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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.

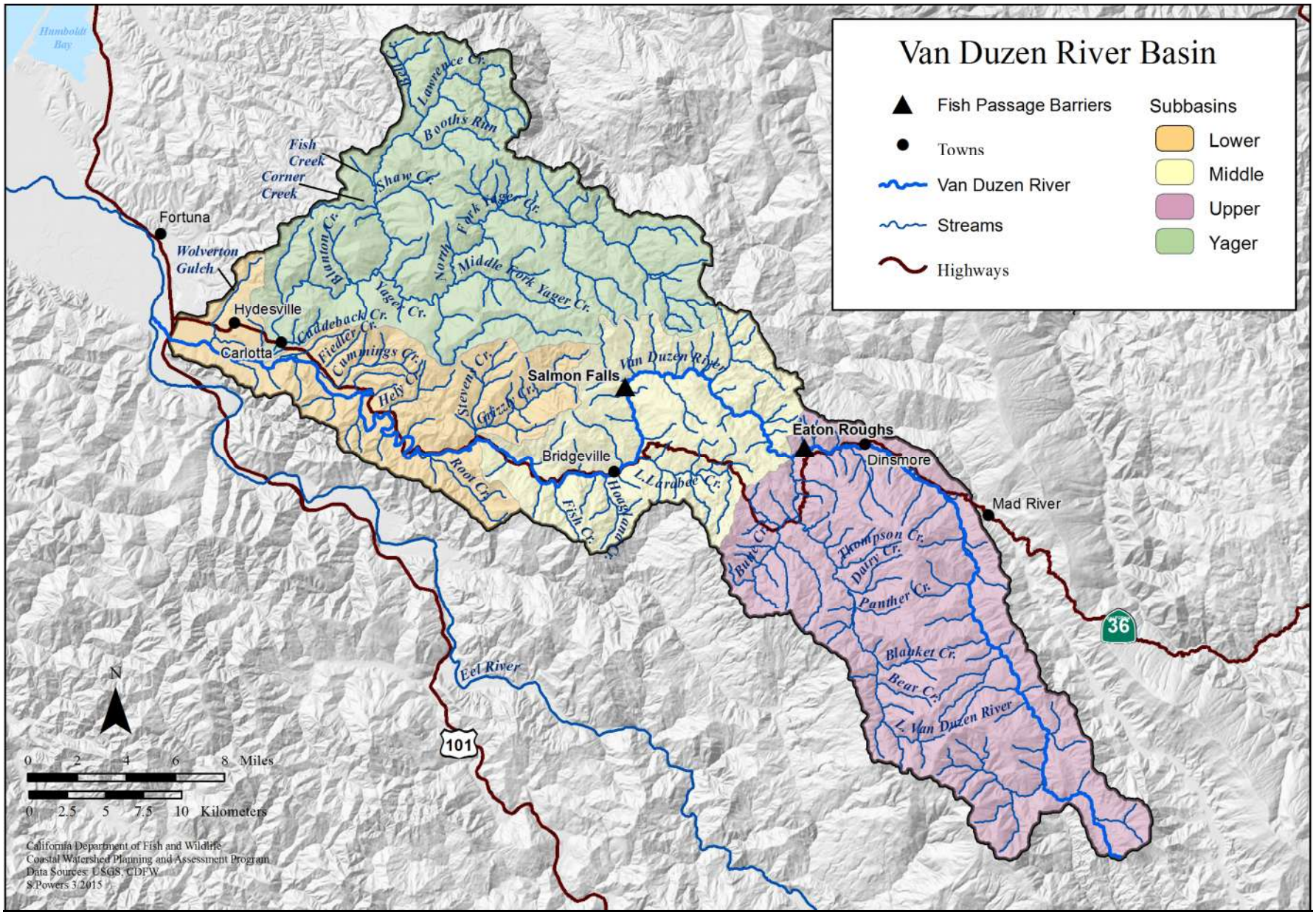


Figure 1. Location of the Van Duzen River Basin and subbasins in Northern California.

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.

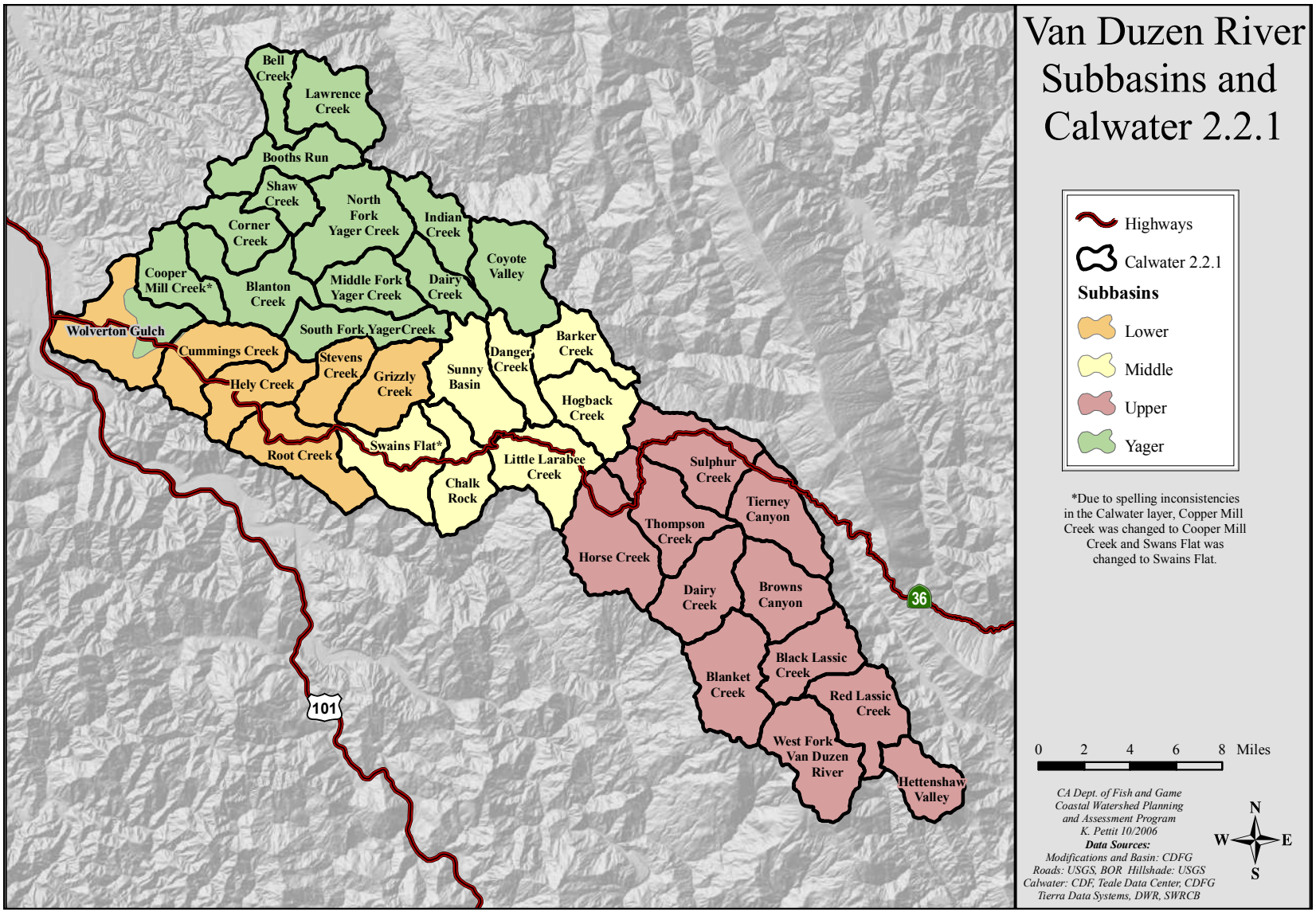


Figure 3. Van Duzen River subbasins and planning watersheds based on Calwater 2.2.1.

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)	88	45	27	0	160
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).

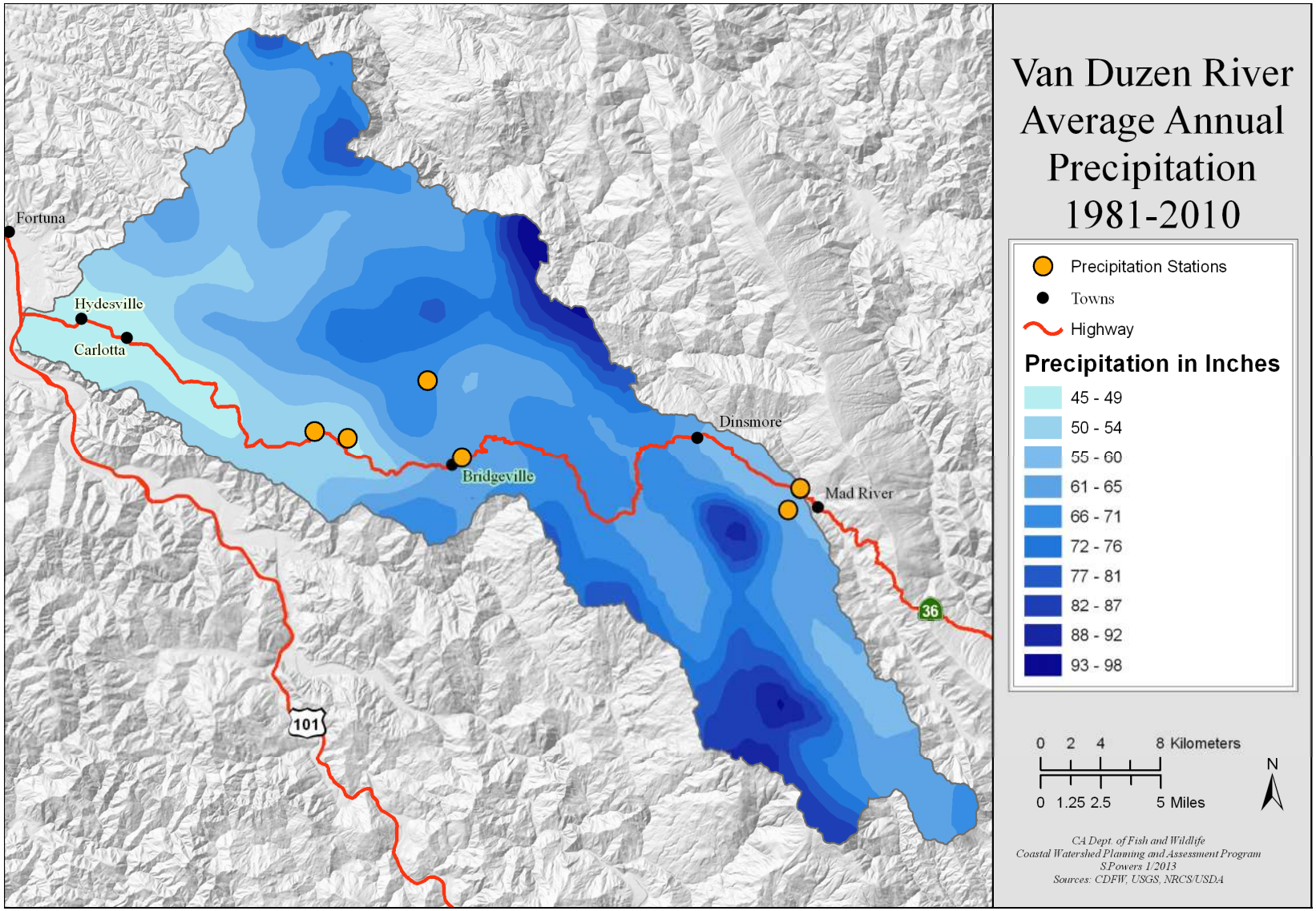


Figure 4. Average annual precipitation from 1961-1990 in the Van Duzen River Basin.

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, McLauglin, 2000.

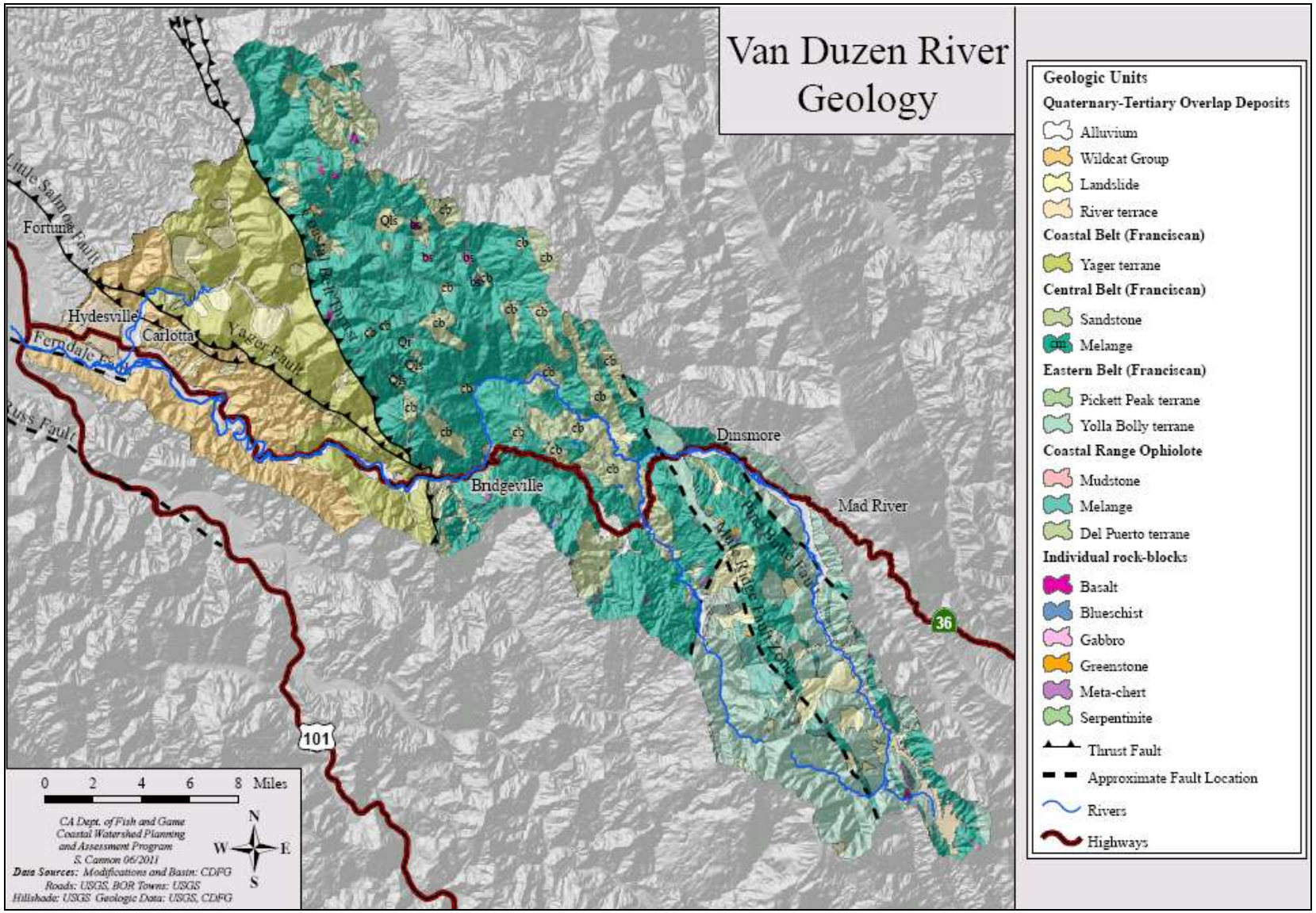


Figure 5. Simplified geologic map of the Van Duzen Basin. Modified from McLaughlin et al.2000.

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.

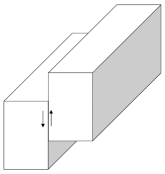
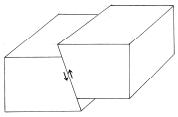
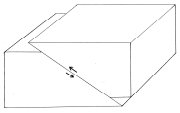
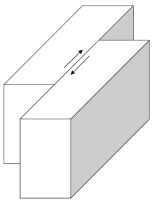
Fault Type	Description	Diagram
Vertical	A fault in which relative movement between the hanging wall and the foot wall occurs along a vertical plain.	
Reverse	A fault in which the hanging wall moves upward relative to the footwall along a plain who's dip is between 46° - 89°	
Thrust	A fault in which the 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.

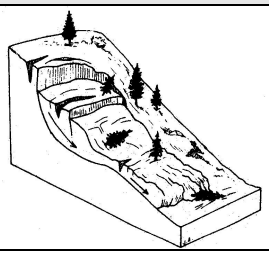
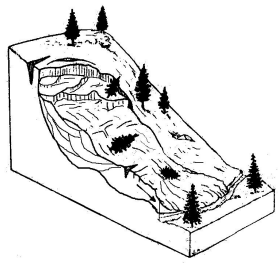
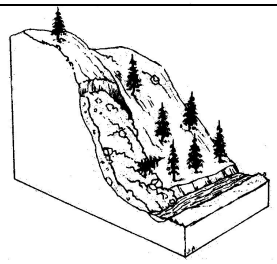
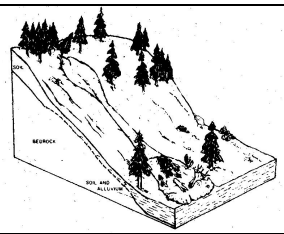
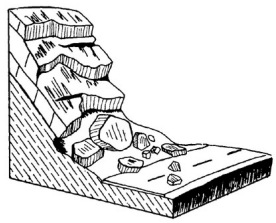
Fault zones are also extremely prone to landsliding and earthflow movement due to their weakened lithology or tectonic movement.

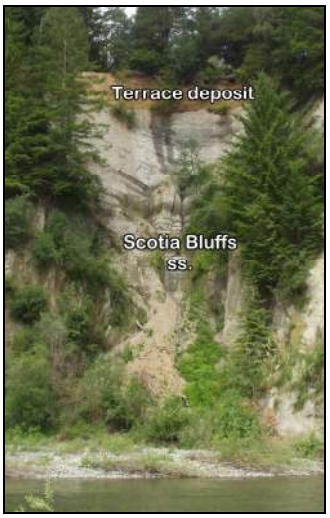
Slope Inclination

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.

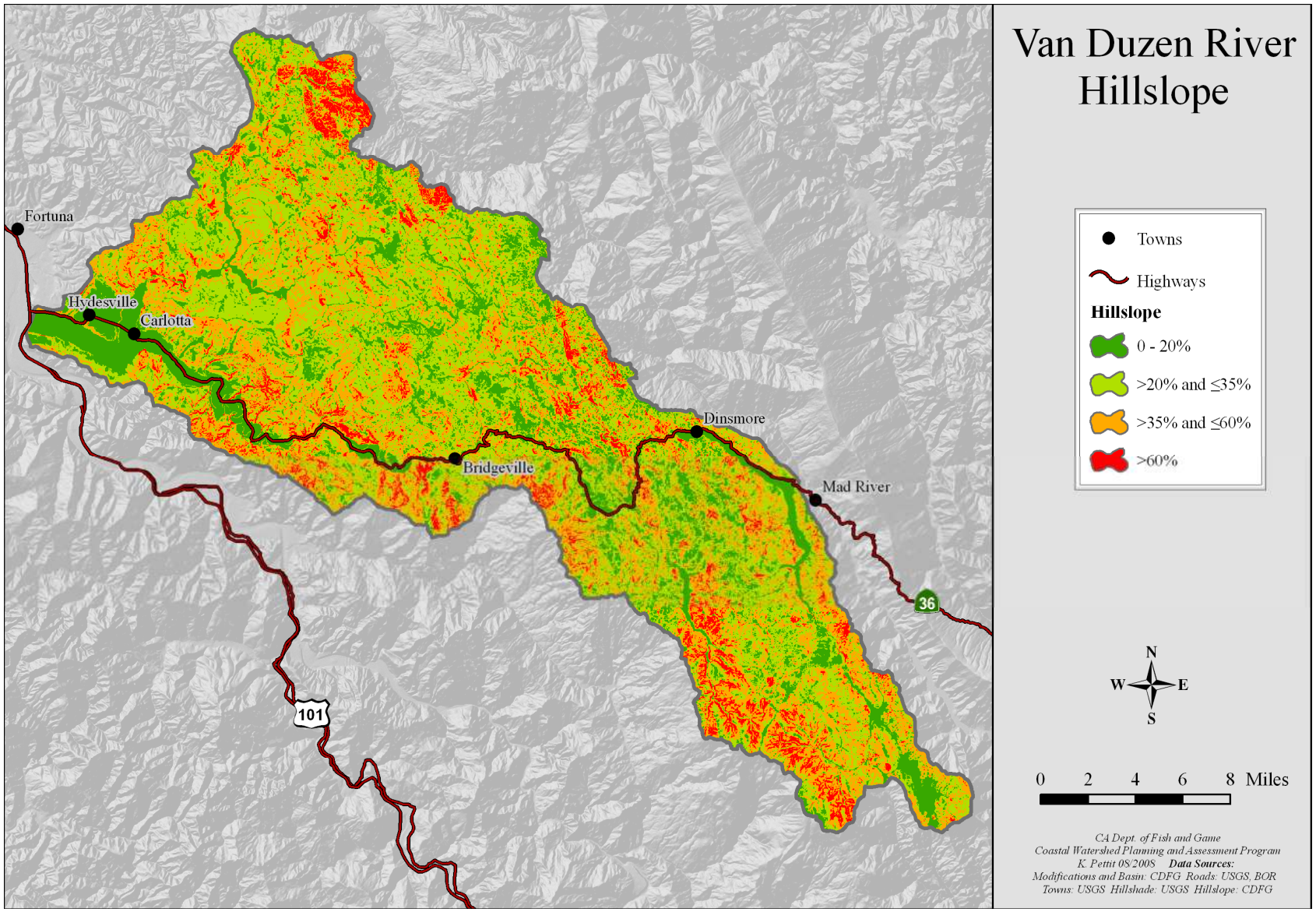


Figure 9. Slope inclination classes of the Van Duzen River Basin.

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.

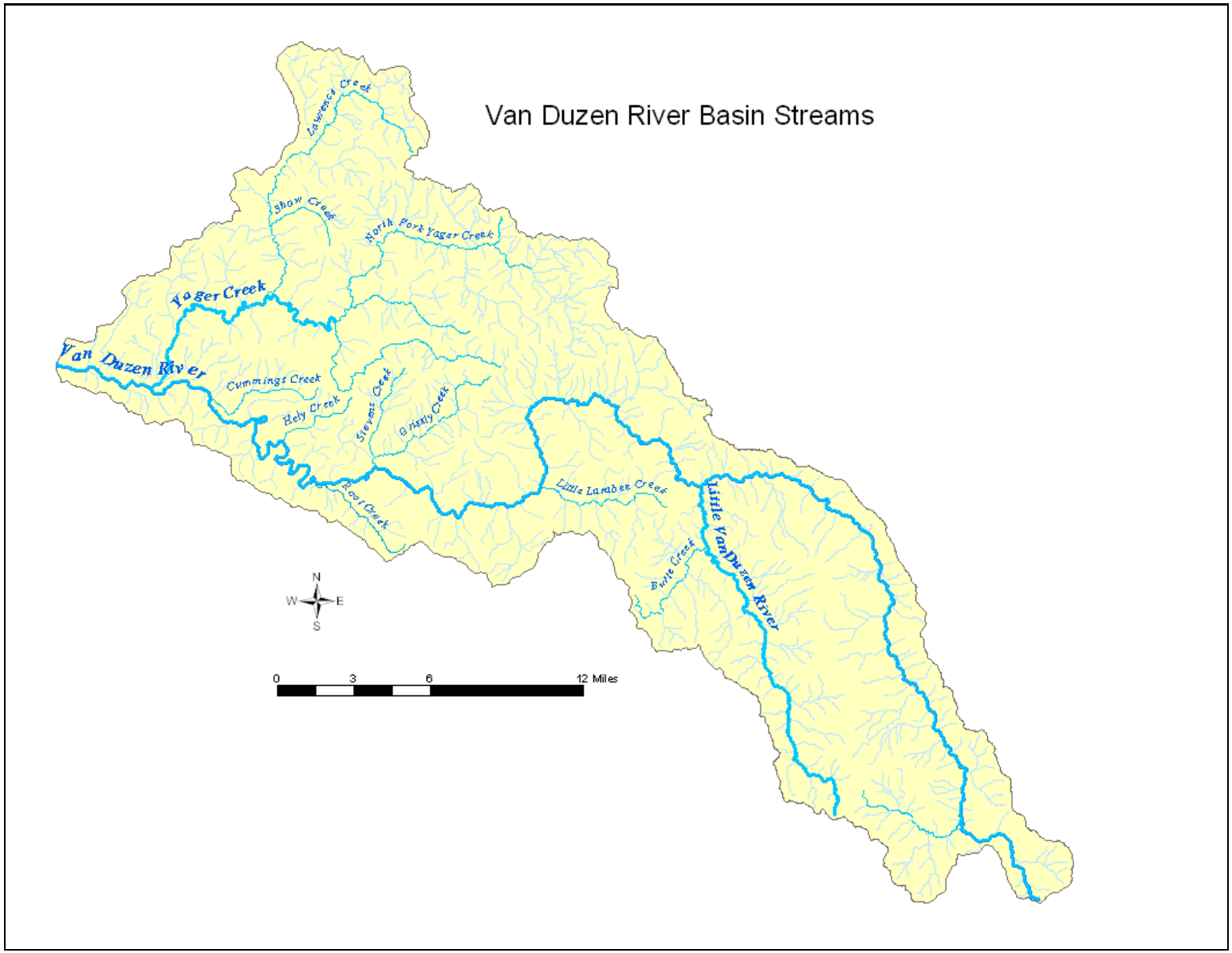


Figure 10. Major streams of the Van Duzen River Basin.

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.

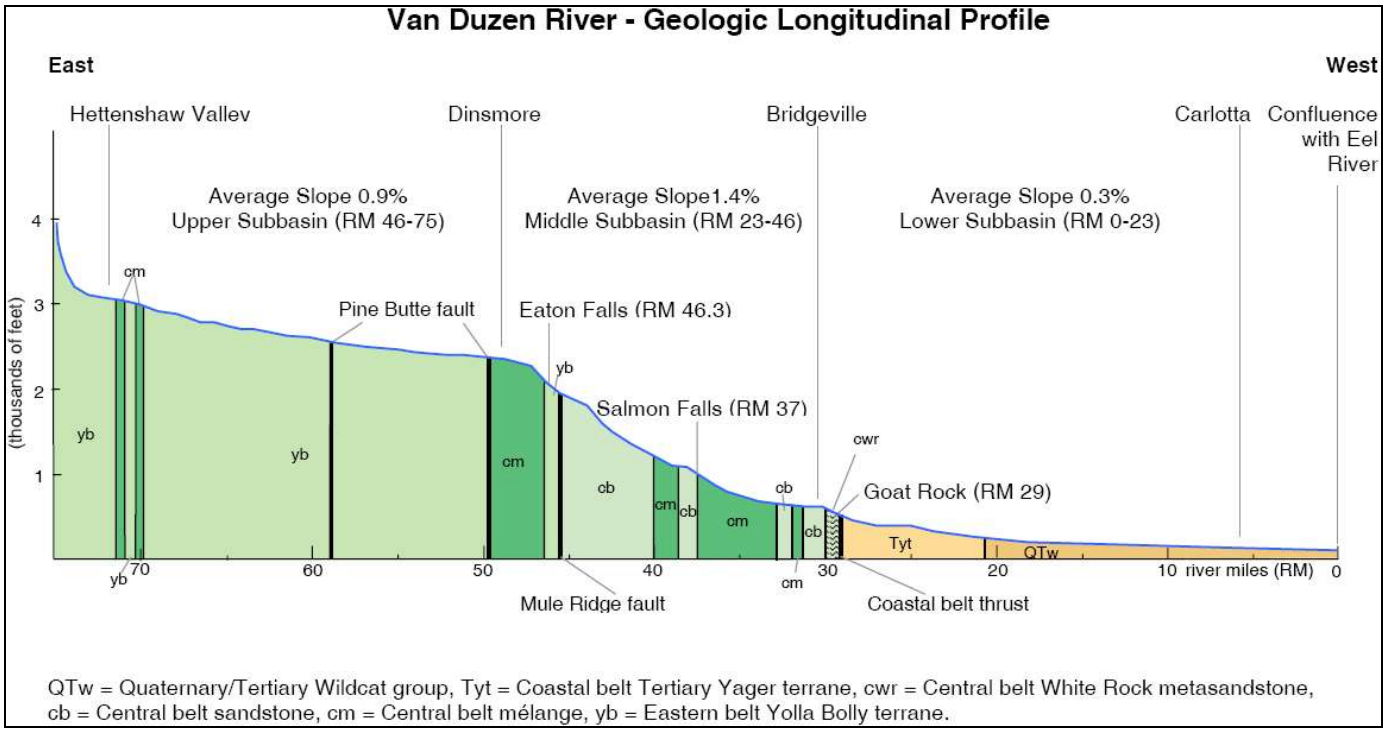


Figure 11. Geologic Longitudinal Profile of the Van Duzen River Basin

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

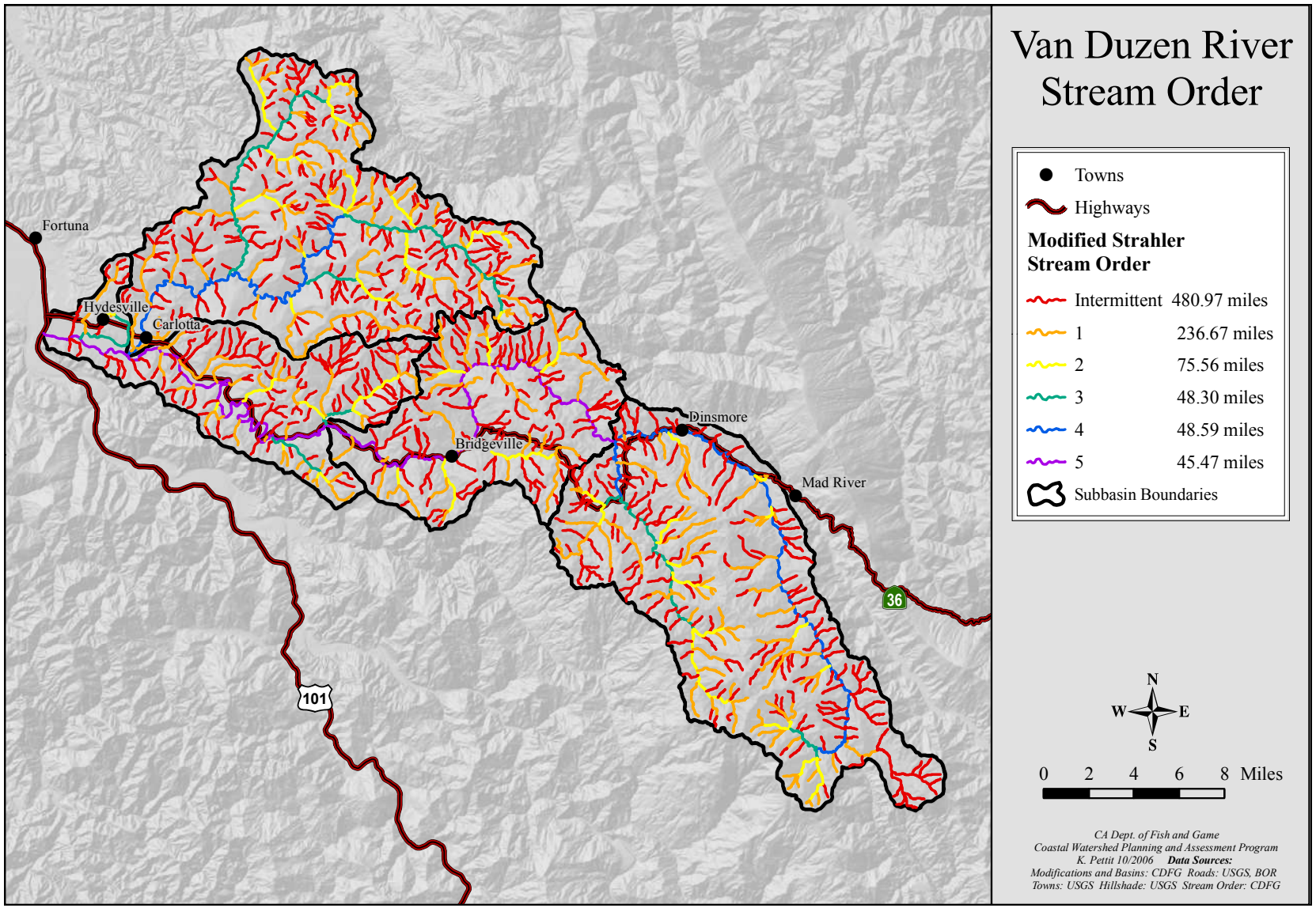


Figure 12. Stream order and subbasin boundaries of the Van Duzen River Basin.

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.

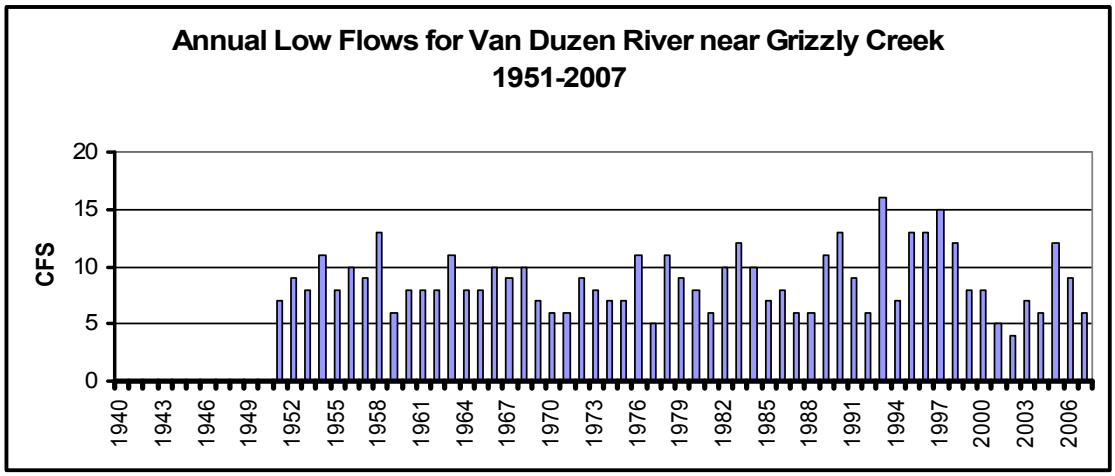


Table 6. Annual peak flow (CFS) from 1940-2006 from USGS gauging station near Grizzly Creek.

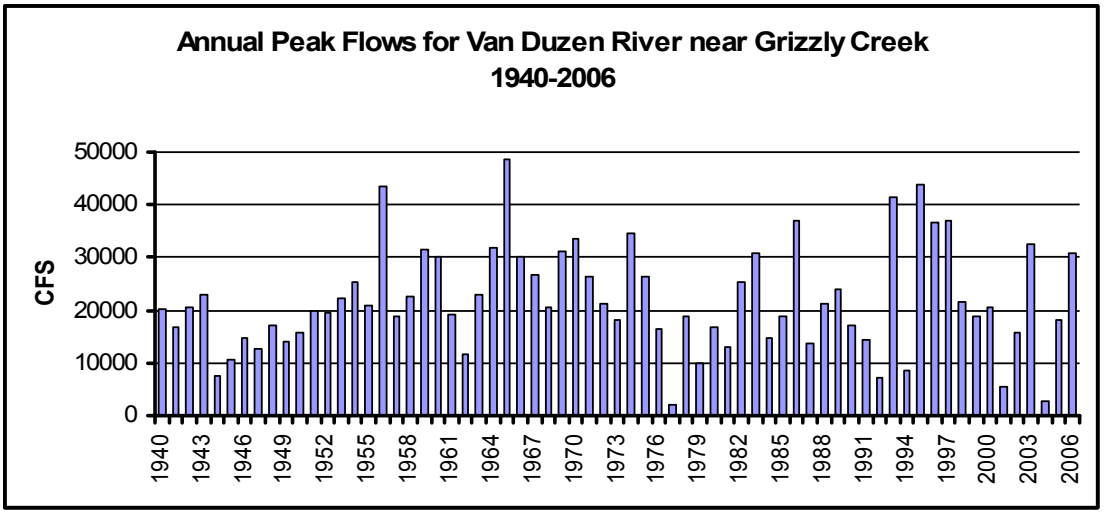
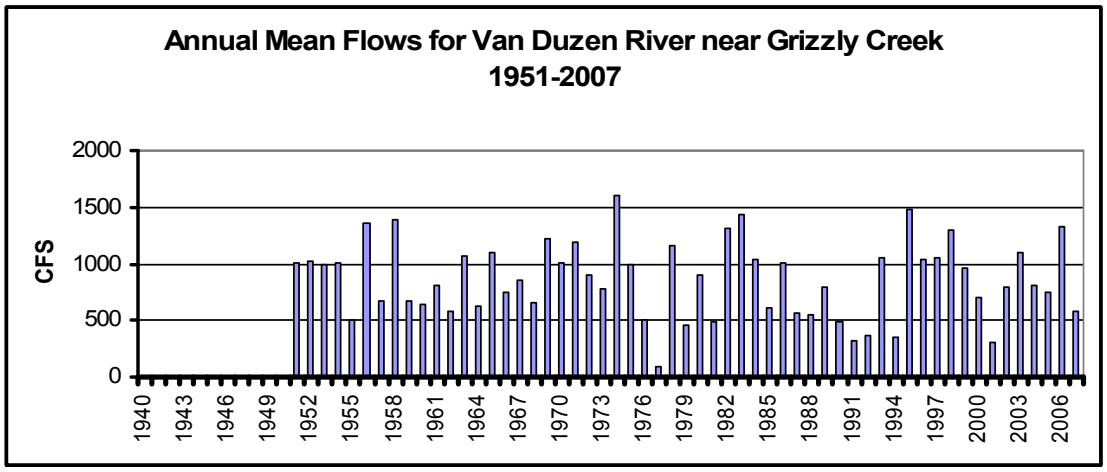


Table 7. Annual mean flow (CFS) from 1951-2007 from USGS gauging station near Grizzly Creek.



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)."

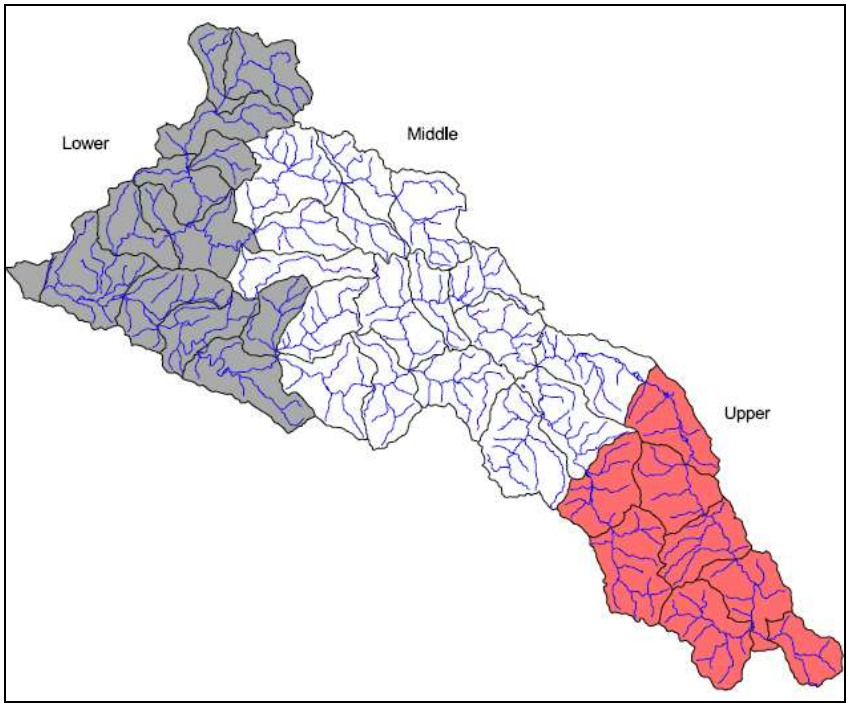


Figure 13. EPA designated subbasins of the Van Duzen River Basin.

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

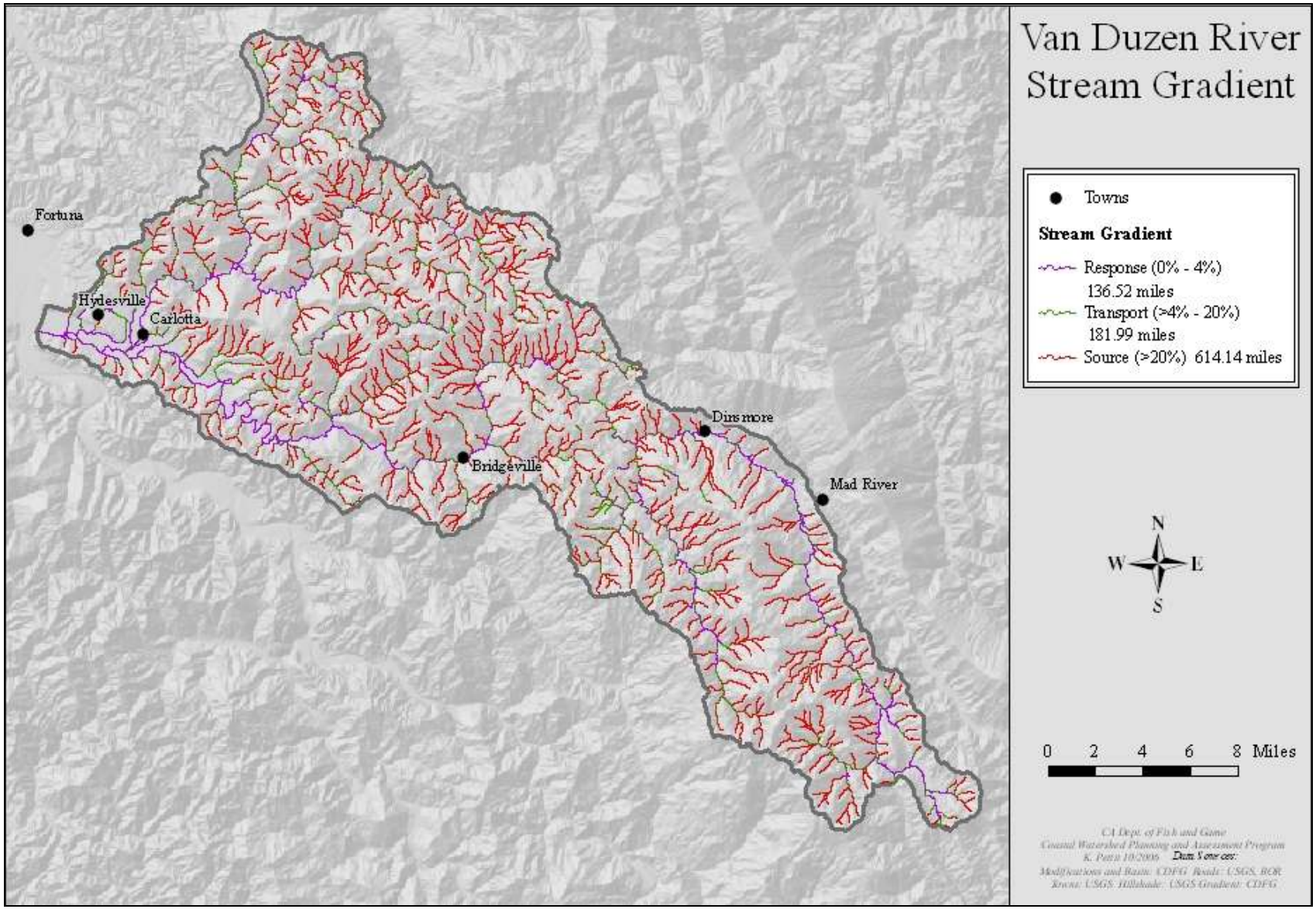


Figure 14. Stream gradient classes based on slope and characterized by process for the Van Duzen River.

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

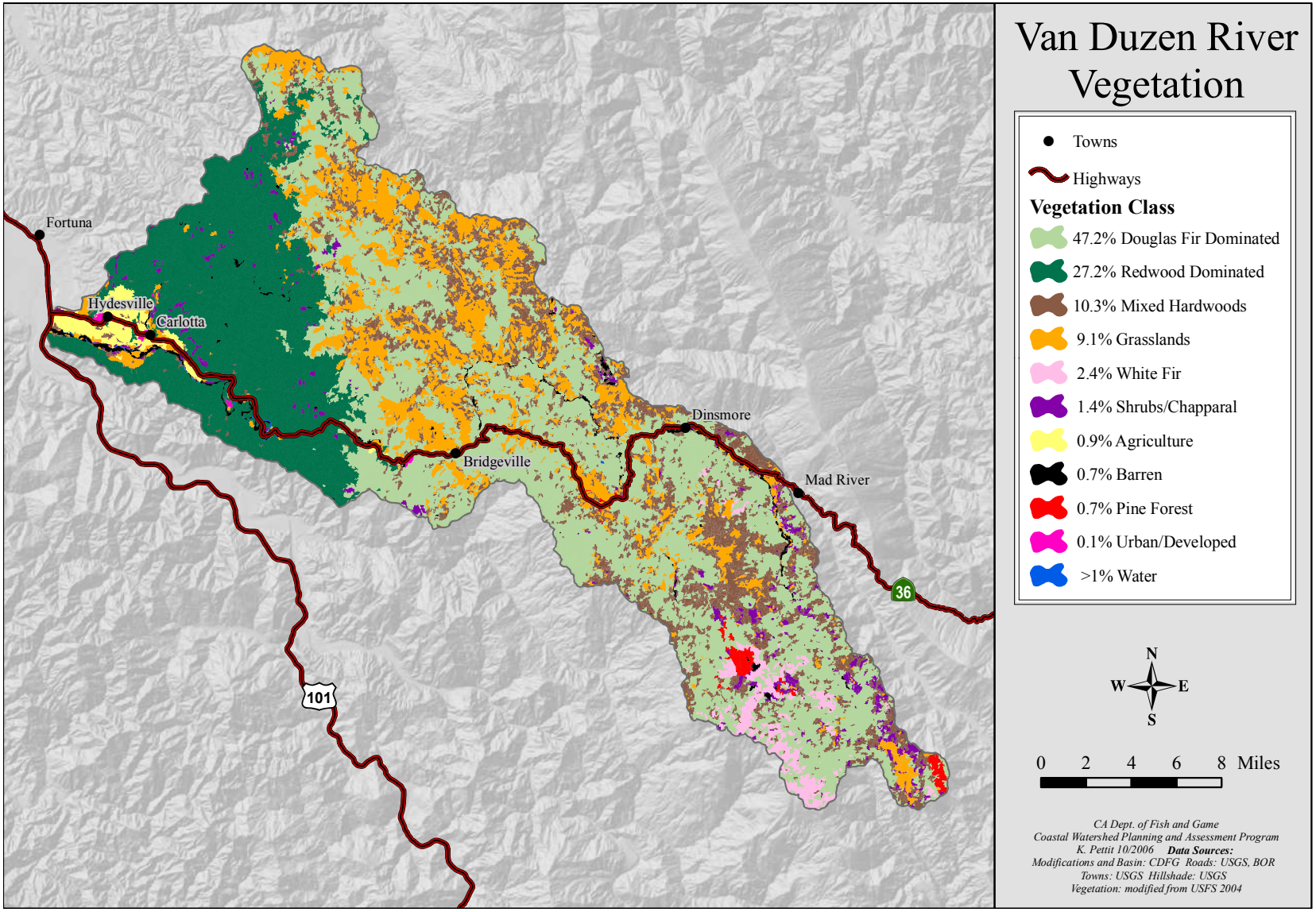


Figure 15. Vegetation categories for the Van Duzen River Basin.

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

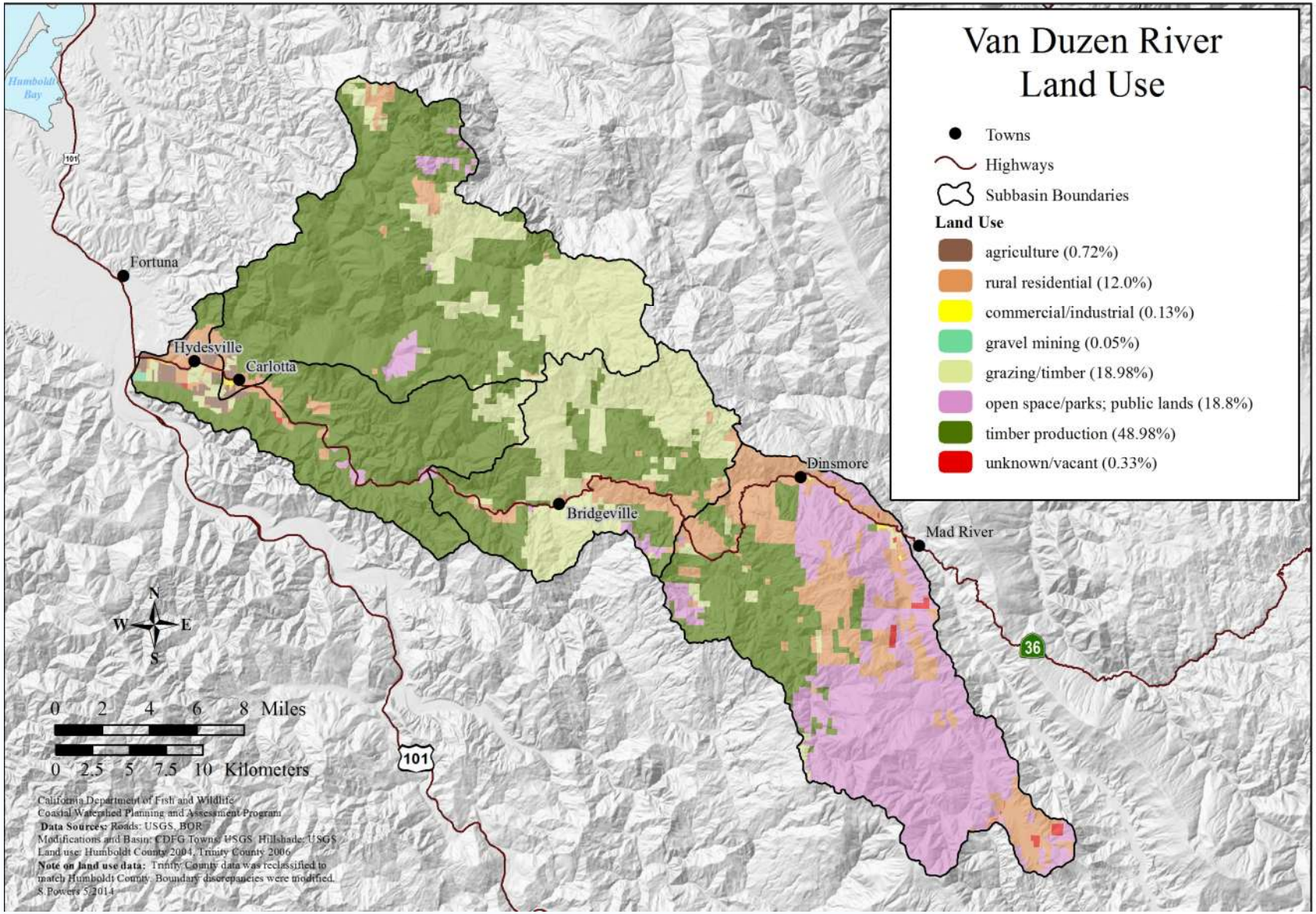


Figure 16. *Land use classification in the Van Duzen River Basin.*

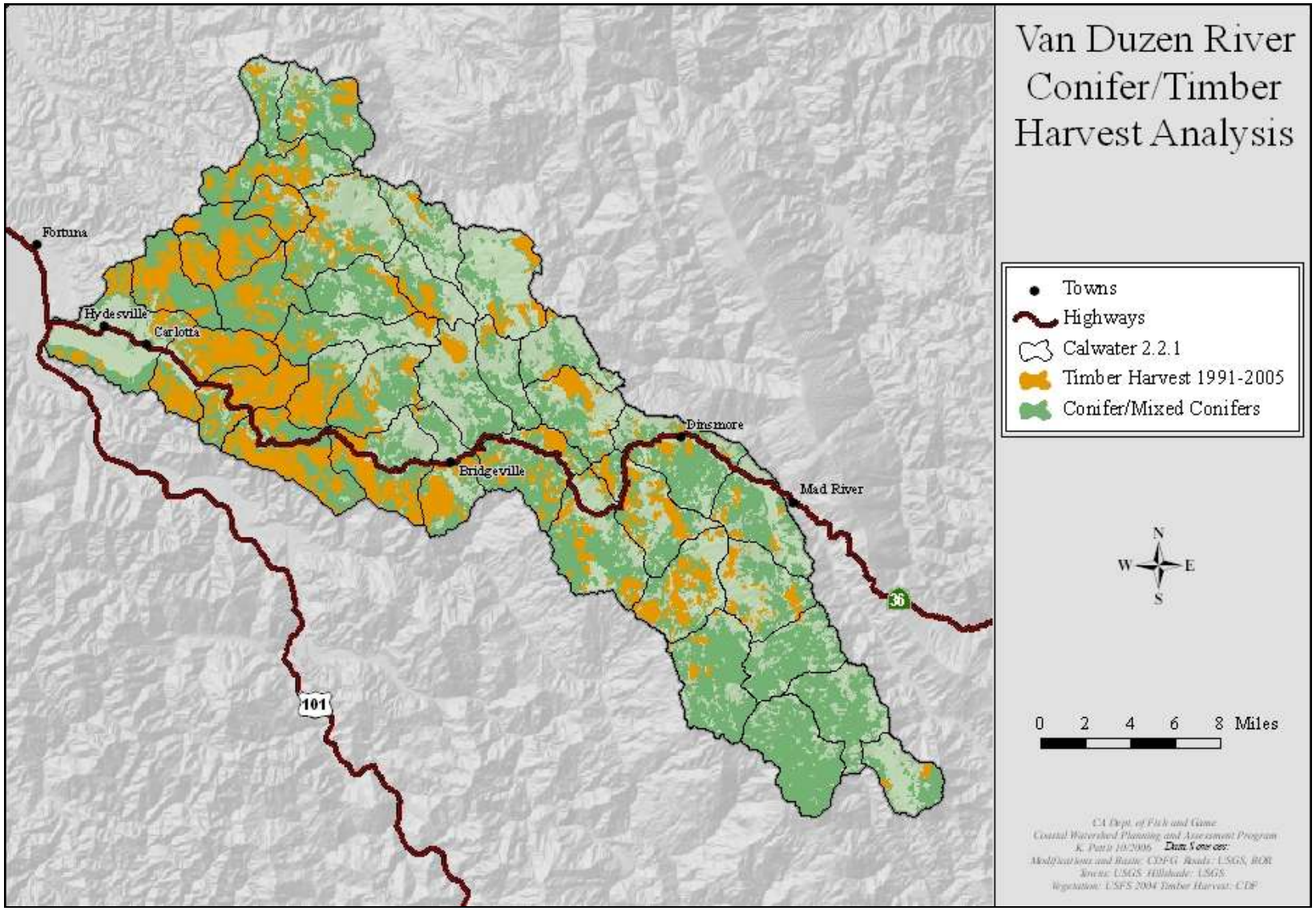


Figure 17. Van Duzen River Basin timber harvest activites from 1991-2005.

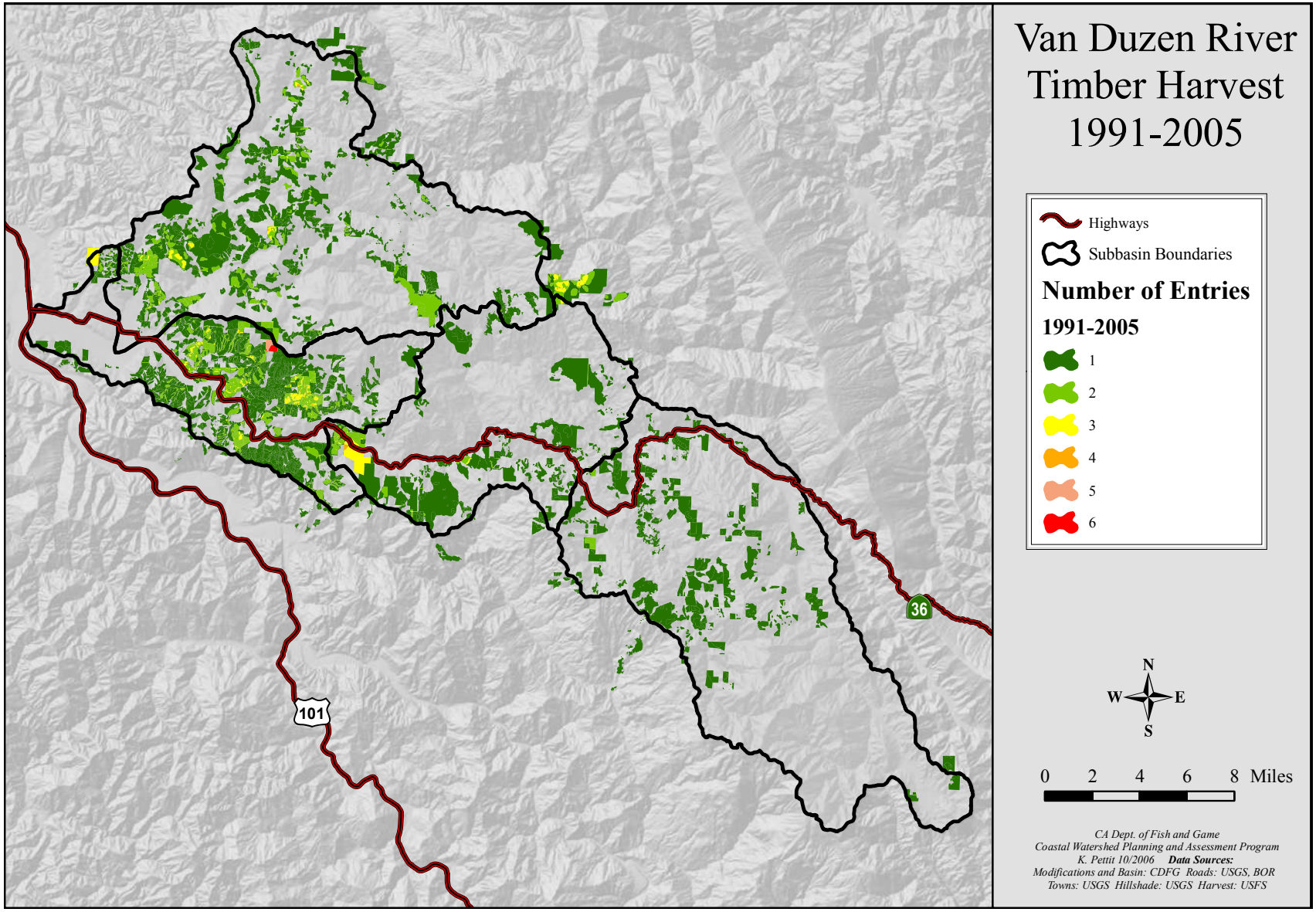


Figure 18. Timber harvest activities in the Van Duzen River Basin from 1991-2005.

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.

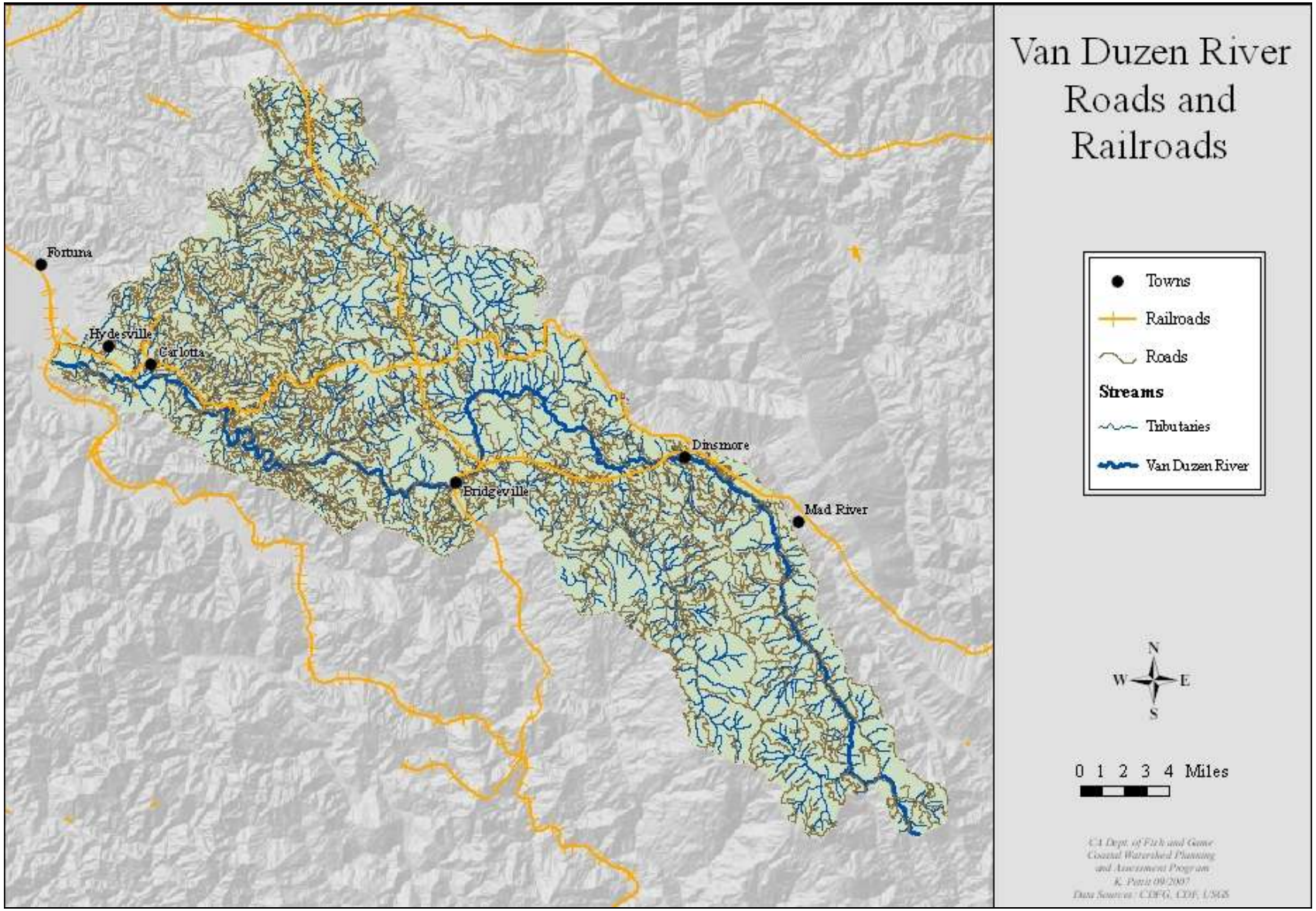


Figure 19. Roads within the Van Duzen Basin. Railroads shown are historic routes and no longer support rail traffic.

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.

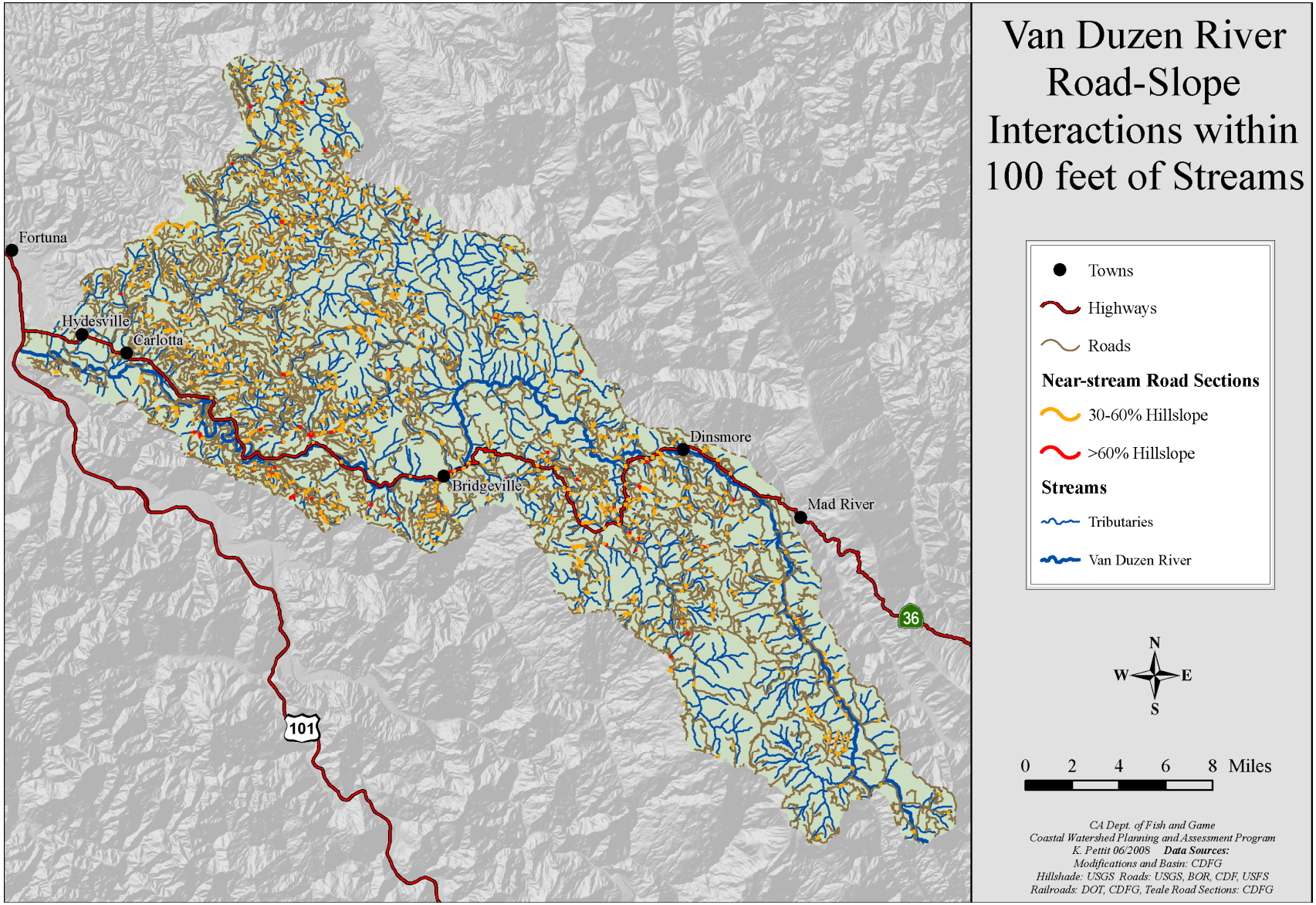


Figure 20. Interactions between roads, hillslope and streams are depicted. Locations with steep slopes near streams are considered high priority areas for restoration

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).

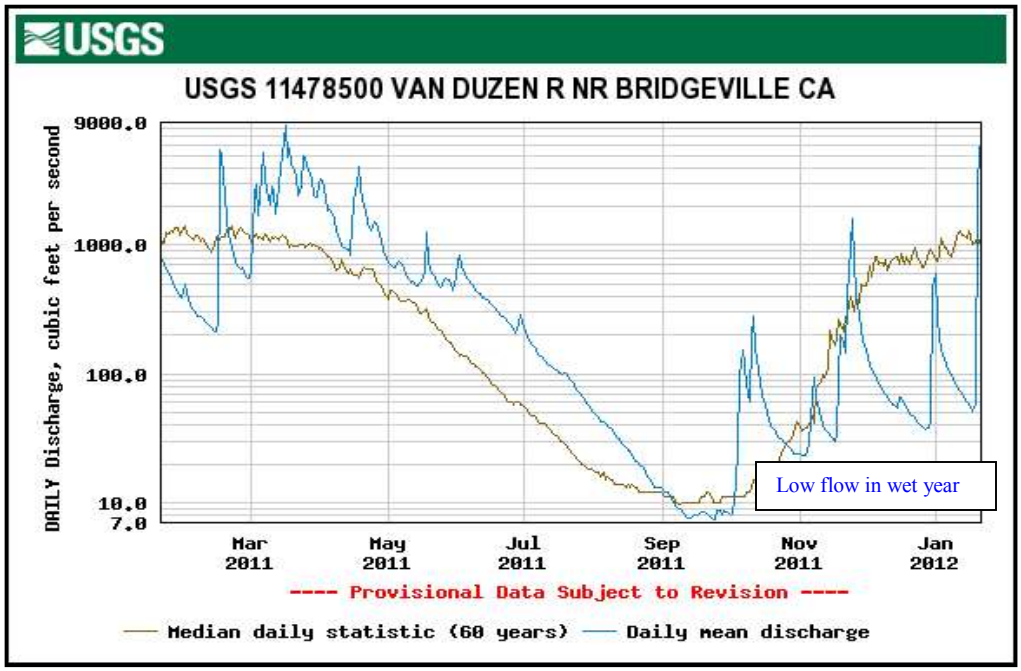


Figure 21. USGS gauging station near Bridgeville showing 2011 daily mean discharge (in cfs) and the mean daily statistic (60-year average in cfs).

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

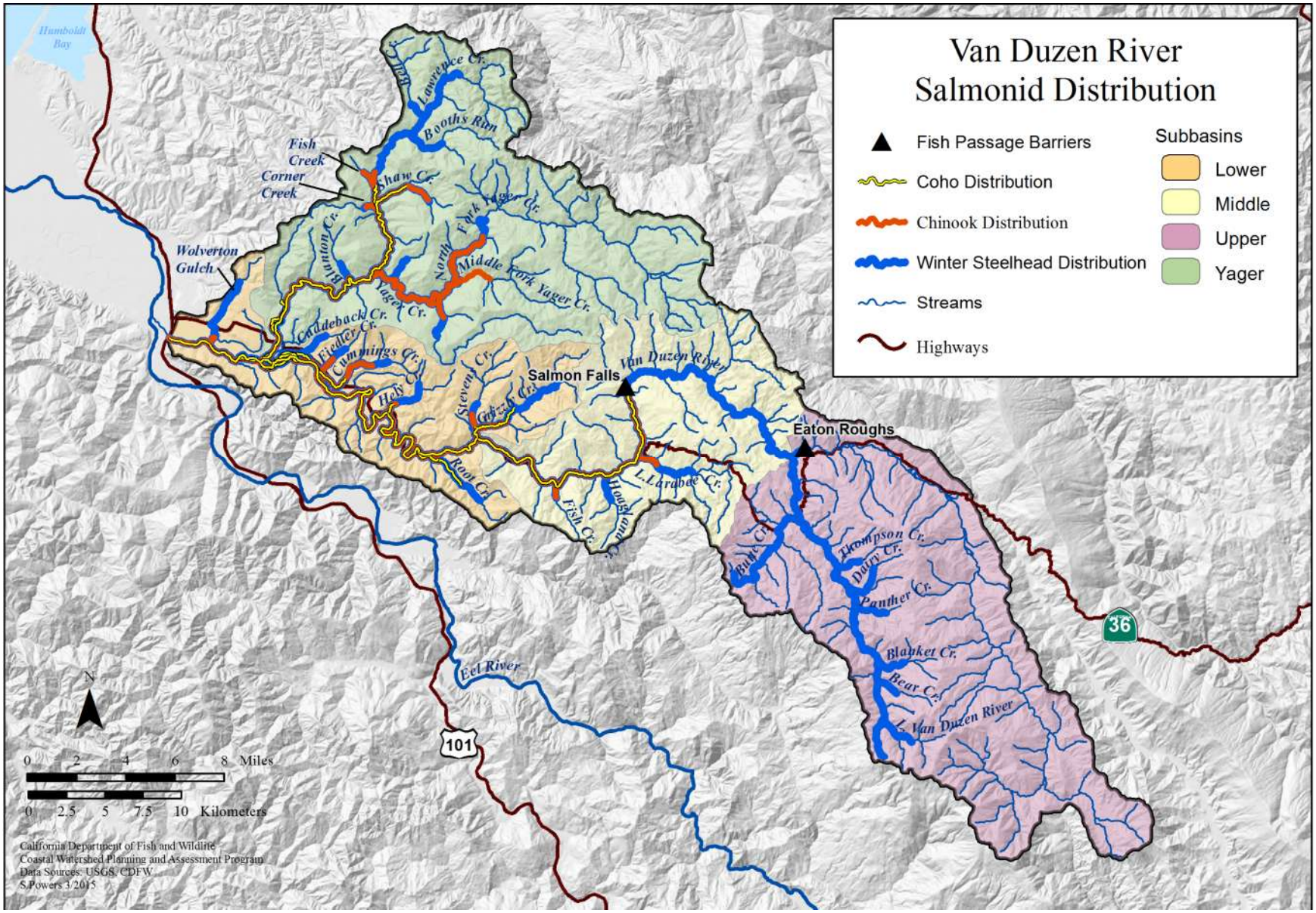


Figure 23. Current range of Coho and Chinook salmon and winter steelhead trout in the Van Duzen River Basin based on California Department of Fish and Game estimates

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° F (19°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.

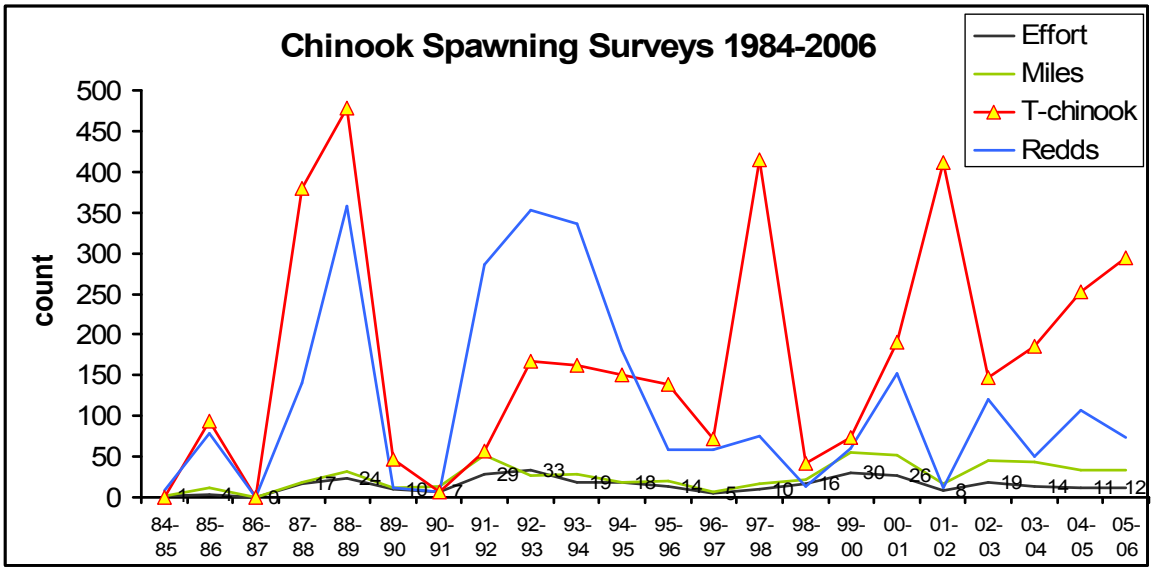


Figure 24. Combined results from CDFG Chinook spawner surveys in Van Duzen Basin streams 1984-2006. Streams surveyed include Lawrence, Shaw, Grizzly, and Root creeks.

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

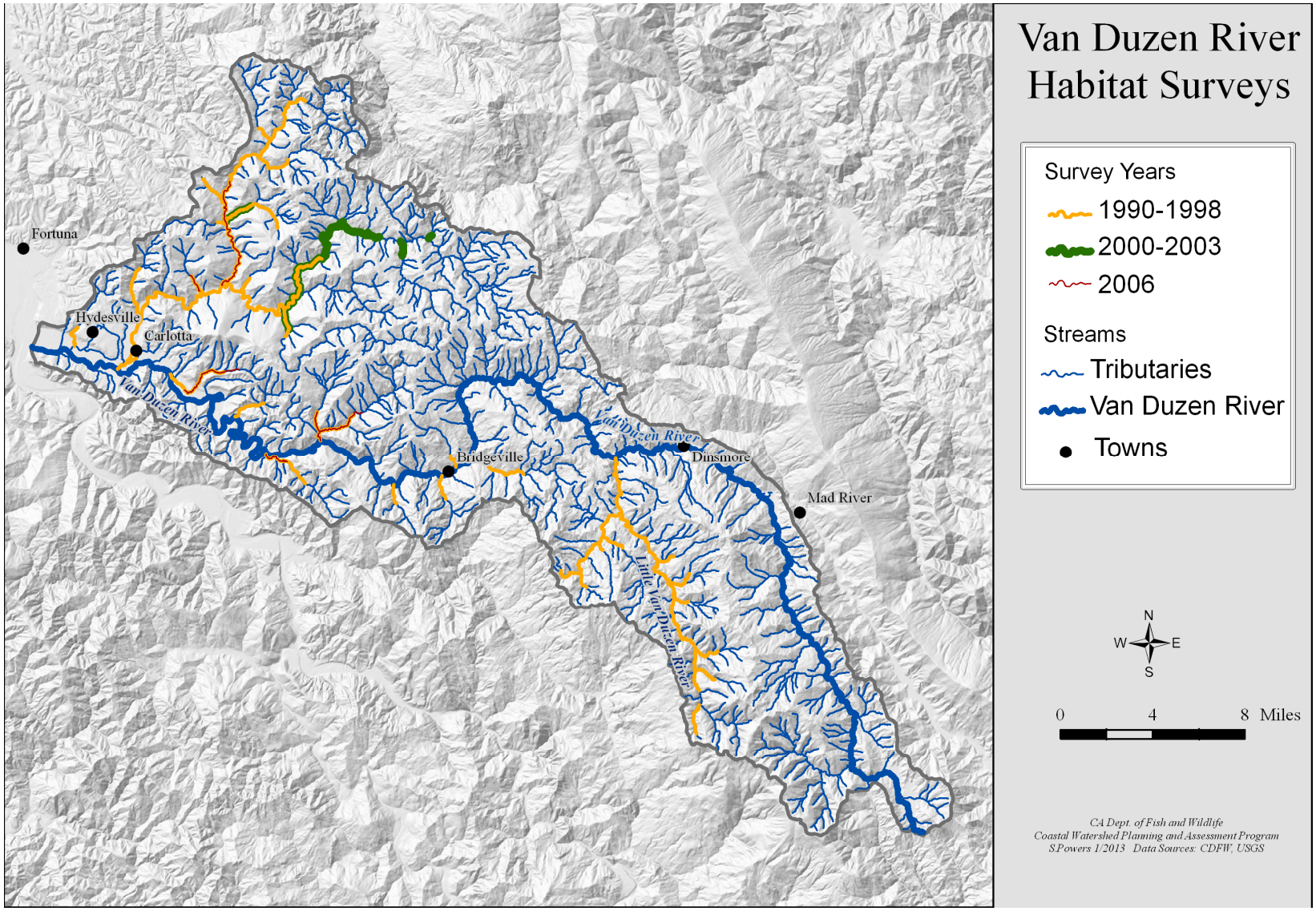


Figure 25. Habitat surveys conducted on the Van Duzen River Basin by California Department of Fish and Game

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).

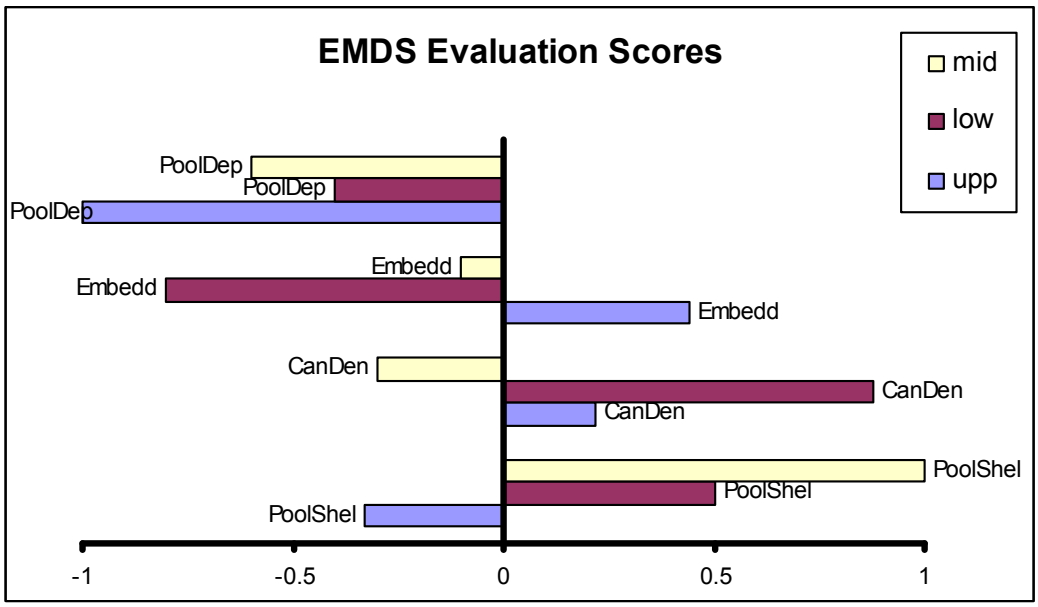


Figure 26. An example of EMDS evaluation utilizing hypothetical stream habitat data.

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**

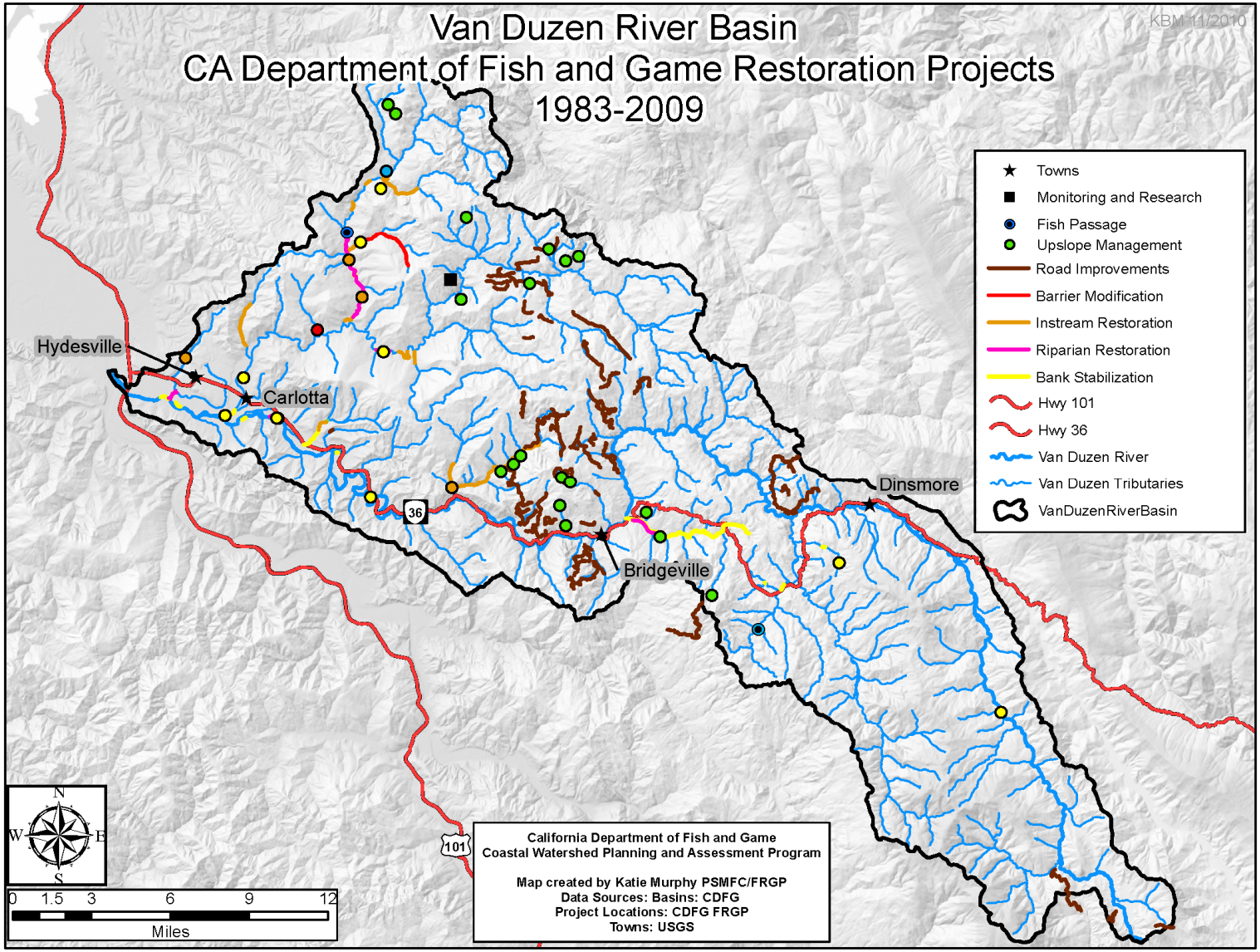


Figure 27. California Department of Fish and Game habitat restoration projects in the Van Duzen River Basin from 1983-2009

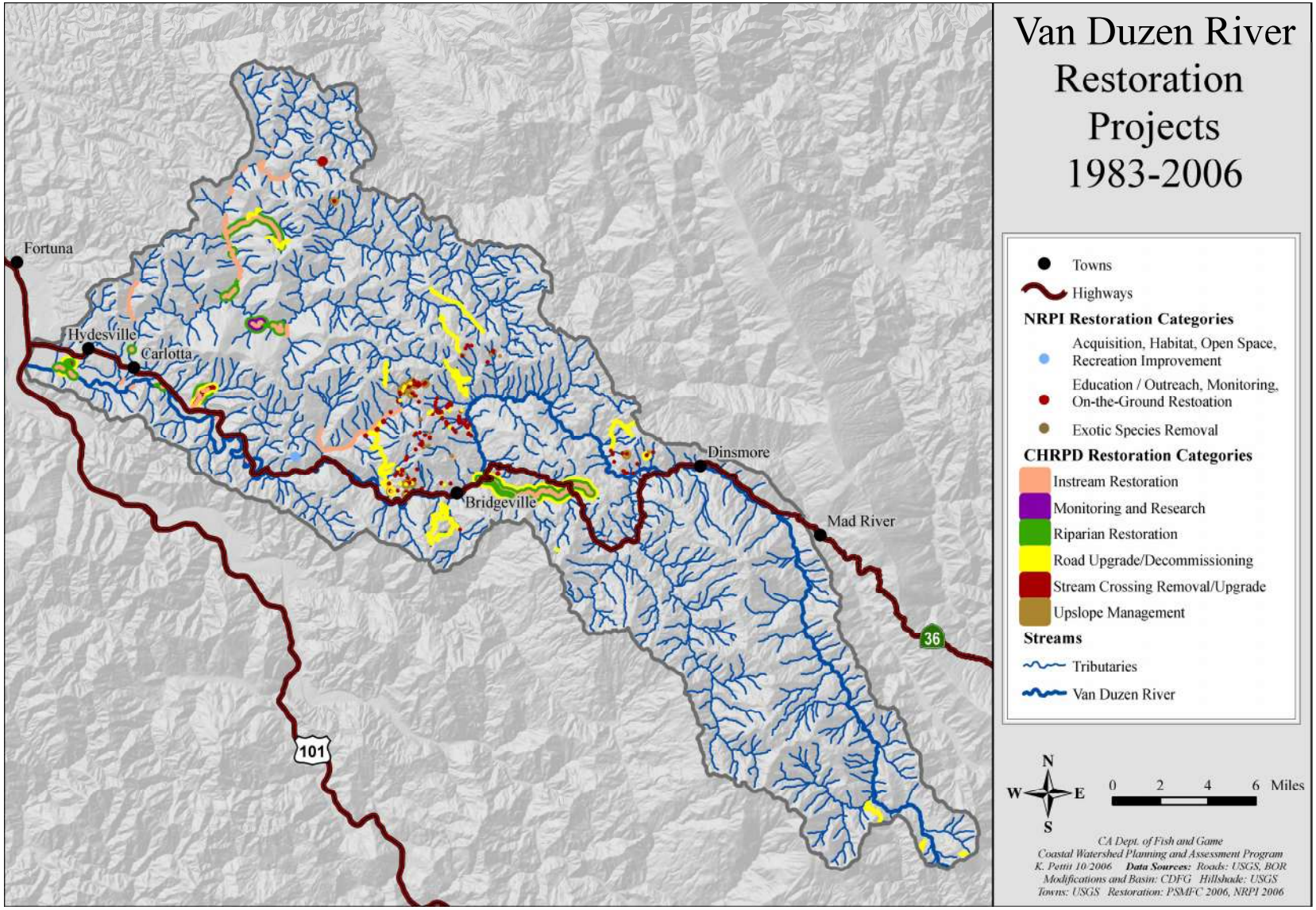


Figure 28. Restoration projects in the Van Duzen River Basin from 1983-2006.

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.

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

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.

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:

- 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.

Erosion and Sediment Delivery Reduction Activities:

- 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).

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 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.

Monitoring, Education and Research Activities:

- 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.