller streams may not meet the general target values, but still provide important fish habitat.

Despite the increasing amount of pool habitat noted above, surveyed Lower Subbasin streams do not meet target criteria for the length of primary pool habitat according to EMDS evaluations (Fig. 24). Based on the most current survey data, the mean maximum residual depth for 1st and 2nd order reaches is 1.6 feet, and 2.4 feet for 3rd order reaches. A low measure of pool area and pool depth is often found in stream channels that are in low supply of LWD and over supplied with sediments, which may indicate a disruption to channel forming processes and/or elevated levels of sediments stored in the stream channel. However, there appears to be a trend of increasing pool depth in streams that were surveyed in 1991 and then again in 2006 (Table 13), which may indicate improving conditions in these streams.

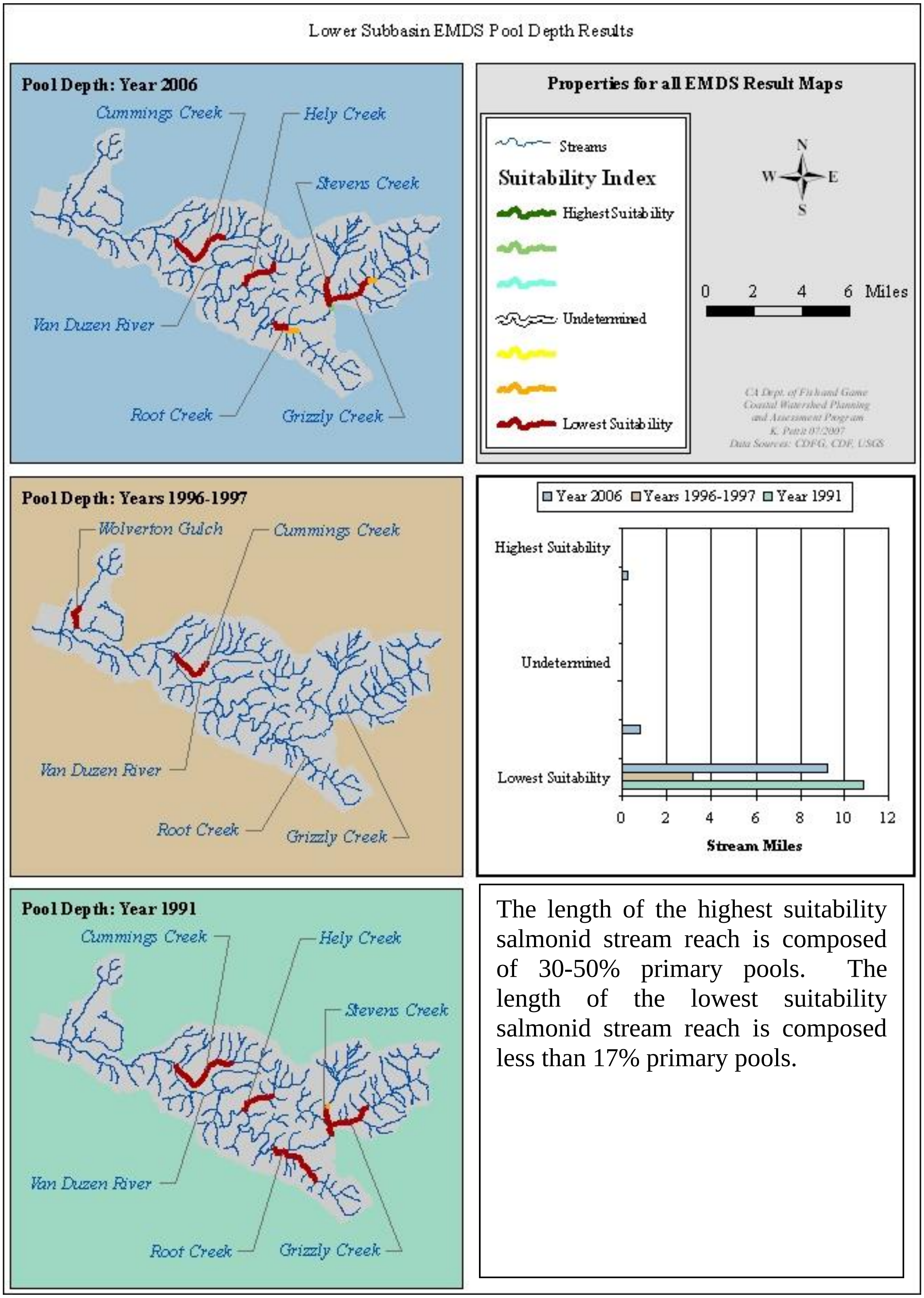


Figure 26. Pool depth suitability based on EMDS for the Lower Subbasin Van Duzen River.

Table 13. Average maximum pool depth in tributaries in the Lower Basin of the Van Duzen River.

Stream Reach	Survey Year	Ave. Max Pool Depth
Cummings Creek	1991	1.6
	1996	1.3
	2006	1.8
Grizzly	1991	2.1
	2006	2.5
Hely Creek	1991	1.4
	2006	1.8
Root Creek	1991	2.0
	2006	2.3
Stevens Creek	1991	1.8
	2006	1.9
Wilson Creek	1991	1.1
Wolverton Gulch	1997	1.6

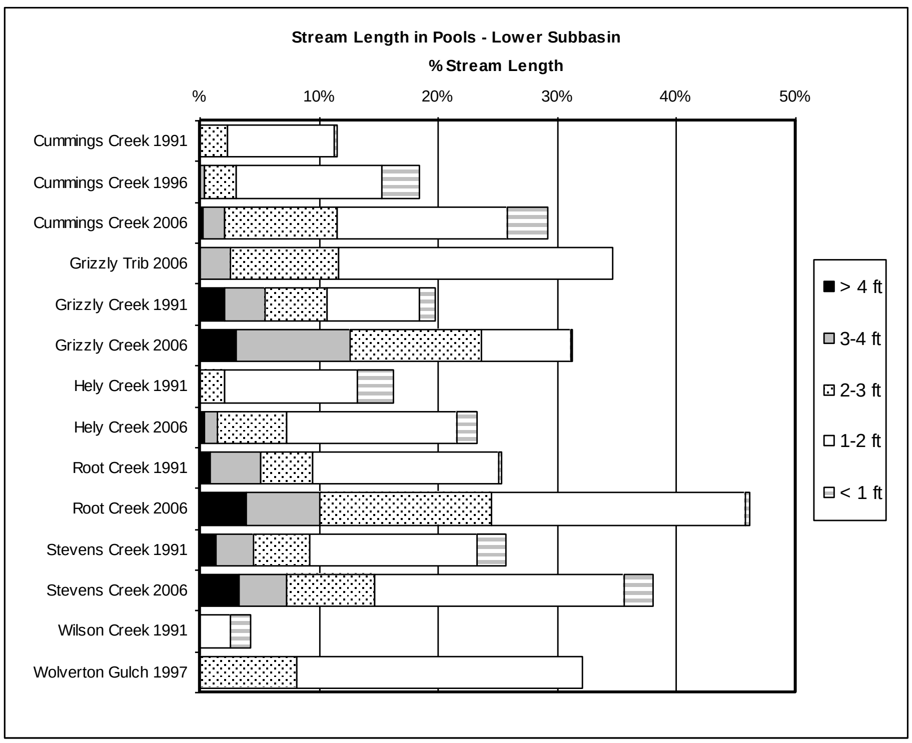


Figure 27. Pool depths for streams of the Lower Subbasin of the Van Duzen River.

Pool Shelter

Significance: Salmonid abundance in streams increases with the abundance and quality of shelter of pools (Meehan 1991). Shelter elements create areas of diverse velocity, provide protection from predation, and separate territorial units to reduce density-related competition. CDFG's stream survey protocol (Flosi et al. 1998), evaluates pool shelter complexity by a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation. The ratings range from 0-300, with ratings of ≥100 considered good shelter values. The ratings do not consider factors related to changes in discharge, such as water depth.

Findings: Pool shelter ratings were below the 100 target value for all streams and stream reaches indicating a general shortage of instream shelter elements (Fig. 26 and Table 14). The highest shelter values were observed in Hely Creek. Although generally in short supply, woody debris makes the largest contribution to pool shelter in Lower Subbasin streams (Table 14). No discernible trends are indicated in each individual stream or the overall set of Lower Subbasin streams as the stream survey data shows some stream shelter ratings have decreased in subsequent surveys while others have increased in more recent surveys (Fig. 27).

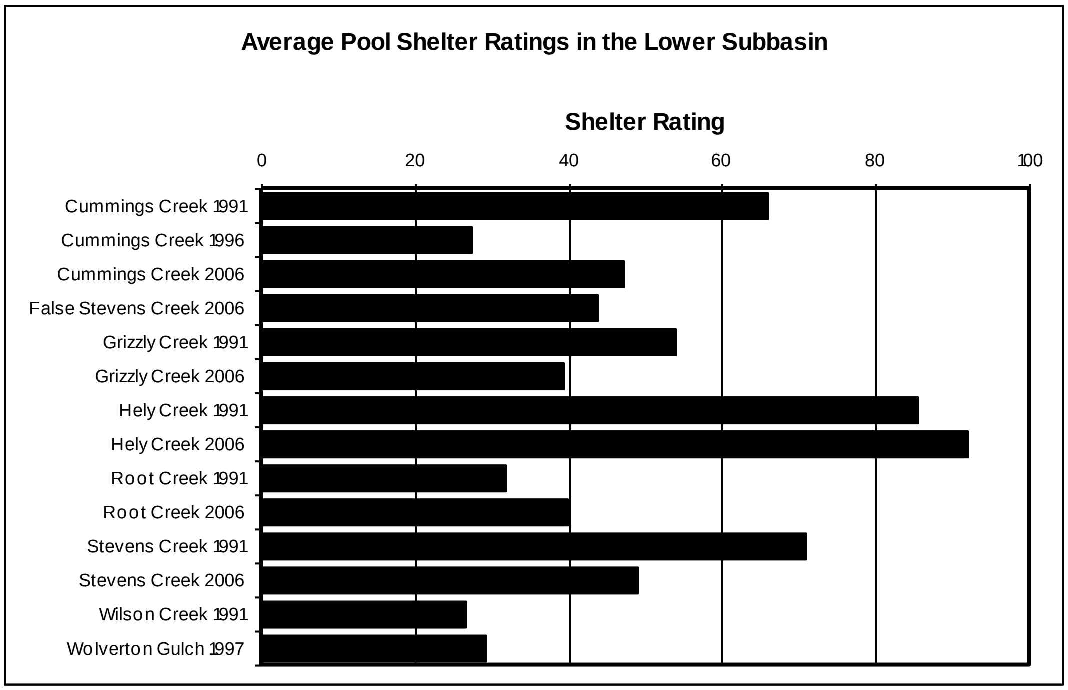


Figure 28. Average pool shelter ratings from CDFG sample reaches in Van Duzen River Lower Subbasin streams. Average pool shelter ratings exceeding 100 are considered fully suitable and average pool shelter ratings less than 30 are below desirable values for contributing shelter elements to salmonids.

Table 14. Pool shelter elements for Van Duzen River Lower Subbasin streams. The percent contribution for each shelter element is shown.

Stream / year	Undercut Banks	Woody Debris	Terrestrial Vegetation	Aquatic Vegetation	White-water	Boulders	Bedrock Ledges
Cummings/ 2006	13	67	2	1	1	11	
False Stevens/2006	11	17	1		10	63	
Grizzly/2006	2	33	6		8	45	2
Hely/2006	7	66	14		14	22	1
Root/2006	18	54	3		4	22	
Stevens/2006	5	61	2		5	24	2

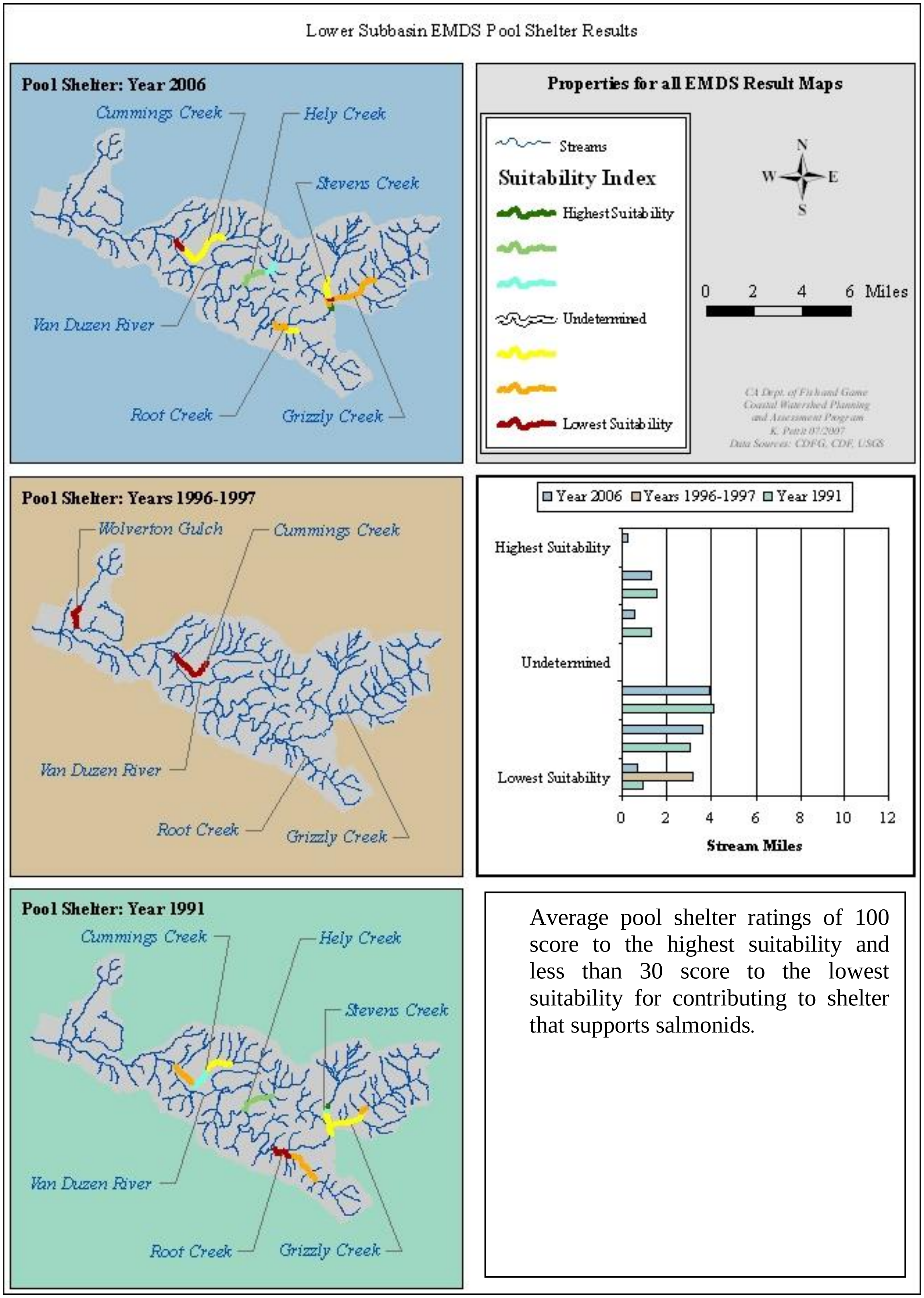


Figure 29. Pools shelter evaluations by EMDS for Lower Subbasin of the Van Duzen River tributaries.

Spawning Cobble Embeddedness

Significance: Cobble embeddedness is the percent of an average-sized cobble piece embedded in fine grained sediments observed in pool tails. Pool tails are sampled because they are commonly selected areas for salmonid spawning. Percent cobble embeddedness provides a subjective measure of spawning substrate suitability for salmonid egg incubation, fry emergence and aquatic insect habitat. Embeddedness observations may indicate where excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds, which may suffocate eggs or developing embryos. Excessive levels of fine sediment accumulations within gravel and cobble substrate may also alter aquatic insect species composition and reduce connectivity of flow between surface and subsurface stream flows needed to moderate water temperature.

High embeddedness ratings may indicate elevated levels of sediment inputs and erosion problems occurring in the watershed. The potential for high levels of fine sediments in streams increases in watersheds of the Lower Subbasin where the unstable geology, high precipitation, steep topography, and land use cumulatively increase erosion potential. Some common land use activities that increases generation of fine sediment are clear cuts, roads, skid trails, and livestock grazing (Cederholm et al. 1981, Duncan and Ward 1985, Swanson et al. 1987, Hicks et al. 1991).

Gravels and cobble that are less than 25% embedded with fine sediments are considered good quality substrate for salmonid spawning and production of stoneflies, mayflies and other aquatic insects. Gravels and cobbles over 50% embedded are viewed as poor quality for salmonid spawning and can impair stonefly and mayfly insect production. At the stream reach scale, spawning cobble embeddedness is considered suitable if at least 50% of all pool tails have embeddedness measures of less than 25%. Pool tails that are covered by wood debris or by fine sediments are considered unspawnable.

Findings: The streams of the Lower Subbasin generally show relatively high levels of cobble embeddedness (Figs. 28 and 29). Stevens Creek, sampled in 2006, was the exception with just over 50% of the 43 pool tails measured showing less than 25% cobbled embeddedness. However that is a decline from the 65% category measured in the 1991 survey. EMDS evaluations showed that 2006 surveyed reaches in Hely and Root creeks were poorest of the Lower Subbasin streams for salmonid spawning habitat. The high levels of embeddedness are an indication of excessive delivery of fine sediments to most Lower Subbasin streams. Salmonid spawning success is likely limited or impaired by the lack of good quality spawning habitat in these streams.

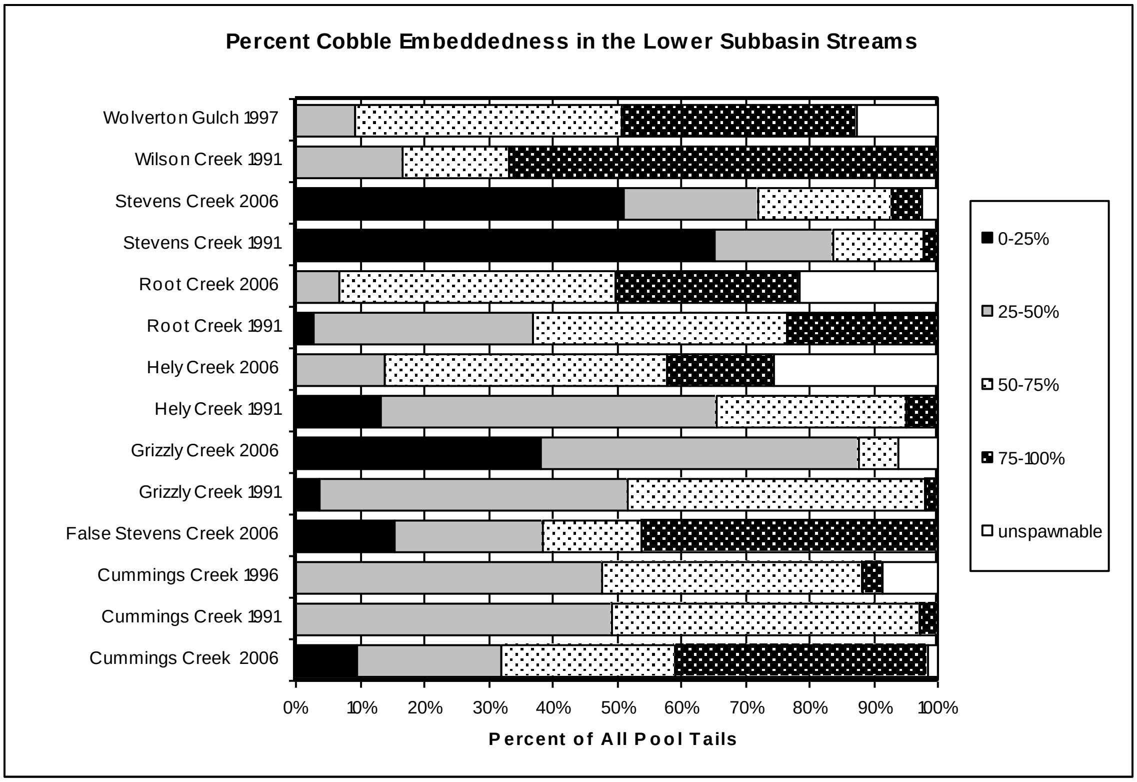


Figure 30. Percent cobble embeddedness in Lower Subbasin streams. Spawning cobble embeddedness is considered suitable if at least 50% of all pool tails are less than 25% embedded in fine sediments.

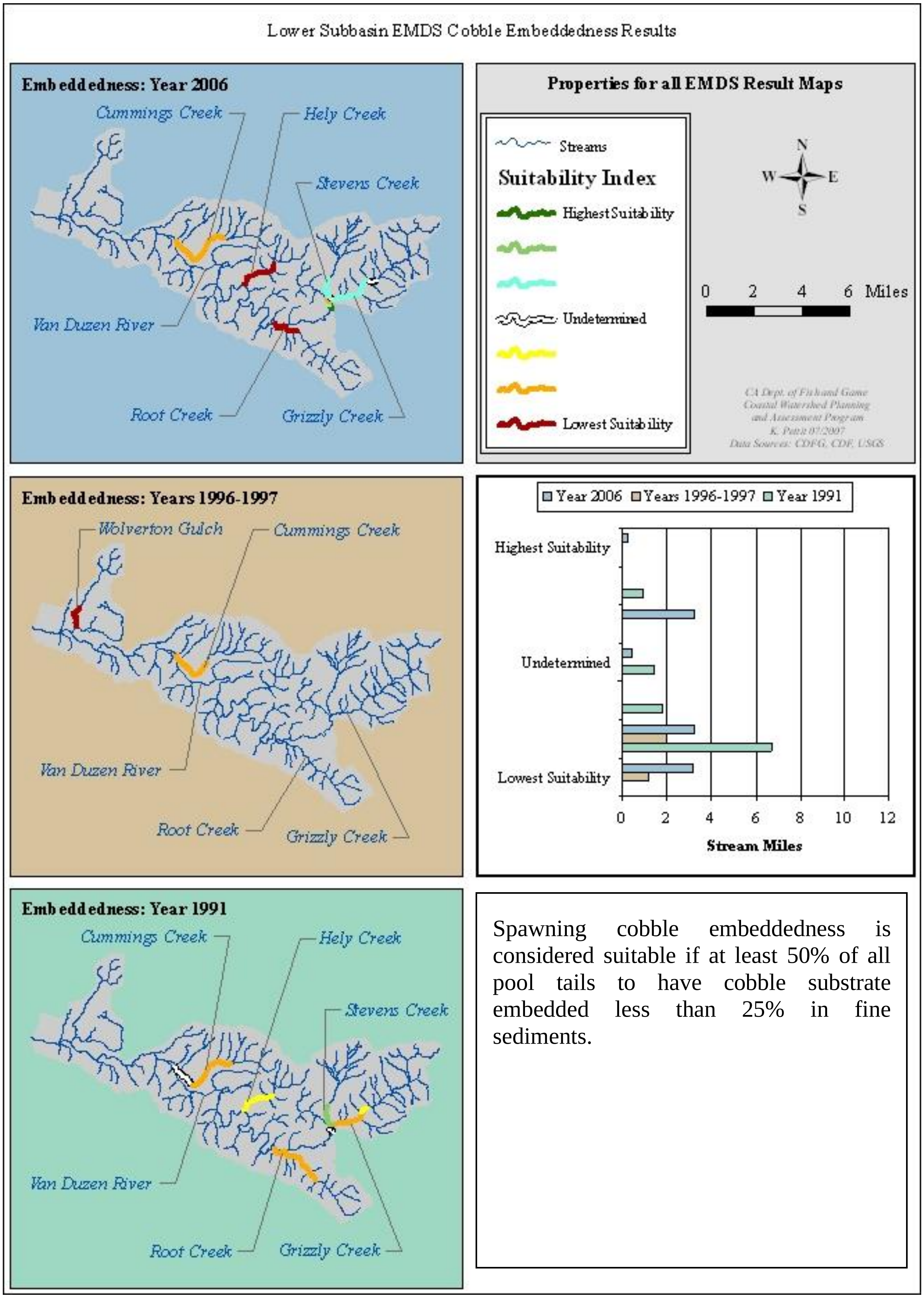


Figure 31. Spawning cobble embeddedness evaluations by EMDS for Lower Subbasin of the Van Duzen River tributaries.

Streamside Canopy Density

Significance: Streamside canopy density is an estimate of the percentage of stream channel that is shaded by riparian tree canopy. An effective tree canopy provides shade to reduce direct sun light from warming water and contributes to maintaining cool microclimates. The condition of streamside canopy can change relatively rapidly with management that removes trees or alternatively by allowing tree growth. Habitat improvement projects are considered when canopy density is less than 80% (Flosi et al. 1998).

A second measurable attribute of streamside canopy is the percent of coniferous and deciduous tree species providing the shade. The percent coniferous and deciduous component of the stream side canopy influences the potential for LWD loading and can influence microclimate. Streams flowing through mature conifer stands tend to have larger amounts of wood with larger average piece size than streams with younger riparian stands, which often are dominated by smaller deciduous species (Bilby and Bisson 1998). LWD produced by conifers is generally favored over deciduous wood because it tends to be larger and less likely to move downstream, it decays more slowly, and stays longer in stream systems. The overstory shade produced by mature conifer stands also helps form cool microclimates along riparian zones which helps keep streams cool.

Findings: The majority of surveyed stream reaches in the Lower Subbasin had streamside canopy density values above 80%, indicating good direct shade cover over the water (Fig. 30). Although most streams had suitable levels of shade, the amount of overstory shade contributed by conifers is below 50% for all streams. The low amount of overstory conifer shade is indicative of small sized or absence of conifer trees along the riparian zones of surveyed streams. It usually takes approximately 40 years to establish mature conifer forest canopy in these coastal forests. Multiple years of surveys show increasing coniferous canopy on Cummings, Stevens, Grizzly, Hely, and Root creeks. The desirable increase in coniferous canopy is due to re-growth of redwood or Douglas firs that were removed from riparian zones during past timber harvests or bank erosion. Wolverton Gulch had the lowest streamside shade contribution from coniferous trees. Redwood trees were recently planted by students of Hydesville School to help address the lack conifers on Wolverton Gulch.

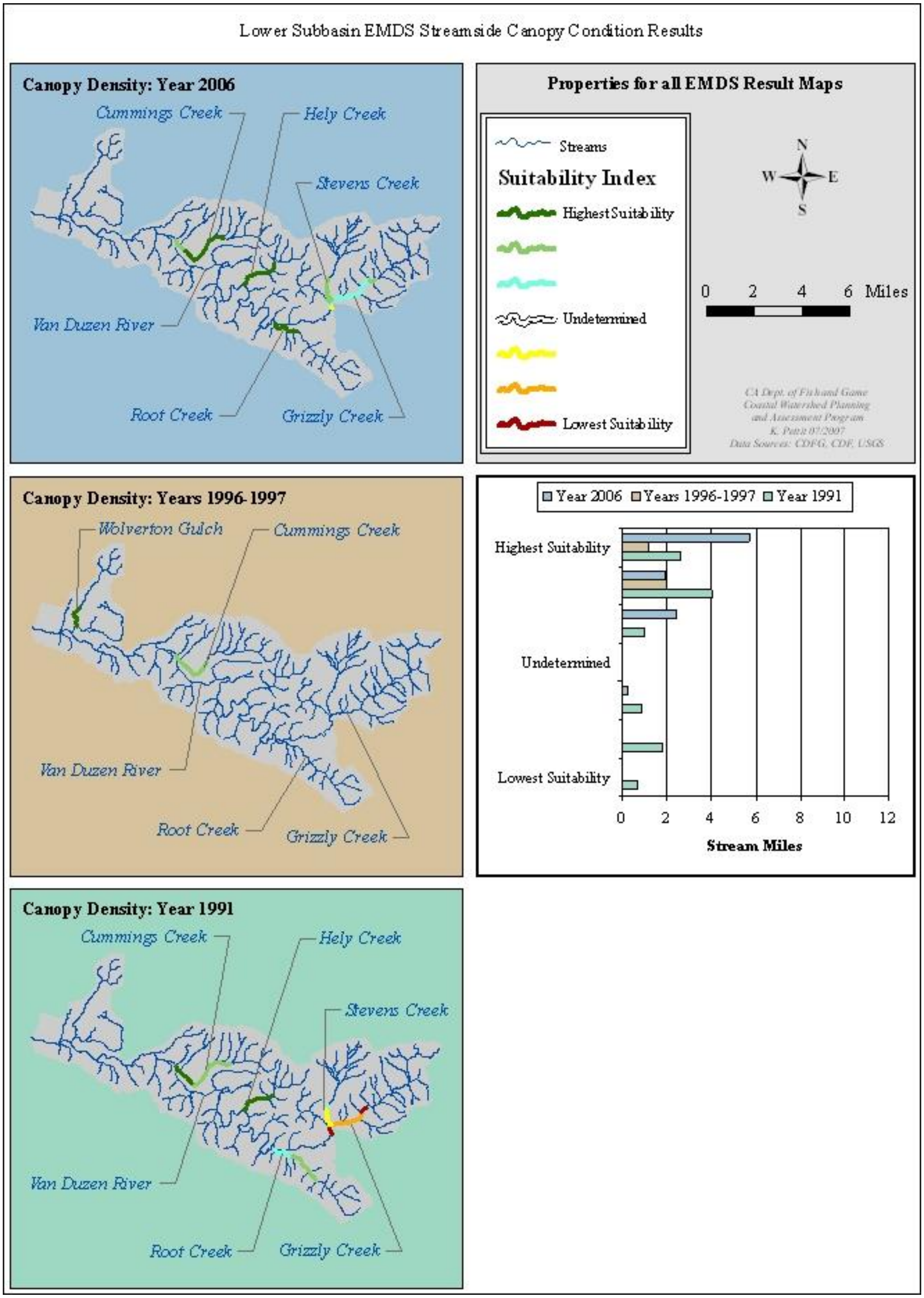


Figure 32. EMDS streamside canopy condition results for the Lower Subbasin of the Van Duzen River.

Habitat Conclusions

Within the Lower Subbasin, CDFG inventoried 6 tributaries between the years of 1991 and 2006 (Table 15). Considering relatively the same reaches were surveyed in Cummings, Hely, Root, Stevens and Grizzly creeks in 1991 as in 2006 two data sets can be compared to show general trends.

Where habitat data were available from both older stream surveys and recent stream inventories it appeared that habitat conditions generally remained the same or showed slight improvement in some habitat categories. However, in a few reaches habitat conditions actually decreased from the 1991 surveys to the 2006 surveys. The percentage of pool occurrence and pool length improved in almost every stream surveyed. Canopy density also improved in some stream reaches, most noticeably in Grizzly Creek. Spawning habitat (embeddedness) improved in some reaches (Grizzly Creek) but decreased in others (Hely and Root creeks). Similarly, pool shelter improved in some reaches but decreased in others within the same stream, such was the case in Root and Cummings creeks.

Canopy density was suitable on all surveyed stream, except for one reach on Grizzly Creek. Aside from Grizzly Creek, water temperatures were found to be suitable for salmonids in on all streams where data was collected. Water temperature is likely a limiting factor for coho in Grizzly Creek. It is important to note that current canopy density measurements do not take into account differences between smaller, younger riparian vegetation versus the larger microclimate controls that are provided by old and second growth forest canopy conditions.

Overall instream habitat conditions were generally poor to moderate in this subbasin at the time of more recent CDFG surveys (late 1990s and mid 2000s). Surveyed reaches fell below target values and were evaluated as unsuitable for salmonids by EMDS for the majority of habitat characteristics, except canopy density and percentage of pool occurrence.

These habitat factors are likely limiting factors to the salmonid populations in nearly all the surveyed streams within the subbasin. High sediment loads in these streams results in decreased pool size, shallow pool depths and highly embedded spawning areas. The lack of pool shelter in all surveyed streams except for Hely Creek could also be considered a limiting factor.

Table 15. Habitat factors that limit (L) or support (S) production of anadromous salmonids in streams of the Lower Subbasin.

Stream	Stream flow	Passage Barriers	Stream temp	Water quality	Spawning substrate	Pool depth	Pool area	Pool Shelter	LWD	Canopy
Wolverton Gulch	S	L	ND*	ND*	L	L	L	L	L	S
Cummings	S	L	S	L	L	L	L	L	S	S
Hely	S	S	S	S	L	L	L	S	L	S
Root	S	L	S	S	L	L	S	L	L	S
Stevens	S	S	ND*	L	S	L	S	L	S	S
Grizzly	S	S	L	L	S	L	L	L	L	S

*ND is no data available

Restoration Projects

Road and instream habitat improvements are the most common watershed restoration projects implemented in the Lower Subbasin (Fig. 31). Goals of road projects are to reduce road related erosion and reduce sediment delivery to streams. Instream projects typically add wood and boulders to channels to build pools or recruit spawning substrate (Fig. 30). Grizzly Creek has received the most CDFG funded instream, road improvement, and stream crossing removal/upgrade work within the subbasin as nearly its entire stream length has benefited from some type of restoration improvement projects. A large amount of restoration work involving instream, riparian, stream crossing removal, and road improvement projects have also been completed in the Cummings Creek watershed.

More information on restoration projects such as date and specific location can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/). Recommendations for potential restoration projects are located below in the Subbasin Scale Responses to Assessment Questions (pgs. 48-49).

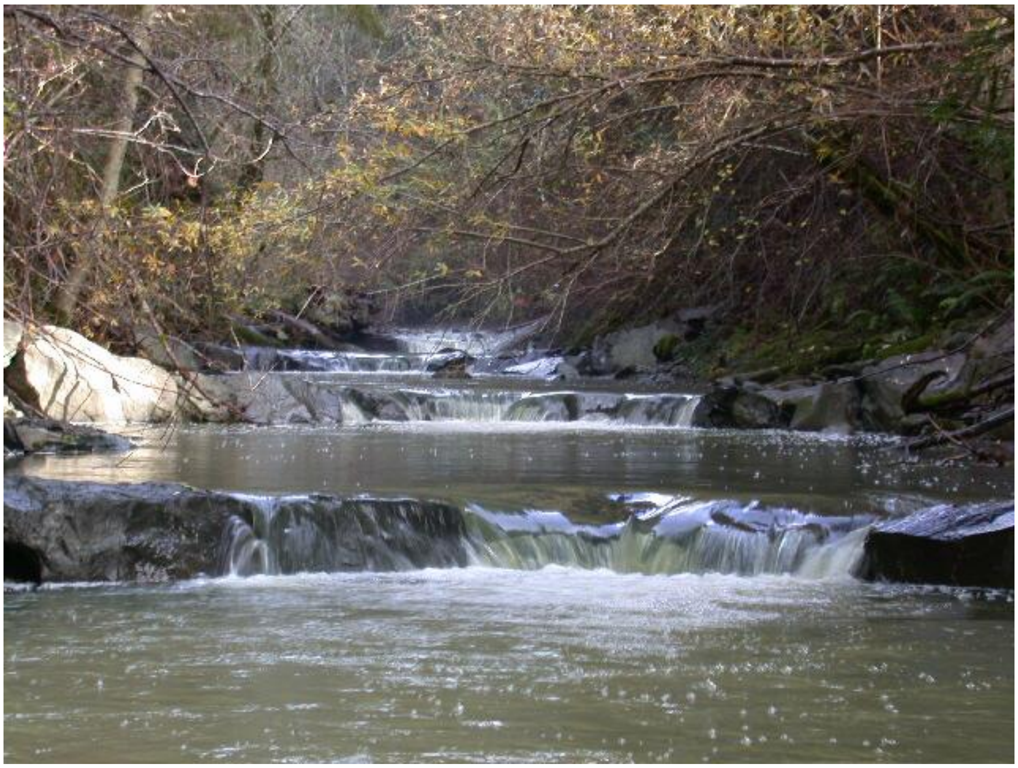


Figure 30. Step pool instream improvement project on Grizzly Creek.

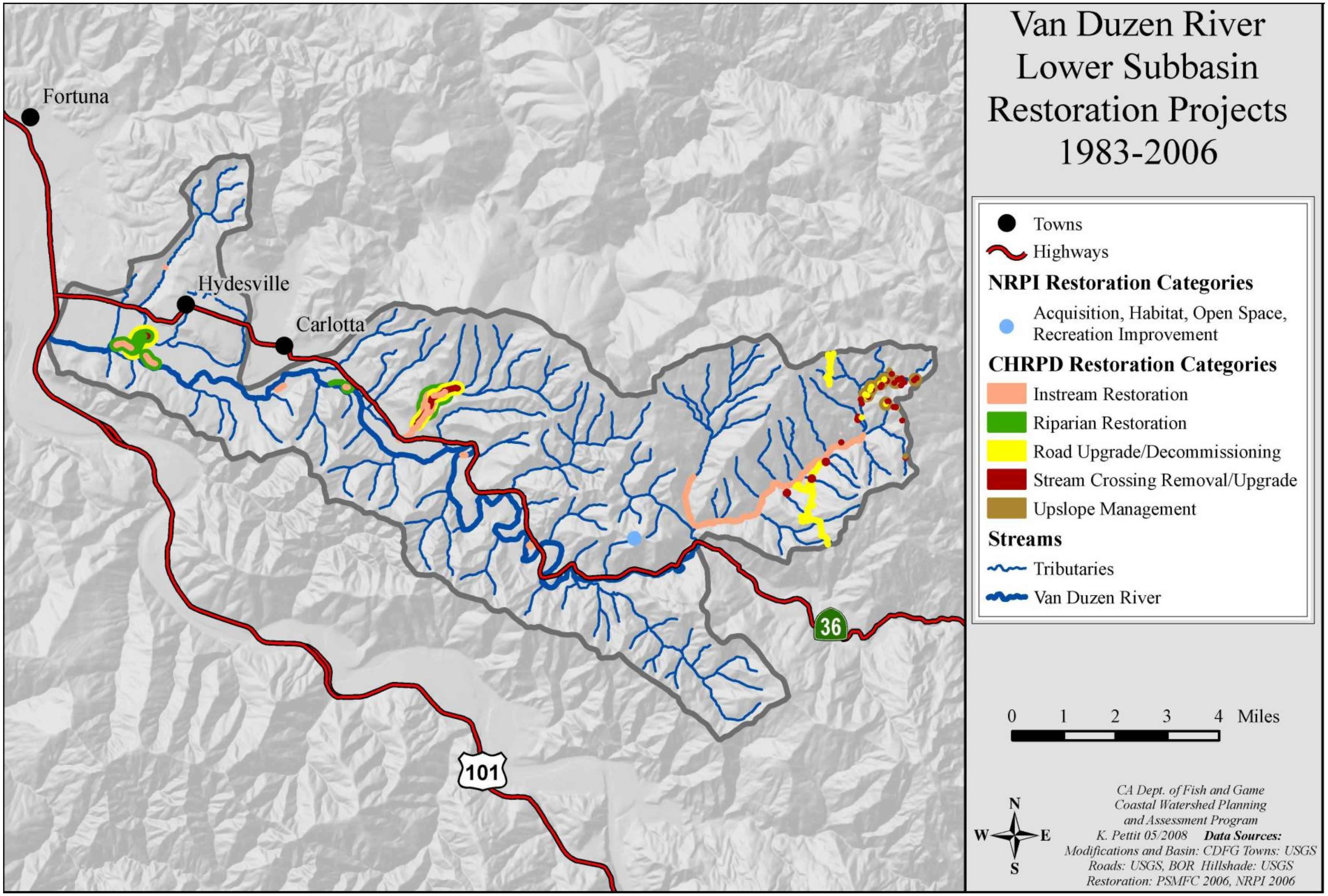


Figure 31. Lower Subbasin restoration projects delineated by the California Habitat Restoration Project Database (CHRPD) and the Natural Resources Project Inventory (NRPI) from 1983 to 2006.

Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Lower Subbasin by using professional judgment and criteria developed for north coast watersheds. The criteria included measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS at the stream reach scale.

The most complete data available in the Lower Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered. Salmonid habitat conditions in the Lower Subbasin on surveyed streams are almost split between a low quality refugia rating and a medium potential refugia rating with there being a few more streams rated as medium potential (Table 16). While the Van Duzen River (mainstem) has medium potential, current conditions reflect a low quality rating. Hely Creek was the only creek to receive a high quality and high potential refugia ranking. Considering the amount of restoration projects that have occurred in the Grizzly Creek watershed, it could be upgraded to a high potential refugia rating in the near future. About 40% of the streams were considered data limited.

Table 16. Refugia category ratings of streams of Lower Subbasin.

Stream	Refugia Categories				
	High Quality	**High Potential**	**Medium Potential**	**Low Quality**	**Data Limited**
Van Duzen River (mainstem)			x	x	
Van Duzen Tributaries					
Barber Creek				x	x
Wolverton Gulch			x		
Wilson Creek			x		
Cuddeback Creek				x	x
Fiedler Creek			x		x
Cummings Creek			x		
Fox Creek				x	x
Flanigan Creek				x	x
Hely Creek	x	x			
Root Creek			x		
Grizzly Creek			x		
Stevens Creek			x		

Subbasin Scale Responses to Assessment Questions

The following discussion of the assessment questions and recommendations for improvement activities are generalized to the subbasin scale.

<u>What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Lower Van Duzen Subbasin?</u>

- A review of recent CDFG spawner survey results (Appendix B) reveals the present number of Chinook and coho salmon returning to spawn in the Lower Subbasin have declined significantly compared to the substantially larger runs reported prior to 1965 (CDFG 1965);
- Coho salmon stocks have declined to drastically low numbers and may be functionally extirpated from the subbasin;
- Because winter steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the subbasin and have persisted in streams where other species have declined or are now rarely observed.

<u>What are the current salmonid habitat conditions in the Lower Van Duzen River Subbasin? How do these conditions compare to desired conditions?</u>

- The Van Duzen River and its tributaries exhibit high and prolonged levels of turbidity. The high turbid water make it difficult for fish to find food. This is especially important if newly hatched fish like Chinook salmon cannot feed;
- Even with recent high rainfall years, decreased summer water flows to tributaries is occurring, which in turn, has decreased summer and early fall base flows in the Van Duzen River;
- Increased nutrient, pollution, and sediment input into streams are causing impairment of habitat for fish, amphibians, and other wildlife;
- Hely Creek has a small but continuous stream flow year round with water temperature cool enough to support coho salmon. While the lower reaches of Cummings and Root Creek dry up during the summer season the mid to upper reaches provide continuous stream flow with suitable water temperatures for year round juvenile salmonid rearing habitat.

<u>What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?</u>

- All of the bedock types in the Lower Subbasin are considered highly prone to landsliding and surface erosion;
- Streams have down cut into the erosive bedrock of the Lower Subbasin during extensive tectonic uplift leaving very steep bank-slopes and terraces which are susceptible to small-scale, frequent slope failure;
- Frequent landslides especially during heavy storm events and/or seismic events contribute a significant amount of sediments to the stream;
- The sediment supply to streams may be easily increased to excessive levels by land management activities;

- 85 miles of intermittent tributary channels drain the Lower Subbasin are sediment source reaches. Most of these stream miles receive minimal protection (class 3) from timber harvests or other land use and may generate excessive amounts of sediments to downstream fish bearing reaches;
- Low gradient reaches of the mainstem as well as the lower reaches of several tributaries are storing sediments;
- Excessive sediment accumulations at the mouths Hely and Root creeks impair fish passage during spawning migrations;
- Recent studies show Wolverton Gulch,, Grizzly Creek, Cummings Creek and other creeks of the Lower Subbasin have extended periods of high turbidity after rain events indicating persistent, high levels of fine sediment inputs to stream channels;
- The original forest stands were integral to stream ecosystem and salmonid production;
- The present forest condition does not provide the same beneficial levels of shade, microclimate, soil stability and supply of organic materials to streams as the old growth forests of the past;
- The lowermost two miles of Van Duzen River is a very wide and shallow reach with a simplified channel lacking in bed form diversity. The lowermost reach requires annual channel maintenance to facilitate fish passage during spawning migrations from the Eel River into the Van Duzen River;
- Since the Lower Subbasin receives runoff from the entire Van Duzen River Basin, it is susceptible to cumulative watershed effects that influence water temperature rates of sediment deposition, and channel morphology;
- Large flow events play a major role in aggradation, degradation, as well as other changes in channel morphology.

How has land use affected these natural processes?

- The present condition of the Lower Subbasin is in part the result of land use activities within the Lower Subbasin and land use that occurs in the watersheds located upstream;
- Primary causes for stream habitat deficiencies can often be traced back to land management actions that reduce stream flow, degrade water quality, increase erosion, and/or activities that alter characteristics of near stream forests;
- Within the past 10 years increasing conversions on private property of large, industrial marijuana agriculture operations have proliferated from the upper portion of the Lower Subbasin throughout the Middle Subbasin and to a lesser extent in the Upper Subbasin. These mostly unregulated operations have decreased summer/early fall stream flows and degraded water quality in Van Duzen River and its tributaries;
- The naturally high potential for erosion of the hill slopes and sediment delivery to stream channels is elevated by land use such as road construction, timber harvest operations and other land use that disturbs top soil or weakens slope stability;
- Some common land use activities that increases generation of fine sediment are clear cut logging operations, roads, skid trails, and livestock grazing.

Based upon these conditions, trends and relationships, are there factors considered to limit salmon and steelhead production?

- Decreased summer/early fall stream flows, potentially higher summer/early fall water temperatures and degraded water quality in the Van Duzen River;
- Spawning substrate embedded in fine sediments likely impairs reproductive success in Grizzly, Stevens, Root, Hely, Cummings and portions of the mainstem;
- Perched sediment deltas may impede spawning fish passage to tributaries in Healy, Cummings, Root creeks and other tributaries;
- A lack of deep, complex, pools needed for critical habitats limits salmonid production in all Lower Subbasin tributaries;
- High levels and prolonged duration of turbid water impairs juvenile salmonid feeding and growth;
- Inputs of LWD and SWD are needed for fish shelter elements, spawning substrate recruitment, and scouring pools on all Lower Subbasin tributraries.

What habitat improvement and other activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Barriers to Fish Passage

- Annual channel maintenance is required to facilitate fish passage into the lower Van Duzen River from Eel River;
- Inspect fish passage into Wolverton Gulch and at culverts located on HWY 36 and Rohnerville Road;
- Fish access into Cummings and Fiedler creeks should be improved by channel reconfiguration in their lowermost reaches;
- Review options for improving salmonid spawner access through sediment deltas into Root and Hely creeks.

Flow and Water Quality Improvement Activities:

- Instream flows to maintain fish habitat in good condition and channel maintenance flows should be preserved during any existing water diversion activities and considered prior to any new water development projects including riparian diversions, industrial marijuana agriculture operations, small domestic water use and water extraction from near stream wells;
- Consider private landowner water storage and forbearance programs were large capacity storage tanks are operated as part of a seasonal water management program;
- Assess roads and implement road improvement projects to reduce sediment delivery to fish bearing streams;
- Reduce fine sediment inputs by avoiding land use on inner gorge slopes and mitigate to reduce sediment inputs for any land use near streams on slopes greater than 25 percent.

Erosion and Sediment Delivery Reduction Activities:

- Consider stabilization of hillslope failure at Hely Creek 1440 feet above HWY 36; 1100 feet up Redwood House Road. Insure stormwater runoff from Redwood House Road is diverted away from this site;
- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams;
- Review potential for bank stabilization projects along Grizzly Creek and Cummings Creek.

Riparian and Stream Habitat Improvement Activities:

- Pool enhancement projects should be implemented at select, existing pool habitat units to increase depth and add shelter complexity on Cummings, Hely, and Grizzly creeks;
- Consider adding elements to recruit and retain spawning gravels in Grizzly;
- Seek opportunities to increase conifer overstory shade canopy over Grizzly Creek by plantings and/or thinning hardwoods around small conifers.

Monitoring, Education and Research Activities:

- Collect genetic samples from any coho salmon found in the Subbasin;
- Consider methods to re-introduce coho stocks into appropriate streams of the Lower Subbasin such as Healy, Cummings, Fielder, Root, Grizzly and Stevens creeks;
- Perform fish surveys on Fox Creek to identify presence and distribution of coastal cutthroat and resident rainbow trout;
- Perform fish surveys on Flanigan Creek to identify presence and distribution of anadromous salmonids;
- Several years of monitoring summer/early fall stream water and air temperatures to detect trends using continuous, 24-hour monitoring thermographs should be done in the Van Duzen River;
- Monitor summer/early fall water quality parameters in the Van Duzen River;
- Conduct community based outreach meetings to discuss approaches that could be implemented to help address the problems created by industrial marijuana agriculture practices.

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Middle Subbasin




Overview

The Middle Subbasin drains approximately 78 square miles of the Van Duzen Basin and includes seven Calwater 2.2 planning watersheds (Table 1 and Figs. 1 and 2). Virtually all the land in this subbasin (98.5%) is privately owned. Primary land use includes timber production, cattle ranching and rural residential developments. The Middle Subbasin is very sparsely populated and contains only one small town for the entire subbasin. Bridgeville, located along the Van Duzen River near RM 31, provides a school, post office and a community center for residents who live in outlying areas. The Van Duzen River and the Middle Subbasin tributary streams support populations of Chinook salmon and steelhead. Coho salmon have been reported to spawn in Middle Subbasin streams, but due to the lack of focused surveys and overall population decline coho have not been documented in the subbasin since the early 1980s (Reynolds et. al 1981 and Decker and Fuller 1984).

Table 1. Summary of Van Duzen River Middle Subbasin attributes.

Square Miles	78
Total Acreage	50,000
Private Acres	49,250
Federal Acres	600
State Acres	150
Predominant Land Use	Timber Harvests
Predominant Vegetation Type	Douglas fir Forest
Total Stream Miles	162
Stream Miles/Subbasin Miles	2.1
Miles of Anadromous Stream	27

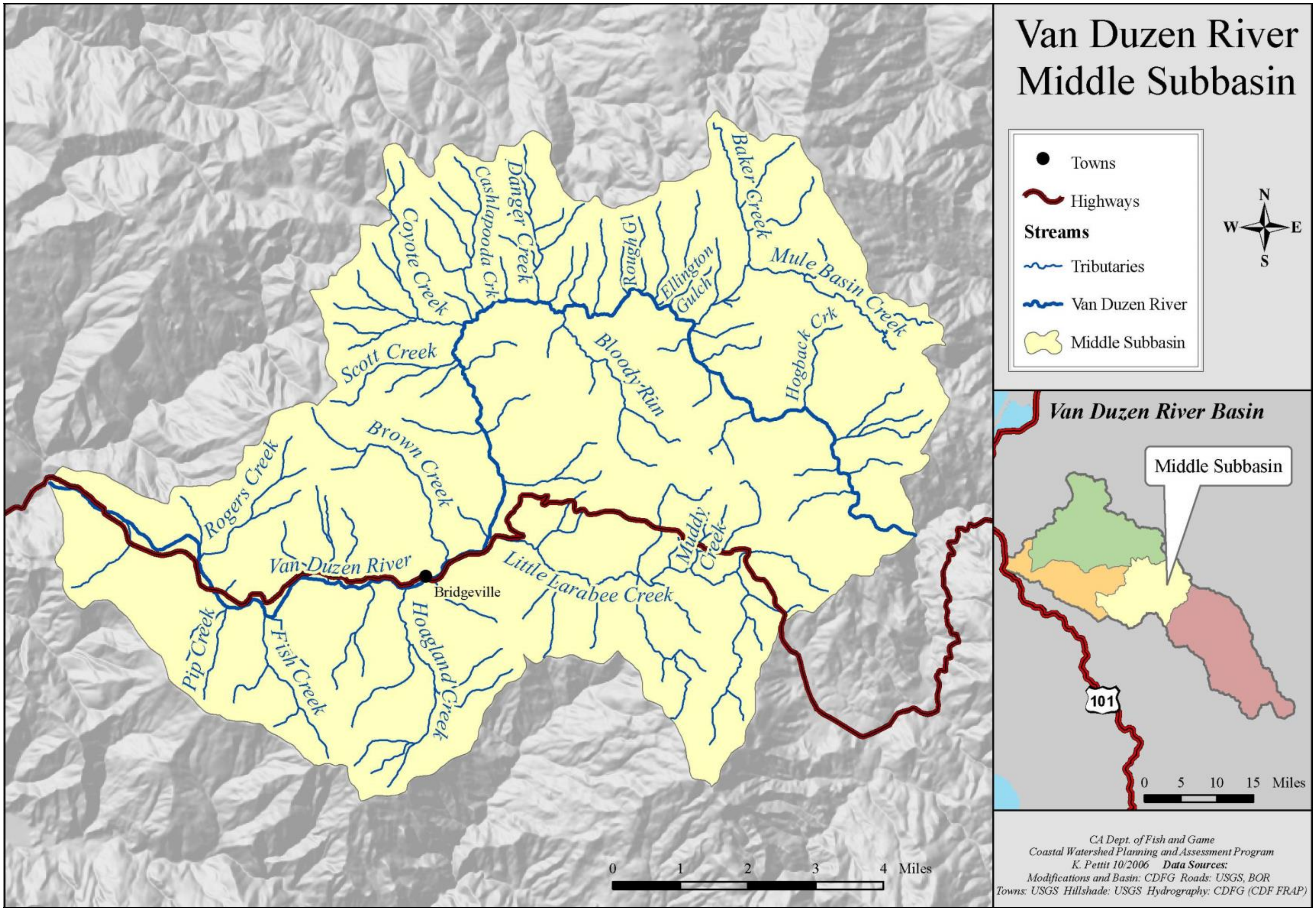

Figure 1. Location and tributaries of the Middle Subbasin of the Van Duzen River.

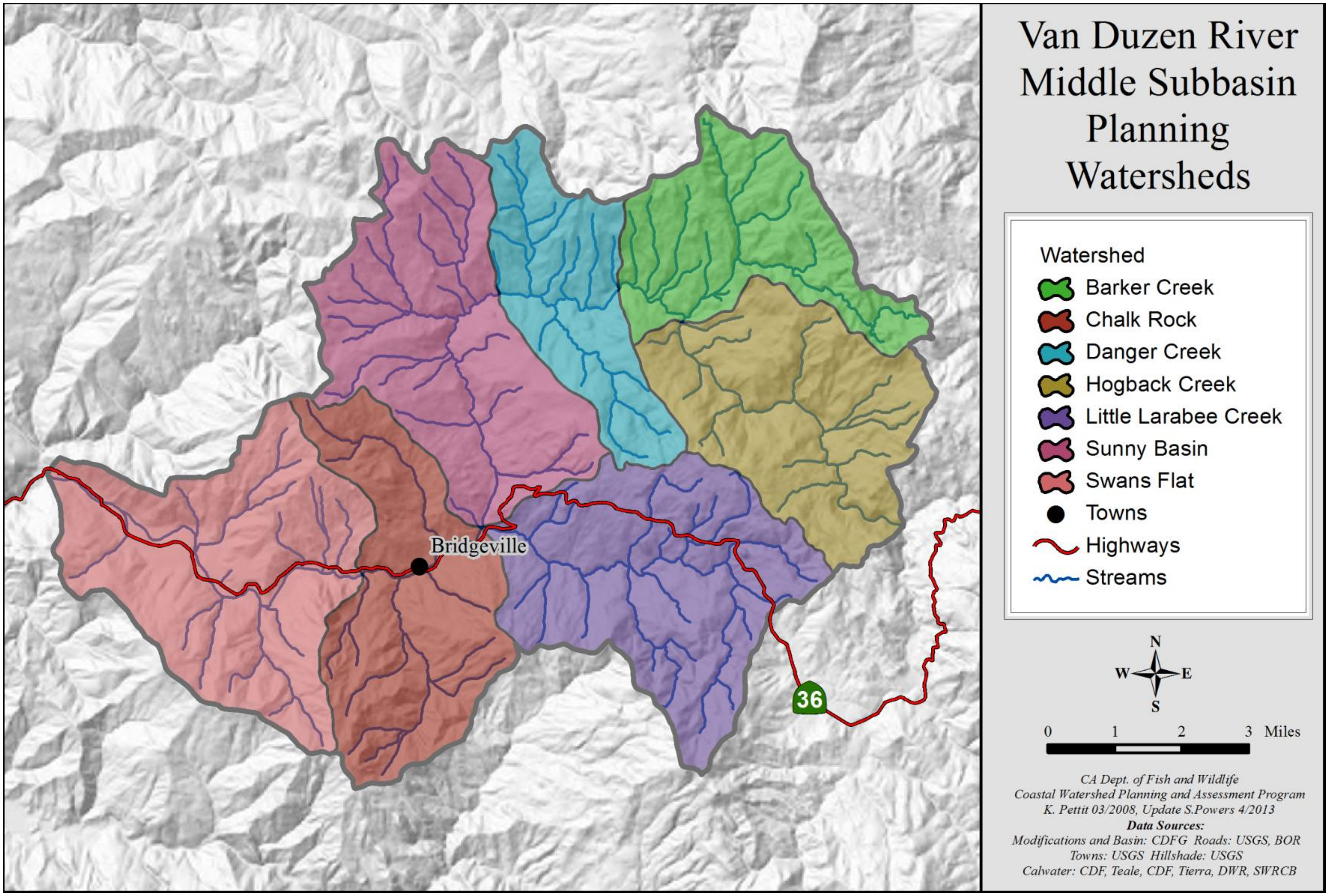

Figure 2. Seven Cal 2.2 planning watershed comprise the Middle Subbasin of the Van Duzen River.

Geology

Bedrock

Central Belt Mélange of the Franciscan Complex is the most abundant bedrock type, occupying 58% of the Middle Subbasin (Figure 3 and Table 2). Mélange of the Central belt formed between 65 million to 200 million years ago in the subduction trench between the Farallon and North American plates as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off the continent (Aalto 1981). This mixture or "mélange" was then scraped off and smashed onto the western edge of the North American continent about 88 million years ago (McLaughlin 2000). Mélange can be described as a mixture of claystone, siltstone, and sandstone that has been metamorphosed, churned, and mixed in a subduction zone to such a degree that its supporting matrix has been completely disrupted by shearing. Because the mélange matrix material is very weak it tends to behave more as an extremely viscous liquid than bedrock, slowly "flowing" over time. The flowing of mélange material over time exposes the more coherent lithologic blocks within the mélange known as "Franciscan Knockers" or "Donakers" (shown in the upper left photo at the beginning of the Middle Subbasin section).

Of all of the lithologies in the Van Duzen River Basin the mélange of the Central Belt is the most susceptible to earthflows and deep-seated landslides (Figure 3). Active and dormant earthflows within the mélange of this subbasin are frequent and sizeable. Active earthflows occur at an average movement of 4 meters/year. Dormant earthflows may reactivate during especially wet seasons, during seismic events, if their toe is worn away by streams, or in response to land use disturbances. Carving roads into earthflows can further destabilize them and initiate subsequent landslides.

Central Belt sandstone of the Franciscan Complex makes up roughly 24% of the surface of this subbasin. The Central Belt sandstone units are described as large blocks of slightly metamorphosed sandstone, greywacke ("dirty" sandstone), and argillite (McLaughlin 2000). They most likely formed 65 to 160 million years ago as sediment eroded from the continent, from sources as far away as Idaho (Underwood and Bachman 1986), and covered the subduction trench. These layers of sediment are not as tectonically mixed as the sediments within the mélange and are preserved relatively intact. Although they were metamorphosed, folded, and sheared to some extent, they are more coherent than the mélange.

The Yager terrane of the Coastal belt makes up 12% of this subbasin. The Yager terrane consists of rather well consolidated sandstone, argillite, and conglomerate. The Yager terrane is relatively stable but contains faulted and/or sheared zones of weakness within the bedrock that are prone to large-scale landsliding. Furthermore, layers of argillite (slightly metamorphosed claystone) within the Yager terrane tend to crumble when exposed repeatedly to water and air leading to sliding along bedding planes and increased sediment delivery to streams.

The Yager terrane was originally deposited around 50 to 34 million years ago from sediments transported by rivers as far as Idaho that accumulated along the continental shelf to the deep ocean floor (Underwood and Bachman 1986, McLaughlin et al. 2000). Quiescent periods of deposition of clay to silt sized particles settling out of suspension were punctuated by large underwater landslide events which deposited sand and gravel. This accumulation of inter-bedded sand, gravel, and mud eventually reached thicknesses of at least 5,000 feet.

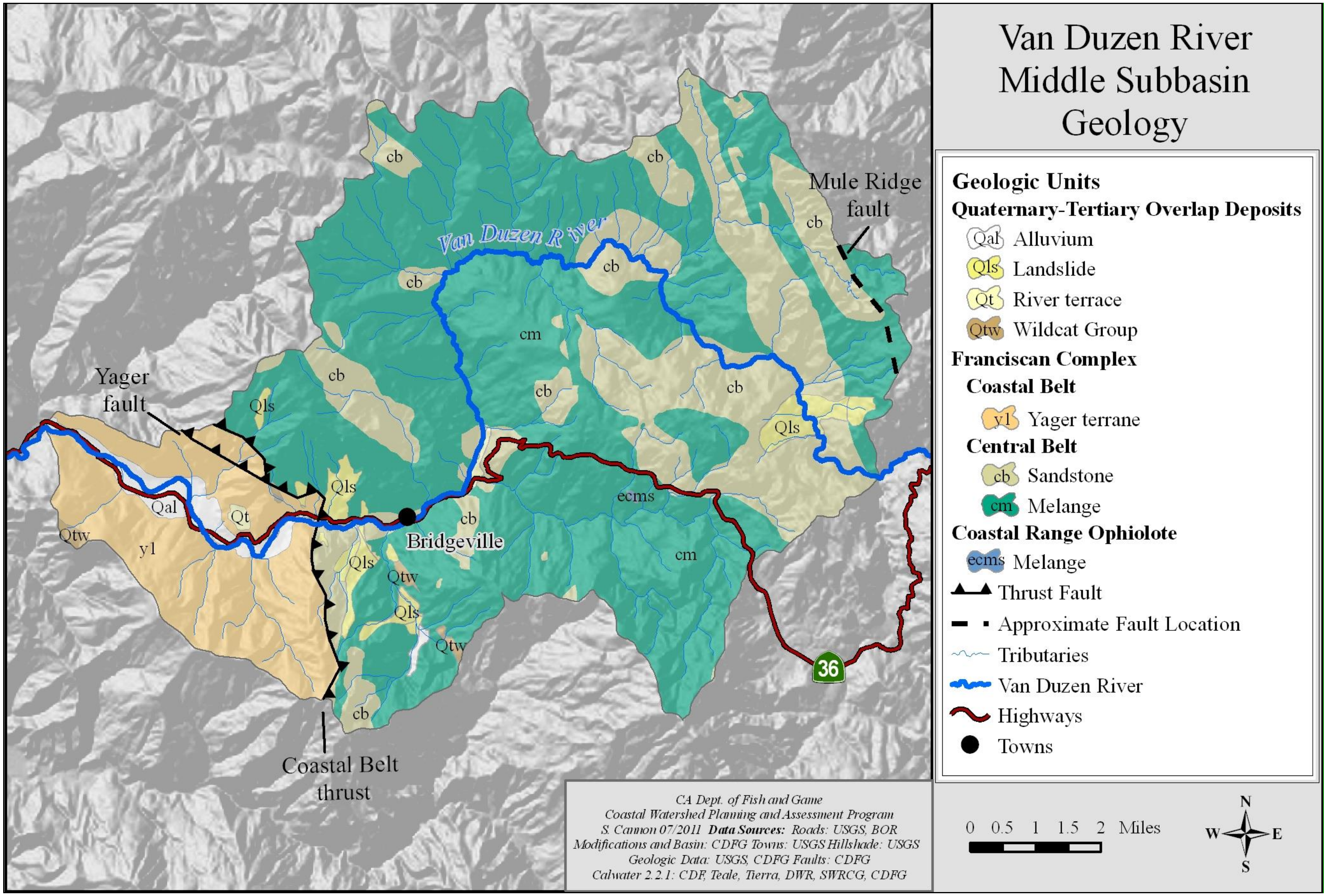

Figure 3. Geologic units of the Middle Subbasin of the Van Duzen River.

Table 2. Lithologic units of the Van Duzen River Middle Subbasin.

GEOLOGIC RELATION AND DESCRIPTION OF MAJOR UNITS WITHIN THE MIDDLE SUBBASIN						
Unit	**Belt/Rock type**	**Formation /terrane**	**Composition**	**Erosion**	**Age ma**	**%**
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes.	0-0.01	2
	River terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.		0.01-2	1
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare.	0.01-2	3
	Wildcat group		Marine mudstone, siltstone, sandstone grading upwards through nonmarine sandstone and conglomerate.	Shallow landslides, debris slides, rotational slides and slumps, and block slides especially along inward dipping bedding planes between sandstone and mudstone layers. Toppling along joints. Some rock falls and slaking of exposed surfaces.	0.78-11.6	<1
Franciscan Complex	Coastal belt	Yager terrane	Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate.	Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers.	33.9-65.5	12
	Central belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.	65.5-161.2	24
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, and metachert.	Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	1.8-65.5	58
Sources: Ogle 1953, Kilbourne 1985, McLauglin et al. 2000. % Data represent an approximation based on GIS mapping.						

Quaternary landslides occupy around 3% of the subbasin (McLaughlin et al. 2000). These areas have been characterized as mostly older landslide features, and therefore have generally been re-vegetated and active movement has been relatively stabilized. However, these areas are still susceptible to enhanced erosion because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. Furthermore, if the toes of these large landslides erode far enough or if there is a large, local seismic event, these landslides may reactivate.

Alluvium and **river terrace deposits** cover approximately 2% of this subbasin. Alluvium includes any actively moving stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. River terrace deposits consist of unconsolidated cobbles, gravels and fine sediments. These terraces were once river channel and floodplain alluvial deposits but have been raised above the hundred-year-flood level during the last 2 million years by regional tectonic uplift. River terrace deposits tend to form steep channel banks that are prone to dry ravel and slumping.

Prominent river terrace deposits in this subbasin include: Weonme Flat, Swain's Flat, Bar W Ranch, Petty Flat (Little Golden Gate subdivision), and Bridgeville.

Wildcat group, which consists of soft marine sedimentary bedrock, is present within this subbasin but accounts for less than 1% (175 acres) of its surface area. The Wildcat group occurs at two areas within this subbasin: just south of Bridgeville as dislocated, faulted remnant within Central belt mélange, and at the western tip of the subbasin where it overlaps the Yager terrane.

Faults and shear zones

The Yager fault, Coastal belt thrust, and Mule Ridge fault run through the Middle Subbasin disrupting the coherency of the bedrock (Fig 3).

The Yager fault is a low-dipping thrust fault that trends northwest through the lower part of this basin. The Yager fault may be an active offshoot of the Little Salmon fault and occasionally generates earthquakes large enough to trigger landslides.

The Coastal Belt Thrust fault is the major fault that juxtaposes the Coastal belt and the Central belt. It trends north to northwest through the Van Duzen River basin. It is most likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal belt when the active subduction moved west to its present location along the Cascadia Megathrust.

The Mule Ridge fault is a steeply dipping to nearly vertical fault that runs northwest through the eastern edge of this subbasin.

Landslides

Large Quaternary landslide features comprise approximately 3 percent of this subbasin (Table 2). Detailed field investigations may document smaller and/or less obvious landslides. Two notable historical slides include the Donaker Creek earthflow (RM 29) and the Fish Creek debris slide (RM 25).

The Donaker Creek earthflow is the largest within the Van Duzen River basin and has been active since before European settlement, and is perhaps the largest single-point source of fine sediments entering the Van Duzen River. Kelsey (1975) determined an erosion rate for the Donaker earthflow to be 89,000 tons/mi^2/year.

The Fish Creek debris slide (RM 25) was associated with a logging road constructed in the 1950s within the active channel of Fish Creek and initiated by the 1964 flood event (Fig. 4). Debris sliding along the banks of Fish Creek was continuous for over a mile upstream of its confluence with the Van Duzen River. It is estimated that the Fish Creek debris slide flushed 4.9 million cubic feet of alluvium into the Van Duzen River (Kelsey 1975) and was the largest slide associated with the 1964 flood.

Figure 4. Aerial photo of Fish Creek debris slide in the Middle Subbasin of the Van Duzen River.

Slope Inclination

Steep slopes (> 30%) cover 53% of the subbasin's terrain and are distributed throughout the subbasin (Table 3, Fig. 5). Moderate slopes (15-30%) covering a third of the subbasin are also spread throughout of the subbasin.

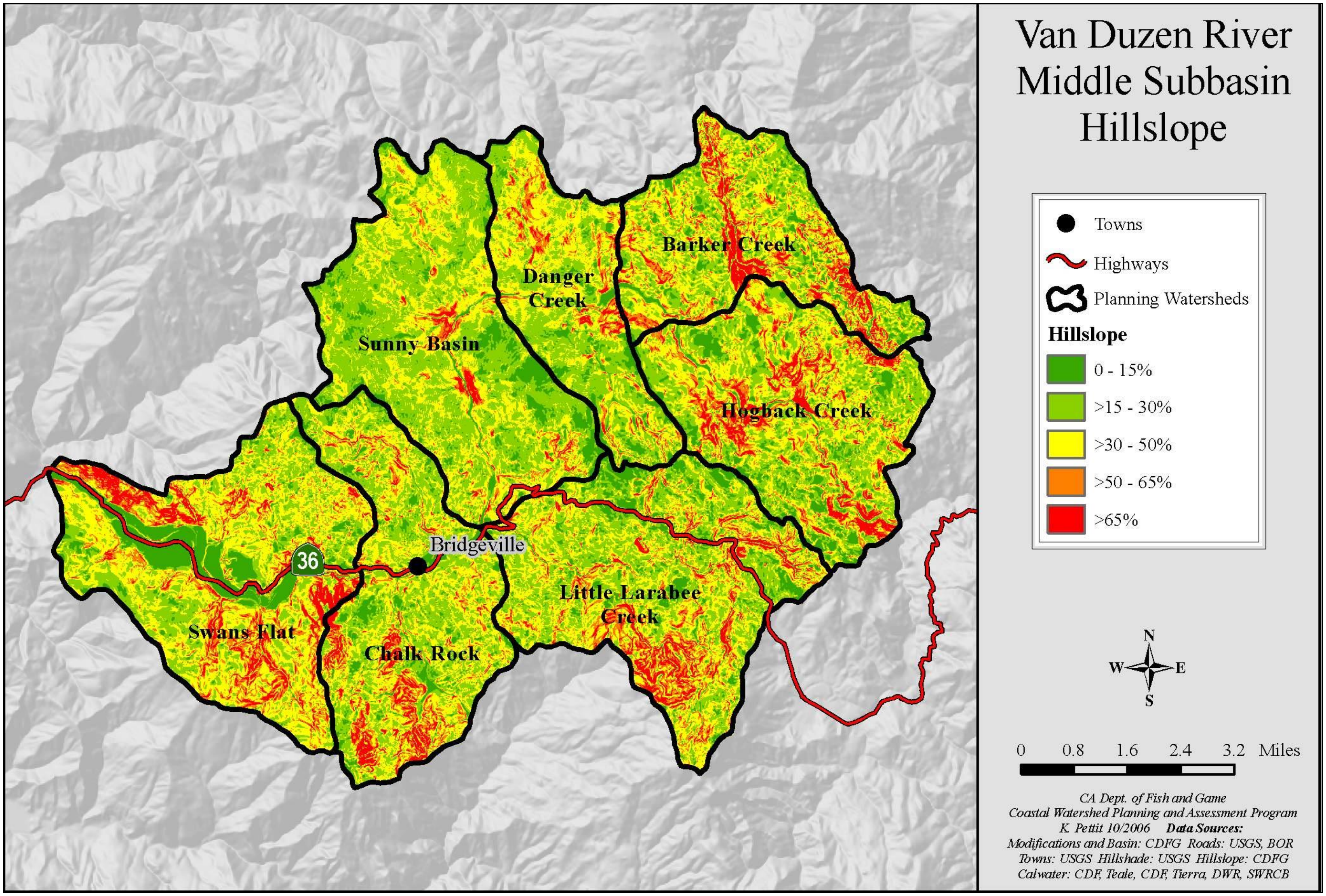

Figure 5. Hillslope classes with planning watersheds depicted in the Middle Subbasin of the Van Duzen River.

Table 3. Hillslope classes and acres associated with each class of the Middle Subbasin of the Van Duzen River.

Slope class	Acres
0 -15% Gentle	5,899 (12%)
>15 - 30% Moderate	17,802 (35%)
>30 - 65% Steep	22,813 (46%)
>65% Very Steep	3,486 (7%)

Regional uplift/basal lowering, offset along local faults, stream power, and nature of bedrock influence the shape of the Van Duzen River's longitudinal profile (Figure 6). In the Middle Subbasin, a prominent knickzone (a locally steep reach separating relatively gently sloped reaches) has developed between RM30 and RM47 within geology of the Central belt. Incision associated with knickzone formation and migration typically leaves relatively steeper canyon walls in the immediately surrounding area which tends to increase the potential for slope failure and surface erosion

Since all the steep hillslope geology of the Middle Subbasin is considered to have high erosion potential, actions such as road construction, intensive timber harvests, and tractor yarding should be mitigated according with Best Management Practices that meet all regulatory agency standards for soil conservation, fish and wildlife values and water quality objectives.

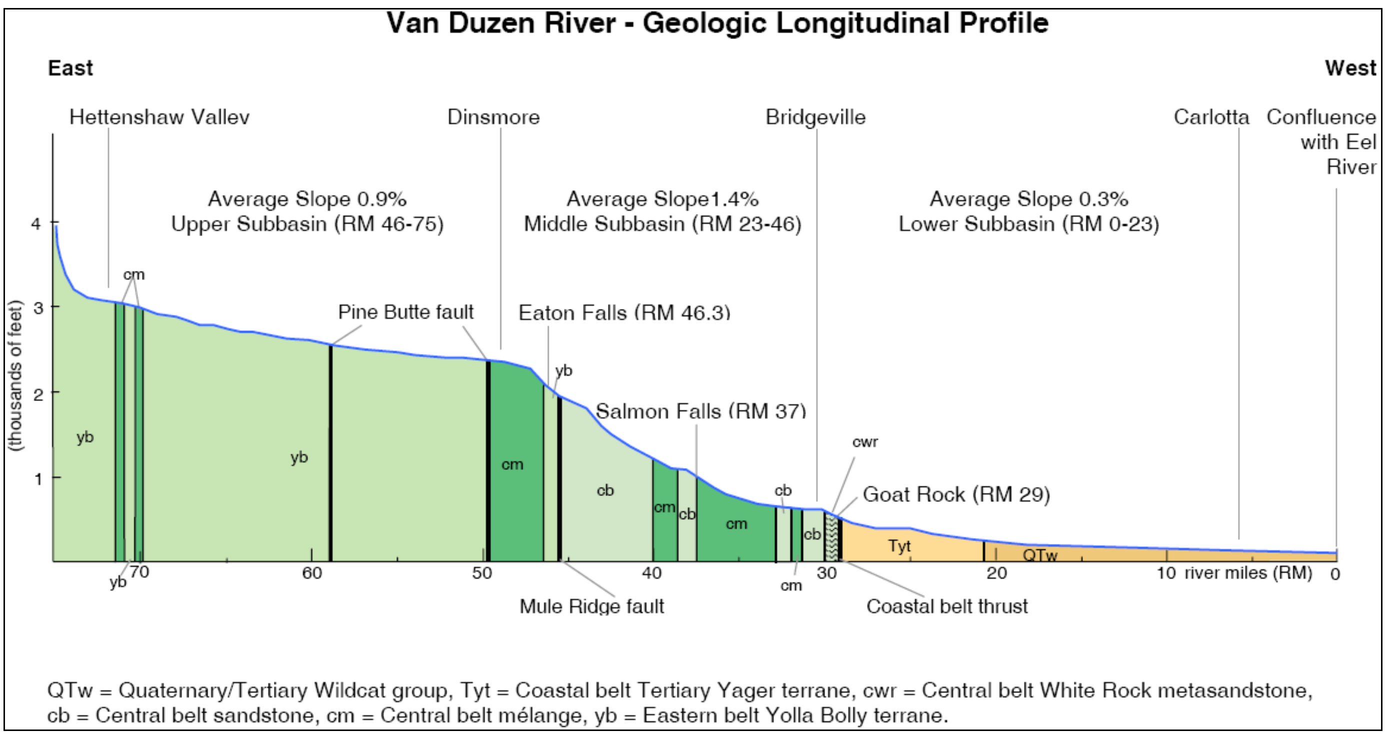

Figure 6. Geologic Longitudinal Profile of Van Duzen River

Hydrology and Sediment Transport

Approximately 23 miles of the mainstem Van Duzen River (a 5^{th} order stream), 53 miles of perennial tributary channels and 86 miles of intermittent tributary stream channels drain the Middle Subbasin according to 1:1000 USGS maps (Figure 6). The Middle Subbasin is a large source of both natural and anthropogenic sediment inputs to the Van Duzen River because it is largely composed of highly unstable mélange terrain. The USEPA (1999) estimated areas of the Middle Subbasin delivers the most sediment to the stream network compared to other subbasins.

Mainstem Van Duzen River

The mainstem Van Duzen River flows within the Middle Subbasin from the confluence with the Grizzly Creek upstream to the confluence with the Little Van Duzen River (RM 23-46). There are both sediment transport and depositional reaches along this length of river channel. The average gradient of the Van Duzen River in the Middle Subbasin is 1.4% with the steepest contiguous sections located above the confluence with Baker Creek (RM 39.2). The lower 15 miles of the river within the Middle Subbasin is generally less than 1% except for a significant rise in gradient along a boulder roughs at Goat Rock (RM 29.5). The Goat Rock roughs may be an obstacle during upstream passage (but not a barrier) to Chinook and coho salmon.

Another significant rise in channel gradient begins near Scott Creek (RM 34.5) where the gradient averages <3% to the confluence with the Little Van Duzen, including a steep section of boulder roughs leading to Salmon Falls (RM 37). It is believed that Salmon Falls typically acts as a barrier to upstream migration of both Chinook and coho salmon, but not steelhead. However, reports of coho salmon in Little Van Duzen River and Butte Creek (Reynolds et al. 1981, Decker and Fuller 1983), suggest that salmon may occasionally migrate past the Salmon Falls.

Streamflow in the mainstem is measured at the USGS stream gauge located approximately one mile upstream of the Grizzly Creek confluence at a site known as Rainbow Bridge (RM 24). The stream gauge measures discharge from the upper half (222 sq. mi.) of the 430 square mile Van Duzen River Basin. Mean annual peak flow from the Bridgeville gauging station is estimated at 22,300 cfs, which is about a two year event or a re-occurrence interval of every two years (Steppen 2002). Additional annual streamflow data from the Rainbow Bridge site is shown/discussed in the Hydrology section of the Van Duzen River Basin Profile (pgs. 18-23).

Tributary Streams

The Middle Subbasin drains approximately 53 miles of perennial tributary channels and 86 miles of intermittent tributary channels (Figure 7). The majority of the tributary channels are characterized as steep (gradient >20%) and are considered sources areas for sediment inputs (Figure 8). A good portion of these steep stream reaches are also intermittent channels and likely do not support anadromous salmonids. However, these tributaries may make critical contributions of flow and sediment to downstream reaches, and their potential contributions should be considered before initiating land use projects that may impact fish, water flow and/or sediment transport.

No stream flow gauging stations exist in the tributaries. Winter flows in the tributaries are generally episodic typified by a rapid rise and fall in flow relative to the intensity and duration of rain events.

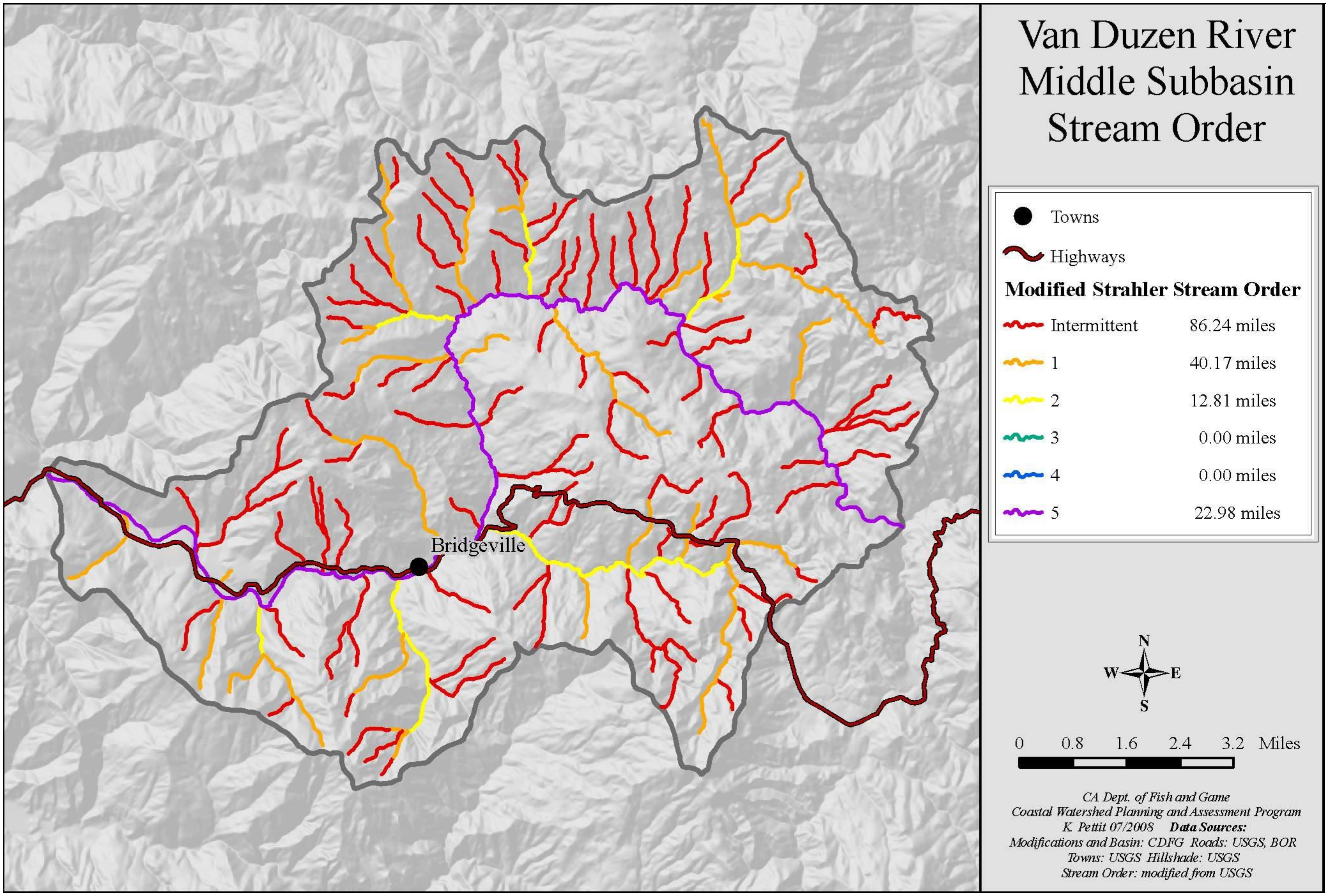

Figure 7. Stream order and intermittent tributaries of the Middle Subbasin of the Van Duzen River.

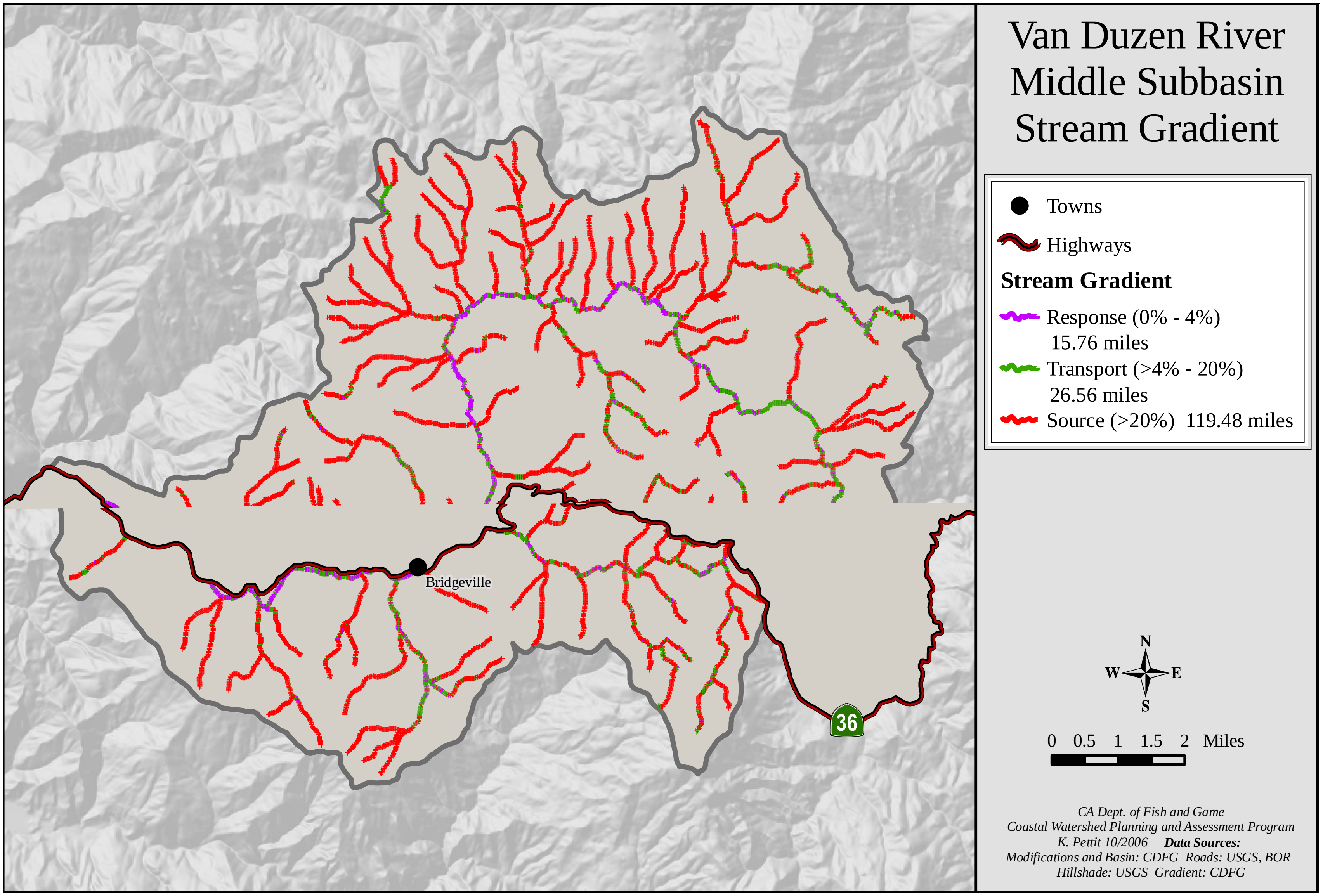

Figure 8. Stream gradient classification for sediment response, transport, and source for Middle Subbasin of the Van Duzen River.

Vegetation

As discussed in the Vegetation section of the Basin Profile (p. 31), the important roles forests play in watershed processes, stream ecosystems and a stream's ability to support viable populations of anadromous salmonids are well documented (Meehan 1991, Murphy 1995, Spence et al. 1996, Lassettre 1999). Douglas fir dominated forests cover approximately 70% of the Middle Subbasin terrain, while grasslands and mixed hardwood forests cover most of the remaining land in the subbasin (Fig. 8). Redwood dominant forest are only found in the western portion of the subbasin as the forest transition into fir dominated forests.

Most tributary stream reaches that support salmonids flow through coniferous forests. However, most of the coniferous forests in the subbasin have been recently logged, leaving early seral stage forest stands predominating the landscape. As discussed in the Basin Profile (pp. 46-47) adverse changes occur to salmonid habitat related to extensive logging of forests (Murphy 1995) and land use that disturbs riparian and near stream forests (Meehan 1991 and Spence et al. 1996).

Land and Resource Use

Land use in the Middle Subbasin is mostly comprised of timber production and livestock grazing (Fig. 9). Rural residential areas occupy land along Highway 36. The only town within the subbasin is the unincorporated community of Bridgeville. With a population of less than 25 people, it consists of a few houses and a post office. Bridgeville has the noted distinction of being the first town in the United States to be auctioned on internet website eBay http://news.bbc.co.uk/2/hi/americas/2605239.stm).

Timber Harvests

A total of 39% of the subbasin's conifer forests were involved in timber harvest activity from 1991 to 2007 (Table 4). During this period, the Swain's Flat and Chalk Rock planning watersheds experienced the highest percentage of harvest activity of their conifer forest with 55% and 52%, respectively, in harvest plans.

Roads

Roads data available from California Department of Forestry (CDF) GIS roads layers show that there is an average of four miles of roads per square mile of land in the Middle Subbasin (Fig. 10). However, the roads layer source data does not cover the full extent of the subbasin, so it underestimates the actual miles of roads on the landscape (ftp.fire.ca.gov/forest). Based on the available data, the road density is above the recommended threshold of 2.5 miles/square mile (Cederholm et al. 1980). Cederholm et al. (1980) suggested the presence of more than 2.5 miles of unpaved roads per square mile of land may increase fine sediment production by approximately 200-400% above natural levels. These fine sediments enter streams from surface erosion and road related landslides.

The highest road densities are in the Chalk Rock, Little Larabee Creek, and Swain's Flat Planning Watersheds. The higher road density in these planning watersheds coincides with a higher percentage of forested land having greater timber harvest activity than compared to planning watersheds containing higher amounts of grasslands (Table 5).

Industrial Marijuana Agriculture

While not displayed in Land Use Figure 10 (p.15), industrial marijuana agricultural operations are locally abundant throughout the rural areas of the Middle Subbasin and are having a significant impact on the landscape and natural resources (including aquatic) of the subbasin and Basin as a whole. The impacts and a discussion of these operations are discussed further in the Basin Profile (pp. as well as in the Lower Subbasin (p. 27).

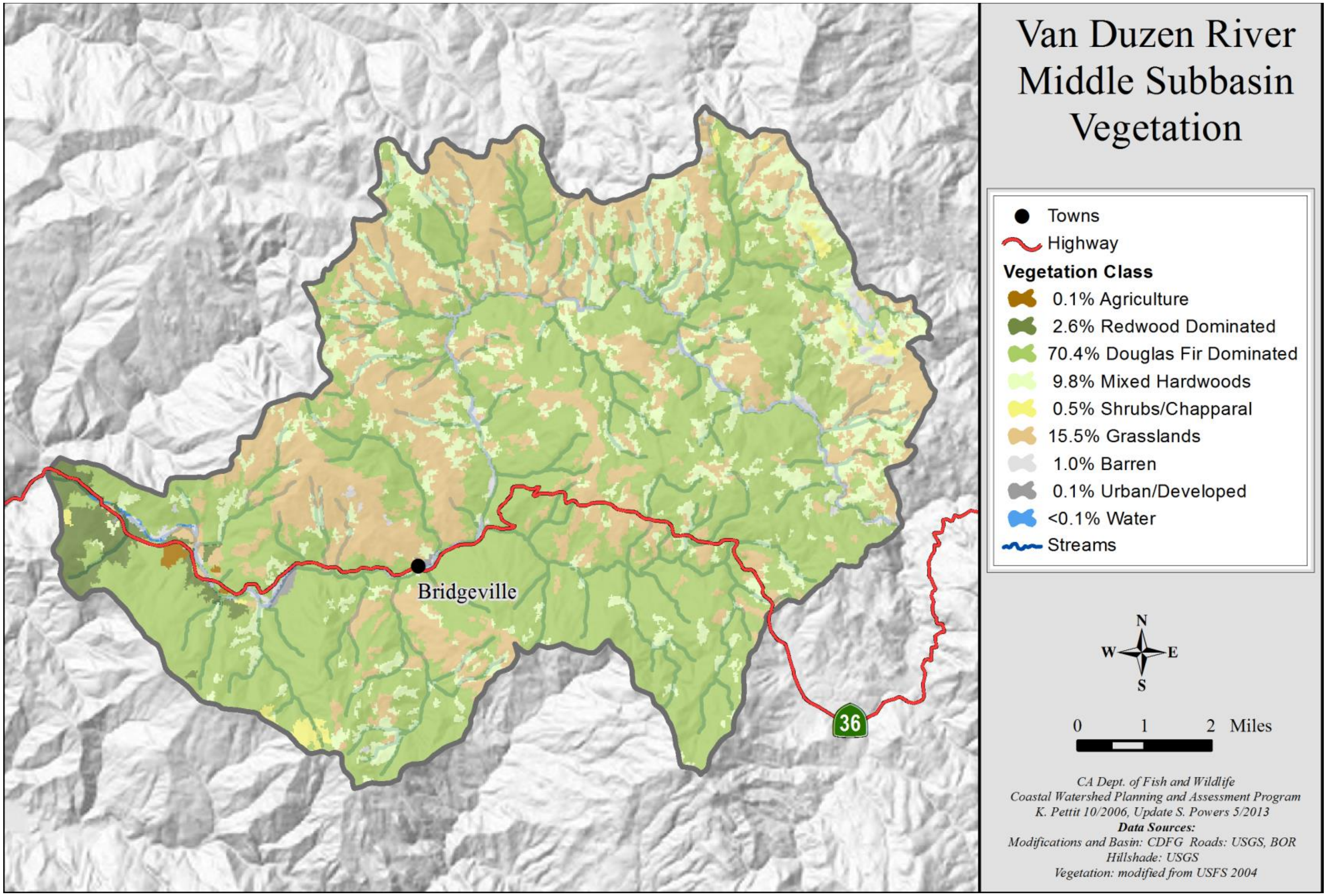

Figure 9. Vegetation classes for the Middle Subbasin of the Van Duzen River.

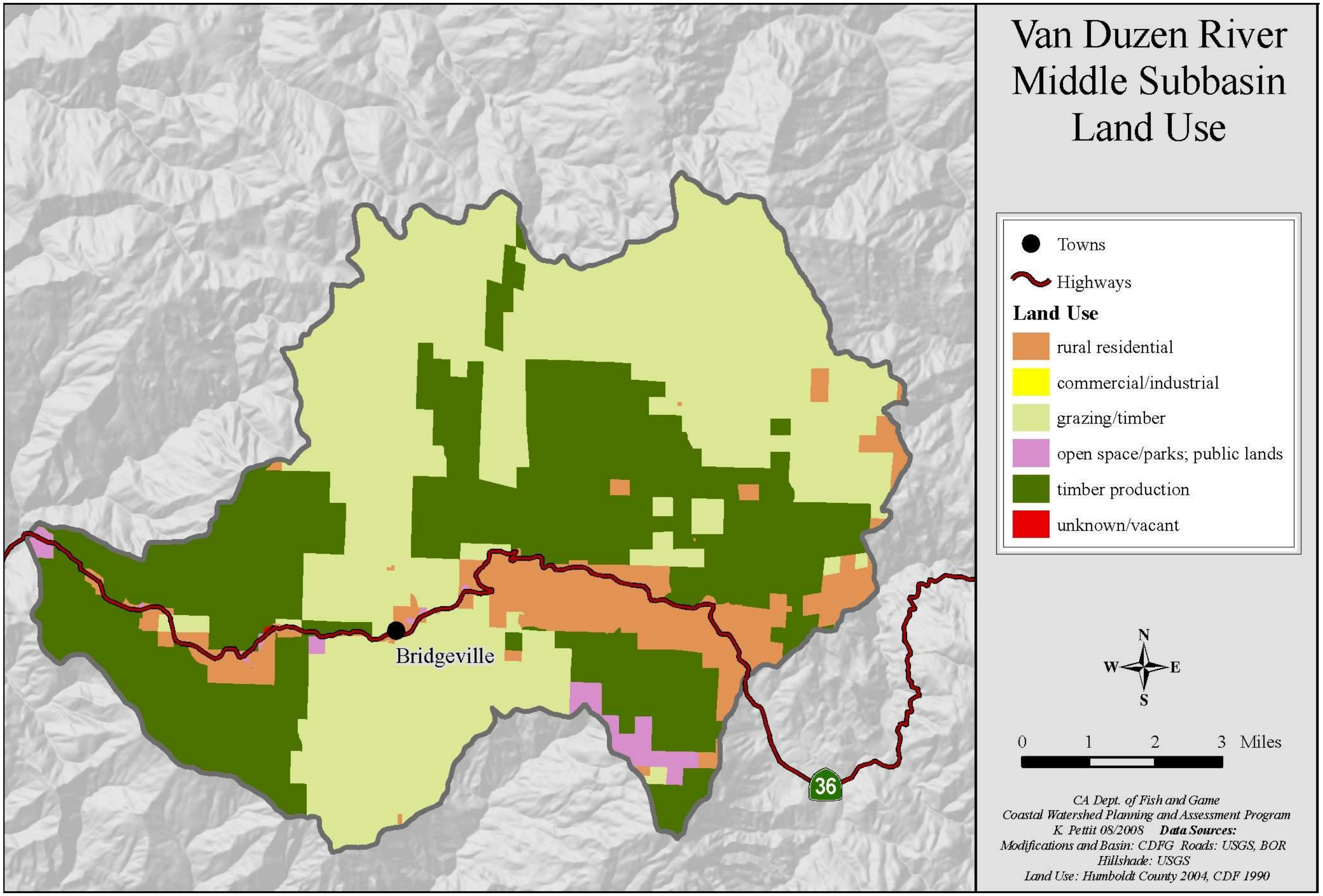

Figure 10. Land use categories in the Middle Subbasin of the Van Duzen River.

Table 4. Middle Subbasin of the Van Duzen River timber harvest plan statistics 1991-2007.

Planning Watershed (PW)	PW Acres	Harvested Acres	% PW Harvested	Conifer Acres	% PW in Conifers	% Conifers Acres Harvested	NCRWQCB* Adjusted %/yr.
Barker Creek	5429	315	6	1911	35	16	0.73
Chalk Rock	7032	2257	32	4329	62	52	2.4
Danger Creek	4590	297	6	2341	51	13	0.5
Hogback Creek	7104	1471	21	3684	52	40	1.1
Little Larabee Creek	8492	2334	27	6776	80	34	1.7
Sunny Basin	8582	1140	13	3571	42	32	1.2
Swain's Flat	8953	3392	38	6218	69	55	2.7
Subbasin Total	50182	11206	22	28830	57	39	1.7

*NCRWQCB = North Coast Region Water Quality Control Board

Table 5. Road miles, square miles and roads per square miles in the Middle Subbasin of the Van Duzen River by planning watersheds.

Planning Watershed	Road Miles	Square Miles	Road Miles per Sq. Mi.
Barker Creek	16.39	8.48	1.93
Chalk Rock	65.37	10.99	5.95
Danger Creek	12.76	7.17	1.78
Hogback Creek	42.61	11.10	3.84
Little Larabee Creek	75.77	13.27	5.71
Sunny Basin	41.50	13.41	3.09
Swans Flat	57.47	13.99	4.11
Totals	**311.9**	**78.4**	**4.0**

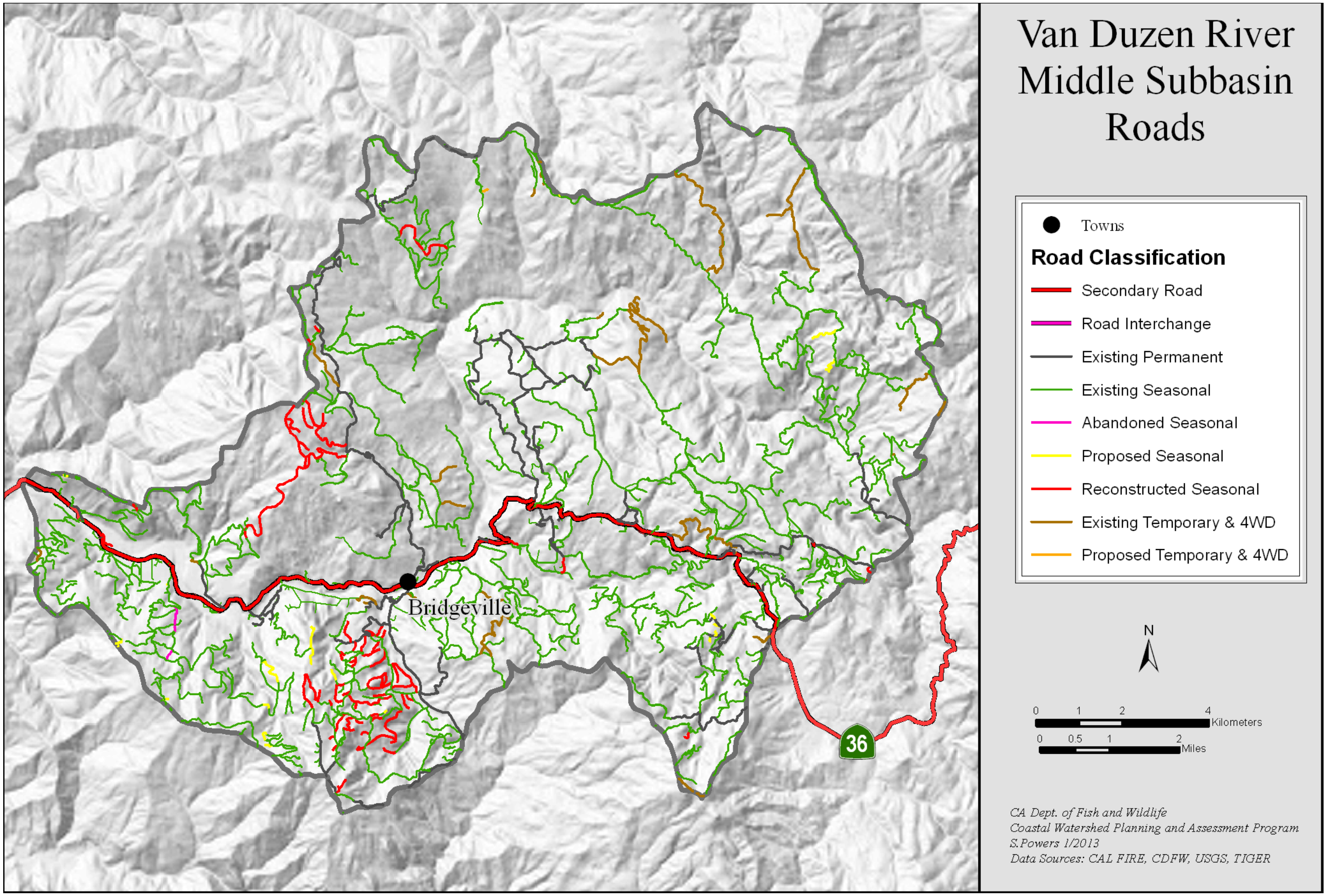

Figure 11. Roads within the Middle Subbasin of the Van Duzen River.

Fish Habitat Relationships

Fishery Resources

The Middle Subbasin supports populations of steelhead, Chinook salmon and possibly coho salmon. Approximately 5 miles of tributaries and 23 miles of mainstem Van Duzen River support steelhead (Table 6, Fig 13) and 15 miles, consisting of mostly mainstem Van Duzen River, are accessible to Chinook salmon (Fig 14). The mainstem Van Duzen is important Chinook salmon spawning habitat and juvenile rearing areas. Salmon and steelhead use the mainstem as an important migration pathways to and from the ocean and as well as for juvenile rearing habitat. The most important tributary streams for salmonids are Fish Creek, Hoagland Creek, and Little Larabee Creek. The tributaries flowing into the Van Duzen from the north are generally too steep and limited by ephemeral flows to provide anadromous salmonid habitat. Figure 14 depicts the passage barrier for Chinook (and coho) salmon at Salmon Falls (RM 37).

Coho salmon prefer small, low gradient tributaries for spawning rather than large mainstem reaches of the Van Duzen used by Chinook salmon. With the exception of the lower mile of Little Larabee Creek, most of the tributaries in the Middle Subbasin are high gradient streams that are unsuitable for coho lifecycle requirements. While coho were historically abundant in the Yager and lower subbasins, reports of coho presence in the Middle Subbasin are limited. A local angler reported catching an adult coho salmon near the confluence of Fish Creek in 2005, and coho salmon have been reported upstream of the Middle Subbasin in the Little Van Duzen (South Fork Van Duzen) (Reynolds et. al 1981) and its tributary Butte Creek (Decker and Fuller 1984). Due to the lack of survey efforts, it is unknown if adult coho currently utilize any of the Middle Subbasin tributaries or mainstem for spawning.

Table 6. Miles of stream accssessable to anadromous salmonids in the Middle Subbasin of the Van Duzen River.

Stream	Steelhead (mi)	Chinook (mi)	Coho (mi)
Brown Creek	0.4		
Hoagland Creek	1.2		
Little Larabee Creek	2.8	1	1
Fish Creek	0.5	0.5	
Winimnome	0.2	0.2	
Van Duzen River	23	14	14

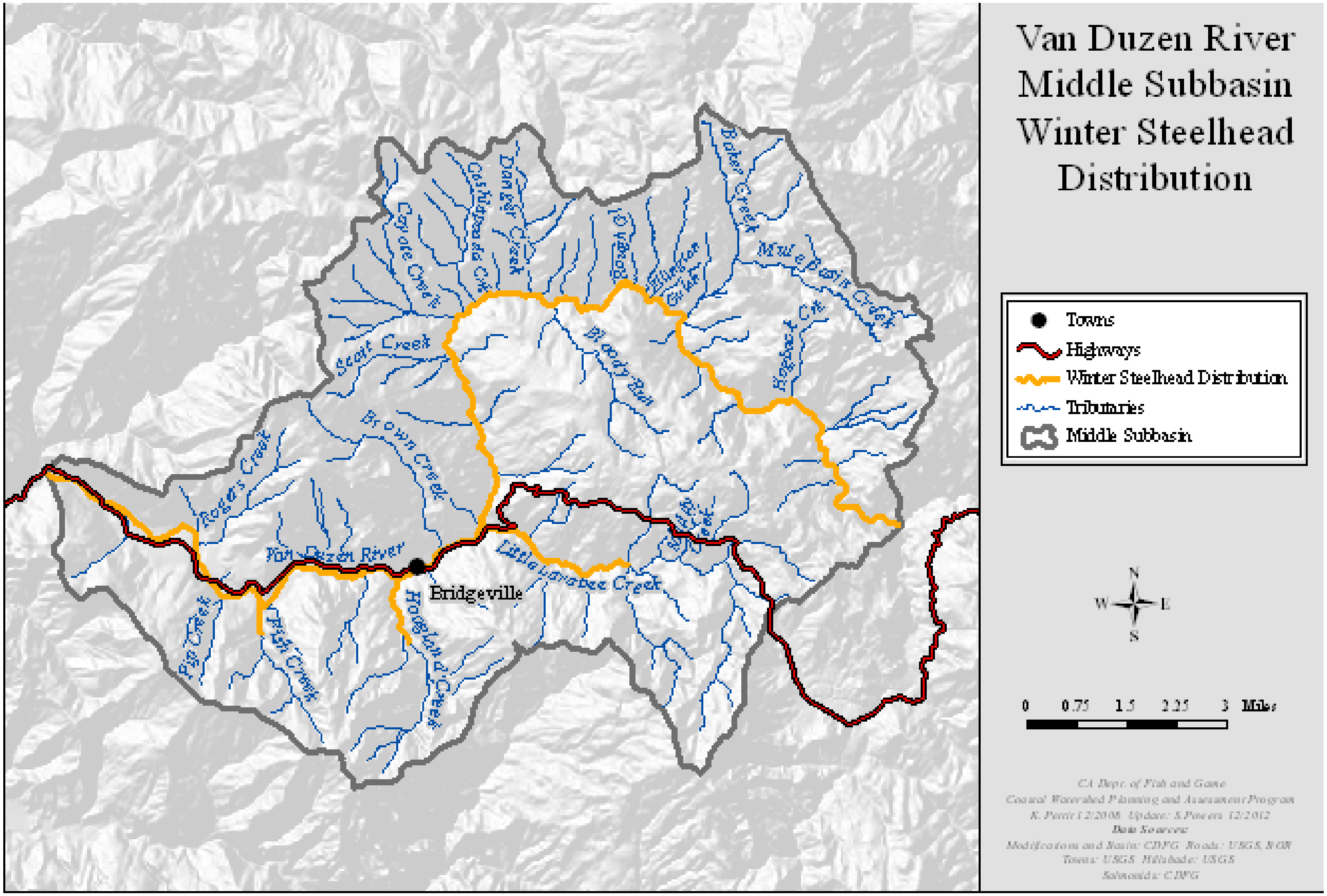

Figure 12. Steelhead migration and spawning habitat within the Middle Subbasin of the Van Duzen River**.**

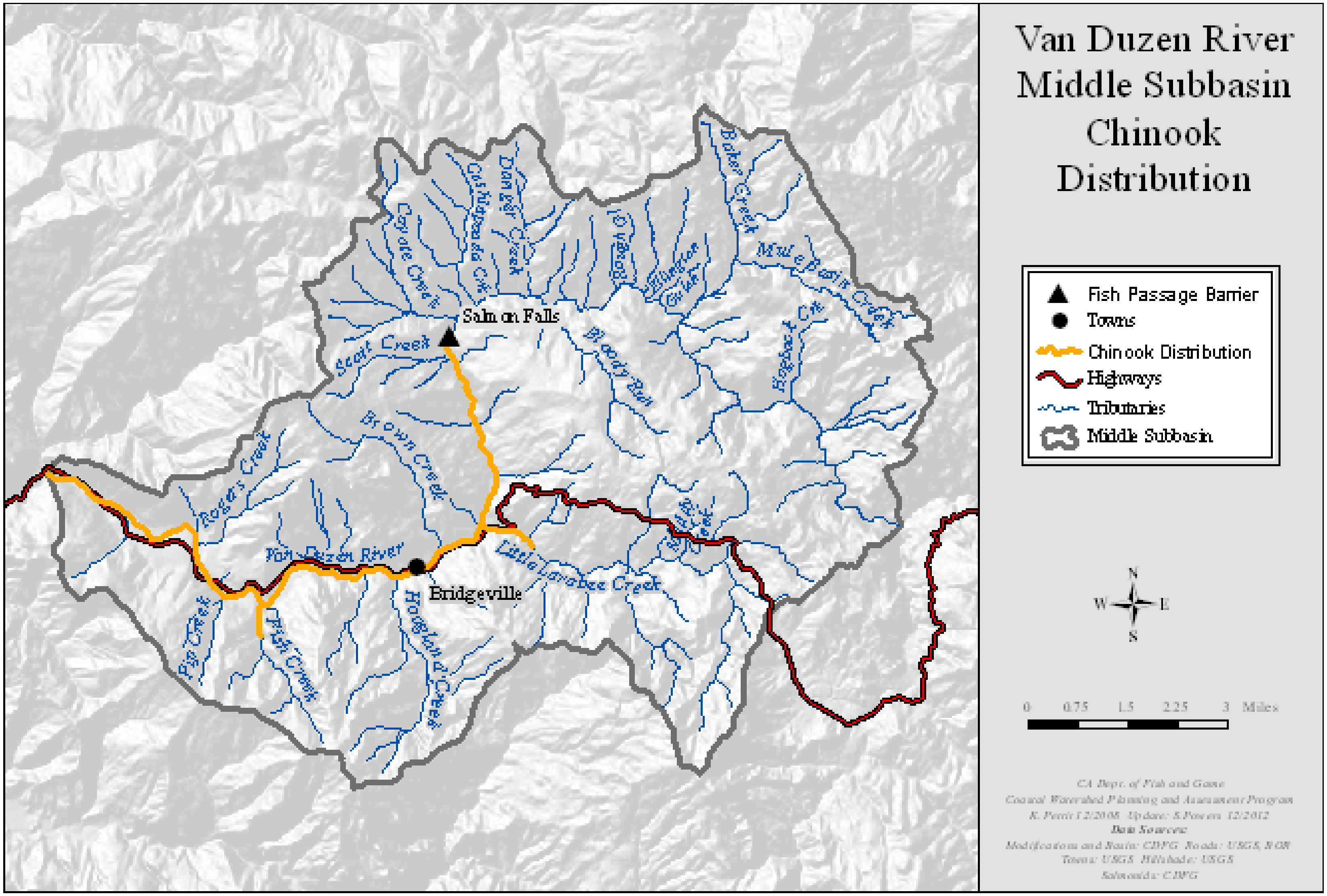

Figure 13. Distribution of Chinook in the Middle Subbasin

Figure 14. Salmon Falls: boulder roughs typically impede Chinook and coho salmon spawning migration, although steelhead are able to pass above the site**.**

Habitat Overview

Historic Conditions

Most historical CDFG stream surveys within the Middle Subbasin date back into the mid-1960s, with the exception of a 1938 survey in Hoagland Creek (Table 7). These early stream survey efforts were neither specific nor standardized until 1990 when the *California Habitat Restoration Manual* (flosi et al. 1998) was published. Most observations in the historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions, including barriers limiting fish passage at the time of survey.

Stream	**Date Surveyed**	**Source**	**Habitat Comments**	**Barrier Comments**
Pip Creek	7/15/1965	CDFG	"Due to the extremely precipitous nature of the stream's mouth region and lack of adequate water flow, the stream was not surveyed beyond the mouth."	"The mouth region was considered to be impassible barrier to anadromous fish due to its extremely precipitous nature."
Hoagland Creek	8/17/1938	CDFG	Fish presence: abundant, steelhead 1½ to 3" Pools: Good Shelter: Good Food: Abundant Spawning area: Good Flow: ⅓ CFS Water Temp: 58F	None observed
	7/25/1963	CDFG	"The habitat is poor in Hoagland Creek. The pools are not deep and shelter area is scarce. Thee stream is shaded about 50%	"About ¾ mile from the mouth, large boulders and some logs form 3 falls 8-10 ft high. These are probable barriers. A

			of the day. Food is available but not plentiful." Fingerling trout observed below barrier and resident trout seen above barrier.	barrier exists 700 yds. from the mouth."
Hoagland Creek	7/20/1965	CDFG	"Numerous small salmonids ranging from 1" to 3" below roughs. In roughs and above there were few fingerling salmonids. Large salmonids, believed to be resident trout, were noted in the pools above the roughs."	Series of roughs and falls to 5 ft high about ¼ of a mile upstream from mouth. Landowner reports anadromous fishes come up Hoagland each year to roughs but never beyond.
	8/12/1975	CDFG	Only lower .25 mile of Hoagland Creek available to anadromous fish as fingerlings were observed in this lower area. Populations of resident trout est. at 90 fish per 100 ft. of stream.	Roughs at 0.25 miles upsteam of mouth prevents upstream migration of anadromous fish. Additional smaller roughs located 0.5 and 1.0 miles upstream from mouth that would prevent upstream migration.
Brown	7/28/1965	CDFG	"Due to the lack of water during the summer months, the precipitous nature of the stream, and evidence of heavy erosion, this stream should not be considered into any fisheries program."	"An impassible barrier was encountered ½ mile upstream from the mouth."
	5/23/1978	CDFG	"Very few salmonids observed. Flow was intermittent for the first 200 yards. Pool to riffle ration was 1:1. Course and fine rubble predominated the stream bottom. Pools formed majority of shelter. Some shelter formed from upperstory vegetation."	"One barrier, considered imapassibe, occurred approximately ½ mile from the mouth."
Little Larabee Creek	7/8/1965	CDFG	"Fisheries habitat far from ideal, but large numbers of fish were seen. Green algae was present in large amounts on the rocks in the stream and aquatic insects were numerous…. Spawning areas contained very coarse gravel and some fine rubble, evidentally suitable for spawning purposes. Cover in the pools was afforded mainly by rocks and undercut banks."	Survey terminated at roughs area approx. 1.5 miles upstrm of mouth. Two waterfalls present in this area. First is 6ft high and unlikely to be barrier. Second is 10ft and probably acts as a complete barrier to migratory fish. No small salmonids were seen beyond this point.
	3/27/1975	CDFG	No fish observed due to turbid water conditions. Additional survey recommended to determine the potential benefits of removal of log jam.	At 1.0 miles upstream of mouth a large log jam, consisting of logs and debris, accumulated in a bend and created a possible barrier to migrating fish.
	5/20/1983	CDFG	Survey inspecting condition of stream after 81 and 82 winter flows. Lower mile was severely damaged by silt deposition due to several active slides caused by adjacent road and its inadequate maintenance and drainage facilities. No fish observed until the end of the survey. One 32mm SH/RT collected and several small salmonids observed (15cm).	Two log jam, partial barriers were observed in the area surveyed (0-2 miles upstream). A slide occurred in the area of the 6 ft fall (1.5 miles) which as diverted some of the stream flow and improved access around the falls. Recommendation to modify 3 log jams.
	6/5/1984	CDFG	Electrofished from mouth to 400 ft. upstream. "Numerous SH/RT were seen, est. at 250 to 300 fish/100' of stream." 35 SH/RT were id and average size was 3.1cm. In addition, 2 SH/RT at 8.0 cm and 7.8 cm.	
Little	12/22/87	CDFG	Surveyed to recover coded wire tags from	"Boulder roughs at 1.5 miles from the

Larabee Creek	and 1/28/88		mouth to 1.5 miles upstream; however, no salmonids were noted on either survey in contrast to previous years carcass surveys. Habitat conditions were generally fair… numerous unstable banks erosion sites contributing fines into stream."	mouth may be barrier to anadromous fish."
Danger	7/27/1965	CDFG	No water in stream channel at time of survey. First 200 yrds of channel was located on a steep gradient. "Due to the lack of water during summer months, the precipitous nature of the stream, and the evidence of heavy erosion, this stream should not be considered into any fisheries program."	

Current Conditions

Recent habitat inventories in the Middle Subbasin are limited to Fish Creek, Hoagland Creek, and Little Larabee Creek. These streams represent the current areas of steelhead and Chinook distribution within the subbasin. Little Larabee was surveyed in 1991 and 1996, while Fish and Hoagland creeks were just surveyed in 1991. Stream habitat inventory methods were conducted according to methods determined in the California Salmonid Stream Habitat Restoration Manual (Flosi, et al. 1998). Analyses of instream habitat conditions include the following:

- Habitat type categories;
- Pools by maximum depth;
- Pool shelter;
- Canopy density;
- Cobble embeddedness.

Habitat Categories

Pool:Riffle:Run Relationships

Significance: Productive anadromous streams are composed of a balance of pool, riffle and runs. Each plays an important role as salmonid and stream community habitat. A pool to riffle ratio of approximately 1:1 has been suggested to provide optimum food production and shelter for juvenile coho salmon (McMahon 1983). Flosi et al. (1998) notes that the length of anadromous salmonid streams should be 40% composed of primary pool habitats.

There are several factors affecting the relationships of pools, runs and riffles. These include channel type, channel gradient, bed and bank materials, sediment inputs, width to depth ratios, scour objects such as boulders and large woody debris (LWD), and the condition of the upstream watershed. Pools in forested mountain streams, such as those in the Middle Subbasin, are often associated with LWD, boulders and rock outcrops that help scour sediments during channel forming flows. A low measure of pool area and aggraded channels are often found when LWD is in low supply and/or when sediments are in excess. Large proportions of run or riffle habitats compared to pools may indicate an aggraded channel.

Findings: Available data shows that the length of pool habitat was generally below suitable levels for salmonid production in tributary streams of the Middle Subbasin. Runs dominated the percent length of habitat types (Table 7). An imbalance in the length of pools and runs is noted in Fish Creek. Fish Creek shows 49% pool occurrence, but only 10% of the stream length is in pools, implying the presence of numerous small pools. Fish Creek has a relatively steep channel gradient which may account for the relatively short length of pools.

Table 7. Pool, riffle and run relationships (% occurrence and % length) from Middle Subbasin tributaries.

Stream Reach	Survey Year	Reach Length (feet)	Pool:Riffle:Run % occurrence	Pool:Riffle:Run % length
Little Larabee	1991	10,450	36:27:37	29:15:46
Little Larabee	1996	15,319	32:29:41	19:20:61
Fish Creek	1991	4,652	49:10:42	10:8:82
Hoagland Creek	1991	6,221	42:29:29	26:27:46

Pool Depth

Significance: Deep pools are important habitats for adult and juvenile salmonids. Deep pools are needed for holding areas by adult salmonids during spawning activities and juveniles use deep pools for year round rearing, escape cover from predators and as shelter from high winter flows. During low summer flows or in streams with intermittent flows, deep pools may provide the only suitable salmonid habitat. A lack of deep pools can limit salmonid production.

The length of deep pool habitat in a stream reach is a geomorphic characteristic commonly used as an indicator of stream conditions. Pool depth and lengths are easily measured without significant observer bias. We use the term primary pool to indicate pools with relatively deep maximum pool depths. The target primary pool depths are scaled relative to the Strahler stream order of the surveyed stream reach. Primary pools are pools with maximum residual depths of at least 2.0 to 2.5 feet for 1st and 2nd order streams, ≥3 feet for 3rd order steams and ≥4 feet deep for 4th order streams (Flosi et al. 1998 and NCWAP 2001). We consider streams with approximately 25-60% of their length consisting of primary pools suitable for salmonids in terms of deep pools. DFG uses these indicator values to assess the pool condition of anadromous salmonid habitat with the Ecological Management Decision Support System (EMDS) and by inspection of maximum pool depth histograms (Table 8, Fig 15).

Findings: Inspection of pool depth data and the EMDS evaluation maps show a general shortage of deep pool habitat with corresponding low habitat suitability in the few surveyed streams of the Middle Subbasin (Fig. 16). For example, Fish Creek shows 49 percent pool occurrence but only 10 percent of the stream length is in pools. This implies numerous small pools in Fish Creek could be enlarged by addition of LWD.

Table 8. Average maximum residual pool depth and length from tributary surveys in the Middle Subbasin of the Van Duzen River.

Stream Reach	Survey Year	Reach Length (feet)	Ave. Max Res. Pool Depth
Little Larabee	1991	10,450	2.1
Little Larabee	1996	15,319	2.4
Fish Creek	1991	4,652	1.5
Hoagland Creek	1991	6,221	1.7

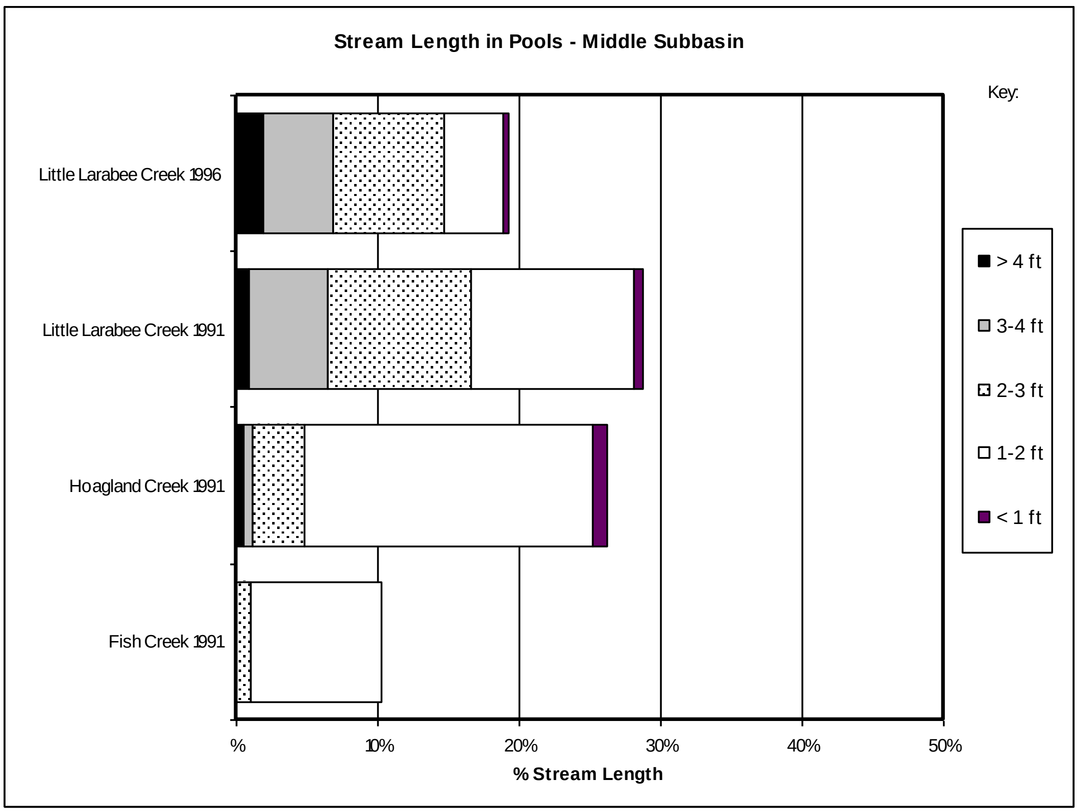

Figure 15. Histogram depicting percentage of stream length that supports four classes of pool depth based on four surveyed streams in the Middle Subbasin of the Van Duzen River.

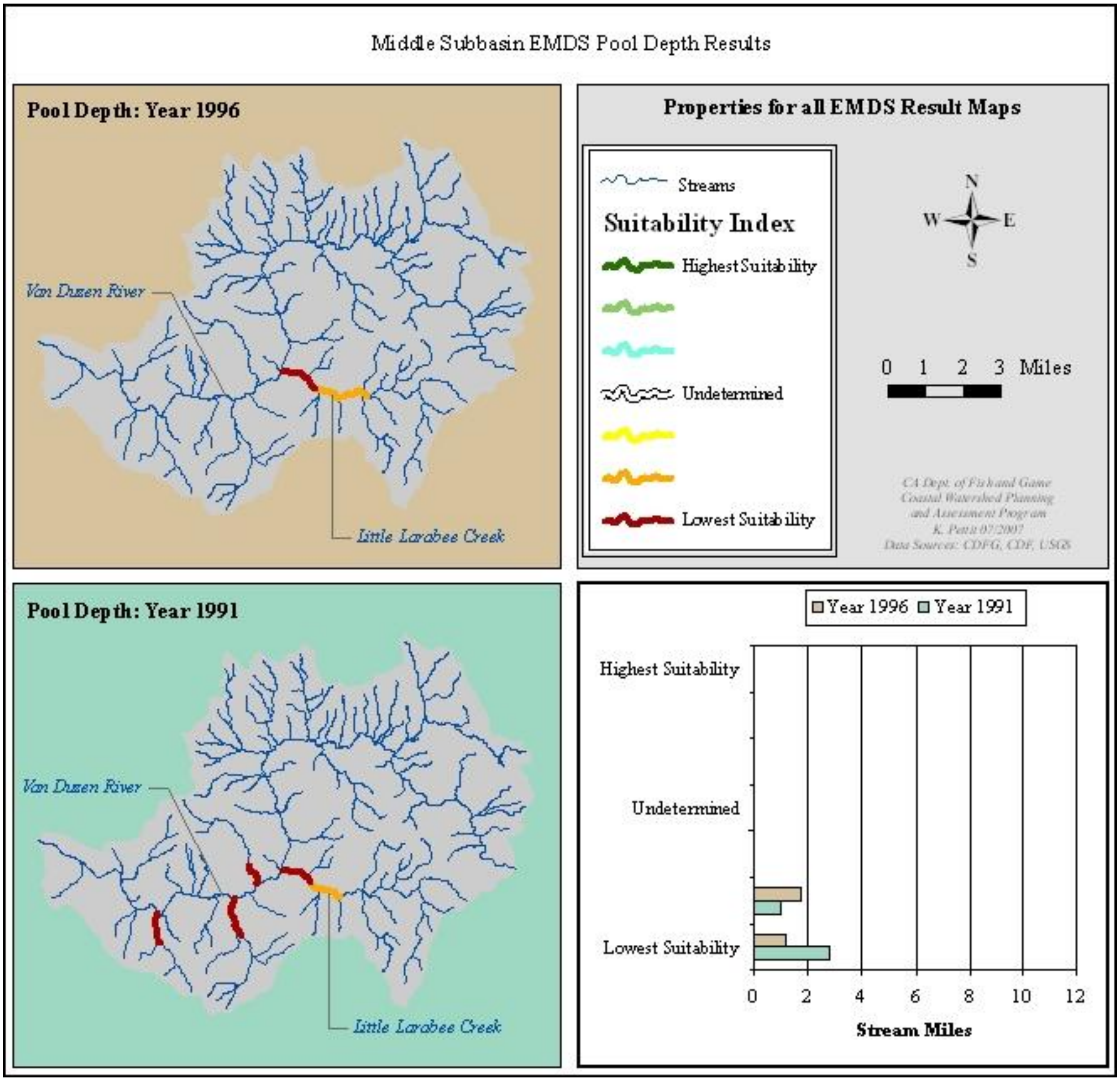

Figure 16. EMDS analysis of habitat suitability for salmonids based on pool depth from stream surveyed in 1991 and 1996.

Pool Shelter

Significance: Salmonid abundance in streams increases with the abundance and quality of shelter of pools (Meehan 1991). Shelter elements create areas of diverse velocity, provide protection from predation, and separate territorial units to reduce density-related competition. CDFG's stream survey protocol (Flosi et al. 1998), evaluates pool shelter complexity by a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation. The ratings range from 0-300, with ratings of ≥100 considered good shelter values. The ratings do not consider factors related to changes in discharge, such as water depth.

Findings: Pool shelter ratings were far below the 100 target value for all streams and stream reaches indicating a general shortage of instream shelter elements (Figs. 17 and 18). The highest shelter values were observed in Little Larabee Creek; however, the values did decrease slightly from the 1991 survey to the 1996 survey (Figs. 17 and 18).

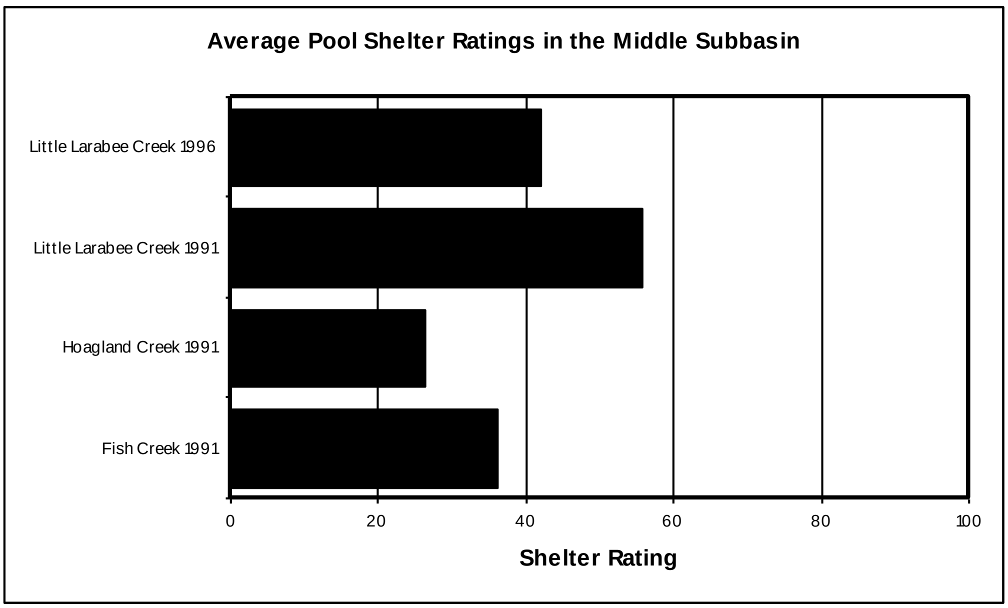

Figure 17. Pool shelter ratings in the Middle Subbasin of the Van Duzen River.

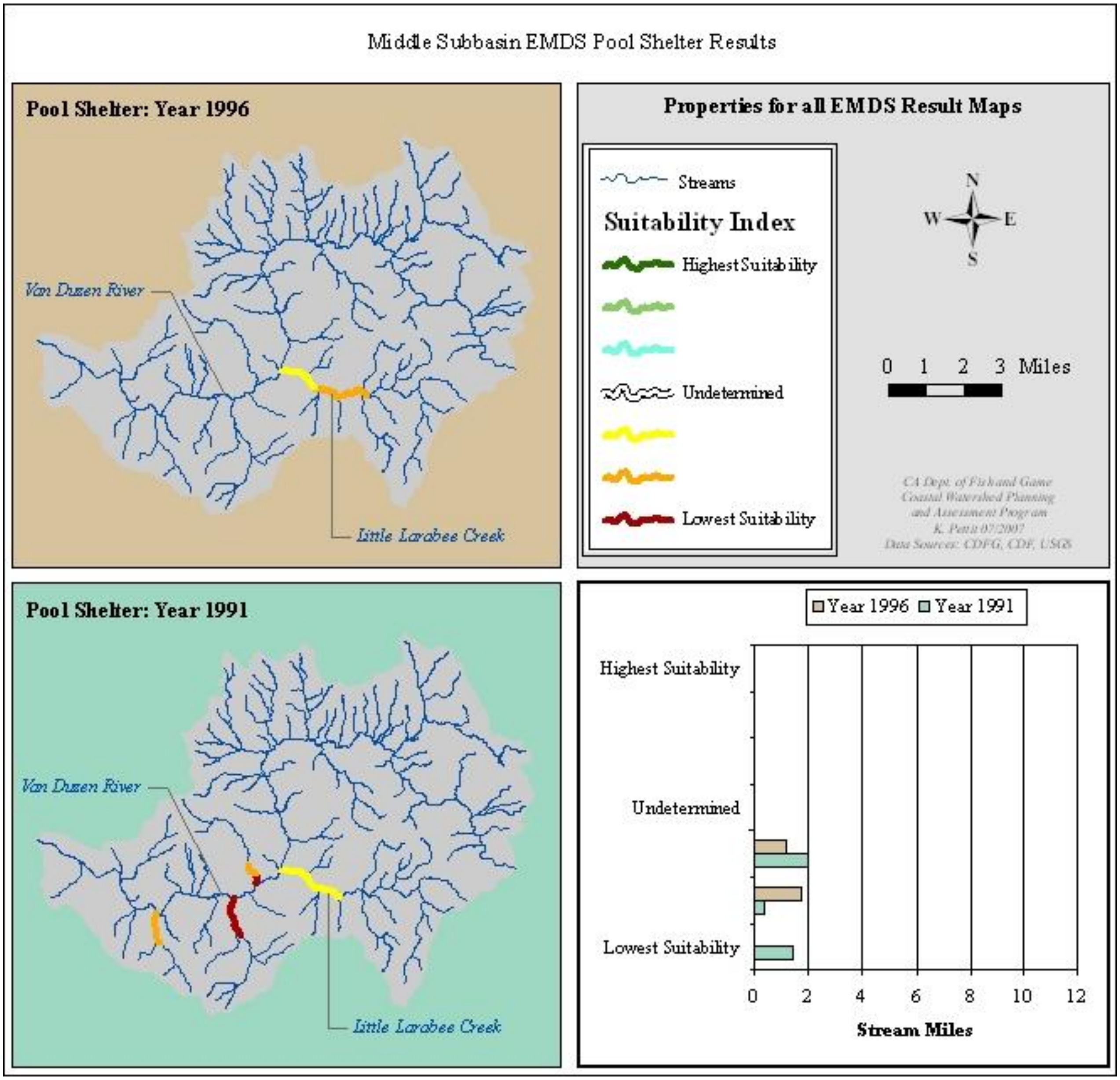

Figure 18. EMDS analysis of habitat suitability for salmonids based on pool shelter from stream surveyed in 1991 and 1996.

Canopy Density

Significance: Streamside canopy density is an estimate of the percentage of stream channel that is shaded by riparian tree canopy. An effective tree canopy provides shade to reduce direct sun light from warming water and contributes to maintaining cool microclimates. The condition of streamside canopy can change relatively rapidly with management that removes trees or alternatively by allowing tree growth. Habitat improvement projects are considered when canopy density is less than 80% (Flosi et al. 1998).

A second measurable attribute of streamside canopy is the percent of coniferous and deciduous tree species providing the shade. The percent coniferous and deciduous component of the stream side canopy influences the potential for LWD loading and can influence microclimate. Streams flowing through mature conifer stands tend to have larger amounts of wood with larger average piece size than streams with younger riparian stands, which often are dominated by smaller deciduous species (Bilby and Bisson 1998). LWD produced by conifers is generally favored over deciduous wood because it tends to be larger and less likely to move downstream, it decays more slowly, and stays longer in stream systems. The overstory shade produced by mature conifer stands also helps form cool microclimates along riparian zones which helps keep streams cool.

Findings: Canopy density in the surveyed stream reaches in the Middle Subbasin are below the target value of 80%; however, Hoagland and Fish creeks with reach values approaching the 80% target still attained suitable EMDS values (Figs. 19 and 20). Although these streams had suitable levels of shade, the amount of overstory shade contributed by conifers is below 50% for all streams. The low amount of overstory conifer shade is indicative of small sized or absence of conifer trees along the riparian zones of surveyed streams. It usually takes approximately 40 years to establish mature conifer forest canopy in these coastal forests.

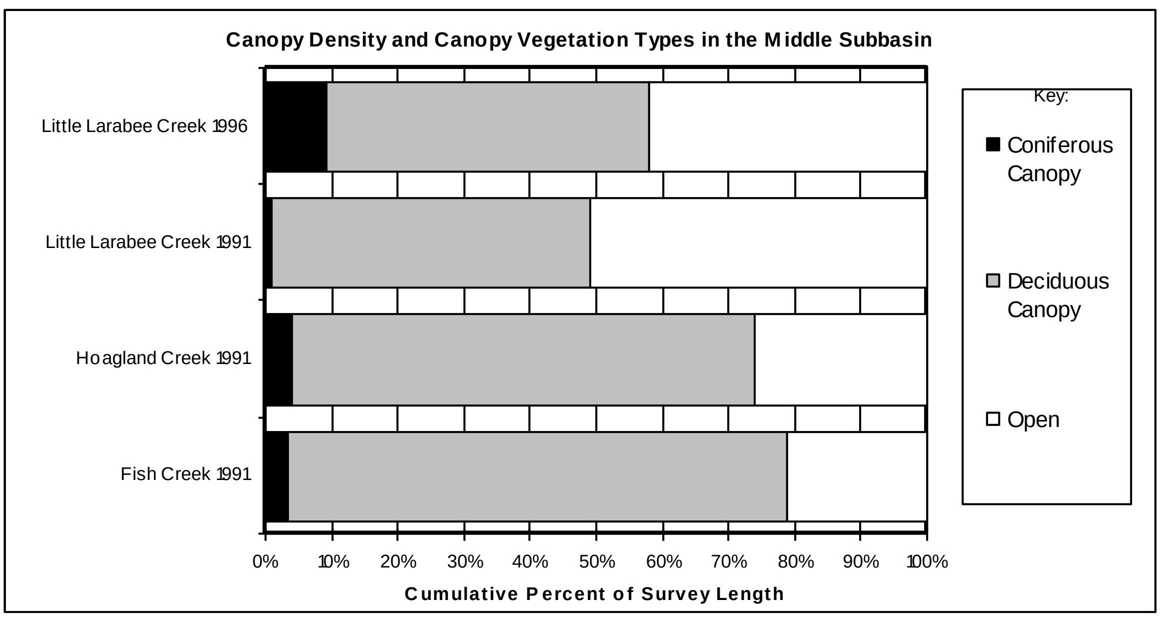

Figure 19. Cumulative percent of canopy density and vegetation types in four surveyed streams in the Middle Subbasin of the Van Duzen River.

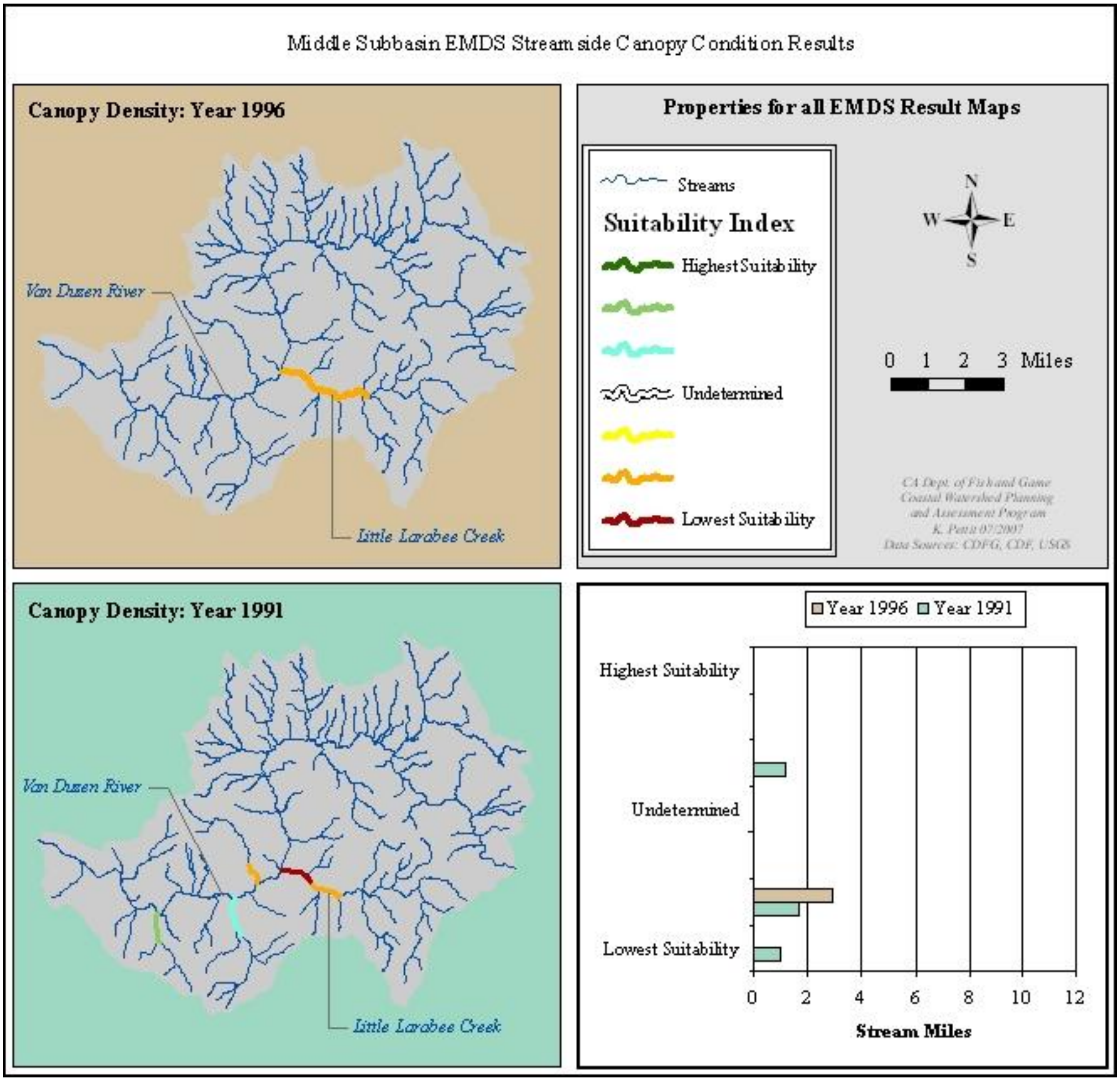

Figure 19. EMDS analysis of habitat suitability for salmonids based on canopy condition from stream surveyed in 1991 and 1996.

Spawning Cobble Embeddedness

Significance: Cobble embeddedness is the percent of an average-sized cobble piece embedded in fine grained sediments observed in pool tails. Pool tails are sampled because they are commonly selected areas for salmonid spawning. Percent cobble embeddedness provides a subjective measure of spawning substrate suitability for salmonid egg incubation, fry emergence and aquatic insect habitat. Embeddedness observations may indicate where excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds, which may suffocate eggs or developing embryos

High embeddedness ratings may indicate elevated levels of sediment inputs and erosion problems occurring in the watershed. The potential for high levels of fine sediments in streams increases in watersheds of the Middle Subbasin where the unstable geology, high precipitation, steep topography, and land use cumulatively increase erosion potential. Some common land use activities that increases generation of fine sediment are clear cuts, roads, skid trails, and livestock grazing (Cederholm et al. 1981, Duncan and Ward 1985, Swanson et al. 1987, Hicks et al. 1991).

Gravels and cobble that are less than 25% embedded with fine sediments are considered good quality substrate for salmonid spawning and production of stoneflies, mayflies and other aquatic insects. Gravels and cobbles over 50% embedded are viewed as poor quality for salmonid spawning and can impair stonefly and mayfly insect production. At the stream reach scale, spawning cobble embeddedness is considered suitable if at least 50% of all pool tails have embeddedness measures of less than 25%. Pool tails that are covered by wood debris or by fine sediments are considered unspawnable.

Findings: The streams of the Middle Subbasin generally show relatively high levels of cobble embeddedness (Figs. 20 and 21). The high levels of embeddedness are an indication of excessive delivery of fine sediments to most Middle Subbasin streams. Salmonid spawning success is likely limited or impaired by the lack of good quality spawning habitat in these streams.

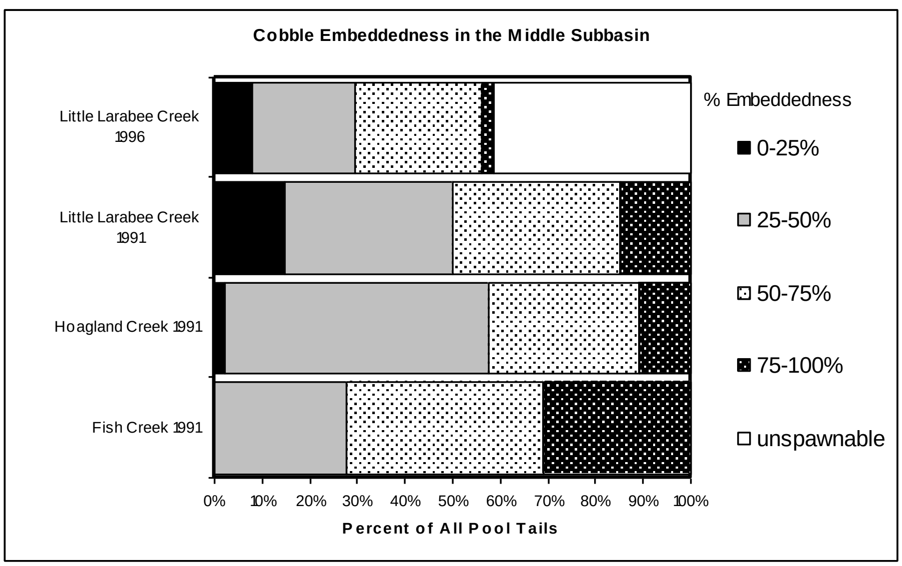

Figure 20. Histogram depicting percent cobble embeddedness in pool tails in four surveyed streams in the Middle Subbasin of the Van Duzen River.

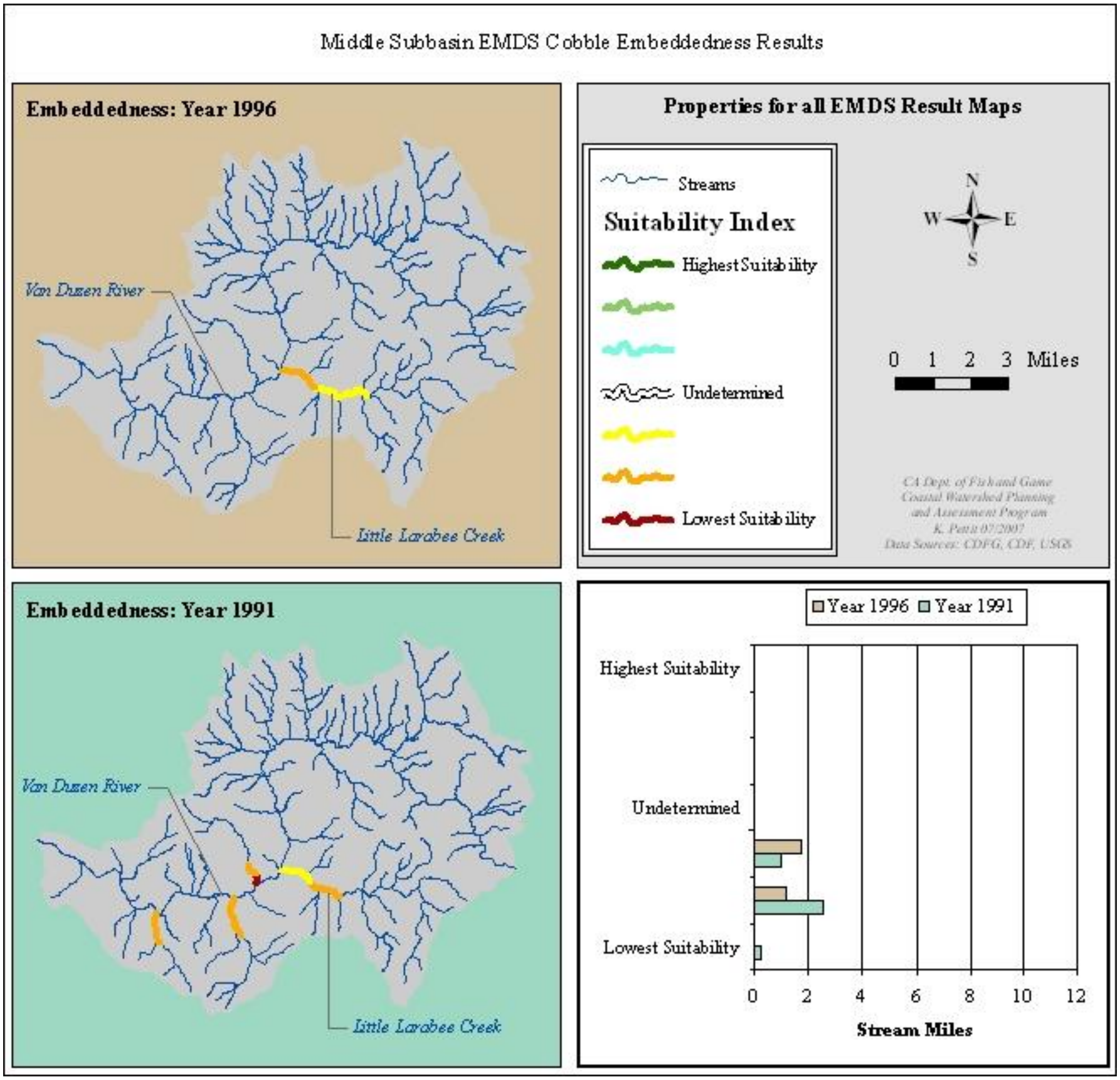

Figure 21. EMDS analysis of habitat suitability for salmonids based on cobble embeddedness from stream surveyed in 1991 and 1996.

Watershed Improvement Projects

A variety of salmonid focused watershed improvement projects have occurred in the Middle Subbasin including instream restoration, riparian restoration, road upgrade/decommission, stream crossing removal/upgrade, and upslope management (Fig. 22). Of these, road upgrade/decommission and stream crossing removal/upgrade have been the most common and spread throughout the watershed. Considered to have the best potential for supporting salmonids of the Middle Subbasin tributaries, Little Larabee Creek has had the greatest extent of restoration projects completed within its watershed.

Some of the first habitat improvement projects in the Middle Subbasin facilitated fish passage along problem sites on the Van Duzen River. Initial improvement projects used explosives to break up passage blocking boulders at Goat Rock, the Salmon Hole, and a site near Baker Creek. The passage problems are attributed to severe hill side erosion and excessive sediment inputs associated with the large flood of December 1964. The flood flows piled boulders across the active channel as well as filled pools needed by steelhead to jump up sections of the river characterized by steep gradients. The passage problems appear to mostly affect upstream migrations of adult summer steelhead (B. Wotherspoon personal communications and CDFG field notes 1965, 1978). In addition to these projects in the mainstem, three log and debris accumulations noted as barriers to migrations were removed in Little Larabee in 1983.

More information on restoration projects such as date and specific location can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/). Recommendations for potential restoration projects are located below in the Subbasin Scale Responses to Assessment Questions (pgs. 35-37).

Figure 22. Adult steelhead caught in the Van Duzen River.

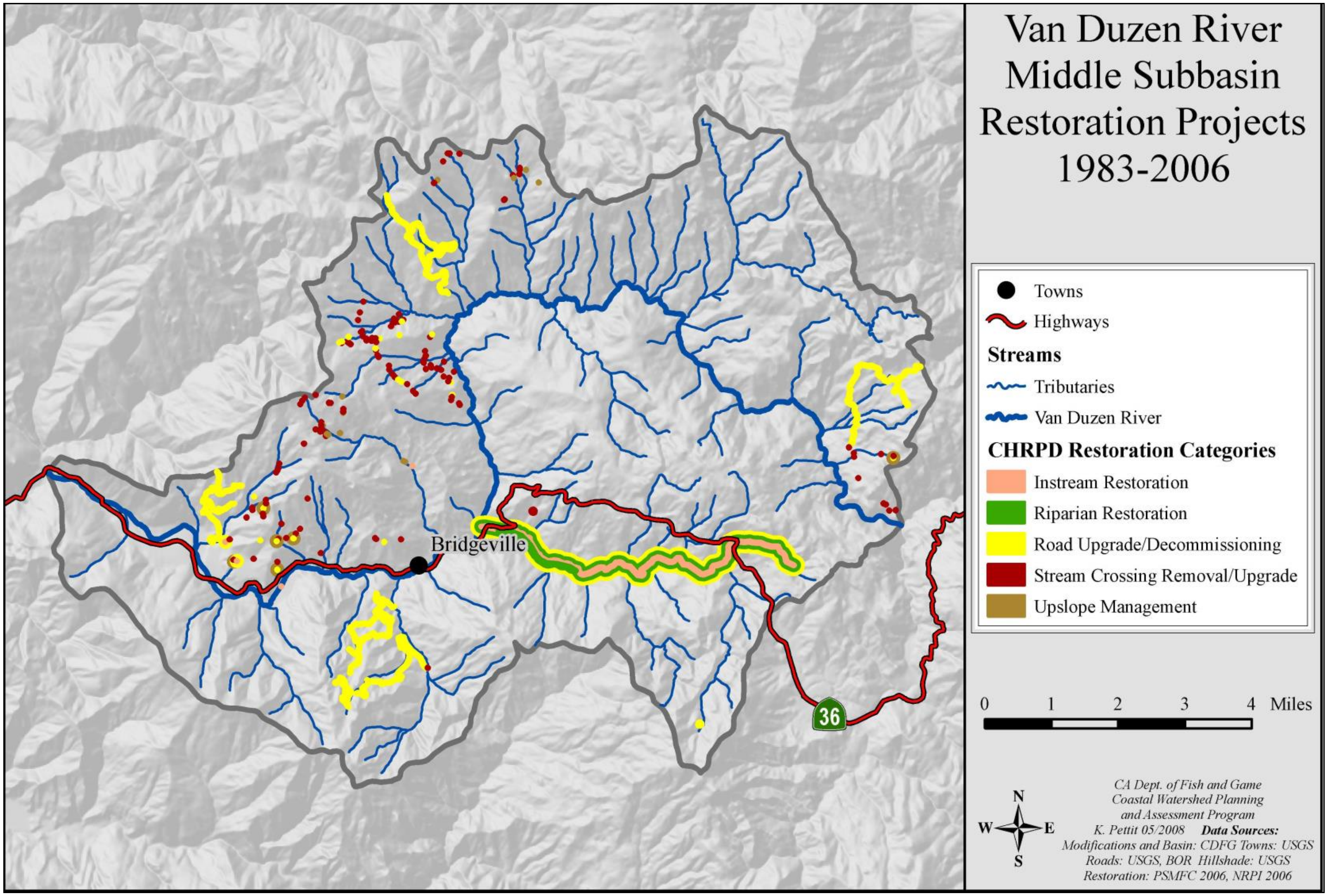

Figure 23. Restoration Projects in the Middle Subbasin 1983-2006.

Subbasin Scale Responses to Assessment Questions

The following discussion of the assessment questions and recommendations for improvement activities are generalized to the subbasin scale.

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Middle Van Duzen Subbasin?

- Historically, large number of Chinook utilized the mainstem Van Duzen River to the barrier at Salmon Falls (RM 37) for spawning and rearing habitat. They also utilized a few tributaries, most notably the lower mile and half of Little Larabee Creek;
- Presently, far few numbers of Chinook utilize the mainstem and have only been observed in three tributaries: Little Larabee, Fish and Hoagland creeks;
- While coho were historically abundant in the Yager and lower subbasins, reports of coho presence in the Middle Subbasin are limited. Stocks have declined to drastically low numbers and may be functionally extirpated from the subbasin;
- Because winter steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the subbasin (including above Salmon Falls) and have persisted in streams where other species have declined or are now rarely observed.

What are the current salmonid habitat conditions in the Middle Van Duzen River Subbasin? How do these conditions compare to desired conditions?

- The Van Duzen River and its tributaries exhibit high and prolonged levels of turbidity. The high turbid water make it difficult for fish to find food. This is especially important if newly hatched fish like Chinook salmon cannot feed;
- Even with recent high rainfall years, decreased summer water flows to tributaries is occurring, which in turn, has decreased summer and early fall base flows in the Van Duzen River;
- Increased nutrient, pollution, and sediment input into streams are all leading to impairment of habitat for fish, amphibians, and other wildlife;
- The most important tributary streams for salmonids are Fish Creek, Hoagland Creek, and Little Larabee Creek. The tributaries flowing into the Van Duzen from the north are generally too steep and limited by ephemeral flows to provide anadromous salmonid habitat.

What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?

- Middle Subbasin channel aggradation and sediment storage has been exacerbated by severe erosion in the upstream subbasins;
- Because of the low gradient of the mainstem as well as the lower reaches of several tributaries the Middle Subbasin acts as a sediment deposition as well as a transportation reach depending on flow and the amount of sediment entering the system;

- Unconsolidated sediments perched steeply above the stream are prone to bank erosion and sliding contributing sediment input to the streams;
- Unstable, severely erodable bedrock, frequent seismic movement, high regional uplift rates, high seasonal rainfall, and land use activities recruit vast amounts of sediment into the stream system;
- Soils and bedrock of the Middle Subbasin are easily eroded;
- Uplift has increased the erosion potential of the area;
- Rapid incision rates of the mainstem and its tributaries have left very steep, high banks which increase its likelihood for rockfalls and landslides;
- Multiple faults cut through this area shearing the bedrock and making it less competent;
- Frequent earthflows and deep-seated landslides within the mélange are especially active during heavy storm events and/or seismic events contribute a significant amount of fine sediments to the stream.

How has land use affected these natural processes?

- The present condition of the Middle Subbasin is in part the result of land use activities within the Middle Subbasin and land use that occurs in the watersheds located upstream;
- Primary causes for stream habitat deficiencies can often be traced back to land management actions that reduce stream flow, degrade water quality, increase erosion, and/or activities that alter characteristics of near stream forests;
- Within the past 10 years increasing conversions on private property of large, industrial marijuana agriculture operations have proliferated from the upper portion of the Lower Subbasin throughout the Middle Subbasin and to a lesser extent in the Upper Subbasin. These mostly unregulated operations have decreased summer/early fall stream flows and degraded water quality in Van Duzen River and its tributaries;
- The naturally high potential for erosion of the hill slopes and sediment delivery to stream channels is elevated by land use such as road construction, timber harvest operations and other land use that disturbs top soil or weakens slope stability;
- Some common land use activities that increases generation of fine sediment are clear cut logging operations, roads, skid trails, and livestock grazing.

What habitat improvement and other activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Flow and Water Quality Improvement Activities:

- Instream flows to maintain fish habitat in good condition and channel maintenance flows should be preserved during any existing water diversion activities and considered prior to any new water development projects including riparian diversions, industrial marijuana agriculture operations, small domestic water use and water extraction from near stream wells;

- Consider private landowner water storage and forbearance programs were large capacity storage tanks are operated as part of a seasonal water management program;
- Assess roads and implement road improvement projects to reduce sediment delivery to fish bearing streams;
- Reduce fine sediment inputs by avoiding land use on inner gorge slopes and mitigate to reduce sediment inputs for any land use near streams on slopes greater than 25 percent;
- Intact forests of increasing age structure and complexity will have a greater water holding capacity than impaired watersheds, where forests are of a single dimension and lack complexity.

Erosion and Sediment Delivery Reduction Activities:

- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams;
- Review potential for bank stabilization projects along the Van Duzen River.

Riparian and Stream Habitat Improvement Activities:

- Pool enhancement projects should be implemented at select, existing pool habitat units to increase depth and add shelter complexity on Fish, Hoagland, and Little Larabee creeks;
- Consider adding elements to recruit and retain spawning gravels in Fish, Hoagland, and Little Larabee creeks;
- Seek opportunities to increase conifer overstory shade canopy over Little Larabee Creek by plantings and/or thinning hardwoods around small conifers.

Monitoring, Education and Research Activities:

- Perform fish surveys on Fish, Hoagland, and Little Larabee creeks to update current knowledge of presence and distribution of anadromous salmonids;
- Several years of monitoring summer/early fall stream water and air temperatures to detect trends using continuous, 24-hour monitoring thermographs should be done in the Van Duzen River;
- Monitor summer/early fall water quality parameters in the Van Duzen River;
- Conduct community based outreach meetings to discuss approaches that could be implemented to help address the problems created by industrial marijuana agriculture practices;
- Continue outreach and education by local agencies and organizations to rural residents regarding proper road design and maintenance.

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Upper Subbasin

The Upper Subbasin drains approximately 143 square miles of mountainous terrain located above the confluence of the mainstem Van Duzen River with the Little Van Duzen River (also known as South Fork Van Duzen River (Figure 1). Approximately half the land is located in each of Humboldt (73 sq. mi.) and Trinity (70 sq. mi.) counties. The upper half of the subbasin is within Trinity County where the majority of land is in Six Rivers National Forest (Table 1). The lower half is mostly in private ownership. Coniferous forest is the dominate type of vegetation. Timber production is the major land use, but in recent years the proliferation of large-scale industrial marijuana grow operations has occurred throughout the upper watershed. Several small rural developments and several large private land ownerships are located near the towns of Dinsmore and Mad River.

This California Department of Fish and Wildlife (CDFW) assessment is focused on anadromous salmonid habitat which is thought to be limited on the mainstem Van Duzen River by Eaton Falls. Eaton Falls, (RM 46) located about two miles downstream of Dinsmore is considered a natural barrier to upstream salmonid migrations, although there have been anecdotal reports of large salmonids (possibly steelhead) above the falls. The Van Duzen mainstem and its tributaries above Eaton Falls is populated by resident trout populations. Winter and summer run steelhead migrate to tributaries and upper reaches of the Little Van Duzen River. Passage of Chinook and coho to the Upper Subbasin is typically blocked at Salmon Falls in the Middle Subbasin, but reports of coho salmon have been made in the Little Van Duzen River and its tributary, Butte Creek (Reynolds et al. 1981 and Decker and Fuller 1983).

The Upper Subbasin is made up of 11 CalWater 2.2.1 Planning Watersheds (Figure 2) which are utilized to delineate tributary drainages.

Table 1. Summary of Van Duzen River Upper Subbasin attributes.

Square Miles	143
Total Acreage	91,520
Private Acres	43,423
Federal Acres	48,084
State Acres	13
Predominant Land Use	Timber Harvests
Predominant Vegetation Type	Mixed coniferous forest
Stream Miles	296
Miles of Anadromous Stream	28
Road Miles/Subbasin Miles	3.5
Low Elevation (feet)	1,540
High Elevation (feet)	5,900

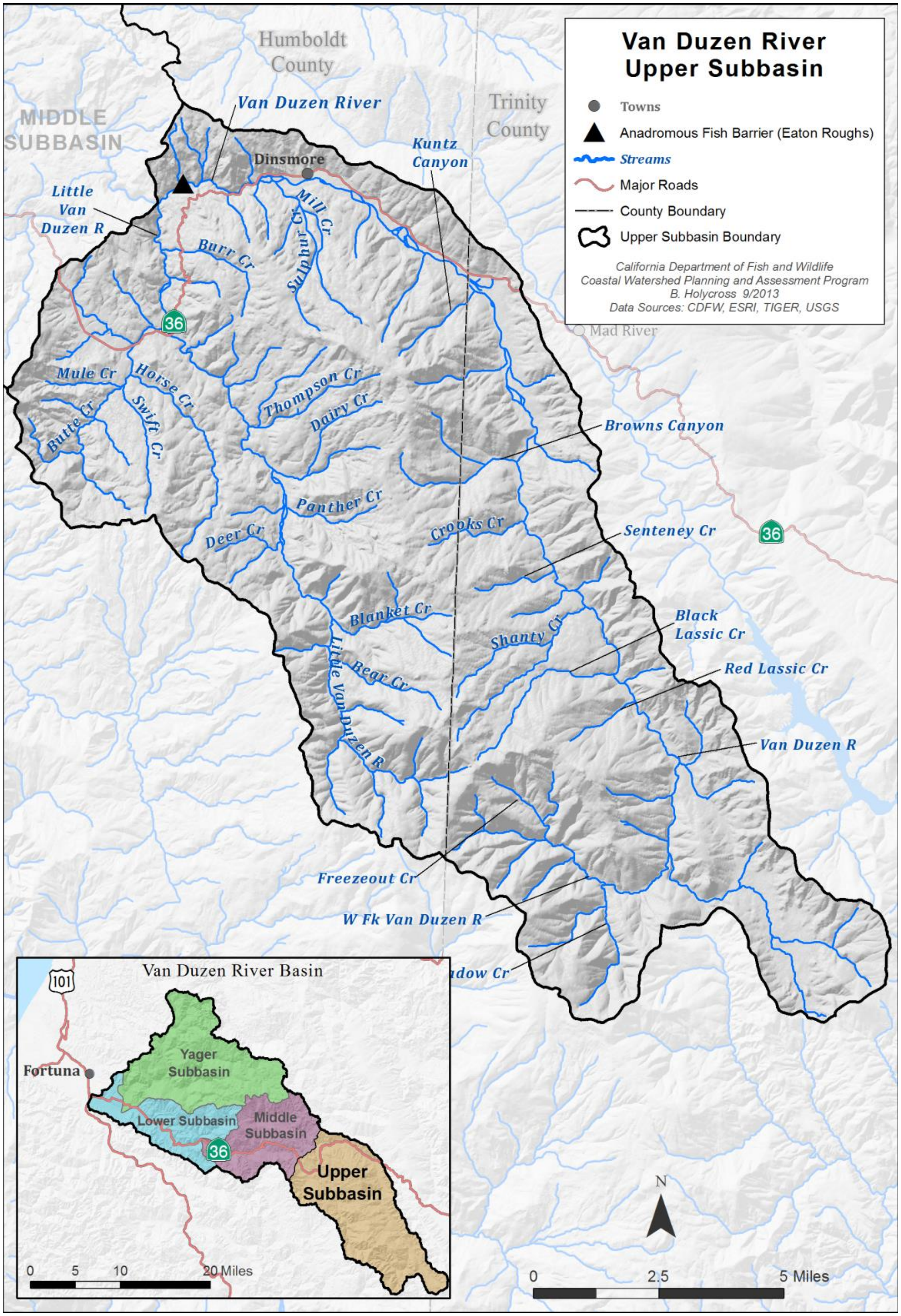

Figure 1. Location and tributaries of the Upper Subbasin of the Van Duzen River

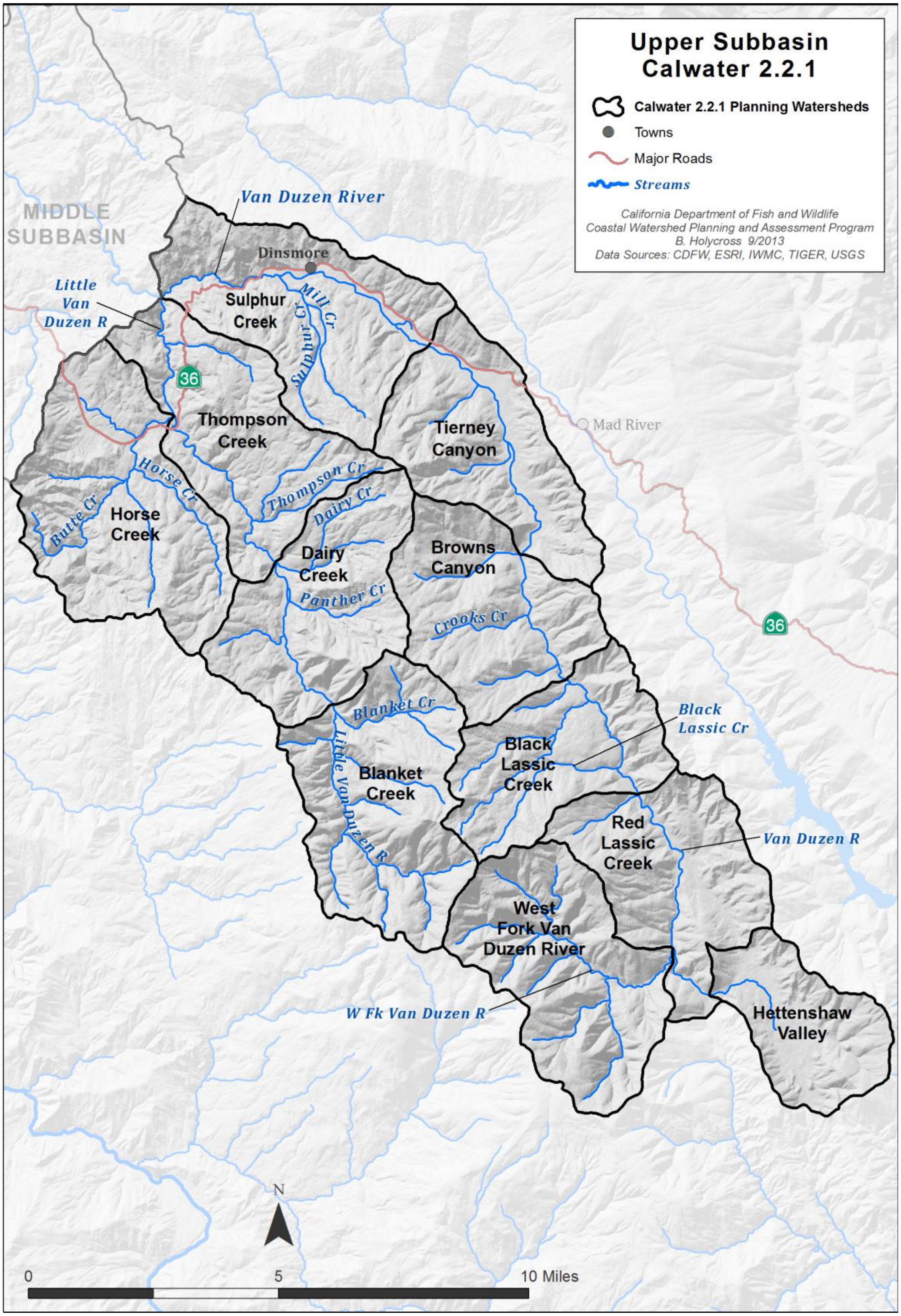

Figure 2. Eleven Cal 2.2 watersheds compose the Upper Subbasin of the Van Duzen River

Geology

Bedrock

The Yolla Bolly terrane dominates this subbasin at about 41% of the surface geology (Figure 3). The Yolla Bolly terrane is predominantly metagraywacke, meta-argillite, conglomerate, and mélange made up of a sheared matrix of the aforementioned rock types. This terrane contains mappable blocks of greenstone, metachert, metagraywacke, and phyllite (a metamorphic rock type between slate and schist in metamorphic grade).

The Yolla Bolly terrane most probably formed 100 million through 175 million years ago as sediments washed off of the continent and blanketed the subduction trench. The segments of Yolla Bolly terrane are considered to be part of the Eastern Belt that has been translated to their current position by movement along the Mule Ridge and Grogan-Red Mountain fault zones (McLaughlin, 2000).

Central Belt Mélange of the Franciscan Complex makes up approximately 35% of this subbasin. Melange can be described as a mixture of claystone, siltstone, and sandstone that has been metamorphosed churned and mixed in a subduction zone to such a degree that its supporting matrix has been completely disrupted by shearing.

This mixture or "melange" was then scraped off and smashed onto the western edge of the North American continent after about 88 million years ago (McLaughlin 2000). Of all of the lithologies in the Van Duzen River Basin the melange of the Central Belt is the most susceptible to earthflows and deep-seated landslides. There are very large, active earthflows (moving several meters per season) as well as dormant earthflows with in the melange of this subbasin. Dormant earthflows may reactivate during especially wet seasons, during seismic events, or if their toe is worn away by streams.

Central Belt sandstone of the Franciscan Complex makes up roughly 6% of the bedrock of this subbasin. The Central Belt sandstone units are large blocks of slightly metamorphosed sandstone, greywacke ("dirty" sandstone), and argillite (McLaughlin 2000). Although they have been metamorphosed, folded, and sheared to some extent they are more coherent than the mélange and tend to form steeper valleys and sharper ridges.

Quaternary landslides occupy around 7% of the subbasin (mapped as of 2000 – McLaughlin et al). Since the mapped landslides have already, at some point, slid, they have less potential for continued sliding; however, they are sensitive to land use because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. Furthermore, if the toes of these large landslides erode far enough, if they become saturated by heavy seasonal rain, or if there is a large, local seismic event these landslides may reactivate.

Several large, active earthflows have been mapped and studied by Kelsey (1977) along the Van Duzen River mainstem (Figure 4) within the upper basin which contribute large amounts of sediment. These earthflows typically form in mélange due to its very low shear strength. Even though large scale GIS mapping shows only 7 percent of this subbasin as landslides it is estimated based upon topographic diversity that on the order of 70 percent shows evidence of past movement (Ellen et al. 2007).

Alluvium which are the active channel sediments being transported downstream over time, include bed, bank, and floodplain deposits and to some extent low-lying river terrace deposits occupy about 4% of this subbasin.

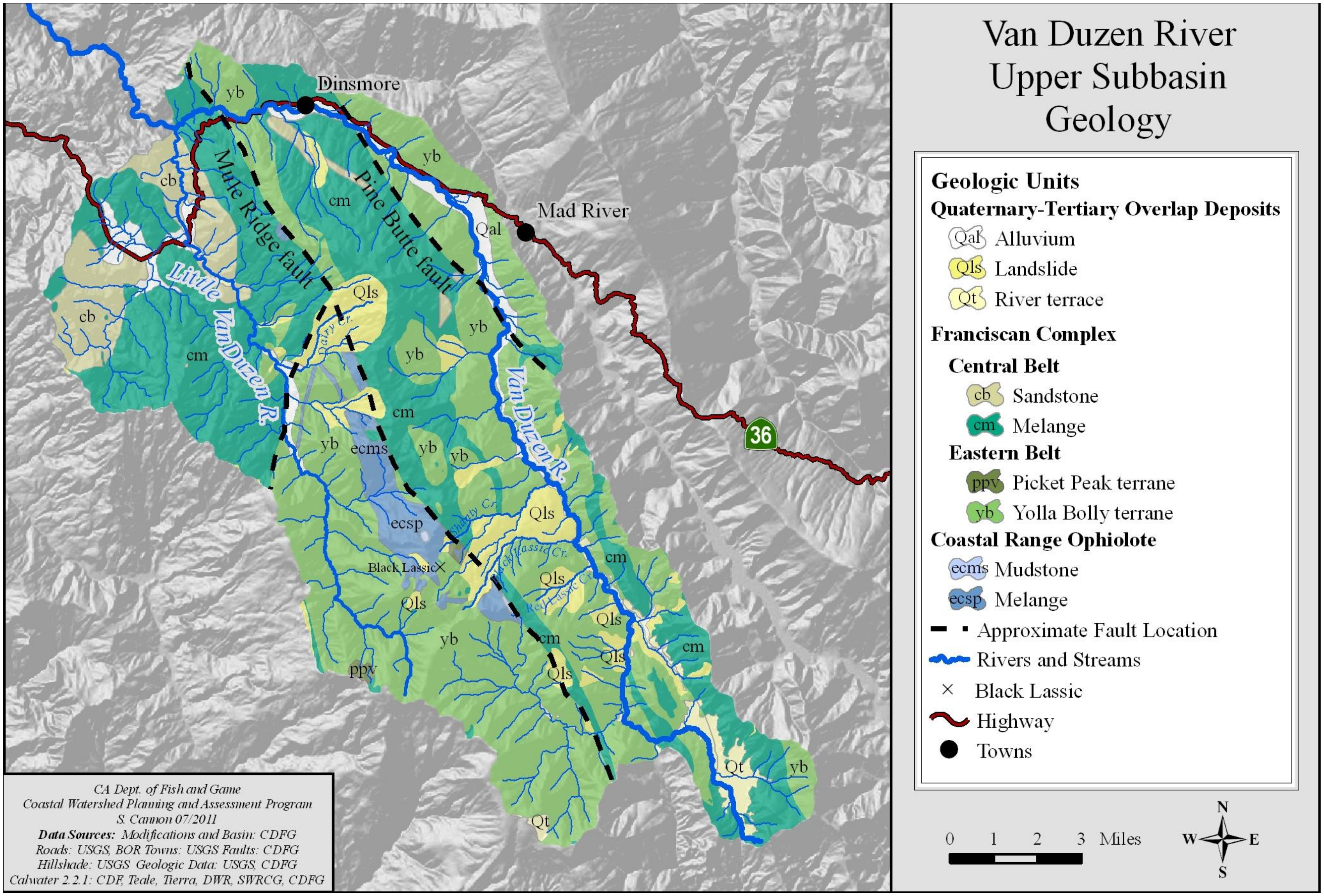

Figure 3. Geology of the Upper Subbasin

River terrace deposits occupy 2 percent of this subbasin. River terrace deposits consist of unconsolidated through poorly consolidated cobbles, gravels and fine sediments. These terraces were once river channel and flood-plane alluvial deposits but have been raised above the hundred-year-flood level during the last 2 million years by regional tectonic uplift. River terrace deposits tend to form steep channel banks that are prone to dry ravel and slumping. Prominent river terrace deposits in this subbasin include: Hettenshaw Valley, Larabee Valley, and Dinsmore.

The Great valley/Coastal Range melange unit makes up about 3% of this subbasin. The Great Valley/Coastal Range melange consists of a disassociated, ophilolitic serpentinite mélange containing blocks of basalt, diabase, gabbro, and ophiolitic breccia (McLaughlin, 2000).

An Ophiolite may be thought of as a sequence of rock types that comprises a cross section through the oceanic crust. Sediments deposited on the ocean floor, pillow basalts, sheeted dykes, gabbro, and peridotite usually represent this sequence. The Great Valley/Coastal Range Ophiolite has been disassociated by tectonic accretion and faulting and translation to its current location leaving the crustal sequence scattered and non-distinct.

The Great valley/Coastal Range mudstone unit comprises around 1% of this subbasin and consists of thinly bedded, fractured mudstone with minor amounts of sandstone and siltstone. These sediments were deposited atop of the Great Valley/Coastal Range Ophiolite from 100 million to 145 million years ago.

The Pickett Peak terrane associated with the Eastern belt of the Franciscan Complex accounts for less than 1% of this subbasin. The Pickett Peak terrane is made up of metamorphosed sedimentary and volcanic rock types including; schist, metabasalt, metagraywacke, mudstone, conglomerate, and metachert that are approximately 100 million to 145 million years old (McLaughlin, 2000).

Figure 4. Halloween Earthflow complex on the right-bank of the Van Duzen River near the confluence of the Little Van Duzen River.

Table 2. Lithologic units of the Van Duzen River Upper Subbasin.

GEOLOGIC RELATION AND DESCRIPTION OF MAJOR UNITS WITHIN THE MIDDLE SUBBASIN						
Unit	**Belt/Rock type**	**Formation /terrane**	**Composition**	**Erosion**	**Age ma**	**%**
Overlap Deposits	Alluvium		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay.	Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes.	0-0.01	4
	River terrace		Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel.		0.01-2	2
	Landslide		Large, disrupted, clay to boulder debris and broken rock masses.	Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare.	0.01-2	7
Franciscan Complex	Central belt	Sandstone	Large blocks of metasandstone and metagraywake, interbedded with meta-argillite.	Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.	65.5-161.2	6
		Mélange	Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, & metachert.	Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	1.8-65.5	35
	Eastern belt	Pickett Peak terrane	Schistose metasedimentary and metavolcanic rocks.	Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages.	1.8-65.5	<1
		Yolla Bolly terrane	Predominantly Semi-schistose metagraywacke, meta-argillite, conglomerate, and mélange made up of a sheared matrix of the aforementioned rock types with minor metachert and metavolcanic rocks.	Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	99.6-199.6	41
Great Valley Sequence	Coastal Range Ophiolite	Mudstone	Thin-bedded mudstone, arkosic siltstone and sandstone.	Prone to debris sliding along steep stream banks and in steep headwater drainages.	65.5-251	1
		Mélange	Sheared matrix of serpentinized dunite containing blocks of basalt, diabase, gabbro, and ophiolitic breccia.	Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation.	65.5-251	3
Sources: Kilbourne, 1985, Ogle, 1953, McLauglin, 2000. % Data represent an approximation based on GIS mapping.						

Faults and Shear Zones

The Mule Ridge fault and Pine Butte fault (Table 3) as well as several smaller faults and shear zones cut across this subbasin disrupting the coherency of the bed rock and increasing the local erosion potential. Uplift of this subbasin associated with northward migration of the Mendocino Triple Junction has increased the potential energy of the streams allowing them to incise and erode the landscape at high rates. Uplift in the area of Hettenshaw Valley has allowed the West Fork of the Van Duzen to capture the headwaters of the East Fork of the North Fork of the Eel River in the recent geologic past.

Table 3. Faults located in the Upper Subbasin of the Van Duzen River watershed.

Fault Name	Displacement	Description
Mule Ridge fault	Vertical/Dextral	The Mule Ridge fault is another steeply dipping to nearly vertical fault that runs northwest. It is believed to be similar to the Grogan-Red Mountain fault zone.
Pine Butte fault (Grogan-Red Mountain fault zone)	Vertical/Dextral	The Pine Ridge fault is considered part of the Grogan-Red Mountain fault zone which is a steeply dipping fault zone that runs northwest within the Upper subbasin. This fault zone separates the Central belt from the Eastern Belt of the Franciscan Complex. It probably marks the zone of active subduction before the Coastal Belt Thrust.
Sources: U.S.G.S. 2011, McLauglin 2000		

Landslides

Seven percent of this subbasin has been mapped with large Quaternary landslide features. These landslides reflect only what has been mapped on a large scale without detailed field investigation. Many smaller and/or less obvious landslides most likely exist that have not been mapped or have been mapped as part of landslide inventories at a much more detailed scale.

Earthflows some of which are very large (≈ 1 mile^2) are prevalent in the Central Belt mélange as well as mélange units of the Yolla Bolly terrane and contribute significant amounts of fine sediment to the river system. Dormant earthflows may become reactivated during large storm/stream flow events and/or seismic events.

Debris avalanches especially in the headwaters region are significant in terms of erosion and delivering sediment to the streams (Kelsey 1982).

Three of the largest mapped landslides in this subbasin occur in the vicinity of Black Lassic, Red Lassic, and Buck Mountain. On the east flank of Black Lassic the landslide encompasses the area of Black Lassic Creek (Figure 5) and Shanty Creek and is in geology of the Yolla Bolly terrane and Central belt mélange. Red Lassic Creek drains the debris avalanche complex on the eastern flank of Red Lassic which is made up of geology of the Yolla Bolly terrane. On the western flank of Buck Mountain, Dairy Creek (tributary to the Little Van Duzen) drains the large mapped landslide within the geology of the Yolla Bolly terrane.

Slope Inclination

Steep slopes (> 30%) cover 54% of the subbasin's terrain and are distributed throughout the subbasin (Table 3, Fig. 7). Moderate slopes (15-30%) covering almost third of the subbasin are also spread throughout of the subbasin.

Table 4. Slope classes and acres associated with the slope classes in the Upper Subbasin.

Slope class	Acres
0-15% Gentle	13817 (15%)
>15 -30% Moderate	27756 (30%)
>30 -65% Steep	34515 (48%)
>65% Very Steep	5703 (6%)

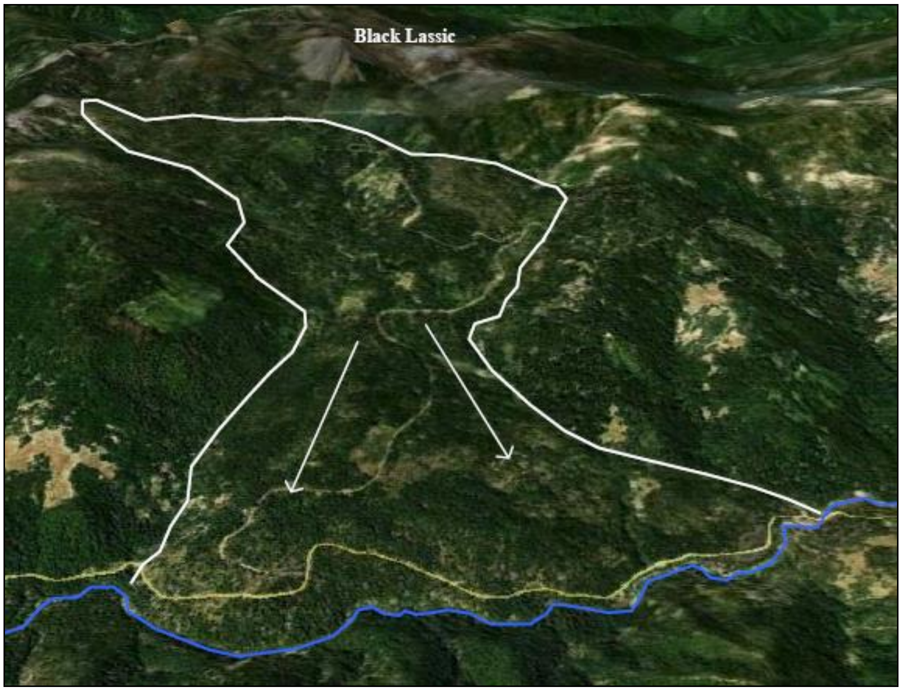

Figure 5. Pseudo-aerial view looking west of the Black Lassic landslide into the Van Duzen River.

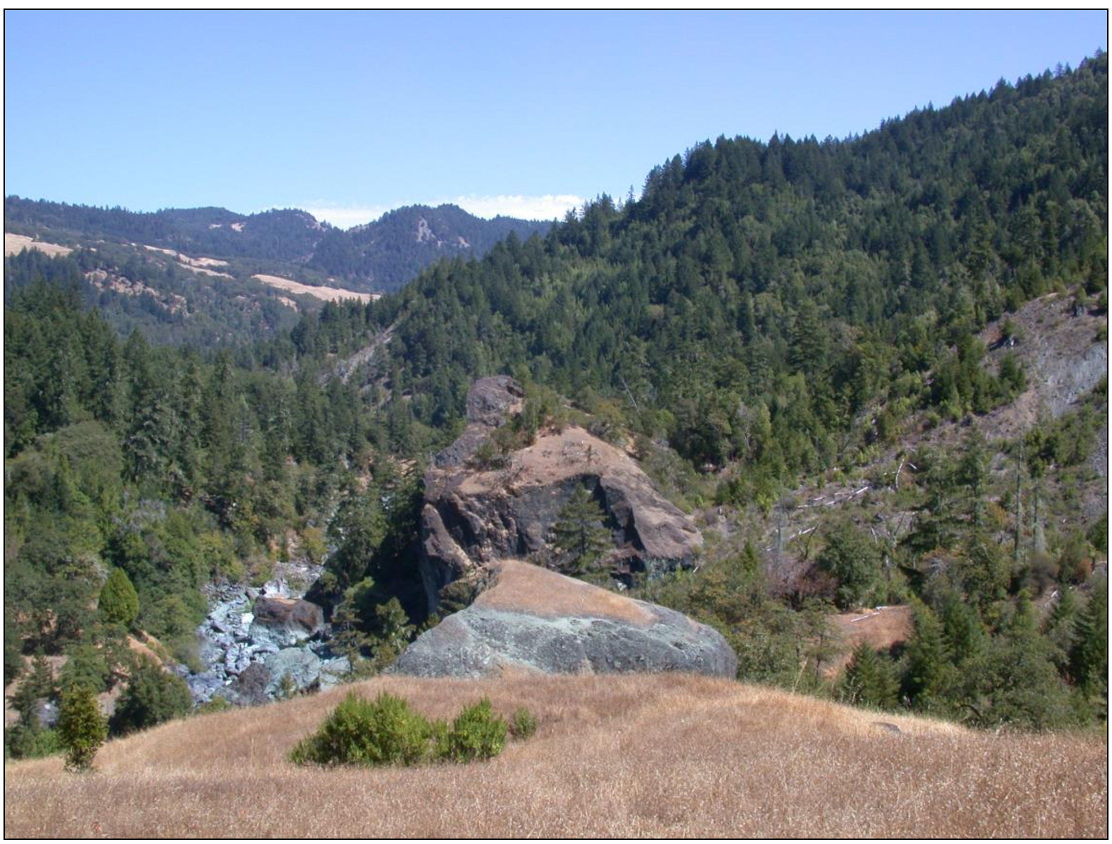

Figure 6. View of older landslide (on right side of photo) in the Upper Van Duzen River near Eaton Falls (RM 46).

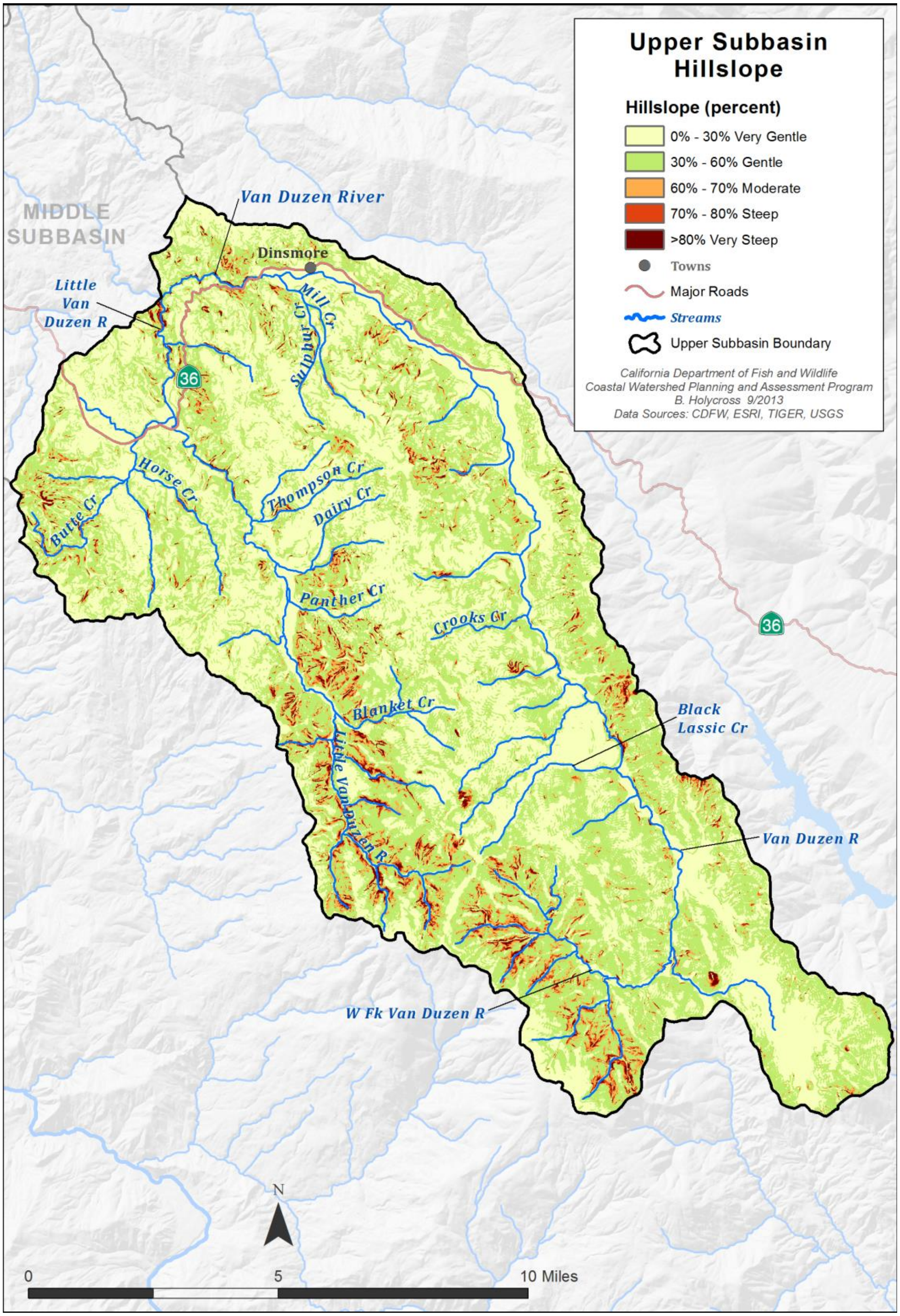

Figure 7. Upper Subbasin hillslope classes.

Hydrology, Fluvial Processes and Sediment Transport

The mainstem Van Duzen River (Figure 8) flows approximately 30 miles from its headwaters in the Six Rivers National Forest down through the Upper Subbasin. There are approximately 121 miles of perennial tributary channels and 149 miles of intermittent channels that flow into the mainstem (Figure 9). The majority of the perennial tributaries (83 miles) are classified as first order streams according to the modified Strahler Stream Order (Strahler 1957). The largest tributary in the subbasin is Little Van Duzen River (also known as South Fork Van Duzen River), which is a 4rth order stream (in its lower reach) that flows 18 miles before joining the mainstem at RM 45.5.

Many of the intermittent stream channels are steep and are considered as sources areas for sediment (Montgomery and Buffington, 1997) delivered to the Van Duzen River (Figure 10). While the Van Duzen River and the Little Van Duzen River are low gradient streams until their headwaters. The average mainstem channel gradient is approximately 1.5 %. The average Little Van Duzen channel gradient is approximately 4.5%.

Figure 8. Upper Van Duzen River at Eaton Falls (RM 46).

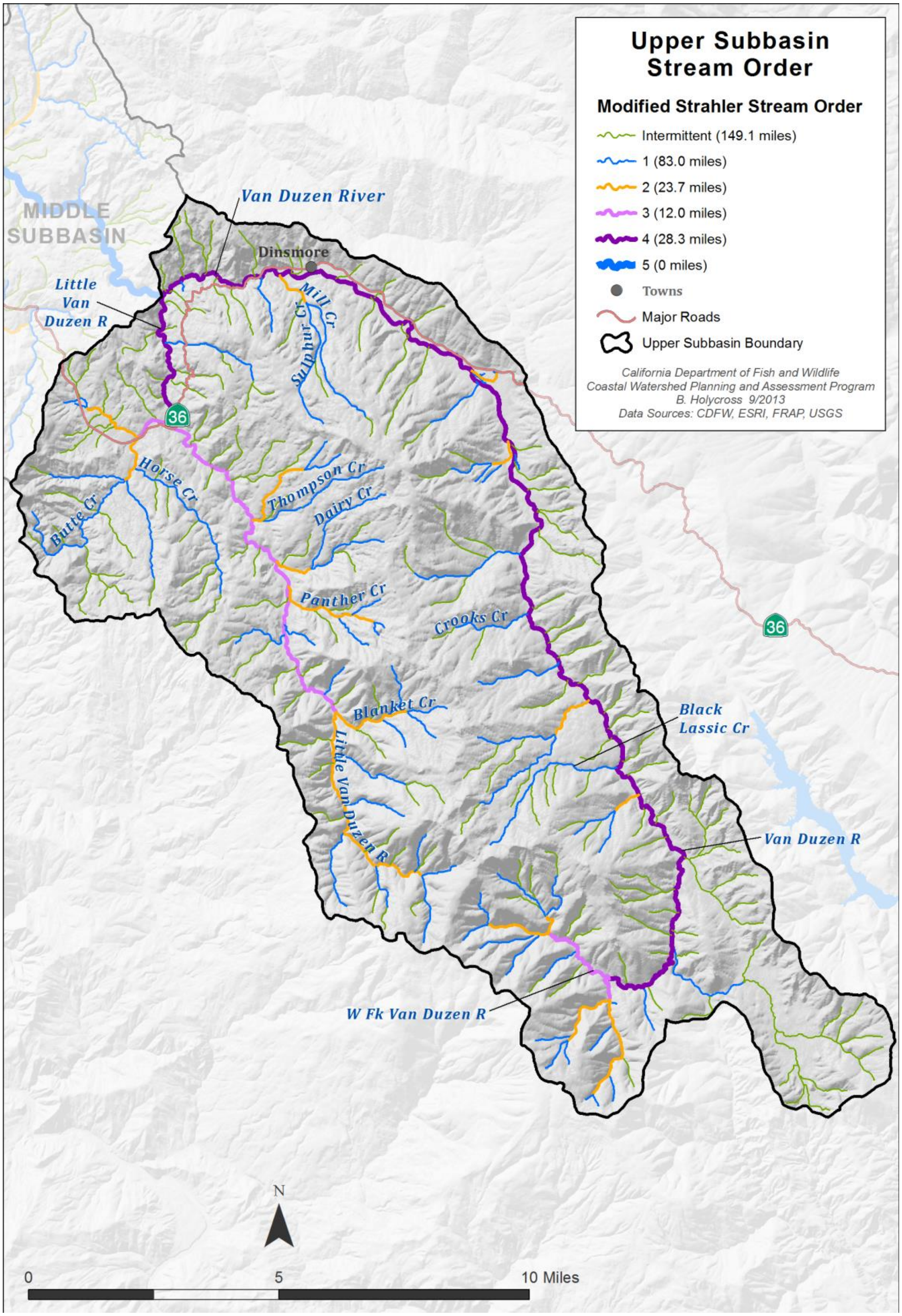

Figure 9. Stream order and intermittent tributaries of the Upper Subbasin

Figure 10. Stream gradient classification for sediment response, transport, and source for Middle Subbasin of the Van Duzen River.

Vegetation

Douglas fir dominated forests and mixed conifer and hardwood forests are the most common vegetation types in the Upper Subbasin composing 39.7% and 32.2%, respectively, of the landscape (Figure 11). The subbasin's complex geology and diverse soils support a rich herbaceous flora (Reynolds et al. 1981), including patchy stands of white fur (7.3%) and pine forests (2%) that do not grow elsewhere in the basin.

Most tributary stream reaches that support salmonids flow through coniferous forests. The important roles forests play in watershed processes, stream ecosystems and a stream's ability to support viable populations of anadromous salmonids have are documented (Meehan 1991, Murphy 1995, Spence et al. 1996, Lassettre 1999) and discussed in the Basin Profile section of the assessment report. Most of the coniferous forests of the Middle Subbasin have been recently logged and now early seral stage forests stands predominate. The adverse changes to salmonid habitat related to extensive logging of forests (Murphy 1995) and land use that disturbs riparian and near stream forests (Meehan 1991 and Spence et al. 1996) also are well documented and discussed in the Basin Profile.

Figure 11. View of the upper Van Duzen watershed.

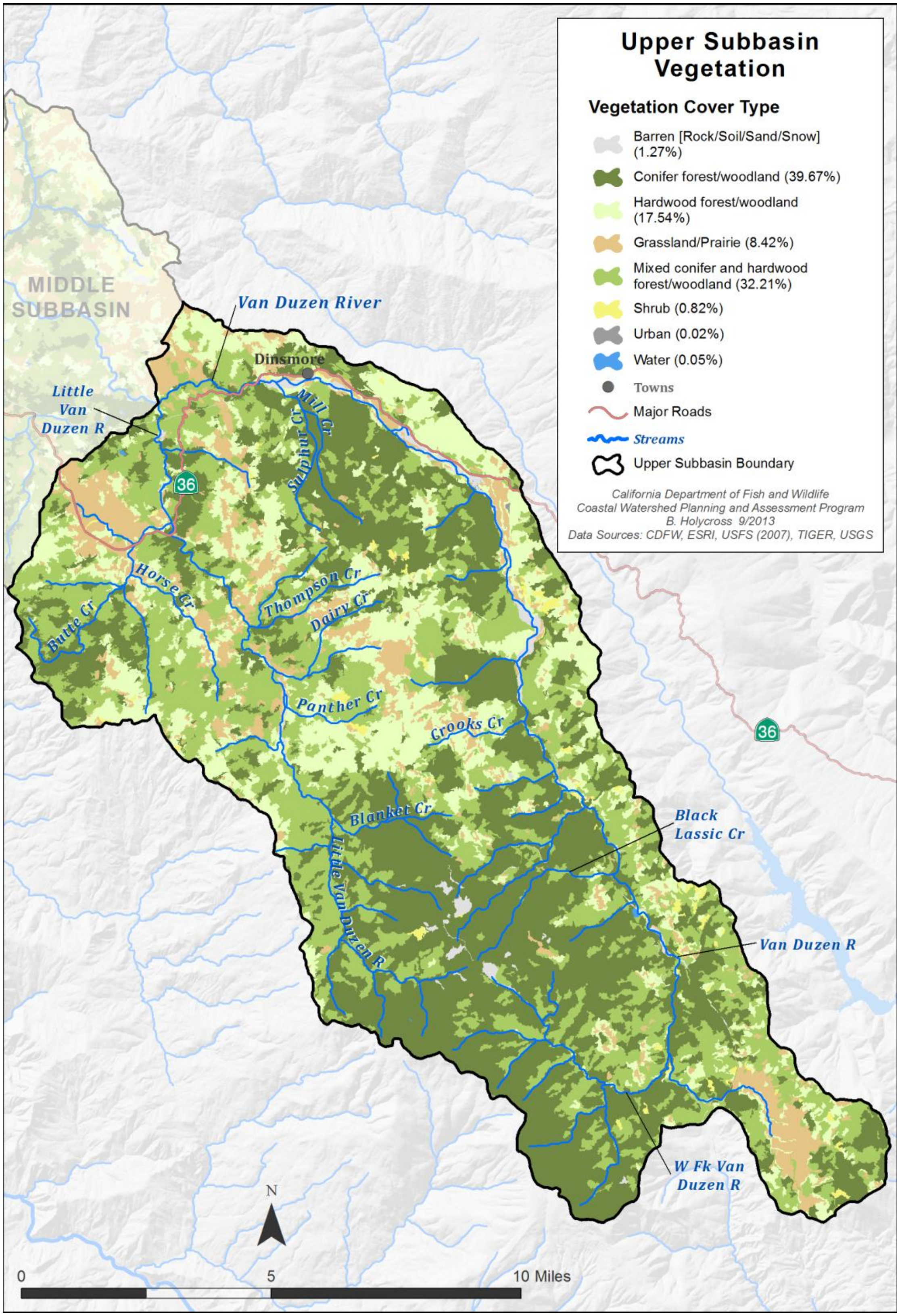

Figure 12. Vegetation classes of the Upper Subbasin

Land Use

Approximately half (50%) of the Upper Subbasin's land area is managed as National Forest by the Six Rivers Forest Service. Timber harvests, livestock grazing and public recreation are the major land use on these public lands (Figure 12). Timber production from private timber companies occupies a large majority of the northwest portion of the Upper Subbasin and composes 21.4% of the land use in the subbasin. For the past several decades, most of the private lands were managed for timber production or used for rural residences and ranchlands; however, in recent years the proliferation of large-scale industrial marijuana grow operations has occurred throughout the upper watershed.

Timber Harvests

A total of 25 percent of the subbasin's conifer forests were involved in timber harvest activity from 1991 to 2008. The majority of the timber harvest activity occurred in the lower to middle portion of the subbasin. The Dairy Creek Planning Watershed (PL) experienced the greatest amount of timber harvest activity with 2,800 acres or 76 percent of its conifer forest lands involved in timber harvest activity. Thompson Creek (2,466 acres harvested) and Browns Canyon (1,255 acres harvested) PWs also had substantial rates of timber harvest activity (Table 5). Appropriately, these three PWs (along with Sulpher PW) also contained the highest number of roads per square miles within the Upper Subbasin (Table 6).

Table 5. Upper Subbasin timber harvest statistics from 1991 to 2008.

Planning Watershed (PW)	PW Acres	Harvested Acres	% PW Harvested	Conifer Acres	% PW in Conifers	% Conifers Acres Harvested
Black Lassic Creek	7109	62	1	4953	70	1
Blanket Creek	9807	516	5	7197	73	7
Browns Canyon	7781	1255	16	2882	37	42
Dairy Creek (Upper)	8106	2800	35	3745	46	76
Hettenshaw Valley	5010	266	5	1873	37	14
Horse Creek	10779	1916	17	6482	60	29
Sulphur Creek	9788	835	9	5867	60	14
Thompson Creek	8507	2466	29	5326	63	46
Tierney Canyon	7894	622	8	3853	49	16
Totals	**74782**	**10738**	**14.4%**	**42176**	**56.4%**	**25.5%**

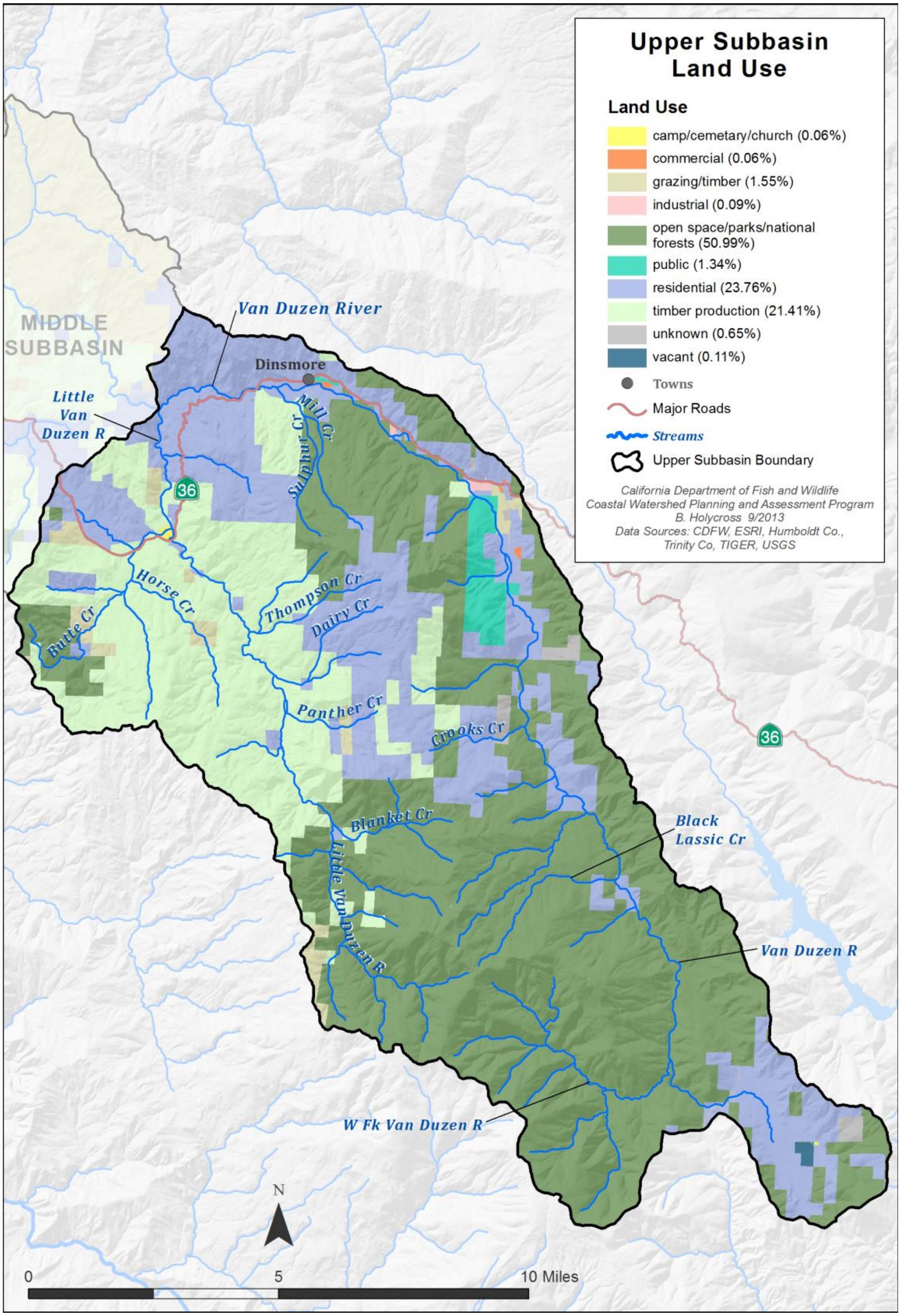

Figure 13. Land use categories in the Upper Subbasin

Roads

Roads data available from California Department of Fire (CDF) GIS roads layers show that there is an average of 3.6 miles of roads per square mile of the Upper Subbasin (Table 6 and Figure 13). The roads data provided by CDF likely underestimates the actual mileage of roads. The majority of these roads are considered existing seasonal roads that are generally utilized during the dry summer and early fall. There are, however, a large number of miles of existing permanent roads as well. The highest road densities are in the Sulpher (5.3 mi/sq. mi.), Thompson (5.1 mi/sq. mi.) and Dairy (4.8 mi/sq mi) creeks Planning Watersheds (Table 6).

Industrial Marijuana Agriculture

While not displayed in Land Use Map (Figure 12, p.17), industrial marijuana agricultural operations are locally abundant throughout the rural areas of the Upper Subbasin and are having a significant impact on the landscape and natural resources (including aquatic) of the subbasin and basin as a whole. The impacts and a discussion of these operations are discussed further in the Basin Profile's Land Use section (pp.47-48) as well as in the Lower Subbasin (p.27).

Table 6. Road miles in the Upper Subbasin planning watersheds.

CDFPWS NAME	**Square Miles**	**Road Miles**	**Road Miles per Sq.Mi.**
Black Lassic Creek	11.1	30.1	2.7
Blanket Creek	15.3	22.6	1.5
Browns Canyon	12.2	46.2	3.8
Dairy Creek (Upper)	12.7	60.3	4.8
Hettenshaw Valley	7.8	25.7	3.3
Horse Creek	16.8	60.6	3.6
Red Lassic Creek	12.0	38.4	3.2
Sulphur Creek	15.3	80.5	5.3
Thompson Creek	13.3	68.1	5.1
Tierney Canyon	12.3	43.1	3.5
South Fork Van Duzen River	14.6	38.8	2.7
Total	143.5	514.3	3.6

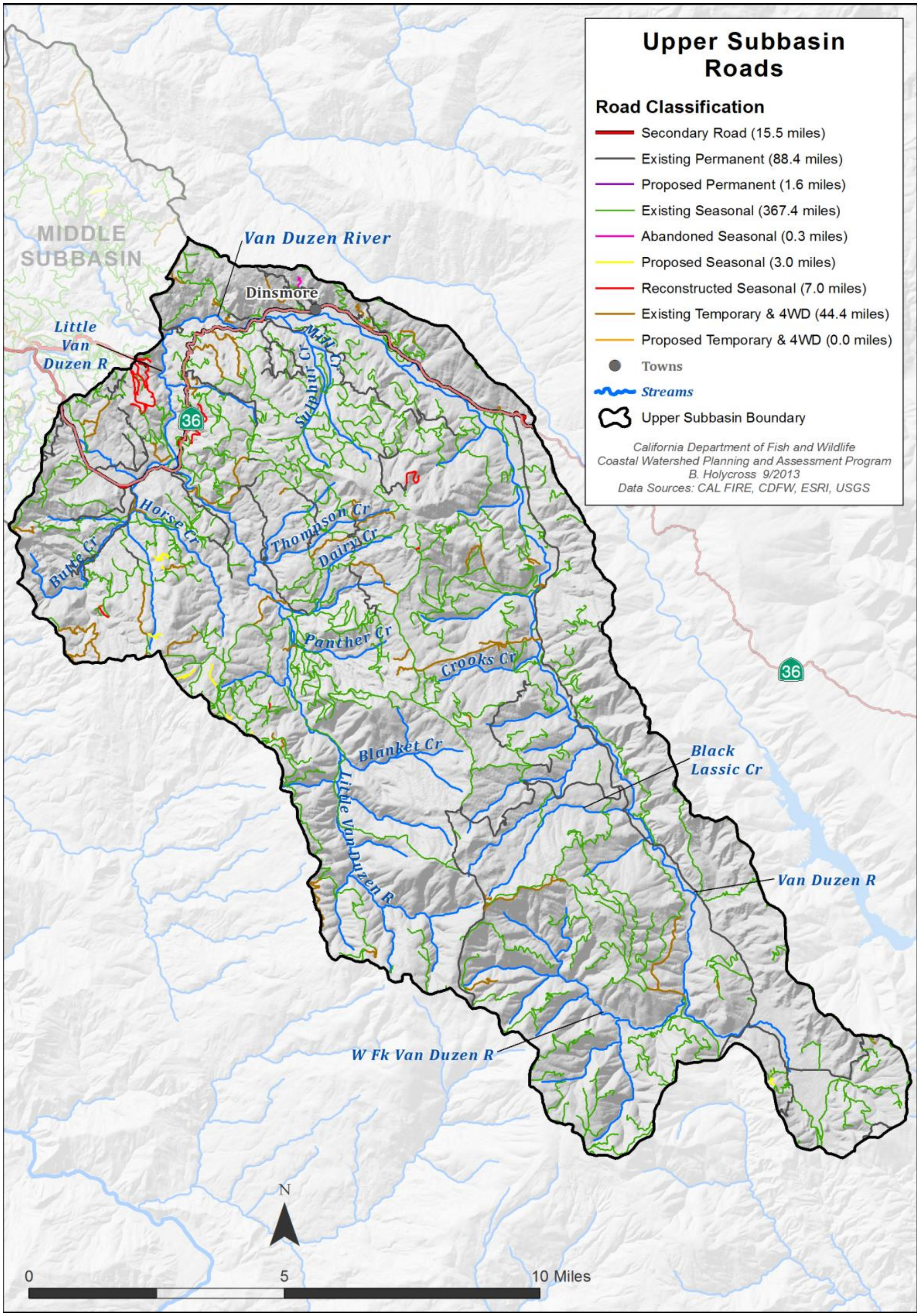

Figure 14. Upper Subbasin roads.

Fish Habitat Relationships

The stream habitat data collected from Upper Subbasin streams is twenty years old and may not be representative of current conditions. However, CDFW staff performed reconnaissance level surveys in reaches of the Little Van Duzen and Butte Creek in 2006 and 2007. These recent surveys found the streams in a generally good condition to support anadromous salmonids with a few habitat discrepancies. The reconnaissance survey summaries are located in Appendix III.

Fishery Resources

Salmon Falls in the Middle Subbasin blocks the passage of Chinook and coho salmon into the Upper Subbasin; therefore, the Upper Subbasin only supports populations of steelhead and resident rainbow trout. With the anadromous fish barrier of Eaton Falls located near RM 46 in the lower portion of the Upper Subbasin, potential steelhead distribution is almost entirely limited to the Little Van Duzen sub-watershed area. The Little Van Duzen River (Figure 14) flows into the Van Duzen River at RM 45 and contains approximately 13 miles of mainstem habitat and an additional 15 miles of tributary habitat available to support steelhead (Table 7 & 8). The most important tributary streams for salmonids are Butte Creek, Dairy Creek, Blanket Creek, and Lost Canyon Creek.

Table 7. Miles of stream accessible to anadromous salmonids in the Upper Subbasin of the Van Duzen River.

Stream	Steelhead	Chinook	Coho
Little Van Duzen River	13		
Butte Creek	6		
Horse Creek	1.1		
Swift Creek	0.4		
Thompson Creek	0.8		
Dairy Creek	1.3		
Panther Creek	0.96		
Dolores Creek	0.04		
Blanket Creek	1.3		
Bear Creek	1.0		
Lost Canyon Creek	1.4		

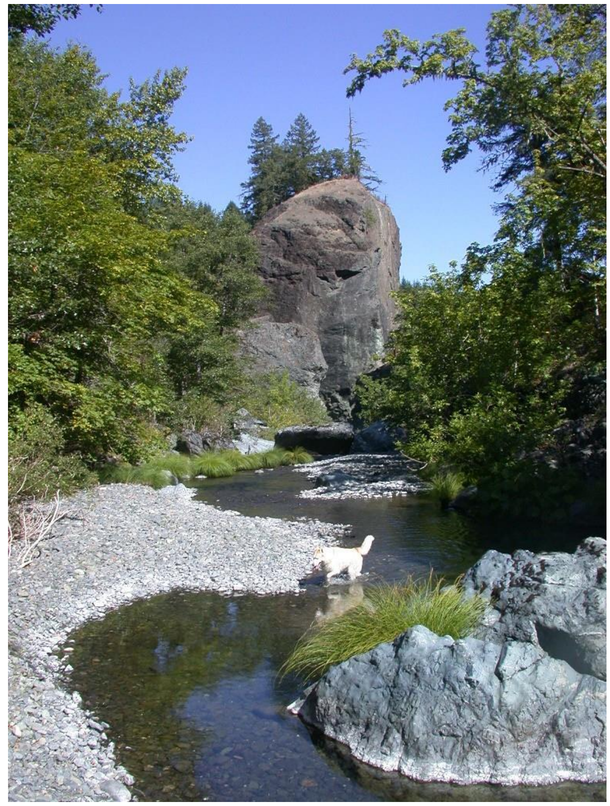

Figure 15. View of the lower Little Van Duzen River (SF Van Duzen).

Habitat Categories

Pool:Riffle:Run Relationships

Productive anadromous streams are composed of a balance of pool, riffle and runs. Each plays an important role as salmonid and stream community habitat. Flosi et al. (1998) suggests that the length of anadromous salmonid streams should be forty percent composed by pool habitats. In contrast, an over abundance of riffles can indicate an aggraded stream channel which often contributes to a reduction in pool occurrence, pool length, and depth.

Table 8. Habitat conditions in surveyed streams in the Upper Van Duzen River Subbasin

Stream Reach	Survey Year	Reach Length (feet)	Ave. Max Pool Depth	Pool:Riffle:Run % occurrence	Pool:Riffle:Run % length	%Length Dry
Little Van Duzen River	1992	71,890	2.5	33:37:30	23:41:35	1
Butte Creek	1992	31,817	2.5	35:30:35	35:21:44	0
Horse Creek	1992	5,861	1.9	34:11:23	28:11:38	24
Swift Creek	1992	2,235	0.6	13:25:13	4:2:3	92
Thompson Creek	1992	4,301	1.6	27:34:36	17:35:46	2
Dairy Creek	1992	6,817	1.8	22:38:29*	8:31:21	40
Panther Creek	1994	5,058	1.4	38:3:38	9:2:37	52
Dolores Creek	1992	226	N/A	33:66:1	7:93:0	0
Blanket Creek	1992	6,625	2.8	32:40:26	22:55:21	2
Bear Creek	1992	5,671		34:42:18*	5:37:16	42
Lost Canyon Creek	1992	7,511	1.4	25:36:36	9:44:37	10

*10% units dry in Dairy Creek and 6% dry in Bear Creek
N/A: no analysis performed because only 1 pool was observed.

Pool Depth

Significance: Deep pools are important habitats for adult and juvenile salmonids. Deep pools are needed for holding areas by adult salmonids during spawning activities and juveniles use deep pools for year round rearing, escape cover from predators and as shelter from high winter flows. During low summer flows or in streams with intermittent flows, deep pools may provide the only suitable salmonid habitat. A lack of deep pools can limit salmonid production.

The length of deep pool habitat in a stream reach is a geomorphic characteristic commonly used as an indicator of stream conditions. Pool depth and lengths are easily measured without significant observer bias. We use the term primary pool to indicate pools with relatively deep maximum pool depths. The target primary pool depths are scaled relative to the Strahler stream order of the surveyed stream reach. Primary pools are pools with maximum residual depths of at least 2.0 to 2.5 feet for 1st and 2nd order streams, ≥3 feet for 3rd order steams and ≥4 feet deep for 4th order streams (Flosi et al. 1998 and NCWAP 2001). We consider streams with approximately 25-60% of their length consisting of primary pools suitable for salmonids in terms of deep pools. DFW uses these indicator values to assess the pool condition of anadromous salmonid habitat with the Ecological Management Decision Support System (EMDS) and by inspection of maximum pool depth histograms (Table 8, Fig 15).

Findings: Inspection of pool depth data and the EMDS evaluation maps show a general shortage of deep pool habitat with corresponding low habitat suitability in the few surveyed streams of the Upper Subbasin (Fig. 15). For example, Panther Creek shows 38 percent pool occurrence but only 9 percent of the stream length is in pools, and the average maximum pool depth is only 1.4 feet. This implies numerous small pools in Fish Creek could be enlarged by addition of LWD.

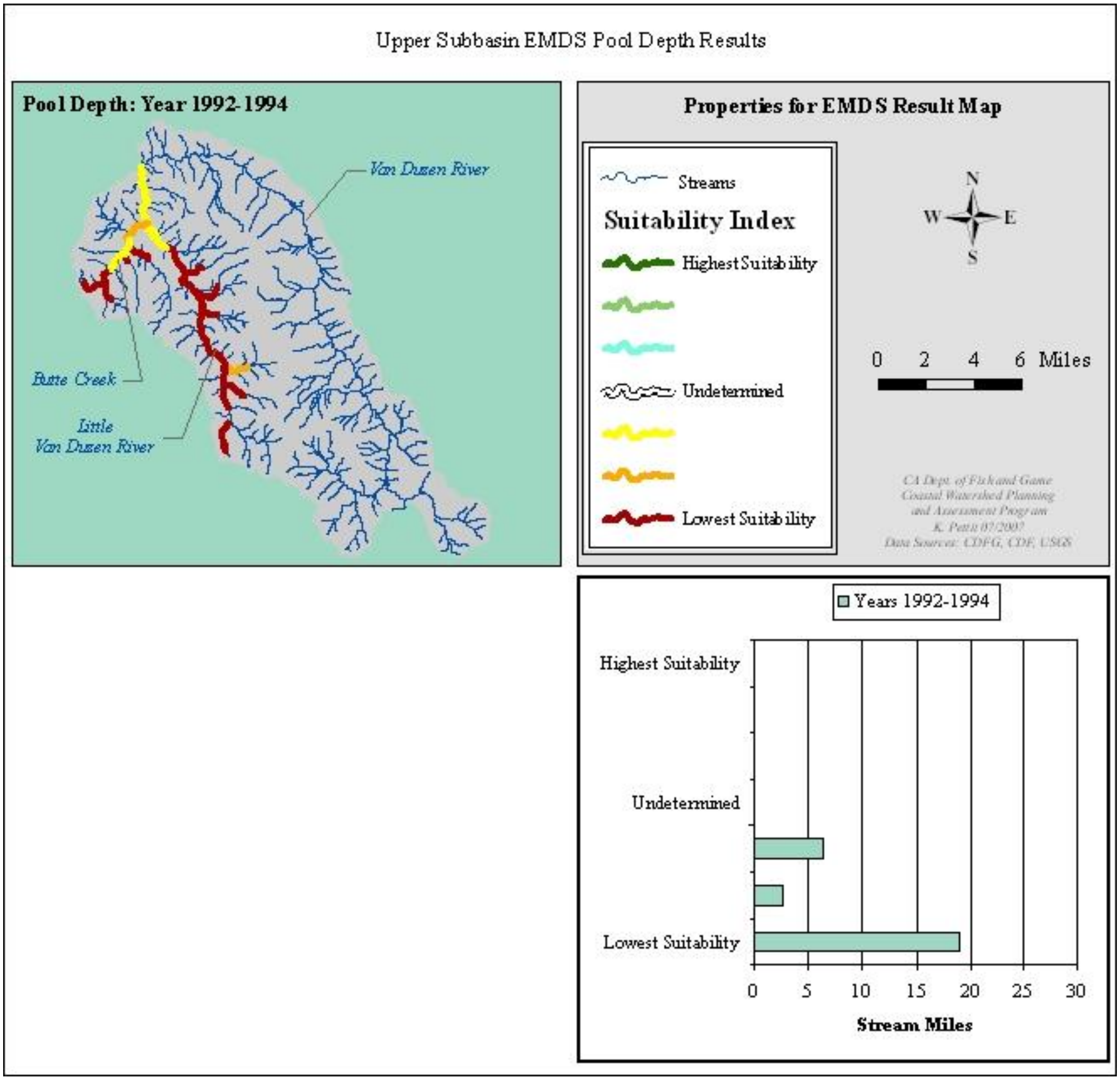

Figure 16. EMDS analysis of habitat suitability for salmonids based on pool depth from stream surveyed in 1992 and 1994.

Pool Shelter

Significance: Salmonid abundance in streams increases with the abundance and quality of shelter of pools (Meehan 1991). Shelter elements create areas of diverse velocity, provide protection from predation, and separate territorial units to reduce density-related competition. CDFG's stream survey protocol (Flosi et al. 1998), evaluates pool shelter complexity by a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation. The ratings range from 0-300, with ratings of ≥100 considered good shelter values. The ratings do not consider factors related to changes in discharge, such as water depth.

Findings: Pool shelter ratings were far below the 100 target value for all streams and stream reaches indicating a general shortage of instream shelter elements (Figs. 16 and 17). The highest shelter values were observed in small tributaries of the Little Van Duzen.

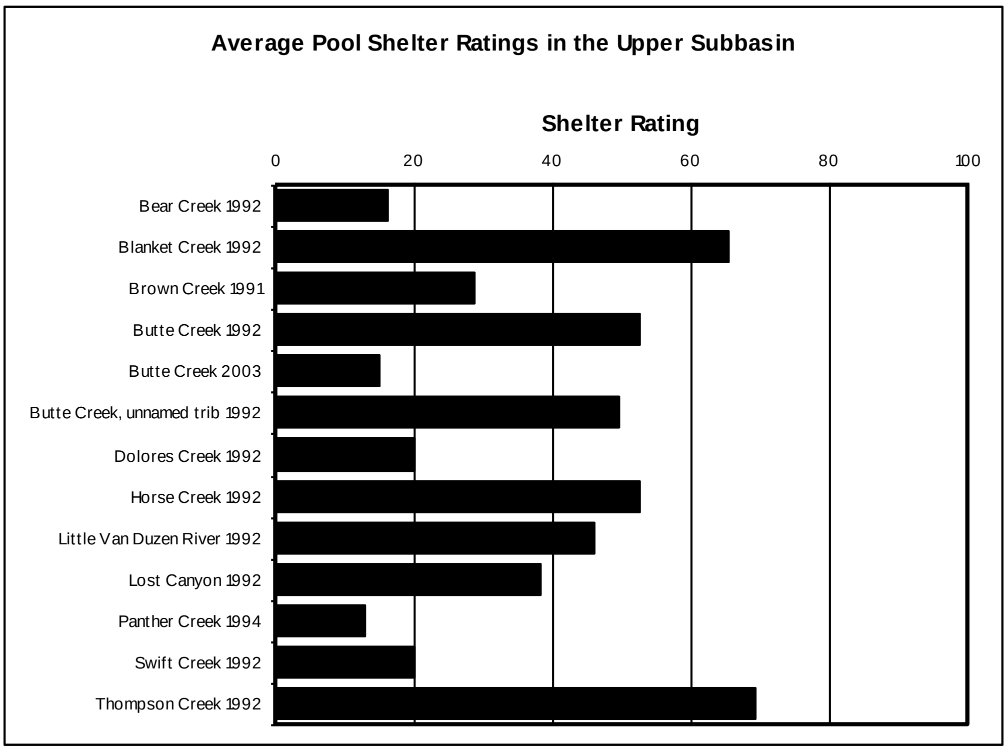

Figure 17. Average pool shelter rating in surveyed streams of the Upper Subbasin 1992-1994.

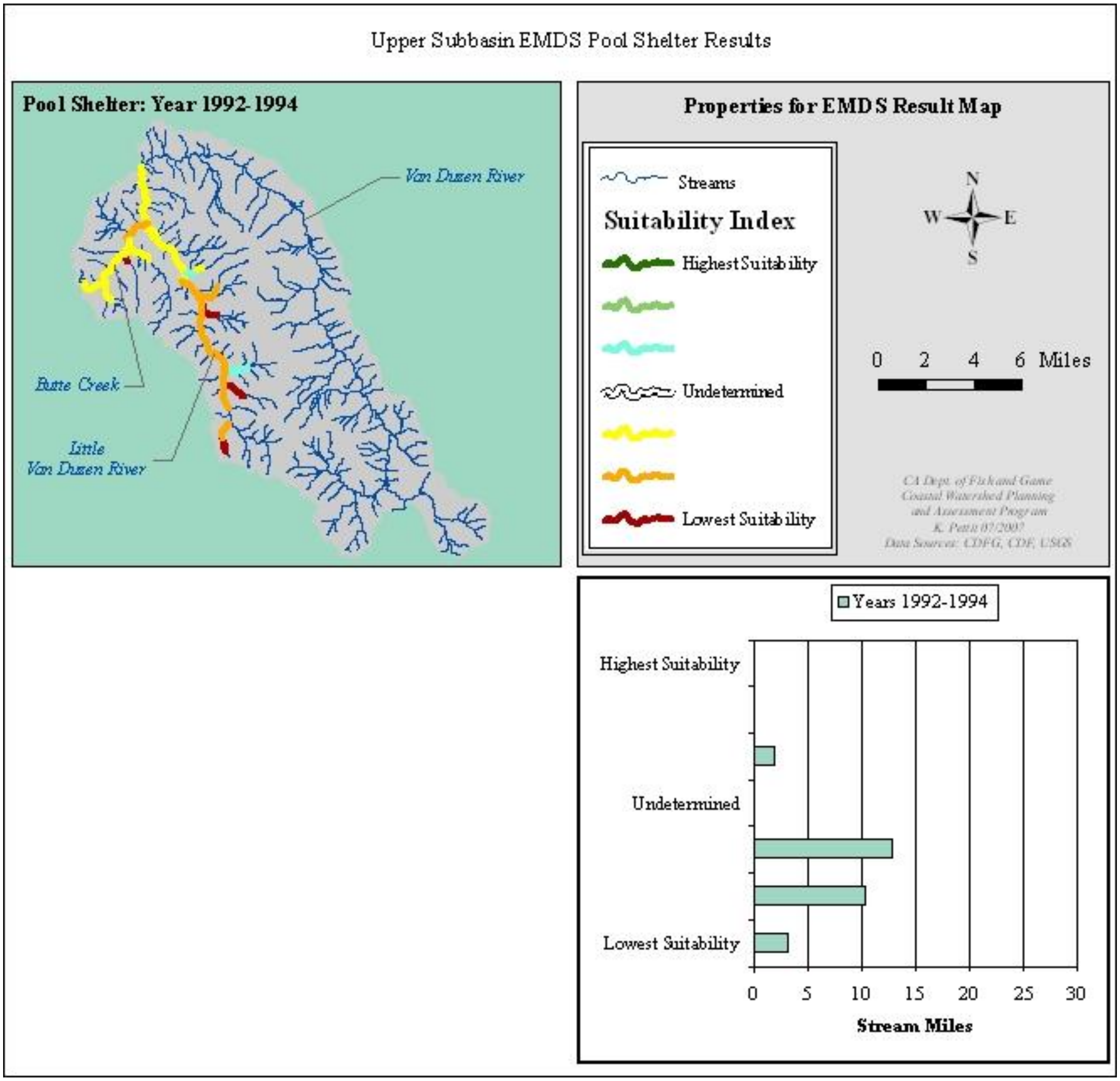

Figure 18. EMDS analysis of habitat suitability for salmonids based on pool shelter from streams surveyed in 1992 and 1994.

Spawning Cobble Embeddedness

Significance: Cobble embeddedness is the percent of an average-sized cobble piece embedded in fine grained sediments observed in pool tails. Pool tails are sampled because they are commonly selected areas for salmonid spawning. Percent cobble embeddedness provides a subjective measure of spawning substrate suitability for salmonid egg incubation, fry emergence and aquatic insect habitat. Embeddedness observations may indicate where excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds, which may suffocate eggs or developing embryos.

High embeddedness ratings may indicate elevated levels of sediment inputs and erosion problems occurring in the watershed. The potential for high levels of fine sediments in streams increases in watersheds of the Middle Subbasin where the unstable geology, high precipitation, steep topography, and land use cumulatively increase erosion potential. Some common land use activities that increases generation of fine sediment are clear cuts, roads, skid trails, and livestock grazing (Cederholm et al. 1981, Duncan and Ward 1985, Swanson et al. 1987, Hicks et al. 1991).

Gravels and cobble that are less than 25% embedded with fine sediments are considered good quality substrate for salmonid spawning and production of stoneflies, mayflies and other aquatic insects. Gravels and cobbles over 50% embedded are viewed as poor quality for salmonid spawning and can impair stonefly and mayfly insect production. At the stream reach scale, spawning cobble embeddedness is considered suitable if at least 50% of all pool tails have embeddedness measures of less than 25%. Pool tails that are covered by wood debris or by fine sediments are considered unspawnable.

Findings: The streams of the Upper Subbasin generally show relatively high levels of cobble embeddedness (Figs. 18 and 19). The high levels of embeddedness are an indication of excessive delivery of fine sediments to most Upper Subbasin streams. Salmonid spawning success is likely limited or impaired by the lack of good quality spawning habitat in these streams.

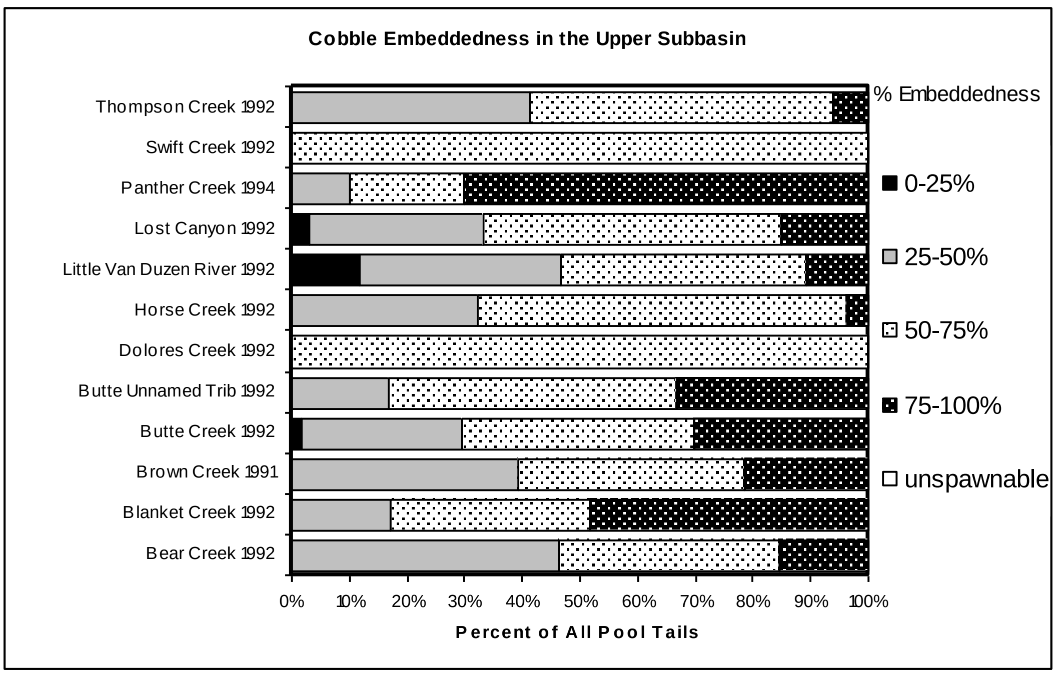

Figure 19. Cobble embeddedness in surveyed streams of the Upper Subbasin in 1992 and 1994.

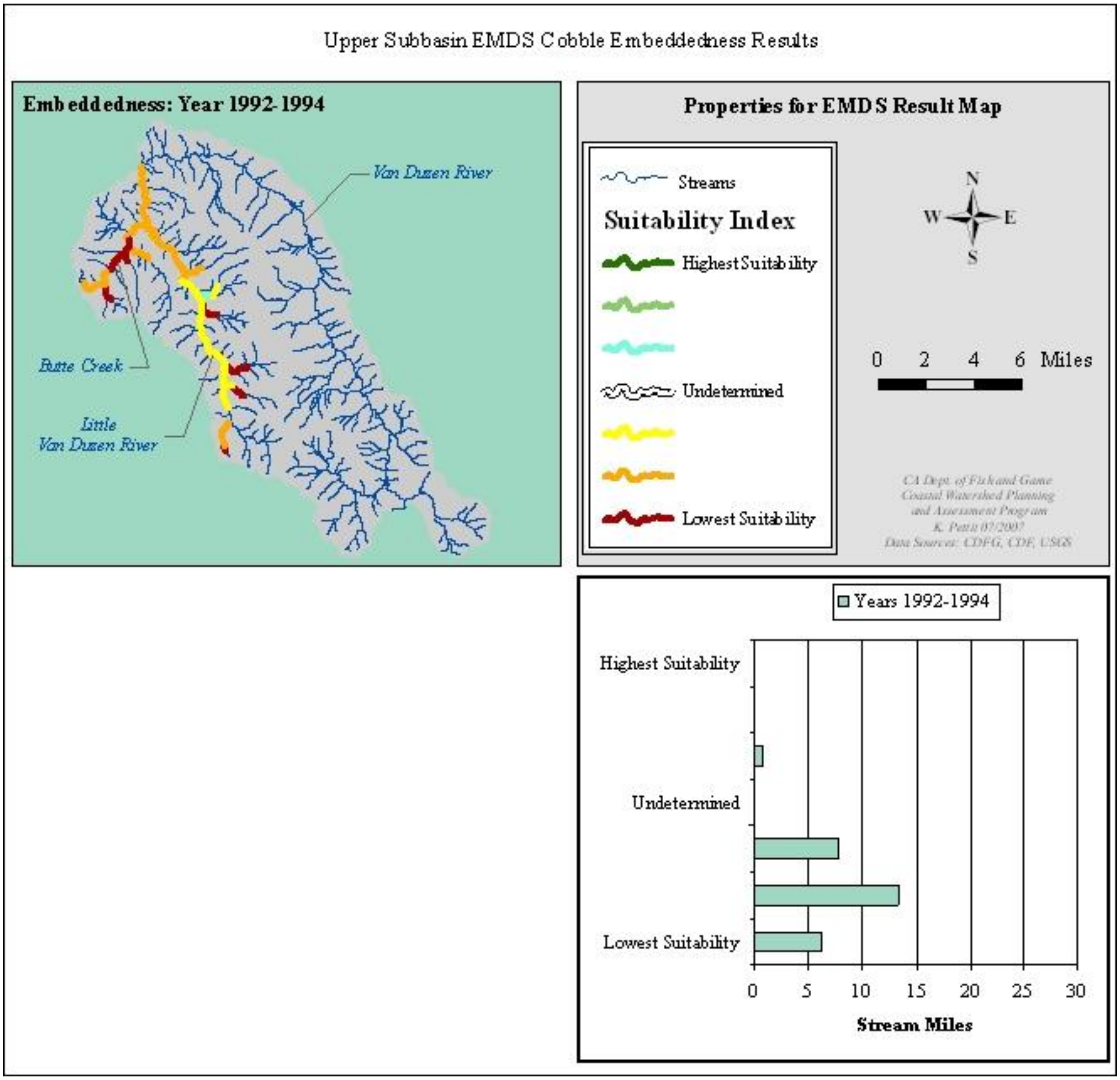

Figure 20. EMDS analysis of habitat suitability for salmonids based on cobble embeddedness from streams surveyed in 1992 and 1994.

Canopy Density

Significance: Streamside canopy density is an estimate of the percentage of stream channel that is shaded by riparian tree canopy. An effective tree canopy provides shade to reduce direct sun light from warming water and contributes to maintaining cool microclimates. The condition of streamside canopy can change relatively rapidly with management that removes trees or alternatively by allowing tree growth. Habitat improvement projects are considered when canopy density is less than 80% (Flosi et al. 1998).

A second measurable attribute of streamside canopy is the percent of coniferous and deciduous tree species providing the shade. The percent coniferous and deciduous component of the stream side canopy influences the potential for LWD loading and can influence microclimate.

Streams flowing through mature conifer stands tend to have larger amounts of wood with larger average piece size than streams with younger riparian stands, which often are dominated by smaller deciduous species (Bilby and Bisson 1998). LWD produced by conifers is generally favored over deciduous wood because it tends to be larger and less likely to move downstream, it decays more slowly, and stays longer in stream systems. The overstory shade produced by mature conifer stands also helps form cool microclimates along riparian zones which helps keep streams cool.

Findings: While canopy density was below the target value of 80% in most of the Little Van Duzen River, most of the small tributaries as well as Butte Creek had suitable canopy density values (Figs. 20 and 21). Although these streams had suitable levels of shade, the amount of overstory shade contributed by conifers is below 50% for all but two of the streams surveyed. The Little Van Duzen River had less than 20% shade contributed by conifers. The low amount of overstory conifer shade is indicative of small sized or absence of conifer trees along the riparian zones of surveyed streams. It usually takes approximately 40 years to establish mature conifer forest canopy in these coastal forests.

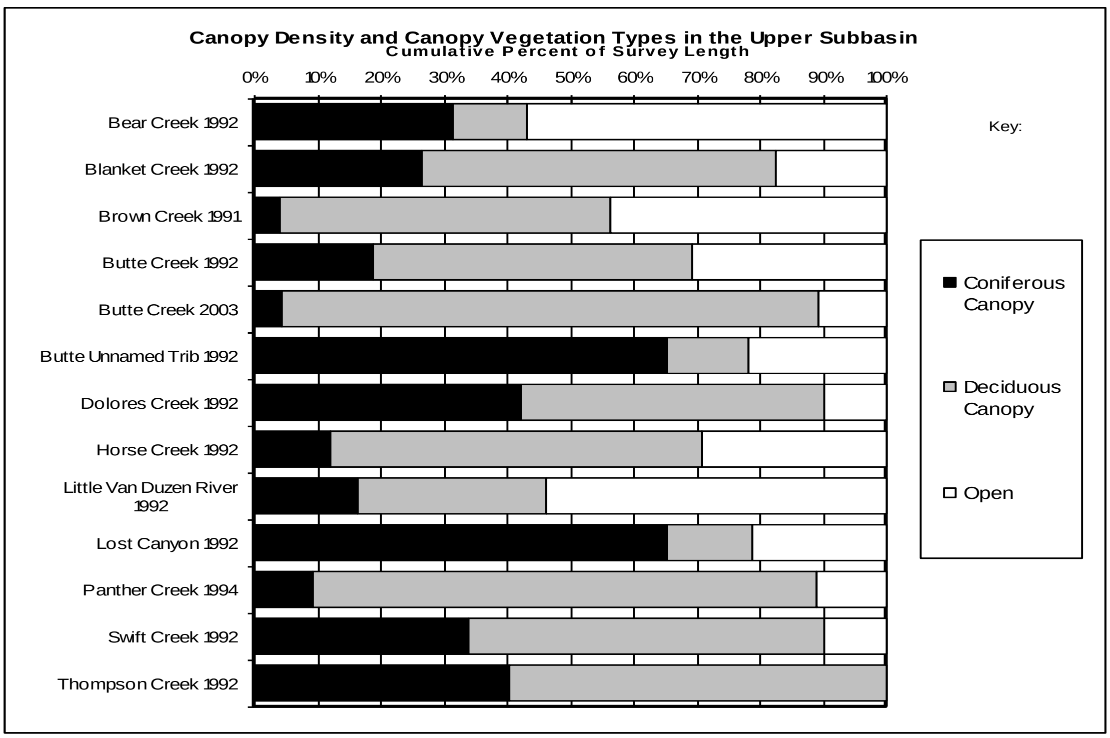

Figure 21. Canopy density and canopy vegetation types in the Upper Subbasin from surveyed in 1992 and 1994.

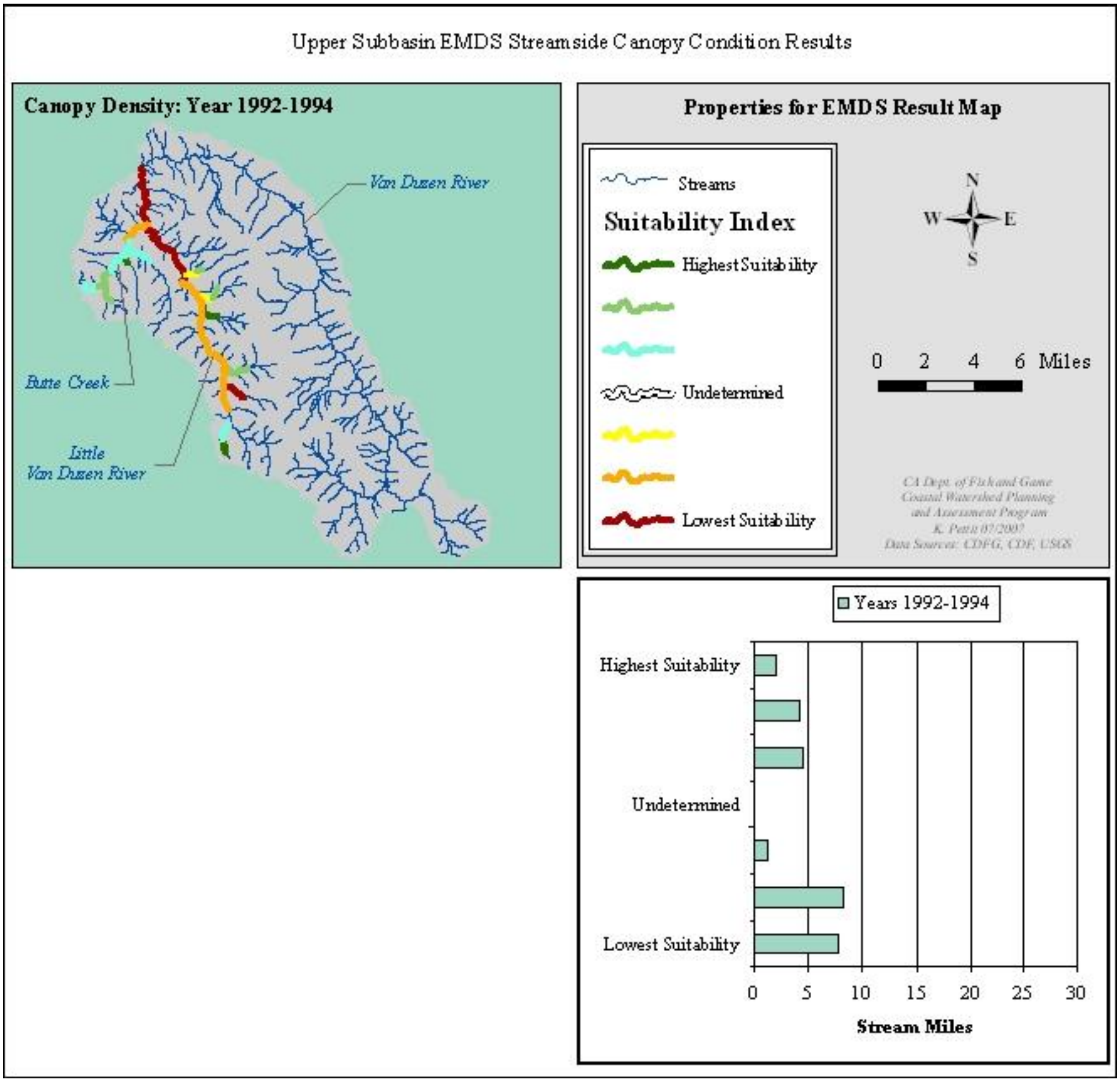

Figure 22. EMDS analysis of habitat suitability for salmonids based on streamside canopy from streams surveyed in 1992 and 1994.

Watershed Improvement Projects

A small sampling of salmonid focused watershed improvement projects have occurred in the Upper Subbasin including road upgrade/decommission, stream crossing removal/upgrade, and upslope management (Fig. 22). The fish passage project consisted of the placement of a series of boulder weirs in Butte Creek to help facilitate fish passage at a multiple culvert stream crossing. Bank stabilization projects were completed in Burr Creek and along the mainstem Van Duzen River. Road improvements/decommissions occurred in the very lower and very upper portions of the subbasin.

More information on restoration projects such as date and specific location can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis. edu/nrpi/). Recommendations for potential restoration projects are located below in the Subbasin Scale Responses to Assessment Questions (pgs. 30-33).

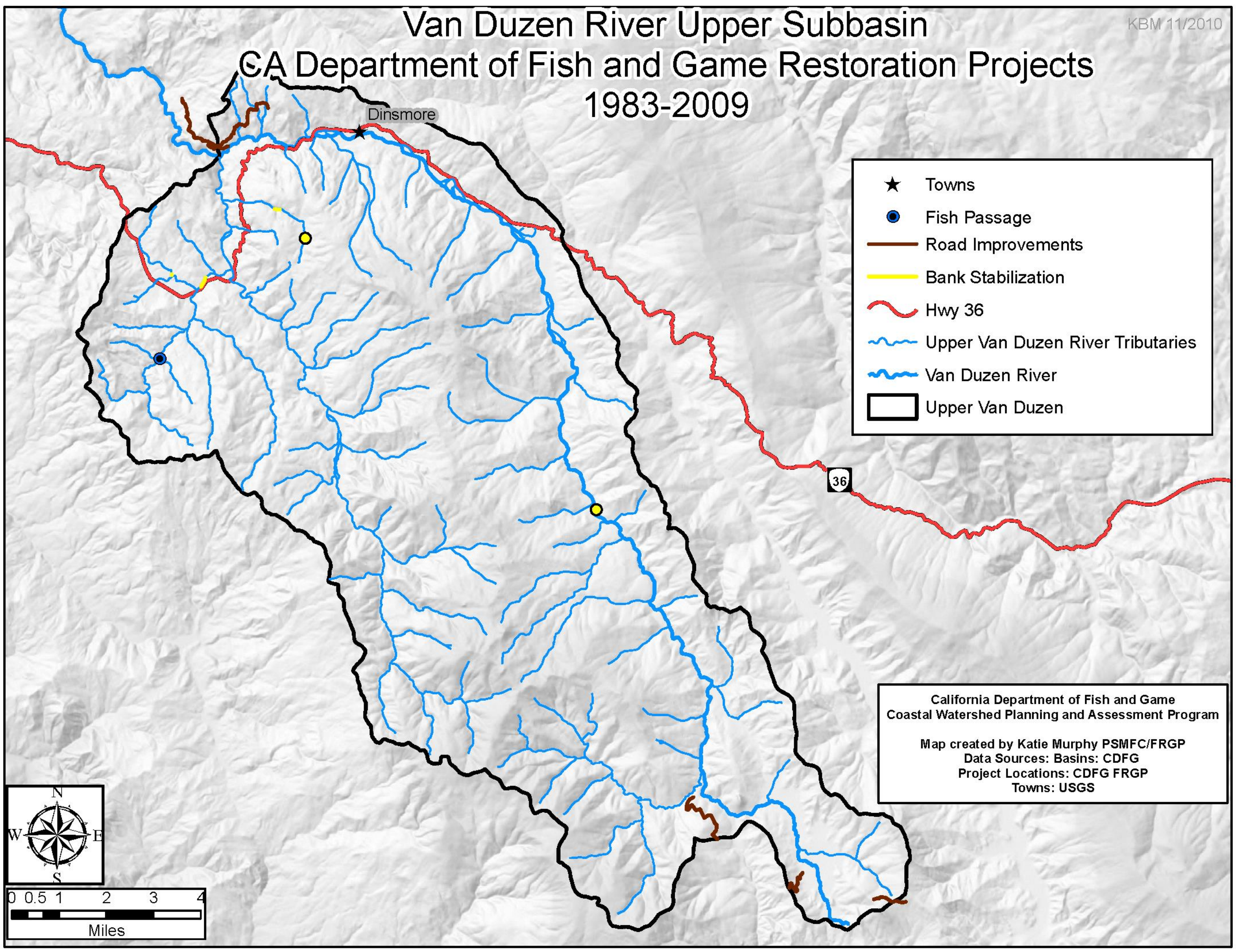

Figure 23. California Department of Fish and Game completed restoration projects in the Upper Subbasin from 1983 to 2009.

Subbasin Scale Responses to Assessment Questions

The following discussion of the assessment questions and recommendations for improvement activities are generalized to the subbasin scale.

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Upper Van Duzen Subbasin?

- Historically, it is unknown if Chinook and coho salmon were ever able to access the Upper Subbasin due to the presence of the barrier at Salmon Falls (RM 37). The channel configuration at the falls may have been different then its present form; however, there are no reported sightings or anecdotal records of either of these species within the subbasin;
- During periods of suitable stream flow conditions that are conducive to passage at Salmon Falls, winter steelhead have been able to access the Upper Subbasin. Eaton Falls, located in the lower portion of the Upper Subbasin at RM 46 prevents the further upstream migration of steelhead in the subbasin, therefore, anadromous steelhead distribution is limited to the Little Van Duzen River and its tributaries;
- Historically, the Little Van Duzen River had a small run of summer steelhead as far up as Panther Creek, approximately RM 7.5 (CDFG 1981). Summer surveys are no longer conducted in the Little Van Duzen River as it is believed that summer steelhead are no longer distributed in the Little Van Duzen;

What are the current salmonid habitat conditions in the Upper Van Duzen River Subbasin? How do these conditions compare to desired conditions?

- Even with recent high rainfall years, decreased summer water flows to tributaries is occurring, which in turn, has decreased summer and early fall base flows in the Van Duzen River and in the Little Van Duzen River;
- Increased nutrient, pollution, and sediment input into streams are all leading to impairment of habitat for fish, amphibians, and other wildlife;
- The Little Van Duzen River provides 13 miles of potential habitat for steelhead and rainbow trout;
- In addition to the Little Van Duzen River mainstem, the most important tributary streams for steelhead are Butte Creek, Dairy Creek, Blanket Creek, and Lost Canyon Creek. These and a few other tributaries provide an addition 15 miles of potential steelhead spawning and rearing habitat;

What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?

- The Upper Subbasin is naturally prone to earthflows, landslides, and erosion during high winter flows;
- Unconsolidated sediment stored in terrace deposits and gravel bars by previous large flow events is easily mobilized and redistributed during high winter river flows;
- Unstable, erodable bedrock, frequent seismic movement, high regional uplift rates, high seasonal rainfall, and land use activities recruit large amounts of sediment into the stream system;
- Large flow events play a major role in aggradation, degradation, as well as other changes in channel morphology;

- Middle Subbasin channel aggradation and sediment storage has been exacerbated by severe erosion in the upstream subbasins;
- Because of the low gradient of the mainstem as well as the lower reaches of several tributaries the Middle Subbasin acts as a sediment deposition as well as a transportation reach depending on flow and the amount of sediment entering the system;
- Unconsolidated sediments perched steeply above the stream are prone to bank erosion and sliding contributing sediment input to the streams;
- Unstable, severely erodable bedrock, frequent seismic movement, high regional uplift rates, high seasonal rainfall, and land use activities recruit vast amounts of sediment into the stream system;
- Soils and bedrock of the Upper Subbasin are easily eroded;
- Uplift has increased the erosion potential of the area;
- Rapid incision rates of the mainstem and its tributaries have left very steep, high banks which increase its likelihood for rockfalls and landslides;
- Multiple faults cut through this area shearing the bedrock and making it less competent;
- Frequent earthflows and deep-seated landslides within the mélange are especially active during heavy storm events and/or seismic events contribute a significant amount of fine sediments to the stream.

How has land use affected these natural processes?

- The present condition of the Upper Subbasin is in part the result of land use activities occurring within the subbasin;
- Primary causes for stream habitat deficiencies can often be traced back to land management actions that reduce stream flow, degrade water quality, increase erosion, and/or activities that alter characteristics of near stream forests;
- Within the past 10 years increasing conversions on private property of large, industrial marijuana agriculture operations have proliferated in the Upper Subbasin. These mostly unregulated operations have decreased summer/early fall stream flows and degraded water quality in Van Duzen River, the Little Van Duzen River and its tributaries;
- A total of 25 percent of the subbasin’s conifer forests were involved in timber harvest activity from 1991 to 2008. The majority of the timber harvest activity occurred in the lower to middle portion of the subbasin;
- The naturally high potential for erosion of the hill slopes and sediment delivery to stream channels is elevated by land use such as road construction, timber harvest operations and other land use that disturbs top soil or weakens slope stability;
- Some common land use activities that increases generation of fine sediment are clear cut logging operations, roads, skid trails, and livestock grazing.

What habitat improvement and other activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Flow and Water Quality Improvement Activities:

- Instream flows to maintain fish habitat in good condition and channel maintenance flows should be preserved during any existing water diversion activities and considered prior to any new water development projects including riparian diversions, industrial marijuana agriculture operations, small domestic water use and water extraction from near stream wells;
- Consider private landowner water storage and forbearance programs were large capacity storage tanks are operated as part of a seasonal water management program;
- Assess roads and implement road improvement projects to reduce sediment delivery to fish bearing streams, especially in watersheds with high road densities and higher rates of timber harvest, such as Thompson Creek, Dairy Creek, and Panther Creek;
- Reduce fine sediment inputs by avoiding land use on inner gorge slopes and mitigate to reduce sediment inputs for any land use near streams on slopes greater than 25 percent;
- Intact forests of increasing age structure and complexity will have a greater water holding capacity than impaired watersheds, where forests are of a single dimension and lack complexity.

Erosion and Sediment Delivery Reduction Activities:

- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams;
- Review potential for bank stabilization projects along the Van Duzen River and the Little Van Duzen River.

Riparian and Stream Habitat Improvement Activities:

- Pool enhancement projects should be implemented at select, existing pool habitat units to increase depth and add shelter complexity on the middle to upper reaches of the Little Van Duzen River as well as Butte Creek;
- Consider adding elements to recruit and retain spawning gravels in the lower Little Van Duzen River and Butte Creek;
- In order to decrease summer and fall high water temperatures in the Little Van Duzen River seek opportunities to increase coniferous tree overstory shade canopy along the Little Van Duzen River by plantings and/or thinning hardwoods around small conifers.

Monitoring, Education and Research Activities:

- Perform fish surveys on the Little Van Duzen River and some of its tributaries, such as Butte Creek, Dairy Creek, Blanket Creek, and Lost Canyon Creek to update current knowledge of presence and distribution of anadromous salmonids;
- Several years of monitoring summer/early fall stream water and air temperatures to detect trends using continuous, 24-hour monitoring thermographs should be done in the Little Van Duzen River;

- Monitor summer/early fall water quality parameters in the Van Duzen River and the Little Van Duzen River;
- Conduct community based outreach meetings to discuss approaches that could be implemented to help address the problems created by industrial marijuana agriculture practices;
- Continue outreach and education by local agencies and organizations to rural residents regarding proper road design and maintenance.

Appendix A

Yager Creek Subbasin
Stream Field Notes

Blanton Creek

Blanton Creek is a tributary to Yager Creek located at approximately RM 7.6 and provides approximately 5000 feet of stream habitat accessible to anadromous salmonids. Chinook salmon and steelhead have been recently documented to use Blanton Creek. Stream surveys were conducted between 1980 and 2006 and the respective field notes are summarized below.

<u>Field Note December, 1980:</u>

The first qualitative stream survey of Blanton Creek was conducted in December, 1980. The survey report noted that there were several debris jams that often included upstream sediment accumulations. The debris and sediment jams were considered passage barriers to upstream salmonid spawning grounds. The pool to riffle ratio averaged 1:3, stream banks were consistently stable and shade canopy provided by redwood and other conifers averaged 90 percent.

<u>Field Note April, 1982:</u>

A second survey conducted in April, 1982 found similar debris jams and passage barriers, but also noted streamside landslides occurring on both sides of the creek about 1,000 feet above the mouth and very turbid water. Shade canopy was from alders, tan oak and redwood trees and averaged 70 percent. Both surveys made recommendations to modify debris jams to facilitate fish passage.

<u>Field Note August, 1985:</u>

A survey in August 1985 noted that work completed by the California Conservation Corps had been successful in removing some passage barriers but not all of them. Juvenile steelhead (yoy) were noted as abundant in the lower reach and then abundant, stressed and confined to intermittent pools in the upper reach. Low streamflow in the upper reach had replaced barriers as a limiting factor to salmonid production. Additional project work in Blanton Creek included construction of rock wing and log deflectors for bank protection, scour pool formation and spawning gravel retention structures. These are not listed in the CDFG habitat improvement database.

<u>Field Note June, 1991 and June, 2006:</u>

Additional stream surveys and habitat inventories were conducted on Blanton Creek by CDFG in early June, 1991 and again in June, 2006. These surveys noted approximately ten pool enhancement structures performing well in both 1991 and in 2006, as well as a functioning fishway built at the mouth in 1991. Passage barriers formed by debris jams were eliminated. In contrast to earlier surveys, the pool to riffle percent occurrence ratio had improved to approximately 1:1, but pools made up only 21 and 25 percent of the stream length in 1991 and 2006 respectively. The average residual pool depths were 1.8 feet in 1991 and 2.2 feet in 2006. The increase in pool habitat and pool depths noted in 2006 compared to 2001 may signal successful function of in stream habitat structures. In addition, cobble embeddedness measurements also showed a trend towards improvement of spawning gravel suitability, but there are still signs of bank instability and erosion that delivers fine sediments to the channel. Stream side canopy had increased to approximately 88 percent canopy over water in 2006 compared to 66 percent 1991. However most of the shade is produced form understory canopy. There is still a shortage of large redwoods capable of providing overstory shade and LWD as channel forming elements and instream shelter. Qualitative electrofishing surveys in 1991 and 2006 did not find juvenile steelhead in high abundance, but did observe presence of both 0+ and age 1+ year classes at each sample site.

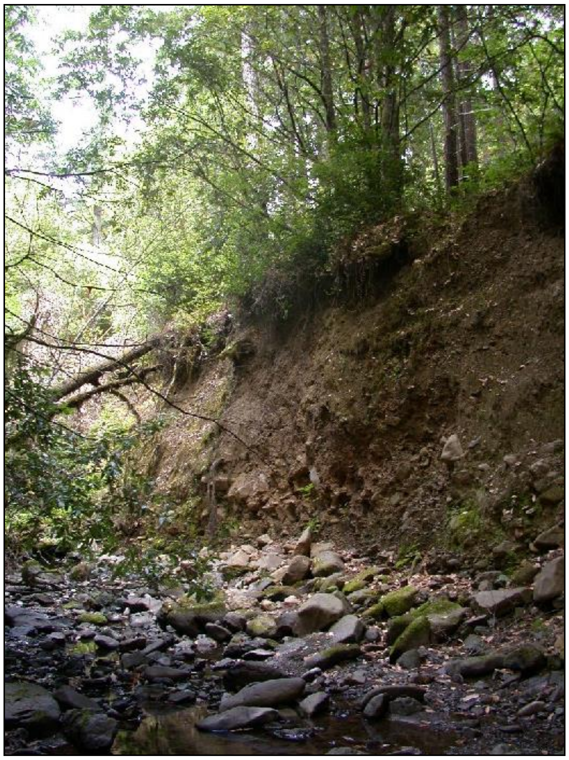

Figure 1. Blanton Creek armored plane bed channel, bank erosion into pre-historic landslide deposits, intermittent flow and lack of large trees needed for shade and LWD loading.

Figure 2. Mouth of Blanton Creek, August 16, 2006.

Coopermill Creek

Coopermill Creek is a tributary to Yager Creek located at approximately RM 2.8. At this time, Historic stream surveys were limited to general reconassaince surveys in January of 1979.

Field Note January10th and 16th, 1979:

In 1979 chinook salmon entered Coopermill Creek on Jan 10. A total of 41 redds and 21 live fish were counted on Jan. 16.

Lawrence Creek

Lawrence Creek is the largest and most significant salmonid tributary within the Yager Creek Subbasin. It is located in lower Yager Creek with its confluence at RM 9. Chinook and coho salmon are thought to have access of approximately 6.6 stream miles within the mainstem Lawrence Creek (just upstream of the Fish Creek confluence). At this point the channel gradient increases and the stream flows through a narrow canyon for about 2,000 feet, which generally precludes passage of coho and Chinook; however, steelhead habitat extends almost another 6 miles. Addition Chinook and coho salmon habitat are available in several tributaries of Lawrence Creek, notably Shaw and Fish creeks.

Stream surveys were conducted between 1938 and 2006 and the respective field notes are summarized below.

Field Note August 8, 1938:

The first survey of Lawrence Creek was conducted by CDFG in the upper reach near the Yager-Kneeland Road crossing on August 8, 1938. This early survey characterized the area as rolling grass covered hills, with some timber, but the dominant trees were oaks. The creek averaged 9 feet wide, spawning gravel was in good condition, water temperature at 12:40 pm was 58 F, the estimated stream flow was 1 cfs, pools and fish shelter were in good condition and juvenile steelhead (1 to 5 inches) were common.

Field Note June 9, 1952:

Another survey conducted on June 9, 1952 noted logging operations at the fork of Lawrence Creek above the Kneeland Road crossing and many log jams in the creek. In addition, the report notes a stream fishermen in three hours caught 33 trout ranging in size from 4 to 7 inches at log jams. Two of these were males (5 inches) that were ripe with milt.

Field Note August 26, 1964:

A third CDFG survey of Lawrence Creek was conducted August 26, 1964. The stream survey report notes that poison oak, heavy brush, and second growth redwoods grow on canyon slopes and near the streambed brush and hardwoods predominate. The average stream width six miles upstream was 5 feet with an estimated flow of 2 cfs and a depth in flatwater of 6 inches. The creek width near the mouth was 7 feet, with a depth of 10 inches and a flow of 4 cfs. Most pools throughout the survey ranged from 2-3 feet deep and there was a pool to riffle ratio of 1:1. Spawning conditions were considered excellent with ½ to 3 inch gravel in riffle areas. There was very little silt or algae covering the gravel. Instream shelter was provided by undercut banks, shaded pools and some large boulders. There was also a log jam of approximately 600 yards long and 40 yards wide located about ½ mile downstream of the Shaw Creek confluence. The log jam was considered a potential barrier to fish passage, although, numerous trout (2-8 inches) and a large number of “fingerling salmonids” were captured throughout the stream with beach seines.

Field Note December 3, 1969:

Field note from December 3, 1969 reported that a study reach about ¼ mile below Bell Creek was composed of 95% riffles by length with a good gravel bottom. Streamside vegetation provided moderate shade. During an electrofishing effort juvenile steelhead (1.5 to 2.5 inches) were common and a few fish 5 inches in length were caught. At a second location, about two miles downstream of Bell Creek, Lawrence Creek was much more open and the stream bed was composed of cobble and boulders. About 95% of the stream length was composed of small pools. Steelhead observed from electrofishing samples were noted as very abundant, in excellent condition and in two size ranges (1-2 inches and 4-6 inches). If this the case then when this happens the dynamics of the pool will changes

A second field note prepared July 17, 1972, noted that there were no known barriers to fish passage, but five log jams were present between 5 and 7 miles from the mouth. The average water temperature was 67 F which is considerably higher than noted in previous surveys. Silver salmon and steelhead fingerlings were observed throughout the seven mile survey reach.

Field Notes June, 1991and August, 2006

Recent stream surveys and habitat inventories were conducted on Lawrence Creek by CDFG in early June, 1991 and again in August, 2006. Data summaries for 1991 and 2006 are shown above. Data for 1991 surveys are summarized in three stream segments of different lengths in Lawrence Creek: 1) Lower, starting at the mouth to 32,900 ft.; 2) Middle (32,900 to 43,100 ft.); and 3) Upper (43,100 to 64,600 ft.). The length of the 2006 survey was 31,900 feet in length and is comparable with the Lower stream segment surveyed in 1991.

A comparison between the two (1991 and 2006) surveys of the lower segment reveals an increase in both pool occurrence and percent of stream length in pool habitats in 2006. The increase is in part due to the addition of about 12 pool forming, instream habitat structures that were built from 1990-1998. In addition to creating pool habitats, these structures made of boulders and large wood pieces also provide shelter and cover for fish. Juvenile salmonids were observed at the structures in densities much higher than aggraded and featureless (no cover) run and riffle habitat commonly found in the lower three miles of Lawrence Creek. The pool enhancement structures succeeded in filling a void left by the near absence of LWD for scour pool forming elements and shelter in the lower reach (*Figures 35 and 36*).

More recently, CDFW collected stream hobo temperature data in the upper reach of Lawrence Creek (just downstream of the Shaw Creek confluence ~RM 5.5) from mid-July to mid-August, 2016. Mean Weekly Average Temperatures range from 16ºC to 17.8ºC and the Mean Weekly Maximum Temperature ranged from 17.1ºC to 19.3ºC. While not representative of the entire summer months, the limited data indicates suitable water temperature during a portion of the extreme stream temperature period and would not be considered a limiting factor to summer juvenile rearing.

Figure 1. Instream habitat structures made of LWD form pool in Lawrence Creek

Figure 4. Lawrence Creek plane bed channel August 15, 2006. The lack of LWD means no pools here.

Shaw Creek

Shaw Creek is a tributary to Lawrence Creek located at RM 4.5. Large debris accumulation is a barrier to fish passage on Shaw Creek. The jam is located approximately 1.5 mile from the confluence with Lawrence Creek. There is approximately one mile of coho habitat located above the passage barrier (cite).

Figure 3 displays the results of Shaw Creek Chinook salmon carcass surveys during the years of 1987 to 2009. Linear regression analysis and ANOVA tests of Shaw Creek spawner survey data indicate no significant change or trend in the redd numbers (R^2=0.024, P value=0.486) or peak numbers of Chinook salmon (R^2=0.104, P value=0.143) observed from 1987 to 2007. Number of survey efforts shown by the blue bars are also displayed numerically.

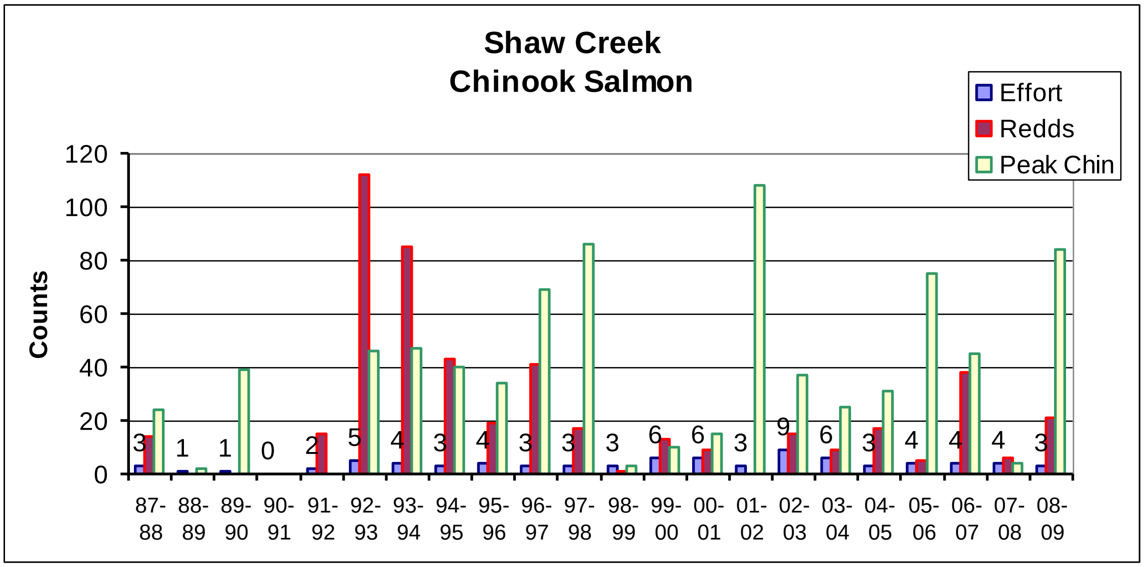

Figure 3. Shaw Creek Chinook salmon carcass surveys from 1987 to 2009.

Appendix B

Lower Subbasin

Stream Field Notes and Spawner Survey Data

Wolverton Gulch

Wolverton Gulch is a smaller tributary to Barber Creek located in the western portion of the Lower Subbasin. Wolverton Gulch flows mostly in a north to south direction between the towns of Rohnerville and Hydesville. Passage impediments include a sediment delta at mouth and culverts on Highway 36 and Rohnerville road. Stream surveys were conducted in 1963 and 1978 and the respective field notes are summarized below.

Field note 1963:

Survey area was from mouth of Wolverton Gulch to 0.5 miles upstream. The terrestrial landscape was characterized as flat farmland. Stream flow was measured as ~ 1cfs, pool depths ranged up to 3 feet deep, a pool riffle ratio of 1:2 and a stream bottom characterized as heavily silted, course gravel. Salmonids were reported as numerous, ranging from small (1 inch) up to 8 inches long.

Field note April 24, 1978:

Stream survey was conducted 0.25 miles above Rohnerville Road. Stream flow was measured as 2-3 cfs, and water temperature was 49ºF at 0930. Three juvenile coho salmon (approximately 1 inch long) were collected using electroshocking techniques.

Cummings Creek

Cummings Creek is a right bank tributary to the Van Duzen River located in the Lower Subbasin at River Mile (RM) 7.9. There is approximately 3.37 miles of stream habitat accessible to anadromous salmonids. Stream surveys have been conducted in 1938, 1952, 1961, 1964, 1966 and 1994 and the respective field notes are summarized below.

Field Note August 16, 1938:

Shapovolov and Vestal (1938) conducted a stream survey of Cummings Creek on the lower mile of the creek**.** They recorded that many juvenile salmonids were present, spawning habitat was in excellent condition and extensive, pools and shelter were in good condition, and a water temperature of 64ºF was reported. Debris from logging was also noted.

Field Note January 14, 1952:

Approximately three miles of Cummings Creek was surveyed on January 14, 1952. Despite extensive logging debris noted as choking the stream for most of its length, particularly near the headwater reach, it was considered an excellent steelhead and coho salmon spawning stream with numerous, highly suitable gravel sites. The stream substrate was mostly composed of gravel with some cobble. Pools were numerous and shelter was very good. The mouth of the creek was noted to dry up during summer months.

Field Note June, 1961:

In June 1961, a survey completed on the lower 3.5 miles of Cummings Creek documented the vegetation as predominantly second-growth redwood, Douglas fir and alder with a thick underbrush growth of willow, berry vines and poison oak. The report notes 24 debris accumulations above Highway 36 that ranged in volume from 250 to 18,500 cubic feet. These accumulations were composed primarily of logging debris in the form of redwood logs and slash. The pool riffle ratio below Highway 36 was reported as 50:50 and composed of 70% riffle and 30% pools above the Highway bridge. The pools were measured as 2 to 4 feet deep and 6 to 8 feet wide. The riffle substrate was composed mostly of gravels from 1 to 6 inches in diameter.

The survey also noted two 80 X 4 foot culverts that pose as fish migration barriers and cause flow problems as they become obstructed at the upstream openings. The culverts were used for railroad crossings that are no longer needed.

Field Note December 15, 1964:

Three miles of Cummings Creek was surveyed to determine the abundance of spawning salmonids. A total of 16 Chinook salmon carcasses, one Chinook skeleton and six live Chinook were observed during the survey.

Field Note March 7, 1966:

A barrier survey was conducted from Highway 36 up to 1.5 miles upstream. . A pool riffle ratio was reported as 1:1, and the stream substrate was composed of loose gravel and a fair amount of quality spawning area. Six large log jams were also noted.

Field Note August, 1994:

In August 1994 a representative reach of Cummings Creek was electrofished to determine the abundance and biomass of salmonids. The reach was 29 meters long and yielded 140 juvenile steelhead and an estimated population of 154 fish. The majority of fish were young–of–the–year with several yearling up to 140 mm present. Steelhead density was estimated at 1.85 fish/meter with a biomass of 9.12 grams per square meter. No coho salmon were captured from the sight.

Cummings Creek Recovery Plan (1997)

Lastly, in 1997, a recovery plan (author) for the Cummings Creek watershed was developed, primarily due to sediment deposition and deltas in low gradient reaches near the confluence with the mainstem Van Duzen River which impede salmonid migration. Subsequent efforts were made to re-route a failing road, decommission an old road bed, replace stream crossings with flat car bridges, and instream improvement work.

Spawner Survey Data

Spawner surveys were conducted in Cummings Creek from 1984 to 2005 (Figure 1). Efforts varied from year to year and during several years no surveys were conducted.

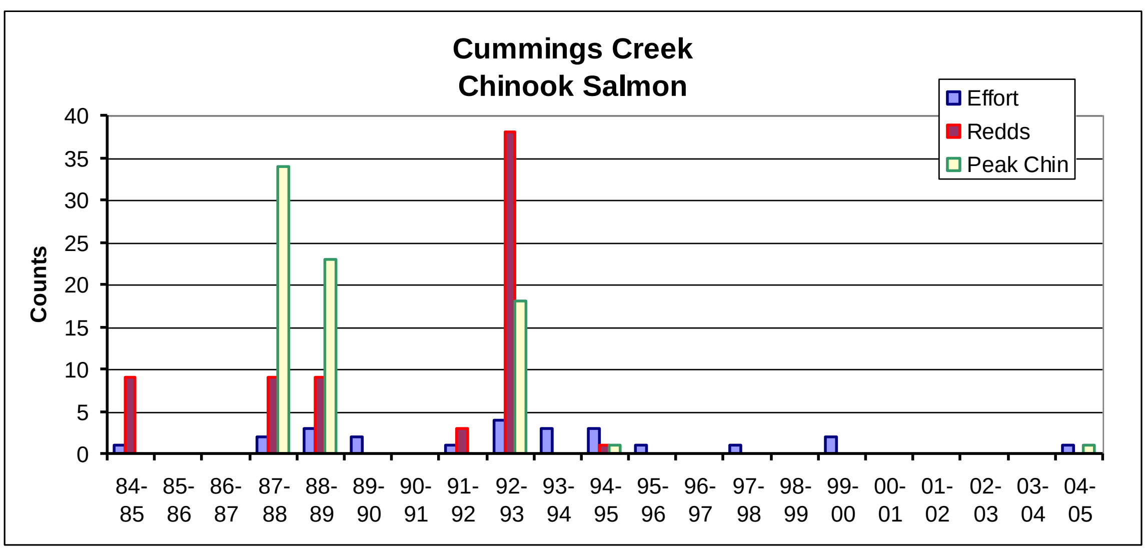

Figure 1. CDFG spawner survey data of Chinook salmon from 1984 to 2005.

Hely Creek

Hely Creek is a right bank tributary to the Van Duzen River located in the Lower Subbasin at approximately RM 14.7. Stream surveys have been conducted in 1938, 1960, 1974, and 1983. The respective field notes are summarized below.

Field Note August 17, 1938:

In a stream survey by Shapovolov and Vestal (1938) it was noted that Hely Creek supported abundant numbers of steelhead and coho salmon. They stated that "natural propagation was extensive and pools and shelter were considered in good condition". Recorded water temperature was 55ºF. They also noted that Hely Creek received heavy fishing intensity.

Field Note August 22, 1960:

On August 22, 1960 CDFG conducted a stream survey in Hely Creek. The area had been logged over recently prior to the survey and the slash was poised for delivery to the stream channel during high water. Flow was reported as approximately 2-3 cfs, there was a good pool riffle relationship, and pools were reported as ranging from 6 inches to 3 feet deep but pool bottoms were covered with silt. In addition, there were adequate undercut banks and collections of woody debris including second growth redwood.

Field Note 1974:

A CDFG field note from Hely Creek states that "during past logging activities it is apparent little regard was given the stream". Much slash and standing timber was reported as sliding into the creek, and many debris jams were silted in causing barriers to fish passage (CDFG 1974).

In 1979 a request was granted by CDFG to Louisiana Pacific (LP) to obtain a shade canopy exemption for a timber harvest plan and for the removal of the merchantable instream log jams (CDFG 1979). CDFG requested to work closely with LP during the project.

Field Note 1983:

In 1983 after heavy rains a debris torrent flooded Hely Creek with large cull logs, slash and sediment (Figure 2) The probable source of the debris torrent was noted as a tributary involved in recent harvest activities (CDFG 1983).

Figure 2. Debris torrent buries lower Heley Creek in 1983. The site is located approximately 1100 feet up Redwood House Road from HWY 36.

Figure 3. After clean up of debris torrent in Hely Creek. Photo taken in 1983.

Figure 4. Riparian vegetation encroaches in Hely Creek channel. The stream forms a braided shallow channel around small islands of sediment and vegetation. Photo taken in 2006.

Figure 5. Hely Creek, photo of vegetation, gravel island and debris blocking channel.

At extremely high fine sediment loading (Figures 5 & 6), the entire channel may become buried by a blanket of fine sediment. Hence the spatial distribution of fine sediment can indicate the relative magnitude of the fine sediment load, but the calibration of this indicator will vary with channel type and other factors such as the local geology (Schnackenberg and MacDonald 1998).

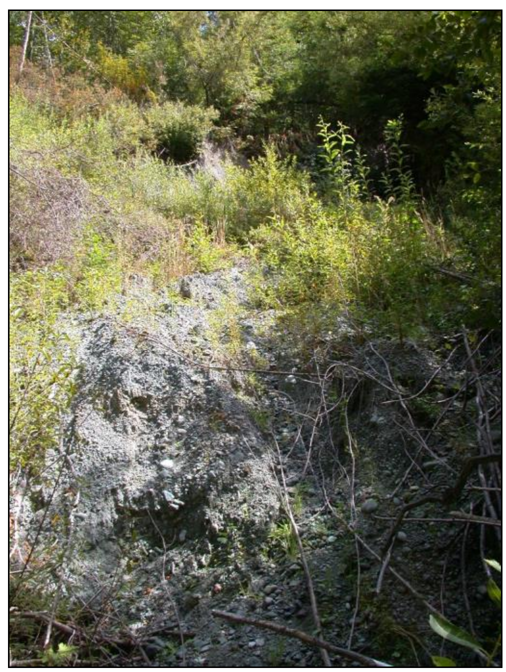

Figure 6. Hely Creek (~1600 feet above Highway 36) showing signs of high delivery of fine sediments in 2006.

Root Creek

Located at RM 20, Root Creek is one of the largest and most important tributaries to anadromous salmonids in the Lower Subbasin, however the stream is considered to be in poor condition attributed primarily to intensive timber harvest activities in the past. Primary limiting factors to salmonids in Root Creek are intermittent stream flow, a series of large debris accumulations that block or impede fish passage, and a shortage of good quality spawning substrate.

A recon survey was done on Root Creek on August 29, 2006. The survey crew described how Root Creek flows parallel to Van Duzen River through river terrace deposits for approximately 2,000 feet before entering the Van Duzen River. At the time of the survey this was a dry reach with a streambed composed predominantly of sand and fines.

Figure 7. Confluence of Root Creek and Van Duzen. Fish access into Root Creek may be limited during low flows by sediment accumulations at creek mouth.

Figures 8 and 9. Lower Root Creek. Just upstream of mouth (left) and dry cobble substrate channel about 50 feet further upstream (right). Photos taken August 29, 2006

Figures 10 and 11. Lower Root Creek transition reach. Channel changes from dry cobble bottom to silt laden reach (left). Further upstream (RM 0.5) flows form pool habitat (right). Photo taken August 29, 2006.

Spawner Survey Data

Spawner survey data collected by CDFG from 1987- 2000 show relatively large runs of Chinook salmon in Root Creek in 1987 and 1988, with a count of 176 and 188 respectively (Figure 12). In 1988, a total of 162 redds were counted which is at least 4-fold greater than any other survey year. The highest level of effort of any year in the survey also occurred in 1988. Number of redds and Chinook were dramatically lower from 1989-1990. The number of redds counted in 1989 and 1990 was five and four respectively. The number of Chinook counted in 1989 and 1990 was zero and six respectively. From 1991-1993, the number of redds increased and were consistent averaging 40 redds, however the number of Chinook ranged from three to 30 to 12 respectively. The number of redds and fish counted dropped to zero or near-zero levels in 1995, 1997, 1998, and 2000 (no spawner surveys were conducted in 1994, 1996, and 1999); however the number of surveys per year (measured by effort) was reduced following 1993 which may account for some of the declines. In addition to 1994, 1996, and 1999, no spawner surveys were conducted following 2000; efforts ceased due to access problems, lack of fish, and logistical issues. Access to Root Creek requires crossing the mainstem Van Duzen River which is often dangerous in the spawning season due to high river flows.

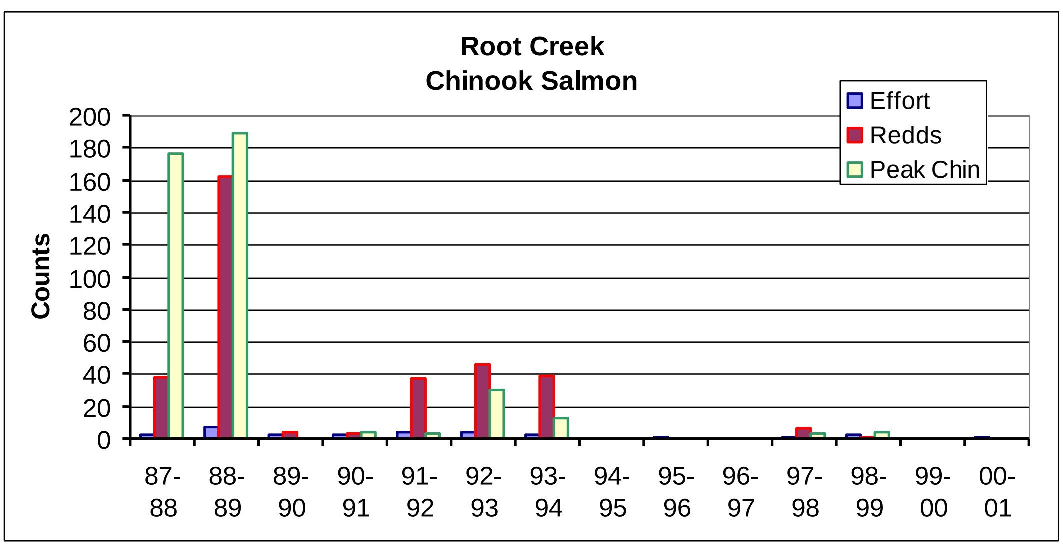

Figure 12. CDFG spawner survey data of Chinook salmon from 1987 to 2000. No data recorded in survey years 1994-95, 95-96, 96-97, 99-00, and 00-01.

Grizzly Creek

Grizzly Creek's confluence with the Van Duzen River is located approximately RM . Grizzly Creek is an extremely important Chinook- producing stream. Spawner surveys have been conducted by CDFG from 1982-1983, 1990-1995, and from 1998-2008 (Figure 13). In a 1982-83 CDFG spawner study of 40 Eel River tributary streams, Grizzly Creek had the highest estimate of Chinook carcasses of all tributaries in the Eel River Basin. CDFG estimated there were approximately 266 ± 104 Chinook carcasses in Grizzly Creek, based on the recovery of 27 of the 61 marked carcasses from a total of 119 of carcasses examined. Other survey years with high Chinook counts include 90 redds in 1994-95, 190 live Chinook in 2001-02, and nearly 60 live Chinook observed in 2005-06.

Grizzly Creek does not support high numbers of coho salmon. Three coho carcasses were observed on January 7, 1983, and only four live coho were observed from a total of 40 tributaries included in the study (Leos and Mills 1983). No coho were positively observed during the 1990-1995 and 1998-2008 surveys.

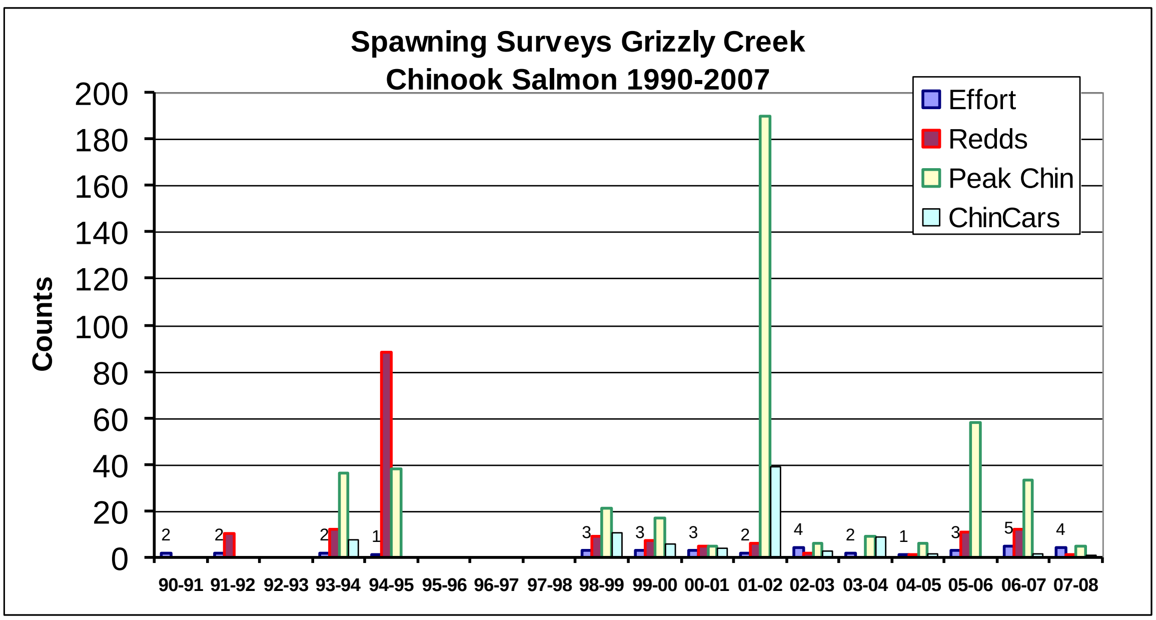

Figure 13. Grizzly Creek spawner surveys 1990 -1995 and 1998 to 2008 to determine counts of Chinook redds, live Chinook observed, Chinook carcasses, and survey effort expended.

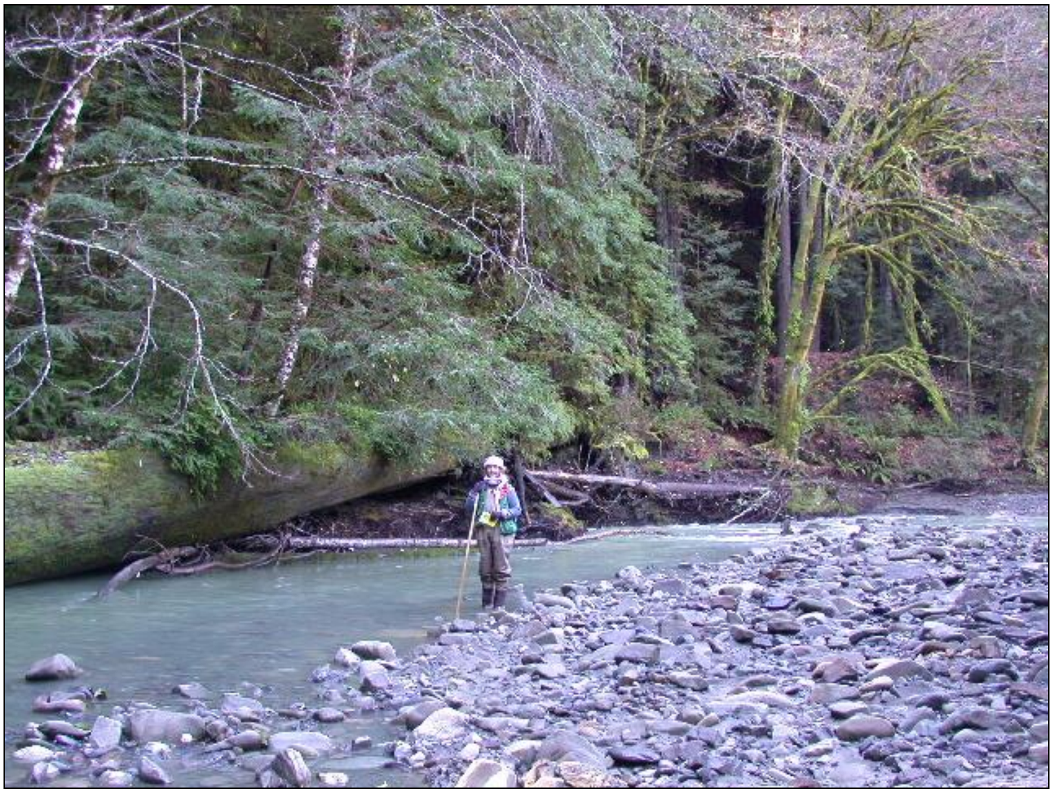

Figure 14. Grizzly Creek.

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