U.S. Environmental Protection Agency
Region IX

Van Duzen River and Yager Creek Total Maximum Daily Load for Sediment

Approved by:

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EXECUTIVE SUMMARY

The Van Duzen River Basin (VDR), located in California's North Coast Range southeast of the City of Eureka, encompasses an area of 429 square miles. A highly active tectonic setting, combined with sensitive terrain and high rainfall amounts, make the VDR one of the most erodible watersheds in the United States (Brown and Ritter 1971). The VDR was listed on California's Clean Water Act Section 303(d) list beginning in 1992 as water quality limited due to impacts of excessive sedimentation on beneficial uses. The primary beneficial uses of concern identified in the VDR basin relate to maintaining aquatic habitat which supports cold water dependent fish, primarily anadromous salmon and steelhead. In response to the listing and a subsequent lawsuit settlement (Pacific Coast Federation of Fishermen's Association et. al. V. Marcus, 1997), the U.S. Environmental Protection Agency (EPA) has committed to establish a sediment total maximum daily load (TMDL) for the VDR in 1999. In the Supplemental TMDL Establishment Schedule developed pursuant to the settlement, EPA agreed that TMDLs would be established for the VDR (Yager Creek), VDR (above Bridgeville), and VDR (below Bridgeville). These three segments are encompassed with this TMDL.

A primary mission of the TMDL program is to protect the health of impaired aquatic ecosystems by ensuring attainment of water quality standards, including beneficial uses (EPA 1998). The development of this TMDL provides a unique and valuable opportunity to look at the entire VDR basin, not just discrete projects or ownership specific projects, to determine the major sediment delivery mechanisms which influence the attainment of applicable state water quality standards (WQS). The results of this TMDL provide a basin-wide framework from which to establish sediment reduction measures to attain WQS.

TMDL Elements

The TMDL analysis is built upon four key areas of analysis: 1) The description of **water quality concerns**, particularly how excessive sedimentation is impacting the beneficial uses, primarily cold water fish; 2) **Water quality targets** that express the desired instream conditions relative to sediment levels supportive of cold water fish and that interpret state WQS; 3) A **sediment source assessment** that describes the major processes by which sediment is delivered to stream channels and the degree to which human management activities influence those processes; and 4) Sediment **loading capacity (TMDL) and load allocations** are expressions of the amount of sediment that must be reduced in order to achieve healthy watershed conditions. The TMDL must also consider seasonal variations and contain a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. Finally, **implementation** and **monitoring** considerations, though not required as part of this TMDL, are included as recommendations for future development by local watershed groups and the Northcoast Regional Water Quality Control Board (NCRWQCB).

Community Involvement

The success of any watershed planning effort relies heavily on the participation, ideas and energy of the landowners and interested public who live, work and recreate in the watershed.

The Van Duzen TMDL effort attempted to address local landowners interests and issues by conducting the following activities: 1) landowner interviews regarding historical perspectives (Moore 1999); 2) request for input regarding local perspectives toward watershed conditions; 3) public outreach meetings, including field trips; and 4) distribution of a newsletter. EPA was assisted in these outreach efforts by key individuals from the Humboldt Resource Conservation District, Yager Environmental Stewards, Natural Resources Conservation Service, University of California Cooperative Extension, and Eel River Watershed Improvement Group.

Basin Stratification

For purposes of organizing, assessing and presenting information on watershed characteristics and processes, along with associated allocations, this TMDL stratifies the VDR Basin into three distinct sub-basins: lower basin, middle basin and upper basin. This stratification is based on general distinctions between the three zones: dominant terrain types, distribution/abundance of anadromous fish, channel types (gradients and sediment transport capabilities), vegetation types, and land management/ownership patterns.

Water Quality Concerns

The primary beneficial use of concern in the Van Duzen River, salmon and steelhead habitat, is strongly impacted by large pulses of sediment that tend to aggrade the stream channel and alter habitat conditions (as occurred in 1964 and other high rainfall years). Certain reaches of the Van Duzen River appear to be recovering from earlier influxes of sediment as indicated by lowering stream bed elevations in alluvial reaches in the middle mainstem (Klein 1998). However, sediment levels are presently still impacting aquatic habitat, particularly the quality and quantity of pools and spawning gravels for salmon and steelhead in the lower basin tributaries (DFG 1996, PL 1998).

Land use practices, particularly road construction and maintenance along with intensive timber management in sensitive watershed areas, have accelerated sediment delivery processes (PWA 1999(b)) and continue to pose a sedimentation risk to recovery of salmon and steelhead habitat. The challenge for resource managers is to reduce the risk of management-associated sediment delivery, particularly in the event of large storms, through implementing a prevention and restoration strategy which will result in protection of these critical habitat values. More specific water quality concerns are identified according to the lower, middle and upper portions of the basin.

Numeric Targets

TMDL targets are intended to express “healthy” watershed conditions that support beneficial uses (i.e., cold water fisheries) and attainment of applicable WQS. The TMDL indicators and target conditions selected for the VDR are intended to track the following objectives: 1) Improvement in the quality and size distribution of spawning gravel for salmon and steelhead; 2) Improvement in channel complexity, particularly pool frequency and depth, and lower bed elevations; 3) Reduction in the risk of sediment delivery from hillslope sources to watercourses. Target conditions are expressed either quantitatively, as a numeric threshold or qualitatively, as an improving trend (Table 3.1, page 26). The suite of stream indicators in this TMDL include: percent fine sediment levels, embeddedness, pebble counts, turbidity, percent pools, pool depths, cross-section, thalweg profiles. The hillslope indicators include: stream crossings with diversion potentials, road drainage "disconnected" from streams, reduced road fill failures, reduced stream crossing failures, reduction of management-related mass wasting from unstable locations.

Sediment Source Analysis

The sediment source analysis identified the amount of sediment delivered to steam channels from various erosional processes which occur on hillslopes and streambanks throughout the watershed. The source analysis provided information necessary to determine the allocation of loading allowances among sources in order to achieve target conditions. Based on a statistically valid approach, consisting of aerial photograph review and extensive field sampling, Pacific Watershed Associates (PWA 1999(b)) determined the following: 1) "older slump earthflow melange" delivered the most sediment (12,657,300 $yds^{3)}$ of the five main terrain types, and the "potentially unstable sandstone" terrain type had the highest rate of delivery (4,265 yds^3/mi^2/year); 2) the middle basin had the highest rate of sediment delivery (1886 yds^3/mi^2/year) followed by upper basin (1433 yds^3/mi^2/year) and the lower basin (1257 yds^3/mi^2/year); 3) the lower basin had the highest percentage (36%) of sediment delivery associated with management activities (roads/skid trails and timber harvest) as compared with 16% in the middle basin and 20% in the upper basin.

TMDL and Load Allocations

Loading capacity is the amount of sediment the VDR can assimilate and still meet water quality standards. Load allocations represent the apportionment of the allowable load between natural and management-related sources. TMDLs were calculated for each subbasin as well as the entire VDR basin. Loading capacities were estimated by comparing existing sedimentation levels with target conditions to determine an approximate load reduction level. Based on this comparison, necessary percent reductions in loads from historic loads were estimated for the upper and middle basin as 10% and for the lower basin as 30%. The allowable loads were then distributed between natural and management-related source mechanisms, primarily roads and skid trails and timber harvesting. The TMDL is defined as the sum of the individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background, such that the loading capacity of the receiving water is not exceeded.

TMDL = WLA + LAs (natural and management-related) + Margin of Safety

Since there are no presently defined point sources of pollution in the VDR, the TMDL wasteload allocation is zero. The margin of safety is expressed implicitly through conservative assumptions. The subbasin TMDLs and basin-wide TMDL are summarized as:

$$\begin{aligned} TMDL_{\text{upper}} &= LA_{\text{upper-natural}} + LA_{\text{upper-roads}} + LA_{\text{upper-harvest}} \\ &= 1162\ yds^3/mi^2/yr + 7\ yds^3/mi^2/yr + 95\ yds^3/mi^2/yr \end{aligned}$$

$= 1264\ yds^3/mi^2/yr$

$$
\begin{aligned}
TMDL_{\ middle} &= LA_{\ middle\text{-}natural} + LA_{middle\text{-}roads} + LA_{\ middle\text{-}harvest} \\
&= 1593\ yds^3/mi^2/yr + 22\ yds^3/mi^2/yr + 73\ yds^3/mi^2/yr \\
&= 1688\ yds^3/mi^2/yr
\end{aligned}
$$

$$
\begin{aligned}
TMDL_{\ lower} &= LA_{\ lower\text{-}natural} + LA_{lower\text{-}roads} + LA_{\ lower\text{-}harvest} \\
&= 815\ yds^3/mi^2/yr + 20\ yds^3/mi^2/yr + 60\ yds^3/mi^2/yr \\
&= 895\ yds^3/mi^2/yr
\end{aligned}
$$

$\mathbf{TMDL_{basin} = 1353\ yds^3/mi^2/yr}$

EPA is expressing the TMDL and load allocations as a 10-year rolling average to account for the large inter-annual variability in sediment loading and long-term timeframes in which beneficial use impacts occur and change. The TMDL and load allocation calculations are found in Chapter 5.

Implementation Recommendations

The overriding implementation need throughout the basin is for resource managers and agencies to conduct assessments to identify and prioritize controllable sediment sources, particularly road networks, and to implement appropriate prevention and control measures in a timely manner. Ideally, implementation of prevention and restoration activities will be prioritized by subwatersheds containing the greatest biological (fisheries) benefit, in accordance with strategies described by Bradbury (1995) and others. Four key implementation mechanisms exist in the VDR for achieving hillslope sediment reduction targets and load allocations: 1) Pacific Lumber Companies (PL) habitat conservation plan in the lower basin (PL 1998); 2) timber harvest plans (THPs) throughout the basin; 3) sediment assessment and reduction strategies contained with ranch plans, primarily on the middle basin rangeland; 4) aquatic conservation strategy of the northwest forest plan for federal land, primarily managed by the U.S. Forest Service (USFS) in the upper basin. Agencies and landowners responsible for implementing these plans must ensure accountability for the sediment source categories and load allocations set forth in this TMDL. EPA encourages collaboration between agencies and landowners to conduct watershed assessments and pool resources for implementing conservation measures. The restoration effort in Cummings Creek is an excellent example of how landowners can work together to assess a problem and leverage resources to fix it.

Monitoring Recommendations

The overall purpose of a TMDL monitoring program is to determine whether load allocations are being achieved and are successful in attaining stream habitat and hillslope targets. Based on the information and knowledge gained through monitoring, the load allocations and/or the implementation actions should be adapted or adjusted. A comprehensive monitoring program should consist of three primary objectives:

* Implementation: Are resource managers implementing sediment control practices according to the appropriate land use plan (i.e., HCP, THP, Ranch Plan, NTMP, etc)?
* Effectiveness: Are implementation measures effective in reducing the amount of sediment to watercourses?
* Aquatic Condition: How are the physical and biological indicators of aquatic habitat condition changing over time?

Presently, various agencies including California Department of Fish and Game (DFG), North Coast Regional Water Quality Control Board (NCRWQCB), USFS, etc. as well as private landowners are conducting some form of monitoring throughout the basin. The development of a basin-wide monitoring plan would likely improve the efficiency between entities conducting monitoring and render the results of an agreed upon monitoring strategy more meaningful. A vital step in the development of a comprehensive monitoring strategy for the VDR is for a local agency (such as DFG or NCRWQCB) or group to play a leadership role in pulling together all the interested parties to develop a monitoring plan for the VDR. A comprehensive monitoring program will provide the basis for adaptive management.

CHAPTER 1
WATERSHED OVERVIEW

1.A Physical and Biological Setting

Location

The Van Duzen River (VDR) basin is located in California's North Coast Range, southeast of the City of Eureka and approximately 50 miles from the "triple junction" of the American, Pacific and Gorda tectonic plates near Cape Mendocino. The VDR drains an area of 429 square miles: 366 square miles are located in Humboldt County, and 63 square miles in Trinity County. Elevations within the watershed range from 5,906 ft. at its headwaters at Red Lassic peak to 62 ft. at its confluence with the Eel River. The VDR is 73.5 miles long and one of the few remaining free flowing rivers in California. State Highway 36 is the major transportation corridor, passing through the towns of Hydesville, Carlotta, Bridgeville and Dinsmore (Figure 1.1).

Figure 1.1 Van Duzen River, major tributaries, Highway 36 and place names

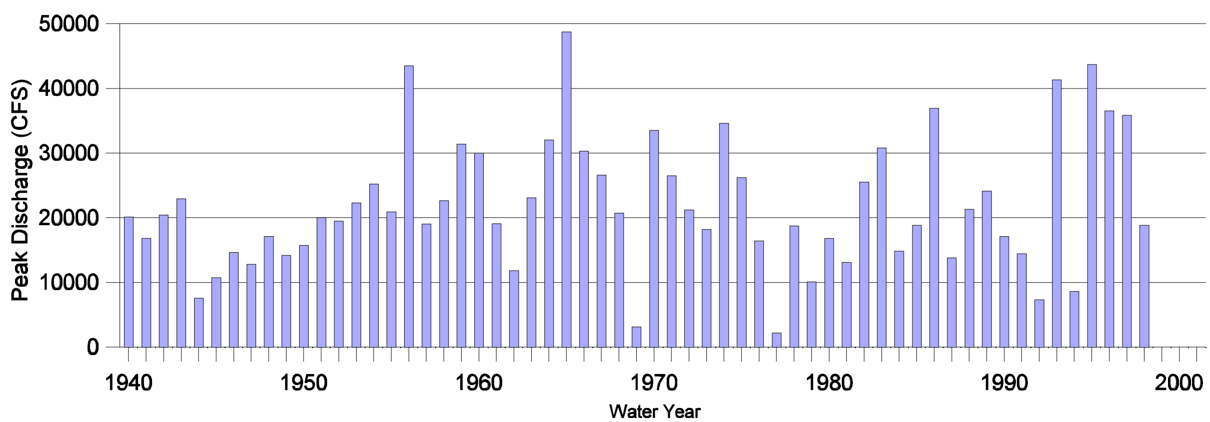
Geology

A highly active tectonic setting, combined with sensitive terrain and high rainfall amounts, make the VDR one of the most erodible watersheds in the United States (Brown and Ritter 1971). The VDR basin can be classified into five primary terrain types based on similar physical character (bedrock) and relative slope stability, as originally characterized by Kelsey (1977): 1) Sandstone, generally stable terrain; 2) Sandstone, potentially unstable active slides; 3) Melange, generally stable, serpentine, alluvial terrain; 4) Melange, older slump-earthflow terrain; 5) Melange, active slump-earthlows. The differences in sediment delivery rates from each terrain type and locations of terrain types are described thoroughly in the Sediment Source Assessment (Chapter 5). Sedimentation rates are considered high in the VDR basin because of the high uplift and stream incision rates into relatively weak bedrock units. This combination has produced a high incidence of landsliding adjacent to stream channels, including large slump-earthflows and extensive zones of debris sliding. Certain land-use activities, as described in the sediment source assessment section, have accelerated sediment delivery.

Rainfall/flooding

The quantity and duration of rainfall during storm events is a major factor influencing geomorphic processes in the VDR. The VDR basin receives 50-100 inches of precipitation annually, which occurs almost entirely from October through April, including a small fraction of snowfall. Between two and six intense rainstorms typically occur each winter. Summer fog provides cooler temperatures in the lower basin while the middle and upper basins are drier and warmer during the summer months. High magnitude, infrequent storms cause widespread flooding and modification of channel characteristics in the VDR. Multiple layers of roots on old redwood trees growing in floodplains are evidence of silt deposition due to prehistoric flooding (Stone and Vasey 1968). Floods in 1861, 1955 and 1964 are considered the largest floods of record in the Van Duzen (Kelsey 1977). Figure 1.2 illustrates the wide variability in the annual maximum peak discharge in water years from 1940 through 1998.

Figure 1.2 VDR annual maximum peak discharge: 1940-98 (Klein 1998)



Fisheries

The primary beneficial uses of concern in the VDR involve maintaining an aquatic habitat which supports coho salmon (Oncorhynchus kisutch), chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus clarkii), particularly summer stocks. The VDR also supports other native and introduced fish species including: resident rainbow trout, pacific lamprey, West coast three-spined stickelback, Sacramento sucker, Coast Range sculpin, prickly sculpin, Coastal cutthroat trout, California roach (introduced), speckled dace (introduced), and Sacramento pike minnow (introduced species, formerly known as squawfish). Salmon and steelhead resources have declined steadily in the VDR Basin over this century, but have undergone the most serious declines following the 1955 and 1964 floods (DFG 1996).

Although the basic life history of most anadromous species is similar, many variations exist in timing and location. Adult salmon migrate from the sea into streams to deposit their eggs in gravel. After spawning, the adults die. The eggs incubate during winter in the gravel, and emerge as free-swimming fry in the spring. Juveniles reside in the stream for a year or more then migrate to sea as smolts. At sea, they rapidly grow into mature adults over the course of eighteen or more months. They return to their natal stream to spawn. Steelhead can be considered as two distinct run-types, winter or summer, based on the timeframe for maturing and spawning. Summer steelhead enter the river in the spring then mature and spawn over the course of several months in freshwater. The Eel River Action Plan (DFG 1996) provides a summary of the specific life cycles of anadromous salmonids in the Eel and VDR basins.

Historians have documented a thriving commercial salmon industry, between 1850 and 1890, including numerous canneries in the Eel River estuary (just downstream of the confluence with the VDR) as evidence of the abundant fish populations at that time. Eel River salmon production in 1857, which would have included VDR salmon, for example, "...equaled that of the Sacramento River and far exceeded the combined Columbia River and Vancouver Island production" (Lufkin 1996). The numbers of fish taken during that period varied tremendously from an estimated 44,688 in 1857 to 585,200 in 1877 according to Humboldt County Department of Public Works (Lufkin 1996). Very little quantitative information exists regarding historic levels of anadromous and resident fish population in the VDR. Historic newspaper articles, compiled by Susie Van Kirk (1998) provide some insight into fish abundance and river condition around the turn of the century through the 1940's:

> *Ferndale Enterprise (8 Nov.1895) The Oracle is informed that the upper Eel river and the Van Duzen have been visited by quite a run of fish this fall, owing to the rise in the river from the September rains. These fish have spawned and will help considerably in keeping up the fish supply.*

> *Ferndale Enterprise (17 April 1917) Steelhead in Yager* -- *The annual run of steelhead salmon is on in Yager and the same conditions prevail as in the past as in regard to the barrier opposite the Porter place. The fish unable to get over the falls gather in great numbers at the foot of the falls and batter themselves against the rocks in their attempts to get over and will soon become unfit for food....*

> *Humboldt Standard (8 Nov. 1940) Fisherman's Luck by Chet Schwarzkopf* --*... at Grizzly creek mouth an the Van Duzen, big red-sided rainbow from eighteen to twenty-five inches in length are biting on single*

eggs. These fellows are coming downstream from the Salmon Hole and Little Van Duzen country it seems, and they are prime sport. So, all in all, the Van Duzen looks like a good bet...

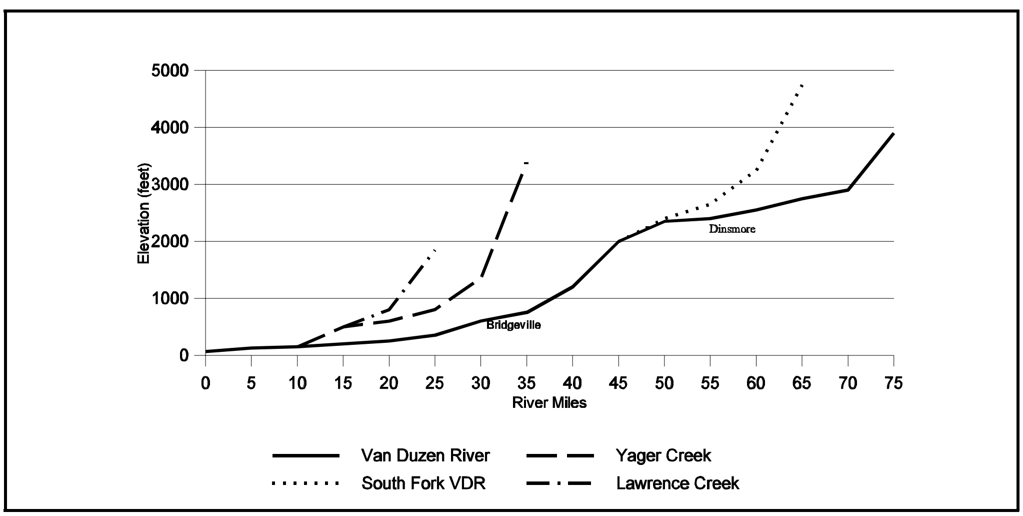
Salmon populations regionally and statewide have continued to decline throughout the 20th century (Nehlsen et al. 1991; Higgins et al. 1992; Brown et al. 1994). A spawning reconnaissance study of chinook salmon carried out by the U.S. Fish and Wildlife Service in 1959 in the VDR indicated that the basin had the capability to support 7,000 chinook and reported 1,500 occupied redds at that time. In 1965, DFG estimated that annual adult salmon runs in the Van Duzen numbered 2,500 chinook and 500 coho. According to DFG (1996), coho salmon populations throughout California could be at less than six percent of their abundance during the 1940s. The Summer steelhead stock, generally considered to be less than 100, is considered at risk (Higgins et al. 1992).

Brown et al. (1994) conclude that the reasons for the decline of coho salmon in California include: stream alterations brought about by poor land-use practices and by the effects of periodic floods and drought, the breakdown of genetic integrity of native stocks, introduced diseases, over-harvest and climatic change. The National Marine Fisheries Service (NMFS) listed coho salmon in the Northern California region as threatened in 1997 according to the Endangered Species Act (ESA). Chinook salmon in Northern California were also recently listed as threatened, and steelhead have been proposed for listing.

<u>Channel Conditions</u>

The VDR's sediment transport mechanisms encompass a range of channel types including: 1) depositional reaches (strongly alluvial, low gradient, low confinement, able to meander relatively freely); 2) transport reaches (weakly or non-alluvial, steeper gradient, more confined, coarse textured sediments); and 3) source reaches (steep headwater swales). A longitudinal profile of the VDR adapted from Kelsey and Allwardt (1975) illustrates the changes in gradient from the lower floodplains to upper Yager Creek and VDR (Figure 1.3).

Figure 1.3 Longitudinal profile of VDR (adapted from Kelsey and Allwardt 1975).



The rates of sediment transport and storage throughout the channel network varies greatly depending on streamflow energy, sediment particle sizes, quantity of material, channel gradient, etc. Sediment generally moves through the channel network as suspended load (particles generally .25mm or less) or as bedload (coarse alluvium). Kelsey (1977) estimated the total amount of sediment transport and deposition for the VDR (above Bridgeville) between 1941 and 1975 (Table 1.1).

Table 1.1 Sediment deposition and transport between 1941 and 1975 (Kelsey 1977)

Component	**Mass volume (tons)**	**Percent**
Channel aggradation	13,235,000	19
Suspended Sediment at Bridgeville (1941-1975)	50,217,000	73
Estimated bedload (10% of Suspended Load)	5,022,000	7
Subtotal	68,474,000	99

Channel aggradation as a result of the 1964 flood measured several feet, as illustrated in cross-section surveys located at Pepperwood Falls (Klein 1998). Some reaches continued to aggrade several years following the 1964 event due to a continued supply of coarse alluvium from aggraded upstream reaches. The greatest amount of aggradation impacted lower gradient reaches by depositing a uniform blanket of coarse sand to cobble and pebble-sized material (USDA 1998). Aggradation from the 1964 event resulted in the filling of formerly incised channels, channel widening, loss of riparian vegetation, increased bank erosion, loss of deep pools, and consequently increased water temperatures. All of these characteristics negatively impact fish habitat. To illustrate the magnitude of the 1964 flood, Kelsey (1977) estimated that 49% more sediment entered the VDR basin during 1941-1975 than would have without the storm. In addition, Kelsey estimated no channel aggradation would have occurred without the 1964 storm. Local landowners' accounts support the dramatic influx of sediment and change to the channel morphology:

> *"...here you have a stream that is full of big rocks and pools that after the 1964 flood you could have driven your jeep right up the creek because there was so much gravel. All the rocks were buried and the pools were gone. You just had a rambling stream all the way. I haven't seen it go clear back to the way it was before 1964 because healing takes a long time." - (cited in Moore 1999).*

The mainstem VDR, particularly the middle reach, is now in a process of recovery from the devastating sediment delivery and flood event of 1964 and subsequent floods in the 1970's. Klein (1998) surveyed several channel cross sections to determine the present river bed elevation compared with levels documented historically. In particular, Klein was able to relocate and resurvey sites originally established by Kelsey (1977) some of which included USGS gaging station sites dating back to 1913. This survey represents the only quantitative data available on stream channel changes over several decades. Regarding the upper basin, the US Forest Service states, “After more than 30 years of recovery, the majority of stream channels in the upper watershed are probably approaching conditions that existed prior to the flood” (USDA 1998).

The annual suspended sediment load during 1941-1975 varied tremendously from 270 tons/sq.mi. to 26,600 with an average of 6,700 tons/sq.mi. and a typical range of 2,500 to 9,000 (Kelsey 1977). To illustrate the magnitude of the 1964 event, seven percent of the total suspended load (3,867,000 tons) moved through the Bridgeville gaging station during 3 days of the 1964 flood. It is important to note that the primary natural source of suspended sediment is earthflow landslides and erosion of melange streambanks, which are more pervasive in the middle and upper basin. The ratios of suspended sediment to bedload, calculated by Kelsey for the middle and upper basin, may be different in the lower basin due to the presence of the more stable sandstone terrain.

Vegetation

The three major vegetation zones within the basin, which include redwood forest, oak woodland/prairie and coniferous forest, have strongly influenced the type and extent of human activity as well as settlement patterns within the basin. The redwood (Sequoia sempervirens) forest type dominates the western third of the basin, particularly at lower elevations influenced by summer fog. Most of the redwood forest is managed for industrial timber production, although a few old growth groves are preserved in Grizzly Creek State Park and Humboldt County Parks. The drier upper slopes and ridges of the redwood zone are characterized by Douglas fir (Pseudotsuga menziesii) and Tanoak (Lithocarpus densiflora) forests. The middle range of the basin is primarily grassland and oak woodland including tan oak, madrone (Arbutus menziesii) and California black oak (Quercus kelloggii) as well as mixed conifer forest. The grasslands have historically supported grazing of sheep and primarily beef cattle in the modern era. The upper basin is primarily coniferous forests of douglas fir, Jeffrey pine (Pinus jeffreyi), ponderosa pine (Pinus ponderosa), incense cedar (Calocedrus decurrens) and white-fir (Abies concolor). The coniferous forest type is primarily managed by the US Forest Service for multiple-use objectives.

1.B Land Ownership and Community Involvement

Land Ownership

Historically, the VDR Basin was occupied by two groups of Native American who were of Athabaskan descent: the Lassik and the Nongatl. They lived along the river during the winter when they harvested fish, then moved to the highland prairies in the summer to gather seeds and bulbs to hunt game. In the Fall, they gathered acorns before returning to their winter settlements along the river.

The first Euro-Americans are believed to have settled in the VDR around 1850, under the Federal Homestead Act. The VDR valley was fertile and good for farming, and highlands contained natural prairies which were well-suited to grazing. Rapid settlement in the VDR led to a war with the Native Americans in which the latter were largely eliminated by 1865 (See VDR Atlas (DWR 1975) for more on Native Americans). Many archaeological sites remain in the watershed, but there are no remaining tribal lands.

Land ownership in the basin today can be generally categorized as follows: Public land (US Forest Service, Bureau of Land Management, State and County Parks), private industrial timber, private non-industrial ranch and timber, and private rural residential. The approximate percentage of land ownership according to these categories is listed in Table 1.2. Since 1975 there may be an increase in the private rural residential category due to subdivisions of larger parcels. The primary community centers in the basin include: Hydesville, Carlotta, Bridgeville and Dinsmore.

Table 1.2 Land ownership areas and percentages (Adapted from DWR 1975)

Ownership Category	**Land Area (sq. miles)**	**Percentage of total area**
Public Ownership	72	17%
Industrial Timber	110	26%
Private Non-industrial Ranch and Timber (> 1 square mile)	133	31%
Private Rural Residential (< 1 square mile)	114	26%
TOTAL	**429**	**100**

Community Involvement in the TMDL Process

A valuable source of information regarding the characteristics, processes and management of the VDR basin is the long-time landowners whose families have lived and worked there for generations. Moore (1999) conducted interviews of several landowners in the Yager Creek and VDR watersheds to document their knowledge and experiences regarding: historic watershed conditions, storm events, wildlife, erosion, creeks and streams and influence of land management practices. Of particular relevance to the TMDL are the landowners' observations and recollections about historic conditions of the river channel, such as the changes in depths of favorite swimming holes, impacts of particular storm events and landslides, and changes in land management practices over time. A common theme throughout the historical narratives is the landowners' commitment to land stewardship and sustaining the quality of rural life for future generations. One landowner states:

> *" I was brought up to take care of it (the land) to the best of the knowledge of the generations before me. I certainly want to be able to pass it on to my children and grandchildren. I think it is a wonderful place to live and a marvelous way of life."* - (Cited in Moore 1999)

The recent formation of watershed groups in and around the VDR has provided a critical avenue of communication between resource agencies and the public. In particular, a group called Yager Environmental Stewards (YES) facilitated the communication between landowners and the consulting firm, Pacific Watershed Associates (PWA), regarding access to private land in order to conduct the sediment source assessment for this TMDL. A group of landowners in Cummings Creek have collaborated to relocate a road that was a significant source of sediment and to conduct sediment monitoring in the stream. In addition, the Eel River Watershed

Improvement Group (ERWIG) provides technical and financial assistance to local landowners interested in conservation.

EPA, with assistance from the Natural Resource Conservation Service (NRCS), also sought input from VDR residents to understand their perspectives about watershed conditions and land management impacts. With regard to sources of impacts to water quality, the residents indicated logging activities, natural causes and road construction as the top three concerns. Many residents also provided specific recommendations for improving the watershed, particularly regarding logging practices, gravel extraction and road maintenance. This input may be useful for establishing effective outreach and communication with the community as well as developing an implementation plan for the TMDL.

EPA, in cooperation with Humboldt RCD, Natural Resources Conservation District (NRCS), University of California Cooperative Extension (UCCE) and the Eel River Watershed Improvement Group (ERWIG), also conducted two TMDL informational sessions with the public in Bridgeville and Carlotta. These sessions provided an opportunity for the public to ask questions regarding the TMDL process as well as express their interests and concerns.

1.C Clean Water Act Section 303(d) and Total Maximum Daily Loads

The VDR, along with several other north coastal rivers, was identified on California's Clean Water Act (CWA) Section 303(d) list beginning in 1992 as water quality limited due to sedimentation. Section 303(d)(1)(A) of the Clean Water Act requires that "Each State shall identify those waters within its boundaries for which the effluent limitations ... are not stringent enough to implement any water quality standard applicable to such waters." The level of sedimentation in the VDR was determined to exceed the existing narrative water quality objectives necessary to protect beneficial uses of the basin, particularly the cold water fishery. A report for the American Fisheries Society by Higgins et al. (1992) regarding fish stocks at risk was cited as a primary source of information for the original 303(d) listing. Higgins et al. (1992) documented the status of salmon and steelhead stocks at risk in California, including the VDR, and attributed declines, in part, to accelerated erosion from land use practices. The fish stock report was based on the input of fisheries professionals throughout northwestern California, data from file information or reports from the California Department of Fish and Game, U.S. Fish and Wildlife Service and the U.S. Forest Service.

Water quality objectives (the term used by the State of California to refer to water quality standards) adopted for the VDR basin are contained in the North Coast Regional Water Quality Control Board Basin Plan ("Basin Plan"). The beneficial uses of water for VDR are described in the Basin Plan as either existing or potential. The water quality objectives are designed to protected the most sensitive beneficial uses.

The beneficial uses in the VDR include: cold freshwater habitat (COLD); migration of aquatic organisms (MIGR); uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered (RARE) and spawning, reproduction, and/or early development (SPAWN).

The water quality objectives address: 1) settleable material: ("Water shall not contain substances that result in deposition of material that causes nuisance or adversely affect beneficial uses"); 2) sediment: ("The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses"): and 3) turbidity: ("Turbidity shall not be increased more than 20 percent above naturally occurring background levels.") (NCRWQCB 1994).

Discharges of sediment are also addressed by two discharge prohibitions specifically applicable to logging, construction and other associated activities, which state:

> "The discharge of soil, silt, bark, slash, sawdust or other organic and earthen material from any logging, construction or associated activities of whatever nature into any stream or watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited."
>
> "The placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.".

Sedimentation is one of several factors (including ocean harvest, hydropower, inadequate passage (culvert blockage), habitat loss due to land-use, interaction with non-native species, particularly Sacramento pike minnow, natural events, predation by pinnipeds, etc.) that combine to affect salmon and steelhead populations throughout the Pacific Northwest (Nehlsen et al. 1991). Although sedimentation is part of the natural ecosystems processes through which anadromous salmonids have evolved, excessive amounts can be deleterious to spawning and rearing habitat and, consequently, to populations.

Sedimentation in the stream channel affects and interacts with various life stages of anadromous salmonids: 1) Aggradation of coarse material in the lower reaches of the mainstem (floodplains) can impede the migration of anadromous fish to and from spawning sites as well as reduce channel complexity necessary for rearing habitat; 2) Excessive levels of fine particles (generally less than .2 mm) can fill interstitial spaces in redds in spawning reaches thereby smothering embryos and sac fry and/or entrapment of emerging fry (Bjornn and Reiser 1991) and 3) Fine and/or coarse material can fill deep pools, which are necessary for rearing habitat throughout the mainstem and tributaries. In addition, suspended sediment, including turbidity, generally has sublethal effects such as reduced feeding and growth, avoidance, respiratory impairment, and physiological stress (Newcombe and MacDonald 1991).

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in various guidance documents (e.g., U.S. EPA 1991). The TMDL is a plan to achieve water quality standards by establishing appropriate load allocations and, if necessary, load reductions based on an analysis of the best existing available information. A TMDL is defined as "the sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the loading capacity) is not exceeded. That is,

$$TMDL=WLAs +LAs+NB$$

Where WLA=waste load allocations, LAs=load allocations and NB= natural background.

A TMDL must include consideration of seasonal variations and include a margin of safety to address uncertainty in the analysis.

This TMDL includes a description of:
* Water Quality Concerns (Problem Statements) - Chapter 2
* Water Quality Goals (Numeric Targets) - Chapter 3
* Sediment Source Analysis - Chapter 4
* TMDL and Load Allocations - Chapter 5
* Implementation and Monitoring Recommendations - Chapter 6

The best readily available information for the development of the VDR TMDL includes, but is not limited to:

* Recent and historical Changes in Channel Cross Sections at Selected Sites in the Van Duzen River Basin (Klein 1998)
* A Sediment budget and an analysis of Geomorphic Process in the Van Duzen River Basin North Coastal California (Kelsey 1977).
* Stream Habitat Surveys by the California Department of Fish and Game (various years).
* Habitat Conservation Plan and Sustained Yield Plan (Pacific Lumber Co. 1998)
* Yager/Van Duzen River Historical Narratives (Moore 1999)
* Sediment Source Assessment (Pacific Watershed Associates 1999)
* Lower Eel Sediment Source Investigation (PWA 1998)
* Van Duzen River Watershed Analysis (USDA 1998)
* Van Duzen River Environmental Atlas (Department of Water Resources 1975)
* Eel and Van Duzen Rivers General Assessment of Historical Change in Channel Morphology (US Army Corps of Engineers 1999).
* Klamath Resource Information System Coho Database (“KRIS”) provided access to relevant data on watershed conditions in the Yager Creek and VDR basins.

CHAPTER 2
WATER QUALITY CONCERNS (PROBLEM STATEMENTS)

For purposes of characterizing watershed conditions and water quality concerns, the VDR Basin is divided into three distinct areas: lower basin, middle basin and upper basin (Figure 2.1). This stratification is based on general distinctions between the three zones in the following areas: dominant geologic types, distribution/abundance of anadromous fish, channel types (gradients and sediment transport capabilities), vegetation types, and land management/ownership patterns, which are summarized in Table 2.1. TMDL problem statements are intended to identify specific water quality concerns. Problem statements in this TMDL include the way in which sediment may be limiting fisheries and hillslope management activities that have contributed sediment to the stream conditions. In this chapter, the problem statements are underlined and followed by supporting explanation. A summary of the concerns is included at the end of the chapter.

Figure 2.1 Map of subwatersheds within the lower, middle and upper basin

Table 2.1 Dominant characteristics within the lower, middle and upper VDR basin.

Dominant Characteristics	Lower Basin	Middle Basin	Upper Basin
Terrain type	Stable sandstone, interspersed with potentially unstable sandstone along steep streamsides and stable melange in lower floodplain	Older slump and active earthflow in melange as well as some potentially unstable sandstone.	Potentially unstable sandstone in the headwaters area and melange and stable sandstone in the lower area
Distribution of Anadromous Fish	Coho, chinook, steelhead and coastal cutthroat present	Chinook and Steelhead present	Steelhead and resident trout
Channel Types/Aquatic habitat	Braided or meandering trunk streams in lower floodplain, low to moderate gradient tributaries accessible for fish spawning and smaller steep gradient transport reaches	Generally steeper, more confined, and transport-dominated reaches. Depositional reach in lower mainstem above Bridgeville.	High gradient, transport-dominated tributary stream feed low gradient, meandering to braided trunk streams.
Vegetation Class	Redwood Forest	Prairie and oak/fir woodland	Mixed conifer forest
Land Management Patterns	Industrial Timber, Farming in lower floodplain, some private residential near river in Hydesville and Carlotta. Recreation and gravel mining.	Ranching, livestock grazing and some timber management	Six Rivers National Forest (interspersed with private res. along mainstem) - Multiple use objectives. - Late Successional Reserve land allocations

2.A Lower Basin Water Quality Concerns

This area encompasses approximately 129 square miles including the lower VDR from the confluence with the Eel River to the confluence with Grizzly Creek as well as lower Yager Creek, including the Lawrence Creek tributary, but excluding the North, Middle and South Fork Yager Creek. The geology is dominated by relatively stable sandstone, interspersed with pockets of potentially unstable sandstone, particularly along steep streamsides and includes stable melange in the lower floodplain. Stream gradients and aquatic habitat conditions in the lower basin are naturally capable of supporting relatively higher diversity and abundance of anadromous fish than in the rest of the basin. The dominant vegetation class is redwood forest and is primarily managed for industrial timber production.

<u>1) Although the lower basin contains subwatersheds with relatively higher values of anadromous fish diversity and abundance, current populations are well below historic levels.</u>

Figure 2.2 illustrates the distribution of coho, chinook, steelhead and coastal cutthroat trout (Scott Downie (DFG) and Jeff Barrett (PL), pers. comm., June, 1999; PL 1998; USDA 1998). Coho Salmon, which is presently listed as threatened under the Endangered Species Act, and Coastal Cutthroat trout are limited to the lower basin. Chinook salmon extend somewhat further into portions of the middle basin and Steelhead extend the furthest of anadromous fish into the South Fork VDR in the upper basin.

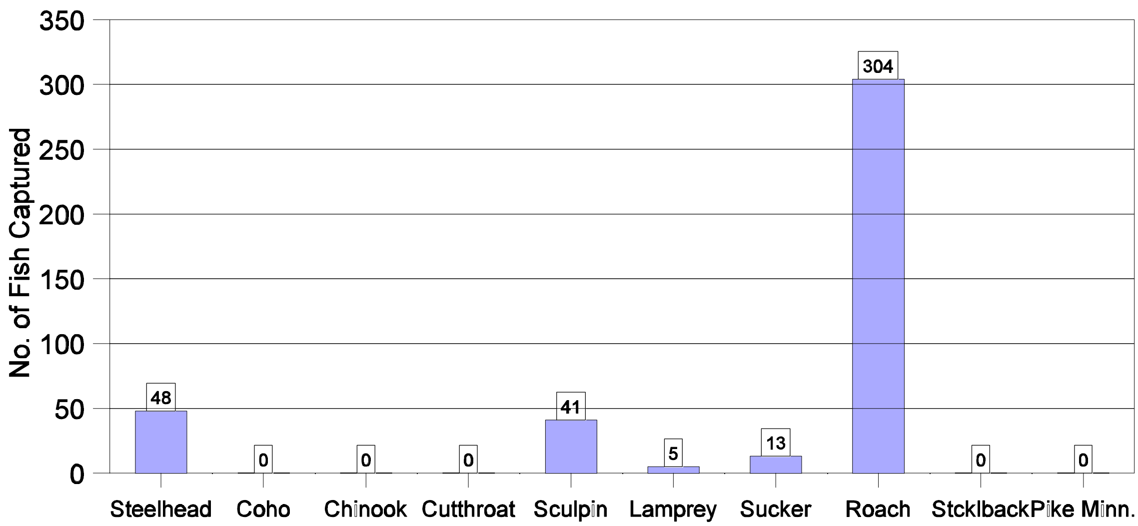
Figure 2.2 Anadromous fish distribution in VDR (Scott Downie (DFG) and Jeff Barrett (PL), pers. comm., June, 1999; PL 1998; USDA 1998)

A DFG (1951) survey in 1951 identified a few tributaries in the VDR (including Cooper Mill Creek, Cummings Creek, Grizzly Creek and Hely Creek) as supporting up to 500 “young of the year” coho. Although precise population numbers for each of these species are not available, DFG (1996) along with local accounts, indicate the most serious decline in population occurred in response to the 1964 flood. A DFG (1964) survey of Yager Creek in August 1964 (prior to the 1964 flood) indicated the following:

“Yager Creek has excellent spawning areas. The gravel is uniform in size (2-5 inches in diameter). There is some silt, but the gravel is still loose. There is not too much shelter for fish--only under rocks and a few logs... Caddis fly larvae are quite abundant ... Salmonids were very abundant. Seining was done near the mouth and the species identified were stickleback, rainbow trout, and silver salmon. The fish ranged in size from 2 inches to 12 inches. The most abundant were the 5-6 inch fish.”

The fish community structure in Yager Creek in 1991, as measured by DFG, was much different than the 1951 account. As illustrated in Figure 2.3, Yager Creek contained a higher ratio of roach compared to steelhead. The presence of western roach and Sacramento pike minnow, both introduced species in much of the lower mainstem VDR and to some extent lower gradient tributaries, may be causing mortality to juvenile salmonids and forcing them to use less suitable habitat. Both species appear to thrive in aggraded channel conditions (described below) and warmer stream temperatures that have persisted since the 1964 flood. DFG (1991) found higher numbers of steelhead in tributaries to Lawrence Creek in 1991 but very few coho or chinook salmon.

Figure 2.3 Yager Creek fish community structure (DFG electrofishing 1991)



<u>2) Aggradation of the lower mainstem channel, persistent from the 1964 flood event, can restrict passage of salmon and steelhead to spawning and rearing reaches, especially during low flow years. The bed elevation in the lower mainstem has slightly aggraded since the late 1960s (USCOE 1999)</u>.

The lower mainstem floodplain is particularly important for providing adequate flows and passage for fish migration to spawning and rearing habitats further up in the basin. Scott Downie (DFG, personal communication, September, 1999), has observed fish passage problems in the lower mainstem, particularly during low-flow years (early 1990s). Unfortunately there is very little quantitative data from which to compare post-1964 floodplain channel conditions with pre-1964 conditions. Based on historical accounts and observed conditions throughout the basin, the lower floodplain likely experienced aggradation in response to the 1964 flood thereby impacting fish passage to some degree. As stated by one landowner:

> *"...I don't think anyone coming to this area now can possibly imagine the millions of yards of material that moved in the 1964 flood. Because every gulch, canyon and draw, deposited considerable yards into each one of these streams.*" (cited in Moore 1999).

Since the 1964 event, it appears the lower mainstem floodplain is presently at slightly higher bed elevations than were present in the late 1960's (following the 1964 flood). The U.S. Army Corps of Engineers (USCOE) conducted an assessment of historical change in channel morphology (USCOE 1999). The USCOE compared data from surveys completed in 1968 and 1998, located approximately 1000 ft and 1 mile upstream from the Highway 101 bridge over the VDR (lower floodplain of VDR). Both cross-sections displayed net aggradation during this period of 1.7 feet and 2.7 feet respectively. Historical aerial photographs, dating back to 1941, confirm that the main channel has meandered within the floodplain during this timeframe. In addition to the slight increase in channel bed elevation, USCOE (1999) measured "..minor to moderate erosion due to sliding..." on the steeper left banks. However, the USCOE determined that sand and gravel mining have not caused a detrimental impact on the river's morphology.

Table 2.2 Lower VDR cross-section comparison of 1968 and 1998 (USCOE 1999)

Cross-Section	Average Level of Aggradation/Degradation			Overall elevation Change	Evidence of Switching
	Left Bar	Right Bar	Invert		
1000 ft. upstream from Highway 101 Bridge	None (Step bank and active slide)	Aggradation +2 ft	Aggradation +2 ft	1.7 ft	Towards left bank
1 mile upstream from Highway 101 Bridge	Aggradation +2.5 ft (Active slide present)	Aggradation +2.5 ft	Aggradation +2.5 ft	2.5 ft	Towards left bank

<u>3) Sedimentation in pools and gravels, particularly in lower basin tributaries, is limiting spawning and rearing habitat of anadromous fish.</u>

The lower basin tributaries are naturally capable of supporting higher quality anadromous fish habitat due to stream gradients, riparian vegetation, temperatures, etc. than the middle and upper basin. Stream habitat data collected within the last 10 years suggest that elevated fine sediment levels, low pool frequency/depth, and low levels of large woody debris are potentially limiting aquatic and consequently spawning and rearing success of anadromous fish in the lower basin. Table 2.3 summarizes the values for percent fine sediments <0.85 mm in size, embeddedness, percent pools and maximum pool depth from data collected by DFG and PL from the 1990s. This data set represents the most recent available information on sediment-related habitat conditions in many of the key tributaries in the VDR.

Fine sediment levels in potential spawning gravels, particularly in the lower VDR tributaries, are not presently achieving “healthy” thresholds. Fine sediment is measured using core samples (McNeil and Ahnell 1964) or shovel samples (PL 1998) of potential spawning gravel then sorted and weighed. Researchers have correlated the percentage of sediments less than 0.85 mm in diameter with a reduction in salmonid embryo survival and emergence (Chapman 1988). Fine sediment can fill the interstitial spaces within spawning gravels thereby reducing permeability and potentially trapping fry from swimming into the water column. Average values for percent fine sediment data from Yager Creek watercourses and lower VDR tributaries are 19% and 26% respectively (PL 1998). Generally, values less than 14%, for fines 0.85 mm in size, are considered “good” spawning habitat (McHenry et al. 1994, CDF 1994). Additional fine sediment data from 1980 and 1981 in the Lawrence Creek watershed (PL 1998), include levels in the range of 5-14% which indicate a trend toward increasing fine sediment levels in the 1990's. However, the validity of the 1980-81 data is questionable because methodologies and precise locations are not known.

DFG also measured the degree to which cobbles are “embedded” in fine sediment. High embeddedness values are indicators that excessive sedimentation is taking place and may be limiting spawning habitat. DFG measures embeddedness by estimating the percentage of a cobble, located in the “tail out” of a pool, is covered or embedded in fine sediment (Flosi et al. 1998). Embeddedness values below the range of 20 -25% are generally considered high quality. For stream surveys in Yager Creek and VDR tributaries, DFG estimated 63% and 57% embeddedness scores, respectively (PL 1998).

The number, volume and depth of pools are important components of fish habitat primarily for providing cold water and protection from predators. Coarse and fine sediment can reduce the frequency and depth of pools thereby impacting salmonid rearing habitat. The percentage of a stream reach composed of pools (percent pools) is one of several methods to measure pools. The percent pools measured, primarily by DFG in the early ‘90's, indicated that many of the tributaries in the lower Yager and VDR are below healthy thresholds. The average percent pools for stream reaches within the Yager WAA and VDR WAA were 26% and 20% respectively. This falls below the “healthy” thresholds of 40% primary pools that are 3 ft deep (in third and fourth order streams) described by Flosi et al. (1998). The Eel River Action Plan (DFG 1996) identifies pools as the number one component in need of restoration for fisheries in many of the important anadromous tributaries in the lower VDR. DFG also reports that riparian vegetation is still recovering and lack of canopy in many stream reaches contribute to water temperatures unfavorable to salmonids.

Table 2.3 Summary of sediment-related habitat values (averages) for lower basin tributaries (Data from DFG stream surveys and PL monitoring in the 1990s (PL 1998))

Watercourse		**% fine sediment <0.85 mm (%)**	**Embeddedness (%)**	**% pools (%)**	**maximum pool depth (ft)**
Target Conditions (explained in chap.3)		<14	<25	>40	>3.0
Lower Yager Creek watershed and key tributaries	Bell Creek	21	70	26	3.01
	Booths Run	10	62	15	2.60
	Fish Creek	n/a	52	34	1.73
	Shaw Creek	22	70	27	2.24
	Lawrence Creek	19	60	31	3.53
	Mainstem Yager Creek	21	83	22	4.94
	Area Ave.	**19**	**63**	**26**	**3.00**
Lower Van Duzen River Tributaries	Cummings Creek	25	63	9	1.92
	Grizzly Creek	23	53	21	2.61
	Stevens Creek	n/a	40	27	2.23
	Hely Creek	16	59	16	1.92
	Root Creek	36	72	25	2.37
	Area Ave.	**26**	**57**	**20**	**2.21**

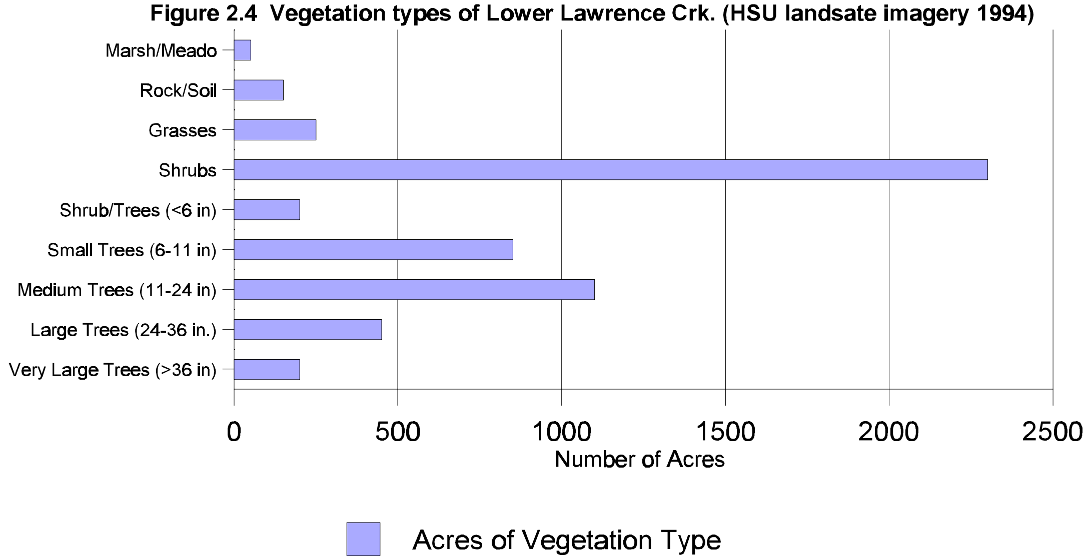
Critical spawning tributaries in the lower basin may also be lacking sufficient quantities of large woody debris (LWD) which provides an important function in routing, storing and sorting sediment, as well as influencing other channel characteristics, such as pools and cover, important for anadromous fish habitat (Swanson and Lienkaemper 1978, Lisle 1986). Very little current, quantitative LWD data exist for the VDR. However, LWD levels are considered to be extremely low, particularly in the areas where it is needed most due to: 1) previous efforts by the government to remove large quantities of LWD from streams for the purpose of reducing migration barriers; and 2) many of the large streamside trees that would have provided a future source of LWD in the channel have been harvested. Consequently, a primary structural component of streams in the redwood zone is missing. PL (1998) acknowledges that historic logging of streamside trees in the Yager Creek watershed has led to low canopy levels and consequently LWD recruitment problems in the near term.

<u>Hillslope sediment delivery concerns in the lower basin</u>

Intensive land management, particularly timber harvest and road-related activities on steep and unstable terrain, has accelerated sediment delivery rates thereby threatening spawning and rearing habitat, particularly in lower basin tributaries. Timber harvesting began in the lower basin redwood zone in the late 1800s then intensified in the late 1940's, as mechanical developments and lumber demand expanded following WWII. Timber practices in those years generally disregarded streamside protection and rendered the hillslopes more vulnerable to the massive effects of the 1964 storm event (Kelsey 1977). Although forest management practices and associated regulations have generally improved since the establishment of forest practice rules in the 1970's, timber-related management actions continue to pose a significant risk to water quality and watershed conditions, particulary within the redwood zone of the lower Basin.

Portions of the lower basin have been heavily harvested within the last decade, thereby increasing sediment delivery risks to watercoarses particularly in critical spawning and rearing subwatersheds, such as Lawrence Creek and associated tributaries. For example, 44% of the Yager Creek area under industrial timber management is dominated by a “young” forest type, indicating a high percentage of relatively recent (within last decade) harvesting and associated soil disturbance (PL 1998). Figure 2.4 displays the timber and vegetation types created from a 1994 Landsat image by the Humboldt State University spatial Analysis Laboratory.

Figure 2.4 Vegetation types of Lower Lawrence Crk. (HSU landsate imagery 1994)



The relatively large acreages of shrub and small tree classes in figure 2.4 are indicative of clear cut or heavy selection logging conducted prior to 1994. Intensive timber harvesting can affect several physical and biological watershed processes including: hydrology (water yield, evapotranspiration, peak flows, timing of runoff, etc.), sediment transport, canopy cover and stream temperatures, large woody debris recruitment rates, etc. as described by Spence et al. (1996). Intensive management on steep streamside slopes, unstable areas and riparian zones can especially affect sediment delivery rates. PWA determined that 20% of the total historic sediment delivery in the lower basin was associated with timber harvest activities, as discussed more thoroughly in Chapter 4.

Associated with timber management in the lower basin are high road and skid trail densities and high road mileage located directly adjacent to streams in Yager Creek and Lawrence Creek. Road densities of 5-6 miles per square miles in timber management areas of the lower basin represent a high risk of road-related sediment discharge. PWA determined that road and skid trail- related sediment delivery mechanisms were associated with 16% of the total historic sediment delivery in the lower basin (Chapter 4). Stream crossings with diversion potential, road segments hydrologically connected to streams, and fill failures from roads, skid trails and landings are often controllable road features that deliver sediment (Weaver and Hagans 1999). Based on a reconnaissance field inventory of timber roads in the lower Yager and VDR basins, PWA (1998) found the following: 1) 63% (69 out of 110) stream crossing contained diversion potentials; 2) 22% (9 mi. out of 43 mi.) of the road ditch length was constructed with either an inboard ditch or has berms at the outside edge of the road which result in the funneling of sediment to the stream; 3) road fill failures were responsible for 60% of the total sediment delivery from road-related sources; and 4) a minimum of 27% (87 out of 142) stream crossings revealed field evidence of eroding a portion or all of the stream crossing fill volume at least once in the past. Road-related sediment delivery is discussed more thoroughly in the target conditions (Chapter 3) and sediment source assessment (chapter 4).

In addition to forest roads, State Highway 36, located directly along the mainstem of the VDR as well as County and rural residential roads throughout the lower basin pose sediment delivery risks to the watercourses in the lower Basin.

2.B Middle Basin Water Quality Concerns

This area encompasses approximately 202 square miles ranging from the upper Yager Creek Basin, including North, Middle and South Fork as well as the middle section of the Van Duzen River from the confluence of Grizzly Creek to the lower tributaries of the South Fork VDR (excluding the upper mainstem VDR). The geology is dominated by older slump and active earthflow in melange as well as some potentially unstable sandstone. Channel gradients within the middle basin are generally steeper and more confined than in the lower basin. Chinook salmon are able to utilize portions of lower North Fork and South Fork Yager Creek as well as the mainstem VDR as far as “Salmon Hole.” Juvenile chinook salmon generally leave the river by June of the same year they hatch which makes them less vulnerable to summer habitat conditions (i.e., warmer temperatures, lower flows). Winter run steelhead are more widely distributed and populations more viable (+/- 10,000) (USFS 1998). Some of the higher utilization areas in the middle basin by winter steelhead include SF Yager Creek, Little Larabee

Creek (trib to mainstem VDR), Butte Creek (Tributary to SF VDR), and Blanket Creek (trib to SF VDR). Coho salmon are generally not found in the middle basin. Vegetation is largely open grassland interspersed with oak woodland, including Douglas-fir forests. Landownership is primarily large private ranches with some rural residential near the mainstem VDR.

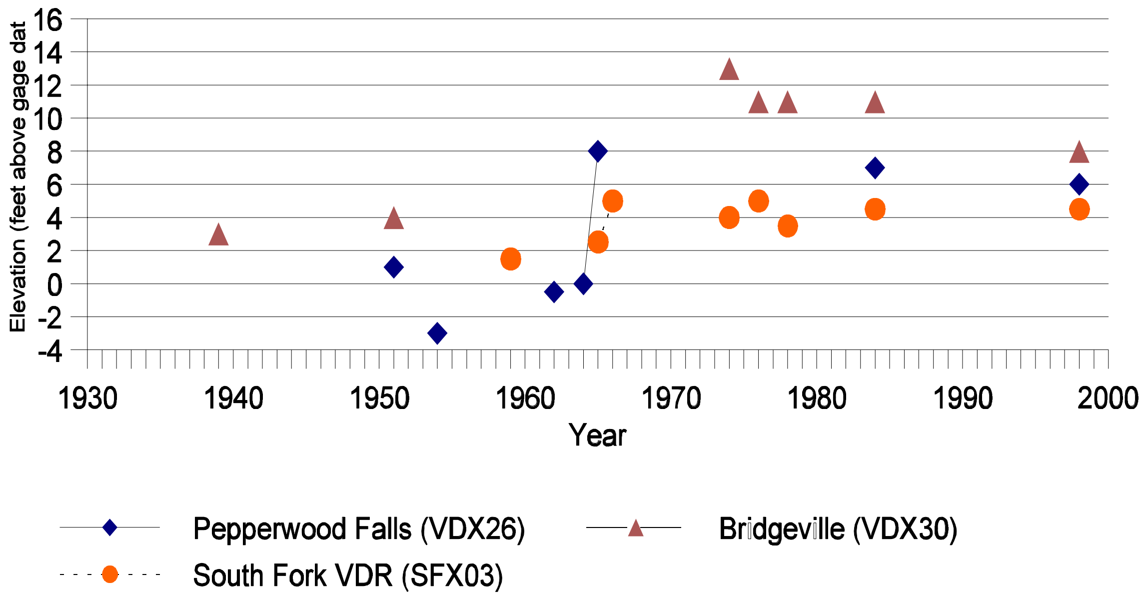
1) Summer run steelhead population is low (probably less than 100) and considered at risk .

Summer steelhead enter the river in the spring then spawn the following spring. The formation of deep pools on the middle mainstem VDR between the confluence of Baker Creek and Eaton Falls is a particularly important channel characteristic for summer steelhead. Summer steelhead depend on the cool water in these deep pools for holding over during the summer. Sedimentation can reduce pool depth and volume thereby limiting available habitat for steelhead. DFG (1996) estimated a population of 31 summer steelhead in 1991 based on a dive survey of 50-69% of the adult summer holding areas. Higgins et al. (1992) classified summer race steelhead at "high risk of extinction."

2) Despite indications of channel recovery (downcutting) in the middle basin, sedimentation levels in low gradient reaches may be limiting salmonid habitat.

The low gradient reach between Bridgeville and Little Larabee Creek in the middle basin was dramatically altered by aggradation due to the 1964 event (Kelsey 1977). This reach of the middle mainstem VDR appears to be recovering toward pre-1964 levels, based on more recent channel cross-sections survey data (Klein 1998). Figure 2.5 illustrates the change in thalweg elevation (deepest point) of cross section measured at three points on the VDR including: the former US Geologic Survey (USGS) gaging station at Pepperwood Falls, the old Highway 36 bridge at Bridgeville, and the former USGS gaging station on the South Fork VDR. Channel downcutting and pool development in the middle mainstem reach between Bridgeville and Baker Creek is particularly beneficial for spawning and rearing of chinook and steelhead.

Figure 2.5 Changes in thalweg bed elevations over time (Data from Klein 1998)



Despite an apparent trend in recovery of the mainstem VDR, stream survey information from DFG indicate sedimentation may be influencing generally poor salmonid habitat conditions exist in the middle basin tributaries. For example, average fine sediment levels (% < 0.85mm) between 1994 and 1996 in the North Fork Yager Creek and Middle Fork Yager Creek were 19.5% and 20% (PL 1998), levels which may effect early life stages of salmonids. DFG (1992) ranked aquatic habitat on North Fork Yager and South Fork Yager as relatively low based on lack of primary pools, lack of woody cover in the pools, unstable stream banks, road erosion, and lack of canopy. Little Larabee Creek and Hoagland Creek, tributaries to the middle mainstem VDR, contained similarly marginal habitat conditions relative to other surveyed tributaries. However, certain stream reaches in the middle basin such as Butte Creek, tributary to South Fork VDR, do consist of relatively suitable habitat, especially for steelhead.

Hillslope sediment delivery concerns in the middle basin

The middle basin is underlain by steep, unstable terrain types and consequently, generates the highest rates of sediment delivery in the basin (1886 yds^3/mi^2/year), as characterized in sediment source analysis (Chapter 4). Natural sediment sources are responsible for delivering the majority (84%) of the historic sediment load to the channel network in the middle basin. Of the management-associated sediment delivery in the basin, certain road and timber harvest activities have historically posed the greatest risk to water quality and fish habitat. Roads/skid trails and timber-related management activities were associated with approximately 16% (110 yds^3/mi^2/year roads, 183 yds^3/mi^2/year, respectively) of the total historic sediment delivery from the middle basin. Moore (1999) described improvements in modern logging and road management practices compared with the 1960's, when logs were skidded up and down creeks and stream crossings constructed without culverts. In addition to private ranch and timber roads, several miles of county and state roads exist in the middle basin. Inventory and prioritization of potential sediment delivery sites on the existing road network could greatly assist in continuing to reduce the road-related sediment delivery risk in the middle basin.

2.C. Upper Basin Water Quality Concerns

The upper basin encompasses roughly 98 square miles including upper portions of the South Fork VDR along with the upper most mainstem VDR. The headwaters of South Fork and West Fork in particular contain steep and unstable terrain. Steelhead are able to migrate throughout areas of the South Fork while the upper mainstem supports resident trout. The US Forest Service is the largest land manager in the upper area.

1) Sediment levels continue to potentially impact spawning gravel and pool habitat for steelhead in the South Fork VDR

The 1964 flood triggered widespread debris landsliding in the headwater drainages of the upper basin (SF VDR and West Fork VDR) which mobilized large quantities of sediment to the downstream channel network (Kelsey 1977). The landsliding resulted in up to 15 feet of sediment aggradation and destroyed riparian vegetation in upper channel reaches of the South Fork and West Fork VDR. Klein's (1998) cross section survey indicates that much of the original pulse of sediment is likely flushing out of the SF VDR, however bed elevations and thalweg levels are still above those that existed pre-1964. Stream habitat data from DFG (1992) indicate that SF VDR tributaries are experiencing high embeddedness scores and low percentages of pools which indicate sedimentation may be affecting habitat quality for steelhead. Bear Creek and Blanket Creek contained low percent pool values (5% and 22%, respectively) which can limit available rearing habitat. DFG stream surveys found 50% of the pool tails contained embeddedness values of greater then 50% indicative of high fine sediment levels which negatively impact spawning gravel.

Hillslope sediment delivery concerns

Timber harvesting and road building on Forest Service land since WWII are the most intensive management actions in the upper basin. Timber harvesting of Douglas-fir in the Six Rivers National Forest started in 1960, in the lower part of the upper basin, much later than harvesting on private land in the basin. No logging or road building had occurred in the head-water basins at the time of the 1964 flood (Kelsey 1977). The US Forest Service managed most of the upper basin for timber production until the early 1990's. Much of the South Fork VDR was designated as Late Successional Reserve (LSR) under the Northwest Forest Plan for the stated purpose to, “maintain a functional, interactive, late-successional and old-growth forest ecosystem (USDA 1994). The historic and present stand conditions as well as management direction for the LSR are described in an LSR Assessment (USDA 1999).

The sediment source assessment (Chapter 4) identified historic timber activities as the principle management-associated source of sediment (271 yds^3/mi^2/year, 20% of total historic sediment delivery) in the upper basin. Although, the sediment source assessment by PWA did not identify roads as a relatively high risk in the upper basin, the USDA (1998) estimates that 10-15% of the road mileage of National Forest lands is in potentially sensitive locations.

2.D Summary of Water Quality Concerns

Overall Statement

The primary beneficial use of concern in the Van Duzen River, salmon and steelhead habitat, is strongly impacted by large pulses of sediment that tend to aggrade the stream channel and alter habitat conditions (as occurred in 1964 and other high rainfall years). Anadromous fish populations are not as healthy as historic levels (DFG 1996). Certain reaches of the Van Duzen River are presently recovering from the dramatic influx of sediment, initiated by the 1964 flood, as indicated by lowering stream bed elevations in alluvial reaches. However, sedimentation levels are presently still impacting aquatic habitat, particularly the quality and quantity of pools and spawning gravels for salmon and steelhead in the lower basin tributaries (DFG 1996, PL 1998).

In addition, road construction/maintenance along with intensive timber management in sensitive watershed areas, have accelerated sedimentation processes and continue to pose a controllable sedimentation risk to instream habitat conditions. The degree to which management related activities, in contrast to natural sources, are associated with historical sedimentation processes for various areas of the basin are set forth in the sediment source assessment section. The challenge for resource managers is to reduce the risk of management-associated sediment delivery, particularly in the event of large storms, through implementing a prevention and restoration strategy. More specific water quality concerns are expressed according to the lower, middle and upper portions of the basin.

Lower Basin

1) Although the lower basin contains subwatersheds with relatively higher values of anadromous fish diversity and abundance than exist in the rest of the basin, the current fish populations are well below historic levels (Higgins et al. 1992, DFG 1996, PL 1998);

2) Aggradation of the lower mainstem channel, persistent from the 1964 flood event, can restrict passage of salmon and steelhead to spawning and rearing reaches, especially during low flow years (S. Downie, DFG, pers. comm., September, 1999). The bed elevation in the lower mainstem has slightly aggraded since the late 1960s (USCOE 1999);

3) Several tributaries in the lower basin still suffer from poor habitat conditions, particularly with regard to insufficient number and depth of pools, excessive fine sediment levels and low levels of large woody debris (DFG 1996, PL 1998);

Intensive management activities, particularly timber harvest and road-related, have exacerbated sediment delivery rates and pose a continued threat, particularly in critical spawning and rearing reaches such as Lawrence Creek, Grizzly Creek and Cummings Creek (See sediment source assessment- Chapter 4). Continued sediment reduction efforts in the lower basin, particularly road storm-proofing and less intensive management on steep unstable areas, could yield beneficial results for anadromous fish habitat more quickly than in other areas of the basin.

Middle Basin

1) Summer run steelhead population is low (probably less than 100) and considered at risk (Higgins et al. 1992, DFG 1992). Depth of pools in the middle mainstem VDR is important for summer steelhead habitat and low gradient reaches in the middle basin are capable of supporting spawning and rearing habitat for chinook and steelhead.

2) Despite indications of channel recovery (downcutting) in the middle mainstem VDR, recent sediment-related habitat conditions may potentially be limiting fish recovery (DFG 1992).

Although natural sediment sources contribute the majority (84%) of sediment from the middle basin, certain road and timber related management activities have historically represented a risk to water quality and fish habitat. Continued sediment reduction efforts, particularly road inventories, storm-proofing and maintenance, would reduce the risk of sediment delivery to low gradient spawning reaches in the middle and lower basin.

Upper Basin

1) Fine sediment levels, as indicated by embeddedness measurements, may potentially be impacting spawning gravel and pool habitat for steelhead in the South Fork VDR. The steep headwater areas of the South Fork VDR and West Fork VDR are capable of supplying large volumes of sediment to the lower depositional reaches thereby impacted steelhead spawning habitat (as occurred as a result of the 1964 event). The main concern in the upper basin is to avoid additional disturbance of sensitive hillslope areas and to correct potential sediment delivery problems associated with existing roads, thereby protecting downstream resources.

CHAPTER 3
WATER QUALITY GOALS (NUMERIC TARGETS)

3.A Introduction

TMDL targets are intended to express "healthy" watershed conditions that support beneficial uses (i.e., cold water fisheries) and the attainment of water quality standards. Numeric targets interpret narrative water quality standards and provide a basis for determining the success of the TMDL. Selecting TMDL indicators and target levels is challenging for several reasons: 1) watershed conditions, particularly sedimentation levels, naturally fluctuate widely over time and space; 2) minimal data exist on reference conditions, 3) many instream indicators can not distinguish between human-induced disturbance versus natural disturbance, and 4) indicators can be difficult and expensive to measure (adapted from Bauer and Ralph 1999). This chapter discusses objectives, reference conditions, descriptions of stream and hillslope indicators and a comparison of the targets with existing conditions.

The indicators and targets in this TMDL are intended to address two primary, interrelated objectives: 1) Achieve sediment loading levels that will lead to aquatic habitat conditions capable of supporting healthy, viable stocks of anadromous fish, thereby meeting water quality standards, 2) Prevent sediment delivery from management-related sources in amounts that will result in the natural recovery of aquatic habitat conditions. Correspondingly, the TMDL contains two categories of indicators: 1) those related to instream aquatic habitat condition, and 2) those related to sediment delivery processes.

One approach to establishing numeric targets is to identify a reference time period or watershed that has not experienced the same level of impact as the VDR and is considered to be healthy and functioning. The U.S. Forest Service suggests that the 1930's represent reference conditions since the watershed was minimally disturbed by logging and road building at that time, fish populations appeared relatively healthy and several decades had passed since the last major flood of 1861 (USDA 1998). However, very little data exist from that time period against which to compare existing data and conditions. Likewise, it has not been possible to identify a reference watershed which has healthy conditions and is physically comparable to the VDR.

In the absence of reference conditions, this TMDL includes both narrative (qualitative) targets expressed as "improving trends" and numeric (quantitative) targets when supported by relevant literature. As discussed in previous chapters, historical cross-section data (Kelsey 1977, Klein 1999) and historical narrative accounts (Moore 1999) provide some indication that portions of the basin, particularly the middle and upper areas, are in a process of recovery but have yet to achieve levels that existed prior to 1964. Thus, while quantified targets may at this point be difficult (or inappropriate in some cases) to identify for some indicators, it is appropriate to facilitate continued trends of improvement. In either case, the targets express water quality or watershed conditions capable of supporting beneficial uses based on the best available information.

In considering whether the target conditions are achieved, a weight-of-evidence approach should be taken. No single target value in any individual year should be singled out as indicating either attainment or lack of attainment of water quality standards. Long-term running averages should be taken of the in-stream indicators in particular, since they can only represent increments of improvements which are highly dependent on climatic and flow conditions.

3.B Description of Instream Sediment Targets

Table 3.1 summarizes the indicators and associated target condition. An explanation of each indicator as well as existing conditions is provided below.

Percent Fine Sediment

Percent fine sediments is a measure of the stream bed substrate that is composed of particle sizes less than 0.85 mm. Higher percentages of fine sediment in potential spawning gravels can fill interstitial spaces, reduce permeability and trap fry from emerging from redds. Fine sediment levels are measured using core samples (McNeil and Ahnell 1964) or shovel samples of potential spawning gravel then sorted, dried and weighed. Klein (1998) provides several recommendations regarding methodology, dealing with channel armor, dealing with large rocks and reporting methods and analytical reports.

CDF (1994) reports that in most studies on this matter, emergence of coho fry was high at <5% fines but dropped sharply at >15% fines. McHenry et al. (1994) reported that salmonid survival dropped drastically when fine sediments exceeded 13% based on a study of five watershed in the Olympic peninsula. Burns (1970) measured fine sediment levels in South Fork Yager Creek in 1967 through 1969 and found average levels of 16.4 through 22.1. Unfortunately, samples are not available to compare with pre-1964 flood conditions. Winzler and Kelley Engineers (1981) reported fines sediment levels in Lawrence Creek in 1980 and 1981 of 9-10%, however, the methodologies and locations for collecting this data are not reported. In the absence of more research to indicate higher percent fine levels are supportive of anadromous fish, this TMDL includes the less than or equal to 14% threshold for spawning tributaries to maximize the potential for coho fry emergence.

Existing conditions: Monitoring stations located on Cummings Creek, Grizzly Creek, Hely Creek, and Root Creek between 1994 and 1996 indicate that fine sediment levels (0.85mm) averaged 29% (PL 1998). Lawrence Creek samples between 1991 and 1996 indicate a 19% average. North Fork Yager and mainstem Yager Creek indicate a 20% and 21% average, respectively, between 1994 and 1996 (PL 1998).

Embeddedness

Embeddedness is a measure of the degree to which cobbles and gravel are “embedded” or covered in fine sediment. Higher embeddedness values are indications of poor spawning gravel quality due to potential impacts of excessive fine sediment. In addition to indicating spawning substrate quality, embeddedness may effect macroinvertebrate productivity or species composition. The Department of Fish and Game measures embeddedness in pool tail outs where spawning is likely to occur (Flosi et al. 1998). Measurements of less than 25% is an indicator of unembedded substrate.

Existing Conditions: Stream surveys conducted by DFG, primarily in 1991, in Yager Creek/VDR tributaries revealed embeddedness values of 63% and 57%, respectively (PL 1998).

Table 3.1 Summary of TMDL indicators and targets

Objective	Location	Indicator/parameter	Healthy Range or Target	References
Improve the quality and size distribution of spawning gravel for salmon and steelhead.	Class I tributaries that support spawning and rearing including, but not limited to: Lawrence, Booths Run, Shaw, Cooper Mill, Cummings, Stevens, Grizzly, Root Creek, SF Yager, Little Larabee, Butte Creek	% Fine Sediment	<14% (mean) as wet volume	CDF 1994, McHenry et al., 1994
		Embeddedness	less than 25% cobble embeddedness measured at pool tail-outs where spawning is likely to occur	Flosi et al. 1998
		Pebble Counts	Increasing trend in size descriptors D_{50} > 69 mm	Klein 1998, Knopp 1993
		Aquatic Insects	Improving trends in indices: Richness, EPT and % Dominant Taxa.	Plafkin et al., 1989; DFG-WPCL 1996
		Turbidity	No greater than 20% above background	Basin Plan 1994
Improve channel complexity, particularly pool frequency and depth, and lower mean bed elevation	Subset of class I tributaries (per the number and location recommendations by Klein (1998)) for all listed indicators. Mainstem VDR, mainstem Yager and SF VDR in historically surveyed locations for just cross sections and thalweg profiles	Cross sections (bed elevations)	Decreasing trend in mean bed elevations toward pre-1964 levels	Kelsey 1977; Klein 1998
		Thalweg Profiles/Pool Depth	Increasing trend in channel complexity and pool depth	Trush 1999, Madej 1999
		Large Woody Debris	Increasing trend in the number and total volume of key pieces of large woody debris per stream length	Bilby et al. 1989; Beechie et al. 1997; USDA 1994
		Percent pools and pool depth	>40% of habitat in primary pools (primary pools = 2' depth in 1st and 2nd order streams and 3' depth in 3rd and 4th order)	Flosi et al. 1998
Reduce the risk of sediment delivery from hillslope sources to watercourse	Basin-wide, with priorities based on subwatersheds containing relatively high biological value and potential for recovery	# of stream crossings with diversion potential	Eliminate diversion potentials on all stream crossings (i.e., functional dips are in place at stream crossings)	Weaver and Hagans 1994 and 1999), Furniss et al 1998
		Ditch drains not connected to watercourse	Road surfaces and ditches are “disconnected” from streams and stream crossing culverts (<5% of stream crossings may infeasible).	Weaver and Hagans 1994 and 1999)
		Reduced fill failures from roads, skid trails and landings	Prevent unstable fill failures that could deliver sediment to streams	Weaver and Hagans 1994 and 1999)
		Reduced stream crossing failure/washout	-No unculverted fill or log crossings of stream channels - Properly sized culverts (min. 50 yr flow)	Weaver and Hagans 1994 and 1999)
		Reduction of management-related mass wasting from inner gorges, steep slopes, and unstable streamside zones	Reduce the number of roads and intensity of timber management on located on inner gorge and potentially unstable headwall areas.	PWA 1999(a)

Pebble Counts

Pebble counts can provide another measure of surface texture in potential spawning gravels. Klein (1998) provides several recommendations for performing pebble counts regarding sampling location, combining with thalweg profiles and cross-section measurements, and ways to reduce observer bias. The d_{50} is the median value of the size distribution in a sample of surface pebble counts. In a study of North Coastal watersheds, Knopp (1993) found a statistically significant difference in d_{50} values when comparing reaches in undisturbed and less disturbed watersheds with reaches in moderately and highly disturbed watesheds. The target for d_{50} is a mean greater than or equal to 69 mm based on Knopp's (1993) study.

Existing condition: Pebble count data (d_{50}) from 1994 -1997 within the lower Yager Creek and lower VDR are widely variable. Therefore, it is difficult to draw any statistically valid conclusions at this point in time. Average d_{50} values for the Yager Creek drainages and lower VDR 80mm and 55mm, respectively (PL 1998).

Aquatic Insects (Benthic Macro invertebrates)

Most species of aquatic insects spend the majority of their life as nymphs or larvae in the water. Measurements of aquatic macroinvertebrate populations provide information on the biological health of the stream and can reflect sedimentation impacts. PL (1998) has conducted macroinvertebrate monitoring on selected stream reaches within their ownership since 1994 following the DFG Water Pollution Control Laboratory (WPCL) (1996) stream bioassessment procedures. Although several indices can be calculated, this TMDL recommends, at a minimum, the following:

- Richness Index: This index represents the total number of taxa represented in the sample. A higher diversity can indicate higher water quality.
- EPT Index: This index is the number of species within the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) commonly known as mayflies, stoneflies and caddisflies. These orders of aquatic insects generally require higher water quality than other orders.
- Percent Dominant Taxa: This index is calculated by dividing the number organisms in the most abundant taxa by the total number of organisms in the entire sample. Collections dominated by one taxa generally represent a disturbed ecosystem.

Definitive thresholds at this time are not established for north coastal watersheds. With collection of additional data, EPA anticipates the development of an index of biological integrity, as described by Karr and Chu (1999) for this region. At this point, target conditions are expressed as improving trends.

Existing Conditions: PL is presently conducting aquatic insect monitoring in several of the lower basin tributaries from which future trends can be established (PL 1998).

Turbidity

Turbidity is a measure of water clarity. Excessive turbidity can have sublethal effects on salmonids such as reduced feeding and growth, avoidane, respiratory impairment, and physiological stress (Newcombe and MacDonald 1991). The proposed numeric target for turbidity is simply a reiteration of the water quality objective for turbidity, as described in the

Basin Plan. Turbidity measurements may be useful in assessing the effectiveness of management practices within the context of a well-designed monitoring program. EPA is aware of an emerging approach for constructing turbidity rating curves, using a citizen-based monitoring program in Humboldt County, in conjunction with discharge records, to determine whether turbidity levels in disturbed watersheds are a problem for salmonids (personal communication with Leslie Reid, USDA Redwood Sciences Lab, November, 1999). Such an approach holds promise as an effective monitoring tool in the VDR basin.

Existing conditions: There is no recent quantitative data on turbidity available for the VDR.

Cross sections

Channel cross sections are surveys of the channel bed elevation across the width of the stream that can serve as a long-term quantitative measure of channel condition and sediment load at a particular point. Channel cross sections consisting of diverse bed elevations are generally more beneficial to fish habitat than a uniform, trapezoid shaped channel. Historical cross sections exist in the VDR from which to compare long term changes as described by Klein (1998).   PL has also begun taking cross section measurements for several additional sites on tributaries. The target value expressed for this TMDL is a continuing trend in bed elevations toward pre-1964 bed elevations.

Existing Conditions: Lower mainstem floodplain measurements by the U.S. Army Corps of Engineers (1999) indicate channel aggradation of 2.1 feet since 1968. On the mainstem VDR between the confluence of Grizzly Creek and Little Larabee Creek, Klein (1998) reports generally that bed elevations are declining since mid-1970's but still above pre-1964 levels.

Thalweg Profiles

Thalweg profiles are measurements of the lowest point of a stream bed along a particular reach for the purposes of assessing changes over time and channel hydraulic diversity, particularly related to the number and depth of pools. Thalweg profiles provide quantitative measures to determine whether the stream channel is aggrading or degrading and whether it is forming structural elements that support fish habitat. Harrelson and others (1994) provide a practical guide for performing thalweg profiles and cross sections. Since there are no baseline thalweg profiles from which to determine a reference or target condition and because conditions will vary with time even in a healthy stream, the target condition is expressed as an increasing trend in diversity and pool formation.

Existing Conditions: PL (1998) began installing stream bed (thalweg) surveys in 1996 from which future trends in channel variation, complexity, pool formation, etc. can be evaluated in the future.

Large Woody Debris

Large woody debris (LWD) affects the storage, routing and sorting of sediment as well as channel form and other aquatic habitat conditions such as cover, pool depths and distribution, temperature and bank stability (Lisle 1986, Bilby and Ward 1989) . LWD is an important indicator for tracking stream health, particularly in the lower basin. However, standardized methodologies are not well established and comprehensive data for the redwood zone is not available. Consequently, expressing thresholds and targets at this point is not possible. This TMDL suggests an improving trend as a target condition. Klein (1998) recommends an adaptation of the Bilby and Ward (1989) methodology for sampling LWD levels. PL, as part of watershed analysis, is developing a comprehensive LWD sampling methodology of its lands in the lower watershed.

Percent Pools and Pool Depth:

Deep and frequently occuring pools are necessary for summer rearing habitat, particularly for coho salmon which are less able than steelhead trout to compete for food supplies in the absence of deep pools. The percent of a stream reach composed of pools (percent pools) is one of several methods to measure pools. The target is derived from Flosi et al. (1998): "DFG habitat typing data indicate the better coastal coho streams may have as much as 40% of their total habitat length in primary pools. In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half the width of the low-flow channel, and be as long as the low-flow channel width. In third and fourth order streams the criteria is the same, except maximum depth must be at least three feet."

Existing Conditions: DFG stream surveys in 1991 - 1993 indicate average percent pool valuers in several Yager Creek tributaries and lower VDR tributaries of 22% and 14% respectively. Maximum pool depths measured by DFG during the same time period averaged 2.87 feet in the lower Yager basin and 2.25 in lower VDR tributaries (PL 1998).

3.C Description of Hillslope Sediment Delivery Indicators

Hillslope indicators are included in the TMDL to describe the types of management activities or conditions that prevent the delivery of sediment to the watercourse, thereby protecting water quality. Road and timber harvest related activities are the dominant controllable sources of sediment in the basin and consequently are included as indicators and targets. However, other landuses such as livestock management and residential activities can have isolated impacts at smaller scales and should not be ignored. "Controllable" sources of sediment are defined as those which are associated with human activity and will respond to mitigation, improved land management or restoration. The hillslope indicators and associated targets are critical for resource and land managers who are interested in identifying, fixing and monitoring typically high priority controllable sources of sediment, thereby preventing sediment from impacting water quality.

Stream crossings with diversion potential

A stream crossing with diversion potential means that if the culvert inlet plugs for any reason, streamflow would be diverted to the road and/or ditch and leave its natural channel. In so doing, the diverted streamflow is likely to cause considerably more sediment delivery to the watercourse, particularly in highly erodible terrains (Weaver and Hagans 1994). The amount of sediment delivered by stream crossing diversion is widely variable but can be significant, particularly in highly erodible terrain as exists in the VDR. Diversion potential can be eliminated through corrective measures such as installing rolling dips at crossings, properly sizing culverts, reducing extent of inboard ditch draining into the watercourse and outsloping roads. The target calls for eliminating diversion potential from all stream crossings (Weaver and Hagans 1999).

Existing Conditions: Based on a reconnaissance field inventory of timber roads in the lower Yager and VDR basins by PWA (1998), 63% (69 out of 110) of stream crossings contained diversion potentials. Of those, 17% had diverted in the past, thereby delivering sediment to a watercourse. Inventories of diversion potential were not available for the middle and upper basin.

<u>Road segments hydrologically connected to streams</u>

When a road is hydrologically connected to a stream, the road surface and/or drainage structure, such as an inboard ditch or outside berm, funnels fine sediment and road runoff directly to adjacent stream channels. Therefore, disconnecting road drainage from the watercourse by methods such as outsloping and/or installing more frequent rolling dips, results in decreased sediment delivery to streams. The target calls for disconnecting road surfaces from streams and stream crossings, unless it is infeasible (approximately <5% may infeasible) (Furniss et al. 1998, Weaver and Hagans 1999).

Existing Condition: Based on a field reconnaissance of timber roads in the lower Yager and VDR basin, PWA (1998) determined that 22% (9 mi. out of 43 mi.) of the road ditch length was constructed with either an inboard ditch or has berms at the outside edge of the road.

<u>Reduced fill failures from roads, skid trails and landings</u>

Road fill and sidecast material increases slope weight and can trigger mass wasting, often many years after they were put on steep hillslopes. Large volumes of fill can be discharged in a single pulse from road and landing fill failures and have long-lasting impacts on the aquatic environment downstream. The target is expressed qualitatively as a guideline to prevent unstable fill failures that could deliver sediment to streams based on Weaver and Hagans (1999).

Existing condition: PWA (1998) determined that road fill failure was responsible for 60% (97,000 yds^3) of the total sediment delivery from road-related sources in the Lower Eel River sediment source investigation which included areas of Yager Creek and lower VDR. 26% (183 out of 698) of the total number of road related erosional features were associated with road and landing fill failures.

<u>Reduced stream crossing failure/washout</u>

Stream crossings in steep timber and rangeland watersheds can contain large volumes of fill and debris. When a stream crossing fails, generally due to a culvert being undersized and plugged, the fill associated with that failure typically delivers directly to the watercourse. The target condition consists of properly sizing culverts (at least capable of passing 50 year flows) and having no unculverted fill or log crossing on stream channels (Weaver and Hagans 1994).

Existing Conditions: PWA (1998) determined that delivery of sediment from stream crossing failures represented 11.5% (18,400yds^3) of the total road related sediment delivery in the Sediment Source Investigation for the Lower Eel River, which includes portions of Yager and lower VDR. A minimum of 27% (87 out of 142) stream crossings revealed field evidence of eroding a portion or all of the stream crossing fill volume at least once in the past.

Reduction of management-related mass wasting from inner gorges, steep slopes, and unstable headwall areas

Roads and timber management on inner gorge areas are particularly prone to failures which can introduce substantial quantities of sediment into watercourses. Likewise, ground disturbance in unstable headwall areas can trigger debris torrents thereby transporting large volumes of sediment to watercourses (Sidle et al. 1985, PWA 1999(a)). Steep inner gorges are generally defined as having slopes in exceedence of 65% while unstable headwall areas generally include the following characteristics: slopes greater than 50%, concave slope shape, convergent groundwater present, erosive underlying geology. Many of the high to extreme mass wasting zones, as classified in the PalCo HCP (1998), consist of these inner gorge, steep streamside and headwall areas. In addition, they occur within the lower basin stream reaches that serve as important spawning and rearing habitat. The target for a reduction of management-related mass wasting from these sensitive areas can be achieved by thoroughly mapping, eliminating or restricting intensity of activity, and conducting site-specific geologic review to assess the risk of slope failure in these areas. The hillslope monitoring program called for in the PalCo HCP should provide information on the effectiveness of management actions to reduce sediment delivery from these locations in the future.

Existing Conditions: Roads located on inner gorges, stream side slopes (>50%), and headwall swales accounted for 43% of the total road-related sediment delivery in the lower basin (PWA 1998). Approximately 80% of the total sediment yield from the Lower Eel Study was delivered from inner gorges (PWA 1998).

3.D Summary of Comparison Between Target and Existing Conditions

Table 3.2 provides a summary of the comparison between target conditions and existing conditions for the indicators identified in the VDR TMDL. Because the data used to determine existing instream sediment conditions is limited (i.e., relatively short sampling period, few samples, high variability between locations, etc.) this comparison is intended to provide a rough approximation of the level of improvement needed in order to attain the target condition. The percentage improvement (third column, Table 3.2) represents the approximate level of change needed from the existing level to achieve the target conditions. For example, in order to achieve the <14% threshold for fine sediment (particles <0.85mm) from an existing condition level of 26%, a 46% decrease is needed. Most of the stream and hillslope condition data was available for the lower basin and therefore the reduction levels are more quantifiable than in the middle and upper basin. The results of this comparison are the foundation of the loading capacity estimate discussed in Chapter 5 - TMDL and Load Allocations.

Table 3.2 Summary of comparison between target conditions and existing conditions

	Indicator/Target	Existing Conditions	Improvement Needed
Stream Indicators	<14%fine sediment <0.85mm	Lower VDR Tribs: 26%ave Lower Yager Creek: 19% ave NF Yager: 19% MF Yager: 20%	approx. 46% reduction in lower VDR; approx. 26% reduction in Yager Creek.
	<25% embeddedness	Lower VDR tribs: 57% Lower Yager Creek: 63%	approx. 60% reduction in embeddedness
	Downcutting (degrading) channel bed elevation	Lower mainstem: 2.1 feet aggradation since 1968 (COE 1999); Middle basin: Downcutting since mid-1970's but still above pre-1964 levels	Continued downcutting in the middle basin and Long-term trend of channel downcutting in the lower basin (may not be noticeable for several decades due to time lags in processing sediment pulse from ‘64 event
	>40% pools	Lower VDR tribs: 20%ave Lower Yager tribs: 26%ave	35-50% increase in percentage of pools
	>3 ft. Pool depth	2.21 ft ave lower VDR tribs 3.01 ft ave. lower Yager Crk	25% improvement in pool depth - VDR tribs
Hillslope Indicators	No stream crossings with diversion potential	approximately 63% of timberland roads in the lower basin have diversion potentials	Reduction of 100% of existing stream diversion potentials along roads in lower basin Inventories needed on middle and upper basin to determine reduction needs
	<5% of road surfaces and ditches are connected to streams	Approximately 22% timberland road miles presently are hydrologically connected	95% reduction from existing level Baseline inventories needed on middle and upper to detemine reduction needs
	Reduced fill failures from roads, skid trails and landings	60% of road-related sediment delivery in the Lower Eel Study was associated with fill failures (PWA 1998)	lower: 90% reduction from existing level middle and upper: 80% (see chapter 5 - load allocations for explanation).
	Reduced stream crossing failure/washout	12% of road-related sediment in the Lower Eel Study was associated with crossing failures (PWA 1998)	lower: 90% reduction from existing level middle and upper: 80% (see chapter 5 - load allocations for explanation).
	Reduction management-associated mass wasting from inner gorges, steep slopes and unstable areas	Roads located on inner gorges, stream side slopes (>50%), and headwall swales accounted for 43% of the total road-related sediment delivery in the lower basin (PWA 1998).	lower: 90% reduction from existing level middle and upper: 80% (see chapter 5 - load allocations for explanation).

CHAPTER 4
SEDIMENT SOURCE ANALYSIS

4.A Objective

The objective of the sediment source analysis is to identify the amount of sediment delivered to stream channels from the various erosional processes which occur on hillslopes and in stream channels throughout the watershed. The source analysis provides information necessary to determine the allocation of loading allowances among sources in order to achieve the TMDL. This sediment source analysis consisted of five main components or tasks conducted by Pacific Watershed Associates (PWA), under contract to TetraTech Inc., for use in developing of the VDR TMDL: 1) a review of previous studies which quantified or discussed past sediment production and yield in the VDR: 2) an aerial photo analysis of large landslides throughout the VDR; 3) a field inventory of 80 randomly selected 41.8 acre parcels to measure all past erosion and sediment yield; 4) extrapolating results from the randomly-selected sample plots to the remainder of the watershed; and 5) an analysis of regional literature to quantify earthflow sediment production processes.

The sampling design and methodology developed by PWA can be replicated in the future for the purposes of monitoring changes in sediment delivery rates and to determine whether load allocations are achieved. This chapter summarizes the approach and results of the sediment source analysis conducted by PWA (1999(b)).

4.B Analysis of Existing Data

Only a few studies have previously been conducted in the VDR which contributed to the development of this sediment source investigation. PWA (1999(b)) considered information from the following sources in developing and conducting the source analysis:

* Kelsey (1977) reports results from a Ph.D. dissertation on landsliding, channel changes, erosion and sediment yield, and landuse throughout the upper 60% of the VDR watershed for the period of 1941 to 1975. The reports are the best source of sediment production data for the VDR, including a estimate of sediment production during the 1964 storm and flood event.

* "The Van Duzen River Basin Atlas" prepared by the State of California Department of Water Resources (1975) contains an excellent series of large-scale maps which characterize watershed conditions, as well as physical and cultural information for the whole Van Duzen River watershed as of the early 1970's. These include: land and water use (including ownership), bedrock geology, soil, vegetation and fire risk data, erosional risk maps, roads, recreational and historical sites, and information on channel conditions in selected portions of the VDR.

* A report by the USDA and the California Department of Water Resources (1970) that assesses watershed processes and sediment delivery to the Eel and Mad River watersheds, including the VDR, and which provides information on sediment yields between 1940 to the mid-1960's.

4.C Approach to Quantifying Sediment Sources

PWA, with assistance from statistician Jack Lewis (U.S. Forest Service, Redwood Sciences Laboratory), developed a statistically valid, stratified, random sampling scheme to estimate total past erosion and sediment yield to the Van Duzen River and its tributary streams. The approach relied on extensive field inventory and aerial photographic analysis throughout the VDR in order to estimate the magnitude of past erosion and sediment yield, and to determine what percent of the past erosion and yield has some association with the variety of land management practices occurring in the watershed.

A total of eighty (80) plots, each totaling 41.8 acres in area, were randomly located throughout the basin, and "weighted" according to predicted rates of sediment delivery from the five main terrain types (i.e., stratum or general bedrock types as depicted in the Van Duzen River Atlas 1975). The sediment yield rates were based on estimates made by Kelsey (1977) from the upper 60% of the watershed through 1975. Table 4.1 identifies the terrain type, the area of the basin each covers (in square miles and percent), percent of the total predicted sediment yield from each terrain type and the associated number of field plots for PWA's study. A higher proportion of plots were located in terrain types consisting of higher estimated percent sediment yield, in order to increase the accuracy in quantifying total sediment yield. For example, 25 random plots were selected for the "sandstone, potentially unstable and active slides" (terrain type #2) which had a projected sediment yield of 40%, compared with only 4 plots located in the "melange, generally stable, serpentine, alluvial terrain (terrain type #2) which had a projected yield of 3% of the total (Table 4.1).

Table 4.1 Area of five terrain types and estimated relative percent sediment delivery (modified from Kelsey, 1977), for the 429 mi^2 Van Duzen River watershed.

Source area # and name	Square miles	% of basin	% of yield (Original Kelsey Est.)	# of sample plots
1. Sandstone, generally stable terrain	205	48%	2%	8
2. Sandstone, potentially unstable and active slides	45	10%	40%	25
3. Melange, generally stable, serpentine, alluvial terrain	48	11%	3%	4
4. Melange, older slump-earthflow terrain	118	28%	30%	25
5. Melange, active slump-earthflows	12	3%	25%	18

In addition to the field plots, PWA conducted an analysis of aerial photographs for selected years throughout the watershed in order to accurately account for the large debris slides which consititute a small area of the basin but a high rate of sediment delivery. In the lower 40%

of the watershed (205 mi^2), PWA (1998) previously analyzed sediment production through 1994 using aerial photographs. For this study, PWA further analyzed 1997 aerial photos for the same lower basin area to document all landslides greater than 5000 yds^3 in size. Likewise, for the upper 60% of the watershed, where landslide histories have been compiled by Kelsey through 1975, PWA analyzed either 1984 or 1988 and 1997 aerial photos to update the occurrence of landslides larger than 5000 yds^3 throughout the watershed. Features smaller than 5,000 yds^3 were accounted for through the field plot samples.

4.D Sediment Source Categories

All erosional features mapped on the aerial photos or within the sample plots had the same suite of data collected for each. These included: 1) whether the feature was road, skid trial or hillslope related; 2) terrain type and dominate vegetation type; 3) type of sediment source; 4) volume of erosion and sediment delivered to the stream; 5) hillslope location and average hillslope steepness; 6) any apparent land use/management associations; 7) geomorphic association; and 8) average slope steepness where the erosion occurred. Due to the complexity of estimating past erosion on active earthflows, PWA (1999(b)) relied on published reports of earthflow average depths and long-term average movement rates (Kelsey, 1978 and 1980; Iverson, 1984; Nolan and Janda, 1995; Swanston, Ziemer and Janda, 1995).

4.E Data Collection

In order to assess the relative amount (or percent) of management-associated sediment yield throughout the VDR watershed, the watershed was divided into three (3) separate subbasins (i.e. upper, middle and lower basin) as discussed in previous chapters. The upper basin is primarily underlain by stable and unstable sandstone geologies with moderate amounts of older slump-earthflow melange terrain. The middle basin is largely underlain by melange terrains and contains virtually all the active earthflow terrain, followed by a moderate amount of stable sandstone and minor amounts of unstable sandstone terrain. The lower basin is dominated by sandstone terrain and contains the highest percentage of terrace/floodplain deposits in the watershed (mapped as stable melange terrain).

Field data

Field collected data was compiled by two different methodologies in order to analyze the relative percent of the total past erosion and sediment yield occurring in the three parts of the watershed. Once sediment yield volumes were determined for each subbasin, then many additional data sorts were required to determine the relative percent of the total volume that was controllable, or what where the primary geologic, landuse, geomorphic or vegetation associations present.

Volumes of past erosion and sediment yield were first tabulated for the 80 sample plots by each of the five terrain types they occurred within. Once the sample plot volumes were totaled, the mean of all past erosion and delivery in a given sample terrain was determined and the sample volumes were extrapolated to the whole VDR watershed. Based on the percent of each terrain type in each of the three subbasins, the percent of the total VDR basin sediment yield was assigned to the subbasin. For each subbasin, the volume of extrapolated sample plot sediment yield was added to the total volume of air photo identified active earthflow and large (>5000 $yds^{3)}$ features in the subbasin to arrive at the total sediment yield for each of the three subbasins. Once the total sediment yield by subbasin was determined, statistical analyses were performed on the stratified sampling to estimate variance at the 75% to 95% confidence interval on the total erosion and sediment yield.

Aerial photographic data

Active earthflows and large erosional features (>5000 yds^3) identified during the aerial photographic analysis of the VDR were tallied and summed according to upper, middle and lower basins. Based on the approximately 10% of the large erosional features which were field verified, a weighted regression (ratio) estimator was used to adjust the volume of the remainder of the air photo identified features.

4.F Sediment Source Assessment Results

The sediment source analysis results consist of four components which are presented below: 1)Total sediment delivery (yds^3/mi^2/year) for the period of 1955 to 1999 by terrain type; 2) Sediment yield (in yds^3/mi^2/year and %) by upper, middle and lower basin and primary land use association; 3) Total sample plot and aerial photograph determined sediment yield by timeframes and potential controllability; and 4) Estimates of confidence in the results. Map 1 (attached) identifies the sample plot locations, large (>5,000yds^3) erosion features and active earthflows. Map 2 (attached) identifies the terrain types and sediment delivery rates by upper, middle and lower basins.

1) Total sediment delivery (yds^3/mi^2/year) for the period of 1955 to 1999 by terrain type

A total of 31,488,800 yds^3 of sediment yield is estimated as being delivered to the VDR basin mostly between 1955 and 1999. Table 4.2 summarized the following three types of data on total sediment yield according to terrain type: **1) Plot Volume and % Yield,** the extrapolated sample plot estimate of sediment yield from smaller debris slide and debris torrents, stream bank erosional processes in confined reaches of stream, and hillslope gullying (both road and non road and skid trail associated); **2) Air Photo identified Sources >5000 yds^3 and % Yield,** which are mostly large debris slides and debris torrents, but also include a few large gullies; and **3) Earthflow Volume and % Yield,** PWA's best estimate of active earthflow contributions to the VDR over the last 44 years based on both toe slope delivery rates and the field sample plot data.

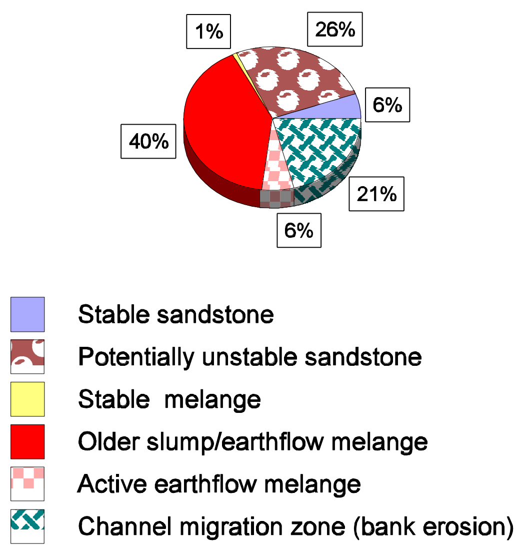
Table 4.2 indicates that the melange, older slump-earthflow (terrain type #4) delivers the most sediment (12,647,300 yds) of all the terrain types followed by sandstone, potentially unstable (terrain type #2) (8,258,000 yds). The highest rates of sediment delivery are found in sandstone, potentially unstable (4,265 yds^3/mi^2/year) and melange, active earthflow (terrain type #5) (3,937 yds^3/mi^2/year). Stable melange and alluvium (terrain type #3) and stable sandstone (terrain type #1) both contribute sediment at relatively low rates of 228 yds^3/mi^2/year and 190 yds^3/mi^2/year, respectively. Terrain type #3 also contains a specific category of estimated bank erosion along stream reaches referred to as "channel migration zones (CMZ)" for the period 1942 and 1997 of 6,635,000 yds^3. All CMZ bank erosion estimates are considered to be not associated with management activities conducted throughout the VDR. However, it could be argued that channel bed aggradation which can trigger channel migration in these reaches is partly associated with the cumulative effects of upstream activities. The percent sediment production by terrain type is graphically displayed in Figure 4.1.

PWA determined that bank erosion and channel migration in sections of the stream prone to rapid shifts in the channel bed, had to be quantified separately (i.e. not as a sediment source measured within the sample plots) in order to accurately estimate total sediment yield from the stable melange (terrain type #3). Two prominent CMZ exist within the VDR watershed. The upper one is 8.5 miles long and is located upstream and downstream of Dinsmore, CA. In the upper sub-basin. The other is a 16.2 mile long reach of river in the lower sub-basin from Root Creek to the mouth of the VDR. Both reaches are referred to as CMZ because they are mostly unconfined stream reaches, bounded by floodplains and terraces on both banks of the active channel, and have extremely high valley floor width to depth ratios. It is in these valley floor locations where severe and dramatic shifts can occur in the sinuosity and pattern of the active stream channel over time.

Table 4.2 Estimated past sediment yield (in cubic yards and yds^3/mi^2/year) for the period of 1955 to 1999 by terrain type for the 3 sample procedures (PWA 1999(b)).

Terrain Type	Area in Mi.^{2}	1. Total Sediment Delivery from Plots (slides, etc.)	2. Total Sediment Delivery from Plots (earthflows)	3. Total Sediment Yield from large (>5000yds^3) features from aerial photos	Total Sediment Delivery by Terrain Type
1. Stable sandstone	207.7	990,500 yds 108 yds^3/mi^2/yr	0	753,000 yds 82 yds^3/mi^2/yr	1,743,500 yds 190 yds^3/mi^2/yr
2. Sandstone, potentially unstable	44	3,093,300 yds 1,596 yds^3/mi^2/yr	171,400 yds 88 yds^3/mi^2/yr	4,993,300 yds 2,579 yds^3/mi^2/yr	8,258,000 yds 4,265 yds^3/mi^2/yr
3. Stable melange and alluvium [1]	38	138,100 yds 83 yds^3/mi^2/yr	71,500 yds 43 yds^3/mi^2/yr	170,600 yds 102 yds^3/mi^2/yr	380,200 yds 228yds^3/mi^2/yr
4. Melange, older slump-earthflow	121.5	2,728,100 yds 510 yds^3/mi^2/yr	9,304,200 yds 1,740 yds^3/mi^2/yr	625,000 yds 117 yds^3/mi^2/yr	12,657,300 yds 2,368 yds^3/mi^2/yr
5. Melange, active earthflow	10.5	559,800 yds 1,216 yds^3/mi^2/yr	843,000 yds 1,829 yds^3/mi^2/yr	412,000 yds 892 yds^3/mi^2/yr	1,814,800 yds 3,937 yds^3/mi^2/yr
Sub-Totals	**421.7**	**7,509,800yds 404 yds^3/mi^2/yr**	**10,390,100yds 560 yds^3/mi^2/yr**	**6,953,600yds 375 yds^3/mi^2/yr**	**24,853,800 yds 1,339 yds^3/mi^2/yr**
[1] Estimated bank erosion sediment yield in “channel migration zones” between 1941 and 1997 (7mi^2):					**6,635,000yds 16,926 yds^3/mi^2/yr**
Basin-wide total					**31,488,800 yds 1,594 yds^3/mi^2/yr**

Figure 4.1 Percent past sediment delivery by terrain type
(PWA 1999(b))



Estimated sediment yield determined by PWA (1999(b)) conforms fairly well to the expectd relative importance of sediment yield (derived from Kelsey 1977). PWA (1999(b)) provides a full discussion of the comparison between PWA's erosion estimates and Kelsey's original projections.

2) Sediment delivery by upper, middle and lower basin and primary land use association

Table 4.3 summarizes the extrapolated estimates of total VDR basin sediment yield by the three subbasins according to the primary land use association. All erosional features mapped in the field sample plots or on the aerial photos were assigned a primary land use association based on field and air photo evidence. Table 4.3 categorizes erosional features as having the following land use associations: 1) no apparent land use linkage, i.e. naturally occurring erosion, 2) road related, whether that be a logging, ranch, county or CalTrans road, 3) skid trail related, 4) associated with either tractor or cable clear-cutting, 5) associated with either cable or tractor partial harvests, and 6) associated with advancing second growth forests, which are defined as generally being greater than 30 years old. Figure 4.2 illustrates the percent sediment delivery by grouped landuse assocation categories (no management, road-related association and timber harvest association.

Both road related and skid trail sediment yield includes failed or washed-out stream crossing erosion, gullies along the road and ditch as well as hillslope gullies associated with stream diversions, and road or landing fill failure volumes. Estimates of surface erosion and sediment yield along roads and their cutbanks (i.e. road and skid trail surface lowering) were not quantified within the 80 field sample plots due to time constraints and therefore are not included in Table 4.3.

Table 4.3 indicates that of the total past sediment yield from the upper, middle and lower basin, approximately 80%, 84% and 58% respectively, was determined to be natural and not clearly associated with any past land management activities. Within the middle and lower subbasins, PWA identified an additional past sediment yield of 0.5% and 6% respectively which was assigned to hillslopes characterized as “advanced second growth”. PWA suggests this additional yield should be viewed as natural erosion since over 30 years have passed since any land use activities were conducted on the hillslopes.

Table 4.3 Sediment yield (yds^3/mi^2/year and %) by subbasin and primary land use association.

Subbasin	No land use association	Advanced second growth	Road Related	Skid trail Related	Tractor clear cut	Cable clear cut	Partial harvest	Total sediment yield
Upper Sub-total/ (%)	1162 (80%)	0	30 (2%)	3 (<1%)	30 (2%)	124 (9%)	84 (6%)	1433 (100%)
Middle Sub-total/ (%)	1585 (84%)	8 (<1.0%)	52 (3%)	58 (3%)	161 (9%)	14 (1%)	8 (0.5%)	1886 (100%)
Lower Sub-total/ (%)	736 (58%)	79 (6%)	92 (7%)	110 (9%)	205 (17%)	23 (2%)	12 (1%)	1257 (100%)
Basin-wide	1233 (77%)	27 (2%)	59 (4%)	61 (4%)	144 (9%)	42 (3%)	27 (2%)	1594 (100%)

For the upper basin, Table 4.3 indicates management-associated sources of sediment yield account for approximately 20% of the total. These are divided between road and skid trail sources (2%) and various timber harvest related sources (18%). Management-associated sediment sources in the upper basin total 271 yds^3/mi^2/year.

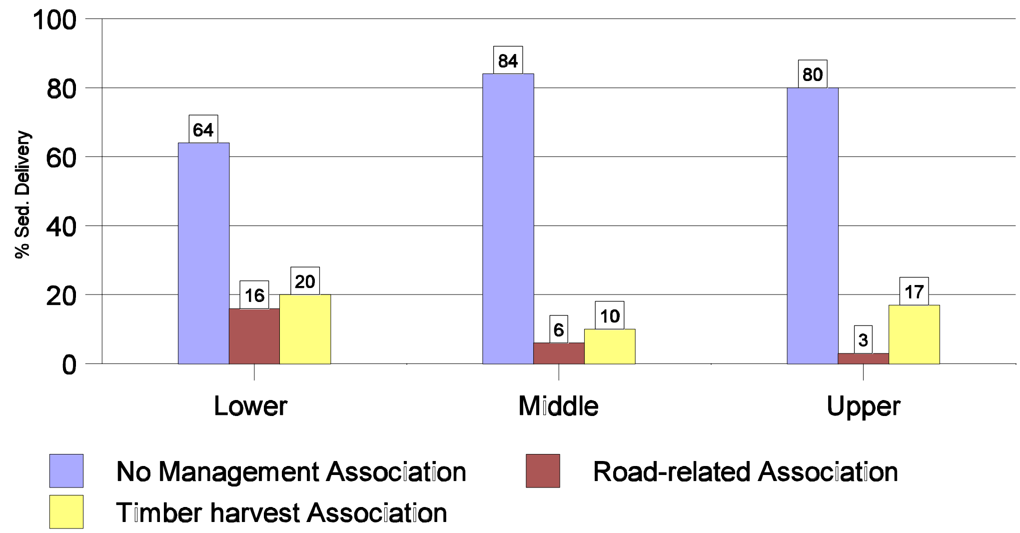
For the middle basin, Table 4.3 indicates management- associated sediment yield accounts for approximately 16% of the total middle watershed yield. Road and skid trail related sources are estimated to account for 6% of the potentially controllable sediment yield, and timber harvest-related sources for approximately 10% of the total. Management-associated sediment sources in the middle watershed total 293 $yds^3/mi^{2/}$year.

For the lower basin, Table 4.3 indicates management-associated sediment yield accounts for nearly 36% of the total lower watershed yield. The management-associated sources include road and skid trail related sources (16%) and timber harvest related sources (20%). Management-associated sediment sources in the lower watershed total 442 yds^3/mi^2/year.

Differences in management-associated sediment yield between the three subbasins can be somewhat explained by the differences in styles of land use within the subbasins. Management-associated sediment yield within the upper basin reflect the dominant mode of timber harvesting by the USFS over the last several decades. Tractor clearcut logging has constituted a minor proportion of timber harvesting compared to cable and partial harvest in the upper basin. Likewise, the low proportion of road-related sediment yield reflects the relatively low road densities and more favorable road locations on USFS managed lands in the upper VDR.

Within the middle basin, management-associated sediment yield associated with tractor harvested areas reflect a low percentage of cable harvesting over the previous three decades. While natural volumes (and rates) of sediment yield are highest in the middle watershed, management-associated sources account for 293 $yds^3/mi^2/year$.

Figure 4.2 Percent sediment delivery by sub-basin and landuse association



It should be noted that livestock grazing is a common land use occurring throughout the middle VDR basin. Most grassland, oak woodland and forested hillslopes throughout the middle domain display widespread evidence of cattle presence during some portion of the year. Evidence includes narrow (average 1-2 foot wide by up to a 0.5 foot deep) treads mostly on contour or sub-contour to the hillslope, heavily hoof punched ground in areas displaying high seasonal groundwater levels, localized bare ground areas adjacent stock watering troughs on the hillslopes and adjacent springs in 1st order grassland streams, and very localized rutting on stream banks where cattle trails cross larger streams. With the exception of the cattle trails across the larger streams, none of the other erosion associated with cattle activities could be directly linked to observable and measurable quantities of sediment yield to streams capable of sediment transport. Where cattle trails have locally damaged stream banks, we observed no locations within any of the 80 sample plots where the cattle trail resulted in 10yds^3 or more erosion and sediment yield (i.e. had gully /tread dimensions 2' x 2' x 70' long = 10.4 yds^3).

While not part of the sample strategy, PWA personnel had the opportunity to traverse and observe many square miles of range land in the middle basin while locating the randomly selected sample plots. Few if any sites were observed where cattle grazing activities could be linked to measurable volumes of sediment yield to streams within the VDR basin. Consequently, according to the results of this analysis of sediment sources, where over 30 million yards of sediment has been delivered to the VDR, there is no credible evidence to suggest current cattle grazing activities are significant contributors to water quality impacts in the VDR basin.

Within the lower watershed, relatively lower volumes of management-associated sediment yield from cable harvested hillslopes as compared with sediment yield from tractor clearcuts (205 $yds^3/mi^2/yr$, 17%) reflects the dominant timber harvesting method on industrial lands over the last four decades. The high management-associated percent of yield associated with roads and skid trails (202 $yds^3/mi^2/yr$, 16%) reflects the much higher road densities (estimated at 5 to 6 miles/ mi^2) and skid trail densities (estimated at 12 to 15 miles/ mi^2) in order to carry out commercial timber harvesting activities.

3. <u>Sediment delivery by timeframes and management association (plot and photo data).</u>

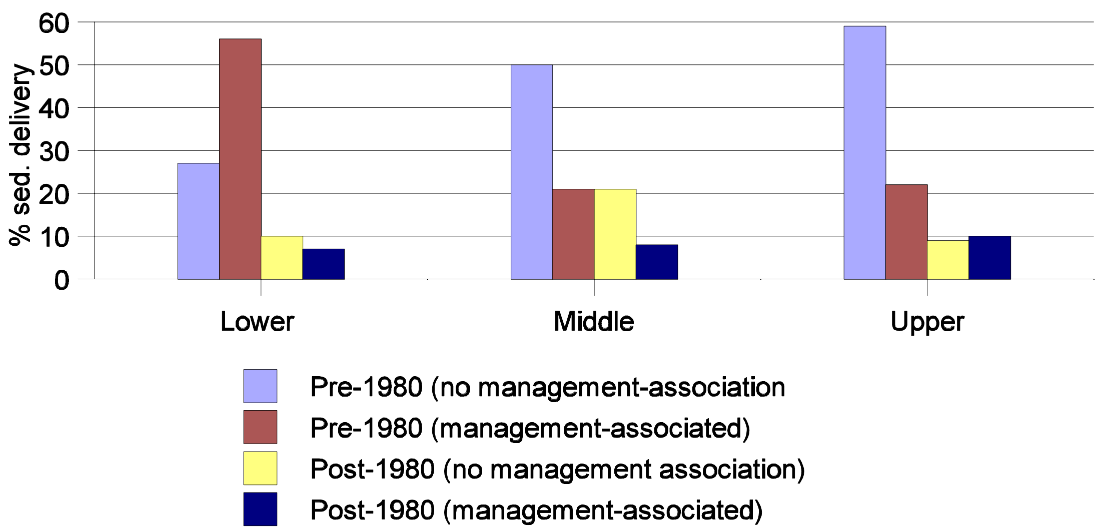
For all erosional features identified within the sample plots or on aerial photographs, PWA attempted to identify the decade in which the erosion was initiated and whether the feature was still actively eroding in 1999. The age of vegetation on or adjacent to an erosional feature provides the most useful information in deriving the origination age and activity level. Table 4.4 identifies all the management and non-management associated sediment delivery features that PWA estimated were initiated prior to 1980 and those that were initiated after 1980. PWA chose to separate the data around 1980 since the California Forest Practice Rules (FPR) were finally fully functional by the late-1970's. Any differences in sediment yield volumes may provide some indication as to the degree to which modern (post-1980) management practice have improved over past practices.

Table 4.4 and Figure 4.3 indicate the following: 1) 79% of all measured sediment yield occurred pre-1980; suggesting both the prevalence of larger storms and possible less protective land use practices; 2) management-associated sediment yield compared to non-management accounted for twice as much sediment yield in the lower basin pre-1980, whereas within the upper and middle basin management related sediment yield accounts for only one-third of the pre-1980 yield; 3) post-1980 sediment yields are considerably lower than during the pre-1980 period; and 4) in the post-1980 period, the ratio between management associated and non-management yield is roughly equal in the upper and lower watershed. In the middle basin, non-management related yield accounts for over twice as much sediment yield during the post-1980 period. However, this reflects an increase in the ratio of management related sediment yield in the middle basin compared to the pre-1980 period.

The data suggests considerably less natural and management related sediment is being produced in the VDR basin in the post-1980 period. This may reflect differences in the frequency and magnitude of storms which trigger widespread watershed response, but also could be partially attributed to improvements in land management practices brought on by the FPR or voluntarily by individual landowners.

Table 4.4 Total sample plot and aerial photograph determined sediment delivery by time period and management or no management-association.			
Sub-watershed		**Total by Time Period for Management Sediment Yield (yds^3) & (%)**	**Total by Time Period for Non-Management Sediment Yield (yds^3) & (%)**
Upper Basin	Pre-1980	394,400 (22%)	1,054,400 (59%)
	Post-1980	176,900 (10%)	167,000 (9%)
	Subtotals	574,300 (32%)	1,222,100 (68%)
Middle Basin	Pre-1980	796,300 (21%)	1,862,500 (50%)
	Post-1980	303,600 (8%)	775,700 (21%)
	Subtotals	1,099,900 (29%)	2,638,200 (71%)
Lower Basin	Pre-1980	1,049,600 (56%)	494,200 (27%)
	Post-1980	136,100 (7%)	183,600 (10%)
	Subtotals	1,185,700 (63%)	677,800 (37%)
Totals for whole basin		**2,859,900 (39%)**	**4,538,100 (61%)**

Figure 4.3 Percent sediment delivery by management-association and time period



4.G Estimated Confidence in Results

One of the advantages in conducting a sediment source assessment utilizing a random sampling methodology is in the ability to estimate statistically the variance, standard error and confidence interval of the results. The sampling scheme for the VDR was designed to predict the relative error of estimating total basin sediment yield within +/- 24% as a minimum bound and +/- 32% as a maximum bound at the 75% to 95% confidence interval. Table 4.5 presents statistical estimates of the confidence in predicting total basin and sub-basin sediment yield as a result of the sediment source investigation. The 95% confidence interval indicates the plus or minus sediment yield volume which could be added to the total to have confidence that the true past sediment yield has been estimated. PWA (1999(b)) provides an extensive discussion of the statistics used for this analysis.

For comparison purposes, the total sediment yields for the three sampling methodologies presented in Table 4.5 are the same as in Table 4.2. For the whole VDR watershed, the plot data and the >5000 yds^3 source data have relatively low variances of 35% and 28% respectively, at the 95% confidence interval, of predicting total past sediment yield. This suggests that the sample plot distribution and the air photo analysis provide a relatively accurate estimate of total basin sediment yield from the types of erosional processes observed.

For the earthflow plot data extrapolated to the whole basin, the confidence interval is much less accurate at 147%. However, this is expected considering the wide range of sizes of earthflows. The poor confidence interval serves to illustrate the difficulty of estimating long term sediment yield from earthflows. For the sub-basins, the relative standard error and confidence interval can be expected to increase considerably primarily because the estimate is based on a sub-set of the total sample population. For the non-earthflow plot data, the estimate of total past sediment yield is best in the middle basin (43%) largely because over half of the sample plots were in the area. The probability of sampling a greater proportion of the true population of past erosional features is higher (i.e. the plots captured a higher percentage of the erosional variability in the middle basin compared to the upper and lower basins).

Table 4.5 Total past yield, standard error and 95% confidence intervals (CI) by sub-basin, Van Duzen River basin.

Sub-basin	Plot yield (yds^3)	Plot standard error (yds^3)	Plot 95% C.I.	>5000 yds^3 sources yield (yds^3)	>5000 yds^3 sources standard error (yds^3)	>5000 yds^3 sources 95% C.I.	Earth flow yield (yds^3)	Earth flow standard error (yds^3)	Earth flow 95% C.I. (%)
Upper	3,459,100	1,500,300	+/-87	1,755,900	NA	NA	48,300	25,000	+/-29
Middle	4,129,300	884,200	+/-43	3,383,000	NA	NA	8,968,000	6,532,900	+/-54
Lower	1,574,000	449,500	+/-57	1,836,200	NA	NA	901,600	700,500	+/-44
Total yield[1]	7,509,700	1,299,600	+/-35	6,953,600	989,500	+/-28	10,390,100	7,611,500	+/-53

[1]Total yields for each sub-basin will not add up to the total yield for the entire Van Duzen River basin since each sub-basin is treated as a separate sampling population and not related to the entire Van Duzen river basin.

CHAPTER 5
TMDL and LOAD ALLOCATIONS

This chapter includes a linkage analysis of sediment sources to target conditions, description of the methodology for estimating the sediment loading capacity (i.e., the TMDL), and calculation of the load allocations necessary for attaining water quality standards. Loading capacity is the amount of sediment the VDR can assimilate and still meet water quality standards. Load allocations represent the apportionment of the allowable load between natural and management-related sources. TMDLs are calculated for each subbasin within the VDR then converted to a basin-wide TMDL.

5.A Linkage Analysis

The purpose of the linkage analysis is to develop a relationship between hillslope sediment delivery processes and instream effects in order to provide a basis for numeric load allocations. Linkages between sediment sources in the watershed and stream conditions affected by sediment are often indirect and highly variable. Madej (1999) discusses the lag time between a watershed disturbance (e.g., landslide) and noticeable geomorphic change in the stream channel. The fact that there are habitat effects in the stream as a result of hillslope processes is well documented by Meehan (1991) and others; however, the mathematical relationships are not. This linkage analysis assumes an approximate one-to-one correspondence between necessary reductions in sedimentation levels in the stream channel with reduction levels needed in hillslope sediment delivery rates.

The method for determining the level of reduction in sedimentation relies on a comparison of existing stream conditions with the target stream conditions, as described below under loading capacity. The necessary reduction levels identified by the comparison of stream indicators, is then applied to sediment source mechanisms on the hillslope to establish load allocations. For example, if existing instream sediment levels exceed target thresholds by 10%, then the necessary reduction in sediment delivery from the hillslope is estimated to be 10%. This one-to-one correspondence is considered a conservative approximation of the quantities of sediment reduction needed to attain the water quality objectives. The time period for measuring the effect of sediment delivery reduction in channel conditions is on the order of decades to account for lag time in sediment delivery rates and detectibility of changes in the stream channel (Reid and Dunne 1996).

5.B Loading Capacity Estimates

The method for determining the loading capacity of the VDR relies on a comparison of existing or recent conditions with target levels for the instream indicators, as discussed in the numeric targets (Chapter 3). Although it includes quantitative comparisons, the assessment is largely qualitative due to the high degree of uncertainty inherent in determining a baseline loading, and inferring linkages between prospective hillslope erosion sources and instream impacts.

The comparison of existing and target conditions (Table 3.2 in Chapter 3) indicates that certain stream reaches and watershed conditions, particularly in the lower basin, are currently not supporting healthy habitat. For example, fine sediment levels, as expressed by percentage of the substrate consisting of fine particles (<0.85 mm) and percentage of cobbles embedded in the substrate, are considerably above target levels and therefore may be limiting the ability of anadromous fish, particularly coho salmon in the lower basin tributaries to spawn. In order to achieve target conditions for fine sediment, average reductions by approximately 26%-46% are needed (Table 3.2, page 32).

Similarly, pool depths and the percent of survey reaches consisting of pools are indicators that coarse and fine sediment levels may be limiting anadromous fish rearing habitat. Percent reductions needed to attain target conditions from existing levels are approximately 35 - 50% for percent pools and 0 - 25% for pool depths (Table 3.2, page 32). All the hillslope indicators described in chapter 3 are presently above the desired levels based on assessments by PWA (1998) in areas of the lower basin, which suggests that recent management activities are contributing to excessive sedimentation.

Based on the comparison of target and existing conditions, EPA estimates that reductions on the order of approximately 30% of sediment delivery in the lower basin subwatersheds are needed to attain the numeric targets. Thus, the loading capacity or allowable load in the lower basin is approximately 70% of the historic load. The 30% reduction in the lower basin should be viewed as an average given the spacial and temporal variation in both channel conditions and delivery mechanism throughout the area. EPA believes 30% is a necessary and reasonable reduction level based on: 1) the data clearly indicate that present sediment levels may be limiting salmonid habitat in certain areas of the basin; 2) the sediment source analysis, combined with the hillslope indicators, indicate that management activities have contributed approximately 36% of the historic sediment load; and 3) historically delivered sediment is still likely routing through the system and therefore a 30% reduction from the hillslope is a conservative approximation to achieve water quality objectives.

Determining the degree to which sediment reduction is needed in the middle and upper basin is more challenging due to minimal sediment and habitat data. In EPA's judgement, 10% reductions appear necessary in the middle and upper basins for the following reasons: 1) sedimentation in the upper and middle basin can impact pool habitat in the middle mainstem VDR which is a critical habitat element for summer steelhead, and 2) sediment generated from the upper and middle basin is eventually routed to the lower mainstem where it has a more direct effect on fish passage for all anadromous species. However, a lesser degree of reduction is warranted in the middle and upper basin compared with the lower basin (10% compared with 30%) because: 1) data indicate the stream channel in the middle and upper basin is recovering toward pre-1964 levels (Klein 1998; USDA 1998), and 2) sediment delivery within the middle and upper has a less direct impact on the diversity and abundance of anadromous fish than in the lower basin. Based on a load reduction of 10% of historical loads, the loading capacity in the middle and the upper basin is 90%.

The allowable loading capacity of the three subbasins (LC_{upper}, LC_{middle}, LC_{lower}) are estimated by multiplying the allowable loading percentages (90% for the upper and middle; and 70% for the lower) by the annual historic loading rates[1] (upper 1433 yds^3/mi^2/year; middle 1886 yds^3/mi^2/year; lower 1257 yds^3/mi^2/year; Column b, Table 5.1):

$$\begin{aligned} LC_{upper} &= \text{Allowable Loading \% (annual historic loading rate)} \\ &= .9\ (1433\ yds^3/mi^2/year) \\ &= 1290\ yds^3/mi^2/year \end{aligned}$$

$$\begin{aligned} LC_{middle} &= .9\ (1886\ yds^3/mi^2/year) \\ &= 1697\ yds^3/mi^2/year \end{aligned}$$

[1] The annual historic loading rates are higher than originally estimated in the draft TMDL due to the inclusion of loading rates from channel migration zones during the public comment period (PWA (1999(b)).

$LC_{lower} = .7\ (1257\ yds^3/mi^2/year)$
$= 880\ yds^3/mi^2/year$

In order to calculate the loading capacity basin-wide (LC_{basin}), the loading capacity for each basin must be converted to total yds^3/year by multiplying each LC by the area of each subbasin, adding the subbasins together, then dividing by the total area of the basin:

$$LC_{basin} = [LC_{upper}\ (Area_{upper}) + LC_{middle}\ (Area_{middle}) + LC_{lower}\ (Area_{lower})]\ /\ Area_{basin}$$

$$= (1290\ yds^3/mi^2/yr\ (98mi^2) + 1697\ yds^3/mi^2/yr\ (202\ mi^2) + 880\ yds^3/mi^2/yr\ (129mi^2))\ /\ 429\ mi^2$$

$$LC_{basin} = TMDL = 1358\ yds^3/mi^2/yr$$

This loading capacity meets the regulatory definition and requirements in 40 CFR 130.2(f) and (g) which state that the loading capacity is "... the greatest amount of loading that a water can receive without violating water quality standards..." and they are, "...best estimates of the loading, which may range from reasonably accurate estimates to gross allotments."

5.C TMDL and Load Allocations

Sediment load allocations represent the maximum allowable level of sediment delivery to the river from various human caused and natural sources that together, do not exceed loading capacity and will, therefore, result in the attainment of water quality standards. A TMDL is defined as the sum of the individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background, such that the loading capacity of the receiving water is not exceeded. Therefore, the TMDL for the VDR can be divided into the natural and management-related load allocations:

TMDL = WLAs + LAs (natural and management-related) + Margin of Safety

Since there are no presently defined point sources of pollution in the VDR, the TMDL waste load allocation is zero. According to 40 CFR 130.2, "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." The VDR TMDL is expressed in cubic yards per square mile per year ($yds^3/mi^2/year$)[2]. The expression of loads in cubic yards is intended to be meaningful to field resource managers who assess and implement sediment prevention measures. Approximately 10 yds^3, for example, is equivalent to one dump truck full of sediment. In addition, EPA is expressing this TMDL as a 10-year rolling average to account for the large inter-annual variability in sediment loading and long term timeframes in which beneficial use impacts occur and change. The process for determining appropriate load allocations included: 1) a review of the historic rates of sediment delivery from the natural and management-related source categories established in the sediment source analysis (Chapter 4); and 2) assigning a "necessary % reduction" factor, based on levels needed to meet the instream loading capacity as well as feasibility of controlling each source.

[2] To convert $yds^3/mi^2/year$ to $tons/mi^2/year$ mutiple yards by 1.76.

Natural Load Allocations

All the natural sediment delivery features (i.e., slides and torrents, bank erosion, gullies and earthflows) are combined into a single source mechanism category within each subbasin on Table 5.1 column b (data derived from sediment source analysis, Table 4.3.) The percent necessary reduction (column c) for the natural source mechanisms is zero, because it is infeasible to control or prevent erosion from these sources. Therefore, the natural load allocation for each subbasin is:

$LA_{upper\text{-}natural}$ = 1162 yds^3/mi^2/yr

$LA_{middle\text{-}natural}$ = 1593 yds^3/mi^2/yr

$LA_{lower\text{-}natural}$ = 815 yds^3/mi^2/year

Management-associated Load Allocations

The load allocations for management-related source mechanisms are divided into two main subcategories, according to the upper, middle and lower basin areas, as identified in Table 5.1, column a: 1) road and skid trail (including crossing failure, gully erosion from diversions and the prism, and fill failures); and 2) timber harvesting (including hillslope slides, torrents, gullies and bank erosion). Table 5.1, column b includes rates and the percentage of sediment delivery from management-related sources relative to total historic sediment load in the upper (20%), middle (16%) and lower (36%) basins.

EPA estimated the percent necessary reduction (column c) for each source category by considering: 1) the degree to which sources can be controlled through the implementation of protective and feasible management techniques, and 2) the degree to which reductions are needed in order to attain the loading capacity in each subarea.

Estimates of the controllability of loads for the road and skid trail and timber harvest categories are based on a combination of new technologies and approaches for preventing and controlling sediment inputs from watershed disturbing practices, such as roads and timber harvest (Spence et al. 1996, Weaver and Hagans 1994, USDA 1994) and the professional judgement and experience in North coastal watersheds by PWA. Spence et al. (1996) describes several improvements in forestry practices, in contrast to historic methods, including harvesting/yarding systems, site preparation, streamside buffer management, etc. that, if implemented, will greatly reduce sediment input due to timber harvesting related activities. Similarly, the aquatic conservation strategy for federal lands (USDA 1994) calls for dramatic reductions in the intensity of management of timber management in unstable areas and riparian zones which will likely result in reduced sediment yield compared with historic loads in the upper basin. Improved methodologies for conducting inventories and “storm-proofing” roads (Weaver and Hagans 1994 and 1999) are also now available to land managers which, if implemented, will lead to dramatic reductions in sediment from historic road-related loads.

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). Sediment delivery from timber harvesting activities can be controlled by 50 - 75% of historic levels by reducing harvest on steep and unstable slopes, applying streamside buffers and minimizing soil disturbance through modified silvicultural prescriptions (personal communication with D. Hagans, PWA, 1999; Spence et al. 1996; USDA 1994). EPA has established similar levels of controllability for road and timber harvest related activities on nearby watersheds, such as the South Fork Trinity (EPA 1998(b)).

In the lower basin, EPA determined that 90% controllability for roads and skid trails and 75% for timber harvesting is necessary in order to achieve the loading reduction estimates (30%) and the loading capacity for the lower basin. This level of sediment control in the lower basin is also justified given the relatively high contribution from management-related sources (36%) and the importance of the lower basin tributaries for salmon and steelhead spawning and rearing habitat.

EPA determined that an 80% necessary reduction for roads and skid trails and 60% from timber harvesting is necessary and achievable in the middle and upper basin for the following reasons: 1) the load reductions necessary to attain the loading capacity is less (10%) in the middle and upper basin than in the lower basin (30%); 2) fish habitat values in the middle and upper basin are naturally lower than in the lower basin; 3) the percentage of the historic load attributed to controllable sources is lower in the middle (16%) and upper (20%) compared to the lower basin (36%). This indicates that management in the middle and upper basin areas has proportionally had less of an impact than in the lower basin and therefore drastic reductions are not as necessary. However, any additional sediment delivery from management-related sources in the upper basin can contribute to water quality impairment and therefore a moderate reduction is both necessary and feasible.

In some areas of the basin, land managers may be currently achieving or exceeding these levels of controllability on sediment delivery. However, the results of these current efforts may not be completely accounted for until the sediment source assessment is repeated in the future to demonstrate improvements from past practices or as a result of conducting erosion assessments across individual ownerships to determine the extent of prevention of sediment delivery.

The load allocations each source mechanism is calculated as follows: Multiplying the historic loads (column b) by percent necessary reduction (column c) equals the reduced load (column d). Subtracting the load reduction (column d) from the historic load (column b) equals the remaining load (column e). The remaining load represents the total amount of sediment (i.e., load allocation) from each source category that can be delivered to the waterbody, based on a 10 year rolling average, and still attain water quality standards.

LA_{source} = historic load - reduced load

Where, reduced load = historic load (% necessary reduction)

$LA_{upper\text{-}roads}$ = 33 - [33(.8) = 26] = 7
$LA_{upper\text{-}harvest}$ = 238 - [238(.6) = 143] = 95

$LA_{middle\text{-}roads}$ = 110 - [110(.8) = 88] = 22
$LA_{middle\text{-}harvest}$ = 183 - [183(.6) = 110] = 73

$LA_{lower\text{-}roads}$ = 202 - [202(.9) = 182] = 20
$LA_{lower\text{-}harvest}$ = 240 - [240(.75) = 180] = 60

TMDL Calculation

TMDLs for each subbasin ($TMDL_{upper}$, $TMDL_{middle}$, $TMDL_{lower}$) equal the sum of the remaining load allocations for natural ($LA_{natural}$) and management-related source mechanisms (LA_{roads}, $LA_{harvest}$) within each subbasin (Table 5.1, column e):

$$
\begin{aligned}
TMDL_{upper} &= LA_{upper\text{-}natural} + LA_{upper\text{-}roads} + LA_{upper\text{-}harvest} \\
&= 1162\ yds^3/mi^2/yr + 7\ yds^3/mi^2/yr + 95\ yds^3/mi^2/yr \\
&= 1264\ yds^3/mi^2/yr
\end{aligned}
$$

$$
\begin{aligned}
TMDL_{middle} &= LA_{middle\text{-}natural} + LA_{middle\text{-}roads} + LA_{middle\text{-}harvest} \\
&= 1593\ yds^3/mi^2/yr + 22\ yds^3/mi^2/yr + 73\ yds^3/mi^2/yr \\
&= 1688\ yds^3/mi^2/yr
\end{aligned}
$$

$$
\begin{aligned}
TMDL_{lower} &= LA_{lower\text{-}natural} + LA_{lower\text{-}roads} + LA_{lower\text{-}harvest} \\
&= 815\ yds^3/mi^2/yr + 20\ yds^3/mi^2/yr + 60\ yds^3/mi^2/yr \\
&= 895\ yds^3/mi^2/yr
\end{aligned}
$$

In order to calculate the basin-wide TMDL ($TMDL_{basin}$), the TMDLs for each basin must be converted to yds^3/year by multiplying each TMDL by the area of each subbasin, adding the subbasins together, then dividing by the total area of the basin:

$$TMDL_{basin} = WLA + [(TMDL_{upper}(Area_{upper}) + TMDL_{middle}(Area_{middle}) + TMDL_{lower}(Area_{lower})) / Area_{basin}]$$

$$= 0 + [(1264\ yds^3/mi^2/yr\ (98 mi^2) + 1688\ yds^3/mi^2/yr\ (202\ mi^2) + 895\ yds^3/mi^2/yr\ (129 mi^2)) / 429\ mi^2]$$

$$\mathbf{= 1353\ yds^3/mi^2/yr}$$

The margin of safety is expressed implicitly in conservative assumptions, explained below under the margin of safety subheading.

Table 5.1. Sediment load allocations by source mechanism for the VDR					
a		b	c	d	e
Sub-basin	**Source Mechanism**	**Historic Sediment Load yds^3/mi^2/year (% of subbasin load)[3]**	**Percent Necessary Reduction**	**Reduced Load yds^3/mi^2/yr**	**Remaining Load yds^3/mi^2/yr (% of subbasin load) = load allocation**
Upper	Hillslope Processes (Plot and Air Photo Data): non-road slides and torrents, bank erosion, earthflows and gullies. (Natural)	1162 (80%)	0%	0	1162 (92%)
	Road and Skid Trail (Plot and Air Photo Data): incl. crossing failure, gully erosion from diversions and on the prism, and fill failures.	33 (3%)	80%	26	7 (<1%)
	Timber Harvesting (Plot and Air Photo Data): incl.. hillslope slides, torrents, gullies and bank erosion.	238 (17%)	60%	143	95 (8%)
	SUBTOTALS	1433	12%	169	1264
Middle	Hillslope Processes (Plot and Air Photo Data): non-road slides and torrents, bank erosion, earthflows and gullies. (Natural)	1593 (84%)	0%	0	1593 (94%)
	Road and Skid Trail (Plot and Air Photo Data): incl.. crossing failure, gully erosion from diversions and on the prism, and fill failures.	110 (6%)	80%	88	22 (1%)
	Timber Harvesting (Plot and Air Photo Data): incl.. hillslope slide, torrents, gullies and bank erosion.	183 (10%)	60%	110	73 (4%)
	SUBTOTALS	1886	10%	198	1688
Lower	Hillslope Processes (Plot and Air Photo Data): non-road slides and torrents, bank erosion and gullies. (Natural)	815 (64%)	0%	0	815 (91%)
	Road and Skid Trail (Plot and Air Photo Data): incl.. crossing failure, gully erosion from diversions and on the prism, and fill failures.	202 (16%)	90%	182	20 (2%)
	Timber Harvesting (Plot and Air Photo Data): incl.. hillslope slide, torrents, gullies and bank erosion.	240 (20%)	75%	180	60 (7%)
	SUBTOTALS	1257	29%	362	895
Basin		**1594**	**15%**	**241**	**1353**

[3] Historic sediment load volumes in this table are aggregated from Table 4.3, page 39.

5.D Margin of Safety, Seasonal Variation and Critical Conditions

Margin of Safety

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations, and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. This TMDL contains an implicit margin of safety based on conservative assumptions that were incorporated into the TMDL as a way of addressing the uncertainty associated with the data. Table 5.2 summarizes the uncertainties from the source assessment and other components of the TMDL, and identifies the adjustments that were made to account for them.

Table 5.2 Uncertainties in TMDL

Uncertainties in TMDL Supporting Documentation	**Adjustments to Account for Uncertainties**
Data regarding historic channel and watershed conditions are limited	The target levels for sediment indicators (channel and hillslope), against which existing conditions were compared, represent optimal conditions for beneficial use support (salmon habitat). The targets are conservative since the represent "ideal" conditions that may not be attainable in all cases in the VDR basin.
There is inherent variability in the spacial scales and physical watershed conditions (terrain, channel type, slope, vegetation, etc.) of sediment delivery from the hillslope to the channel.	The VDR basin is subdivided spatially between lower, middle and upper to account for fundamental differences in watershed and erosional processes within each subarea. EPA considers the targets and load allocations as averages to account for variability.
There is inherent annual and seasonal variation in the delivery of sediment to the stream channel from the source mechanisms.	The yearly load allocations are considered over a 10 year rolling average timeframe to account for variability in yearly delivery rates. The TMDL also includes hillslope targets as indicators to reflect sediment delivery
The degree to which sediment storage in the mainstem is functioning as both a source and sink for sediment was not fully assessed.	The TMDL assumes a one-to-one ratio between instream and hillslope sediment reductions (linkage analysis) as a conservative approximation of the amount of sediment reduction needed to attain water quality objectives.
The degree to which management practices can be controlled is generally not well understood.	The percent reductions called for in the TMDL from management-related sources are aggressive and conservative in order to compensate for the uncertainty in the source assessment (estimate of confidence - chapter 4).
The sediment source analysis did not directly estimate surface erosion as a delivery mechanism.	The aggressive levels of sediment reduction from management associated sources are expected to address surface erosion originating from management mechanisms.

Seasonal Variation

There is inherent seasonal and annual variation in the delivery of sediment to stream systems. Winter rainfall is typically the triggering mechanism for most erosional activity. As discussed in the sediment source analysis (chapter 4) as well as the watershed overview (chapter 1), water years with higher peak discharge tend to result in a higher incidence of landsliding and sediment delivery. However, even in low flow years, sedimentation can occur. This TMDL accounts for annual and seasonal variation by incorporating a 10 year rolling average into the interpretation of sediment load allocations.

Critical Conditions

The regulations at 40 CFR 130.7 state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters. This TMDL does not explicitly estimate critical flow conditions for several reasons. First, unlike many pollutants (e.g. acutely toxic chemicals) sediment impacts on beneficial uses may occur long after sediment is discharged, often at locations far downstream from the point of discharge. Second, sediment impacts are rarely correlated closely with flow over short time periods. Third, it is impractical to accurately measure sediment loading, transport, and short term effects during high magnitude flow events which usually produce most sediment loading and channel modification in systems such as the Van Duzen River and Yager Creek. Therefore, the approach used in this TMDL to account for critical conditions is to use indicators which are selective of the net long term effects of sediment loading, transport, deposition, and associated receiving water flows. These indicators may be effectively measured at lower flow conditions at roughly annual intervals. Inclusion of a large margin of safety helps to ensure that the TMDL will result in beneficial use protection during and after critical flow periods associated with maximum sedimentation events.

CHAPTER 6
IMPLEMENTATION and MONITORING RECOMMENDATIONS

6.A Introduction

This section recommends an implementation strategy that agencies, landowners and watershed groups could pursue in order to address the primary sediment source categories and allocations set forth in the TMDL. Federal regulations require the State to identify measures needed to implement TMDLs in the state water quality management plan (40 CFR 130.6). EPA expects that the State will incorporate the TMDL and associated implementation measures in the State water quality management plan (the RWQCB Basin Plan) upon approval by EPA. This section is intended to provide guidance to the State and other watershed stakeholders involved in implementing this TMDL.

The State's Nonpoint Source Management Plan (1988) describes the authorities by which Regional Water Boards can use their regulatory authorities to achieve implementation of conservation measures. One is to waive adoption of waste discharge requirements on condition that the dischargers implement adopted conservation practices. The second method is to enter into a Management Agency Agreement (MAA) with another agency which has authority to require implementation of conservation measures. The third is to adopt waste discharge requirements. The RWQCB has already entered into MAA's with the California Department of Forestry and Fire Protection (CDF) and the U.S. Forest Service (USFS). With the adoption of an implementation plan for the VDR into the Basin Plan, CDF and USFS will be required to consider the requirements therein prior to approval of individual management actions, such as THPs. In previously proposed TMDL implementation plans (e.g., Garcia River and Redwood Creek), the RWQCB has encouraged voluntary efforts to develop and implement site specific Erosion Control Plans by waiving the two existing prohibitions against discharges associated with logging, construction and other related activities. The proposed Redwood Creek TMDL Implementation Plan describes the necessary elements of the Erosion Control Plan. EPA endorses the RWQCB's proposed approach to implementation.

The implementation recommendations contained herein describe the primary mechanisms for determining appropriate implementation actions according to landuses and ownerships within the lower, middle and upper basins. As described in earlier sections of the TMDL, these three areas generally contain different physical and biological features as well as unique land use and owernship patterns. As such, different strategies for achieving implementation goals are warranted within these three zones.

The overriding implementation need throughout the basin is for resource agencies and landowners to conduct assessments to identify and prioritize controllable sediment sources, particularly road networks, and to implement appropriate conservation measures in a timely manner. Ideally, implementation of prevention and restoration activities will be prioritized by subwatersheds containing the greatest biological (fisheries) benefit, in accordance with strategies described by Bradbury (1995) and others. EPA encourages collaboration between agencies and landowners to conduct the assessments and pool resources for implementation. The restoration effort in Cummings Creek is an excellent example of how landowners can work together to assess a problem and leverage resources to fix it.

6.B Lower Basin

Forest Roads and Timber Harvest

Industrial timber management is the dominant land use that influences the harvest and road related sediment sources in the lower basin. The timber harvest plan (THP) process and sustained yield plan (SYP) under the California State Forest Practice Rules, as well as Habitat Conservation Plans (HCPs) under the Endangered Species Act are the major land use authorities that influence management practices on industrial timber lands. A Scientific Review Panel (SRP) conducted an independent review of the California Forest Practice Rules (FPRs) with regard to their adequacy for the protection of salmonid species, as required by the March 1998 Memorandum of Agreement (MOA) between the National Marine Fisheries Service and the Resources Agency of California. The SRP provided recommendations for changes to specific rule sections addressing: watercourse and lake protection zones and large woody debris recruitment, geologic review and maps, road construction and maintenance, watercourse crossings, winter operations, and THP preperations, review and implementation (Ligon et al 1999). The SRP also emphasized the need for a watershed analysis approach capable of assessing cumulative effects attributable to timber harvesting and other non-forestry activities on a watershed scale (Ligon et al 1999).

The Pacific Lumber Company, the largest landowner in the lower basin, recently has entered into an agreement with the National Marine and Fisheries Service (NMFS) and the Fish and Wildlife Service (FWS) to implement a HCP for their ownership including lands in the Yager Creek and VDR. The HCP contains several provisions that, if properly implemented, could address source categories in the TMDL as well as the concerns expressed by the SRP:

- Timber harvest restrictions on steep or unstable slopes including high, very high and extreme mass wasting zones such as inner gorge areas;
- Riparian management zones on Class I, II and III streams that provide large tree retention for recruitment as large woody debris and bank stabilization;
- Road storm-proofing process of assessing the road network to identify controllable sources, such as stream crossings, and assigning implementation priorities, according to principles described in the Handbook for Ranch and Forest Roads (Weaver and Hagans 1994);
- Watershed Analysis including assessments of fisheries, stream channel conditions, mass wasting, surface erosion, riparian conditions, and cumulative effects. The schedule for watershed analysis completion is: Van Duzen 2001, Lawrence Creek 2002, Lower Yager Creek 2002, North Fork Yager 2003.
- Monitoring program consisting of aquatic stations as well as compliance and effectiveness monitoring of management measures.

The successful and timely implementation of these provisions on PL's land is critical to the achievement of sediment allocations in the lower basin. EPA encourages PL to cooperate with other landowners, agencies and the public to conduct watershed analyses for Lower VDR, Lawrence Creek and Yager Creek, according to the process set forth in PL's HCP and further modified in the Freshwater Creek example. The watershed analysis process will provide a scientifically-based mechanism to aggregate all existing data, assess unstable areas, prioritize areas for restoration and pool resources for implementation actions. In the meantime, other industrial timberland THPs should address the SRP recommendations and the TMDL load allocations categories and numeric targets including:

- Eliminating diversion potentials from stream crossings;
- Disconnecting road surfaces and ditches from streams;
- Controlling unstable road, skid trail and landing fills;
- Preventing stream crossing failure/washout; and
- Reducing the number of roads and intensity of timber management on inner gorge, steep slopes and unstable headwall areas.

<u>County Roads and other State and Private Roads</u>:

Road related sediment allocations and hillslope targets in the TMDL must also be achieved for roads under the jurisdiction of the County of Humboldt, California Department of Transportation (CalTrans) and private landowners/road associations. The University of California Cooperative Extension (UCCE) conducted a review of County policies, ordinances and practices regarding the protection of salmonids at the request of the Five County Planning Group (which includes Humboldt, Del Norte, Mendocino, Siskiyou and Trinity Counties). The UCCE reported several needs including increased funding for the maintenance and upgrading county roads and bridges, and general plan updates to include policies for protecting anadromous salmonids and their habitats (UCCE 1998).

EPA commends the Five County Planning Group for identifying ways for improving protection of salmonid habitat. EPA urges the counties to comply with targets and allocations set forth in the TMDL and to continue to collaborate with local watershed groups and agencies to conduct training for county and local operators regarding assessment and implementation of road maintenance and sediment reduction techniques. Local agencies and watershed leaders could pursue grant funding (e.g., SB 271, CWA 319) for implementing sediment control projects. Assistance can be provided by UC Cooperative Extension, Humboldt RCD, NRCS, DFG, etc. Smaller landowners can follow the sediment source guidelines set forth by the UCCE (1998). In addition, Humboldt County should set forth a timeline for pursuing, in conjunction with the public, the policy change recommendations put forth in the UCCE Report (1998) for protecting anadromous salmonids as part of the Five County Planning Effor.

6.C Middle Basin:

<u>Ranch Roads and Livestock</u>

Several ranching landowners in the middle zone are involved in the voluntary Ranch Water Quality Management Planning (Ranch Plan) program sponsored by the UCCE (Gary Markegard, UCCE agricultural advisor, pers comm. 1999). The Ranch Plan program includes training workshops on nonpoint source pollution, fish habitat, water quality, grazing effects on riparian areas, monitoring, etc. In addition, the UCCE provides training on conducting sediment source inventories by private agricultural landowners (UCCE 1998). One of the challenging aspects of the Ranch Plan program, in terms of a compliance mechanism for TMDLs, appears to be a feed-back loop to determine whether Ranch Plans are being implemented and effective in reducing sediment and protecting water quality.

EPA recommends the UCCE work with local watershed leaders and participants of the Ranch Plan program, along with the NCRWQCB, to develop an accountability mechanism for implementing and reporting on ranch plans. The formation of interest-based watershed groups, such as coordinated resource management planning (CRMP) groups, may facilitate improved communication between all parties and obtaining grant funds.

Forest Roads and Timber operations

THP submittals and/or Nonindustrial Timber Management Plan (NTMP) are the primary existing mechanisms to ensure that the TMDL controllable source categories of concern related to timber management in the middle basin are addressed. Agencies and landowners should ensure that controllable sediment sources and hillslope targets are addressed through the THP and NTMP approval process.

Rural Residential Roads

EPA recommends additional outreach and education by local agencies and organizations to rural residents regarding proper road design and maintenance. As mentioned above, the formation of watershed groups, such as coordinated resource management planning (CRMP) groups, may facilitate improved communication between all parties and obtaining grant funds to implement conservation measures.

6.D Upper Basin

US Forest Service Land Management

The Aquatic Conservation Strategy (ACS), as part of the Northwest Forest Plan (NFP) sets forth the overall direction for protecting aquatic resources for the upper basin. The VDR Watershed Analysis (USFS 1998) provided several recommended actions for achieving the goals of the Northwest Forest Plan's Aquatic Conservation Strategy including:

* In the subdrainages with the best remaining fish habitat, protect Federal lands where good conditions exist and restore deteriorated areas where feasible. Emphasize decommissioning and flood proofing of roads in these subwatersheds, especially areas underlain by melange, to maximize the likelihood of cost-effective restoration efforts;

* Inventory landslides for potential revegetation on National Forest lands in the watershed. Emphasis should be placed first on the Little Van Duzen and secondarily on the West Fork;

* Explore cooperative efforts with private landowners and other groups to restore riparian vegetation and reduce erosion and sedimentation;

* Priority restoration work includes: decommissioning roads in problem areas, especially where landslide processes are active; designing culverts to withstand 100-year storms; installing waterbars; applying protective aggregate surfacing to prevent gullying; and armoring existing c ulvert outlets in erodible terrain;

* Revisit and update existing inventory (1981) of road-related sediment sources on NFS roads (and possibly some private or county roads) within the upper watershed to find and correct site specific problems.

EPA encourages the USFS set forth a timeline, and public involvement process, for implementing the above recommendations.

6.E Monitoring Objectives

The overall purpose of a TMDL monitoring program is to determine whether load allocations are being achieved and to assess the condition of stream and hillslope indicators relative to target levels. Based on the information and knowledge gained through monitoring, the load allocations and/or the implementation actions should be adapted or adjusted. A comprehensive monitoring program should consist of three primary objectives:

* Implementation: Are resource managers implementing sediment control practices according to the appropriate land use plan (i.e., HCP, THP, Ranch Plan, NTMP, etc)?
* Effectiveness: Are implementation measures effective in reducing the amount of sediment to watercourses?
* Aquatic Condition: How are the physical and biological indicators of aquatic habitat condition changing over time?

Monitoring programs can also fill other objectives such as: a) increasing education and awareness about watershed conditions/processes and b) serve as an avenue of coordination and communication among agencies and landowners in a basin. Presently, various agencies including CDFG, NCRWQCB, USFS, etc. as well as private landowners are conducting some form of monitoring throughout the basin. The development of a basin-wide monitoring plan would likely improve the efficiency between entities conducting monitoring and render the results of an agreed upon monitoring strategy more meaningful. A vital step in the development of a comprehensive monitoring strategy for the VDR is for a local agency (such as CDFG and NCRWQCB) or group to take a leadership role in pulling together all the interested parties to tailor the elements described below into a monitoring plan for the VDR.

EPA recommends that the sediment source analysis conducted by PWA for this TMDL be conducted again in 5 - 10 years or following a large storm event, following the same procedures, as a tool to measure progress in achieving sediment load allocations. Continued and expanded monitoring of the TMDL stream and hillslope indicators is also necessary to measure watershed conditions.

6.F Monitoring Elements and Adaptive Management

Several documents discuss methodologies for measuring the quality of aquatic habitat as well as the watershed processes that effect stream conditions such as MacDonald et al. (1991), Spence et al. (1996), Klein (1998) and Bauer and Ralph (1999). Some of the common elements are described below for consideration by agencies and landowners to tailor specifically to the VDR.

* Establishing Key Questions, Objectives and Hypotheses: All parties should agree on the questions that the monitoring program is intended to answer. In addition to the implementation, effectiveness and aquatic conditions objectives described above, the resource managers may also wish to ask more specific questions such as relative abundance of anadromous fish between tributaries or transport rates of large woody debris, etc.
*The objectives will help determine the appropriate spacial and temporal scale for monitoring. For example, determining the effectiveness of a particular management practice is more accurately measured at the point of the activity or within the closest channel. Conversely, measuring the cumulative effect of several activities and/or natural processes can be accomplished further downstream

and at longer time intervals.

* Select indicators and variables based on the needs defined by the objectives.

* Methodologies should be consistent across ownerships and over time in order to provide comparable data.

* Quality assurance and quality control plans should be developed to ensure data is collected, analyzed and reported in a manner that is usable and defensible.

* The monitoring plan should identify locations and frequency of monitoring.

Between agency representatives, company representatives, landowners and watershed groups, the VDR has a tremendous amount of expertise available from which to develop an effective and long-term monitoring program. The development and implementation of a such a program could greatly assist in the understanding of watershed conditions and provide a basis for adaptive management. Adaptive management is: “The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans” (USDA 1993).

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GLOSSARY

Adaptive Management	"The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans" (USDA 1993)
Aggradation	To fill and raise the elevation of the stream channel by deposition of sediment.
Anadromous	Refers to aquatic species which migrate up rivers from the sea to breed in fresh water.
Baseline data	Data derived from field based monitoring or inventories used to characterize existing conditions and used to establish a database for planning or future comparisons.
Beneficial Use	Uses of waters of the state that may be protected against quality degradation including, but not limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and the preservation and enhancement of fish, wildlife and other aquatic resources or preserves.
Controllable source	Any source of sediment with the potential to enter a water of the State which is caused by human activity and will respond to mitigation, restoration, or altered land management.
Debris torrents	Long stretches of bare, generally unstable stream channel banks scoured and eroded by the extremely rapid movement of water-ladened debris, commonly caused by debris sliding or road stream crossing failure in the upper part of a drainage during a high intensity storm.
Deep seated landslide	Landslides involving deep regolith, weathered rock, and/or bedrock, as well as surficial soil. Deep seated landslides commonly include large (acres to hundreds of acres) slope features and are associated with geologic materials and structures.
Drainage structure	A structure or facility constructed to control road runoff. These structures include but are not limited to fords, inside ditches, water bars, outsloping, rolling dips, culverts or ditch drains.
Erosion	The group of processes whereby sediment (earthen or rock material) is loosened, dissolved and removed from the landscape surface. It includes weathering, solubilization and transportation.
Flooding	The overflowing of water onto land that is normally dry.
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
Interstices	The space between particles (e.g. space between sand grains).
Inner gorge	A geomorphic feature formed by coalescing scars originating from mass wasting and erosional process caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream, having a slope generally over 65% and being situated below the first break in slope above the channel.
Inside ditch	The ditch on the inside of the road, usually at the foot of the cutbank.
Landslide	Any mass movement process characterized by downslope transport of soil and rock, under gravitational stress by sliding over a discrete failure surface-- or the resultant landform.

Large woody debris	A piece of woody material having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) that is located in a position where it may enter the watercourse channel.
Loading Capacity	The amount of sediment the river network can assimilate and still meet water quality standards.
Load Allocation	The apportionment of the allowable load between natural and management-related sources.
Mass wasting	Downslope movement of soil mass under force of gravity-- often used synonymously with "landslide." Common types if mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents.
Numeric targets	A numerical expression of the desired instream environment. For each stressor or pollutant addressed in the problem statement of the Strategy , a numeric target is developed based on the numeric or narrative State water quality standards which are needed to recovered the impaired beneficial use.
Permanent drainage structure	A road drainage structure designed and constructed to remain in place following active land management activities while allowing year round access on a road.
Planning Watershed	The uniform designation and boundaries of sub basins within a larger watershed. These Watersheds are described by the California Department of Forestry as Cal Water Watersheds.
Redd	A gravel nest or depression in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and incubated.
Sediment	Fragmented material that originates from weathering of rocks and decomposed organic material that is transported by, suspended in, and eventually deposited by water or air.
Sediment budget	An accounting of the sources, movement, storage and deposition of sediment produced by a variety of erosional processes, from its origin to its exit from a basin.
Sediment delivery	Material (usually referring to sediment) which is delivered to a watercourse channel by wind, water or direct placement.
Sediment discharge	The mass or volume of sediment (usually mass) passing a watercourse transect in a unit of time.
Sediment source	The physical location on the landscape where earthen material resides which has or may have the ability to discharge into a watercourse.
Sediment yield	The sediment yield consists of dissolved, suspended and bed loads of a watercouse channel through a given cross-section in a given period of time.
Shallow seated landslide	A landslide produced by the failure of the soil mantle (typically to a depth of one or two meters, sometimes includes some weathered bedrock), on a steep slope. It includes debris slides, soil slips and failure of road cut-slopes and sidecast. The debris moves quickly (commonly breaking up and developing into a debris flow) leaving an elongated, concave scar.
Skid trail	Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.

Smolt	A young salmon at the stage at which it migrates from fresh water to the sea.
Steep slope	A hillslope, generally greater than 50% that leads without a significant break in slope to a watercourse. A significant break in slope is one that is wide enough to allow the deposition of sediment carried by runoff prior to reaching the downslope watercourse.
Stream	See watercourse.
Stream class	The classification of waters of the state, based on beneficial uses, as required by the Department of Forestry in Timber Harvest Plan development. See definitions for Class I, Class II, Class III, and Class IV for more specific definitions.
Stream order	The designation (1,2,3, etc.) of the relative position of stream segments in the drainage basin network. For example, a first order stream is the smallest, unbranched, perennial tributary which terminates at the upper point. A second order stream is formed when two first order streams join. Etc.
Sub basin	A subset or division of a watershed into smaller hydrologically meaningful Watersheds.
Swale	A channel-like linear depression or low spot on a hillslope which rarely carries runoff except during extreme rainfall events. Some swales may no longer carry surface flow under the present climatic conditions.
Tectonic	Forces related to the deformation of the earth surface.
Terrain Type	Physical features, such as bedrock and slope, of land areas.
Thalweg	The deepest part of a stream channel at any given cross section.
Thalweg profile	Change in elevation of the thalweg as surveyed in an upstream-downstream direction against a fixed elevation.
Unstable areas	Characterized by slide areas, gullies, eroding stream banks, or unstable soils. Slide areas include shallow and deep seated landslides, debris flows, debris slides, debris torrents, earthflows and inner gorges and hummocky ground. Unstable soils include unconsolidated, non-cohesive soils and colluvial debris.
Watercourse	Any well-defined channel with a distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil.
Waters of the state	Any surface water or groundwater, including saline water, within the boundaries of the state.
Watershed	Total land area draining to any point in a watercourse, as measured on a map, aerial photo or other horizontal plane. Also called a basin, drainage area, or catchment area.
Water quality objective	Limits or level of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.
Water quality standard (WQS)	Consist of the beneficial uses of water and the water quality objectives as described in the Water Quality Control Plan for the North Coast Region.