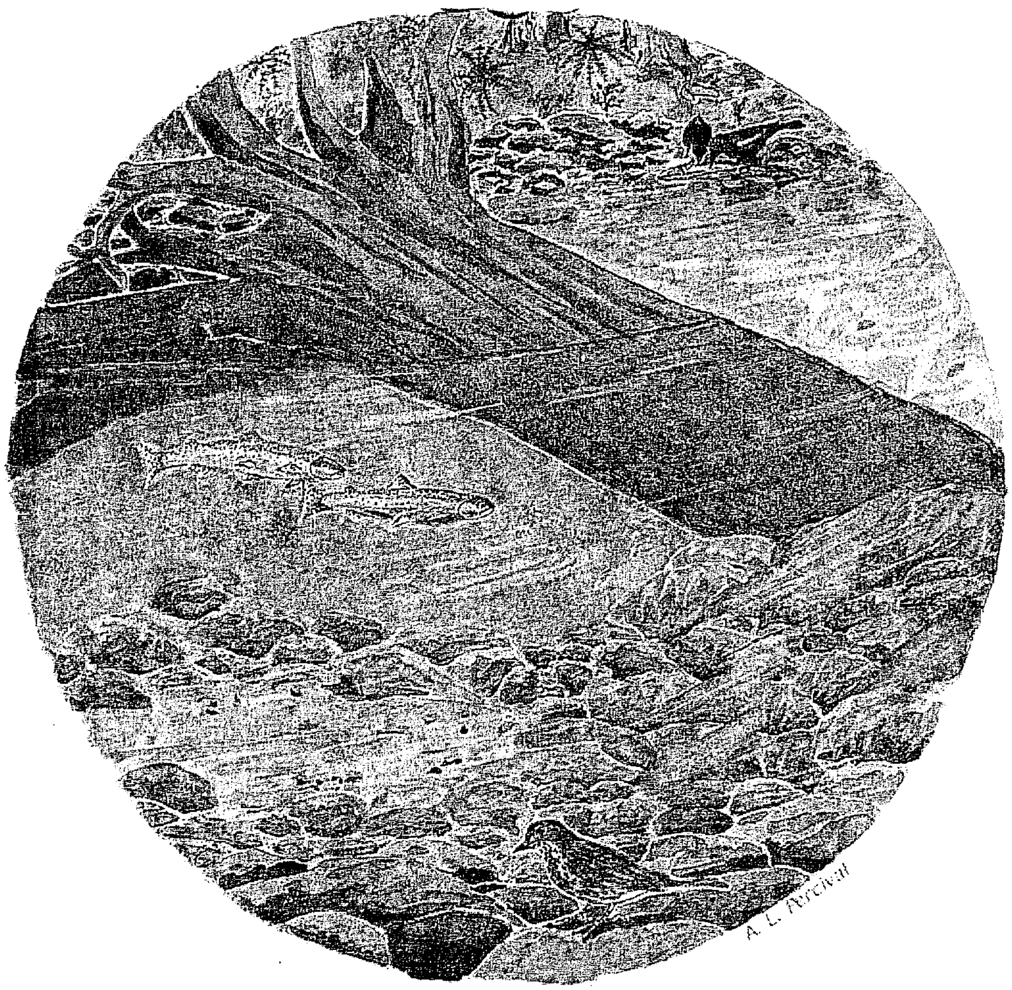
ATTACHMENT 8

Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat

June 1999



Prepared for

The Resources Agency of California and the National Marine Fisheries Service
Sacramento, California

Scientific Review Panel

Frank Ligon
Alice Rich, Ph.D.
Gary Rynearson, R.P.F., Coordinator
Dale Thornburgh, Ph.D., R.P.F.
William Trush, Ph.D.

45

Executive Summary

The Scientific Review Panel (SRP) was created under the auspices of the Watershed Protection and Restoration Council, as required by the March 1998 Memorandum of Agreement (MOA) between the National Marine Fisheries Service (NMFS) and The Resources Agency of California. Under this agreement the state agreed to organize an independent panel of scientists to undertake a comprehensive review of the California Forest Practice Rules (FPRs), with regard to their adequacy for the protection of salmonid species.

NMFS and The Resources Agency jointly developed a letter that posed a series of questions regarding a review of the FPRs, the THP review and approval process, and the rule-making process. They also requested that the public be involved and provide comments and information to the SRP. Beyond this input, no state or federal agency provided any direction to, or had any control over, the SRP. The state and federal MOA specifically addressed steelhead in the Northern California and Klamath Mountains Province ESUs within California. Considerations and recommendations presented in this report apply to this geographic area and are not necessarily applicable to other areas.

APPROACH

To implement the project, the SRP (first convening in November 1998) agreed to operate by consensus, with one member serving as coordinator. The SRP also developed a plan to involve the public, state and federal agencies, landowners, and other interested parties. A total of 29 constituency groups (comprising 128 interviewees) interested in salmonid issues was invited to meet with the SRP. Interviewees included state and federal agency representatives, environmental representatives, large and small landowners, foresters, geologists, watershed specialists, fisheries representatives, fish/habitat restorationists, South of San Francisco ("856 counties") representatives, and fish biologists, Following the interviews, the SRP visited THP sites in Humboldt and Mendocino counties.

OVERALL CONCLUSIONS

The SRP concluded that the FPRs, including their implementation (the "THP process") do not ensure protection of anadromous salmonid populations. The primary deficiency of the FPRs is the lack of a watershed analysis approach capable of assessing cumulative effects attributable to timber harvesting and other non-forestry activities on a watershed scale. As currently applied, Technical Rule Addendum No. 2 does not provide the necessary cumulative effects assessment at the appropriate temporal and spatial scales. Therefore, with regard to the SRP's mandate, the state will need to sponsor and conduct watershed analyses in all watersheds within both steelhead ESUs. Also, specific rules governing onsite operations and road maintenance need stronger enforcement and/or modification to further minimize sediment production, improve stream habitat, and guarantee unrestricted passage by migrating juvenile and adult salmonids. The SRP focused on the following rule sections: watercourse protection measures, road construction and maintenance, and winter operations limitations, Finally, the SRP reviewed Timber Harvesting Plan (THP) implementation issues, especially RPF involvement throughout the THP process as well as THP review and approval procedures, and developed recommendations for improving this process.

Watershed Analysis

The SRP recommends watershed analysis as the best available tool to evaluate past, ongoing, and potential future cumulative watershed effects (CWEs) resulting from forest management and other watershed activities, and to identify strategies to avoid, minimize, and/or mitigate adverse CWEs on salmonid populations and their habitat. All THPs within a specific watershed would rely upon the same watershed-specific analysis to identify key concerns and potential factors limiting salmonid populations. Because widespread availability of watershed analyses will be required, the state must develop and manage an interagency watershed analysis program. This should be done in consultation with NMFS, EPA, the forest industry, and academic and other non-agency scientists. All watershed analyses should be peer reviewed and then certified by a panel of scientists. The SRP has developed general guidelines for a watershed analysis that can result in specific harvest prescriptions, quantifiable performance targets, and prioritized mitigation opportunities.

Success of the watershed analysis process relies on the following two key items: (1) the credibility of the science and methodologies used, and (2) the professionalism of the scientists and specialists involved in the process. To succeed, data collected for the watershed analysis must be done in a consistent manner agreed to by all parties involved, with protocols established well before a watershed analysis program is implemented. Quality Assurance/Quality Control (QA/QC) must be an integral part of the process.

Although a watershed analysis program may require several years to develop and implement, certain actions can begin immediately. The SRP recommends the following preliminary actions until watershed analyses are completed: (1) identify legacy sediment problems that should be immediately mitigated in high priority watersheds, (2) assess anadromous fish migration corridors (both within and outside watersheds), and prioritize barriers for potential removal or replacement, and (3) modify specific forest practice rules (see below).

Pending completion of watershed analyses, the SRP recommends the Board of Forestry consider whether a harvest limitation based on percent of watershed area is warranted. This percentage would function as a red flag rather than as a moratorium. Predictably, the environmental community advocated a maximum harvest of 10% to 15% of watershed area per decade, whereas timber industry constituencies offered a maximum of 70% to 85% per decade. The SRP believes a more likely value would range from 30% to 50% per decade, but will depend on numerous factors including geology, harvest prescriptions, past disturbance, etc. The SRP recommends that a blue-ribbon science panel be commissioned in 1999 to consider the need for harvest limitations.

Specific Rule Recommendations

Recommendations by the SRP for changes to specific rule sections and issues include:

Watercourse and Lake Protection *Zones* and LWD Recruitment (WLPZ) :

- Increase Class I WLPZs to 150 ft and encourage thinning and selection harvesting to grow bigger trees faster; increase shade requirements to 85% for the first 75 ft and 65% for the remainder; permanently retain the 10 largest conifers trees for every 100 meters of stream channel; restrict salvage logging of downed trees within 75 ft of the watercourse; provide special harvesting zone on steep slopes and adjacent to evenage management.
- Class IIs: increase WLPZ to 100 ft and require 85% overstory canopy within 30 ft and 65% overstory canopy for the remainder; restrict salvage logging within first 30 ft; require retention of a minimum of 25% post-harvest overstory of conifers; assign a special operating zone adjacent to evenage management units.
- Class III: 30-50 ft ELZ; limit burning within zones; minimize and pre-designate all tractor crossings.

- General recommendations; all slopes >55% within inner gorge harvested under evenage prescriptions must be reviewed by a geologist; all slopes >65% must be reviewed by a geologist; combine all exemptions into one rule section.

- Develop program to introduce LWD into streams.

- Redefine the watercourse transition line to include the flood plain.

Geologic Concerns:

- Geologist to conduct broad review of properties to identify any potential problems: geologist to review all proposed activities on unstable features: develop more geologic training for RPFs; all evenaged harvesting on slopes >65% must be reviewed by a geologist: develop better geology maps for resource specialists.

Road Construction and Maintenance:

- Designate roads as either permanent, temporary, or abandoned; remove watercourse and cross drain culverts from abandoned roads: eliminate road construction during winter period; develop rocking standards and consider other road stabilization measures for winter hauling; require geologist review for construction on slopes >65%; no blading of roads during wet conditions; use outsloped roads with rolling dips (where appropriate); treat and stabilize fill slopes at watercourse crossings to prevent erosion; remove legacy roads within WLPZs.

Watercourse Crossings:

- Require 100-year flood capacity for culverts with a design standard $HW/D \leq 1$; permanently maintain or remove drainage structures following road use: all Class I watercourse crossings must have a natural bottom or naturally formed bottom (culvert, pipe arch, or bridge); show all watercourse crossings on THP map; restrict ditch drainage into a watercourse to no more than 100 ft; design and reconstruct crossings to avoid diversion potential and use a "fail-soft" design; minimum cross drain culvert should be 18 inches in diameter.

Site Preparation:

- Limit tractor site preparation to period before soils become saturated (see Winter Operations); reduce use of broadcast burning; restrict burning of Class III watercourses to retain LWD in channels: require a "Site Preparation Completion Report" showing the area treated.

Winter Operations:

- Use "Antecedent Prescription Index" (API) to define winter period; RPF required to oversee winter operations; allow limited use of ground-based skidding equipment under specified conditions; require a full winter operating plan that addresses sediment issues: no road or landing construction during winter period.

THP Preparation, Review and Implementation:

- THP length to be reduced following watershed assessment – THP to address concerns identified in the watershed assessment and to serve as a disclosure and operational document; RPFs should pre-consult with agencies during plan preparation.

- RPFs should consult with other resource specialists during plan preparation; THP should be signed by the landowner and timber owner; require RPF involvement in THP implementation similar to the requirements of Santa Cruz County; LTO should sign the THP and major amendments, and attend the PHI (if a LTO is identified on THP); extend agency review to minimum of 10 days between PHI and second review; extend public review to a minimum of 10 days after second review: increase agency budgets to support involvement in more PHIs, operational, and post-harvest inspections, and provide pre-consultation with RPFs; reduce THP paperwork and focus emphasis on field review: post THPs and related information on the Internet: limit case level of CDF inspectors to 40-50 active plans; develop civil penalties for FPR violations; meeting with LTO and RPF to convey plan contents should be on site; increase training for RPFs and other resource specialists; RPF should maintain role as the lead coordinator and author of the THP; make the FPR more efficient and friendly; centralize all rules pertaining to a topic, even though this may cause some rules to be repeated.

Social and Economic impacts:

- Nearly all the constituency groups interviewed supported incentives to landowners to improve and maintain salmonid habitat. This included the use of tax deductions, conservation easements, and restructuring of the federal tax codes to allow expensing rather than amortizing capital road expenditures such as culvert replacements, A program of incentives must be developed to allow the value of the permanently designated standing and downed trees to be deducted from the timber owners yield or other state taxes. The valuation of these trees could be based on the yield tax value schedules, and would be claimed when harvesting is completed for the associated harvest unit adjacent to the WLPZ. This may also help encourage landowners to include watercourse protection zones in conservation easements. The benefit of providing landowners tax credits against the retained recruitment trees will encourage the retention of important habitat features and is likely to prevent legal proceedings for property taking. If the state and federal governments are going to pay millions for salmonid rehabilitation, then tax credits for the retention of key habitat features may be a reasonable step.

Some of our recommendations can be independently evaluated, while others must be considered as complete packages that cannot be separated. For example, recommended widths for the WLPZ depend on our definition of the channel zone. If the SRP's channel zone definition is modified, then the width of the WLPZ must be re-evaluated. Winter hauling is another example. A recommendation for continued winter hauling depends on formulating and enforcing adequate rocking and road surface stabilization standards. Finally, all our recommendations depend on implementing an adequate watershed analysis program.

Critical research needs were too numerous to adequately address in this report. The SRP listed a few research needs including quantification of salmonid-habitat relationships, LWD recruitment dynamics, and sediment studies on Class III watercourses.

ACKNOWLEDGEMENTS

The SRP would like to acknowledge and thank the numerous interviewees who took time from their busy schedules to meet with our panel and express their views and concerns regarding salmonids. We would also like to express our gratitude to the staff members at Natural Resources Management Corporation and Stillwater Sciences, particularly Juanita Petersen, Angela Percival, Bill Sears, and Sabrina Simpson. Without their support and assistance the development and completion of this report in a timely manner would not have happened. We would also like to thank the local, state, and federal agencies that provided our panel with meeting facilities during our interviews.

Cover illustration by Angela Percival.

Contents

APPENDICES

I INTRODUCTION

The Scientific Review Panel (SRP) was created under the auspices of the Watershed Protection and Restoration Council, as required by Memorandum of Agreement (MOA) between the National Marine Fisheries Service (NMFS) and The California Resources Agency. This MOA was signed in March of 1998, and was instrumental in deferring the listing of the steelhead (*Oncorhynchus mykiss*) along the north coast of California. As part of the MOA, The Resources Agency agreed to organize an independent panel of scientists, the Scientific Review Panel (SRP) to undertake a comprehensive review of the California Forest Practice Rules (FPRs), with regard to their adequacy for the protection of salmonid species. A copy of the MOA is included as Appendix A.

The SRP met initially in November of 1998. This meeting was attended by representatives of NMFS, The Resources Agency, the California Department of Forestry and Fire Protection (CDF), and the California Department of Fish and Game (DF&G). This meeting included a general discussion of the goals and objectives of the scientific review and the timing necessary to meet the objectives of the federal and state agencies. NMFS stated that it was their goal to have the SRP report completed and presented to the agencies so that any potential rule changes could be considered in time for implementation by January 1, 2000. In order to provide sufficient time for the Board of Forestry or other rule making bodies to review the report and hold public hearings on any proposed rule changes, it was necessary to complete the report by June 1999. The completed report was to be submitted to The Resources Agency and NMFS.

NMFS and The Resources Agency jointly developed a letter that posed a series of questions, regarding a review of the FPRs, the THP review and approval process, and the rule making process. A copy of this letter is included as Appendix B. The agencies also requested that the public be involved and be able to provide comments and information to the SRP. Beyond this input, no state or federal agency provided any direction to, or had any control over the SRP.

THE SRP'S MANDATE

The MOA required (MOA, Sec 9(f)) that the SRP conduct a review of "California's forest practices regulations, their implementation and enforcement in order to determine their adequacy". This same section of the MOA directed the SRP to develop the following products: " (1) define properly functioning habitat conditions which adequately conserve anadromous salmonids; and (2) jointly review the adequacy of the California Forest Practice Rules, including implementation and enforcement, to achieve properly functioning habitat conditions," Given this direction, the SRP assumed that the scope of the review and analysis was to include all anadromous salmonids, and was not limited to steelhead.

In order to address requirements of the MOA and the four questions posed to the SRP by The Resources Agency in the October 19, 1998 letter from Undersecretary Jim Branham (see Appendix B), the SRP members agreed that a comprehensive review of the rules and process was necessary, including a review of the rule making process, the rules, rule implementation through the Timber Harvesting Plan (THP) review and approval process, administration during harvesting, and post-harvest follow up.

The SRP recognizes that there are many factors that may impact salmonids other than forest management, The SRP was aware of these factors, but our analysis and resulting report focuses on interactions between forestry and salmonids.

Because the charge of the SRP was to review the rules for adequacy specific to protecting salmonids, we did not consider other non-related resources. Therefore, recommendations presented in our report may or may not affect (either in a positive or negative manner) other resources. The SRP also recognizes that there may be financial impacts to landowners and state programs resulting from the implementation of recommendations contained herein to achieve properly functioning salmonid habitat. The SRP provides additional recommendations to address this issue.

GEOGRAPHIC RANGE OF APPLICATION

The state and federal MOA specifically addressed steelhead in the Northern California and Klamath Mountains Province ESUs. The California portion of these ESUs ranges from the Oregon border south to the northern boundary of the Russian River basin, and inland to the crest of the Coast Range (see Figure 1). The SRP interviews included representatives from the Oregon border south to Santa Cruz, and east to the crest of the Coast Range. This is consistent with the region included in the Northern California and Klamath Mountams Province steelhead ESUs, and includes portions of the Coast Forest District and the Northern Forest District. Considerations and recommendations presented in this report apply specifically to this geographic area and are not necessarily applicable to other areas.

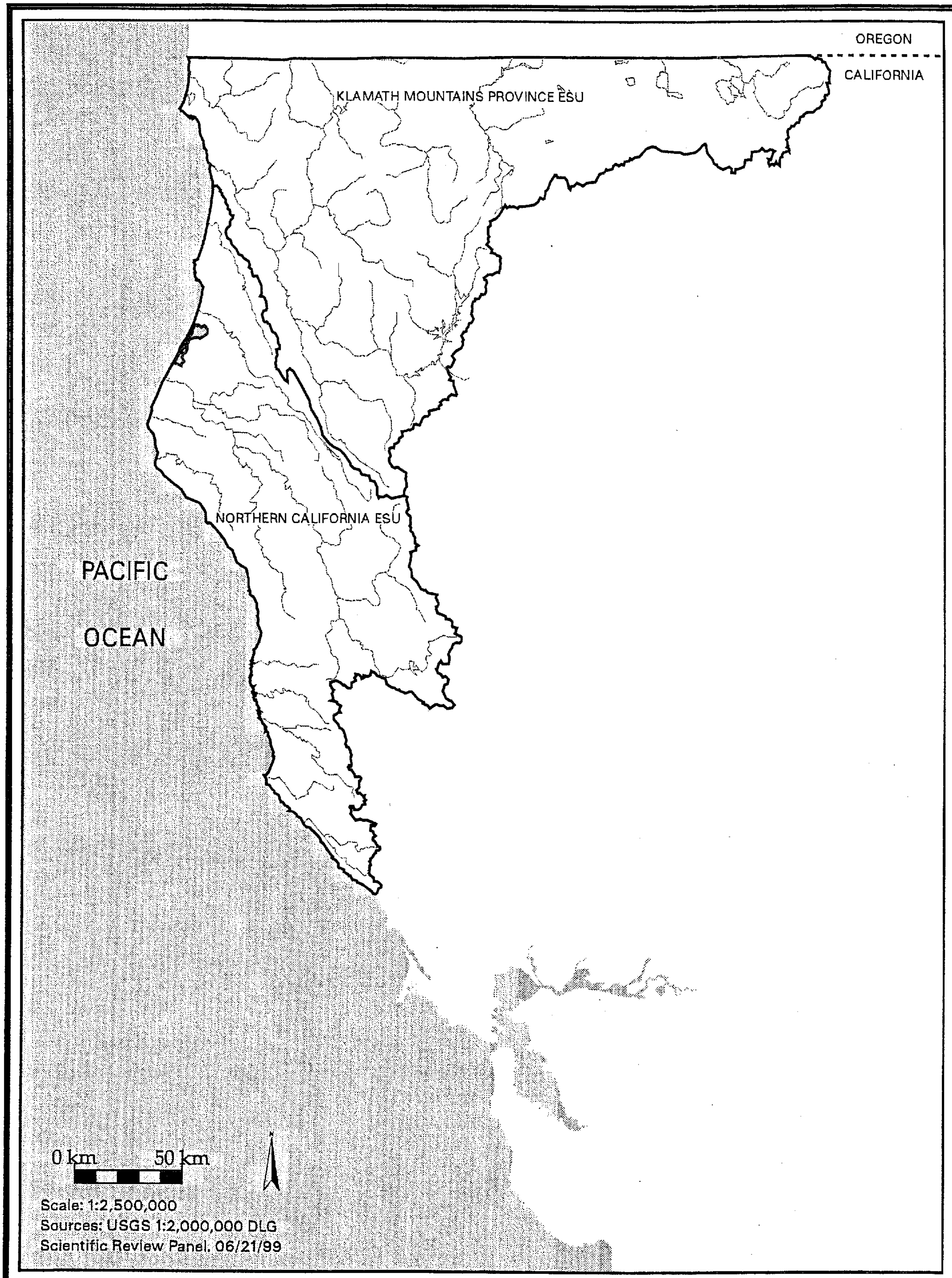


Figure 1. Northern California and Klamath Mountains Province steelhead ESUs within California

II APPROACH AND METHODOLOGY

To implement the project, the SRP met independently in November of 1998. The SRP decided to operate as a consensus group, with one panel member serving as coordinator. The SRP also developed a plan to involve public, state and federal agencies, landowners, and other interested parties. Various constituency groups interested in salmon issues were invited to meet with the SRP. The SRP identified 28 different constituency groups. The participants were selected by recommendation and agreement of the SRP members, and were invited by letter (Appendix C) to partake in panel interviews and discussions. The letter of invitation included, or was followed by, a series of prepared questions. Different questions were prepared for each constituency group (Appendix D) . The interviewees were asked to respond to these questions candidly and were promised that they would not be quoted as individuals, but might be quoted as a constituency group. These discussions were not recorded or video taped. SRP members took notes and often engaged interviewees in discussion.

The interviews were conducted between January and May of 1999. Interviewees included state and federal agency representatives, environmental group representatives, large and small landowners, foresters, geologists, watershed specialists, fisheries and fish restoration representatives, South of San Francisco ("856 counties") representatives, and fisheries biologists. Interviews were conducted in Sacramento, Berkeley, Santa Rosa, Ukiah, and Eureka. A total of 128 people were interviewed by the SRP, mostly in discussion groups involving three or more interviewees. The industrial landowner representatives were interviewed separately due to potential antitrust issues.

To evaluate their adequacy for protecting salmonids, the SRP was charged with a review of the FPRs. This required a review of the rules, the Board of Forestry rule making process, and how the rules are actually applied once THPs are approved. Several interviewees noted that the rules were the minimums required by law, and it would be unlikely that a THP would ever be approved in the north coast region of California, if submitted under these standards. One agency representative stated that he felt that the rules themselves were inadequate, but that the THP approval process was adequate. This is because the rules contain intent language that allows the agencies to require higher protection standards than the minimums provided in the rules. A representative of the environmental community noted that this broad intent language and the "explain and justify" sections of many rules provided an "equal and opposite" exception to every rule.

In order to better understand the rules and the THP approval process, the SRP reviewed the 1999 version of the rules, THPs that had recently been approved, and supporting documents utilized by CDF during THP review and approval. This included the "Coho Salmon Considerations" document prepared by CDF (1997), and a subsequent document that reviewed the FPRs prepared by NMFS (1998). The Resources Agency (1998) also prepared a review of the NMFS report titled "Resources Agency's response to NMFS California Forest Practice Rules". The SRP also reviewed the report produced by NMFS and USFWS (1997) titled "Aquatic Properly Functioning Condition Matrix" (Matrix). The NMFS matrix puts forward a condition for the landscape that NMFS believes to be properly functioning with regard to the needs of anadromous salmonids and other aquatic organisms in northern California.

To obtain a better understanding of how the THP review and approval system works, the SRP interviewed representatives of the full complement of agencies involved in the THP review and approval process, as well as RPFs preparing THPs and members of the public reviewing THPs.

The SRP also reviewed the 2090 Agreement (CDFG 1996) that was developed to address forestry activities and potential impacts to the coho salmon in the area located south of San Francisco. Coho salmon in this area were listed under the state ESA (CESA) before the federal listing.

The state provided SRP members with copies of the current FPRs (CDF 1999). This version was compiled by the CDF for use by licensed timber operators (LTOs) and registered professional foresters (RPFs) "to provide field personnel with working rules for their use." The authoritative FPRs are printed by Barclays Official California Code of Regulations. The Barclays version is printed in a larger format, and contains the history of each rule section.

The "Coho Salmon Considerations" document was prepared by CDF and sent to all RPFs on April 29, 1997. The complete title of this document is "Coho Salmon (*Oncorhynchus kisutch*) Considerations for Timber Harvesting Under The California Forest Practice Rules." The stated purpose of the document was "to provide some biological background regarding coho salmon and its habitat, provide guidance to RPFs, landowners and CDF in their assessments of possible adverse impacts to salmon habitat and to describe potential conservation measures for timber operations within the Central California Coast and Transboundary ESUs." The introduction to the document states it is for guidance only, and encourages RPFs to seek input during plan development from NMFS, DF&G, and/or non-agency fisheries biologists.

THPs submitted after the release of the "Coho Salmon Considerations" were required to incorporate considerations for impacts to coho salmon in the THP. While the benefits of these measures may not be agreed to by all of the agencies, CDF Forest Practice Inspectors indicated that after the document was released they had seen the canopy retention levels on Class I watercourses increase to 70-80% as compared to the minimum of 50%.

NMFS released a document identifying their concerns with the FPRs on May 22, 1998 entitled "Effectiveness of the California Forest Practice Rules to Conserve Anadromous Salmonids." Under "General Concerns" the document states:

"Two areas of concern that the National Mat-me Fisheries Service has with the implementation of the California Forest Practice Rules relate *to the large number of rules under which adequate conservation for anadromous salmonids depends heavily on the Registered Professional Forester (RPF) having a high level of biological, ecological, and/or geological expertise. It is unrealistic to expect ail RPFs have such knowledge. Often, the conservation of ecological resources, including anadromous salmonids, depends upon protective measures that are inserted in to Timber Harvest Plans (THPs) during the review process. Two state agencies, the California Department of Fish and Game (DF& G) and the Regional Water Quality Control Board (RWQCB) have been given statutory responsibility to review THPs for compliance with the California Fish and Game Code and Clean Water Act, respectively. The Division of Mines and Geology also reviews THPs. No integrated guidelines or policies* are *available to provide a framework for treatment of THPs through the review process (Little Hoover Commission 1994). In addition, the agencies can review only a small fraction of the THPs, and thus are forced to rely on RPFs, not agency personnel, to determine problems and design mitigation measures. Furthermore, even when these agencies participate in a review, there is no requirement that the agencies recommendations must be incorporated into THPs."*

The NMFS report reviews specific rule sections of the FPRs and provides opinions on whether the rule is adequate or inadequate, if the rule requires a high level of expertise to implement, or if implementation relies on agency review that is not consistent. The report displays the analysis of the rules in a matrix format, and provides additional narrative comments on selected rules. Of the rule sections reviewed, NMFS listed nine as adequate and 20 as inadequate.

The Resources Agency responded to the NMFS report in an 81-page report dated July 2, 1998. In the preface the report states:

"Taken in isolation, the individual sections of the rules may not appear to provide adequate protection for watercourses of the habitat and species that rely on watercourses. California relies on an adaptive management approach to in regula ting timber harvesting. This approach relies heavily on mitigating any significant impact on environmental resources. It is a process that allows the reviewing agencies to ask the question 'How is coho being protected?' and ends up with a plan that fully protects the species and its habitat."

The Resources Agency report included the original NMFS comments and the response to each issue raised by NMFS.

Another document that specifically addresses salmon is the 2090 Agreement (CDFG 1996). This is a Biological Opinion (BO) under the CESA issued on April 17, 1999 by the DF&G to CDF for the "Review And Approval Of Timber Harvest Plans And Timber Operations Plans In The Range Of The Coho Salmon South Of San Francisco." The BO found that DF&G and CDF concur with these Conservation Measures prescribed in the BO:

- Provide foresters specific information and guidelines for coho salmon protection;
- Allow CDF to approve a majority of plans with minimum delays;
- Ensure the Board of Forestry's Forest Practice Rules are applied appropriately to protect coho salmon without the need for new regulations;
- Give Registered Professional Foresters (RPFs) flexibility with respect to their projects by allowing them to develop alternatives to the mitigation and avoidance measures prescribed in this Biological Opinion where such alternatives provide equal or greater protection for coho salmon;
- Obviate the need for consultation with DF&G in most situations;
- Provide DF&G the option, as necessary and in concert with CDF, to create a citizen advisory group for exchanging concerns and suggestions: and
- Provide monitoring information that will help determine the level of success achieved by the Conservation Measures.
- The conservation measures in the agreement include: (1) requirements for a more intensive cumulative effects analysis (but not a full-scale watershed analysis); (2) conclusions regarding potential impacts to coho salmon; (3) baseline conservation measures for watercourse protection; (4) director's approval standards for THPs; and, (5) requirements for a monitoring program.

Under the 2090 Agreement, the baseline conservation standards for Class I streams require 85% shade canopy within 25 feet of the watercourse and 75% for the remaining Watercourse and Lake Protection Zone (WLPZ) if there are concerns regarding water temperature for protection of salmonids. DF&G must approve all new road or landing construction within the WLPZ except at crossings, All roads within the WLPZ must be rocked or otherwise stabilized before the start of the winter operating period, and all skid trails within the WLPZ must be covered with tractor-packed slash before the start of the winter period. Any area of disturbed soil greater than 100 square feet within the WLPZ must be treated prior to the winter period. The trees in the WLPZ must be marked prior to the pre-harvest inspection (PHI) and, if large woody debris (LWD) is lacking, the RPF must propose measures for its recruitment, including placing LWD in the channel (in cooperation with DF&G). The minimum road maintenance period is three years.

Standards for Class II and III watercourses are more restrictive than the current rules. This includes 75% canopy cover on Class II streams where there are temperature concerns. Class III's must have suitable Equipment Limitation Zones

(ELZs) to prevent the generation of erosion into watercourses, and all tractor crossings must be flagged prior to PHI. All operations must avoid dislodging LWD currently in the channels of Class III streams and site preparation cannot occur if it will generate sediment into Class IIIs.

Of all the constituency groups interviewed by the SRP, there was broad agreement among the participants of the 2090 group even though they included landowners, RPFs, and agency representatives from CDF, RWQCB, and DF&G. This group had worked together extensively and it was clear they had developed mutual trust. All members of the 2090 group felt the 2090 Agreement was sufficient to protect coho salmon and was not overly burdensome to landowners.

III BIOLOGICAL CONSIDERATIONS

LIFE STAGE REQUIREMENTS OF SALMONIDS

Timber harvesting can adversely affect aquatic systems and therefore negatively impact salmonids. Timber harvesting operations involving log skidding, road and landing construction, road maintenance, and harvest of trees in riparian areas can increase input of fine sediments into stream channels, increase water temperatures, affect aquatic food resources, and reduce long-term recruitment of LWD (Chamberlin et al. 1991, Furniss et al. 1991, Beschta et al. 1987).

Understanding the biological and physical factors that are necessary to sustain salmonid populations is critical to developing forest management strategies to protect and, if possible, improve habitat and populations. Salmonid production is affected by environmental conditions at each life stage. Salmonids have different habitat requirements for the successful completion of each of their life stage; i.e., egg development and hatching, fry and juvenile growth and survival, parr-smolt transformation, and life in the ocean. Thus, it is essential to understand what a watershed has to offer each of these species of fish, before one can determine: (1) potential impacts of a timber harvesting; and, (2) whether or not mitigation measures would offset impacts to the point of no net impact.

Life history events for salmonids must be discussed in concert with key life stage requirements. Life stage requirements are those features of an organism's environment that are essential to its continued survival and reproductive success. Critical life stage requirement variables for salmonids include:

- Appropriate water temperatures
- Appropriate water quality;
- Abundant food;
- Accessibility to spawning and rearing areas: and,
- Appropriate physical habitat.

Each of the life stage requirements may vary, depending upon the season and the life stage and condition of the fish. If any life stage of any species is deprived of a life stage requirement, the population as a whole can be negatively affected. When life stage requirements are not met, or are limited in some way, the fish's survival and reproductive success can be jeopardized.

Factors limiting to populations are called "limiting factors." Fry (1971) used the term to describe environmental factors (e.g., food, dissolved oxygen, other respiratory gases) that limited the metabolic rate of fishes. Limiting factors operate by restricting the supply or removal of materials involved in metabolism. Thus, a reduction in the supply of dissolved oxygen (DO) below a certain level can reduce metabolic rate, and below that level it can be said that the oxygen supply is limiting. The effect of a limiting factor is to reduce the maximum metabolic rate that would be permitted by the existing levels of controlling factors, such as temperature. During the past decade, agency and forest industry biologists working on THPs and watershed analyses have expanded the limiting factors concept to apply to ecological systems. Thus, the terms "lethal", "controlling", "limiting", "masking", and "directive", that were originally used to describe physiological processes, are now being used to describe both environmental and physiological processes that affect fish production (Reeves et al. 1989). Potential limiting factors from an ecological context include: water temperature, sediment, water quality, and the quantity and quality of habitat suitable for spawning and rearing. Some potentially limiting factors can be influenced by human intervention: others, such as the lack of water, often cannot be altered.

Before one can assess whether or not a proposed THP could have an impact on salmonids, one must identify the following:

- the requirements of the species: and,
- any potential factors that may be limiting to populations of the species.

As each life stage of a salmonid has specific habitat requirements, it is imperative to understand the factors that influence habitat quantity and quality for each life stage and the thresholds required for successful survival to the next life stage. For example, the prediction that a temperature increase would limit growth rate by a specified amount without knowledge of other potentially limiting factors (e.g., food availability) can lead to significant errors in predicting potential population responses, such as decreases in smolt production in a watershed. In order to understand how environmental factors influence salmonid productivity, it is necessary to first identify the components that strongly influence fish survival. Each of these components is influenced by physical and ecological processes that may be affected by forest management activities in a watershed.

Ideally, by integrating knowledge of salmonid habitat requirements with that of historical and existing conditions, one can determine how habitat conditions for salmonids have been affected by past and ongoing watershed activities and how a proposed timber harvest may further affect these habitat conditions. In addition, by determining what salmonids need, it may be possible to mitigate negative impacts, and, thus, restore the health of salmonid populations within the watershed. The use of this general approach, together with a monitoring and adaptive management plan may improve fish habitat and populations.

The best method for identifying salmonid life stage requirements, determining whether or not these requirements are being met, and determining what is needed to maintain or restore salmonid populations is to use site-specific data. However, site-specific information is often incomplete for one or more of the life stages of the salmonids. Thus, when site-specific data are not available, it is customary to extrapolate using information from other areas. Then, ideally, as more site-specific information becomes available, requirements for each life stage of a salmonid would be re-evaluated in a particular area and/or watershed on an ongoing basis. If necessary, the standards for one or more of these requirements could be modified, if there were a scientific basis for such a change.

In the absence of appropriate site-specific studies, it is common to analyze information from other areas or laboratories and to identify a "threshold value" or "threshold effect". "Threshold values" and "threshold effects" are two commonly used terms that are rarely defined during the THP process, but are often determined using laboratory data. Biologically speaking, a "threshold" is a level or value that must be reached before an event occurs; a "threshold effect" is the harmful effect of a small change in the environment that exceeds the limit of tolerance of an organism or population, and (Lawrence 1995). There are several problems with using thresholds based on data from laboratories or areas other than the site of interest. First, in the laboratory environment, one is forced to control or eliminate many of the factors (e.g., effect of ration size on thermal requirements, effect of energy expenditure as a result of escaping predators or seeking prey, effect of previous stressors) that affect fish in the wild. Thus, laboratory data are not analogous to those collected in a stream. Therefore, wherever possible, site-specific information should be used to determine life stage requirements and impacts of proposed THPs and incorporated into the watershed analysis for areas where timber harvest is going to occur.

In the following paragraphs, critical life stage requirement variables for salmonids are discussed. No specific threshold values or quantitative estimates are provided because such information should be based on site-specific data.

Appropriate Water Temperatures

Of all of the life stage requirements for fish, water temperature may be the most important, and yet least understood by those involved with the THP process. A major problem hindering precise understanding of temperature effects is that many environmental factors (e.g., food availability, previous exposure to stress, genetic adaptation, age and size) simultaneously influence a fish's response to temperature. Water temperature can be considered in two ways: (1) as a factor affecting the rate of development, metabolism, and growth; or (2) as a stressful or lethal factor. The two, of course, are inseparable. Fishes are poikilotherms, or cold-blooded animals, which means that their internal body temperature varies, according to the external environment. This means that a fish has little physiological control (i.e., thermoregulation) over its body temperature; if the water is hot, the fish is hot and if the water is cold, the fish is cold, etc. Thus, fish have no physiological way to quickly acclimate to changes in water temperature. And a fish's metabolism, which controls all aspects of its body, is directly proportional to water temperature, within certain limits. Thus, as water temperatures increase, so does the metabolic rate and the need for food. If there is enough food available and dissolved oxygen conditions are sufficient, then the fish will grow, within certain thermal ranges. However, if the amount of food is limited and/or other stressors exist (e.g., low dissolved oxygen, pollution), the fish will not grow. Beyond certain physiological limits, however, even an increase in food availability will not assist the fish; beyond this point, water temperature can be stressful and even lethal,

Despite a fish's inability to change quickly, physiologically, they often use behavior to thermoregulate. This is of great importance when their habitat provides more than one thermal option. For example, in studies on the Navarro River (Rich 1991), juvenile coho salmon were collected in water temperatures that would be considered stressful according to results in the scientific literature. Yet, the fish had good growth rates and appeared to be healthy: It was surmised that both the abundant food resources and cool thermal "refugia" accounted for this apparent anomaly (Rich 1991). Thus, within the thermocline in the pool, the cooler areas provided a refuge for the salmonids during the hot part of the day. The fish could then digest their food at physiologically acceptable water temperatures, even though a large percentage of the pools were characterized by high water temperatures.

In establishing criteria for setting safe limits of water temperatures for each life stage of a selected fish species, chronic sublethal stressful water temperatures are usually of more importance to fishes than acute lethal temperatures. Sublethal stressful water temperatures are more common and the results less easily studied and understood than a "fish kill", resulting from lethal water temperatures. However, sublethal water temperatures can effectively block migration, reduce growth rate, create disease problems, and inhibit smoltification (Elliott 1981). All of these stress indicators have been directly and indirectly linked with survival in natural populations of salmonids. In addition, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of the exposure. Thus, the longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival. In fact, sublethal thermal stress is as decisive as lethal temperatures to continued survival (Brett 1956). It is of paramount importance that the impacts of sublethal stressful water temperatures be understood and, when possible, mitigation measures be implemented to reduce potential impacts on salmonid production.

Water temperature criteria used for salmonids are often subject to debate. One primary reason for this problem stems from the fact that it is common to base water temperature standards on selected laboratory data, rather than on site-specific field data for a given species. For example, water temperature requirements for salmonids are often developed from laboratory data reported in the scientific literature without any understanding of the physiological and/or behavioral response of the fish to changes in water temperature in the area proposed for timber harvesting. Therefore, water temperature standards established under a laboratory setting often do not agree with field data for a given fish species and impacts of water temperature on salmonids in the field can differ, depending upon ambient conditions.

The interaction of water temperature and the physiology of fishes in the wild is far more complex than in a controlled laboratory setting. Consequently, extrapolation of results from such tests to the natural environmental can often lead to incorrect evaluations and inaccurate predictions of thermal impacts on salmonids. For example, a summer temperature might enhance coho salmon production in a northern stream, but depress it in a southern one. Thus, to identify appropriate water temperature requirements and determine whether or not a particular timber harvest will result in impacts on salmonids, the best method is to use a site-specific thermal physiology approach that integrates information on water temperature, food use, and fish growth. The approach needs to: (1) permit the detection of stress-related variables that are biologically and ecologically relevant; and, (2) maximize predictive capabilities (Adams 1990).

The variety of methodologies used to assess thermal impacts can result in a variety of interpretations of the data. The lack of standardized methodologies among fish physiologists has resulted in many definitions for the same term. Similar to all specific areas of scientific inquiry, fish thermal physiology has its own nomenclature that can be confusing when there are different meanings for "optimal", "lethal", "preferred", "tolerance ", "threshold", and "stressful" temperatures. Such a lack of standardization is problematical when one compares the results of one "optimal temperature" study with those of another, and the results of the former are based on "thermal tolerance" while those of the latter are based on growth rate. Similarly, the term "lethal" can be used literally, as a percentage of the eggs or fish that die. But, the term "lethal" is often also used by physiologists to identify the temperature at which 50% of the eggs or fish die within 28 days, or 7 days, or even 14 hours within a laboratory setting, hardly something one can directly apply to a field situation (Fry et al. 1942, Brett 1944).

Another problem with determining the water temperature requirements of salmonids is one of misinterpretation, primarily from biologists with no background in fish physiology, Following are some examples of such misinterpretations/misapplications (Rich 1997).

- Transferring of numbers (e.g., percent mortality, thermal optimum) directly from a laboratory study to a field situation in another geographical area. The impacts of water temperature are not only species and life stage specific, they are site specific, as well, because the wild fish's responses to water temperature is far more complicated than those of a laboratory fish in a controlled environment.
- When conducting a review of information, disregarding some of the thermal studies reported in the scientific literature. This is an unfortunate problem because, by selectively excluding studies, one does not have an accurate representation of the range of. thermal impacts that have been reported, and thus, one cannot accurately establish unstressful thermal ranges for salmonids.
- "Inputting" field data from a salmonid study directly into an unvalidated growth-temperature model, such as the model designed by Brett et al. (1982). The problem with this is at least two-fold: (1) most of the bioenergetics models reported in the scientific literature have not been validated; and, (2) unless site-specific studies are undertaken, one has no idea what percent of maximal ration the fish consume in the field, as they rarely, if ever con-

sumer the maximal rations usually reported in the laboratory studies.

By incorrectly applying the results of the studies, incorrect conclusions are made, with regard to optimal, stressful, and lethal water temperatures. Thus, to determine potential impacts of a THP, it is important to understand and correctly apply the results of thermal studies, using site-specific data.

A method commonly used by fish physiologists for determining both thermal requirements and impacts on fishes is bioenergetics (Brett and Groves 1979). Very simply stated, bioenergetics is the study of where food goes, once an organism ingests it. Once food is eaten, the energy must first go to maintaining the fish's basic metabolism. Then, if there is energy left over, the energy is used for swimming or reproduction or growth. However, if water temperatures are high, more energy is needed for basic metabolism and for swimming and hence, more food is needed. If the food available satisfies the basic requirements for the fish, then energy will be used for swimming and, eventually for other functions such as growth and reproduction. As water temperature, food availability and fish growth are integral components to bioenergetics, it is possible to determine optimal water temperatures for a given life stage of a fish, if one knows how fast the fish grows and what and how much the fish eats over a given time period.

A functional (from the standpoint of a meaningful site-specific field studies) method for determining optimal water temperatures and impacts is the use of the Computerized *Fish Bioenergetics* models originally developed in the late 1980s at the University of Wisconsin (University of Wisconsin 1997; Hewett and Johnson 1992, 1989). These computerized models were developed from sythesizing the results of many fish bioenergetics studies and, provided one collects the appropriate site-specific data, can be adapted to any life stage of salmonids. Thus, instead of using an upper optimal threshold of about 15°C for juvenile coho salmon for any stream inhabited by this species, one would determine the appropriate range of water temperatures for a specific stream, based on food availability and existing water temperatures. Using bioenergetics modeling, in conjunction with thermal modeling, it is also possible to predict both short-term (i.e., months) and long-term (i.e., years) impacts on the total productivity of salmonids emigrating out of a system.

In summary, knowledge of temperature tolerance and sublethal stress responses of salmonids is far from adequate to define safe thermal limits and determine potential thermal impacts for each THP Key factors that affect thermal requirements and stress include food availability, dissolved oxygen, previous exposures to stressful situations, and innate metabolic rate (i.e., fish with more hatchery genes have lower metabolic rates that their wild counterparts), Until a more site-specific physiological approach is used in conjunction with a watershed analysis, determining site-specific thermal requirements and impacts on salmonids as a result of timber harvesting will remain in the realm of conjecture.

Suitable Water Quality Conditions

Dissolved Oxygen

Of the various fish species, salmonids are particularly sensitive to low dissolved oxygen (DO) concentrations. Except for rare occasions, dissolved oxygen is not likely to be limiting to salmonid populations in the geographic range covered by this assessment. To establish DO concentration requirements, a limited amount of site-specific data should be collected as part of the watershed analysis, which can integrate water temperatures, food eaten, and ambient DO concentrations.

Contaminants

Forest fertilization and the use of chemicals such as fire retardants, herbicides, pesticides may affect water quality and nutrient cycling processes in watersheds occupied by salmonids. Detailed discussion of potential effects of such forest management practices was considered beyond the purview of the SRP.

Sedimentation and Turbidity

Salmonids require and seek out clean (silt-free) gravel, They will spawn and rear in embedded substrate if nothing else is available; however, there is usually a subsequent reduction in survival to emergence. Successful spawning, incubation, and fry emergence depends upon the following factors: (1) size class composition of the substrate; (2) existing degree of embeddedness; (3) substrate permeability down to below the point of egg deposition in the fish's redd; and, (4) percolation rate of water through the substrate.

It is well known that fine sediments can influence the survival of salmonids, particularly at the egg and alevin life stages. Considerable research has shown that varying amounts of fine sediments (defined in most studies as particles with a diameter of less than 3 mm or 0.85 mm) may reduce intergravel flow and the delivery of dissolved oxygen to incubating eggs and developing alevins in the redd (McNeil and Ahnell 1964; Cooper 1965). Fines may also form a seal or cap in the upper layers of the redd gravel (Einstein 1968), impeding or obstructing the emergence of alevins in a process known as "entombment" (Koski 1966, Cloern 1976, Phillips et al. 1975). Filling of pools with fine sediments can reduce carrying capacity of rearing habitats for juvenile salmonids (Bjornn et al. 1977). Sedimentation also may fill interstitial spaces in the substrate used as velocity refuges by juvenile salmonids during high flow events or low temperatures (Hillman et al. 1987). Such filling of interstitial spaces also reduces habitat for aquatic macroinvertebrates and may therefore reduce juvenile salmonid production (Crouse et al. 1981). Increased input of fine sediment may most seriously impact salmonid habitat when the source continues to deliver sediment over a long period of time (Chamberlin 1982). It is generally accepted that increased input of fine sediment can be harmful to salmonids; however, determining the exact threshold amount that may limit production of salmonid populations within a watershed is more problematic. Many stream systems in California have naturally high sediment loads, including an abundance of fine materials less than 1 mm diameter, yet, historically these streams supported healthy populations of salmonids (Sedell and Swanson 1984). Nevertheless, in many streams within the region covered by this review, delivery of fine sediment may have increased over background rates and legacy effects of poorly constructed roads or poorly conducted logging on unstable hillslopes may be a continuing source of fine sediment to streams.

Chronic turbidity that is caused by fine sediment suspended in the water column may interfere with feeding by juvenile salmonids and thereby reduce growth. Other potential effects of suspended sediment on salmonids include irritation of gill tissues, avoidance behavior, and mortality at very high concentrations (Noggle 1978).

Abundant Food Resources

Salmonids are opportunistic predators that eat a wide variety of aquatic invertebrates, as well as terrestrial invertebrates that fall into the stream (Mundie 1969, Elliott 1973, Tippets and Moyle 1978). Abundant food is particularly important to salmonids during warm summer months, when water temperatures and metabolisms are high. In order to survive and grow, young salmonids require a large and constantly replenished supply of food, The relationship between food availability and water temperature is an extremely important phenomenon that is too often ignored when fisheries biologists attempt to determine the optimal temperatures for salmonids. Consequently, evaluation of food availability should be included with assessment of water temperature in the watershed analysis.

Access to Spawning and Rearing Areas

Physical barriers (e.g., culverts, waterfalls, debris jams) may sometimes delay, or block upstream and downstream movements by salmonids. Such barriers may reduce the amount of spawning habitat available for salmonids. Information on barriers that prohibit access to areas historically accessible to salmonids must be included in a watershed analysis.

Appropriate Physical Habitat

The amount of streamflow, substrate quality and quantity, appropriate water depths, and adequate shelter or cover affect all life stages of salmonids. Sedimentation of substrate is discussed under “Suitable Water Quality Conditions” above.

Large Woody Debris

Reduction of in-channel LWD through splash-damming, stream cleaning, and harvesting of trees in riparian areas may lead to the loss of habitat features important to juvenile salmonids. Reductions in LWD may cause decreased frequency, depth, and complexity of pool habitat used by rearing juvenile and holding adult salmonids. In particular, the carrying capacity of streams for older age classes of juvenile salmonids may be reduced as these life stages typically prefer deeper pool habitats (Bisson et al. 1988). Reduced LWD may also limit formation of backwater pools and the complex stream margin habitat used by emergent fry (McCain 1992). Stream channels tend to become simpler and less stable after the removal of LWD, and the structural complexity that provides substrate diversity, low-velocity refugia during high flows, and cover from predation is also lost (McMahon and Reeves 1989). Other impacts of reduced in-channel LWD may include reduced retention and sorting of spawning gravels and fine sediment, and reduced retention of fine and coarse organic materials important for maintaining macroinvertebrate communities used as food by juvenile salmonids, as well as reduced retention of salmonid carcasses that contribute important nutrients to the stream and food for juvenile salmonids.

I nstream Flows

Of the factors known to influence anadromous salmonids’ ascent of streams, flow connected with storm events is one of the most important. Once the fish immigrate into a stream, there has to be enough water for them to pass over barriers in order for the fish to reach their spawning areas. Streamflow regulates the amount of spawning area available; as flows increase (up to a point), more gravel is covered and becomes suitable for spawning. During egg incubation and fry emergence, adequate streamflows are necessary to cover the eggs, provide oxygen, and wash away metabolic waste. During rearing, the amount of food and physical habitat available is related to streamflow. Streamflow is also an important factor during the pat-r-smolt transformation and emigration of anadromous fishes.

Water depth is important to salmonids, particularly during the immigration and spawning season. Preferred depths have been determined by measuring the water depth over active redds (Shapovolov and Taft 1954, Thompson 1972, Hooper 1973, Smith 1973). Cover is an important factor in a fish’s life. Cover provides protection from predators (e.g., birds, mammals, other fishes), as well as, sometimes, reduced water temperatures during hot days. Cover can be provided by overhanging vegetation, undercut banks, submerged rocks and vegetation, submerged objects such as logs, floating debris, and even turbulence and depth, sometimes. Young salmonids prefer habitats characterized by abundant cover. The nearness of cover to a spawning area may be a factor in the actual selection of spawning sites; some salmonids select areas adjacent to undercut banks and overhanging vegetation (Moyle 1976, Reiser and Bjornn 1979). Although, it is generally accepted that salmonids require cover, there is a large body of evidence demonstrating that abundant shade may result in the reduction in density of both salmonids and invertebrates, the food sources of salmonids. Many investigators have found that heavily-shaded streams were less productive than open-canopied streams (Murphy and Hall 198 1, Bisson and Sedell 1984); however, greater productivity does not guarantee healthier salmonid populations. In summary, site-specific studies should be conducted on physical habitat requirements, as part of the watershed analysis.

Biological Interactions

In determining the impacts of a proposed THP, there are a myriad of complex ecological interactions within the freshwater aquatic environment that can affect salmonids and that we have not discussed. For example, the introduction of non-native fish species such as bass and brown trout have certainly had a negative impact on salmonid populations in some areas, Predation by birds, mammals, and piscivorous fishes also can affect salmonid populations. In addition, disease, including pathogens introduced by hatchery stocks, may be an important factor in some streams. As these ecological interactions are important in determining the impacts of timber harvesting, they should be addressed as part of the watershed analysis approach.

Ocean Impacts

Ocean conditions affect survival and productivity of anadromous salmonid stocks during their life cycle. Similar to the freshwater environment, unfavorable ocean and estuarine conditions act as limiting factors to the successful completion of the anadromous salmonid's life cycle. Recent studies indicated that fluctuations in climate (e.g., El Niño and other global weather phenomena) were the ultimate source of widespread, regionally coherent changes in marine survival rates for many anadromous salmonids (Lawson 1993, Beamish and Bouillon 1993, Hare et al. 1999). From 1977 to the early 1990's, ocean conditions generally disfavored West Coast stocks and favored Alaska stocks (Hare et al. 1999). It was postulated that unfavorable ocean conditions were confounding recent management efforts focused on increasing West coast Pacific salmon production. Due to the lo-year climatic cycle apparently affecting productivity in the Pacific Ocean, recovery of at-risk (i.e., threatened and endangered) salmonid stocks may have to await the next reversal of the productivity cycle (Hare et al. 1999). Detailed discussion of the factors that affect salmonids in the ocean was beyond the SRP's assigned purview. However, it is important to be aware of and consider these impacts in the context of the life history of these salmonids when conducting a watershed analysis that will later be used as the foundation for biological considerations for a THP.

Genetic Impacts

Intentional or incidental releases of hatchery-reared fishes into areas inhabited by naturally-reproducing populations potentially threaten the wild populations. The negative impacts of hatchery-bred salmonid stocks on their wild counterparts are well-known. Studies have demonstrated that hatchery stocks exhibited: (1) less of the "fight or flight" reaction associated with more hardy wild strains; (2) inferior swimming performance; (3) low survival rates: (4) low incidence of re-spawning by steelhead; and, (5) low reproductive success. These negative attributes, as well as others, are often passed on genetically to subsequent generations when interbreeding occurs with wild populations, Any, or all, of these characteristics ultimately result in genetic loss at the population level (Miller 1953; Vincent 1960; Reisenbichler and McIntyre 1977; Rich 1979; Chilcote et al. 1986; Leider et al. 1986; Johnsson et al. 1993, 1994). Detailed discussion of the influence of genetics (i.e., hatchery introductions) on productivity of salmonids in timber harvest areas was beyond the SRP's assigned purview. However, it is important to identify hatchery influences and consider their impacts in the context of the life history and productivity of salmonids in a particular watershed. Therefore, the influence of genetics on salmonids may need to be considered in the watershed analysis.

REVIEW OF AGENCY BIOLOGICAL APPROACHES

The SRP concluded that the FPRs, as currently written, do not ensure sufficient protection of salmonid habitat nor offer scientifically-based determinations of the potential impacts of THPs on salmonids. The "Coho Salmon Considerations" document (CDF 1997), while providing useful biological information, does not establish a process to evaluate potential impacts on salmonids. In order to protect and, if possible, enhance salmonid habitat and populations in forested areas, the following biologically-related steps may need to be undertaken, with regard to salmonids:

- Determine each life stage requirement needed, on a site-specific basis, to sustain each of the salmonids that inhabit the area to be harvested;
- Determine the conditions that could affect each of the species within the proposed harvested area;
- Identify protective measures that could be used to limit harvesting impacts;
- Either undertake the timber harvesting, using the protective measures or, if the proposed THP would result in one or more significant impacts that could not be mitigated, deny the THP; and,
- Monitor both short- and long-term impacts of the timber harvesting on the salmonids.

Until a scientifically meaningful methodology is designed and implemented, such as the watershed analysis approach, which can address "cause-and-effect" type interactions, it may not be possible to identify completely all impacts of THPs on anadromous salmonids. Following is an analysis of the existing biological approaches used by the agencies during the THP process.

NMFS Aquatic Properly Functioning Condition Matrix

The Aquatic Properly Functioning Condition Matrix (NMFS and USFWS 1997) was meant to be a work in progress that would be able to respond to information not previously considered.

An underlying concern with the Matrix is that one cannot determine what is "properly functioning" without conducting a watershed analysis of the area in which the timber harvesting is to occur. In addition, there needs to be an emphasis on collecting and analyzing site-specific data, rather than emphasizing the use of information from the scientific literature. Currently, there are enormous gaps in the type of scientific information needed to determine the "properly functioning condition" of a system, with regard to salmonids. For example, site-specific studies are needed to determine if and how much in-channel LWD is needed. Similarly, there has been a wide variation in the amount of sediment or silt that causes damage to salmonids and other aquatic organisms. The Matrix was intended as a work in progress and does recommend site-specific studies for many of the parameters. However, in practice, such site-specific studies rarely occur. Data meant to be used for guidance may, due to the lack of suitable alternatives, be used as minimum standards. Furthermore, the water temperature issue is not being addressed in a manner that is physiologically meaningful in the field. The Maximum Weekly Average Temperature (MWAT) method (Appendix A of the Matrix) needs to be replaced with a site-specific bioenergetics approach that includes an evaluation of food availability.

In an attempt to advance beyond the search for a "magic number" in establishing theoretical temperature tolerance limits, Brungs and Jones (1977) developed the concept of the MWAT. The MWAT is defined as follows:

$$\text{MWAT for growth} = \text{Optimum temperature} + \frac{\text{Ultimate Upper Incipient Lethal Temperature} - \text{Optimum Temperature}}{3}$$

The objective of the MWAT used in the Matrix was to provide thermal thresholds that were safe, as well as productive, for each life stage of the salmonid species. MWAT, however, as it is being used in the THP process, does not achieve that objective for the following reasons:

- Recent studies suggest that the MWAT method is not a validated hypothesis:
- The MWAT method used in the THP process does not incorporate the appropriate site-specific physiological approach that is needed to determine optimal thermal ranges and impacts; and,
- The "optimum" temperatures used for salmonids in the THP process do not appear to be based on all thermal studies reported in the scientific literature, but appear to be derived from a few selected studies.

The MWAT method, or hypothesis, has never been rigorously validated in the field. In fact, in recent years there have been an increasing number of field studies that invalidate the results of the MWAT. Two examples illustrate the importance of: (1) using site-specific data, rather than relying on a few laboratory studies; (2) using all information reported in the scientific literature, rather then selecting one or two studies upon which to base one's conclusions regarding thermal optimal ranges; and, (3) collecting the appropriate type of information.

The first example concerns the optimal temperature range for coho salmon. Brungs and Jones (1977) used 5-17°C as an optimal thermal range, depending on the season, with 15°C being optimal in laboratory fish fed maximal rations. The upper lethal temperatures they used ranged from 23-25°C. If one uses these optimal and lethal thermal ranges in the MWAT equation, the MWAT ranges between 11.0-19.7°C for coho salmon. The NMFS (1997) Matrix uses an "optimum" temperature of 13.2°C and a range of upper lethal temperatures of between 24-25.8°C for late summer rearing coho salmon. If one uses these optimal and lethal ranges in the MWAT equation, the MWAT ranges between 16.8-17.4°C. However, after the 1980 Mt. St. Helens eruption, juvenile coho salmon were collected in streams where water temperatures exceeded 20°C during much of the summer months. Despite the apparently unfavorable environment, both growth and survival rates were higher during these months than during those times when water temperatures were considered to be unstressful (i.e., below 15.6°C. And, the long-term (i.e., 3-6 years posteruption) consequences of the elevated water temperatures demonstrated a high productivity (Bisson et al. 1985). This example illustrates the importance of site-specific long-term growth-temperature (i.e., bionenergetics) studies. It also illustrates the fact that every system is unique, with regard to it food availability and salmonids' physiological response to water temperature.

A second example concerns the optimal temperature range for rearing rainbow trout and steelhead. Brungs and Jones (1977) used 17-19°C as an optimal thermal range and an upper lethal temperature of 27°C. If one uses these optimal and lethal thermal ranges in the MWAT equation, the MWAT ranges between 20.3-21.6°C. However, in Pescadero Lagoon south of San Francisco, juvenile steelhead grew quickly in water temperatures well above 21°C. The reason that the steelhead were able to grow well at temperatures that would be considered stressful from the results of laboratory studies was because of an abundant food source, primarily *Neomysis* shrimp (Smith 1990). Thus, if one were to use the MWAT equation in the Matrix for the Pescadero fish with the intent of minimizing thermal stress on salmonids, one would conclude that the temperature in that lagoon should never exceed 21.6°C, yet site-specific studies prove otherwise.

Although, in the examples above, the emphasis was on the upper optimal thermal thresholds, the same type of field validation is warranted for the lower optimal thermal thresholds, as well: low water temperatures can impede the growth process The point is that using "optimal" and "lethal" temperatures based on laboratory studies and inserting them into the MWAT equation often will not provide a realistic outcome, in terms of both thermal requirements and thermal impacts, as a result of a land use such as timber harvesting. In fact, some streams during the summer will always exceed the MWAT calculations for salmonids, yet one or more species may be present in abundance. In other instances, higher water temperatures probably either preclude the existence of, or result in stress to, salmonids. Thus, to determine the optimal range for salmonids, one must include factors not currently being assessed in the THP process. These other factors include the availability of food and food eaten, whether or not there are cool water refugia for the fish to reside in and digest their food, and site-specific thermal studies conducted during each life stage. Only then can one determine whether or not there will be thermal impacts as a result of timber harvesting and, if so, develop measures to mitigate for those impacts.

Coho Salmon Considerations Document

To assist foresters on how to address the take of coho salmon, CDF issued the document "Coho Salmon (*Oncorhynchus kisutch*) Considerations for Timber Harvests Under the California Forest Practice Rules" (CDF 1997). In the cover letter, dated April 29, 1997, to "All Registered Professional Foresters" from Craig Anthony, Deputy Director, the following statement was made:

"The enclosed document is intended to provide some biological background regarding coho salmon and its habitat, provide guidance to RPFs, landowners and CDF in their assessment ofpossible adverse impacts to salmon habitat and to describe potential conservation measures for timber operations within the Central California Coast and Trans-boundary ESUs. The two ESUs encompass all coastal watersheds that contain coho salmon from the San Lorenzo River to the Oregon border. Timber operations south of San Francisco Bay are still under the provisions of the 2090 Agreement between DFG and CDF."

The FPRs require that impacts to species sensitive to the effects of timber operations must be mitigated to a level of insignificance.

Although the "Coho Salmon Considerations" document provides general background information on the various factors (e.g., water temperature, dissolved oxygen, turbidity, LWD) that affect salmonids, it does not provide specific measures that would result in the avoidance of take of coho salmon from direct, indirect, and cumulative effects. With regard to water temperatures, although the document correctly identifies some factors (e.g., thermal refugia) that can affect coho salmon, it does not summarize all relevant thermal studies. In addition, it identifies preferred water temperatures as between 12-14 °C, which may or may not be valid, depending upon the system. The section on ranges of MWAT values may be misleading, as the MWAT, as it is currently being used in the THP process, is not an appropriate tool for determining either thermal requirements or impacts on coho salmon. With regard to DO, turbidity, food sources, space, LWD, and out-migration, this document summarizes some results of studies that have been conducted in these areas.

In the "Coho Salmon Considerations" document, it states that, CDF expects the RPF to assess how their plan could affect coho salmon and their habitat and include in the plan appropriate measures to reduce any identified impacts to less than significant. It is the consensus of the SRP that the RPF would not be able to do this, without the data and synthesis provided by a watershed analysis.

Limiting Factors Analysis

To date, there is no standardized "limiting factors analysis" method used by either the agencies or industrial biologists during the THP process, Although, some of the environmental factors used in a limiting factors analysis (e.g., water temperature thresholds, physical habitat characteristics) are used in the Aquatic Properly Functioning Condition Matrix (NMFS and USFWS 1997), they are not used in the context of a limiting factors analysis. Thus, one needs a limiting factors analysis before one can assess whether or not a proposed THP could have impacts on salmonids.

IV FINDINGS AND PROPOSED STRATEGY

INTRODUCTION

The SRP has concluded that if salmon and steelhead populations are to be maintained and restored in a manner that does not place undue burdens on forest landowners and local communities, substantial modifications to the timber harvest planning process are necessary. While the approach we are advocating may depart from the current system in some respects, it has the potential to be well received by resources agencies, forest landowners and the environmental community, as it is based on ideas that are currently being discussed and promoted in many different forums and are rapidly gaining wide acceptance.

The SRP believes that healthy salmonid populations can be completely compatible with a robust timber industry. The SRP has found, however, that the current THP process is not conducive to finding the appropriate balance between salmonid habitat protection measures and economic concerns. Some THPs may thus contain costly but scientifically unwarranted measures for protecting salmonids while other THPs may be woefully inadequate to protect salmonids. In this section, the SRP discusses what it perceives to be the major problems with the current forest practice rules and the THP planning and implementation process and our proposed approach to addressing them.

RESPONSES TO THE MANDATES GIVEN TO THE SCIENTIFIC REVIEW PANEL

Mandate A: Define properly functioning habitat conditions which adequately conserve anadromous salmonids.

It is the SRP's understanding that the concept of "properly functioning conditions" is meant to represent conditions in a managed system as opposed to pristine conditions which are referred to as "fully functioning." The Properly functioning conditions concept acknowledges that a managed system will not likely have the same habitat quality and salmonid population characteristics (e.g., size, stability) as a pristine stream, but that a managed system can provide "sufficiently" good habitat to maintain a "sufficiently" large "healthy" population (i.e., a "properly functioning population"). A key obstacle to applying this concept is the lack of guidance or agreement on what constitutes a properly functioning population. For example, is a properly functioning population, on average, 99% or 50% as large as a population that existed under pristine conditions? (Admittedly, focusing on average population size alone oversimplifies the issue.)

The SRP believes that the concept of properly functioning conditions is useful and appropriate. But to differentiate properly functioning from pristine conditions would assume some consensus as to the characteristics of a "properly functioning" population. Even with such guidance, the SRP believes properly functioning conditions would sometimes vary significantly between watersheds and between stream reaches within a watershed. One of the primary goals of a watershed analysis would be to define properly functioning conditions for various watersheds and types of channels and use them to evaluate trends in current channel conditions. We have not, therefore, attempted to define properly functioning conditions, but rather lay out a watershed analysis framework for determining them.

Mandate B: Jointly review the adequacy of the California Forest Practice Rules, including implementation and enforcement, to achieve properly functioning habitat conditions.

The SRP believes that the current FPRs, particularly in their treatment of assessing cumulative effects, are not adequate to ensure achievement of properly functioning habitat conditions for salmonids (although in some cases the rules may be currently achieving properly functioning conditions). The majority of the report addresses this mandate and the specific questions addressed to the SRP (Appendix B) .

MAJOR CONCERNS

Concerns with Inadequate Cumulative Effects Assessment

The words "cumulative effects" may be interpreted in many ways and are not necessarily restricted to the CEQA definition[1]. The SRP has interpreted cumulative effects to mean the effect of all past and ongoing watershed activities that are affecting or have affected the quantity and quality of salmonid habitat in a manner that may influence salmonid population size, stability, and resiliency to disturbance (see Watershed Analysis and Cumulative Effects section for a more complete discussion). To be effective in protecting salmonid populations, a cumulative effects assessment should determine what factors are limiting to the populations of concern in a watershed. Once it is established which factors are limiting, appropriate timber harvest prescriptions can be developed to prevent additional cumulative effects and mitigate cumulative effects of previous watershed activities adversely affecting salmonid habitat. The SRP found that the cumulative effects assessment as currently required under the FPRs does not provide insightful information about which watershed activities may be preventing the recovery of salmonid populations, nor does it provide a decision-making process for addressing such activities on a watershed scale. The SRP believes that this is the primary obstacle to protecting anadromous salmonids under the current system regulating forest practices. Without such an assessment methodology, the only recourse to ensure the protection of salmonids is to have very conservative non-site-specific prescriptions that may entail severe economic consequences relative to current rules. The section "Recommendations Regarding Institution of a Watershed Analysis Approach to Address Cumulative Effects and Guide Forest Management" gives further details on SRP concerns and recommendations on this subject.

Concerns with Specific Rules

The SRP believes that without a watershed-analysis-based cumulative effects assessment it may be difficult, if not impossible, to judge the adequacy of particular forest practice rules for protecting salmonid populations for any given THP The same rule may in some cases be completely inadequate, while in others overly restrictive. The SRP found some rules generally inadequate; primary examples include rules requiring retention of only

1. "'Cumulative impacts' are defined as 'two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts' [CEQA Guidelines Sec. 15355]. '[I]ndividual effects may be changes resulting from a single project or a number of separate projects' [CEQA Guidelines Sec. 15355, subd. (a)]. 'The cumulative impacts from several projects is the change in the environment which results from the incremental impact of the project when added to other closely related past, present, and reasonably foreseeable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time' [CEQA Guidelines Sec. 15355, subd. (b)]" (Remy et al. 1996).

two 16-in DBH trees per acre be left along Class I and II streams. Recommended changes to these rules are discussed under "Recommendations Regarding Specific Forest Practice Rules" in the following sections:

1. Watercourse and Lake Protection Zones (WLPZs)
2. Large Woody Debris (LWD) Recruitment
3. Geological Concerns
4. Road Construction and Maintenance
5. Watercourse Crossing Structures
6. Site Preparation
7. Winter Operations
8. Harvest Limitations

Concerns with THP process

Potential Breakdown Between Planning and Implementation

A well-developed THP based on a clear understanding of what is needed to protect salmonids may be of limited value without proper implementation. The SRP has concluded that the current system is conducive to a breakdown between the plan, public review, and its implementation. Improving actual implementation of THPs should therefore be a critical step in restoring salmonid populations.

Not Enough Early Involvement By Specialists in THP Preparation

Currently, THPs are usually prepared by an RPF and submitted to CDF without prior substantive input from the scientific staff of state and federal resources agencies (e.g., DF&G, RWQCBs, DMG, CDF). This is often a consequence of state agency budget limitations. The preharvest inspection is often the first time that agency scientists visit the area covered by the THP. The SRP believes that discussions between agency scientists and the RPF at the beginning of the THP planning process would result in substantially better THPs and reduce the number of revisions needed.

Uneven Allocation of Effort Committed to THP Paperwork vs. Field Review and Inspections

The SRP believes that excessive time and money are devoted to RPFs writing and agencies reviewing and revising long THPs that often do little more than restate forest practice rules or attempt to protect the THP from procedural challenges. This ultimately limits the resources devoted to mitigation and supervision of THP implementation.

Recommendations concerning the THP process are included under "Recommendations Regarding the Timber Harvesting Plan Process" in the following sections:

9. Timber Harvesting Plan (THP) Preparation
10. Timber Harvesting Plan (THP) Review and Approval
11. Involvement of Other Resource Professionals in THP Review and Implementation
12. Involvement of RPF in THP Implementation

Other Concerns

Additional recommendations included under "Other Panel Recommendations" in the following sections:

13. Rule Organization
14. Additional Research Needs
15. Social and Economic Impacts

PROPOSED STRATEGY

The SRP believes there are two main approaches that could be used to modify FPRs for ensuring protection of salmonid habitat: (1) develop highly restrictive rules to be applied universally regardless of conditions, or (2) use watershed analysis to develop tailored, cost-effective prescriptions based on a clear understanding of what is needed in a particular watershed. The SRP believes that the second alternative is far preferable both from the perspective of salmonid restoration and for minimizing economic impacts, The SRP therefore did not try to develop more restrictive rules that would be needed in the absence of instituting a watershed analysis program.

Institute a Watershed Analysis Approach

To address the major concerns outlined in the previous section, the SRP believes that there should be a major restructuring of how the state approaches timber harvest regulation, and in particular, how it addresses past and ongoing cumulative effects to salmonid habitat. With regard to the SRP's mandate concerning steelhead, we believe that the state should sponsor and conduct watershed analysis in all watersheds that are located in the Northern California and Klamath Mountain Province steelhead ESUs. Watershed analysis may likely be necessary throughout California to protect sensitive aquatic and riparian species from habitat degradation incurred during timber harvesting; however, the SRP did not specifically evaluate the need for watershed analysis outside the MOA-mandated area.

Goals of the SRP's proposed watershed analysis are to: (1) identify for individual watersheds the extent to which habitat alteration by past or ongoing watershed activities has adversely affected the health of salmon and steelhead populations (the term "health" refers to a population's size, stability, and resilience to disturbance), and (2) determine what steps are necessary to maintain adequate salmonid habitat or restore degraded habitat (i.e., achieve properly functioning conditions). One goal of such a watershed analysis is to provide a document that summarizes cumulative effects (past and ongoing) within the watershed in terms of their effects on salmonid population health. Individual THPs to be implemented within the watershed will then incorporate the findings of the watershed analysis as the basis for addressing the potential additional cumulative effects of the proposed THP. The watershed analysis also must recommend specific timber harvest prescriptions, performance targets, and mitigation opportunities for the entire watershed. The THP can then do one of the following: (1) incorporate the prescriptions included in the watershed analysis, (2) demonstrate how it will meet performance targets included in the watershed analysis, (3) describe which mitigation alternative identified in the watershed analysis it will pursue, or (4) adopt some combination of the first three options.

Revise Certain Forest Practice Rules

In the "Recommendations Regarding Specific Forest Practice Rules" section, the SRP specifically recommends changing the FPRs. The SRP believes that these changes would be adequate to protect salmonid habitat in the near-term before watershed analysis is conducted, with one significant exception discussed below. However, the SRP considers these rules minimum standards that need to be combined with watershed-specific prescriptions and mitigation measures in order to achieve properly functioning conditions for salmonid habitat. In the absence of the watershed analysis program, these rules may not, and in some cases will not, be expected to adequately protect salmonid habitat. If a watershed analysis program is not instituted, therefore, the rules would need to be revisited. In the near-term, the agencies and the Board of Forestry must address the issue of potential watershed impacts that may result from intensive harvesting within a watershed. The SRP has not resolved this issue, and believes watershed impacts should be reviewed by a panel of specialists (see "Harvesting Limitations").

Modifv THP Preoaration Process

The RPF will consult with resources agency staffs (CDF, DMG, DF&G, RWQCB) during preparation of the THP, including whenever possible a field reconnaissance of the area in which the proposed action will take place. The RPF and the agency staff will discuss the cumulative impacts assessment contained in the watershed analysis and the most appropriate ways of addressing its conclusions during plan preparation. The THP will be much shorter than is currently the norm and will consist primarily of a map showing where various activities will take place, a description of how performance targets will be reached, or what mitigation will be undertaken. The RPF will sign the THP accepting oversight responsibility to work with the LTO ensuring that all forest practice rules will be followed, including the prescriptions or performance standards of the watershed analysis cumulative effects report. The SRP believes that a shorter THP could result in significant cost savings in THP preparation that could be applied toward better implementation and mitigation

Increase RPF's Responsibility for THP Implementation

To reduce the effort allocated to producing individual THPs, changes must be made in the planning process to ensure that THPs are properly implemented. The RPF will be responsible for THP preparation and submittal as is currently the case, but an RPF will also be responsible for working with the LTO and landowner to ensure proper implementation of the THP. This so-called cradle-to-the-grave responsibility is necessary to ensure that THPs are not misunderstood by licensed timber operators (LTOs). The FPRs and the timber harvest planning process in general are built on the foundation of the RPF's professional responsibility to manage and protect natural resources (e.g., timber, fish, wildlife, water quality and supply). Extending the RPF's responsibility to include THP implementation oversight would be the most effective way to ensure that the RPF's vision will be fully realized. The SRP believes that a necessary condition for establishing the short THP described above is including oversight of plan implementation as one of the RPF's responsibilities. This would be verified in the completion report prepared by the RPF. As is now the case, the RPFs that do not follow the rules would be subject to disciplinary action. While there are many excellent LTOs, RPF oversight (as is currently done in Santa Cruz County) is the best way to achieve proper THP implementation. This is especially true with the added complexity of the rules to protect salmonids.

Begin a Directed Science Program (Monitoring and Adaptive Management)

The SRP believes that the state should coordinate a directed science program that uses focused monitoring to evaluate the effectiveness of specific prescriptions and validate the overall approach to protecting salmonids based on watershed analysis and the revised FPRs described in this report. This program of effectiveness and validation monitoring needs to be focused on testing key hypotheses, particularly those with both a high degree of scientific uncertainty and a high risk of adverse impacts (including both environmental impacts to salmonids or other aquatic resources and economic impacts on landowners) if they are incorrect. Directed research will also be needed to help resolve critical uncertainties in our understanding of how forest practices may affect salmonids and their habitat. Some examples of such research needs are provided under Recommendation 14 in Section V. This program of monitoring and directed research should be conducted within an adaptive management framework, which should include a clear decision-making process to ensure that the results of such research and monitoring provide timely feedback to land managers and resources agencies.

V RECOMMENDATIONS

RECOMMENDATIONS REGARDING INSTITUTION OF A WATERSHED ANALYSIS APPROACH TO ADDRESS CUMULATIVE EFFECTS AND GUIDE FOREST MANAGEMENT

Watershed Analysis and Cumulative Effects

The SRP believes watershed analysis is the best tool for (1) evaluating existing and potential cumulative watershed effects (CWEs), and (2) identifying means of avoiding, minimizing, or mitigating adverse CWEs on salmonid populations and their habitats. This section provides background on cumulative effects, and existing watershed analysis approaches. It then outlines a specific watershed analysis approach that the SRP believes is needed for effective protection and restoration of anadromous salmonids in the geographic area covered by the MOA.

It is important to define what one means by watershed analysis and to state its primary objectives. The SRP intends watershed analysis to mean something quite specific--a watershed *analysis should establish the linkages between past and ongoing land management activities, geomorphic processes, aquatic and terrestrial habitat, and salmonid population responses* (Figure 2). The emphasis, at least initially, should be on assessing the linkages between changes in stream and estuarine habitat and salmonid population responses. The watershed analysis should result in some understanding of how to improve timber management practices in ways that will actually benefit salmonid populations.

Background on Cumulative Effects

The potential importance of cumulative silvicultural effects in forested watersheds has been recognized for some time (Coats and Miller 1981). Our understanding of cumulative effects has increased in recent years, but there is still debate about the best methods to identify and predict signficant cumulative adverse impacts, the use of regulation to reverse adverse cumulative effects, and approaches for avoiding adverse cumulative effects (Reid 1998).

Cumulative effects result from the combined effect of multiple activities at different locations, sequential activities over time at the same site, or a combination of the two (Reid 1993, 1998; MacDonald *in press).* The idea of cumulative watershed effects is based on a simple concept. A single action of limited size, such as a 20-acre clearcut in the middle of a mature forest in a large watershed, is unlikely to have a measurable effect on, say, downstream peak flow or water quality. However, as the proportion of the watershed subjected to clearcutting during a given time period increases, the likelihood of detectable changes increases. At some point, the amount of change will be sufficient to be both detectable and to have substantial adverse impacts on resources of concern in the watershed.

The concept of cumulative effects implies a persistence of impacts through time, often coupled with a transmittal mechanism through space (MacDonald *in press).* Figure 3 illustrates the possible' combinations of activities over space or time that can lead to a cumulative effect; Figure 4 illustrates the conceptual process for predicting downstream cumulative watershed effects that forms the foundation for the watershed analysis approach (described below).

Although basic in concept, assessment of cumulative effects is often problematic in practice because of the following factors: (1) the large number of potentially affected resources; (2) the numerous mechanisms (or pathways) by which resources can be affected; (3) the potential for the combination of different land use activities to produce effects that would not have necessarily

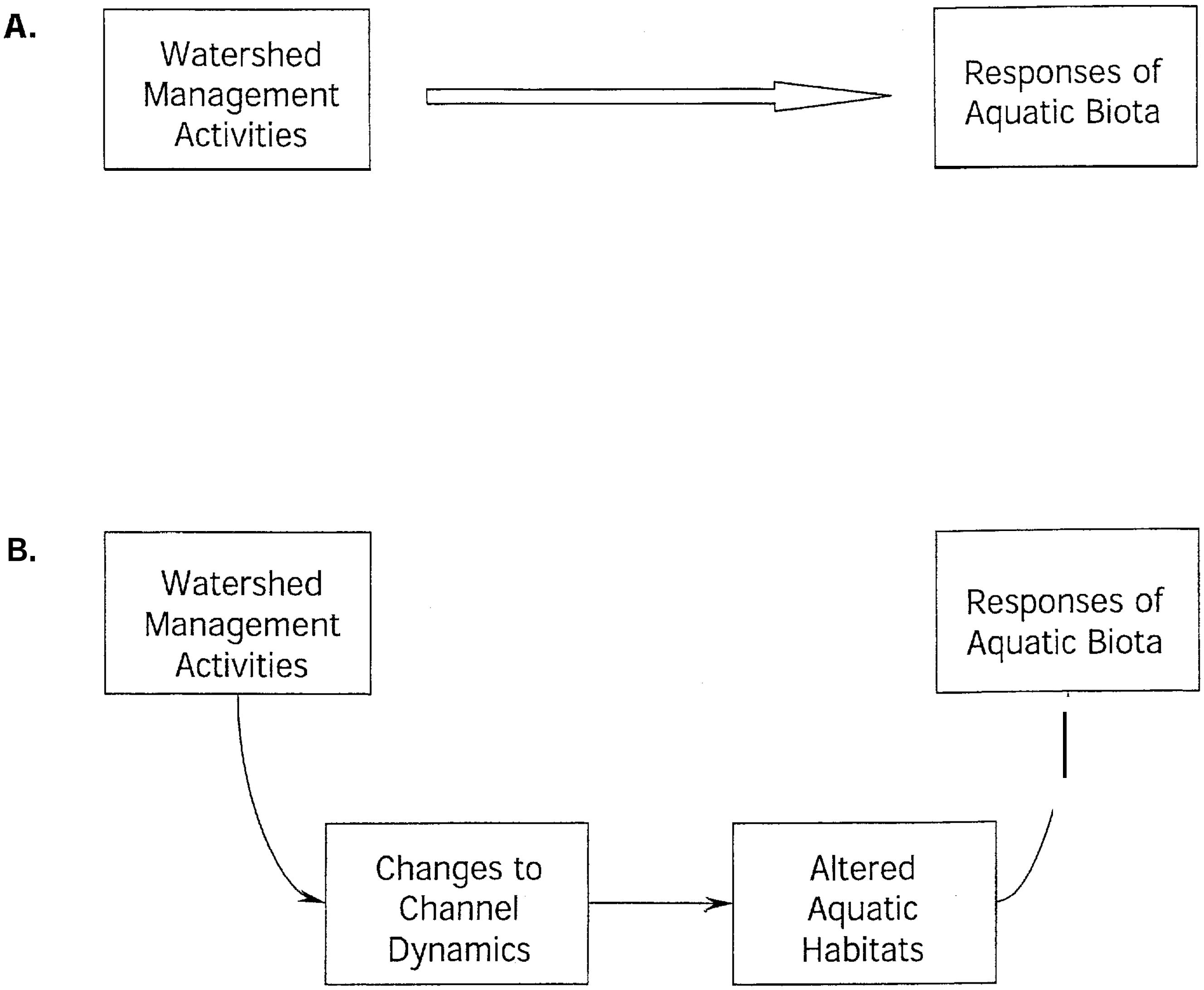


Figure 2. Conceptual framework for a watershed analysis reference model. (A) The primary objective of the reference model is to predict the effects of watershed management. activities on aquatic biota of interest (e.g., salmonids). (B) This is achieved by linking the effects of management activities to changes in channel dynamics, which cause alterations in aquatic habitat conditions, resulting in some response by aquatic organisms (for example, a decrease or increase in salmonid production),

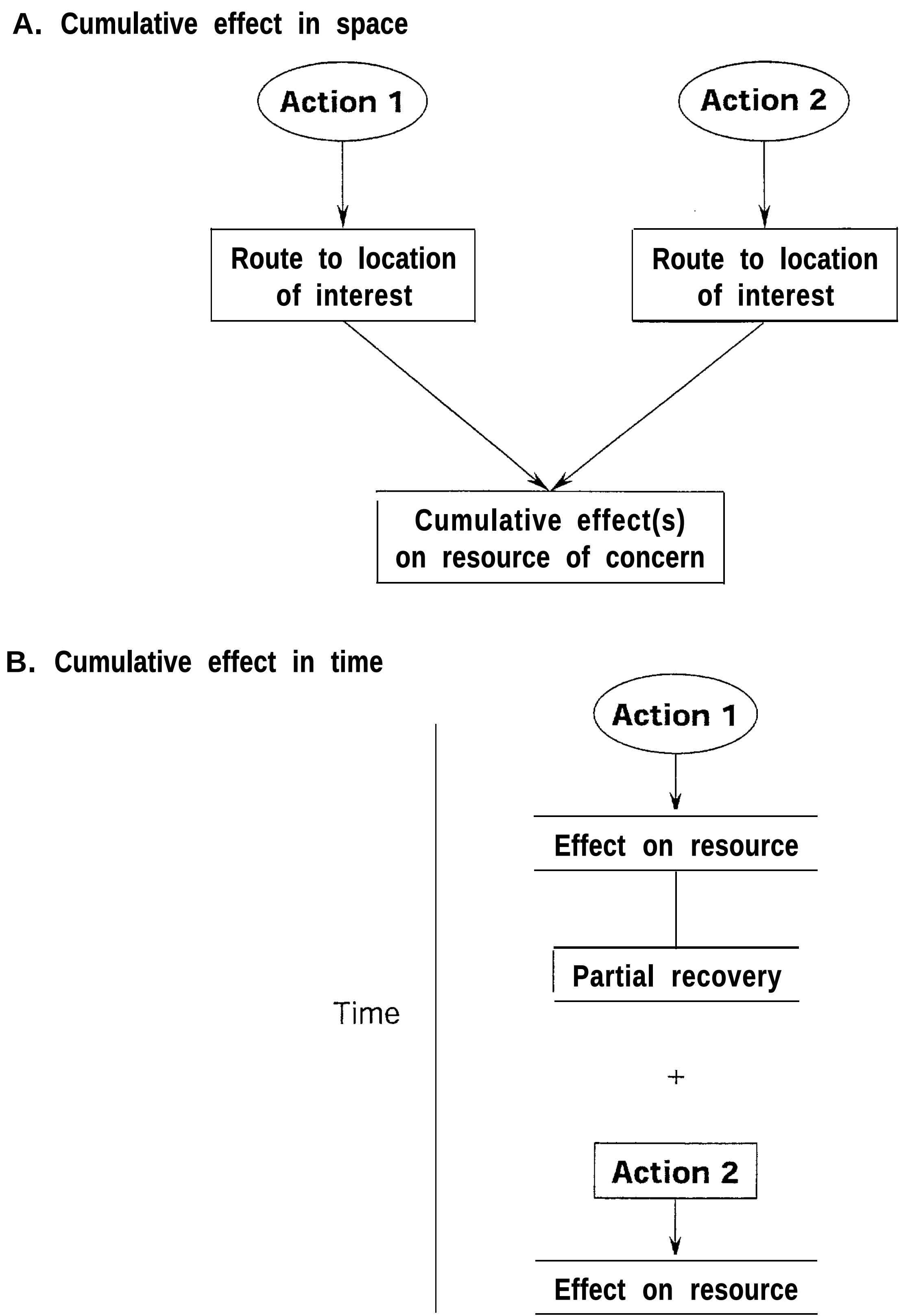


Figure 3. Possible combinations of management actions over space (A) and time (B) that will lead to a cumulative effect (from MacDonald *in* press).

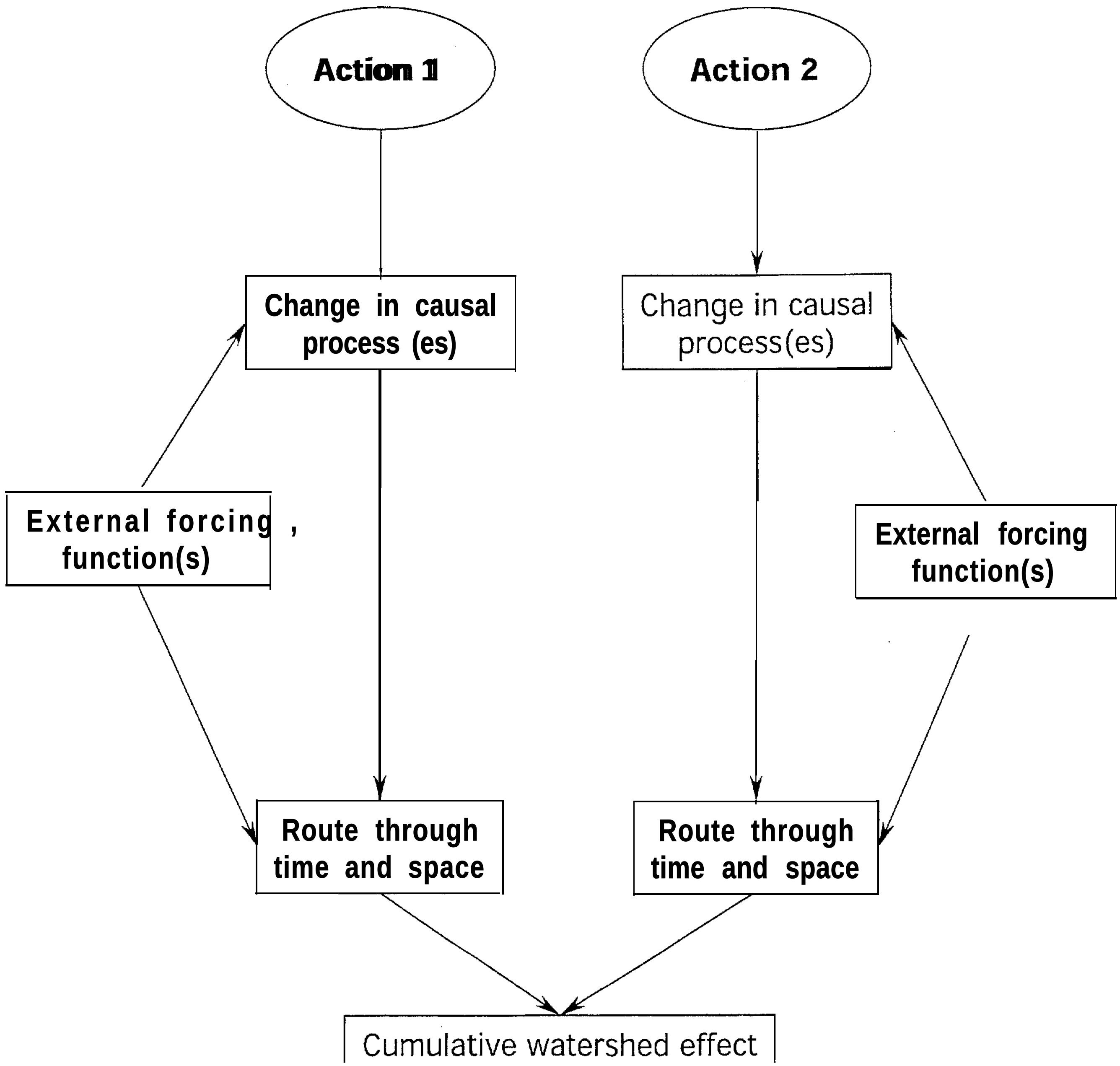


Figure 4. Conceptual framework for predicting an off-site (downstream) cumulative watershed effect (from MacDonald *in press*),

resulted from each individual action; (4) the difficulty of defining recovery rates; (5) uncertainty over the appropriate spatial and temporal scales for the assessment; and (6) the uncertainty of future events (both management and natural events) (Berg et al. 1996, MacDonald *in* press).

A number of recent reviews provide detailed descriptions of cumulative effects, inherent difficulties in assessing and avoiding cumulative effects, and various approaches that have been proposed to assess them (NCASI 1992; Reid 1993, 1998; Beschta et al. 1995; Berg et al. 1996; Bunte and MacDonald 1998; MacDonald *in* press). The three most recent studies (Berg et al. 1996, Reid 1998, MacDonald *in* press) reviewed existing approaches to addressing cumulative watershed effects and came to the following similar conclusions:

- cumulative effects can be important and must be considered in environmental assessment and management planning;
- cumulative effects analysis should focus on issues and resources of greatest concern (e.g., resources at risk);
- cumulative effects analysis should identify key cause-and-effect processes;
- a tiered approach is likely the most efficient and cost-effective means of addressing cumulative effects; such an approach starts with a coarse screening of potential issues at broad spatial and temporal scales and then focuses more detailed analysis on issues of greatest concern (i.e., management effects that are most likely to occur and that would result in significant adverse impacts on resources of concern):
- because of time lags in effects and uncertainty in our ability to predict cumulative effects, the most effective means for avoiding cumulative effects is probably a proactive approach characterized by minimizing on-site effects through use of site-specific prescriptions (which, in some cases, might be coupled with the use of an index of activity or disturbance to set upper thresholds on the amount of activity allowed for a given area and time period), coupled with a well-defined process for adaptive learning through the use of focused monitoring to test the effectiveness of prescriptions and validate the key assumptions underlying the cumulative effects assessment procedures.

A National Research Council (NRC 1995) study was commissioned to assess the condition of anadromous salmonid stocks in the Pacific Northwest. The NRC's scientific panel evaluated the causes of decline, analyzed options for management, and concluded that: "There is an increasing need to understand cumulative effects not only on a site-specific basis, but also across entire watersheds. Only through a broad geographic perspective can the unique qualities of each watershed and their spatial and temporal effects on aquatic habitats be effectively understood." Clearly, the recent scientific literature indicates a consensus view that cumulative effects on salmonids and other aquatic resources are often best addressed in a watershed context. Berg et al. (1996) concluded that watershed analysis, although not perfect in its current form, was likely the best available tool for addressing cumulative effects on aquatic resources. Reid (1998) also concluded that future methods for assessing cumulative effects would likely be based on watershed analysis strategies.

Why the Current Cumulative Effects Process is Inadequate

The current guidance in the FPRs (Technical Rule Addendum No. 2) does not lead to cumulative effects assessments in THPs that provide useful information on how to alter watershed activities that may be impeding or preventing the recovery of salmonid populations, Most THP cumulative effects assessments address site-specific conditions in the THP area. However, the assessment of the larger CWE assessment area is usually just a paper exercise based only on existing information

(Technical Rule Addendum No. 2 states: "The RPF preparing a THP shall conduct an assessment based on information that is reasonably available before the submission of the THP") and avoids collection of new field data (Technical Rule Addendum No. 2 states: "No actual measurements are intended"). These analyses focus mainly on the plan area with very limited reference to the larger assessment area (which is often a single planning watershed with no reference to the larger river basin). These analyses qualitatively describe previously known problems, and conclude that there are no significant cumulative effects associated with the proposed THP. The Little Hoover Report (1994) concluded that the existing THP process had "proven less than effective in protecting the environment" and that this was, in part, because the "process looks at potential damage on a site-by-site basis rather than across entire ecosystems, making it difficult to assess cumulative impacts over time and throughout watersheds."

Some of the practical problems with the current process that were identified during the SRP review of the THP process and constituency group interviews are described below:

- Full disclosure of watershed conditions (e.g., riparian conditions, in-channel LWD levels and recruitment potential channel habitat conditions, road systems, mass movement) are rare. In particular, quantitative information, such as road density, landslide density, or sediment yield, is rarely presented.
- Water temperature assessments often lack data or meaningful analysis of potential on-site impacts, let alone downstream cumulative impacts.
- Analysis of past activities is often limited to a simple list of the THPs that have occurred in the assessment area in the past 10 years, with little or no reference to potential continuing legacy effects (i.e., past significant effects that may be continuing to impact salmonids and their habitat).
- Analysis of other current and reasonably foreseeable activities in the watershed assessment area, especially non-forestry activities, is typically cursory.

In summary, the "checklist approach" and accompanying narrative to cumulative effects assessment specified in the FPRs have been found adequate to meet the procedural requirements of CEQA (see the 1993 decision: East Bay *Municipal Utility District v. California* Department of Forestry *and Fire Protection).* However, the existing approach has failed in some circumstances to adequately protect salmonids and other aquatic resources in watersheds in the Northern California and Klamath Mountains Province steelhead ESUs. One particular problem is that ownership patterns in many watersheds make it difficult for any single landowner to have access to all of the relevant data. This is especially true for smaller landowners The SRP, therefore, feels that it should be the role of the state to examine CWEs at the basin level. The CWE analysis for an individual THP would then "tier" off of this basin-level assessment.

Background on Watershed Analysis

The concept of watershed analysis arose from the need to improve our ability to predict and then prevent or minimize cumulative impacts on aquatic resources, including salmonids (see Montgomery et al. 1995, Berg et al. 1996, and Reid 1998). Efforts initiated in the 1980s by a consortium of various organizations involved in the Washington State Timber/Fish/Wildlife Agreement led to the development of the Washington Watershed Analysis (WWA) approach (see Berg et al. 1996 and Montgomery et al. 1995). It was first published in 1992 and continues to evolve through feedback from participants (WFPB 1992, 1997). The WWA approach describes detailed methods for evaluating processes such as landsliding and road surface erosion. The method defines areas of sensitivity or hazard (such as mass wasting hazard areas or riparian areas) within each watershed and then evaluates the vulnerability of resources of concern (specifically, fish habitat, water quality, and public works) to adverse impacts associated with timber harvesting and other forest management activities, The approach includes a specific and detailed policy framework that lays out the steps, operating rules, key links, and decision requirements for the assessment teams, which are composed of scientists and managers. The approach does not, however, require evaluation of the potential effects of future activities in the watershed and does not specifically evaluate the cumulative effects that might result from implementation of the prescribed practices. One of its key assumptions is that cumulative effects will not be produced if the prescribed practices are followed (WFPB 1994, 1997; Reid 1998). This assumption needs to be validated through monitoring. A more comprehensive review of the WWA approach and some of its successes and failures to date is provided in Collins and Pess (1997a, 1997b).

The other common approach currently in use is the Federal Interagency Watershed Analysis (FWA) methodology (RIE'C 1995). It was developed in response to recommendations made by the Forest Ecosystem Management Team (FEMAT 1993) on implementation of an ecosystem management approach to managing federal lands within the range of the northern spotted owl. The FWA is a more flexible information gathering process than the WWA. It is designed to interpret the structure, composition, and function of ecosystems within a given watershed. It differs from the WWA in that it explicitly is not a decision process: formal management decisions (which must follow the NEPA process) are made at the smaller site-specific scale (e.g., timber harvest unit) or the larger landscape-scale (e.g., the forest plan), One of the problems with implementation of the FWA approach is that analyses to date have tended to be prepared as a series of mono-disciplinary chapters, rather than as a true interdisciplinary effort as originally envisioned (Reid 1998).

Both the WWA and FWA approaches emphasize that interdisciplinary analysis is required and that process (i.e., "cause-and-effect") interactions must be evaluated over large areas in order to understand their significance. Neither approach currently provides the quantitative linkages among management actions, changes in watershed processes and channel dynamics, alterations in aquatic habitat conditions, and responses of the aquatic biota (e.g., salmonid populations). Reid (1998) and Berg et al. (1996) both concluded that watershed analysis approaches appeared to be the best available tool for addressing cumulative effects. They also concluded, however, that both approaches were still in need of improvement before they could fulfill the goal of understanding watershed systems well enough to have confidence that land-use activities can be planned to prevent future impacts, Reid (1998) states that evaluation of the results of watershed analyses completed to date should enable us to learn enough to design an improved watershed analysis approach that effectively addresses cumulative effects. The SRP believes that it is possible to develop an improved watershed analysis process, founded on the existing methods of the WWA and FWA approaches, that will allow effective evaluation of cumulative effects and promote protection and recovery of anadromous salmonids.

State-sponsored and Conducted Watershed Analysis Program

The SRP recommends that a watershed analysis program be developed and managed by the state. It is important that it be a multi-disciplinary and multi-agency program involving staff from CDF, DF&G, RWQCB, and Division of Mines and Geology (DMG). The SRP believes that the state should develop a standardized watershed analysis methodology in consultation with NMFS, EPA, timber industry scientists, and academic scientists. The SRP decided not to recommend specific techniques to include in the program (although these could be provided if desired), but rather to specify the type and quality of the products that are needed to ensure that salmonids are protected. Inadequacies inherent in some approaches and the scientific challenges to implementing a useful watershed analysis program are discussed below.

Having the watershed analyses conducted by the state will help foster consistency and confidence in the resulting work products. In addition, for watersheds containing multiple landowners it would not be practical for individual landowners to conduct watershed-scale analyses when they own only a portion of the watershed. Because a standardized methodology will be developed and published, however, iandowners may participate in the analysis or, where landowners own all or most of a watershed, conduct the analysis themselves. All watershed analyses should be peer-reviewed and certified by a panel of state, federal, and timber industry scientists whether or not the state staff or scientists working for the landowners conduct the watershed analysis. This scientific panel would determine if the analysis was properly conducted and whether the conclusions and recommendations are consistent with the guidelines presented in the state watershed analysis manual.

Watershed Analysis Goals and Products

The goal of watershed analysis as the SRP envisions it is not to describe the watershed or to catalog various geomorphic or ecological features. Rather, it should focus specifically on maintaining or restoring healthy salmonid populations while minimizing economic impacts to landowners. The watershed analysis would include the following: (1) a comparison between historical and current freshwater and estuarine salmonid habitat conditions and how watershed activities have resulted in changes to reference conditions, (2) an analysis of the extent to which watershed changes may have affected salmonid populations in the watershed, and, (3) specific recommendations for management actions necessary to maintain or restore properly functioning salmonid populations. The key point is that prescriptions for a given watershed coming out of a watershed analysis will be driven by the needs of salmonids in that watershed, i.e., what specifically is needed to maintain properly functioning conditions.

While the SRP is not recommending a particular watershed analysis methodology, it believes that there are certain elements of watershed analysis that are critically important to include in any such assessment. Most watershed analyses that focus on salmonids have modules addressing fish distribution and life history, roads, mass wasting, temperature, etc. However, the following components are sometimes lacking or ill-defined.

1. Historical Disturbances

The watershed analysis should, for each watershed, document the historical and-to the extent possible-the present-day consequences of major natural and anthropogenic disturbances. For example, the historical analysis should account for such factors as occurrence of large floods and splash damming, effects of these disturbances on watershed processes and salmonid habitat conditions, and ongoing effects of these disturbances. Without this information, interpreting the effects of present-day activities and predicting the effects of proposed activities may be difficult or impossible. In some watersheds, addressing the legacy of past disturbances (through active restoration) may be more important for the benefit of salmonids than mitigating the effects of current or proposed activities.

2. Integrated Analysis of Management Activities, Channel Processes, and Salmonid Habitat

The watershed analysis should establish how watershed activities have affected the input of water, sediment, wood, light, and nutrients to a stream. More importantly, it must address how changes in these inputs have altered physical processes and, in turn, how these processes have altered salmonid habitat, An integrated analysis based on changes in channel processes and conditions that documents trends in habitat quality and quantity should be included in a watershed analysis.

3. Limiting Factors Assessment

A biological response model that links changes in habitat conditions in streams and estuaries (and the ocean if data are available) to responses of salmonid populations is critical. This model would assess how changes in habitat over time (i.e., from reference conditions to current conditions) have likely contributed to the decline of salmonids. In addition, the model would identify where habitat improvements would most likely result in benefits to salmonids. This type of analysis makes it possible to determine properly functioning habitat conditions that are necessary for maintaining properly functioning populations (keeping in mind, however, that other factors such as ocean conditions and harvest may also affect such populations).

4. Consideration of All Watershed Activities

The watershed analysis should evaluate all watershed activities, not just forestry. Without knowing the relative impact of different watershed activities (e.g., gravel mining, housing construction or urbanization, agriculture) on salmonid habitat, it would be difficult to develop prescriptions for forestry that would be effective and fair.

5. Multiple Scales

The watershed analysis should be conducted at biologically relevant scales. Prescriptions from the watershed analysis may address local conditions or issues at a much larger scale. For example, in a larger watershed of several hundred square miles, a dearth of LWD in a particular subwatershed (of, say, ten square miles) may limit salmonid production and may need to be addressed through altered management or mitigation. But chronic turbidity downstream in the main channel and the estuary may also be an important limiting factor and may require prescriptions addressing fine sediment inputs, even though fine sediment is not limiting salmonid production in any of the subwatersheds located upstream.

The current cumulative effects analysis requirements do not lead to effective protection for salmonids, thus, it is important that cumulative effects be addressed in the short term in a meaningful manner, even if only to a limited degree. A full watershed analysis might not be completed on all watersheds for several years. The SRP therefore recommends that watershed analysis be developed and implemented in the following two phases: (1) Phase I-analysis of existing information, and (2) Phase II-implementation and scientific research. Phase I would begin in the year 2000, and Phase II would begin later. The approach and products for the proposed Phase I and Phase II are described below.

Phase I

- Identify high priority watersheds for Phase II analysis. The screening procedure for identifying high priority watersheds might include factors such as current status of salmonid populations in a watershed, 303(d) listing, status and timeframe for TMDL development, and use of a Watershed Relative Risk Index (WRRI) approach. The WRRI approach uses a GIS and digital terrain modeling (DTM) process to generate comparisons among watersheds of the estimated potential for adverse cumulative watershed effects related to sediment delivery to stream ecosystems. It combines measures of the potential for hillslope sediment production with the value and vulnerability of downstream beneficial uses (e.g., salmonids and their habitat). CDF is currently exploring various GIS models (such as SHALSTAB) and (in cooperation with USGS) is developing 10-m DEM coverages for the north coast area of California that would greatly facilitate such an effort. This process may also identify legacy sediment problems that could be addressed without the watershed analysis assessment.
- Assign priority rankings to culvert problems based on degree of problem and potential quality and quantity of habitat upstream of the

culvert. This could be performed using a GIS DTM analysis in conjunction with field surveys to create a stream network model to estimate the quality and quantity of habitat upstream of culverts. Replacement of high priority culverts could serve as mitigation for THPs prior to completion of watershed analysis. Coordination with counties, CalTrans, and landowners would be required.

- In the short term (3-5 years), prior to a watershed analysis being conducted, the changes in the rules that are recommended would help reduce the potential for cumulative effects. In some cases, the watershed analysis may conclude that one or more of the rules as adjusted by Section V are inadequate to reverse cumulative effects in a watershed and the recommended prescriptions would be more restrictive.

Phase II

Directed *Science Program*

Ideally the watershed analysis would establish quantitative relationships for the linkages shown in Figures 2 and 5. These linkages would enable the development of prescriptions or mitigation are necessary to benefit salmonid populations. However, despite continuing advances in the field of watershed science and salmonid ecology the SRP believes that the current state of knowledge limits the ability to confidently establish these linkages. This is not to say that a watershed analysis methodology would not provide immediately useful information. Rather, the SRP recommends a focused scientific effort to address key scientific uncertainties. Such an effort should greatly increase the confidence in the results of the watershed analysis. The SRP believes that if the linkages shown in Figures 2 and 5 are not established to some degree, then watershed analysis cannot protect salmonids from habitat degradation resulting from timber harvesting. In addition, a focused monitoring and adaptive management program should be coordinated by the state to speed up our learning process and reduce key uncertainties in our understanding of the effects of forest management activities on salmonids.

Relationship *Between the* Watershed *Analysis* and *the THP*

To achieve properly functioning conditions, the results of the watershed analysis will include the following three types of management actions: (1) specific prescriptions, (2) performance targets, and (3) prioritized mitigation opportunities. The results of these management actions would provide the means for individual THPs to address cumulative effects.

Specific Prescriptions

The results of the watershed analysis may offer the opportunity to (1) identify significant cumulative effects in the watershed, and (2) recommend temporally and spatially explicit timber harvesting prescriptions over and above what is required by the FPRs to address these cumulative effects. Alternatively, the watershed analysis may conclude that although significant cumulative impacts from past activities have occurred, the current rules are sufficient to prevent further impacts. In these cases the watershed analysis may suggest mitigation for addressing cumulative effects, such as repairing legacy roads that contribute sediment to stream channels. When a THP falls within the area of a watershed where rule changes have been specified, the RPF may elect to follow the more restrictive rules. The watershed analysis prescriptions would simply be referenced in the THP and it would be the responsibility of the RPF to ensure the rules are properly followed. There would be no penalty for the RPF or landowner if the desired effects (i.e., properly functioning conditions) are not achieved.

Perform ance Targets

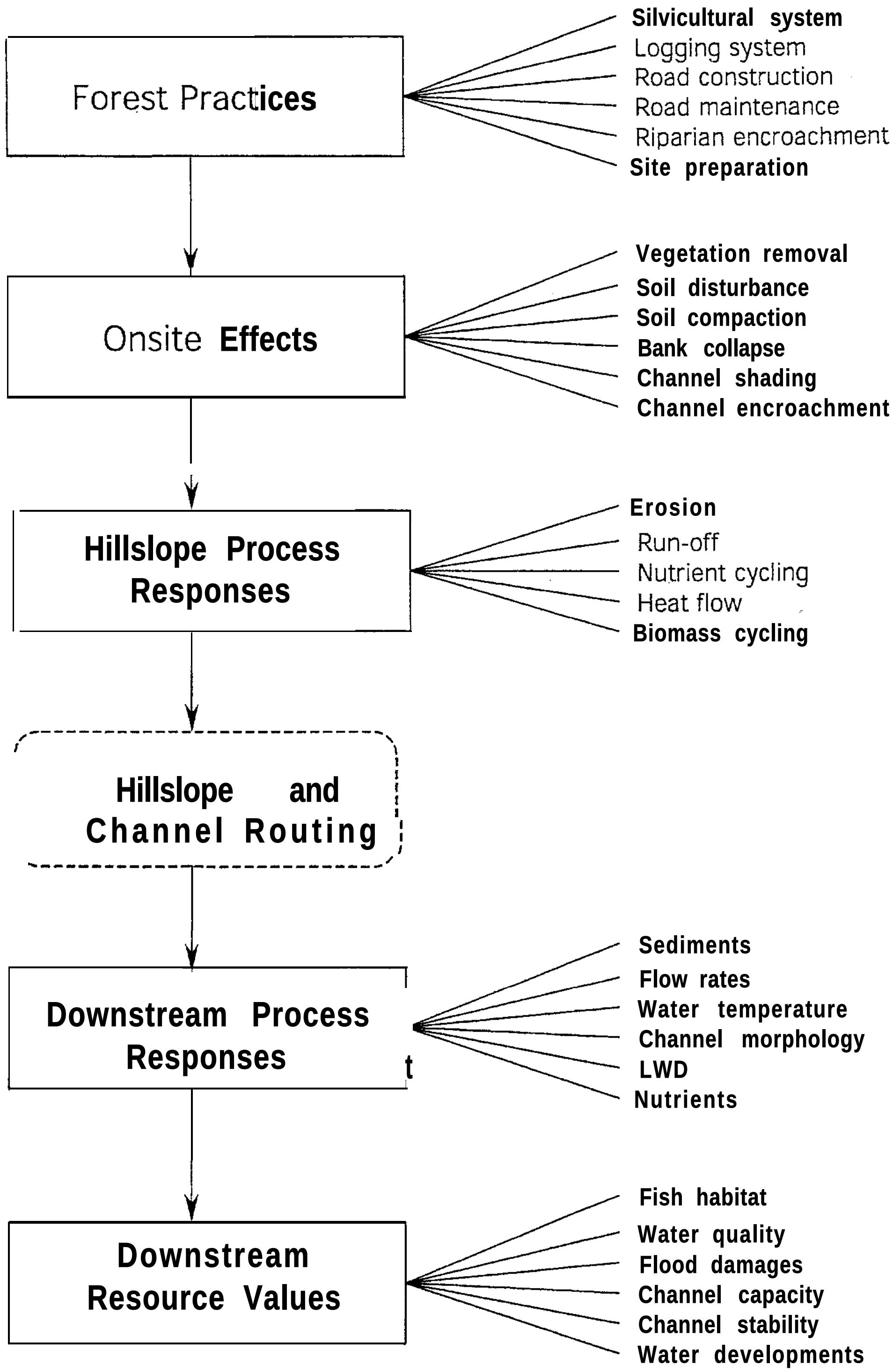


Figure 5. Components linking forest management to water resource values (from NCASI 1992).

Whenever possible, the watershed analysis would present performance targets to achieve properly functioning conditions as an alternative to more restrictive rules. The RPF may propose an alternative strategy to meet the performance standards in the THP. This would allow the RPF the flexibility to adjust timber harvest prescriptions if local conditions allowed for a more efficient means of achieving the same goal. In this situation, the RPF would discuss the alternative with state agency scientists and describe in the THP the alternative measures that were developed. Under this option, the RPF and the landowner would be responsible not only for successful implementation of the measure, but also for achieving the performance targets. This would require that a monitoring component be included in the THP. If the performance targets were not met, the landowner would be required to undertake mitigation actions (in addition to whatever mitigation was originally required under the THP) .

Mitigation

The watershed analysis would also include identification of mitigation measures expected to reduce cumulative effects and benefit salmonid populations in the watershed. Mitigation measures would address cumulative effects that were not associated with the current THP (e.g., legacy roads, offsite habitat restoration). The watershed analysis would rank these mitigation measures in terms of their potential benefit to salmonid populations in the watershed. Depending on the severity of existing cumulative effects, the watershed analysis may specify how much mitigation is required in addition to following the prescriptions or meeting the performance targets.

RECOMMENDATIONS REGARDING SPECIFIC FOREST PRACTICE RULES

1. Watercourse and Lake Protection Zones

Background

The stated intent of the WLPZ rules is to ensure the protection of beneficial uses derived from the physical form, water quality and biological characteristics of watercourses and lakes. This rule further states "It is the intent of the Board to restore, enhance, and maintain the productivity of timberlands while providing equal consideration for the beneficial uses of water," (CCR916.) Under 916.2, the measures to protect the beneficial uses of water for each watercourse and lake shall be determined by the following:

The quality and beneficial uses of water as specified by the applicable water quality control plan.

The restorable uses of wa ter for fisheries as identified by the Department of Fish and Game.

The biological needs of the fish and wildlife species provided by the riparian habitat.

Sensitive near stream conditions as specified in 14CCR 916.4(a).

The regulations then separate the state's waters into four classes (I-IV) with Class I being a fish-bearing stream, or a stream that is being used for domestic water supplies. The regulations also have a provision at 916.2(c) that state "When the protective measures contained in 14 CCR 916.5 are not adequate to provide protection to beneficial uses, feasible protective measures shall be developed by the RPF or proposed by the director under the provisions of 14 CCR 916.6. Alternative Watercourse and Lake Protection, and incorporated in the THP when approved by the Director."

The rules require that "During timber operations, the timber operator shall not place, discharge, or dispose of or deposit in such a manner as to permit to pass into the water of this state, any substances or materials, including, but not limited to, soil, silt, bark, slash, sawdust, or petroleum, in quantities deleterious to fish, wildlife, or the quality and beneficial uses of water. All provisions of this article shall be applied in a manner which complies with this standard."

Item (5) of this same section allows either party to request an increase or decrease in the width of a WLPZ, and such a decrease shall not exceed 25% of the standard width. Such changes in zone widths shall be based upon considerations of soil, slope, climatic factors, biological, hydrologic, and geologic values as identified in CCR 9 16.4(b), and silvicultural methods, yarding systems, road location and site preparation activities. In addition to the overstory canopy requirements, within the WLPZ at least 75% surface cover and undisturbed area shall be retained to act as a filter strip for raindrop energy dissipation, and for wildlife habitat. (CCR 916.4(b)(6).) Also there are no specific provisions for a WLPZ on a Class III watercourse. The rules require a 25-ft wide equipment limitation zone (ELZ) where sideslopes are less than 30%, and a 50-ft wide ELZ where sideslopes are greater than 30%. A Class III watercourse within a logging area where the erosion hazard rating (EHR) is low and the slopes are less than 30%, will not require an ELZ unless proposed by the RPF or required by the Director. Where necessary to protect the beneficial use of water, the RPF shall designate and the Director may require a WLPZ for Class III and IV watercourses or an ELZ for Class IV waters. (CCR 916.4(c)(1).) The width of the WLPZs for Class I and II watercourses is determined by slope classes (less than 30%, 30 to 50%, and greater than 50%) and are presented in Table I at CCR 916.5 (see Table 1).

WLPZ widths for Class I watercourses vary from 75 to 150 ft (depending upon slope). However, 50 ft may be subtracted where cable-yarding operations are conducted, resulting in a 100-ft wide WLPZ along Class I watercourses with sideslopes greater than 50%. Class II WLPZs range in width from 50 to 100 ft; however, the 100 ft zone may be reduced to 75 ft where cable yarding operations occur on slopes greater than 50%. For Class I waters, at least 50% of the overstory and 50% of the understory canopy covering the adjacent ground shall be left in a well-distributed, multistory stand with a species composition similar to that found prior to the start of operations. The residual (post-harvest) canopy shall be composed of at least 25% of the existing overstory conifers. For Class II watercourses, at least 50% of the total canopy covering the ground shall be left in a well-distributed multi-story stand with a species composition similar to that found prior to the start of operations, At least 25% of the residual overstory canopy shall be composed of existing overstory conifers.

Discussion

The width and canopy requirements of the WLPZs have received more discussion than any other section of the FPRs relative to salmonid protection considerations. Following the listing of the coho salmon in 1996, many environmental advocates called for the designation of critical habitat compatible with that of the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994). On federally owned lands, these standards require an approximately 300-ft wide (two site-tree heights) buffer along Class I (fish-bearing) watercourses. Management was not precluded from these 300-ft zones, but requires an intensive assessment of resource implications before occurring within this zone. In the designation of critical habitat, NMFS recognized that the 300-ft buffers identified in the FEMAT report were intended to maintain functions other than riparian functions, including protection of terrestrial wildlife habitat (NMFS 1999). In their review of the literature and documentation presented at hearings for consideration of the designation of critical coho habitat, NMFS cited several

TABLE 1. 916.5, 936.5, 956.5 Procedures for Determining Minimum Watercourse and Lake Protection Zone Widths and Protective Measures [All Districts]

Procedures for Determining Watercourse and Lake Protection Zone Widths and Protective Measures[1]

Water Class Characteristics or Key Indicator Beneficial Use	1) Domestic supplies, including springs, on site and/or within 100 feet downstream of the operations area and/or 2) Fish always or seasonally present onsite, includes habitat to sustain fish migration and spawning.		1) Fish always or seasonally present offsite within 1000 feet downstream and/or 2) Aquatic habitat for nonfish aquatic species. 3) Excludes Class III waters that are tributary to Class I waters.		No aquatic life present, watercourse showing evidence of being capable of sediment transport to Class I and II waters under normal high water flow conditions after completion of timber operations.		Man-made watercourses, usually downstream, established domestic, agricultural, hydroelectric supply or other beneficial use.	
Water Class	Class I		Class II		Class III		Class IV	
Slope Class (%)	Width Feet	Protection Measure	Width Feet	Protection Measure	Width Feet	Protection Measure	Width Feet	Protection Measure
					[see 916.4(c)] [see 936.4(c)] [see 956.4(c)]		[see 916.4(c)] [see 936.4(c)] [see 956.4(c)]	
<30	75	BDG	50	BEI	See CFH		See CFI	
30-50	100	BDG	75	BEI	See CFH		See CFI	
>50	150[2]	ADG	100[3]	BEI	See CFH		See CFI	

1 - See Section 916.5(e) for letter designations application to this table.
2 - Subtract 50 feet width for cable yarding operations.
3 - Subtract 25 feet width for cable yarding operations.

references regarding riparian protection zones. Two of these citations (Johnson and Ryba 1992, Castelle et al. 1994) identified a riparian zone width of 30 m (98 ft) as the minimum necessary to provide riparian function (NMFS 1999). Also cited was "An Ecosystem Approach to Salmonid Conservation" (Spence et al. 1996) that stated that a protected buffer of approximately one site-tree height (30-45 m) would provide 90 to 100% of a fully functioning riparian corridor in terms of years or decades. A fully protected 30-45 m-wide riparian buffer may therefore provide "fully functioning habitat," as compared to "properly functioning habitat."

The two direct functions of the WLPZ are to provide shade for temperature control and long-term input of LWD. Other benefits include screening input of fine sediments, maintenance of microclimates for temperature and humidity, and the input of energy in the form of organic debris that supports other biota, including invertebrates and other vertebrates. Many of the agency representatives, environmental representatives, and other resource specialists commented on the inadequacy of the current WLPZ rules for the recruitment of LWD. They cited the current standard of two trees 16 inches or larger per acre within the WLPZ as being inadequate for both short- and long-term LWD recruitment needs. Several suggestions were offered, including near-stream no-cut riparian buffers and permanently designated trees within the WLPZ.

The Monitoring Study Group (MSG) team reviewed WLPZs for compliance with rules and effectiveness as a sediment buffer (MSG 1999). They found:

"Watercourse and lake protection zones (WLPZs) have been found to generally meet Forest Practice Rule requirements for width, canopy, and ground cover. Additionally, very few erosion features associated with current THPs were recorded in WLPZs."

"Approximately three-quarters of the WLPZs evaluated to date have been *on Class II watercourses, which are much more* common than *the generally larger Class* I waters. *The* data *collected in WLPZs indicates that minimum canopy requirements following harvesting on* Class *I* and *II watercourses are being exceeded, since an average of greater than 70% canopy cover following harvesting has been measured using* the *spherical densiometer. Similarly, mean ground cover requirements in WLPZs following logging was estimated to exceed 85%. Required WLPZ widths generally met Rule requirements, with major departures from Rule requirements noted only about 1% of the time. Erosion events originating from current THPs and encountered on mid-zone or streambank WLPZ transects were found to be rare. The implementation data suggests that RPFs should do a better job of taking existing roads and erodible, unstable stream banks into account when designing WLPZs and specifying protection measures."*

Unfortunately, there is currently a lack of science on the necessary amount of LWD for either properly functioning or fully functioning conditions for various stream orders and conditions. Two of the constituency groups interviewed recommended no-cut buffers along Class I watercourses. One of these groups recognized the difficulties and issues that would result from no-cut buffers, but felt that they needed to support this standard because they did not trust the system to properly prescribe and maintain adequate WLPZs. Many of the landowners and RPFs interviewed felt the current WLPZ standards, as required under the "Coho Salmon Considerations Document", were adequate. Recent studies conducted by the Monitoring Study Group of the Board of Forestry found that, although the requirement for Class I watercourses was to retain 50% overstory canopy, the average canopy closure for Class I watercourses exceeded 70% (see above). The MSG rarely found problems in WLPZs on industrial ownerships, and commonly found trees left in the WLPZ that were designated for harvest with paint, but were not cut.

Of the landowners interviewed, many have increased their WLPZ standards over those required in the FPR. One industrial landowner uses a tiered WLPZ on Class I watercourses that includes 80% overstory canopy retention within the 25ft of the WLPZ closest to the watercourse and 65% for the remainder of the WLPZ. In addition to these standards, this company also retains at least 10 trees per 1,000 ft of watercourse (considering both sides of the stream) that represent the larger trees in the stand including leaning trees and wildlife trees. On Class II watercourses, this landowner retains 75% canopy in the zone 0 to 25 ft from the watercourse and 65% overstory canopy in the remainder of the WLPZ. On Class III watercourses, the company maintains a 20-50-ft wide ELZ.

Another landowner has also adopted 70% overstory canopy for Class I and II watercourses. They use standard WLPZ widths and exclude all salvage logging from these zones, retain six trees per acre 32 inches in diameter or larger, as well as l-2 snags per acre. No harvesting may occur in the WLPZs unless there is at least 70% overstory canopy. Within Class III watercourses, they follow the standard rules regarding the equipment limitation zones (ELZs) and retain all hardwoods. A third industrial landowner also maintains 70% canopy closure on all Class I and II watercourses and provides more protection to larger Class II watercourses that support coldwater species such as salamanders. On Class III watercourses, this same landowner retains LWD on adjacent hillslopes for slope stability. Field observations by the SRP indicated that this landowner had also instituted no-cut buffers on a site-specific basis for geologic hazards and other site-specific concerns,

Based on the interviews and review of THPs both on paper and in the field, it appears that most landowners are exceeding the current minimum WLPZ standards, When asked why landowners would not support retention of a 70% canopy closure (the amount that is currently being achieved by almost all landowners on Class I watercourses), landowners and RPFs expressed concern that such a modification would cause a "ratcheting-up" of the required regulations, Under the current requirements, RPFs are retaining 70% canopy along Class I watercourses where the regulations only require 50%. Landowners and RPFs fear that if the new standard is 70%, then to err on the side of the conservative, the de facto standard will approach 7540% canopy retention requirements. RPFs in particular were very concerned of meeting both the intent and the letter of the law when designating and marking WLPZs. Because of the variability within a WLPZ and the difficulty in accurately measuring canopy closure, RPFs said they tend to leave more trees than is stated in the THP requirements. The CDF has recently adopted a standardized methodology for calculating compliance with WLPZ canopy closure requirements. The so-called "sighting tube" used in this method requires a substantial number of sample points to determine canopy closure, and does not appear to be a repeatable sampling methodology.

Several constituency groups expressed concerns regarding the classification system used for watercourses. The definition of Class I and III watercourses were generally considered acceptable, but it was suggested that the definition of a Class II watercourse be reviewed. Class II watercourses represent a wide range of steam conditions and flows. They can include streams of stream order 1, 2, 3 or higher, and may have substantial water flow. The larger streams have the capacity to transport LWD and substantial amounts of sediment directly into Class I streams. The larger Class IIs may have all of the characteristics of Class I streams, but are defined as Class 11s only due to the absence of fish.

For salmonid protection, the SRP is not recommending permanent designation of recruitment trees along Class II watercourses, except for retention of l-3 snags per acre. The SRP believes that the high canopy retention requirements (85%), and restrictions on salvage logging of downed trees within Zone A of Class II WLPZs (see recommendations below), will produce adequate amounts of suitably sized LWD in the majority of Class II watercourses, The larger Class IIs that enter Class I watercourses, however, may be an important source of LWD to these channels through the mechanism of downstream transport. This process needs to be addressed through the watershed analysis process, and may result in the need to provide for additional LWD recruitment opportunities for these types of Class II watercourses.

The constituency group made up of agency fish biologists reported the need to protect critical "metapopulations" of salmonids. The locations of these metapopulations are known to the biologists, and they recommend a program to identify which areas may be critical for maintenance of these metapopulations and provide extra protection to these areas. This may include increased WLPZ widths, harvest limitations, and sediment control. It is important that the landowners are informed of these metapopulations to coordinate protection.

The watershed specialist constituency group, as well as other groups, emphasized the importance of Class III watercourses for sediment metering and storage. These channels typically have stepped profiles formed by LWD largely consisting of smaller pieces from limbs or broken tree tops. These channels tend to be stable until there is disturbance creating a catch point that migrates headwords. It is therefore important to minimize disturbance to these channels, and to stabilize crossings where they occur.

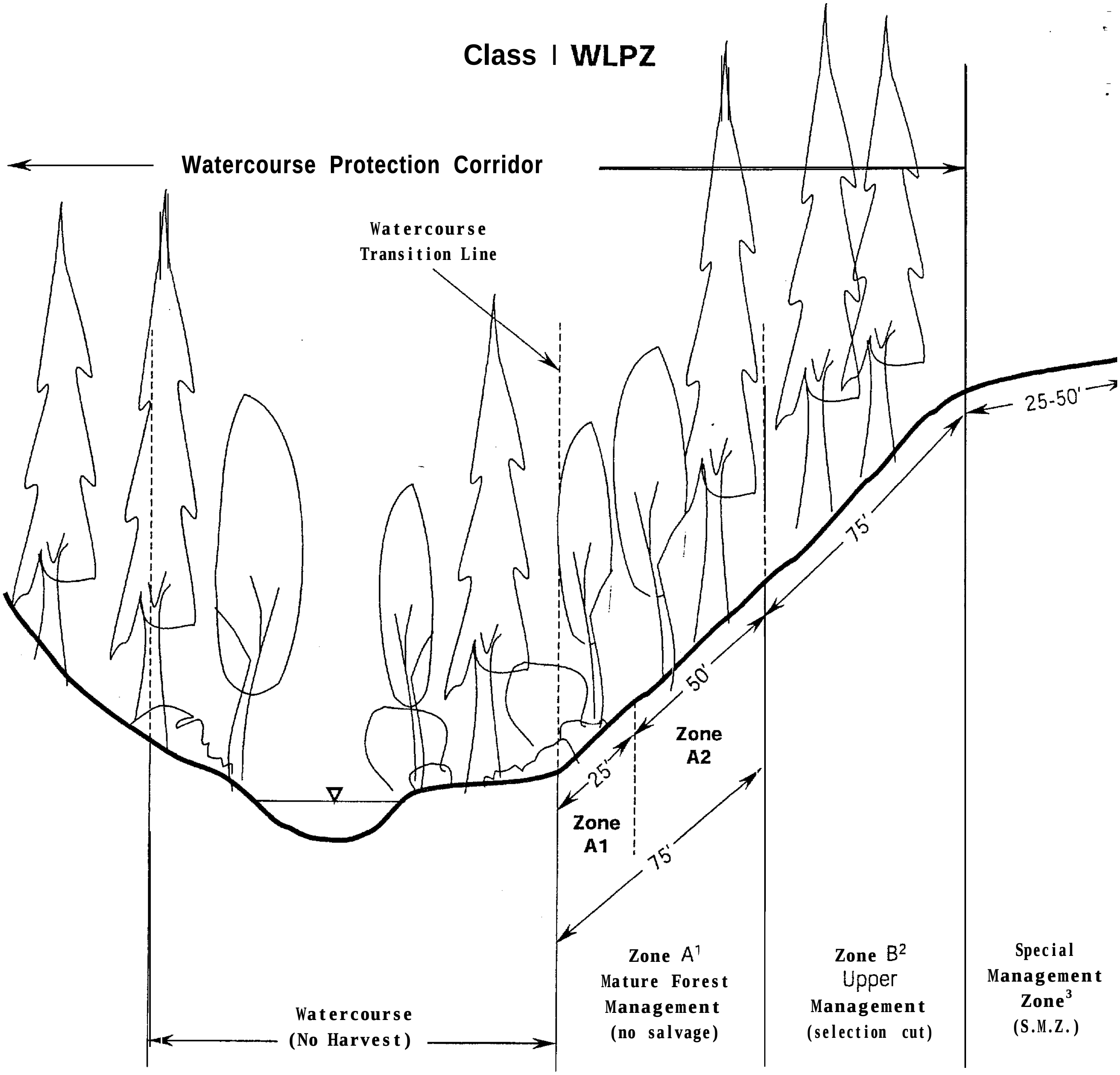
The SRP realizes (and has been told by many constituency groups) that the regulatory expectation that "one-size-fits-all" is unrealistic and undesirable to all. The FPRs must include flexibility. However, changes to the standard WLPZ prescription may result in significant adverse on-site and cumulative impacts to salmonid habitat. As written, most proposed changes do not explicitly require this level of evaluation; rather, the RPF need simply explain and justify proposed changes. While we respect the RPFs' abilities to address many potential on-site adverse impacts, adverse cumulative impacts are considerably more difficult to evaluate.

Recommendations

1. The SRP recommends the following watercourse protection standards:

Class I Watercourses

- Re-write CCR 916.5(e) and "G" to include the following: Minimum riparian buffer widths on Class I streams of 150 ft (slope distance) tiered with the following canopy requirements: Zone A = O-75 ft wide with 85% overstory canopy closure; Zone B = 75-150 ft wide with 65% overstory canopy closure (see Figure 6). For evenaged treatments adjacent to WLPZs (and rehabilitation with the same effect as a clearcut), an additional 25-50 ft wide (25-ft wide on slopes 0-50%; 50-ft wide on slopes greater than 50%) special operating zone shall retain understory and mid-canopy trees at a density sufficient to reduce the impacts of edge effects. Within this special operating zone, understory and mid-canopy conifers and hardwoods shall be retained and protected during falling, yarding, and site preparation. Zone A shall be divided into two zones: Zones A-l and A-2. Zone A-l shall extend from 0-25 ft above the watercourse transition line (WTL) and shall be managed for salmonid habitat purposes using salmonid-directed silviculture (see Definitions). Zone A-2 shall extend from 25-75 ft above the watercourse transition line. It is the goal of Zone A-2 to create a multi-aged stand with late-successional forest characteristics including: (1) maintaining a mix of small, medium, and large diameter trees managed on a selection harvest basis to create large diameter LWD recruitment trees and allow shade-intolerant trees to reproduce: (2) maintaining snags at a density of 1-3 per acre; and (3) retaining downed wood, while maintaining height growth function. This stand should be representative of the tree species composition that would have naturally



[1] A1 special zone managed specifically for salmon habitat through limited selection harvests or thinning: 85% canopy; no salvage.

A2 zone managed for large diameter trees through thinning and selection harvest: 85% canopy; no salvage

[2] B upper management zone; selection harvest; salvage of downed trees O.K.

[3] Special Management Zone: for even-aged management only; retain understory and hardwood trees

Figure 6. Proposed Class I Watercourse Protection Standards

occurred on the site under reference conditions, including hardwoods. To create larger diameter trees at a younger age, the thinning of younger stands within this zone is encouraged. In order to provide and maintain LWD recruitment trees, the ten largest trees per 100 m (328 ft) of stream channel (considering both sides of the stream) within 50 ft of the watercourse transition line (WTL) shall be marked for permanent retention. The RPF may trade the next smaller diameter tree more conducive to LWD recruitment, or shading, or bank stability, if DF&G concurs. Criteria for the selection of alternative recruitment trees shall favor leaning trees, large-diameter decadent trees, and the next largest diameter trees lowest on the slope within the zone. Trees shall be permanently designated (see Definitions) prior to the PHI (unless alternative trees are proposed), and shall be marked with paint, tags, or other suitable means both above and below stump height. Recruitment trees shall be remarked upon each reentry, and additional recruitment trees shall be designated to replace those trees that have fallen. No salvage of dying, dead, or downed trees may occur within Zone A, except for safety reasons. Trees that have fallen uphill into Zone B must have at least 30% of their lower bole retained regardless of location. Trees that occur within the channel zone (defined as the area between opposing watercourse transition lines) may not be harvested. These trees may not be counted as recruitment trees.

- Drop all exemptions for cable logging; require full WLPZ width for all operations.

- Standards for Class I watercourses shall apply only to fish-bearing streams and not to watercourses designated for use as domestic water sources; Class II protection measures shall apply to these watercourses.

- Zones A and B shall be managed through thinning or selection harvest, including small group openings each less than or equal to ¼ acre.

- Where an inner gorge is present above the WLPZ and slopes are greater than 55%, a special management zone shall be established that requires the use of selection harvesting (see Figure 7). This zone shall extend upslope to the first major break-in-slope, or 300 ft as measured from the watercourse transition line (WTL) , whichever is less. Evenaged management above the 300 ft zone within the inner gorge on slopes of 55-65% shall be reviewed by a geologist prior to approval. All slopes exceeding 65% (both inside and outside the WLPZ) within the inner gorge shall be reviewed by a Certified Engineering Geologist (CEG) prior to plan approval.

- No harvesting may occur on any unstable feature within the WLPZ without review by a CEG. Trees retained on these features within Zone A may be counted as LWD recruitment trees if size criteria are met (or DF&G concurs with a smaller diameter tree).

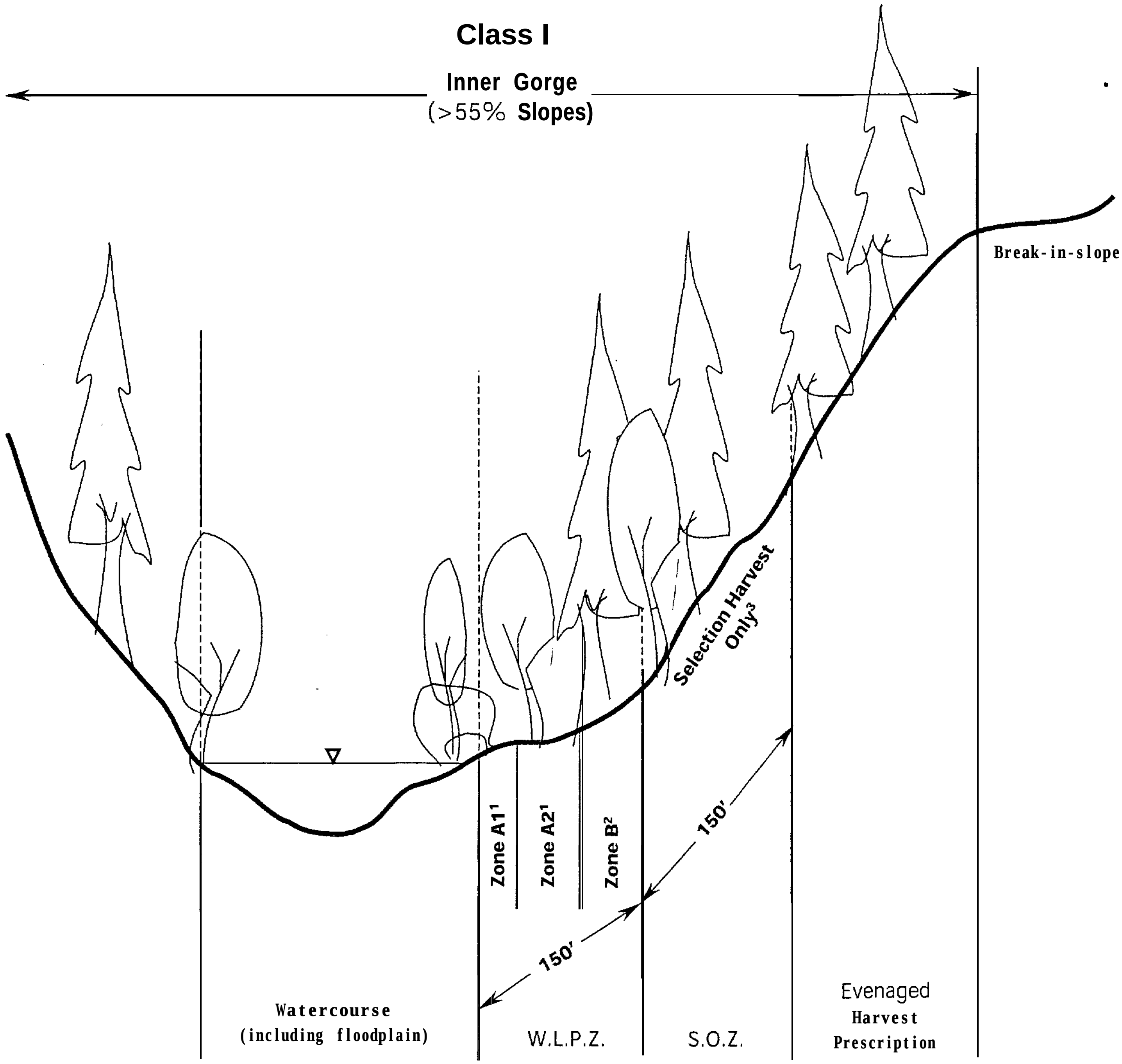
- Where water temperature is not limiting, and Zone A-2 is occupied with evenaged conifers, the canopy requirements within this zone may be reduced to 70% as part of a “low thinning” prescription (see Definitions).

- Equipment is excluded from the WLPZ except on existing active haul roads.

Class II Watercourses

- Rewrite CCR 916.5 (e) and “I” to read: 100 ft minimum (slope distance) WLPZs tiered with the following overstory canopy retention requirements: Zone A = 30 ft wide with 85% canopy; Zone B = 30-100 ft wide with 65% canopy. This must be composed of at least 25% overstory conifer canopy post-harvest.

- Drop exemptions for cable logging – maintain minimum WLPZ widths.



[1] A1 special zone managed specifically for salmon habitat through limited selection harvests or thinning: 85% canopy; no salvage.

A2 zone managed for large diameter trees through thinning and selection harvest: 85% canopy; no Salvage

[2] B upper management zone; selection harvest: salvage of downed trees O.K.

[3] Special Operating Zone: Required for slopes >55% within inner gorge when evenaged harvesting is proposed above; selection harvesting required within S.O.Z.

General Requirement: All harvesting on slopes >65% anywhere in the inner gorge must be reviewed by a geologist.

Figure 7. Recommended Class I Inner Gorge Protection Standards

- To increase LWD, salvage logging shall be prohibited in Zone A of the WLPZ. Trees that fall into Zone A may be removed with the following stipulations: (1) the portion of the tree that extends outside of Zone A may be removed if such removal does not destabilize the remaining portion of the tree; and (2) no portion of the tree may be removed if the tree has become incorporated into the duff layer and is metering or storing sediment.

- To reduce the edge effects of the WLPZ adjacent to evenaged harvest areas, a special operating zone extending 25 ft upslope of the WLPZ shall be established. Within this zone, understory and mid-canopy conifers and hardwoods shall be retained and protected during falling, yarding, and site preparation.

- Where temperature is not limiting, and Zone A is occupied with evenaged conifers, canopy requirements may be reduced to 70% to facilitate a "low thinning" (see Definitions).

- Natural seeps and springs shall be protected as on Class II watercourses.

- No equipment shall enter the WLPZ except at currently active permanent roads or designated crossings (i.e., abandoned roads shall not be reopened).

- To ensure larger, lower gradient (less than 10%) Class II streams that do not have fish present during some portion of the year (i.e., to ensure that they are not actually Class I streams), more rigorous fish investigations by qualified fisheries biologists should be conducted.

- Retain l-3 snags per acre.

Class III Watercourses

- No WLPZ shall be required. Rewrite CCR 916.4(c) to read: "Maintain a 30-50 ft wide EEZ (depending on slope) and retain all hardwoods within the ELZ. No equipment may enter this zone except at pre-designated tractor crossings, Such crossings are to be kept to a minimum, shown on the THP map, and shall be removed and stabilized prior to October 15."

- Minimize burning within the EEZ; retain all downed woody material that is currently acting to store sediment within Class III watercourse channels and on adjacent banks and slopes. The protection of Class III watercourses during broadcast burning must be addressed in the Site Preparation Plan. Where broadcast burning is used and burning through Class 111s cannot be prevented, only cool spring burning shall be used. Fall burning may be used only where LWD in Class III watercourses is protected. No ignitions may occur within 50 ft of the channel as measured from the center of the channel.

General WLPZ Recommendations

- Slopes greater than 65% within the WLPZ shall be reviewed by a geologist prior to THP approval.

- From a salmon protection perspective, salvage of downed trees in Zone B is not considered detrimental, if properly conducted.

- Site-specific watercourse protection standards that may exceed the minimums in CCR916.5 (as modified) based upon needs identified through if a watershed analysis indicates that this is necessary for the protection of salmonid habitat.

- The issue of converting hardwood-dominated WLPZs shall be addressed through the watershed analysis, This may allow more intensive harvesting within Class I and II WLPZs that are currently hardwood dominated.

- Consider differential WLPZ standards for properties managed through selection harvest versus evenaged harvest. This would include considering reduced buffer widths where there is no marked change between the WLPZ and the silvicultural hillslope harvesting applications. This should be addressed in the watershed analysis.

2. The WLPZ rules include too many exemptions that are scattered throughout the FPRs. Regulatory exemptions within the WLPZ rules include: CCR 916.1 In Lieu Practices, CCR 916.6 Alternative Watercourse and Lake Protection, CCR 916.4(b) (5) width adjustments for WLPZs, CCR 916.4(b) (6) surface cover adjustments, and CCR 916.4(d) heavy equipment use in the WLPZ. Assign all WLPZ exemption language to one section, essentially CCR 916.6, to: (1) clearly define the standard prescription, and (2) require specific evaluation for proposed changes in the cumulative effects assessment. For example, use of existing roads within the WLPZ should be evaluated in CCR 916.6, and not CCR 916.3(c); heavy equipment use exemptions within WLPZs should be evaluated similarly. At present (refer to Cumulative Effects Assessment section), Technical Rule Addendum No. 2 is not designed to adequately address proposed exemptions. With an adequate cumulative effects analysis in place, future THP approval could allow more intensive harvesting for hardwood conversion within Class I and II WLPZs by stating, then justifying, a future desired stand structure. Thinning of younger stands within the WLPZ could be encouraged to promote diameter growth and more rapid development of large trees for future LWD recruitment. Until an adequate cumulative effects analysis is implemented, the SRP recommends formal interagency review of all proposed exemptions. This should require two of the three review agencies (CDF, DF&G and RWQCB) to formally approve the changes (and their justification), rather than requiring two or more agencies to deny proposed exemptions (as required in CCR 916.6(b)).

2. Large Woody Debris Recruitment

Background

In several locations under Article 6, "Watercourse and Lake Protection" (CCR 916), the rules both directly and indirectly discuss LWD recruitment and function within stream channels and riparian areas. The specific recruitment requirements developed for LWD are described under 916.3 (g): "Recruitment of large woody debris for instream habitat shall be provided by retaining at least two living conifers per acre at least 16 inches diameter breast height and 50 feet tall within 50 feet of all Class I and II watercourses." LWD is indirectly addressed at 916.2(a) (3) as "The biological needs of the fish and wildlife species provided by the riparian habitat." LWD is identified by name and referred to under 9 16.4 (b) "Vegetative Structure Diversity" where determination of the WLPZ width is described: "A combination of the rules, the THP, and mitigation measures shall provide protection for the following: . . .stream bed and flow modification by LWD. , . and vegetation structural diversity for fish and wildlife . . . "

Discussion

Current FPR standards for maintaining LWD recruitment to stream channels were criticized by numerous constituency groups as being grossly inadequate. Landowners, RPFs, and some agency representatives noted, however, that the number of trees remaining after harvest greatly exceeded these standards. However, there is nothing in the regulations that requires the permanent retention of any individual trees that could be recruited as LWD. This was considered a high priority by several constituency groups, including some representatives of the state and federal agencies, as well as of the environmental community, fisheries biologists, and habitat restorationists.

As described under "Watercourse and Lake Protection Zones," there is a lack of data identifying those characteristics of LWD that promote the creation and maintenance of habitat for anadromous salmonids. A watershed analysis could provide information on current abundance and distribution of LWD in various watersheds throughout the north coast region of California: however, further analysis of these data would be needed to identify reasonable ranges for adequate abundance and distribution of appropriately sized LWD by stream size.

Several interviewees considered LWD to be a critical factor influencing the quality of salmonid habitat, especially for coho salmon. Others felt that the role of LWD might be overemphasized and other factors, such as suspended sediment and stream temperature, might have equal or greater importance. There was also much discussion regarding the natural background levels of LWD in north coastal California streams. There were some mentioned instances where reference streams with little to no LWD were observed to have high salmonid densities. Other streams, such as Prairie Creek, contain large amounts of LWD and are known to be important coho salmon streams. Without further analysis, the question of "how much LWD is enough" can not be readily answered. Further studies and analysis should be undertaken, regarding the role of LWD in north coastal California streams and its effect on salmonid habitat and populations.

Comments received from various constituency group members, including state and federal representatives and several other groups, indicated that rates of LWD recruitment to streams has been dramatically reduced from historical rates through timber harvesting and other activities. LWD that enters the system in the upper reaches is often removed by private landowners and firewood cutters in the lower reaches of the drainage. To many small landowners, LWD represents diversion potential that can damage their property, public and private roads, culverts, and bridges. The economic opportunity presented by a large redwood log on a river bar also results in the rapid removal of LWD by firewood cutters and fence post/shingle-bold makers.

Several of the constituency groups engaged the SRP in discussions regarding both short- and long-term LWD recruitment needs. Rules created today for increasing recruitment of LWD by retaining more trees in the WLPZ may not result in measurable increases to in-channel LWD for several decades. Within this time frame, it is possible that runs of salmonids could become extirpated within certain watersheds while waiting for trees to grow and recruit LWD to the stream channel. There may be a need to increase in-channel LWD in the short term in some stream systems by direct placement of LWD. Several of the large landowners who were interviewed supported this concept and said that they would be willing to work with the state and federal agencies in the placement of LWD, where it was identified as a critical limiting factor. The landowners and RPFs noted that when logging equipment, such as cable yarders and helicopters is on site, these machines could be used to place LWD into watercourses at pre-designated locations. This LWD could originate from trees felled during road construction or hillside logging activities. Where there is a lack of LWD in the streams, but a relative abundance of larger diameter trees along the watercourses, logging equipment could be used to pull trees over into stream channels. This may provide very stable and geomorphically functional pieces of LWD, as they would consist of both an intact bole and a root wad. The SRP received several comments that preferred LWD would come from a larger diameter tree and would contain an intact root wad.

The SRP also heard many discussions of what may be the best methods to ensure long-term recruitment of LWD. One suggestion was for a near-stream, no-cut zone that would allow for the development of large trees that could then fall into the stream over time. This would not of course preclude increasing recruitment of LWD from upslope of this zone through additional protection measures. Another discussion considered the permanent designation of trees for LWD recruitment. These trees would be selected from within the WLPZ and would include conifers that had the highest likelihood of entering the stream in the near term, and would therefore most likely include larger diameter, more decadent, and leaning trees. These characteristics are often those associated with the "wildlife tree" designation. One landowner has already undertaken this program and has permanently designated such trees with plastic "wildlife tree" signs. An issue raised by some state representatives was the state's ability to require the protection and maintenance of these trees over time. There was a question regarding the state's jurisdiction once the THP had been completed and stocking requirements had been met. Because the harvest and removal of any trees from private property requires a permit from the state, this may provide sufficient safeguard.

Most interviewees, including foresters, landowners and state agencies, stated that the current FPRs do not ensure adequate recruitment of LWD. Landowners indicated that they could put more LWD into streams by using stumps and logs remaining after road building and logging. Some foresters stated that the current rules tended to convert the WLPZ into hardwood stands. Such conversion would reduce recruitment of conifers, which tend to enter the channel at larger sizes and decay more slowly.

The conversion of most of the old-growth redwood forests with their abundance of large decadent trees into relatively vigorous, young-growth stands has greatly reduced the recruitment of large trees into streams and replaced it with recruitment of smaller pieces of woody debris. These smaller pieces tend to be less stable in the channel and have less influence on stream channel morphology and salmonid habitat (Bragg and Kershner 1999). Recent forest management has altered natural disturbance regimes affecting LWD recruitment. Natural forest fires and Native American burning resulted in episodic delivery of riparian trees to stream channels in a variable recruitment pattern, During the conversion of the old-growth forest to young-growth, a considerable number of riparian areas and streams were cleared of large wood and many coastal streams were used for dragging, hauling, or floating logs downstream. Until recent years, the LWD that was left in north coastal California streams was removed under the mistaken belief that it often hindered or blocked fish migration. In hindsight, this was a poor decision. Many studies have since indicated that LWD performs critical geomorphological and ecological functions in fish-bearing streams. Science has not yet defined what types of management will ensure adequate recruitment of LWD into streams and the actual amounts required for protection of salmonid habitat. To determine the amount of LWD currently present in the many different streams of the region, adaptive management and monitoring will be needed.

The simplest way to increase LWD in streams in the short term and ensure that variable recruitment of LWD in these streams continues is to establish wide no-cut riparian buffer strips. Since a considerable amount of riparian zones are currently occupied with smaller diameter young-growth, hardwoods and shrubs, however, most riparian areas need some type of active management to promote regrowth of large conifers that historically occurred in these areas. A 1 00-foot no-cut riparian buffer zone would be simpler to implement in the field and politically more acceptable to some. However, we have always tended to simplify our management of nature by making uniform prescriptions. Such simplified approaches, however, may not result in LWD recruitment patterns similar to those that existed under pristine conditions. Prior to intensive management of the redwood forests, recruitment of LWD into streams was very chaotic with a large inherent variation in the amount of LWD present in any one stream at any given time. This inherent variation probably resulted in ecosystem stability in terms of providing salmonid habitat on a landscape scale with at least some streams having suitable levels of LWD abundance at any one point in time. On the landscape scale, at any one point in time, some watersheds or streams would likely have had high densities of LWD while others would be relatively lacking in LWD due to natural disturbance events including catastrophic windthrow, disease and insect epidemics, fire, flooding, and mass wasting. Some portion of the landscape would therefore likely have contained high quality habitat for salmonids while other portions were in a state where habitat for salmonids was limited (Reeves et al. 1995).

A riparian buffer zone with a patchy distribution of different management treatments would result in a variety of different stand structures and successional stages that would more closely mimic natural forest patterns. These management treatments could include small patch cuts, selective cuts, and thinning to foster regrowth of larger-diameter conifers in the riparian zone, as well as maintenance of some lightly managed and unmanaged patches. The buffer zone width would vary depending on channel type and stream dynamics. The size, shape, and spatial configuration of these differently managed patches should therefore depend on the riparian zone's expected response to such treatments and whether or not the desired results may occur. Several of the interviewees expressed concern that much of the vegetation within riparian zones had been converted to hardwoods, and therefore needed to be actively managed to promote regrowth of conifers.

The Aquatic Properly Functioning Conditions Matrix (Matrix) was produced by NMFS in order to address habitat needs for salmonids on the lands of the Pacific Lumber Company. Attachment E to the Matrix identifies numeric targets for trees per acre by diameter (DBH) groups for both redwood and Douglas-fir. For redwood stands NMFS recommends leaving 23.8 trees per acre greater than 32-in DBH and 17.4 trees per acre greater than 40-in DBH. For Douglas-fir stands the recommendations are for leaving 18.5 (16.3) trees per acre greater than 30-in DBH and 11.0 (9.0) trees per acre greater than 40-in DBH (numbers in parentheses are for different site classes). These tree-per-acre requirements are not additive: the requirement for trees per acre greater than 40 DBH is a subset of the trees per acre for the greater than 32-in DBH group. These recommendations were developed from data included in a master's thesis at Humboldt State University (Combs 1984) and from the Old-Growth Program at the USDA Forest Service Pacific Southwest Forest and Range Experiment Station (Bingham 1991) (B. Condon, 1999, pers. comm.). The redwood recommendations were based on inventory data from 48 %-acre plots in undisturbed redwood stands greater than 200 years of age in Redwood National Park (Humboldt County) and the Northern Coast Range Preserve in Mendocino county. The source of the Douglas-fir data is not clearly identified. These data were originally compiled for use in development of the "Old Growth Protection" rule package considered by the Board of Forestry in 1992. The riparian data in the Matrix represents undisturbed old-growth conditions that are "fully functioning."

The following is an example of a timber management strategy that could be used to maintain high levels of properly functioning (i.e., approaching fully functioning) riparian conditions for protecting salmonid habitat. The stand used in this example was located along a small Class I stream in the redwood region (D. Thornburgh, unpublished stand inventory data for Mendocino County, California). Prior to the first timber harvest, the natural disturbance in this stand consisted of light to moderate fire occurring at 40-year intervals, and single- and multiple-tree blowdown. Partial "high grade" harvest occurred 100 years ago, followed by natural stand regeneration. This stand represents ideal conditions for a mature (1 OO-year-old) Site I streamside stand that contains residual old-growth. This stand does not represent an average mature young-growth stand, and exceeds the basal area found in average late-successional (i.e., old-growth) stands. Stand characteristics included:

- a riparian zone of variable width
- a streamside stand composition of multiaged redwoods and mixed conifers
- riparian-associated hardwood trees growing along stream (e.g., alders, cottonwoods)
- basal area of 700 sq. ft. per acre
- 5-7 trees per acre greater than 40-in DBH
- 50–60% of basal area made up of trees from 15- to 40-in DBH
- remaining basal area made up of trees 0- to 15-in DBH
- 5-8 snags per acre greater than 15-in DBH
- 10 -20 dry tons per acre of downed wood
- growth rate of 2,440 BF per acre per year (periodic annual increment)

For management purposes, the structure and distribution of tree sizes in the stand can be averaged over an area of five acres allowing for wide variability in stand structure. The following management measures could be used in this stand to maintain riparian stand functions important for protecting salmonid habitat:

- harvest 85% of the annual growth in IO-year increments equal to 20,740 BF every 10 years
- cut timber in small patches to form single- to multiple-tree-size gaps large enough to allow Douglas-fir to become established (l/4-acre or larger)
- maintain vertical canopy structural diversity of 5-7 trees greater than 40-in DBH and 50-60% of remaining basal area in 15- to 40-in DBH trees
- if a stream reach is believed to be lacking in LWD, retain larger trees (greater than 40-in DBH) in a strip along that reach to allow for future LWD recruitment
- avoid disturbing or compacting the soil
- allow light to moderate burning of slash following timber harvest

The above management scheme may mimic natural disturbances that result in the input of some coarse and fine sediments to the stream. Rather than require a specific number of trees to leave or the specific width of a no-cut zone, the desired condition should be described as a management objective.

Average conditions for old-growth stands can be determined by reviewing historical timber inventories. Based on an intensive inventory of approximately 3,000 acres of undisturbed redwood stands in Humboldt County, the average basal area per acre was 531 ft^2 and the average number of trees (conifers, greater than 8-in DBH) was 51 trees per acre (NRM 1984). Of this total, 18 trees per acre were greater than 40-in DBH. This represents historical (reference) conditions that were considered to be "fully functioning", and that are very similar to the requirements contained in the NMFS Matrix (17.4 trees per acre). Recreating these conditions would likely require several hundred years.

The expected yield of a go-year-old stand of Douglas-fir is predicted to be 118 trees per acre (site index = 180, trees greater than 7-in DBH) (McArdle et al. 1961). The "Empirical Yield Tables for Young-Growth Redwood" (Lindquist and Palley 1963) predicted yields for a site Class II (site index = 180) stand of redwood to have an estimated basal area of 576 ft^2 per acre and 158 trees per acre (greater than 10.5-in DBH) at 90 years of age. These predicted yields for young-growth redwood have a higher basal area and a higher number of trees per acre compared to empirical measurements of old-growth stands. By comparison, empirical measurements of a naturally regenerated, unmanaged stand of 90-year-old redwood and Douglas-fir (site index = 180) in Humboldt County indicated a basal area of 402 ft^2 per acre and 132 trees per acre (greater than or equal to 10-

in DBH) (NRM 1991). This stand had the following tree diameter (DBH) composition:

DBH Group	Trees per Acre
10–28 inches	98
28–38 inches	31
40 inches +	3

The differences between the young-growth versus old-growth stands are reflected in the number of trees per acre and the distribution of tree diameters. Although the young-growth redwood yield tables for a 90-year-old stand indicate basal areas similar to an old-growth stand (576 ft^2 per acre verses 53 1 ft^2 per acre), the number of trees per acre is significantly different. The old-growth stand has 51 trees per acre (greater than 8-in DBH, conifers only) while the 90-year-old young-growth stand is predicted to have 158 trees per acre (including hardwoods), The actual 90-year-old stand has a similar number of trees per acre at 132, including hardwoods. When hardwoods are excluded, this stand has 105 conifer trees per acre. The old-growth stand has 18 trees per acre greater than 40-in DBH, while the 90-year-old stand has 3 trees per acre greater than 40-in DBH.

Basal Area

Basal area by itself is not a good measure of the number of trees per acre, size of trees in a stand, percent of full occupancy, or amount of canopy cover. Normal basal area is a function of age and site. For example, depending on the site, the basal area of 300 square feet can be:

Site	Stand Age	Trees per Acre
V	80 years	194
IV	58 years	180
III	45 years	190
I	20 years	377

The above represents evenaged stands and these data are not applicable to unevenaged management. Although some HCPs and the Washington State Watershed Assessment Program use basal area to define standards for riparian stands, the SRP believes that this is not a good measure to use to achieve desired goals. Instead, we support the use of canopy closure requirements and describing the desired stand characteristics for functional riparian habitat. Stand tables need to be developed that illustrate the desired stand characteristics essential for properly functioning salmonid habitat. The stand tables need to illustrate multi-aged, multi-story stands that provide optimum canopy coverage, recruitment of LWD, and regeneration of conifers that will eventually replace the larger trees. The stand table needs to cover all the different sites and tree species in the geographic area covered by the two ESUs in California.

To create and maintain stands within the WLPZ that contain elements common to late-successional stands, it will be necessary to grow and maintain larger diameter conifer trees. To accomplish this, 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.

Oliver et al. (1994) found that young-growth redwood responded well to thinning. The authors concluded that up to 50% of the stand density (as measured by basal area) could be removed without significant loss in volume production. This would result in transferring stand growth to the remaining trees and significant acceleration of basal area growth. Over the 15-year study period, stands that were thinned at 50% of initial stand density increased annual basal area growth by 34% compared to the untreated stands. Stands thinned at 25% of initial stand density (75% retained) increased annual basal area growth by 25% compared to the untreated stand. There are many other considerations for management of the riparian zone, but it appears 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. 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.

To enhance riparian protection and LWD recruitment, many of the constituency groups interviewed supported incentive programs. Incentives proposed by interviewees included tax credits for retaining trees in riparian areas and financial rewards for re-establishing and maintaining healthy riparian buffers, creating conservation easements, and for being good land stewards.

The FEMAT report (1993) identifies two management goals: (1) provide appropriate solar shading, streambank protection, and sufficient inputs of LWD to maintain/restore necessary instream physical habitat; and (2) maintain/restore the riparian community. Both are inter-related and both depend, site-specifically, on adjacent hillslopes. A watercourse protection corridor should have four zones spanning a range of acceptable management goals and prescriptions. These are: (1) the watercourse channel: (2) a riparian buffer; (3) the transition zone; and (4) the upper hillslope (for steeper slopes and inner gorges). Each requires as unambiguous a demarcation as possible, as well as clear scientific justification.

A "watercourse transition line", as defined in CCR *969.7* is *"that line closest to the watercourse where riparian vegetation is* permanently *establishes'*. This transition line will generally occur at an elevation lower than frequent flood stage heights, including the bankfull discharge. The bankfull discharge or greater, often considered the normal high flow, has an average annual recurrence of approximately once annually (Leopold et al. 1964). Many woody riparian species (e.g., white alder) in the north coast region of California typically establish at or below the bankfull stage height. A "watercourse bank" as defined at CCR 895.1 (definitions) is "*that portion of the* channel *cross-section* that confines *the normal* high *water* flow". In a meandering alluvial channel, the bank on the outside bend will typically have an elevation as great or greater than the bankfull stage, whereas the inside bend will be flooded by the bankfull discharge. This inside bend is often occupied by red or white alders, bigleaf maples (on the backside), and willow species. The watercourse transition line, as defined, would therefore occur below bankfull stage on the inside bend where permanent woody riparian vegetation is established. The watercourse transition line (as currently defined) thus generally separates the active stream channel from its floodplain.

Floodplains are variably defined. Leopold (1994) defines a floodplain simply as "a level area near a river channel, constructed by the river in the present climate and overflowed during moderate flow events." Maddock (1976) notes that "There are two definitions of a floodplain, each of which is equally important. The geologist defines a floodplain as that area of a river valley covered with material deposited by floods. The hydrologist says that a floodplain is that area of a river valley that is periodically overflowed by water in excess of the stream channel's capacity. Any definition more precise than these two is arbitrary to some degree." Both authors agree, however, that the river channel and its floodplain inseparably comprise a stream.

A watercourse is composed of an active channel and a floodplain, although the floodplain may be subtle. For example, dense rows of white alders lining the streambanks are rooted well below bankfull stage. The floodplain may extend only 10 horizontal feet landward, behind the alders, along confined channels with 1.5-3.0% channel gradients. On less steep and less confined channels, the floodplain often extends between valley walls with unequivocal evidence of recently abandoned side-channels among dense stands of white and red alders.

Why is the floodplain important to anadromous salmonids? First, the floodplain is extremely important as habitat to other riparian-dependent species (e.g., FEMAT 1993). Their protection is sanctioned in CCR 916.2(a)(3): *"Themeasures used to protect the beneficial uses of water for* each *watercourse and lake shall be determined by the following . . . (3) The biological needs of the fish and wildlife species by the riparian habitat."* Second, floodplains provide winter refuge habitat for juvenile anadromous salmonids during high flows. Backwaters, old scour channels, and the vegetated floodplain surface greatly reduce water velocities during even the highest floods. Third, floodplains supply and store LWD. In Prairie Creek, Humboldt County, the channel can migrate over individual LWD pieces, and back again, given the low decomposition rate of submerged redwood. Finally, the floodplain provides hydraulic roughness that buffers potentially radical changes in channel morphology.

A watercourse transition line should demarcate the Class I and II watercourse from the hillside by identifying the outer (landward) edge of the floodplain. There is no single distinguishing feature for demarcation, but rather a preponderance of evidence can be used for identification of this line. This uncertainty should not detract from applying the definition in the field. Several excellent indicators include: (1) evidence of recent flood debris: (2) upper depositional limits of sands and silts; (3) remnant channel features, especially oxbow wetlands and relict scour channels; and (4) immature soils. A brief workshop would benefit RPFs, fisheries biologists, CDF inspectors, and others in field identification of the watercourse transition line.

The next zone, the riparian buffer, should begin at the watercourse transition line (i.e., the floodplain boundary) and extend upslope. Primary and secondary functions of the riparian buffer will define its width and acceptable management prescriptions. If possible, site-specific characteristics and objectives should influence these prescriptions.

Many reviews of riparian buffer function are available. These reviews generally conclude that a buffer width equivalent to 100 ft wide or to one site-potential tree (SPT) height delivers most LWD into the stream channel (momentarily disregarding hillslope processes such as mass wasting). For example, the ManTech report (Spence et al. 1993, p. 218) concludes: "In summary, most recent studies suggest buffers approaching one site-potential tree height are needed to maintain natural levels of recruitment of LWD." With respect to a short segment of watercourse, most LWD will be supplied either by the floodplain or from the adjacent hillslope. The actual proportion of LWD delivered to the stream channel will be site-specific.

Analysis of downed timber on 17-70% hillslopes in the Oregon Cascades (R. L. Beschta, unpublished data) indicated that the probability of a tree falling downslope was greater than 75% (Robison and Beschta 1990, p. 791). Another source (Cummins et al. n. d.) stated that it was essential that rootwads remain on wood that recruits to a stream. McDade et al. (1990) found, for mature conifer stands in western Oregon and Washington, that 85% of the LWD was recruited from within 23 m (75.5 ft) of the stream channel.

In the north coastal area of California, one site-potential tree height is not a good indicator to use as a criteria for determining buffer widths that would maintain natural levels of recruitment of LWD and canopy coverages that would protect against changes in stream temperatures. Site curves of average total height for average DBH redwood and Douglas-fir are curvilinear with rapid initial increases up to age 20-40 years, less rapid increase with age from age 60-100 years, and only a slight increase in height after 100 years of age. The main problem with using site-potential tree height is the difference between Site I and Site V. In the upper reaches of some north coast California streams that are located outside of the fog belt on hot dry sites, one site-potential tree may be 80 ft tall at 100 years of age. At lower elevations within the redwood region, one site-potential tree could be 240 ft tall. Consequently, if one site-potential tree height is used to determine buffer width in the hot dry zones, the buffer would be 80-ft wide, while in the lower zone it would be 240-ft wide. This would result in more shade and LWD in the cooler stream zone and considerably less shade and LWD in the warmer stream zone. This is probably the reverse of what is actually needed for protection of salmonid habitat.

A state program that could have an impact on LWD is the DF&G program for issuing "stream alteration" permits under Section 1600 of the Fish and Game Code. The SRP believes that this program should be reviewed to ensure that its goals are consistent with regard to maintaining LWD recruitment for protection of salmonid habitat. These permits are issued by the DF&G and are usually reviewed and approved in the field by the wardens. This program needs to be reviewed for its possible impacts on LWD.

Recommendations (see WLPZ section for additional LWD recruitment recommendations)

1. The state and federal government should work closely with landowners to develop programs for the placement of LWD into streams where the watershed analysis indicates that the lack of in-channel LWD may be limiting to salmonid populations. Incentive programs should be developed to encourage landowners to participate in this program through tax benefits and other incentives.

3. Geological Concerns

Background

Impacts to unstable features are addressed at CCR 923.(c), pertaining to road construction where the rules state "logging roads and landings shall be planned and located, where feasible, to avoid unstable areas." The rules also allow the Director to approve exceptions to this rule where crossing the unstable feature is unavoidable when mitigation measures are provided in the THP. At CCR 914.2 (d), the rules require tractor operations to avoid unstable features, and allow the same exception to operate on such features where the RPF explains and justifies the THP and incorporates mitigation. This same rule section at (f) excludes tractors from operating on slopes greater that 50% where the erosion hazard rating is high or extreme.

All unstable features must be shown on the THP map, as required by rule section CCR 1034 (x) (10). There are no specific requirements for the RPF to consult with a private geologist. However, they must identify the locations of all the existing slides on the ground and show them in the THP, and provide migration if they proposed to operate on these features,

Discussion

Both foresters and geologists are required to be licensed by the state, and RPFs are required to consult outside specialists when they exceed their area of expertise (CCR 1602 (b)). Professional organizations, such as CLFA, have co-sponsored workshops for foresters, and the staff of the respective licensing boards for the two professions are working on a geological training program for RPFs. The geologist constituency group was supportive of training for foresters, and supported the development of better, up-to-date geologic maps from the state Division of Mines and Geology (DMG). State representatives confirmed that they are updating maps.

During the THP review process CDF utilizes the services of the DMG. The purpose of this review is to identify impacts that may result to unstable features from timber operations. This review is based on the information provided in the THP, inspection of available geologic maps, and, if necessary, a field inspection. However, this review depends heavily upon the recognition and identification of unstable features described and mapped in the THP

The geologists constituency group, as well as several other interviewees, recommended that geologists provide a review of THPs at the following two levels: (1) provide a broad overview of geological conditions on the CWE assessment area; and, (2) recommendations for harvesting or road construction on unstable slopes, They suggested that a registered geologist could provide the overview on a property-wide basis, similar to the way that archeology is reviewed. This review would be photo and map-based, and would identify any areas of potential geological concern that would need field review. This review would not replace a thorough field inspection of any THP area. It is, therefore, important for RPFs, who are the primary resource professional performing field reconnaissance, to have a basic understanding of geology. To assess impacts of harvesting operations or road construction on an unstable feature, and recommend mitigation, a certified engineering geologist would be required.

Several constituency groups, including the environmental community, the geologists, and the watershed specialists, expressed concern that there needed to be more consideration of geological concerns, with respect to silviculture on unstable slopes. In the last few years there have been several high-profile slides on timbered properties that occurred on or near where logging had occurred. Regardless of the cause of these slides, the public has a concern for safety issues and adverse impacts to fishery resources.

The issue of landslides on soft, poorly consolidated sedimentary rock has been the subject of recent studies that found slides on steep innergorge slopes, not roads, were the primary source for erosion on this geologic type (PWA 1998). This has raised concern regarding the use of evenaged, or in some cases, any harvesting, on these types of geology. Geologists have been assisting foresters with harvest prescriptions on these geologic types. An issue raised by several interviewees was whether or not RPFs were qualified to locate slides and unstable slopes (especially potential slides and unstable areas), and propose mitigation.

Another area of concern identified by several studies was the steep, headwater areas with concave slopes that might occur at the top of Class III watercourses, These types of slope conditions were identified in the Critical Sites Erosion Study (Durgin et al. 1989) and are, in part, the basis to identify potentially unstable slopes in the SHALSTAB Model, Failures initiated in these headwall areas may result in debris torrents in the Class III watercourse downstream of the failures. Additional geological issues are addressed in the watercourse and lake protection section.

Recommendations

1. To identify any known or likely unstable areas, RPFs (or landowners) should have a geologist conduct a broad geologic review of the property. This review would be conducted using maps and aerial photographs and would identify areas of geological concern that would then require field investigations by a geologist.

2. A review by a CEG or Registered Geologist should be conducted where road construction or harvesting is proposed on an unstable feature.

3. Programs need to be developed that provide RPFs with geologic training through field-based workshops. These programs need to provide RPFs with a basic understanding of geologic processes and recognition of unstable features. This training is not intended to supplant the role of geologists. This RPF geologic training should be required for RPFs preparing plans in the north coast region of California.

4. Due to the increased risk of impacts of harvesting on steep slopes, the SRP recommends that no evenaged harvesting be allowed on slopes greater than 65% unless the plan is reviewed by a geologist and suitable mitigation is available for avoiding adverse significant sediment impacts.

5. Steep headwall areas at the top of Class III watercourses should be carefully evaluated for geologic issues before harvest, and alternative silviculture utilized where needed to protect slopes.

6. CDF and DMG should work together to provide RPFs and geologists up-to-date geology and slope hazard maps.

4. Road Construction and Maintenance

Background

The Forest Practice Rules require (CCR 923) that all logging roads and landings shall be planned, located, constructed, reconstructed, used and maintained in a manner that "is consistent with long-term enhancement and maintenance of the forest resource; best accommodates appropriate yarding systems, and economic feasibility; minimizes damage to soil resources and fish and wildlife habitat: and prevents degradation of the quality and beneficial uses of water." Factors that the RPF shall consider when selecting feasible alternatives for road locations shall include, but not be limited to, the use of existing roads wherever feasible; the use of systematic road layout patterns to minimize total mileage; roads are to be planned to fit topography to minimize disturbance to the natural features of the site: and avoidance of routes near the bottoms of steep and narrow canyons, through marshes and wet meadows, on unstable areas, and near watercourses or near existing nesting sites of threatened or endangered bird species. Roads are also to be located in such a way as to minimize the number of watercourse crossings. Roads should be located on natural benches, flatter slopes and areas of stable soils to minimize the effects on watercourses, Logging systems are to be selected that will reduce excavation or placement of fill on unstable areas (CCR 923 (a-g)).

The FPRs also require that all roads be designated as permanent, seasonal, or temporary (CCR 923.1) Landings associated with roads and yarding activities that will require substantial excavation or exceed 1/4 acre in size are to be located and shown on the THP map (CCR 923.1 (a)). The rules also require that roads and landings are to be planned so that an adequate number of draining facilities structures are installed to minimize the erosion on roadbeds, landing surfaces, sidecast, and fills. Unless otherwise explained and justified, the regulations require logging roads to be a single-lane width with turnouts at reasonable intervals. Roads are also planned to achieve as close a balance to the cut and fill volume as feasible (CCR923.1(f & g)). Roads also shall be planned to stay out of watercourse and lake protection zones; however, the RPF may propose an alternative for better protection of water quality or other forest resources (CCR923.1 (h)).

The regulations require that drainage structures and facilities shall be a sufficient size and number and location to carry runoff of roadbeds, landings and fill slopes. The drainage structure and facilities shall be constructed as to minimize erosion, to ensure proper functioning, and to maintain or restore the natural drainage pattern (CCR923.2 (h)).

The rules also require that no road construction shall occur under saturated soil conditions, except that construction may occur on isolated wet spots (CCR923.2(r)), and road construction that takes place between October 15 and May 1 shall be adequately drained concurrent with construction operations (CCR923.2(s)). Roads that are to be used for log hauling during the winter period shall be, where necessary, surfaced with rock in depth and quantity sufficient to maintain a stable road surface through the period of use, and no road activities may occur within the WLPZ except for stream crossings or a specified in the THP (CCR923.2(t & v)).

The current FPRs require that all logging roads, landings, and associated drainage structures used in a timber operation shall be maintained in a manner that minimizes concentration of runoff, soil erosion, and slope instability which prevents degradation of the water quality and beneficial uses of water during timber operations and throughout the prescribed maintenance period. In addition, those roads which are used in connection with stocking activities shall be maintained throughout their use even if this is beyond the prescribed maintenance period (CCR 923.4). The prescribed maintenance period is defined as at least one year for roads and associated landings and drainage structures that have not been abandoned in accordance with CCR 923.8. The Director may prescribe a maintenance period extending for up to three years in accordance with CCR 1050 that states (923.4(a)):

"Upon approving a work completion report, the Director may prescribe a maintenance period which extends for as much as three years after filing the work completion report based on physical evidence that erosion controls need to be maintained for the extended maintenance period in order to minimize soil erosion or slope instability or to prevent degradation of the quality and beneficial uses of water."

The road maintenance section (CCR 923.4) requires temporary roads to be blocked or otherwise closed to normal vehicular traffic before the winter period. Subsection (h) requires all road running surfaces in the logging area shall be treated as necessary to prevent excessive road surface loss of materials by rocking, watering, chemically treating, asphalting, or oiling. Subsection (i) also requires soil stabilization treatments on road or landing cuts, fills or sidecast, and shall be installed or renewed when such treatment could minimize surface erosion that threatens the beneficial uses of water. Required soil stabilization is reinforced by subsection (k) that states: action shall be taken to prevent failure of cut, fill or sideslopes from discharging materials into watercourses or lakes in quantities deleterious to the quality of beneficial uses of water."

Discussion

Forest roads have typically been blamed as the culprit for the majority of sediment associated with harvesting and forest management operations. This is still accurate not withstanding more recent reports that for certain geologic types in the Coast Range mountains, mass wasting in the inner gorge area may be the primary source of sediment (PWA 1998). The Critical Sites Erosion Study (CSES), Volume I (Durgin et al. 1989) found that although roads accounted for only 4% of the area, they accounted for 76% of the erosion measured. However, Rice noted (citing McCashion and Rice 1983) that approximately one-third the sediment production was from surface erosion. This same study also supports the findings of more contemporary works that found landslides were concentrated in "soft sedimentary bedrock" that were "geologically young, poorly consolidated and therefore little strength, yet may be on steep slopes" (Durgin et al. 1989). The geologist of the CSES team, also commented that "one of the surprises of the study is that there weren't more failures than we found. Many of the slopes we were on were extremely steep and we had to watch out for our own safety. We had thought cutting trees on these slopes would have resulted in failures but that was rarely the *case*. There generally had to be some other contributing factors for failures to occur."

The CSES study (Durgin et al. 1989) recommended increased road maintenance until at least following restocking, and recommended that a culvert should be maintained "as long as it remains in the ground." In Volume II of the CSES (Lewis and Rice 1989), Rice wrote that "the lack of follow up has been one of the greatest weaknesses in the erosion control rules." He went on to say that the three year maintenance period may not be enough and a "more hydrologically meaningful rule would be for monitoring to continue for at least 8 years or until the THP had withstood a 4-year or larger storm."

An interview with the Monitoring Study Group of the Board of Forestry and Fire Protection (MSG) and its contractor conducting THP audits provided some interesting preliminary findings to the SRP. The MSG had found little evidence of sedimentation from the road surface or skid trails entering watercourses. However, they did report that the most common source of sedimentation into watercourses was from the fillslope immediately adjacent to the watercourse crossing. They also noted that WLPZs provided sediment filtration for mobilized fines associated with surface disturbance immediately above the WLPZ. However, these buffer zones did not prevent sedimentation from entering the watercourse in Class III waters or in gullies or rills that were created by concentrated runoff from poorly maintained or poorly designed road drainage systems.

Representatives of the MSG group felt that one weak link in the system was the implementation of the THP and the follow-up following harvest, including the implementation and maintenance of road maintenance facilities. The MSG noted few erosion problems from landings and skid roads. Older roads on steep slopes that were reopened generated some problems and they noted some sidecast in the stream from these types of roads. The MSG also noted outsloped roads worked very well, and the best roads they observed were outsloped roads that had been rocked. They also felt that proper maintenance efforts would have prevented some observed crossing failures.

In the final report, the MSG (MSG 1999) found:

"Roads and their associated crossings were found to have the greatest potential for sediment delivery to watercourses.. . Results to date indicate that greater attention should be focused on improvement of crossing design, construction, and maintenance due to the high levels of departures from Rule requirements and the close proximity of crossings to channels. For roads, better implementation of Rules related to drainage structure design, construction, and maintenance is needed, Mass failures associated with current timber operations were mostly related to roads and produced the highest sediment delivery to watercourse channels when compared to other erosion processes The majority of the road related mass failures were associated *with fill slope problems -indicating that proper road construction techniques are critical for protecting water quality." (p. iii)*

A summary of key findings from the MSG report can be found in Appendix F.

Many interviewees noted that past road construction practices, and so-called "legacy" roads, have been and are continuing to be, the source of many sedimentation problems. Many of these roads are in a state of disrepair and several interviewees felt these are critical or key sources of sediment. Both landowner representatives and RPFs noted that newer, more modern road construction efforts have greatly reduced the sediment discharges, including better maintenance efforts and better designed drainage structures. Several landowners have adopted the use of outsloped roads with rocked or unrocked surfaces. Except at watercourse crossings, these outsloped roads had few (if any) cross drain culverts, and field inspections indicated minor surface runoff associated with this type of road drainage design, However, at least two other landowner representatives felt outsloped roads worked well where winter road usage was not planned, and believed that crowned roads with adequate cross-drain culverts and rock surfaces were far better to minimize sedimentation during winter hauling operations. The interviewees stated that the crowned roads provided more direct and rapid road surface drainage, thereby minimizing the distance water traveled on the road surface before entering the ditch line. A representative from the geologist constituency group recommended that if rocked roads were to be used during the winter, then an increase in the number of cross-drain culverts would help reduce sedimentation.

Numerous interviewees, including agency representatives, environmental representatives, and other resource specialists felt very strongly that road maintenance should be extended well beyond