Riparian Protection Committee

Flood Prone Area Considerations in the Coast Redwood Zone

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Dale T. Geldert
Director
California Department of Forestry and Fire Protection

Mike Chrisman
Secretary for Resources
The Resources Agency

Arnold Schwarzenegger
Governor
State of California

Executive Summary

Possible approaches that Registered Professional Foresters (RPFs) can use when proposing to harvest flood prone areas in the coast redwood zone of northwestern California are discussed in this paper. These areas are the highest productivity timberlands available, but are also biologically important for aquatic and terrestrial species, some of which are listed by federal and state agencies. Disagreements on potential impacts of proposed timber operations for these areas between timberland managers and reviewing agencies, and sometimes among the reviewing state and federal agencies responsible for regulating timber harvesting on private and State-owned timberlands, led to the formation of the interagency Riparian Protection Committee (RPC) and the need for this paper. The existing California Forest Practice Rules (FPRs) require RPFs to evaluate flood prone areas and to consider the ecosystem functions of these areas when developing protection measures. In the past this rule has been misunderstood and inconsistently applied. The RPC was comprised of representatives from the California Department of Forestry and Fire Protection (CDF), the California Department of Fish and Game (DFG), the California Geological Survey (CGS), and the North Coast Regional Water Quality Control Board (NCRWQCB).

The basic procedures suggested by the RPC for flood prone area protection and restoration include: (1) inventorying flood prone areas for all of the hydrologic, geomorphic, and biological functions present that may be affected by proposed timber operations; (2) determining the category of inundation of the flood prone area proposed for management (i.e., very frequent, frequent, moderately frequent, or infrequent), and (3) conducting an appropriate analysis for the functions present in light of possible significant adverse impacts from management. Disclosure and analysis requirements will increase with increased risk associated with the proposed level of activity, and with increased frequency of inundation of the flood prone area. In particular, management proposed within the 20-year recurrence interval floodplain in a watershed with anadromous fish habitat (particularly coho salmon habitat or restorable habitat) requires detailed analysis. Several possible approaches are suggested for consideration by RPFs for analyzing potential impacts for the various flood prone area functions, including shading, large wood recruitment, and protection of overflow channels. If a flood prone area has an active channel migration zone, where a stream is prone to movement with near-term loss of riparian function and associated habitat adjacent to the stream, proposed practices will require more detailed analyses and additional mitigation than required for those channels that have remained laterally stable over many decades and can reasonably be expected to continue to exhibit stability in the future.

Numerous studies have been published showing that significant thinning of coast redwood stands on hillslope areas can substantially increase tree growth over time, but the RPC was not aware of any published studies that have examined stand growth with varying stocking levels on alluvial floodplains. Therefore, the RPC requested that an experienced timber harvest scheduling expert model three silvicultural systems commonly employed in high productivity timber site flood prone areas, along with a no harvest alternative. These alternatives included no harvest, conservative sanitation

(harvest of intermediate and suppressed trees), thinning from below, and standard single tree selection (approaching the minimum standards under the FPRs). The four alternatives evaluated the effects on stand structure over 60 years. Results from the modeling revealed that the conservative sanitation and thinning from below alternatives produce similar numbers of large trees (>36 inch dbh) over the 60 year modeling period, when compared to the no harvest alternative (at least for this modeling exercise). The single tree selection method produced a lower number of large trees at the end of the planning period.

While an understanding of flood prone area functions is necessary for project-level planning, this paper also stresses that Timber Harvesting Plans (THPs), Nonindustrial Timber Management Plans (NTMPs), and Program Timber Harvesting Plans (PTHPs) must also be evaluated in the context of a larger watershed perspective that includes consideration of the stream network condition, impacts of past activities in the basin, and planning for large disturbances. Floodplain surfaces should be managed within the context of long time periods and very infrequent events, so that the effects of large disturbances on landscape diversity can occur. While large channel-influencing floods, landslides, and other disturbances can radically change channel characteristics, these changes are natural processes under which fluvial systems have evolved over long time frames. Within the spatial context of watersheds, timber management of flood prone areas must consider the potential for channel migration and other naturally occurring disturbances. A primary mechanism to allow for disturbance on flood prone areas is to leave enough mature trees over long time frames to permit large wood to enter the river with episodic events. Additionally, there must be consideration of the current condition of the floodplain. If the flood prone surface has been highly impacted by past timber operations, then proposed operations must lead to recovery of flood prone area functions in impaired watersheds, as specified in 14 CCR § 916(a).

Recommendations by the RPC include: (1) removing separate definitions in the FPRs for confined and unconfined channels, (2) pre-consultation with state and federal agencies when appropriate, (3) reliance on programmatic approaches such as Habitat Conservation Plans (HCPs), Natural Communities Conservation Plans (NCCPs), Programmatic Timber Environmental Impact Reports (PTEIRs), and watershed-wide Waste Discharge Requirements (WDRs) for a longer-term perspective on large tree retention in flood prone areas and watershed-scale issues, and (4) broad training on flood prone area functions and assessment techniques for RPFs and agency personnel.

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Emanuel Fritz's Wonder Plot, documenting very high second-growth coast redwood growth on a floodplain located in the Big River watershed in western Mendocino County (photograph taken in 1989). CDF file photo.

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Riparian Protection Committee

Flood Prone Area Considerations in the Coast Redwood Zone

I. Introduction and Background

Land management activities, including timber operations, on floodplains, riparian zones, watercourse and lake protection zones, and other flood prone areas can affect flooding, aquatic and riparian terrestrial habitats, water quality and other environmental and public safety concerns. In the northern California coastal redwood region, these flood prone areas are also often the highest productivity timberlands. This situation leads to potential disagreements between timberland managers and reviewing agencies, and sometimes among the reviewing state and federal agencies responsible for regulating timber harvesting on private and State-owned timberlands. The primary issues relate to identifying flood prone areas and determining the types and intensities of timber harvesting activities that will not adversely impact both the ecological characteristics of the floodplain and the ability of the floodplain to influence its adjacent channel (Benda 2004).

In response to a recommendation by the California Department of Fish and Game (DFG), California Department of Forestry and Fire Protection (CDF) Assistant Deputy Director Duane Shintaku formed the interagency Riparian Protection Committee (RPC) to work collaboratively to reach common understandings on riparian issues related to logging operations on **coast redwood-dominated** floodplains and flood prone areas (Figure 1). The group was asked to identify problems with the Timber Harvesting Plan (THP), Nonindustrial Timber Management Plan (NTMP), and Program Timber Harvesting Plan (PTHP) [referred to collectively as "plan" in this document] Review Team process and to document substantial evidence where these problems are not being adequately addressed by the current process. More specifically, the committee was asked to determine the items that are being missed with use of the Threatened and Impaired Watersheds Rule Package (part of the California Forest Practice Rules), which was implemented in July 2000 and covers the entire coast redwood region (Figure 2). For purposes of discussion, issues raised for recent THPs in the Gualala River and Big River watersheds were reviewed in order to develop a better understanding of how to address related areas of concern in future plans.

The RPC met four times in the winter and spring of 2005, prior to development and review of this paper, to discuss issues of concern related to flood prone area timber operations. These meetings included one field trip to the Coast Range in western Mendocino County. While several issues were identified during these discussions, one of the most significant related to the current practice of beginning the Class I watercourse and lake protection zone (WLPZ) for unconfined channels where trees are at least 25 years in age at breast height. This location is known as the watercourse transition line (WTL) and typically occurs near the active channel edge at bankfull stage. While the current Forest Practice Rules allow for expansion of the Class I WLPZ width and application of appropriate mitigation measures as required for adequate protection and/or restoration of aquatic habitat, it was stated by some of the public trust agencies in the RPC meetings that there has been inadequate use of protection measures beyond the minimum standards described in the Forest Practice Rules in flood prone areas. These agencies stated that standard WLPZ widths have been used and have been inadequate for flood prone area protection/restoration. In some cases, flood prone areas that exist outside the WLPZ edges have been treated silviculturally similarly to areas on hillslopes located above the floodplain (i.e., the Class I WLPZ has not been extended to the edge of the flood prone area, or the WTL has not been established at the landward edge of the flood prone area—making the channel zone the entire flood prone area, instead of only a small part).

This issue and others are addressed in the current paper. Our approach is to show resource professionals how to adequately document existing flood prone area functions, analyze potential impacts, and develop appropriate mitigation measures to protect or restore these functions. The report was written to provide direction to agency staff, RPFs, and the public on the type of plan information needed to address concerns over harvesting in flood prone areas in California. In addition, it is to assist in training and provide a reference for those people involved in Forest Practice plan review.

This document is not meant to endorse a ban on harvesting big trees within flood prone areas, but to provide guidance when these harvest objectives are proposed. In some cases, existing and anticipated future conditions may support harvest of big trees in flood prone areas. In other cases, conditions support retaining these trees for flood prone area function.

List of Participants

The Riparian Protection Committee included the following participants:

Pete Cafferata, CDF, Chair, Forest Hydrologist

Dr. Marty Berbach, DFG, Staff Environmental Scientist

Jim Burke, NCRWQCB, Engineering Geologist

Jon Hendrix, DFG, Environmental Scientist

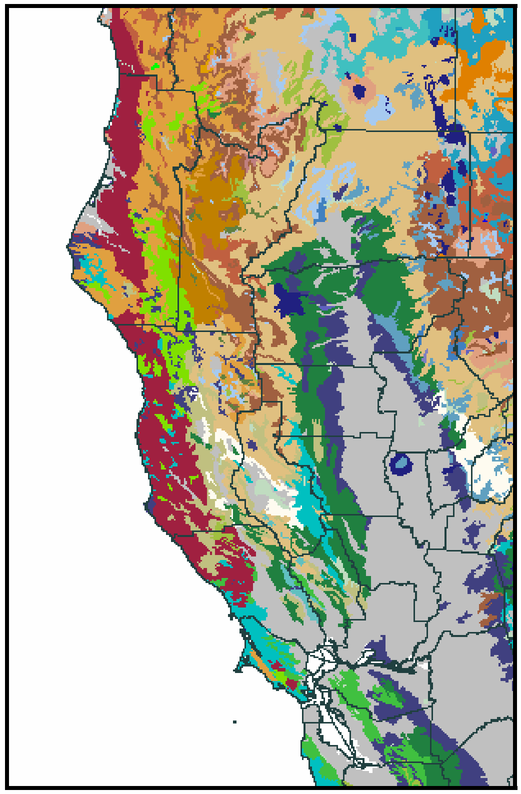
Bob Klamt, NCRWQCB, Division Chief, Timber Harvest Division

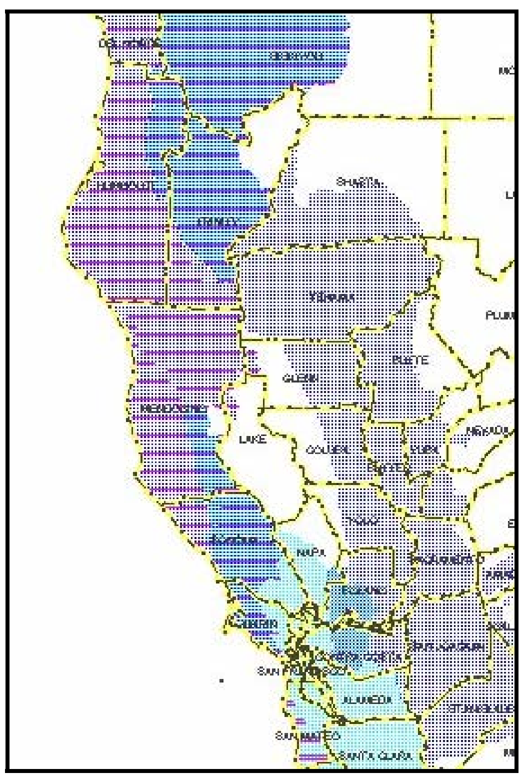
Rick Macedo, DFG, Senior Environmental Scientist

Tom Spittler, CGS, Senior Engineering Geologist

Kris Vyverberg, DFG, Senior Engineering Geologist

Christine Wright-Shacklett, NCRWQCB, Senior Engineering Geologist





Figures 1 and 2. California Vegetation (CAL VEG) data layer for northwestern California, with the redwood-Douglas-fir region shown in red (ICEMAPS 2.0, UC Davis ICE website); Boundaries for watersheds with threatened or impaired values for coho salmon, Chinook salmon, and steelhead ESUs (Salmon and Watershed Mapping Tool, CDF—FRAP website).

Flood Prone Area Regulation Authorities

A brief listing of state agency authorities related to timber operations on flood prone areas is provided below.

CDF—Numerous sections of the 2005 ***California Forest Practice Rules (FPRs)*** relate to flood prone area protection. Many of these rules (or additional rule language) originated in the Threatened and Impaired Watersheds Rule Package that went into effect on July 1, 2000. In particular, Title 14, California Code of Regulations § 916.9, Protection and Restoration in Watersheds with Threatened or Impaired Values, is a critical section when considering flood prone area protection measures and is a significant part of the Threatened and Impaired Watersheds Rule Package. CCR § 916.4(a)(1) is older language, but is highly significant since it requires the RPF to evaluate areas near and areas with the potential to directly impact watercourses and lakes for sensitive conditions, including changeable channels, overflow channels, flood prone areas, and riparian zones. It further requires that the RPF consider these conditions and those measures needed to maintain and restore for, among other things, spawning and rearing habitat for salmonids, when proposing WLPZ widths and protection measures.

CGS—Under the ***California Environmental Quality Act (CEQA)***, CGS and the Department of Conservation are listed with other State Agencies as having statutory authority for, among other things, floodplains and watersheds, mineral land reclamation, erosion and hydrologic conditions, water quality and water pollution control, and open space policy. Additionally, the ***Surface Mining and Reclamation Act (SMARA)*** applies when dealing with removal of gravel or rock materials in or near watercourses.

DFG— The DFG is the trustee agency for fish and wildlife of the state (14 CCR § 15386, CEQA Guidelines). The DFG implements and enforces the **California Endangered Species Act (CESA)** (Fish and Game Code 1600 *et seq*.), Streambed Alteration Agreements (Fish and Game Code 1600 *et seq*.), and consults on projects that may affect Threatened and Endangered Species (PRC 21104.2). At present, coastal coho salmon are listed as endangered south of Punta Gorda and threatened north of Punta Gorda. No other fish species are presently state-listed in areas that are the focus of this report. Several state-listed animals and plants do exist within or near the focus area. Several Fish and Game code sections relate to floodplains and riparian protection, including: 1385, 1600, 5650, and 6920, 6902(a). Pursuant to Fish and Game Code Section 1600 *et seq*., the DFG may issue agreements under their authority for projects or activities within or near lakes and watercourses that substantially diverts or obstructs the natural flow of, or substantially changes or uses any material from the bed, channel, bank of, any river, stream, or lake.

NCRWQCB—The NCRWQCB's mandate and authorities to protect, maintain, and restore water quality and the beneficial uses of water are derived from the federal **Clean Water Act (CWA)**, the state **Porter-Cologne Water Quality Control Act**, and the **Water Quality Control Plan for the North Coast Basin (Basin Plan)**. The State Water Board and regional water boards implement the CWA under the oversight of Region IX of the U.S. Environmental Protection Agency (EPA). The federal Clean Water Act (CWA, section 303, 33 U.S.C. § 1313) requires states to adopt water quality standards (state water quality objectives and beneficial uses) and to update those standards on a triennial basis. Key beneficial uses identified in the Basin Plan for the North Coast region related to flood prone areas include: ground water recharge; freshwater replenishment; commercial and sport fishing; cold freshwater habitat; wildlife habitat; biologically significant areas; rare, threatened or endangered species; migration of aquatic organisms; spawning, reproduction, and/or early development; water quality enhancement; flood peak attenuation/flood water storage; and wetland habitat. The Basin Plan provides protection to the beneficial uses through narrative and numeric objectives for pollutants such as sediment and turbidity; prohibitions such as the waste discharge prohibitions contained in the Action Plan for Logging Construction, and Associated Activities; and the anti-degradation policy.

II. Flood Prone Area Definitions

A **flood prone area** was defined by the RPC as the area adjacent to a watercourse or lake that is periodically covered with water and contributes to the interchange between terrestrial and aquatic components of the watershed (Figure 3). The frequency of inundation can vary from more than once a year to greater than every 100 years.

Figure 3. Example of a flood prone area in the Big River watershed. The silt line is approximately 3 feet high and inundation is estimated to occur on average approximately once every 10 years. DFG file photo.

Floodplains are a subset of flood prone areas. In the geomorphology literature, Dunne and Leopold (1978) define a floodplain as the flat area adjoining a river channel constructed by the river in the present climate and overflowed at times of high discharge. Similarly, Leopold and others (1964) define a floodplain as a strip of relatively smooth land bordering a stream and overflowed at a time of high water. The Washington Forest Practices Board (WFPB 2001) defines a floodplain as a generally flat landscape feature immediately adjacent to most stream and river channels that begins at the edge of the bankfull channel and receives overbank flow during most years (Figure 4).

Figure 4. Example of overbank flooding on the lower Elk River floodplain in Humboldt County during February 2004. CDF file photo.

Hydrologically, the extent of floodplains are defined in terms of their statistical frequency of inundation. For example, a "100-year floodplain" is the area subject to a one percent probability of a certain size flood occurring in any given year. One-hundred year floodplains are commonly referenced, since the Federal Emergency Management Agency (FEMA) places restrictions on building in these areas and requires pre-existing structures to have federally subsidized flood insurance. Since the 100-year floodplain is statistically determined with a small data set, it changes over time. Mount (1995) states that in California, where historic data is limited, the 100-year estimated discharge will increase following a major flooding event, causing an expansion of the designated 100-year floodplain.[1] Any statistical frequency of a flood event may be chosen, depending on the degree of risk that is selected for evaluation (e.g., 5-year, 20-year, 50-year floodplains). **In the North and Central Coast regions, the most biologically critical area is generally considered by riparian ecologists to be that area inundated at less than or equal to every 20 years, based on coho salmon life cycle requirements.**

[1] As an example, the Merced River at Happy Isles Bridge in Yosemite National Park experienced a flood flow of 10,000 cfs on January 2, 1997. The recurrence interval of this discharge in 1996 was 92 years, while it was only 65 years following the runoff event in 1997 (Hunrichs and others 1998). Therefore, the 100-year discharge was elevated considerably and the 100-year floodplain expanded in Yosemite Valley.

For the purposes of this report, the RPC has defined flood prone area **frequency of inundation** as follows:

Very Frequent	1-5 year recurrence interval
Frequent	5-20 year recurrence interval
Moderately Frequent	20-50 year recurrence interval
Infrequent	50+ year recurrence interval

There is some suggestion in the literature that these intervals are reasonable, although there is no standard for categorizing flood sizes. Ziemer (1998) reported that the minimum return interval for a flood event is about once a decade and stated that events that occur every 1-2 years are not generally considered “floods.” Mount (1995) called floods that occur with return intervals of less than 20 years as “high frequency events” and defined “very large storm events” as those with recurrence intervals of greater than 20 years. Wahl and others (2005) categorized recurrence intervals as follows for the Upper Mississippi River basin: 10 to 50 years, 50 to 100 years, and greater than 100 years. Ziemer and Lisle (1998) state that high flows occurring on average every one to five years are most important for transporting sediment and forming channels in many regions, but that less frequent large floods can have greater geomorphic effect in the Pacific coastal ecoregion, particularly in mountain channels.

The following additional definitions are provided, since they are terms used in this paper:

Bankfull stage is the river stage that occurs when discharge fills the entire channel cross section without significant inundation of the adjacent floodplain, and generally occurs with a frequency of 1.5 to 2 years for natural, undammed rivers (Mount 1995). In stable, unaltered alluvial streams, this stage is often delineated by the presence of a floodplain at the elevation of incipient flooding and indicated by deposits of fine sediment such as sand or silt at the active scour mark, break in stream bank slope, and/or perennial vegetation limit. Bankfull stage can be difficult to identify, particularly in steep cobble-boulder streams, in alluvial channels with a strong bedrock influence, and along braided, incised, or aggraded channels (Simon and Castro 2003).

Bankfull depth is the average vertical distance between the channel bed and the estimated water surface elevation required to completely fill the channel (WFPB 2001).

Bankfull width is the channel width at bankfull discharge (Figure 5).

Stream terraces are abandoned floodplain areas constructed by the river under different climatic or tectonic conditions, or in response to changes in land management practices. Terraces are infrequently inundated by floodwaters associated with the current climactic period (Dunne and Leopold 1978; Simon and Castro 2003).

Channel migration zones (CMZs) are areas where the active channel of a stream is prone to move, resulting in a potential near-term loss of riparian function and associated habitat adjacent to the stream, except as modified by a permanent levee or dike. For this purpose, near-term means the time scale required to grow forest trees that will provide properly functioning conditions.

Channel avulsion is when large-scale switching of the main flow occurs and new channels are cut or older ones are reoccupied.

Channel zone includes the bankfull channel and floodplain, encompassing the area between the watercourse transition lines (WTLs) (Ligon and others 1999).

Riparian forest is defined as extending laterally from the active channel to include both the active floodplain and adjacent terraces (Naiman and others 1998).

Hyporheic Zone is defined as the region beneath and adjacent to streams and rivers where surface and groundwater mix.

Roughness refers to resistance to flow of water in channels and on floodplains. For floodplains, major roughness is caused by trees, vines, and brush (Arcement and Schneider, undated). Manning's roughness coefficient, n, has been well studied for stream channels, but little work has been completed for densely vegetated floodplains.

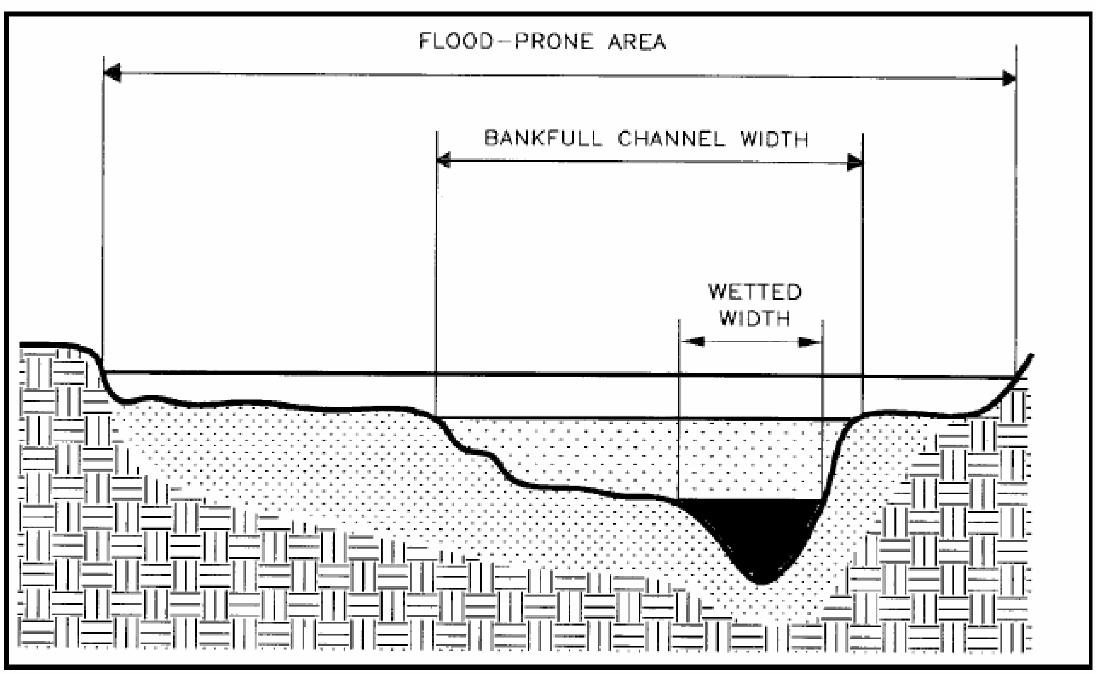


Figure 5. Diagram of stream channel and flood prone area cross-section (Figure III.1 in California Salmonid Stream Habitat Restoration Manual, Third Edition; [Flosi and others 1998]).

III. Flood Prone Area Functions

The Riparian Protection Committee reviewed the existing literature to develop a list of floodplain/flood prone area hydrologic, geomorphic, and biological processes and functions (Welsh and others 2000, Naiman and others 1998, USFS 2004). A summary of these functions is provided in Table 1. Table 2 displays some potential impacts of harvesting along streamside zones on salmonid growth and survival. Similar tables could be developed for other beneficial uses of water. A brief narrative description of these functions and processes follows.

It is important to note that while the literature has abundant information on riparian zone functions, little of the reported research has been conducted along larger river systems with extensive floodplains—especially within the coast redwood zone.

Hydrologic Processes and Functions of Flood Prone Areas

Floodplains and flood prone areas in forested watersheds may affect or be affected by hydrologic processes in several ways. Due to high roughness associated with a forested stand condition, flood flow velocities are reduced considerably. Additionally, when flow on the floodplain occurs, there is a large increase in cross-sectional area. In most instances, both the velocity and depth of water flowing outside the channel declines with distance away from the channel. This allows flood waters to recharge alluvial groundwater aquifers and can modify the hydrograph flood peak, which would alter downstream flood flows. As displayed in Figure 6, once flow is over the floodplain surface, the slope of line defining the relationship between river stage and discharge markedly decreases due to increased surface roughness and shallow water depth. The function of vegetative roughness will need to be identified and protected in the planning of timber harvesting operations on flood prone areas.

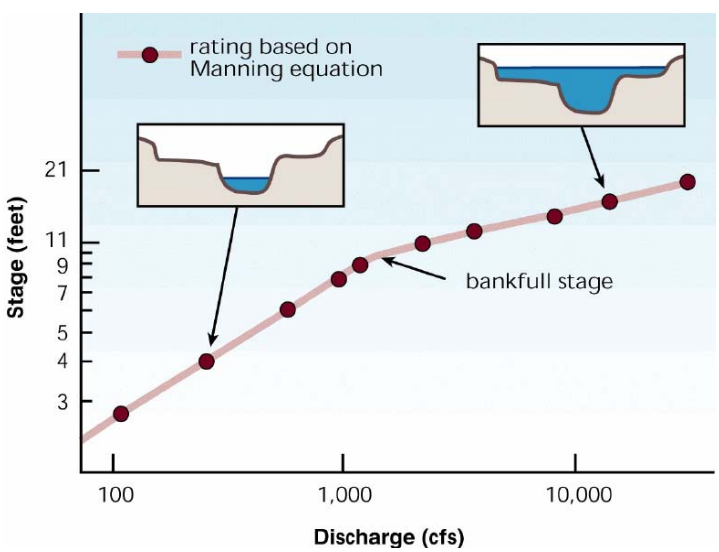


Figure 6. Hypothetical stage-discharge relationships for both the main river channel and for the floodplain surface. Bankfull stage can be determined from this rating curve [Figure 7.4 in Stream Corridor Restoration, FISRWG (1998)].

Table 1. List of flood prone area functions.

Hydrologic Processes/Functions/Properties and Role of Vegetation
Accommodation of floods above bankfull or channel-full flow
Modification of the flood hydrograph
Storage of runoff to allow for infiltration and recharge alluvial groundwater
Roughness to a floodplain that expends the energy of flood waters (e.g., slowing flood water velocity)
Temporary storage of water to moderate downstream flood flows
Hyporheic zone function
Geomorphic and Geologic Processes/Functions/Properties and Role of Vegetation
Area of deposition for suspended sediment in flood waters
Source of sediment through erosion of stored material by flood flows
Storage and metering of sediment transported from hillslope and upstream portions of the watershed (sediment filtration)
Roughness of floodplain vegetation slows flood waters and permits the deposition of fine-grained sediment adjacent to high-energy channels
Vegetation provides both surface and subsurface resistance to soil erosion
Vegetation provides cohesion that aids in bank stabilization
Biological Processes/Functions/Properties and Role of Vegetation
Potential site of overflow channels that serve as refugia for fish during floods
Large wood for recruitment to watercourses, enhancing aquatic habitat structure and complexity
Direct shading of watercourses and reduced heating from solar radiation
Wetland area that provides habitat such as ponds and vernal pools for a variety of mesic-(moisture) zone associated and dependant plants and animals
Riparian woodland that provides habitat for terrestrial organisms
Acceptable riparian microclimate conditions (air temperature, relative humidity, soil temperature, soil moisture, etc.)
Migratory corridors for wildlife species
Overhanging bank cover
Meters naturally occurring nutrients transported from hillslopes
Input of fine organic matter, leaf litter, and insects directly into watercourses that may be used for food for aquatic organisms
Moderation of air temperature above and immediately adjacent to stream channels
Alluvial aquifers that moderate surface water temperatures
Possible support of species of concern
Deposition and storage of large wood (both in and on the floodplain for potential delivery downstream), while providing habitat (e.g., nests, dens, food caches, and water/moisture sources) for wildlife species. Also, colonization sites for some coniferous species
Filtration of agricultural nutrients (nitrogen and phosphorus) and pesticides
Hyporheic zone function

Table 2. **Factors and consequences of timber harvest on salmonid survival.** The influences of timber harvesting from streamside areas on physical characteristics of stream environments and on potential consequences for salmonid growth and survival are displayed (modified from Welsh and others 2000, Table 6.2). Note that while timber harvesting operations may be designed to enhance the physical environmental factors considered in this table, only the potential negative impacts are identified here.

Potential Change in Physical Stream Environment	Potential Change in Quality of Salmonid Habitat	Potential Consequences for Salmonid Growth and Survival
Increased solar radiation	Increased stream temperature; higher light levels; increased autotrophic production	Reduced growth efficiency; increased susceptibility to disease; increased food production; changes in growth rate and age at smolting
Decreased supply of large wood	Reduced cover; loss of pool habitat; reduced protection from peak flows; reduced storage of gravel and organic matter; loss of hydraulic complexity	Increased vulnerability to predation; lower winter survival; reduced carrying capacity; less spawning gravel; reduced food production; loss of species diversity
Addition of logging slash (needles, bark, branches)	Short-term increase in dissolved oxygen demand; increased amount of fine particulate organic matter; increased cover	Reduced spawning success; short-term increase in food production; increased survival of juveniles
Erosion of streambanks	Loss of cover along edge of channel; increased stream width; reduced depth; increased fine sediment in spawning gravels and food production areas	Increased vulnerability to predation; increased carrying capacity for age-0 fish, but reduced carrying capacity for age-1 and older fish; reduced spawning success; reduced food supply

Geomorphic and Geologic Processes/Functions of Flood Prone Areas

Increases in channel cross-sectional areas, declines in channel gradients, and significant increases in bed roughness all result in decreases in flow velocities on floodplains and flood prone areas (Mount 1995). This allows floodplains to be depositional areas.[2] As water velocities decrease on wide, rough, low gradient flood prone areas, the amount of sediment the river can carry declines. The coarsest sediment falls out adjacent to the channel and the finest sediment is deposited away from the channel on the floodplain (Figure 7). As stated above, the function of vegetative roughness will need to be identified and protected in the planning of timber harvesting operations on flood prone areas. In many locations, levees constructed in the past 50 years have greatly restricted natural floodplain functions for larger river systems in California and the Pacific Northwest (Bolton and Shellberg 2001).

Since floodplain surfaces are nearly flat, they provide sediment filtration and act as natural collection features for hillslope erosion moving colluvially downslope from anthropogenic and naturally-caused rills, gullies, and mass wasting features. The ability

Figure 7. Coast redwood tree located on the Navarro River floodplain in the vicinity of the USGS gaging station at the 4.5 mile marker on State Highway 128. Note the freshly deposited fine sediment near the base of the tree from a flood event estimated to have a 5-year return interval. The silt line is approximately 6 feet high. DFG file photo.

[2] Nolan and others (1987) reported that for five rivers in northwestern California, floodplain formation appears to be due more to overbank deposition during large discharges than to lateral channel migration.

of riparian buffers to control sediment inputs from surface erosion depends on several site characteristics, including the presence of vegetation or organic litter, slope, soil type, and drainage characteristics. These factors influence the ability of buffers to trap sediments by determining the infiltration rate of water and the velocity (and hence the erosive energy) of overland flow. Timber harvesting operations will need to complement riparian protection measures with practices for minimizing sediment contributions from outside the riparian area, particularly those from roads and associated drainage structures, where sediment is often produced (Cafferata and Munn 2002). In addition, activities within the riparian zone need to be designed and implemented to minimize the potential for disturbing or compacting soils, destroying organic litter, removing large downed wood, or otherwise reducing the effectiveness of riparian buffers as sediment filters (Spence and others 1996).

Floodplain vegetation provides resistance to surface erosion on the flood prone area surface, and greatly aids in bank stabilization. Roots of vegetation help to develop soil structure, stabilize stream banks by binding soil in place, and provide resistance to erosive forces of flowing waters (Beschta 1991). Root-stabilized banks may facilitate bank building during high flow events by slowing stream velocities, which in turn helps to filter sediment and debris from suspension (Swanston 1991; Spence and others 1996). Most root strength at streambanks is from vegetation growing near the channel. Buffer widths for protecting other riparian functions (e.g., large wood recruitment, shading) are likely adequate to maintain bank stability, provided that trees near the channel edge are not cut.

In addition, floodplain vegetation may provide hydraulic roughness that may reduce the potential for significant changes in channel morphology, such as possible large-scale channel migration or channel avulsion (Ligon and others 1999). Channel avulsion is a rapid channel shift during flood flows from a main channel into side channels (Figure 8). An example of recent channel avulsion in a forested watershed is provided by Weiland and Schwab (1996) for the Copper River in British Columbia.

While vegetation immediately adjacent to a stream channel is most important in maintaining bank integrity (FEMAT 1993), in floodplains with actively shifting stream channels or floodplains adjacent to streams with a high potential for channel avulsion, vegetation throughout the floodplain is important for bank stability over longer periods of time. In the case of avulsion, channel migration is sudden and can occur anywhere within the channel migration zone (CMZ). Consequently, riparian forest conditions across the floodplain must be maintained to guarantee that large wood will be available for recruitment wherever the new channels form.

Biological Processes and Functions of Flood Prone Areas

Floodplains are very important in providing habitat for riparian-dependent species (Ligon and others 1999). Flood prone areas are zones of very high biological diversity, having the highest biodiversity for both terrestrial and aquatic species of any part of the landscape at the watershed scale (Naiman and others 1998). In light of this high biodiversity, the California Forest Practice Rules require that native aquatic and riparian-associated species and the beneficial functions of riparian zones must be maintained

Figure 8. Example of channel avulsion on Alder Creek in western Mendocino County. Channel avulsed due to a debris jam that occurred in 1995. Photo provided by Dr. Matt Kondolf, UC Berkeley.

where they are in good condition, protected where they are threatened, and restored where they are impaired (in so far as is feasible) [14 CCR § 916(a)].

Aquatic Habitat-Related Functions

An important biological function of flood prone areas is providing secondary or overflow channel areas for anadromous fishes (Figure 9). These areas are habitat units located away from the main channel (Rasmussen 1999). Overflow channels and backwater, isolated, or alcove pools are important as refugia areas for juvenile coho salmon during strong winter storm events (Bell 2001, Ligon and others 1999, Welsh and others 2000, Bock and others 2004). Streams with increased secondary channels, dammed/beaver pools, and backwater habitat (along with other beneficial variables such as high amounts of gravel, wood) have been found to be more productive for juvenile salmonids. Therefore, it is important to recognize and protect secondary channels and other slow-water refugia areas found on flood prone surfaces.

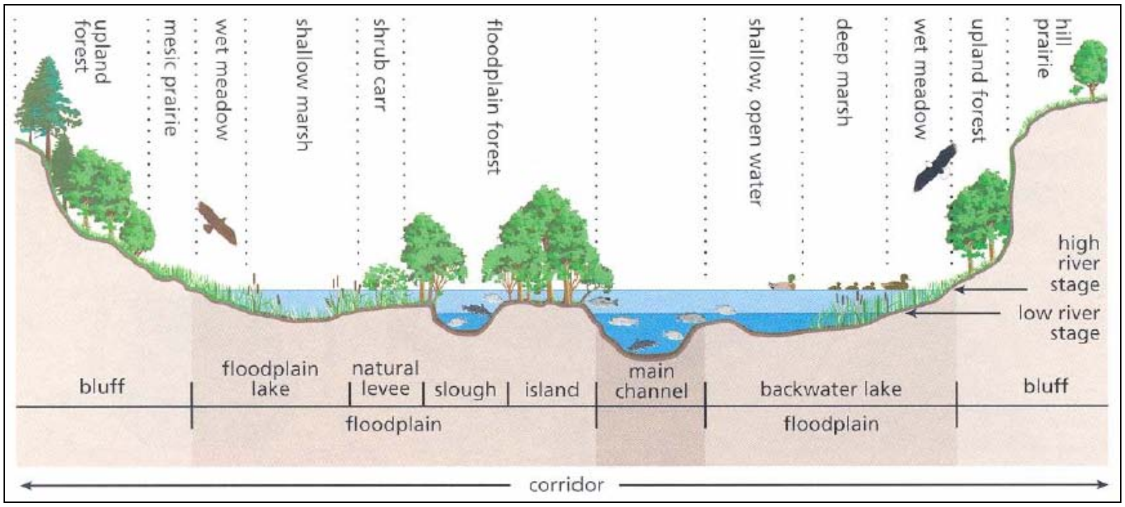


Figure 9. Example of a channel cross section with overflow channels commonly present on a flood prone area [Figure 1.11 in Stream Corridor Restoration, FISRWG (1998); used with permission].

In the North and Central Coast regions of California, flood prone areas function to provide much needed large wood to watercourses. Reduced large wood recruitment and active removal of large wood through historic logging and stream clearance efforts have left most streams in the coast redwood region depleted of large wood that is essential in creating pool and off-channel habitats, retaining sediments and organic materials, creating hydraulic and physical complexity, and providing overhead cover for salmonids (Ligon and others 1999) (Figure 10). Input mechanisms for large wood recruitment to stream channels varies depending on the location in the watershed. For steep, headwater channels, landsliding and windthrow are often the dominant input mechanisms (May and Gresswell 2003, Reid and Hilton 1998). May and Gresswell (2003) reported that windthrow was the dominant recruitment process for wood derived from local hillslopes and riparian areas along a third-order alluvial stream in the

Figure 10. North Fork of the Gualala River showing very low existing large wood loading. CDF file photo.

southern Oregon Coast Range. For larger, lower gradient channels with floodplains, bank erosion and mortality are more important input mechanisms, as well as streamside landsliding in some watersheds (Benda and others 2002, Benda and Associates 2004a,b) (Figure 11). Additionally, flotation[3] and logging-related anthropogenic input are often responsible for significant portions of the current wood loading in larger channels (Lassettre and Harris 2001, Benda and Associates 2004a). Channel stability is a critical factor in considering the appropriate zone for large wood recruitment in flood prone areas. Laterally stable channel systems that have not changed positions in many decades to centuries can reasonably be expected to have the majority of wood recruited from bank erosion near the existing channel edge. In contrast, if a flood prone area has an active channel migration zone, commonly applied buffer widths beginning near the channel edge for long-term wood recruitment are likely to be inappropriate, since the active channel will move through the floodplain over time.

Figure 11. Navarro River showing recent bank erosion on the floodplain. DFG file photo.

Additionally, floodplains supply and store large wood (Ligon and others 1999). As an example, Ligon and others (1999) state that in Prairie Creek, an old-growth redwood reference watershed located in Humboldt County, the channel can migrate over individual large wood pieces, and back again, given the low decomposition rate of submerged redwood (Figure 12).

[3] Flotation, or the transport of wood during elevated streamflows, is common in larger streams and is an important large wood recruitment mechanism in reaches that have relatively low input of trees from the adjacent riparian forest (Keller and Swanson 1979).

Figure 12. Prairie Creek channel in Humboldt County. Example of an undisturbed old-growth redwood system. Photo from Thomas Dunklin, Arcata, CA (used with permission).

A critical function of floodplain vegetation is to provide shading of watercourses, reducing stream temperatures related to heating from direct solar radiation. Riparian vegetation regulates stream temperature by providing shade that reduces direct solar heating. This is especially important in smaller streams (Murphy 1995). Factors that affect stream shading include stream orientation, stream size, local topography, tree size, tree species, stand age, and stand density (Murphy 1995). These factors influence how much incident solar radiation reaches the forest canopy and what fraction passes through to the water surface. Timber harvesting adjacent to streams can lead to increases in daily maximum stream water temperatures largely due to the increased exposure of the stream surface to direct solar radiation. Buffer strips along Class I and II watercourse channels are to be designed to prevent exposure of the stream channel to direct solar radiation.

Another important function of floodplain vegetation is to moderate riparian microclimate conditions in flood prone areas (air temperature, relative humidity, soil temperature, soil moisture, etc.). Insufficient stream buffers have been reported to allow air temperatures to increase and relative humidities to decrease over undisturbed conditions in riparian zones, with potential adverse impacts on terrestrial riparian flora and fauna (Ledwith 1996).

Floodplain vegetation inputs fine organic matter and insects into stream channels, an important food source for aquatic organisms. Smaller pieces of organic litter (leaves, needles, branches, tree tops, and other wood) enter the stream primarily by direct leaf or debris fall, although organic material may also enter the stream channel by overland flow of water, mass soil movements, or shifting of stream channels in unconstrained reaches. In most cases buffers designed to provide adequate large wood recruitment and shading will likely provide adequate input of small organic litter and insects as well.

Floodplain vegetation meters naturally occurring nutrients transported from hillslopes to stream channels (Spence and others 1996). Riparian vegetation takes up nutrients and other dissolved materials as they are transported through the riparian zone by surface or near-surface water movement. However, the relationship between buffer width and filtering capacity is less well understood than other riparian functions. Buffer widths for nutrient and pollution control should be tailored to specific site conditions, including slope, degree of soil compaction, vegetation characteristics, and intensity of land use. In many instances, buffer widths designed to protect other floodplain functions such as large wood recruitment and shading may be adequate to prevent excessive nutrient or pollution concentrations (Spence and others 1996).

Additionally, floodplains have a hyporheic zone or area below the channel and floodplain where surface and ground water mix. Hyporheic zones link aquatic and terrestrial systems and serve as transition areas between surface water and groundwater systems. The hyporheic zone contains species common to both surface and subsurface systems, including a diverse community of invertebrates. Maintenance of the hydrologic exchange between streams and hyporheic zones keeps surface water in close contact with chemically reactive mineral coatings and microbial colonies in the subsurface, which has the effect of enhancing the biogeochemical reactions that influence downstream water quality (Harvey and Wagner 2000).

Terrestrial Wildlife-Related Functions

The functionality of flood prone areas to wildlife reflects three attributes: the presence of water, local microclimatic conditions, and the more diverse plant assemblages found in these areas compared to surrounding uplands. These attributes are derived from the dynamic nature of riparian zones, which typically leads to a mosaic of plant assemblages in different stages of ecological succession (Spence and others 1996).

Although floodplain ecosystems, and more broadly riparian forests, typically occupy a small proportion of the landscape, they contain important habitats and species that are not present in the drier uplands. They also have high value as travel corridors, nesting sites, and feeding areas. Riparian forests can provide a landmark for visual cue of wildlife during migration, provide refuge from upland disturbance and high temperatures, and provide a source of woody debris for wildlife habitat (USFS 2004).

FEMAT (1993) documented the importance of riparian areas for different types of wildlife. Dependence of a majority of species on riparian zones has been demonstrated for all major vertebrate classes. For example, 8 of 11 species of amphibians and 5 of 6 species of reptiles in Oregon either reside or breed in aquatic or riparian habitats. In northern California, approximately 50% of both reptiles and amphibians prefer riparian or aquatic habitats. About two-thirds of native large mammals in the Pacific Northwest either depend on riparian areas or are more abundant in riparian areas than in surrounding uplands. Similar preferences for riparian habitat by small mammals, and especially bats, have also been documented. Roughly half of the species of birds in Oregon depend on or exhibit preferences for riparian habitats (Spence and others 1996).

IV. Considerations for Timber Operations on Flood Prone Areas

In this section of the report, we outline three steps that should be utilized when completing a field examination per 14 CCR § 916.4(a)(1) to analyze potential impacts associated with the biological, physical and hydrological functions found on flood prone areas proposed for management. 14 CCR § 916.4(a)(1) currently requires an RPF to evaluate areas near and areas with the potential to directly impact watercourses and lakes for sensitive conditions, including changeable channels, overflow channels, flood prone areas, and riparian zones. **Therefore, we are providing suggested approaches for using the existing California Forest Practice Rules to address potential impacts within flood prone areas**. The functions listed in Table 1 can be used in evaluating potential impacts.

Step 1. Inventory of Flood Prone Area Functions

Inventory/evaluate the flood prone area within the proposed plan and consider the hydrologic, geomorphic, and biologic functions listed in Table 1 that might be affected by the proposed timber operations (i.e., possibly producing significant adverse impacts). Conduct a detailed field examination based on the proposed level of activity, using suitable protocols and involving personnel with appropriate education and experience. Document (possibly including photographs) the floodplain functions present.

Step 2. Determine Frequency of Inundation Category

Identify the category for frequency of inundation of the flood prone surface proposed for management (i.e., very frequent, frequent, moderately frequent, or infrequent) [see Section II]. This can be established by a combination of short-term and long-term field observations, local contacts, published and unpublished reports, and possibly a flood frequency analysis using existing USGS gaging station information. **The frequency of overtopping flows is very important in determining floodplain sensitivity to timber operations.** One approach for determining the “activity” of a floodplain is to compare the environmental characteristics of the site to the numerous physical and biological characteristics of floodplains described in the literature (Benda 2004). These characteristics include:

- Evidence of periodic flooding/disturbance by flooding
- Recent sediment deposition
- Natural river levees
- Diverse fluvial landforms and substrates
- Wetlands and bogs
- Close proximity to the groundwater table
- Evidence of channel migration
- Oxbow lakes (Figure 13)
- Multiple channels, side channels, and backwater alcoves
- Hydric vegetation (e.g., scouring rush, horsetail, hedge-nettle, cattail, bulrush, sedge, willows)
- High plant and animal diversity
- High plant productivity
- Large tree age diversity due to flooding (e.g., red alders, big-leaf maples, willows)
- Islands of conifers within stands of deciduous forests
- Log jams and beaver dams

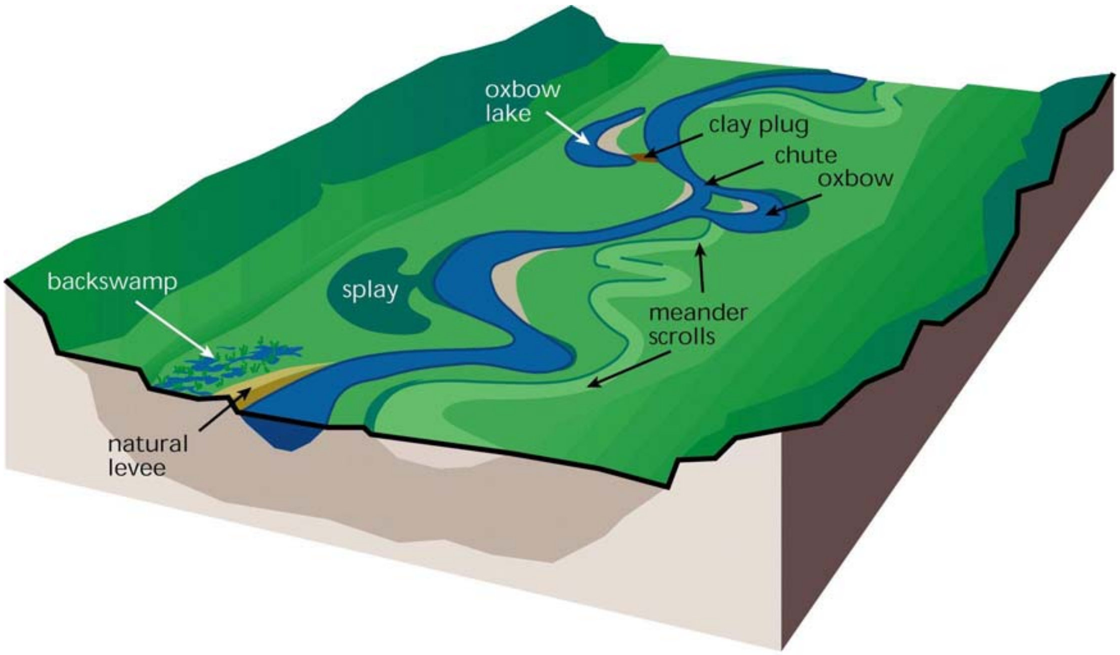


Figure 13. Diagram showing the formation of an oxbow lake on a floodplain [Figure 1.21 in Stream Corridor Restoration, FISRWG (1998)].

Step 3. Conduct an Appropriate Analysis

Conduct an appropriate analysis to protect and maintain the disclosed flood prone area functions and to evaluate them in light of possible significant adverse impacts from management on the flood prone surface. In general, it is important to note that:

- **Disclosure and analysis requirements increase with increased risk associated with the proposed level of activity in the flood prone area.** For example, if no activities are proposed within the 20-year recurrence interval flood prone area, the analysis required will be vastly different than if intensive management is proposed within this zone.

- **The detail of disclosure and analysis increases with the frequency of inundation of the floodplain surface.** For example, the outer extent of a 100-year flood prone area is likely to be less sensitive to timber operations compared to the portion of floodplain that is overtopped every 2 to 5 years.

- **Concern and risk tolerance may vary geographically due to the increased potential for species range constriction in areas near known range limits.** For example, impacts to coho salmon near their southern range limit may illicit greater concern than similar impacts to northern populations.

As stated above, 14 CCR § 916.4(a)(1) already requires the RPF to evaluate areas near and areas with the potential to directly impact watercourses and lakes for sensitive conditions, including changeable channels, overflow channels, flood prone areas, and riparian zones. ***In the past, this Forest Practice Rule has been misunderstood and inconsistently applied, which is partially responsible for agency disagreements regarding the adequacy of proposed flood prone area protection measures.***

If management is proposed within the approximate 20-year return interval floodplain in a watershed with anadromous fish habitat (particularly coho salmon habitat or habitat restorable for coho salmon), we outline below possible approaches that may be used for analyzing potential impacts for the various floodplain functions previously discussed in Section III.

Hydrologic Functions and Processes

Limited harvesting in a Class I WLPZ associated with a flood prone area alone should not affect flood frequency and magnitude. In general, substantial harvesting in small to moderately sized watersheds over short time periods is required to noticeably increase small to moderate recurrence interval peak flows associated with timber harvesting. For instance, clearcutting approximately 50 percent of the North Fork of Caspar Creek (484 ha or 1,195 acres) in seven years increased the two-year recurrence interval peak flow about nine percent (Ziemer 1998). Researchers have found that logging operations do not appear to substantially increase peak flows for infrequent floods (i.e., greater than 20-year recurrence interval), or in larger basins (Mount 1995; Beschta and others 2000). Forest practices have less influence on large floods because during these events, a much higher percentage of the watershed is involved in producing runoff when compared to that which occurs for smaller discharge events (Mount 1995). Additionally, stormflow response of large basins is governed primarily by the geomorphology of the channel network, which is unlikely to be affected by forest practices (Ziemer and Lisle 1998).

An important factor to analyze for hydrologic functions on floodplains is the degree of roughness that will remain following harvesting operations (Figure 14). In detailed studies, engineers and hydrologists use Manning's coefficient of roughness (n) to determine how water will flow in channels and over floodplains. The larger the size and density of large wood and vegetation, the larger the roughness coefficient (Kittredge 1948). Recent work has shown that LIDAR (acronym for LIght Detection And Ranging) and/or aerial photography can be used in this analysis (Smith and Priestnall 2005). Sellin and others (2003) review several methods for predicting vegetative resistance to flow. This level of assessment is beyond the scope of that expected for most timber harvesting operations. **A reasoned professional judgment on the degree of vegetative roughness reduction that will be present following timber operations, and how that will change over the next five years will often be sufficient for plan preparation.**

Where a more detailed approach is needed, Arcement and Schneider (undated) provide excellent guidance on selecting roughness coefficients for floodplains. This USGS

Figure 14. Example of post-harvest vegetative roughness remaining in a floodplain following harvest in the Big River watershed showing the post-harvest Class I WLPZ and area harvested beyond the WLPZ. CDF file photo.

document includes numerous photographs illustrating roughness values for floodplains with differing levels of vegetation. The range is from 0.10 to 0.20, depending on tree size and density. In addition, they state that where trees are the major factor affecting floodplain roughness, the roughness coefficient can be calculated following the completion of a field survey by measuring the number of trees and trunk sizes in a representative sample area. A sampling area 30 m (~100 ft) along the cross-section by 15 m (~50 ft) in the flow direction is adequate to determine the vegetation density of an area when the sample area is representative of the floodplain. Every tree within 7.5 m (~25 ft) along either side of the 30 m (~100 ft) tape is counted. The position of the tree is plotted on a grid system by measuring the distance to each tree from the center line along the 30 m (~100 ft) tape, and the diameter of the tree is recorded on the grid system. The area occupied by trees in the sampling area can be computed from the number of trees, their diameter and location on the floodplain, and the depth of flow in the floodplain. An example is provided and a roughness coefficient of 0.13 was calculated. [see the following webpage for the USGS paper: http://www.fhwa.dot.gov/bridge/wsp2339.pdf]. If necessary, a pre and projected post-harvest roughness coefficient could be calculated for a given flood prone area surface. Primary consideration should be for preventing a large change in the roughness coefficient, not in maintaining an absolute value.

Geomorphic Functions and Processes

Geomorphic analysis may include, depending on the practices proposed, documentation of existing natural levees in place, the degree of vegetative roughness change anticipated, the degree of soil disturbance anticipated on the floodplain surface, the anticipated changes in bank stabilization, and the potential for channel avulsion. Vegetative roughness considerations are discussed above. The degree of soil disturbance anticipated can be analyzed by the percent of the flood prone surface to be exposed by skid trails, and how they will be treated following the completion of logging (Figure 15). Factors to be considered include whether skid trails will cause new overflow channels to be formed and whether the water table will be exposed. Tractor slash packing of skid trails and/or tractor layouts is an effective mitigation measure to reduce surface soil exposure and potential for sediment remobilization following harvesting.

Anticipated changes in bank stabilization can be addressed based on the amount of harvesting proposed in the most critical zone near the channel bank (Figure 16). This area is generally considered to be approximately one-half of the diameter of a tree crown (conservatively estimated to be the first 9.1 m (30 feet) landward from the channel edge for coast redwood), but site-specific conditions may require the zone to be extended inland.[4] If no harvesting is proposed in this zone, then it would be possible to conclude that little if any change in bank stability would be anticipated (particularly for a

Figure 15. Example of a proposed skid trail on a floodplain surface in the Gualala River watershed. Photo from the North Coast Regional Water Quality Control Board.

[4] In a comprehensive review of FEMAT (1993) recommendations, CH_2M-Hill and Western Watershed Analysts (1999) reported that buffer distance to maintain the effectiveness of root strength for bank stability probably does not extend beyond 10-15 m (30-50 feet) (Newton 1993; Newton and others 1996), or one-half a tree crown diameter (Wu 1986). FEMAT (1993) suggests that the role of roots in maintaining streambank stability is negligible at distances of greater than one-half of a site-potential tree height. In their review of the FEMAT report, however, CH_2M-Hill and Western Watershed Analysts (1999) could not locate literature to support the ½ site potential tree estimate. Crown diameters for coast redwood can be estimated with the following equation: largest crown width (LCW) = 12.0128 + 0.4576(D), where D = dbh (in.). For example, a 36 in dbh redwood is estimated to have a LCW of ~29 ft, 70 in dbh = ~44 ft, and 100 in dbh = ~ 58 ft (Bechtold 2004). Therefore, one-half crown diameter for second-growth redwood is expected to be 30 feet or less.

Figure 16 Example of proposed timber harvest within 30 feet of the channel edge on a in the Gualala River floodplain. Photo from NOAA Fisheries.

laterally stable channel network). **The 14 CCR § 916.4(a)(1) write-up should clearly document how much harvesting is proposed within one-half of the diameter of a tree crown distance from the edge of the streambank.**

Channel migration by avulsion occurs in response to reductions in channel capacity (typically due to sediment deposition and/or large wood) that forces the streamflow out of the existing channel. The potential for avulsion is higher in relatively unconfined channels with good floodplain connectivity where the elevation of the active stream channel is similar to that of the adjacent flood prone area. The difference in elevation of the floodplain surface and the stream channel can be determined, if necessary, with a cross sectional survey using an engineer's level, tape, and Philadelphia rod. Additionally, the roughness effects of existing and post-harvest vegetation must be considered in a channel avulsion assessment (Spittler 2004). Weiland and Schwab (1996) provide an example of channel avulsion in British Columbia.

Biological Functions and Processes

Overflow channels

As discussed in Section III, floodplains are commonly the site of overflow channels and provide winter refuge habitat for juvenile anadromous salmonids during high flows (Ligon and others 1999). Water velocities are much slower in overflow channels on floodplains, providing highly valuable refugia during strong winter storms. When fish are present, even if infrequently, overflow channels can be Class I watercourses and Class I watercourse protection measures may be required. Additionally, in some circumstances, the channel zone may be required to extend to the outside edge of the overflow channel. **If ground-based harvesting is proposed within flood prone areas and the inventory of floodplain functions (Step 1) indicates that these features are present, the plan proponent must consider the need for mitigation measures to protect these features.** In particular, it is critical to show that harvesting operations are designed to avoid overflow channels and there will not be skid trail crossings. If this is not possible, then there must be assurance provided in the plan that these channels will be properly restored following timber operations. Adequate protection of channel bed and banks is crucial.

Large Wood Recruitment

Large wood recruitment to stream channels is one of the most important functions of flood prone areas. Many factors must be considered with proposing harvesting in flood prone areas in relation to large wood recruitment. **If the channel system is not laterally stable and the channel is actively moving through the floodplain, or can reasonably be expected to in the next few decades, and/or experiencing active bank erosion (Figure 17), a set WLPZ distance for large wood recruitment such as 150 feet is likely to be unacceptable.** In contrast, if the channel is somewhat incised with relatively stable banks (and may reasonably be expected to remain incised for many decades), producing a laterally stable channel configuration that can be documented by viewing sets of aerial photographs over several decades (Figure 18), then it can reasonably be expected that large wood recruitment will occur within a defined band along the channel edge. In other words, the rate of channel migration needs to be assessed, and appropriate protection measures included in a plan based on this rate of movement.

Figure 17. Example of large wood recruitment from bank erosion in western Mendocino County, Navarro River watershed. The flood event causing this bank erosion was estimated to have a 5-year return interval. DFG file photo.

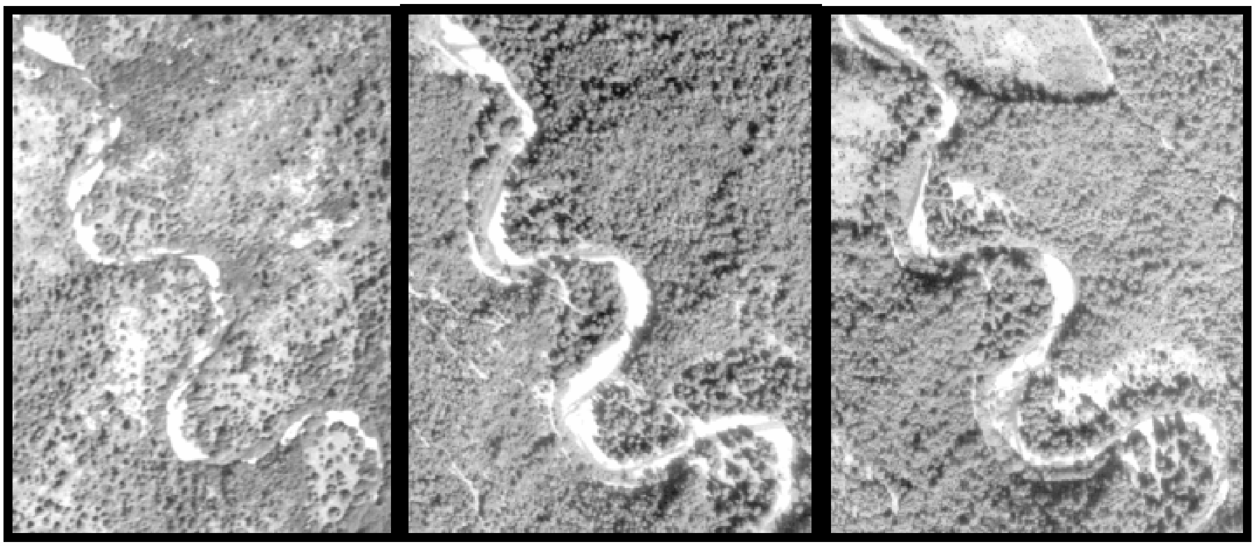


Figure 18. Example of high channel stability exhibited over six decades along the North Fork of the Gualala River. Graphic provided by Tom Spittler, CGS, produced for THP 1-04-032 MEN (Spittler 2004).

Many studies support the contention that most large wood is recruited from within 20 m (66 ft) to 40 m (130 ft) of laterally stable channel banks, but wood recruitment source-distance curves are highly related to input (or recruitment) process (Naiman and others 2000, Benda and others 2003, Benda and Associates 2004a). For example, Benda and others (2002) reported that in the absence of landsliding, wood recruitment in both old-growth and second-growth Humboldt County study sites originated from within 20 to 40 m of the stream. The field sites that had significant recruitment from bank erosion had approximately 90 percent of wood originating from within 10 m (~33 ft) of the bank (Figure 17). Landsliding caused recruitment distances to extend to over 60 m (~200 ft), but landslide recruitment tended to be highest in small channels. For second-growth redwood forests, Benda (2003) reported that in non-landslide areas, 90% of wood originates from 45 feet, while in landslide areas, 90% of wood can originate from 200 feet.

If significant harvesting is proposed in a flood prone area, as stated above, the level of required analysis will significantly increase. For addressing large wood recruitment, possible approaches may include:

- Conducting an aerial photograph survey spanning several decades by a qualified analyst to determine channel mobility/presence of a channel migration zone (WFPB 2001, 2004). If a CMZ is present, modification of floodplain management is appropriate.[5]

[5] For example, O'Connor (1998) used historical aerial photographs spanning 30 to 40 years to evaluate potential channel migration zones in western Mendocino County. He reported that a history of significant channel migration existed only in lower Usal Creek. Where evidence of channel migration was found for

- o Conducting a stream bank survey to determine active channel erosion throughout the assessment area. If active streambank erosion is present, modification of floodplain management is appropriate.

- o Conducting a rapid survey of dominant wood input mechanisms (i.e., bank erosion, windthrow, flotation, logging-related, mass wasting, etc.). Large wood recruitment zone strategies should be developed based on the dominant input mechanisms present.

- o Providing data on how the large trees (e.g., over 36 inches dbh) in the 20-year recurrence interval flood prone area for higher order watersheds are going to be managed over a 40 year or longer planning period. Smaller diameters trees (e.g., <36 inches dbh) will likely be acceptable for smaller watersheds with narrower channels.

- o Conducting rapid plan-specific instream large wood surveys to determine appropriate retention standards prior to designing WLPZ prescriptions. If instream wood loads are low or very low, WLPZ silviculture should be designed to promote growth on the larger diameter trees while improving large wood recruitment potential (see Section V of this report).

- o Assessing the potential of placing large wood into the Class I channel (Figure 19). Where assessments indicate that large wood levels are low and instream placement is feasible, consider placement of unanchored logs and/or rootwads in streams (permits from state and federal agencies are required). Logs should exceed one bank-full width in length.

- o Providing data on permanent or long-term retention of large trees (>36 inch dbh for higher order watersheds) most likely to be recruited to the stream channel.

Determining trees that are most likely to be recruited to the channel may be relatively easy. For example, large, old trees located near the channel bank that are leaning towards the channel, on unstable areas, or on areas immediately downslope of unstable areas are much more likely to be recruited than those located more than 100 feet from the channel edge (GDR 2002) (Figure 20).[6] The trees that are more likely to be recruited are preferable to be retained, and the 10 largest dbh conifers per 330 feet of stream channel length within 50 feet of the watercourse transition line (WTL) must be retained for wood recruitment, as specified in the Threatened and Impaired Watersheds Rule Package [14 CCR § 916.9 (i)].

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the Big, Noyo, and North and South Forks of Ten Mile Rivers, it was almost exclusively caused by bank erosion. O'Connor (1998) concluded that there was a very low likelihood of channel migration events that would cause a channel to migrate beyond proposed riparian management zones. In Humboldt County, O'Connor and PWA (2001) reported that Freshwater Creek has not experienced major changes in channel location and planform geometry since the 1940s, while Bear, Jordan, and Cuneo Creeks show major changes in planimetric channel form over the period of record.

[6] Edges created by adjacent clearcuts or other forest openings may also result in a greater opportunity for recruitment of trees due to windthrow.

Figure 19. Placement of large wood in the Little North Fork of the Gualala River. Photo provided by Henry Alden, Gualala Redwoods, Inc.

Figure 20. Example of a tree with a high potential for large wood recruitment to a watercourse channel with a floodplain (Douglas-fir located on the edge of a bank in the floodplain next to the South Branch of the North Fork Navarro River). DFG file photo.

Considerable debate exists regarding appropriate coast redwood silviculture in highly productive floodplain areas.[7] Much of this discussion has centered on future large wood recruitment. Ligon and others (1999) state that while the simplest way to increase large wood loading is to establish a wide no-cut riparian buffer strip, it may not always be appropriate. They report that since many riparian zones (broader than flood prone areas) are currently stocked with smaller diameter young-growth, hardwoods, and shrubs, "most riparian areas need some type of active management to promote regrowh of large conifers that historically occurred in these areas."[8] A detailed discussion on possible management approaches and modeling results for varying silvicultural systems is provided in Section V of this report.

Stream Shading

Many of the discussion points presented above for large wood recruitment apply for stream shading as well. For example, if an active channel migration zone exists or active channel bank erosion is occurring, leaving a narrow strip of dominant and co-dominant trees will be ineffective in shading the channel in the foreseeable future. In contrast, if the channel is laterally stable and exhibits little active bank erosion, a more normally defined WLPZ with a set distance may be appropriate. In either case, the required shade producing trees should remain in place for at least the first 100 feet to 125 feet from the channel edge, based on results from past research studies.[9]

For example, Beschta and others (1987) and Murphy (1995) state that buffer strips with widths of 30 m (approximately 100 feet) or more generally provide the same level of shading as that of an old-growth Douglas-fir stand. FEMAT (1993) stated that full shading can be maintained by buffer widths equal to one site potential tree height (i.e., the potential height of a mature tree at a particular location). In a comprehensive review of the FEMAT (1993) standards, however, CH_2M-Hill and Western Watershed Analysts (1999) reported that data in the literature show that the relationship between shading and distance from the stream channel is considerably more curve linear than that provided in the FEMAT (1993) report. As an example, the recommended curves in their diagram show that nearly 80 percent of the cumulative riparian shade effectiveness is reached within approximately 0.5 site-potential tree heights (Figure 21). For a 250 foot coast redwood site potential tree, this distance would be 125 feet.

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[7] Site Class IA for coast redwood is capable of growing a 150 foot tall tree in 50 years or a 222 foot tall tree in 100 years (Krumland and Eng 2005).

[8] Russell (2002) found that the basal area of red alder was correlated negatively to "years since harvest" and "buffer width", indicating that past timber harvesting in coast redwood riparian forests has favored hardwood species.

[9] The Washington Forest Practices Board Manual (2000) suggests methods for determination of adequate shade requirements on streams. For example, it specifies that when a harvest unit is within bull trout habitat in the eastern part of the state, all available shade must be retained within 75 feet of the bankfull width or the CMZ, whichever is greater. All available shade would be equivalent to the existing pre-harvest canopy closure, which is measured with a spherical densiometer.

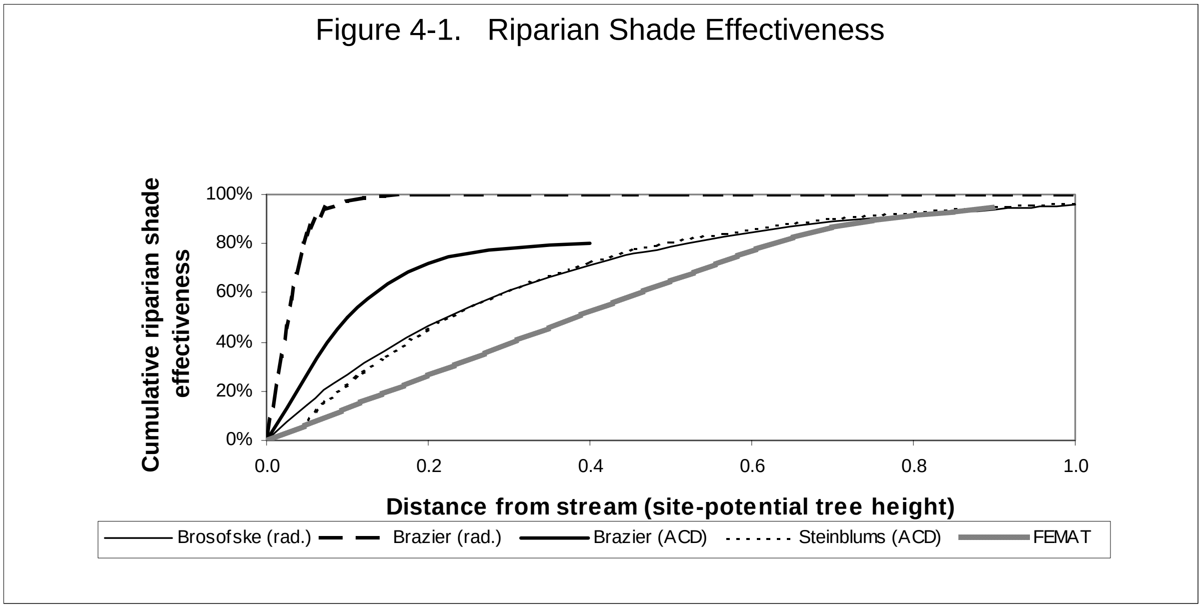

Figure 21. Riparian shade effectiveness curves (CH_2M-Hill and Western Watershed Analysts 1999). The Brososke (1997) and Steinblums and others (1984) curves were recommended.

A more detailed analysis of stream shading will be triggered when there is evidence that potentially significant shade-producing trees may be proposed to be harvested, particularly in 303(d) listed watersheds with impaired conditions related to water temperature. Tools such as the Solar Pathfinder can be used to document pre and post-harvest blockage of solar radiation (often referred to as shading) [Figure 22]. This device can be used to determine the percentage of solar radiation blocked by both vegetation and topography (Amaranthus 1983, Platts and others 1987, Cafferata 1990a). Additionally, angular canopy density (ACD) can be estimated with the Pathfinder to determine how shade varies along this stream reach. ACD provides a direct estimate of shading effects of streamside vegetation (Beschta and others 1987) and has been defined as that portion of the canopy actually providing shade to the stream during the critical summer season midday hours. It can be approximated as the portion of the sky occupied by canopy along the sun’s path from 10:00 a.m. to 2:00 p.m. for July and August (Beschta and others 1987, Teti 2001).

While the Solar Pathfinder displays an image of the overhead canopy on a spherical, plastic dome that covers the top of the instrument, it does not provide a very large viewing area for actually delineating which exact trees are shading the watercourse and does not allow individual trees to be easily separated in a dense, forested canopy. Therefore, it is desirable to have a device with a larger mirror (8 to 12 inches). Brown (1980) provides an alternative procedure for determining critical trees actually shading streams. The portion of the canopy providing shade to the stream during the critical midday hours can be determined by standing in the channel, using a clinometer and sighting directly to the south along the zenith angle of the sun during the critical period.

Figure 22. Solar Pathfinder set up in a stream channel in the Gualala River watershed. The angular canopy density (ACD) was recorded at this site as greater than 90 percent. CDF file photo.

Trees whose canopy is seen can be identified for inclusion in the buffer strip, since they have the ability to cast a shadow across the water during the critical summer period.[10]

If extensive harvest is proposed in a watershed that is known to have significantly elevated summer water temperatures (beyond the range acceptable for anadromous fish life cycles), other techniques besides documentation of existing shading and anticipated post-harvest shading will likely be required. For example, the Heat Source computer model (Boyd 1996, Boyd and Kasper 2004) can be used to model stream and river water temperature via dynamic heat and mass transfer. While not easy to utilize, this method has been found to be a good tool for predicting changes in water temperatures associated with harvesting at the watershed scale (James 2003, WWA 2001, Schult and McGreer 2004). Brown's modified water temperature prediction equation can be utilized much more simply for short segments of stream channel and known (or anticipated) changes in solar shading. Validation of this simple model has occurred in several California watersheds (McGurk 1989, James 2003, Cafferata 1990b).

Microclimate Regulation

Past research has shown that streamside vegetation can have a significant influence on local microclimate parameters near a stream channel (FEMAT 1993, Spence and others 1996). FEMAT (1993) presented generalized curves relating protection of microclimatic

[10] Both the Solar Pathfinder for ACD and the clinometer methods are documented for THP 1-00-484 SON in Cafferata 2003.

variables relative to distance from stand edges into forests showing widely varying distances depending on the specific microclimate variable being considered (Figure 23).

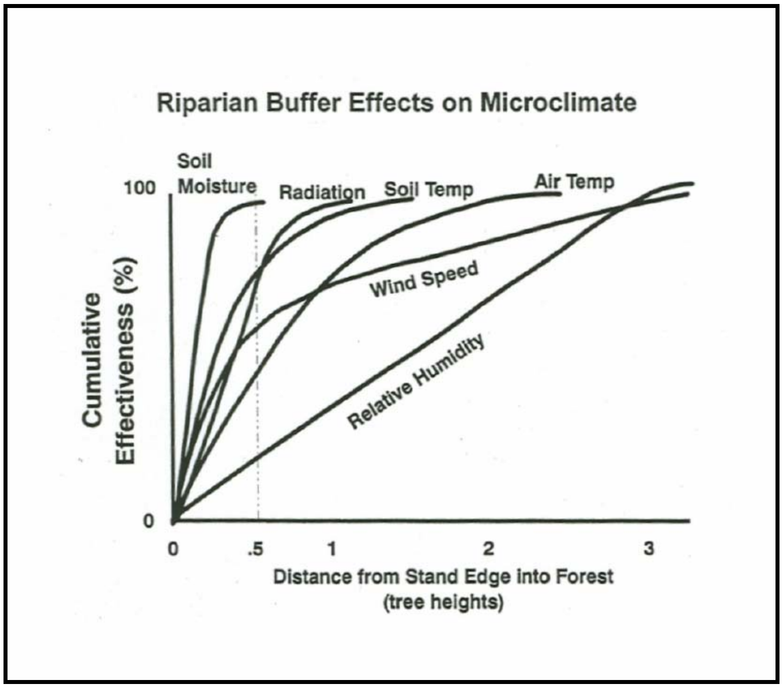

Figure 23. Riparian buffer effects on various microclimate parameters, as defined by FEMAT (1993).

These curves suggest that buffers need to be extended one to two tree heights to maintain natural levels of solar radiation and soil temperature within the riparian zone and even larger buffers (up to three tree heights) to maintain natural air temperature, wind speeds, and humidity. Individual studies have generally reported shorter required distances. Brosofske and others (1997), for instance, concluded that a buffer at least 45 m (~150 ft) on each side of the stream is necessary to maintain a natural riparian microclimatic environment along streams in western Washington. Their study site was characterized by moderate to steep slopes, 70–80% overstory coverage (predominantly Douglas-fir and western hemlock), and clearcut silviculture.

Ledwith (1996) studied air temperatures and relative humidities in riparian zones at two sites that had been clearcut with buffers in the Six Rivers National Forest. Air temperatures above the stream increased exponentially with decreasing buffer width, with a 6.5° C increase in mean air temperature along the riparian zone between the 150 m (~500 ft) and 0 m buffer width sites. Ledwith (1996) concluded that buffer strips wider than 30 m (~100 ft) will still affect microclimate in the riparian zone, but at a lower rate of change than narrower zones (e.g., 1° C or 2° C), and that buffer strips at least 30 m (~100 ft) wide are necessary to avoid significant impact to riparian environments.

None of these studies, however, were conducted along larger river systems with extensive floodplains. The riparian buffer effects on microclimate reported in FEMAT (1993) were derived from upland forest data. The interim buffer widths proposed under

FEMAT (1993) exceed the minimum recommended by most studies, but were intended to provide a high degree of protection pending more detailed watershed analysis and site-specific design (Ledwith 1996). CH_2M-Hill and Western Watershed Analysts (1999) state that the FEMAT (1993) microclimate curves represent the maximum possible riparian zone effects shown by previously collected upland forest data from the Pacific Northwest.

Input of Organic Matter

Riparian vegetation provides significant amounts of organic litter to stream channels, and this material is an important food source for aquatic organisms (Spence and others 1996). FEMAT (1993) reported that most organic material that reaches the channel comes from within 0.5 tree heights from the channel edge. CH_2M-Hill and Western Watershed Analysts (1999) state that the reports by Newton and others (1996) and Rhoades and Binkley (1992) suggest that the FEMAT litterfall relationship over emphasized the contribution of litter from trees more than 0.2 site-potential tree height from the channel and underestimates contributions from trees within 0.2 site-potential tree height. In either case, providing adequate watercourse protection zones for the other riparian functions should allow for acceptable levels of organic matter input.

Wildlife Habitat

Overstory and understory vegetation on coast redwood flood prone area surfaces provides breeding, feeding, and shelter habitat for numerous species of wildlife (Welsh and others 2000) [Table 3]. Altering streamside vegetation in coast redwood forests can have consequences for both aquatic and terrestrial life forms (Russell 2002). When state or federally listed species are potentially present, adequate field surveys are required by qualified specialists or trained staff. Development of late-seral forest conditions is a generally accepted approach for protecting/restoring acceptable wildlife conditions on flood prone surfaces. Second-growth stands in these areas can be managed to promote their ecological succession to late-seral forest conditions, ensuring that terrestrial and aquatic resources and the ecological functions of the flood prone surface are protected and improved or restored. This can include retaining and enhancing the vertical structural diversity of these stands, and protecting riparian zone special habitat elements such as snags and large wood to improve habitat values (CDF 2001). Many of the management practices discussed above for stream shading, large wood recruitment, etc. are also appropriate for protecting/restoring wildlife habitat elements, particularly for amphibian species.

When a detailed analysis is merited for evaluating the potential impacts of proposed management in coast redwood flood prone areas, one approach is to use the California Wildlife Habitat Relationships (CWHR) software readily available to the public.[11] CWHR is the most extensive compilation of wildlife habitat information in California to date, and includes life history information, geographic distribution, legal status and habitat relationships for 675 regularly occurring birds, mammals, reptiles, and amphibians in California. The expected post-harvest quadratic mean diameter (QMD) distribution at

[11] See the following webpage: http://www.dfg.ca.gov/news/news02/02098.html

dbh is required to use the software.[12] An example of this approach is displayed in the Appendix for the four silvicultural alternatives (i.e., no harvest, conservative salvage, thin from below, and single tree selection) modeled with CRYPTOS in Section V of this paper. Habitat values for 212 species potentially found in "Montane Riparian and Redwood habitat" in Mendocino County are displayed for CWHR 6 verses 5D.

Table 3. Selected vertebrate species associated with aquatic ecosystems in the redwood region (Welsh and others 2000, Jones and Stokes 1997, CDF 2001).

Birds	**Amphibians**
Northern spotted owl *(Strix occidentalis caurina)*	Southern torrent salamander (*Rhyacotriton variegates)*
Osprey (*Pandion haliaetus)*	Coast giant salamander (*Dicamptodon tenebrosus)*
Bald eagle (*Haliaeetus leucocephalus)*	California giant salamander (*Dicamptodon ensatus)*
Belted kingfisher (*Ceryle alcyon)*	Northwestern salamander (*Ambystoma gracile)*
American dipper (*Cinclus mexicanus)*	Rough-skinned newt (*Taricha granulose)*
Great blue heron (*Ardea herodias)*	Red-bellied newt (*Taricha rivularis)*
Common merganser (*Mergus merganser)*	Northern red-legged frog *(Rana aurora aurora)*
Killdeer (*Charadrius vociferous)*	Tailed frog (*Ascaphus truei)*
Spotted sandpiper (*Actitis macularia)*	Foothill yellow-legged frog (*Rana boylii)*
Great egret (*Ardea albus)*	Pacific tree frog (*Hyla regilla)*
Cooper's hawk *(Accipiter cooperii)*	Western toad (*Bufo boreas)*
Sharp-shinned hawk *(Accipiter striatus)*	
Northern goshawk (*Accipiter gentiles)*	**Reptiles**
Vaux's swift (*Chaetura vauxi)*	Oregon aquatic garter snake (*Thamnophis atratus)*
Purple martin (*Progne subis)*	Northwestern pond turtle (*Clemmys marmorata)*
Olive-sided flycatcher (*Contopus cooperi)*	
	Fish
Mammals	Coho salmon (*Oncorhynchus kisutch*)
River otter (*Lutra canadensis)*	Chinook salmon (*Oncorhynchus tshawytscha*)
Mink (*Mustela vison)*	Steelhead/rainbow trout (*Oncorhynchus mykiss*)
Muskrat (*Ondatra zibethicus)*	Cutthroat trout (*Oncorhynchus clarki*)
Raccoon (*Procyon lotor)*	Pacific lamprey (*Lampetra tridentata*)
Black bear (*Ursus americanus)*	Threespine stickleback (*Gasterosteus aculeatus*)
California myotis (*Myotis californicus)*	Coastrange sculpin (*Cottus aleuticus*)
Little brown bat (*Myotis lucifugus)*	Klamath smallscale sucker (*Catostomus rimiculus*)
Long-legged bat (*Myotis volans)*	
Long-eared bat (*Myotis evotis)*	
Yuma myotis (*Myotis yumanensis)*	
Hoary bat (*Lasiurus cinereus)*	
Silver-haired bat (*Lasionycteris noctivagans)*	

[12] QMD is defined as the average diameter corresponding to the mean basal area.

V. Silvicultural Considerations within Flood Prone Areas

Historical harvesting of coast redwoods, including flood prone areas, has significantly altered stream ecosystems (Welsh and others 2000). Currently, silvicultural applications for harvesting coast redwood on flood prone areas on private ownerships is integrated into management plans for these landowners because of the high levels of stand productivity typical of these high site areas. As an example, exceptional growth has been documented on high site I timberland over 80 years on a Big River floodplain which has been denoted as the "Wonder Plot" (Allen and others 1996) [see cover photo]. Established in 1923 by Emanuel Fritz, this plot sets the standard for growth and yield in the redwood type (Figure 24). At 137 yrs, second-growth redwoods at the Wonder Plot had over 900 square feet of basal area/acre, illustrating the tremendous potential of redwood for timber production on these types of growing sites (Allen and others 1996).

Old-growth coast redwood has been found to reach its maximum size on alluvial floodplain flats, such as along Bull Creek in Humboldt Redwoods State Park in southern Humboldt County. This species is able to tolerate and thrive with periodic flooding and silt deposits by sending up vertically oriented roots into these sediments and then later sending out a horizontal root system right below the surface of the deposit (Stone 1965, Stone and Vasey 1968). Old-growth coast redwood trees can obtain remarkable size on alluvial floodplain flats partly due to the fact that competitors such as Douglas-fir, grand fir, tanoak, and California bay laurel cannot withstand a combination of flooding and fire (Stone and Vasey 1968). The late-seral redwood ecosystem has been described as one of the most stable on the planet (Welsh and others 2000). Alluvial flat redwoods eventually die from wind-throw, failure to maintain balance, extremely large floods (such as occurred in December 1955 and January 1956 in Bull Creek), and heart rot (Stone and Vasey 1968).

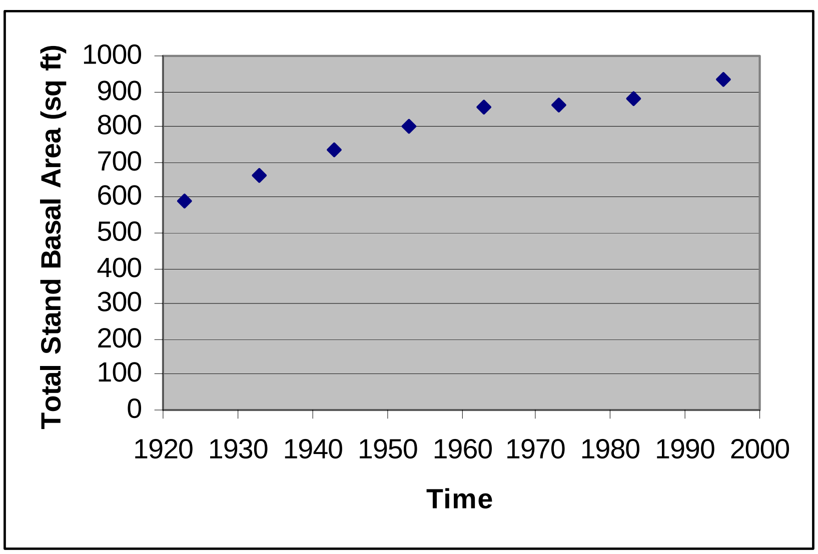

Figure 24. Wonder Plot total stand basal area over time (Allen and others 1996).

While harvesting of redwood trees on floodplain surfaces is allowed under the Forest Practice Rules, the question for timberland owners remains how much and what types of harvesting can occur, while providing for the protection and recovery of the watershed functions outlined in Section III of this report.

The California Forest Practice Rules allow for timber harvest on unconfined floodplain surfaces. There is debate, however, regarding where and whether use of any type of silvicultural system is appropriate for these areas, given the need to provide adequate protection and recovery for these coastal watershed systems. Recent reviews of forestry practices for California have stated that harvest on floodplains is inappropriate. For example, NOAA Fisheries (2000) state in their "Salmonid Guidelines for Forestry Practices in California" that: "If a flood prone zone is present, riparian zones are measured from its outer edge, so the stream and flood prone zone are protected together." Similarly, Ligon and others (1999) state that "A watercourse transition line should demarcate the Class I and II watercourse from the hillside by identifying the outer (landward) edge of the floodplain." These statements have largely led to the current agency debates on this topic and the need for this paper.

For the more broadly defined "riparian area," Ligon and others (1999) concluded that to grow and maintain larger diameter conifer trees, creating stands that contain elements found in late-successional stands, "it may be necessary to manage these zones through thinnings and selection harvests to promote the growth of the larger trees present that have the best opportunity to maximize diameter and height growth." They reported that … "thinning, if properly applied (while giving equal consideration to the other functions of the riparian zone), can increase tree growth in a manner that is compatible with the objectives of achieving properly functioning habitat conditions." They go on to state that "However, this must be combined with the near-term retention of larger diameter trees and treatment of the WLPZ to increase recolonization and regrowth by conifers. These combined efforts will provide the best opportunity to ensure long-term recruitment of LWD."

For proper watershed and aquatic functions, large coast redwood trees (both in diameter and height) are much preferred to smaller trees. Reasons for this are numerous. For example, taller trees provide more shade and larger diameter trees provide higher quality large wood in stream channels for pool formation, habitat complexity, cover, and sediment storage functions. Large redwood trees can be produced more quickly if they are provided with additional growing space (i.e., thinned). But if too few trees remain following thinning, shading, wildlife habitat, and others riparian functions will be adversely impacted. Clearly, if large trees are harvested with single tree selection in flood prone areas (Figure 25), it is imperative that they are to be removed from areas that do not adversely impact flood prone area functions.

When timber harvesting is proposed by an RPF on a floodplain surface, the silvicultural system that is often specified in plans is thinning from below, or low thinning—especially within the first 75 to 150 feet of the WTL (as defined by the current FPRs). Ligon and others (1999) defined low thinning as follows: *"This thinning involves the removal of the understory, mid-canopy, and very limited numbers of co-dominant trees. Co-dominant trees may be removed only to improve spacing and enhance growth. Dominant trees*

Figure 25. Example of proposed thinning operations on a highly productive redwood floodplain in the Gualala River watershed. CDF file photo.

may not be removed, and average stand diameter must increase following harvest." Thornburgh and others (2000) concluded that this system can work well for redwood and associated tree species. They state that trees with less than 30 percent live crown are thinned out, leaving redwoods with greater than 30 percent live crown more light and growing space. Additionally, they reported that: "Redwood trees respond by filling out their crowns with greater growth of branches and more needles on each branch; this creates a much greater photosynthetic surface with less respiration cost, thus increasing growth. Furthermore, most of the growth is in larger trees, which increases their economic value."

There are several studies in the literature that provide evidence that thinning redwood trees allows the remaining trees to grow more rapidly—with the more volume removed, the more accelerated growth experienced (Thornburg and others 2000). These studies, however, have not been conducted on floodplain surfaces. For example, Lindquist (2004a) reported that third-growth redwood stands thinned at age 19 had statistically larger average diameters than unthinned stands in the Caspar Creek watershed in western Mendocino County (Figures 26a, 26b, 26c, and 26d). Average stem diameters were 10.4, 14.1, 15.3, and 19.7 inches for the control, 300 trees/ac, 200 trees/ac, and 100 trees/ac plots, respectively.

Figures 26a, 26b, 26c, and 26d (**following page**). Photos displaying varying stocking levels in a 43-year old coast redwood stand in the Caspar Creek watershed (Lindquist 2004a) in western Mendocino County. Top left photo shows a control plot (unthinned), bottom left photo shows a plot with 300 trees/ac, top right photo shows 200 trees/ac, and bottom right photo shows 100 trees/ac. Thinning treatments with an unthinned control were initiated on a 19-year old third growth stand. Average stand diameter for trees >1.5" dbh in 1998 were 10.4, 14.1, 15.3, and 19.7 inches, respectively. Photos from Tim Robards, CDF.

The response of well-stocked second-growth coastal redwood stands to three levels of commercial thinning after 29 years of growth was recently summarized by Lindquist (2004b). Commercial thinning treatments left 25%, 50%, 75% and 100% (uncut control) of the original basal area (400 sq. ft.) in a 40-year old stand on the Jackson Demonstration State Forest. Marking of trees was done to favor healthy dominant and codominant redwoods, and was described as a thinning from below. Analysis of the periodic growth rate revealed strong statistical differences between the treatments in diameter growth, but no significant differences in the basal area or cubic and board foot volume growth. By 1999, the average diameters ranged from 14.2 inches in the control to 31.8 inches in the 25% retention treatment. Lindquist (2004b) concluded that intensive thinning from below is capable of producing larger diameter trees relatively quickly in stands at 40 year-of-age. The response of the understory regeneration was strongly affected by the density of the overstory canopy. A precommercial thinning study of the redwood sprouts at this study site showed a response only in the 25% overstory retention treatment. The relationship between understory growth and overstory density indicates that growth of redwood regeneration was inversely proportional to overstory canopy. In addition, thinning from below will promote the regeneration of more tolerant conifer tree species, such as western hemlock and grand fir, considerably less valuable commercially, as was documented by the Caspar Cutting Trials (Lindquist 1988).

Similarly, Jameson and others (2005) evaluated three older second-growth redwood stands harvested with the variable retention silvicultural system in western Mendocino County on Jackson Demonstration State Forest. A total of 12, 14, and 18 conifer trees per acre remained in the units sampled. Four years following timber harvesting, the growth rate of the residual redwood trees increased dramatically, with the basal area increment increasing three-fold. The growth of Douglas-fir also increased, but not nearly as much as that documented for redwood.

Since past studies have been conducted on hillslope areas and generally reported on thinning levels of coast redwood that exceed what is proposed in flood prone zones, the RPC determined that computer modeling of several potential silvicultural systems used in these areas was appropriate.

Modeling Results

The following simulation was conducted to evaluate the effects on stand structure over 65 years of different management regimes applied to coast redwood stands on high site alluvial floodplains.[13]

Alternatives

Four management situations (alternatives) were considered:

1) No harvest.
2) Conservative sanitation. Harvest only intermediate and suppressed trees.
3) Thinning from below. Harvest intermediates and co-dominants only. Quadratic mean diameter (QMD) of the stand must increase after harvest.
4) Standard single tree selection silviculture, adhering to the minimum standards under the California Forest Practice Rules.[14]

Methods

The growth model CRYPTOS was used to project the development of typical forest stands under different management situations.[15] **Results of the simulations for a typical stand are available from CDF upon request.** The projection interval was 65 years. Parameters of interest were stand structure, as measured by diameter distributions of trees in the stands, board foot volume, basal area, and trees per acre. Data came from private land ownerships in the coast redwood region. Data were aggregated and data gaps were smoothed by imputing from similar stands in the area.

Results

Alternative 1: No Harvest

In the absence of harvesting or other significant natural mortality, the stand profile, not surprisingly, transitions over time from few large trees and many small trees to many large trees and few small trees.

Alternative 2: Conservative Sanitation

Under this alternative, only intermediate and suppressed trees are harvested. This alternative produces a similar effect to the No Harvest alternative, shifting the direction of the diameter distribution curve towards larger average tree diameters to speed up the

[13] Dr. Helge Eng, CDF State Forests Program Manager, Sacramento, conducted the CRYPTOS simulation.
[14] The minimum post-harvest basal area for Site I land in the Coast Forest Practice District is stated in the Forest Practice Rules as 125 square feet per acre. Alternative 4 has basal area reduced to 144 square feet following harvest at 60 years.
[15] The website for information on CRYPTOS is: http://www.cnr.berkeley.edu/~wensel/cryptos/crypt.htm.

transition to a predominance of large trees by removing the low end of the size distribution.

This alternative does not allow for creation of openings to allow for growth of regeneration. This harvest regime also allows only limited opportunities to influence stand structure development over time. Harvesting will achieve riparian management goals associated with increasing tree size more rapidly under this scenario.

Alternative 3: Thinning from Below

Under this alternative, harvest occurs in the intermediate and co-dominant crown classes only, with the objective of increasing the quadratic mean diameter (QMD) of the post-harvest stand. Harvesting exclusively in intermediate and co-dominant canopy layers leads to the creation of a one-layered stand consisting of the uniform overstory with few trees underneath.

As was the case with Alternative 2, this alternative speeds up the transition to a predominance of large trees by removing the low end of the size distribution. Additionally, as was the case with the sanitation alternative, this alternative will not allow for creation of openings to allow for growth of regeneration. In comparison to Alternative 1, harvesting will achieve goals associated with increasing tree size more rapidly under this scenario.

Alternative 4: Standard Single Tree Selection

This was the only alternative under which it was consistently possible to create and to maintain an inverse J-shaped diameter distribution characteristic of uneven-aged and multi-layered stands. Rapid regeneration of redwood, primarily through sprouting, is more likely to be plentiful under this alternative, especially if small group openings are used.

Canopy closure levels are likely to be somewhat lower under this alternative than under Alternatives 1 through 3, due to the more intensive harvest regimes and lower residual basal area.

Discussion

There will always be a trade-off in riparian forest stands between management objectives directed toward timber production and those objectives directed to retaining or recovering riparian function of near-stream forests.

Canopy cover was not explicitly analyzed here, but canopy cover is consistently correlated to basal area. Differences in stand structure are also reflected in different basal area levels. Consequently, at least at a general level, the higher basal area levels found in the overstory monocultures of Alternatives 1 through 3 are generally indicative of greater canopy closure than the lower basal area found in the more structurally diverse stand types of Alternative 4.

In the long run, silviculture and harvesting activities will likely be a combination of these four alternatives, with near-stream silvicultural prescriptions being driven by factors which emphasize retention or recruitment of trees to facilitate riparian functions. In flood prone areas, as distance from the active channel increases, variations on Alternative 4 should provide flexibility for managing stands on these areas. This allows for timber production over long time intervals through regeneration and trees moving up through the size cohorts to replace the next larger trees, while still achieving high levels of riparian function associated with these stands.

Table 4 summarizes the diameter distribution information from the computer simulations. Specifically, it presents the number of trees per acre greater than 36 inches dbh under the different alternatives for the projection interval. Additionally, this information is displayed graphically in Figure 27. Minor differences in trees per acre greater than 36 inches dbh for Alternatives 1 through 3 are shown in this table and figure, ranging from 25 to 30. It is unlikely that these differences are statistically significant.

This analysis suggests that it is possible to thin from below or use a conservative sanitation cut without reducing the number of large trees (>36 inches dbh) that can be produced over 60 years (i.e., capturing mortality). Conversely, the simulation suggests that, at least for the plot data used for this modeling exercise, these types of silvicultural treatments are not likely to generate an increase in the number of large trees produced over this planning period. This may be attributed to the fact that in this particular stand, the stand may have been open enough that a sanitation-type harvest did not have the effect of stimulating growth on the remaining trees, but rather primarily captured mortality. It is possible that a more densely stocked stand with more competition for growing space would show a different result.

Table 4. Summary of diameter distribution information for the four alternatives modeled. Note that "tpa" refers to the number of trees per acre, and "BH" and "AH" denote before harvest and after harvest, respectively.

Time (yr)	tpa > 36 inches dbh				Time (yr)	Total tpa			
	Alt. 1	Alt. 2	Alt. 3	Alt. 4		Alt. 1	Alt. 2	Alt. 3	Alt. 4
0 BH	5	5	5	5	0 BH	80	80	80	80
0 AH		5	5	5	0 AH	80	73	75	70
20 BH	10	10	10	5	20 BH	79	72	74	69
20 AH		10	10	3	20 AH	79	62	67	52
40 BH	15	16	16	9	40 BH	79	62	66	51
40 AH		16	16	4	40 AH	79	57	46	40
60 BH	30	28	25	10	60 BH	78	57	46	40
60 AH		28	25	5	60 AH	78	48	38	35
	Percent of tpa > 36 inches dbh								
	Alt. 1	Alt. 2	Alt. 3	Alt. 4					
0 BH	6	6	6	6					
0 AH		7	7	7					
20 BH	13	14	14	7					
20 AH		16	15	6					
40 BH	19	26	24	18					
40 AH		28	35	10					
60 BH	38	49	54	25					
60 AH		58	66	14					

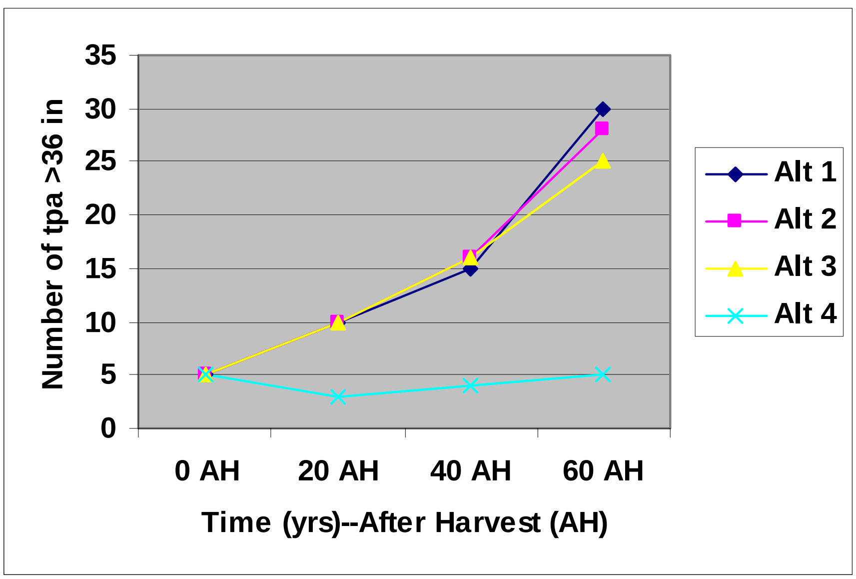

Figure 27. Plot of number of trees per acre greater than 36 inches dbh for the four alternatives after harvest over the 60 year modeling period.

VI. Example of a Successful Past Effort Evaluating a Flood Prone Area

The "Bucha" THP, 1-04-244 MEN[16], provides a reasonable example of how an RPF evaluated flood prone areas in a coast redwood-dominated watershed pursuant to 14 CCR § 916.4(a)(1). This Campbell Timberland Management plan assessed the activity of flood prone areas adjacent to the North Fork of Ten Mile River in western Mendocino County on the Hawthorne Timber Company ownership.

The RPF found that the channel of the North Fork of Ten Mile River near the THP area was unconfined and investigated whether the streamside areas were within the boundaries of a 20-year return interval floodplain (Figure 28). Considerable evidence was gathered to determine the floodplain status for this area. Evidence presented in the THP included:

- Results of inquires made to people familiar with the area over several decades, indicating that the area had not flooded over several decades.

- Field evidence showing that silt lines were not present on trees greater than 25 years of age at dbh.

- Documentation of flood recurrence intervals for hydrologic years 1965 and 1993, based on synthetic data created by Graham Matthews and Associates (GMA). Recurrence intervals for these flood events were estimated to be 48 and 24 years, respectively.

Additionally, the following language was included in the plan:

> “Lastly, the findings that these are not 20-year floodplains is supported by the research GMA did for the [Ten Mile] TMDL, stating under ‘slope analysis’ that “The low gradient valley floors of the Mainstem Ten Mile, Lower North Fork, …What is not evident at this scale, is that much of the channel through these reaches is incised into the valley floor to such an extent that these surfaces do not function as floodplains, but instead act to store hillslope generated sediments.” This is bolstered by GMA’s findings that in the lower three miles of the North Fork there has been some widening of the river, leading to an average loss of floodplain height of five feet. As an aside, large scale channel migration is not a concern supported by GMA’s photo review, 1942-1999.”

Based on all these sources of information, the RPF was able to conclude that it was unlikely that the area proposed for management along this reach of the North Fork of Ten Mile River was within the 20-year return interval floodplain.

[16] Excerpts from Section III, Support Documentation, written by Mr. Kirk O’Dwyer, RPF, Campbell Timberland Management, Fort Bragg, CA.

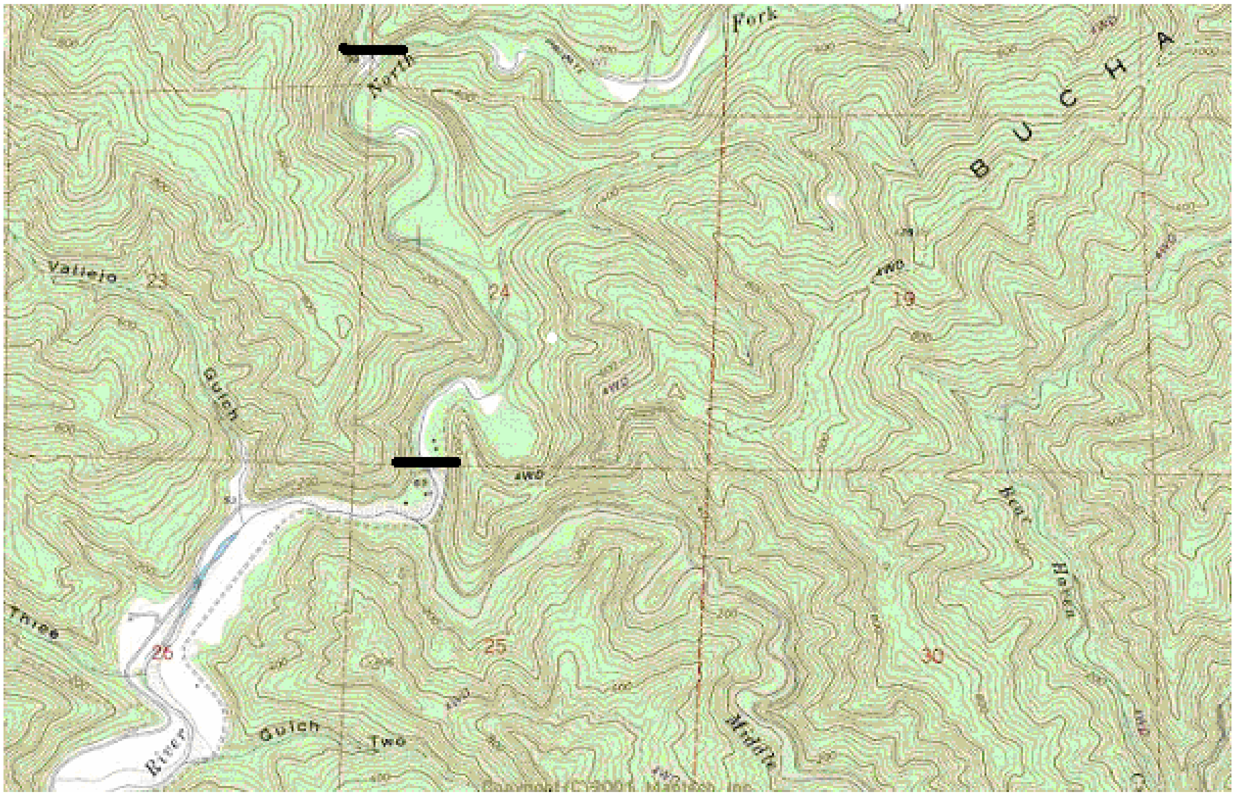

Figure 28. Topographic map of the general area of "Bucha THP", 1-04-244 MEN. The North Fork of Ten Mile River within the vicinity of the THP is located between the two black lines, primarily in Section 24, T 20N, R 17W, MT DIAB.

VII. Discussion of Larger Temporal and Spatial Scales

Disturbance by events such as infrequent floods, fires, large channel-influencing landslides, and extreme wind storms is currently recognized as extremely important in producing properly functioning aquatic ecosystems, benefiting the system in a long-term perspective (Ligon and others 1999, Welsh and others 2000, Reeves and others 1995, Reid 1996). Reeves and others (1995) advocate modifying human-imposed disturbance regimes to create and maintain the necessary range of habitat conditions in space and time within and among watersheds across the range of an Evolutionary Significant Unit (ESU). In particular, floodplain surfaces should be managed for long time periods and very infrequent events, so that it is possible to capture the effects of large infrequent disturbances and continue to maintain landscape diversity. Large channel-influencing floods, landslides, and other disturbances can radically change channel characteristics in the short term, but benefit the system over the long term (i.e., several centuries).

A primary mechanism to capture this disturbance element on flood prone areas is to leave enough streamside timber to allow large wood to enter with episodic events (Reeves and others 1993), and with a temporal perspective of at least 100 years, not, for example, 5 to 8 years (time frames often associated with individual plans). It is important to manage riparian areas for large, very infrequent events by using appropriate silviculture in these zones (see Section V). Retention of large trees (36 to 40+ inch dbh) in higher order watersheds over longer time periods lowers the risk associated with currently proposed timber management in flood prone areas. RPFs should provide some discussion of the frequency of future logging operations in flood prone areas. Providing data on how the large trees over 36 inches dbh in the 20-year recurrence interval flood prone area are going to be managed is highly beneficial for plan review.[17] Required wood diameter and length varies depending on channel width, with smaller width channels needing smaller wood (Table 5).

Ensuring that very large trees remain in riparian flood prone areas over time is problematic, however, since tagging, painting, and many other techniques are not considered permanent. Also, for economic reasons landowners have not been receptive to permanent dedication of large trees on highly productive timberlands in the past.[18] Landscape-level documents such as Habitat Conservation Plans (HCPs),

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[17] It is not possible to determine the exact numbers of large trees that should be present in a flood prone area for properly or fully functioning aquatic habitat without first conducting a watershed assessment (Ligon and others 1999). With this provision, the Aquatic Properly Functioning Condition Matrix (NMFS and USFWS 1997) was developed as a work-in-progress for the PALCO HCP to provide some guidance on properly functioning riparian zone conditions for large wood recruitment potential. For redwood (SAF type 232), it suggests that the average number of large redwood trees per acre by dbh class should be: 23.8 >32 inches per acre; 17.4 >40 inches per acre. As Reeves (2003) has explained, however, it is important to note that it is unreasonable to assume that aquatic systems are static over time and that all systems and conditions within them should be similar at any point in time.

[18] This reluctance relates to the fact that industrial timberlands in California are generally zoned as Timber Protection Zone (TPZ). TPZ designation establishes the presumption that timber harvesting is expected to and will occur on such lands. TPZ lands have not been expected to grow to an old-growth

Table 5. Aquatic Properly Functioning Condition Matrix table (NMFS and USFWS 1997), showing how mean wood length and diameter vary with channel width. Data is from Bilby and Ward (1989) and Fox (1994).

Channel Width (feet)	Bilby and Ward				Fox "Key Pieces"/5			
	Debris per 100 feet (1)	Geometric mean debris diameter (inches) (2)	Geometric mean debris length (feet) (3)	Mean debris piece volume (cubic feet) (4)	Debris per 100 feet	Average debris diameter (inches)	Average length (feet)	Average debris piece volume (cubic feet)
15	16	14	18	13	3.3	16	27	35.3
20	12	16	20	26	2.5			
25	9	17	22	38	2.0	22	32	88.3
30	7	18	25	51	1.7			
35	6	19	27	63	1.4			
40	5	21	29	72	1.2	25	59	211.9
45	5	22	31	88	1.1			
50	4	23	33	100	1.0			
55	4	25	35	113	1.0	28	78	317.8
60	3	26	37	125	0.8			
65	3	27	40	137	0.8			

conservation easements, or conservation (mitigation) "banks" are potential approaches for addressing this issue. Conservation easements have been used successfully in the state of Washington for timberlands within channel migration zones.[19]

Green Diamond Resources' (formerly Simpson) Draft Habitat Conservation Plan (HCP) (GDR 2002) provides an example of one possible programmatic longer-term approach for addressing large wood recruitment, as well as other functions, on floodplain surfaces. Green Diamond Resources' approach is to establish a Riparian Management Zone (RMZ) of at least 150 feet for all Class I watercourses. Where the floodplain is wider than 150 feet, the outer zone of the RMZ is to extend to the outer edge of the floodplain, and an additional buffer is to be added to the RMZ immediately adjacent to the floodplain (30 to 50 feet, depending on side slope category). For relatively flat floodplains, the inner zone of the RMZ is 50 feet, and the outer zone is to the outer edge of the floodplain, with the additional buffer zone described above. The inner zone is to have 85% overstory canopy closure, while the outer zone is to have at least 70% closure. The draft HCP states that no trees are to be harvested that contribute to bank stability, or are likely to be recruited to the watercourse. Trees likely to be recruited are defined as:

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age or to fully exhibit old-growth characteristics because they are anticipated to be subject to periodic harvest.

[19] Private landowners in Washington were able to apply to the Riparian Open Space Program in 2002, which allows the state to purchase forested areas in channel migration zones. The Washington legislature appropriated $1 million for WDNR to acquire these parcels in 2002. Funding pays for acquisition of private lands or permanent conservation easements in "unconfined avulsing channel migration zones." For more information, see: http://www.dnr.wa.gov/htdocs/adm/comm/nr02-92.htm.

- Tree is on the streambank,
- Tree has roots in the streambank or stream,
- Tree is leaning toward the stream,
- Tree is tall enough to ensure it will reach the stream,
- Tree is on a slope that is sufficiently steep such that gravity would likely carry the fallen tree into the stream, and
- Tree is on an unstable area or immediately downslope of such an area.

Additionally, the draft Green Diamond Resources' HCP states that no salvage operations are to occur within an identified floodplain or channel migration zone.[20]

Another longer-term approach is illustrated with the Garcia River TMDL Implementation Plan.[21] This document states that an improving trend in large wood loading in a stream channel can be represented by an increase in the volume of large woody debris measured within a given stream segment over a rolling 10-year period (NCRWQCB 2001). Approved techniques for acquiring an improving trend in large wood loading include:

1) No removal of downed large woody debris from watercourse channels unless the debris is causing a safety hazard,

2) On Class I and II watercourses, at least five standing conifer trees greater than 32 inches in diameter at breast height (dbh) are permanently retained at any given time per 100 linear feet of watercourse (where sites lack enough trees to meet this goal, there shall be no commercial harvest of the five largest diameter trees per 100 linear feet of watercourse),

3) No removal of trees from unstable areas within a riparian management zone that have the potential to deliver sediment to a water of the State unless the tree is causing a safety hazard.

In addition to longer-term perspectives for large wood recruitment, the RPF preparing a plan involving a flood prone area must consider the current condition of the floodplain. If the flood prone surface has been highly impacted by past timber operations (i.e., high density of roads [Figure 29] and skid trails, lack of downed wood, disruption of overflow channels, few large conifer trees, etc.), then proposed operations must lead to recovery of these functions in impaired watersheds. This is a higher standard than avoiding significant adverse impacts under the California Environmental Quality Act (CEQA).

[20] The PALCO HCP (1999) states that harvesting shall not occur in the CMZ, but CMZ prescriptions may be modified as a result of watershed analysis.

[21] Recovery in the Garcia River watershed was planned to take 40 years.

Finally, the proposed floodplain operations must be considered within the context of the larger watershed. While flood prone area vegetation helps regulate delivery of watershed products (e.g., sediment, wood, etc.) to stream channels, redwood-region stream and floodplain conditions are heavily influenced by watershed-scale processes (Welsh and others 2000). Coast redwood watersheds are generally located in erodible terranes prone to landsliding due to steep slopes, high rainfall, and frequent earthquakes. If a watershed in this region has been heavily disturbed by legacy logging practices that took place prior to the implementation of the modern Forest Practice Act of 1973, as well as by more recent harvesting impacts, adverse cumulative impacts are commonly exemplified by channel widening and aggradation in low gradient reaches. Significant changes in sediment regimes in coast redwood-dominated watersheds can present substantial and long-term consequences for stream channels and floodplains, as well as their biota (Welsh and others 2000). As an example, large, infrequent floods in combination with poor logging practices adversely impacted old-growth redwoods on flood prone surfaces along lower Bull Creek in 1955 and 1964 (Stone and Vasey 1968) and lower Redwood Creek following the December 1964 storm (Nolan and Marron 1995).

The Riparian Protection Committee recognizes that flood prone areas are often the most productive timberlands found in watersheds, capable of rapidly producing large, high quality wood. The decision on when, where, and how many trees may be harvested within flood prone areas must be based on existing and anticipated future conditions within those areas within the context of physical, biological, and water quality conditions within planning watersheds and hydrologic basins. It is from the understanding of the full range of past, present, and future conditions that sound land management decisions can be made and documented.

Figure 29. Example of a flood prone area impacted by past land use activities. A Class I WLPZ truck road is proposed for re-use in a Gualala River watershed flood prone area. Photograph provided by the NCRWQCB.

VIII. Summary

Possible methods for determining if limited harvesting on flood prone surfaces are appropriate have been discussed in this paper. Important summary points include:

- Timber management in flood prone areas may be appropriate, but must be planned and executed with proper care, and supported by appropriate analysis in the plan for the flood prone area functions present (i.e., hydrologic, geomorphic, biological processes and functions).

- The existing Forest Practice Rules can accommodate any Class I WLPZ width and prescription determined to be necessary for adequate protection or restoration in impaired waterbodies.

- Based on coho salmon life cycle requirements in the North and Central Coast regions, the most biologically critical flood prone area is inundated at less than or equal to every 20 years, on average.

- While using the 25-year old tree Forest Practice Rule for defining the WTL and the start of the Class I WLPZ for unconfined channels may provide for adequate amounts of shading and large wood recruitment with laterally stable channel systems, the other floodplain functions must also be considered—which may require expansion of WLPZ beyond 150 feet and inclusion of other mitigation measures as necessary.

- In laterally unstable channel systems, with active channel migration zones and/or active bank erosion, standard WLPZ widths will not be appropriate for flood prone areas.

- Results from the CRYPTOS modeling suggested that conservative thinning methods produce similar numbers of large trees (>36 inch dbh) over 60 years as the no harvest alternative, but that, at least in this modeling exercise, the number of large trees was not increased. The single tree selection method produced a lower number of large trees at the end of the planning period.

- An understanding of basic flood prone area functions is necessary for project-level planning, but plans must also be evaluated in the context of a larger perspective that includes consideration of the stream network and past activities in the entire watershed (USFS 2004).

- Floodplain surfaces should be managed within the context of long time periods and very infrequent events, so that the effects of large disturbances on landscape diversity can occur. While large channel-influencing floods, landslides, and other disturbances can radically change channel characteristics, these changes are natural processes under which fluvial systems have evolved over long time frames. Within the spatial context of watersheds, timber management of flood prone areas must consider the potential for channel migration and other naturally occurring disturbances.

- There must be consideration of the current condition of the floodplain. If the flood prone surface has been highly impacted by past timber operations, then proposed operations must lead to recovery of flood prone area functions in impaired watersheds.

- Whatever the management that is planned for flood prone areas, there should be a strong "logic train" provided in the plan to justify the actions proposed. If greater amounts of management are proposed, a correspondingly greater analysis is to be provided in the plan. Similarly, the detail of disclosure and analysis increases with the frequency of inundation of the floodplain surface.

IX. Recommendations

The RPC recommends that the FPRs no longer include separate definitions for confined and unconfined channels.   While the physical distinction exists, in practice the definitions have led to confusion and proven difficult to use in the field. It is more important to adequately define flood prone areas and the attributes of these features that require protection than to accurately characterize the degree of channel confinement. Rather than relying on distinctions in channel confinement, the RPC considers the identification of riparian functions and proper management to protect or restore those functions to be a more direct route to adequate riparian protection goals.

The RPC recommends that private RPFs pre-consult with DFG, NCRWQCB, and possibly other public trust resource agencies when management is proposed in flood prone areas (particularly the 20-year return interval floodplain surface).

The RPC recommends that more programmatic approaches, such as Habitat Conservation Plans (HCPs), Natural Communities Conservation Plans (NCCPs), Programmatic Timber Environmental Impact Reports (PTEIRs), Watershed-Wide Waste Discharge Requirements (WDRs), and Memorandum of Understandings (MOUs), be pursued to develop an integrated strategy for management of flood prone areas at the watershed scale.

The RPC recommends broad training on flood prone area functions and assessment techniques for RPFs and agency review personnel.   This may include development of a shorter paper appropriate for distribution in documents such as the State Board of Forestry and Fire Protection (BOF) California Forestry Licensing News, California Licensed Foresters Association (CLFA) Update, CDF Mass Mailings, etc.

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Appendix

California Wildlife Habitat Relationships (CWHR) Model Run based upon Simulation of Forest Structure Development for Four Flood Prone Area Silvicultural Alternatives

The diameter distribution graphs for each simulation run was given a California Wildlife Habitat Relationships (CWHR) classification based upon the following rules (Mayer and Laudenslayer 1988):

CWHR	DBH (QMD)
3	6-11"
4	11-24"
5	>24"
6	Size class 5 trees over a distinct layer of size class 3 or 4 trees, total tree canopy exceeds 60% closure

Closure Class	Percent Closure
D (Dense cover)	60-100%

Most of the pre and post-harvest simulations per 20 year period did not result in different CWHR classifications, except as indicated under Alternative 2.

Alternative 1: No harvest

Year	CWHR
0	6
20	6
40	6
60	6
80	5D
100	5D

Alternative 2: Conservative sanitation

Year	CWHR	
0	6	
20	6	
40	6	(pre-harvest)
40	5D	(post-harvest)
60	5D	
65	5D	

Alternative 3: Thinning from below

Year	CWHR
0	6
20	6
40	6
60	5D
65	5D

Alternative 4: Single tree selection

Year	CWHR
0	6
20	6
40	6
60	6
65	6

As shown above, all the alternatives result in either a CWHR 6 or 5D classification. Therefore, the CWHR model was run to compare these two conditions.

The CWHR 6 vs. 5D for Montane Riparian and Redwood habitat value comparison report follows, based on the following:

- All habitat elements included.
- Location: Mendocino County.
- Arithmetic mean was used for all model runs (version 8.0).
- Habitat values are expressed as a value of 0 (lowest) to 1.0 (highest).

The table below shows change in values indicated with a negative or positive trend when compared with Redwood and Montane Riparian 6 to a 5D condition. A negative value indicates a loss in habitat value, and a positive value indicates a gain in habitat value for that species. A value of 0.0 indicates no change in habitat value:

Results are meant to indicate trends only. Predictions from the CWHR model should be validated with field surveys.

CWHR Code	Species	Δ Habitat Value
B289	CALLIOPE HUMMINGBIRD	-1.0
B294	LEWIS' WOODPECKER	-0.6
B339	TREE SWALLOW	-0.6
B338	PURPLE MARTIN	-0.6
B554	PLUMBEOUS VIREO	-0.5
B475	BLACK-HEADED GROSBEAK	-0.5
B299	RED-BREASTED SAPSUCKER	-0.4
B415	CASSIN'S VIREO	-0.4
B321	BLACK PHOEBE	-0.3
B267	NORTHERN PYGMY OWL	-0.3
B304	HAIRY WOODPECKER	-0.3
B307	NORTHERN FLICKER	-0.3
B532	BULLOCK'S ORIOLE	-0.3
B536	PURPLE FINCH	-0.3
M072	CALIFORNIA GROUND SQUIRREL	-0.3
M075	GOLDEN-MANTLED GROUND SQUIRREL	-0.3
R022	WESTERN FENCE LIZARD	-0.3
B264	WESTERN SCREECH OWL	-0.2
B438	HERMIT WARBLER	-0.2
B127	AMERICAN KESTREL	-0.2
B302	NUTTALL'S WOODPECKER	-0.2
B435	YELLOW-RUMPED WARBLER	-0.2
B103	BUFFLEHEAD	-0.2
B263	FLAMMULATED OWL	-0.2
B265	GREAT HORNED OWL	-0.2
B303	DOWNY WOODPECKER	-0.2
B356	MOUNTAIN CHICKADEE	-0.2
B411	EUROPEAN STARLING	-0.2
B417	HUTTON'S VIREO	-0.2
B418	WARBLING VIREO	-0.2
M166	BOBCAT	-0.2
B542	PINE SISKIN	-0.1
M080	NORTHERN FLYING SQUIRREL	-0.1
M176	WILD PIG	-0.1
M052	MOUNTAIN BEAVER	-0.1
R061	COMMON GARTER SNAKE	-0.1
B346	STELLER'S JAY	-0.1
B437	TOWNSEND'S WARBLER	-0.1
B296	ACORN WOODPECKER	-0.1
B305	WHITE-HEADED WOODPECKER	-0.1
B341	NORTHERN ROUGH-WINGED SWALLOW	-0.1
B426	NASHVILLE WARBLER	-0.1
M033	WESTERN RED BAT	-0.1
M151	BLACK BEAR	-0.1
M177	ELK	-0.1
B309	OLIVE-SIDED FLYCATCHER	0.0
B471	WESTERN TANAGER	0.0
M157	LONG-TAILED WEASEL	0.0
M165	MOUNTAIN LION	0.0
B108	TURKEY VULTURE	0.0
M011	MARSH SHREW	0.0
A002	NORTHWESTERN SALAMANDER	0.0
A004	CALIFORNIA GIANT SALAMANDER	0.0
A005	SOUTHERN SEEP SALAMANDER	0.0
A006	ROUGH-SKINNED NEWT	0.0
A007	CALIFORNIA NEWT	0.0

A008	RED-BELLIED NEWT	0.0
A012	ENSATINA	0.0
A014	CALIFORNIA SLENDER SALAMANDER	0.0
A020	BLACK SALAMANDER	0.0
A021	CLOUDED SALAMANDER	0.0
A022	ARBOREAL SALAMANDER	0.0
A026	TAILED FROG	0.0
A032	WESTERN TOAD	0.0
A040	RED-LEGGED FROG	0.0
A043	FOOTHILL YELLOW-LEGGED FROG	0.0
A046	BULLFROG	0.0
A048	PACIFIC GIANT SALAMANDER	0.0
B051	GREAT BLUE HERON	0.0
B052	GREAT EGRET	0.0
B053	SNOWY EGRET	0.0
B058	GREEN HERON	0.0
B059	BLACK-CROWNED NIGHT HERON	0.0
B076	WOOD DUCK	0.0
B110	OSPREY	0.0
B113	BALD EAGLE	0.0
B116	COOPER'S HAWK	0.0
B117	NORTHERN GOSHAWK	0.0
B123	RED-TAILED HAWK	0.0
B129	PEREGRINE FALCON	0.0
B131	PRAIRIE FALCON	0.0
B134	BLUE GROUSE	0.0
B136	RUFFED GROUSE	0.0
B140	CALIFORNIA QUAIL	0.0
B141	MOUNTAIN QUAIL	0.0
B240	MARBLED MURRELET	0.0
B251	BAND-TAILED PIGEON	0.0
B255	MOURNING DOVE	0.0
B270	SPOTTED OWL	0.0
B274	NORTHERN SAW-WHET OWL	0.0
B281	VAUX'S SWIFT	0.0
B282	WHITE-THROATED SWIFT	0.0
B291	RUFOUS HUMMINGBIRD	0.0
B293	BELTED KINGFISHER	0.0
B308	PILEATED WOODPECKER	0.0
B311	WESTERN WOOD-PEWEE	0.0
B317	HAMMOND'S FLYCATCHER	0.0
B320	PACIFIC-SLOPE FLYCATCHER	0.0
B340	VIOLET-GREEN SWALLOW	0.0
B344	BARN SWALLOW	0.0
B345	GRAY JAY	0.0
B354	COMMON RAVEN	0.0
B357	CHESTNUT-BACKED CHICKADEE	0.0
B360	BUSHTIT	0.0
B361	RED-BREASTED NUTHATCH	0.0
B362	WHITE-BREASTED NUTHATCH	0.0
B364	BROWN CREEPER	0.0
B367	CANYON WREN	0.0
B368	BEWICK'S WREN	0.0
B369	HOUSE WREN	0.0
B370	WINTER WREN	0.0
B373	AMERICAN DIPPER	0.0
B375	GOLDEN-CROWNED KINGLET	0.0

B376	RUBY-CROWNED KINGLET	0.0
B386	HERMIT THRUSH	0.0
B389	AMERICAN ROBIN	0.0
B390	VARIED THRUSH	0.0
B407	CEDAR WAXWING	0.0
B425	ORANGE-CROWNED WARBLER	0.0
B430	YELLOW WARBLER	0.0
B463	WILSON'S WARBLER	0.0
B528	BROWN-HEADED COWBIRD	0.0
B539	RED CROSSBILL	0.0
B546	EVENING GROSBEAK	0.0
B699	BARRED OWL	0.0
B702	CHIMNEY SWIFT	0.0
B798	WHITE-THROATED SPARROW	0.0
M001	VIRGINIA OPOSSUM	0.0
M005	FOG SHREW	0.0
M006	ORNATE SHREW	0.0
M010	WATER SHREW	0.0
M012	TROWBRIDGE'S SHREW	0.0
M015	SHREW-MOLE	0.0
M018	BROAD-FOOTED MOLE	0.0
M021	LITTLE BROWN MYOTIS	0.0
M025	LONG-EARED MYOTIS	0.0
M026	FRINGED MYOTIS	0.0
M027	LONG-LEGGED MYOTIS	0.0
M028	CALIFORNIA MYOTIS	0.0
M030	SILVER-HAIRED BAT	0.0
M031	WESTERN PIPISTRELLE	0.0
M032	BIG BROWN BAT	0.0
M034	HOARY BAT	0.0
M037	TOWNSEND'S BIG-EARED BAT	0.0
M038	PALLID BAT	0.0
M039	BRAZILIAN FREE-TAILED BAT	0.0
M055	YELLOW-PINE CHIPMUNK	0.0
M056	YELLOW-CHEEKED CHIPMUNK	0.0
M057	ALLEN'S CHIPMUNK	0.0
M077	WESTERN GRAY SQUIRREL	0.0
M079	DOUGLAS' SQUIRREL	0.0
M112	AMERICAN BEAVER	0.0
M119	BRUSH MOUSE	0.0
M127	DUSKY-FOOTED WOODRAT	0.0
M132	CALIFORNIA RED TREE VOLE	0.0
M141	NORWAY RAT	0.0
M143	WESTERN JUMPING MOUSE	0.0
M145	COMMON PORCUPINE	0.0
M146	COYOTE	0.0
M154	AMERICAN MARTEN	0.0
M155	FISHER	0.0
M156	ERMINE	0.0
M158	AMERICAN MINK	0.0
M163	NORTHERN RIVER OTTER	0.0
R004	WESTERN POND TURTLE	0.0
R036	WESTERN SKINK	0.0
R039	WESTERN WHIPTAIL	0.0
R040	SOUTHERN ALLIGATOR LIZARD	0.0
R042	NORTHERN ALLIGATOR LIZARD	0.0
R046	RUBBER BOA	0.0

R048	RINGNECK SNAKE	0.0
R049	SHARP-TAILED SNAKE	0.0
R051	RACER	0.0
R053	STRIPED RACER	0.0
R058	COMMON KINGSNAKE	0.0
R059	CALIFORNIA MOUNTAIN KINGSNAKE	0.0
R062	WESTERN TERRESTRIAL GARTER SNA	0.0
R076	WESTERN RATTLESNAKE	0.0
R078	PACIFIC COAST AQUATIC GARTER SNAKE	0.0
B115	SHARP-SHINNED HAWK	0.05
M153	RACCOON	0.05
M023	YUMA MYOTIS	0.06
M181	MULE DEER	0.06
B436	BLACK-THROATED GRAY WARBLER	0.11
M162	STRIPED SKUNK	0.11
B385	SWAINSON'S THRUSH	0.12
M117	DEER MOUSE	0.17
M128	BUSHY-TAILED WOODRAT	0.17
M129	WESTERN RED-BACKED VOLE	0.17
M134	CALIFORNIA VOLE	0.17
B510	WHITE-CROWNED SPARROW	0.22
B353	AMERICAN CROW	0.33
B489	CHIPPING SPARROW	0.33
B505	SONG SPARROW	0.33
B543	LESSER GOLDFINCH	0.33
B545	AMERICAN GOLDFINCH	0.33
M113	WESTERN HARVEST MOUSE	0.33
M149	GRAY FOX	0.33
M161	WESTERN SPOTTED SKUNK	0.33
R057	GOPHER SNAKE	0.33
B391	WRENTIT	0.44
B512	DARK-EYED JUNCO	0.44
B524	BREWER'S BLACKBIRD	0.55
B348	WESTERN SCRUB-JAY	0.66
B105	COMMON MERGANSER	0.67
B138	WILD TURKEY	0.77
B126	GOLDEN EAGLE	0.78
B342	BANK SWALLOW	0.89
B119	RED-SHOULDERED HAWK	1.00
M003	VAGRANT SHREW	1.00
M139	COMMON MUSKRAT	1.00

Total Number of Species Affected: 212