Final Report on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks

Authored by the Humboldt Watersheds
Independent Scientific Review Panel

Under the Auspices of the
North Coast Regional
Water Quality Control Board

Convened and Facilitated by CONCUR, Inc.
27 DECEMBER 2002

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TO: Susan A. Warner
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FROM: David Hope
David Leland
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DATE: January 6, 2003

SUBJECT: REQUIREMENTS OF THE FOREST PRACTICES ACT AND BUSINESS AND PROFESSIONS CODES FOR PRACTICING FORESTRY, ENGINEERING, AND GEOLOGY FOR PURPOSES OF ISSUANCE OF: "FINAL REPORT ON SEDIMENT IMPAIRMENT AND EFFECTS ON BENEFICIAL USES OF THE ELK RIVER AND STITZ, BEAR, JORDAN AND FRESHWATER CREEKS," PREPARED BY AN INDEPENDENT SCIENTIFIC REVIEW PANEL

On June 27, 2002, the North Coast Regional Water Quality Control Board (Regional Water Board) directed staff to convene a team of independent scientific experts to provide input regarding sediment impairment in the Freshwater, Bear, Jordan, Stitz, and Elk River watersheds. The panel was convened in August of 2002, and, produced the above-noted document on December 27, 2002.

The Supervising Geologist at the Department of Conservation, California Geological Survey, subsequently raised her concern that, while noted experts in their respective fields, none of the panelists were licensed in California "as a geologist, hydrogeologist, civil engineer, geotechnical engineer, or forester as required by State law for these disciplines." In follow-up on this concern, the Regional Water Board inquired with the Department of Consumer Affairs, Board for Professional Engineers and Land Surveyors (BPELS), and the Board of Forestry and Fire Protection, Professional Foresters Registration office. In response to the cumulative feedback on this point from these three agencies, and at the specific suggestion of the BPELS, you sought the professional review of the above-noted document by the undersigned staff, duly licensed in our respective disciplines.

We have reviewed the attached document and determined that the report has investigated the questions posed to the Independent Scientific Review Panel in a manner consistent with the State of California professional codes for our respective disciplines. The analyses and discussions presented in the report rely on and employ techniques in accordance with practices generally accepted by other scientists, engineers, and foresters practicing under similar conditions in California.

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Attachment

(stampcover2.doc)

WE, THE UNDERSIGNED MEMBERS OF THE HUMBOLDT WATERSHED INDEPENDENT SCIENTIFIC REVIEW PANEL, AUTHORED AND HEREBY CONFIRM OUR CONCURRENCE WITH THE FULL TEXT OF THIS REPORT:

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LIST OF ACRONYMS

CDF	California Department of Forestry
CGS	California Geologic Survey
CWE	Cumulative Watersheds Effects
GIS	Geographic Information Systems
HCP	Habitat Conservation Plan
ISRP	Independent Scientific Review Panel
MWAC	Mass Wasting Areas of Concern
NCRWQCB	North Coast Regional Water Quality Control Board
PALCO	Pacific Lumber Company
PBDM	Physically Based Distribution Models
SYP	Sustained Yield Plan
THP	Timber Harvest Plan
TOR	Terms of Reference
TMDL	Total Maximum Daily Loads
USDA	United States Department of Agriculture
WEPP	Water Erosion Prediction Project

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EXECUTIVE SUMMARY

The North Coast Regional Water Quality Control Board (NCRWQCB) convened an Independent Scientific Review Panel (ISRP) in August 2002 to address three questions which will assist the NCRWQCB in fulfilling its mission to protect and restore sediment impaired beneficial uses of waters of the state in Freshwater, Bear, Jordan, Stitz, and Elk watersheds in Humboldt County, California. The assignment to the ISRP is detailed in the Terms of Reference (TOR) in Appendix A. A compendium of 22 documents was transmitted to the Panel on August 14th along with a list of additional documents that would be made available upon request. The ISRP interacted by email and conference calls during the months of August through December 2002.

The Panel conducted face-to-face deliberations in Eureka, California, from October 9th to 11th. During that time, the Panel participated in a site visit and flyover of all five watersheds, received input from the stakeholders, and discussed the three questions assigned by NCRWQCB. The Panel endeavored to make use of available data and worked to evaluate the quality of science and make recommendations for strengthening future analysis.

The three questions addressed by the Panel and the Panel's findings are summarized below. The order has changed from that presented in the TOR. Please note, the Panel acknowledges that the five watersheds in question have different physical characteristics and that the approach to addressing issues of water quality in each will have to be tailored to the specific watershed.

QUESTION 1

Please review the provided documents, and any other relevant information, regarding calculation of appropriate rates of timber harvest that would not impede recovery from excess sediment loads and would not cause or contribute to exceedence of water quality objectives. Please discuss the technical strengths and weaknesses of the varying approaches described in some of these documents to address harvest rate and flood severity, as well as any other reasonable approaches to calculate a rate of harvest for each of the five watersheds that is protective of water quality, which considers natural and other anthropogenic sediment sources.

Key Findings

Although a wide range of literature was reviewed, the Panel focused on two contrasting approaches of watershed behavior in response to timber harvest. These models seek to represent complex physical environmental systems as less complex numerical systems so that the effect of changes in inputs can be predicted in terms of changes in outputs. They each have their strengths and limitations. A description of the two primary models reviewed and the Panel's findings are below.

MODELED SEDIMENT BUDGET

The Modeled Sediment Budget approach (O'Connor, 2002) attempts to represent in detail all the physical processes involved in the production of sediment.

Physically based distributed models (PBDMs), such as the Modeled Sediment Budget approach, usually represent environmental systems via differential equations where all the terms in the equations are measurable physical quantities (for example rainfall, soil erodibility, etc.). Their inputs and outputs are spatially distributed. This means, for example, that soil erodibility must be calculated for all different parts of the watershed and separate values applied for all sub-watersheds, but also that sediment yield is calculated as a spatially varying amount in the sub-watersheds.

The Panel concluded that although the Modeled Sediment Budget method has promise over the long-term, major problems are inherent in the use of a complicated sediment budget approach to establish allowable timber harvest rates. For example, many qualitative judgements about sources of sediment are poorly supported by quantitative studies. Also, the quality and quantity of empirical data that are available or likely to become available over the short-term, particularly regarding the efficacy of proposed mitigation techniques, are key limiting factors.

EMPIRICAL SEDIMENT BUDGET

The Empirical Sediment Budget approach (Reid, 1998a & Reid, 2000), represents the physical system through empirical relationships that relate inputs to outputs. Empirical models use relatively simple regression-derived equations to relate inputs to outputs. They are not distributed, meaning that they produce outputs that carry a value for the whole system (e.g. sediment yield for a whole watershed). The equations contain constants and coefficients that are not directly related to physically measurable properties of the system. However, they generally have the advantage of being able to produce reliable results with sparse data.

Overall, the Panel found the Empirical Sediment Budget approach to be fundamentally sound and at a level of detail commensurate with the kinds and amounts of data that are available, or can be made available, in the near future. The field-based land class rate factors necessary to use this approach can be estimated from existing aerial photographs, publicly available geologic hazard maps, and published studies of representative similar watersheds such as Caspar Creek.

RECOMMENDATIONS

The Panel suggests that the following steps be taken to refine the Empirical Sediment Budget approach to the point where it can be used to calculate timber harvest rates that will not impede recovery of impaired watersheds:

- GIS data acquisition and analysis to stratify watersheds into sediment production land classes.
- Development of land class rate factors based on empirical sediment production information.
- Review and refinement of land classes and rate factors.
- Independent peer review of harvest rate calculations based on land class rate factors.
- Performance monitoring to measure the reliability of harvest practices and mitigation measures in terms of limiting sediment production and meeting land class rate factor estimates.
- Adaptive revision of allowable harvest rates based on outcomes from performance monitoring measurements.

The Panel notes that due to the complexity and variability of the physical systems involved and to the lack of measurements, precise prediction of harvest rates that will not impede recovery is not possible. This is further compounded by the untested nature of some of the innovative mitigation measures proposed. The most reasonable approach to ensure recovery is to develop an adaptive policy that relies on monitoring and the measurement of reliability of measures to limit sediment production during timber harvest or restoration practices.

> **QUESTION 2**
> What options are available (e.g. dredging, and modification of activities resulting in, or reducing, sediment delivery) that can be immediately implemented and will be effective in lessening the adverse flooding conditions and impacts to beneficial uses? Please discuss the potential benefits, limitations, and tradeoffs of these options for each watershed.

Key Findings

The Panel has evaluated the options available to lessen adverse flooding conditions and impacts to beneficial uses of water. It has also developed a matrix of benefits and impacts that may be used to prioritize these options based on the planning priorities of the decision making organizations. Options are presented in three major categories of response. The order does not reflect a preference for some options over others.

- Reduce sediment and peak flows from the watershed by decreasing the rate of timber harvest, reducing tractor and skidder yarding, increasing the ripping of previously compacted areas, efficiently reforesting and seeding highly disturbed areas, decommissioning roads, and stabilizing landslides.

- Increase transport capacity of the channel by re-constructing bridges to accommodate increased flow, removing channel obstructions in low gradient reaches.

- Place instream woody debris or other structures in upper and mid channel reaches, and construct sediment detention basins between the mid channel and lower residential floodplain reaches. The instream woody debris or structures would help trap coarse and medium sized sediment during moderate runoff events, improving stream structure and fish habitat. These structures are, however, subject to removal during large storm events. Further analysis is required to determine cost-benefit ratios. A source of funding would have to be identified.

- Increase the transport capacity of the channel by dredging the lower reaches of the Elk River and Freshwater Creek. This may offer short-term relief from flooding, but it is unlikely to provide a long-term solution, because continued sedimentation would likely refill the channel. Dredging would remove streamside vegetation, damaging both wildlife and stream habitat. Detailed cost-benefit analyses should precede any action.

QUESTION 3

What additional data or piece(s) of information, if any, will be useful in the future for refining approaches to address the above issues? This can include monitoring information, modeling exercises, etc.

Key Findings

The Panel focused on a few key issues and organized its findings according to the timeframe over which responses could be implemented.

IMMEDIATE RECOMMENDATIONS

In the immediate future (next few months), progress can be attained by:

- Clarifying the definition of “background level” of suspended sediment. In a strict sense, background levels of sediment and flow should be determined in watersheds that have not been disturbed or that have had a long (e.g., over 50 years) recovery period.

- Setting rates of timber harvest that allow for adjustments over time based upon new information.

- Corrective actions, including prescriptions on timber harvest, need to be developed on watershed-by-watershed basis because of differences in sediment production processes between Freshwater, Elk, Stitz, Bear, and Jordan. Moreover, it is essential that corrective actions be started soon and not be postponed awaiting research and monitoring that will take place over a period of years.

SHORT-TERM RECOMMENDATIONS

In the short-term (e.g., 6 months to 2 years), it should be possible to collect and re-assemble information that already exists but is not currently being used for decision support, including use of geographic information systems (GIS) and field data. To help all interested parties, a digital library should be established containing key documents (literature, reports, maps, and memoranda).

LONG-TERM RECOMMENDATIONS

In the longer term (next 4 to 5 years), hydrologic and geomorphic monitoring could be developed against which mitigation measures adopted by Pacific Lumber Company (PALCO) can be assessed. An adaptive management strategy could be developed that would allow re-evaluation of the interim harvest rate as new information becomes available

INTRODUCTION

The North Coast Regional Water Quality Control Board (NCRWQCB) convened an Independent Scientific Review Panel (ISRP) to address questions that will assist the NCRWQCB fulfill its mission to protect and restore sediment impaired beneficial uses of waters of the state in Freshwater, Bear, Jordan, Stitz and Elk watersheds in Humboldt County, California, and to advise on interim physical actions that can be initiated in the short-term to fulfill this mission. Longer-term issues, including Total Maximum Daily Load (TMDL) development and implementation issues, will be addressed in a different process.

The Panel was convened in response to a five-part motion that the NCRWQCB unanimously approved on June 27th, 2002. The motion in part directed staff to invite stakeholders from all five watersheds to assist NCRWQCB staff in finalizing an initial set of Terms of Reference (TOR) for an Independent Scientific Review Panel charged with identifying and evaluating a set of actions that could be initiated in the short-term to protect beneficial uses and reduce flooding in all five watersheds.

Impetus for the Panel

For several years, the NCRWQCB received comments from members of the public regarding sedimentation and flooding in these five watersheds. On April 17, 2000, the Humboldt Watershed Council and other residents submitted a petition to the Regional Water Board requesting consideration of waste discharge requirements in these watersheds. After several hearings were scheduled and postponed, the Humboldt Watershed Council and others submitted a petition on March 1, 2001 to the State Board to take action.

In response, the State Board adopted an Order, WQO 2002-0004 on January 23, 2002 that remanded the issues raised by the Humboldt Watershed Council and other Petitioners back to the NCRWQCB. The State Board further directed the NCRWQCB to expedite development of TMDLs in these watersheds.

On February 28, 2002, the NCRWQCB reviewed the State Board Order and directed staff to (1) expedite TMDL development in the watersheds, (2) immediately pursue water quality monitoring, and (3) require technical information from Pacific Lumber Company regarding these watersheds. The NCRWQCB also directed the Executive Officer to pursue mediation among the parties involved and affected in these watersheds as an alternative to a lengthy legal process. The concept was to develop a locally constructed agreement through a consensus process that could be immediately implemented and sustainably provide for water quality protection, community protection, and timber harvesting needs.

On April 18 and 19, 2002, the NCRWQCB conducted an adjudication hearing. At this time, the NCRWQCB directed its staff to pursue the option of mediation and a NCRWQCB sub-committee was formed to advise and assist Ms. Warner (NCRWQCB Executive Officer) in the mediation efforts. Ultimately, the team decided to retain CONCUR Inc., a Bay Area-based environmental policy analysis and dispute resolution firm, to evaluate the potential for mediation and outline a potential mediation process as appropriate.[1]

Among other findings, CONCUR recommended that, given the history of "advocacy science" on this issue, an independent scientific review process should be part of any mediation effort.

1. In its report to the NCRWQCB dated May 15, 2002, CONCUR recommended organizing a Convening Committee to bring together parties for mediation.

TABLE 1: LIST OF QUESTIONS POSED TO PANEL

QUESTION 1	Please review the provided documents, and any other relevant information, regarding calculation of appropriate rates of timber harvest that would not impede recovery, meaning that the water body can support all designated beneficial uses of water and meet the water quality standards as outlined in the Basin Plan, from excess sediment loads and would not cause or contribute to exceedence of water quality objectives. Please discuss the technical strengths and weaknesses of the varying approaches described in some of these documents to address harvest rate and flood severity, as well as any other reasonable approaches to calculate a rate of harvest for each of the five watersheds that is protective of water quality, which considers natural and other anthropogenic sediment sources.
QUESTION 2	What options are available (e.g. dredging, and modification of activities resulting in, or reducing, sediment delivery) that can be immediately implemented and will be effective in lessening the adverse flooding conditions and impacts to beneficial uses? Please discuss the potential benefits, limitations and tradeoffs of these options for each of the five watersheds.
QUESTION 3	What additional data or piece(s) of information, if any, will be useful in the future for refining approaches to address the above issues? This can include monitoring information, modeling exercises, etc.

In addition, CONCUR recommended a Convening Committee be established to determine the appropriate structure and focus for the mediation process.

The NCRWQCB agreed to ask CONCUR to establish a Convening Committee, consisting of representatives from the Pacific Lumber Company, Humboldt Watershed Council, the Freshwater Working Group, the Environmental Protection Information Center, and several non-industrial timber interests. NCRWQCB staff participated as consultants to the Convening Committee (April through June, 2002) in order to assist the group in developing measures likely to be acceptable to the Regional Water Board, while maintaining the Regional Water Board's independent authority over measures or other actions that it will be required to approve. The Convening Committee was originally focused on resolving issues in the Freshwater, Bear, Jordan and Stitz watersheds only.

History of the Convening Committee

The Convening Committee met five times from May 30th to June 26th. Its self defined and adopted mission was "to develop and agree on a set of interim measures, by August 31, 2002 aimed at protecting and restoring beneficial uses and to mitigate nuisance in the Freshwater, Jordan, Bear, and Stitz watersheds prior to TMDL development". One primary recommendation of the Committee was to establish an Independent Scientific Review Panel to provide guidance on a suite of possible interim options that could be used to protect beneficial uses and address flooding in the four watersheds.

During the four-week process, the Convening Committee members worked diligently but ultimately reached an impasse while attempting to frame an initial set of questions to guide the scientific review process. This result was reported at the June 27, 2002 NCRWQCB meeting. After hearing a report from NCRWQCB staff and testimony from Convening Committee members and facilitators, the NCRWQCB directed staff to: (1) initiate its own facilitated Scientific Review Process which would build upon the work on the Convening Committee to address issues in all five watersheds, and (2) invite the original members of the Convening Committee, as well as Elk River representatives, to assist the NCRWQCB staff in finalizing an initial TOR that laid out the objectives, timeline, and deliverables for the proposed ISRP.[2]

Consistent with this motion, CONCUR and the Regional Water Board staff organized a July 12th meeting among the original members of the Convening Committee, along with several Elk River representatives to provide advice to the Regional Water Board staff on finalizing the TOR.

2. Refer to TOR (Appendix A).

TABLE 2: PANELISTS' AFFILIATIONS AND AREAS OF EXPERTISE

PANELIST	AFFILIATION	EXPERTISE
Andrew Collison, Ph.D.	Philip Williams & Associates San Francisco, CA	Fluvial Geomorphology, Hydrology, Slope Stability, Environmental Modeling
William Emmingham, Ph.D.	College of Forestry, Oregon State University Corvallis, OR	Silviculture, Forest Management
Fred Everest, Ph.D.	University of Alaska Sitka, AK	Fisheries, Aquatic Riparian Ecology
William Haneberg, Ph.D.	Private Consultant Port Orchard, WA	Engineering Geology and Hydrogeology, Slope Stability and Geologic Hazard Assessment
Richard Marston, Ph.D.	School of Geology, Oklahoma State University Stillwater, OK	Geomorphology/Hydrology, Terrain Analysis, Fluvial Geomorphology, Debris Torrents and Landsliding Issues
David Tarboton, Sc.D.	Utah Water Research Laboratory, Utah State University Logan, UT	Hydrology, Civil Engineering
Robert Twiss. Ph.D.	Environmental Planning, University of California – Berkeley Berkeley, CA	Watershed Planning and Geographic Information Systems

Panel Nomination and Selection

Members of the Convening Committee were invited to propose selection criteria as well as potential candidates for the Panel. They were then asked to offer feedback on the suitability of candidates based on the following jointly developed selection criteria outlined in the TOR: 1) technical capability in their respective disciplines plus an ability to work across disciplines; 2) objectivity, as reflected by their willingness and ability to integrate diverse viewpoints; 3) ability to work collaboratively; 4) track record of science advising for environmental decision-making; 5) availability; 6) experience evaluating cumulative watershed effects in a forested setting; 7) proven track record of meeting deadlines; 8) experience with practical application; and 9) broad acceptability by the stakeholders. Final selection was to be made by the NCRWQCB staff.

Informed by the advice of the expanded Convening Committee and its facilitators, the NCRWQCB staff then evaluated each of the proposed candidates to recruit a Panel that could collectively provide analysis and understanding in Hydrology, Hydraulics and Fluvial Geomorphology, Aquatic Ecology/Fisheries Biology, Civil Engineering/Water Quality, Geotechnical/Slope Stability, Restoration Ecology, and Forestry/Silviculture. NCRWQCB staff took into consideration the need for representation on all of these disciplines in the final selection process. The Panel selected by the NCRWQCB, including their affiliations and expertise, is shown in Table 2.

The Independent Scientific Review Panel was convened by the NCRWQCB to address three specific questions defined in the final TOR document dated August 6, 2002. The Panel was officially appointed on August 10th, 2002 and began communication by email and conference calls during the August, September and October time frame. A compendium of 22 documents was transmitted to the Panel on August 14th along with a list of additional documents to be made available upon request.

Site Visit and Deliberations

The Panel conducted face-to-face deliberations from October 9th to 11th. During that time, the Panel participated in a one-day site visit. The itinerary[3] for the site visit was arranged by CONCUR with considerable input and support from local stakeholders. A majority of the day was spent in the Freshwater Creek and Elk River watersheds. There was also a brief tour of the Bear Creek watershed. Representatives from various stakeholder groups accompanied the Panel and afforded the opportunity to answer questions and interact with the Panel throughout the day. While it was not possible to meet with all who expressed interest, Panel members considered additional material provided during and following the meeting.[4]

The objectives of the site visit were to familiarize the Panelists with the watersheds and the differences between them and to provide the Panelists with the opportunity to see and hear first hand from local stakeholders where impacts have occurred and what types of monitoring and mitigation efforts have been undertaken to date to address the issues. The site visit included several stops in the Freshwater watershed, including the Howard Heights bridge, a fish trapping station, and the monitoring station at Dr. Terry Roelof's home. In addition, there were stops along the road to Elk River, Bridge Creek, Kristi Wrigley's Ranch, the USGS gauging station, a properly abandoned road site, and the bridge at Bear Creek. The site visit was followed the next morning with an aerial surveillance of all five watersheds. In this way, the Panel met with Dr. Matt O'Connor, consultant to Pacific Lumber Company (PALCO), and Dr. Jeff Barrett of PALCO. Additional briefings were provided by Mr. John Munn of CDF, Dr. Leslie Reid of RSL, and Ms. Trinda Bedrossian, Mr. Bill Short, and Mr. Gerald Marshall of CGS.

Organization of this Report

This report is organized into seven sections. It begins with an executive summary followed by the introduction section. The introduction outlines the historical context, the impetus for the Panel, and the method by which Panel members was convened. The third section presents the Panel's perspective on its assignment. This section includes an overview of the physical setting, a description of the Panel's methodology and a commentary on the relationship between science and policy. The fourth section describes the Panel's response to each of the three questions outlined in the TOR.

To improve the written flow of its final report, the Panel elected to address the questions in a different order than appears in the Terms of Reference. The report first addresses the TOR Question 2 regarding calculation of appropriate rates of harvest. Second, the report addresses TOR Question 1 concerning evaluation of short-term options to mitigate flooding and promote recovery of beneficial uses. Finally, the report addresses TOR Question 3 with a series of recommendations for additional analysis and data collection.

3. See Appendix B.
4. Two documents received from PALCO on December 16 were too late for inclusion in this report but could be considered as part of a phase two effort.

THE ASSIGNMENT

Introduction

Freshwater, Bear, Jordan, Stitz, and Elk watersheds lie within the redwood region of the North California Coast. The soils and climate combine to create highly productive forests, with timber production rates among the highest for north temperate coniferous forests. Redwood and Douglas fir, the two major timber species, produce high quality wood that is valued both nationally and internationally. Most of the timber is milled locally, supporting a major portion of the local economy. The Panel recognizes the importance of developing a sustainable balance that preserves and uses the productive capacity of the land and sustains the local economy, while protecting the beneficial uses of downstream rivers sensitive to additional sediment inputs and increases in runoff.

The Panel acknowledges the conflicting views of the region's residents, PALCO, and other stakeholders. Significant points include PALCO's desire to carry out harvest at specific rates while providing significant levels of environmental protection as provided by the Habitat Conservation Plan (HCP) agreement and the Forest Management Plan. PALCO deserves recognition for its considerable effort and expenditure to improve existing roads and decommission roads that are no longer used, and for its efforts to use logging methods that minimize adverse impacts (e.g. the increased use of cable and helicopter yarding systems). The company's efforts to develop and use sediment budgeting and increase monitoring are noteworthy.

Residents in the watersheds downstream of PALCO are concerned with apparent increased flooding and sedimentation. In response, the residents have initiated efforts to monitor sedimentation and streamflow. These data may eventually help arrive at a better understanding of the hydrology of these watersheds. The Panel is grateful to all the stakeholders and Agency participants—PALCO, residents, California Geologic Survey (CGS), California Department of Forestry (CDF)—for their time, energy, and honest perspectives in bringing the Panel quickly up to speed on the issues and current situation.

The Panel acknowledges the scientifically complex nature of the issues being addressed and is aware of the limitations imposed by the paucity of empirical data on streamflow, sedimentation, and many biological indicators. In addition, the cyclic nature of climate and stochastic nature of individual storms make prediction of flooding, landslides, and siltation extremely difficult. The Panel recognizes that due to the active tectonic setting of the area, the relatively erodible nature of the geologic materials, and climatic variability, these watersheds experience high sediment yields even under natural disturbance regimes, and that determining impacts from timber harvest on these yields is difficult. The Panel also recognizes the difficulty in addressing these issues in a scientifically rigorous manner because of the highly complex relationship between the geology, ecology, and the range of land management activities within the watersheds.

Complexity and Variability of the Physical Setting

The five watersheds are underlain by bedrock units that are subjected to different rates of uplift, are differently susceptible to weathering, produce different kinds of sediments, and exhibit different modes of mass wasting. Even for a single formation within a particular watershed, the orientation of structural and stratigraphic elements relative to topography can be expected to influence susceptibility to erosion and mass wasting. Episodic tectonic activity and a fluctuating but generally wet climate would produce large amounts of sediment, sometimes catastrophically, even in the complete absence of human activity (e.g., Dumitru, 1991; Clarke, 1992; Li and Carver, 1992; Carver, 1994; Jacoby and others, 1995; Merritts, 1996; Sommerfeld and others, 2002). There is evidence in the Holocene geologic record, however, suggesting that major floods during the 20th century have delivered considerably more sediment than those of previous centuries. This difference has been attributed to a combination of changing precipitation patterns and land use practices (Li and Carver, 1992; Sommerfield and others, 2002).

Data are lacking to help define the background level of activity prior to intense human disturbance of the landscape during earlier logging eras. This makes it difficult to accurately assess the impact due to current land management and mitigation practices. In recent years a serious effort has been made to initiate more extensive mitigation practices and make use of new and improved road construction, road maintenance, and logging methods. The impact of these practices, however, has not been monitored long enough to demonstrate their effectiveness. While the long-term benefits have been estimated the short-term consequences have not been adequately quantified. For example, improving roads for all-weather use by installation of adequate culverts and gravel surfaces can have short-term negative effects such as the generation of sediment. Likewise, the long-term benefits of decommissioning roads by removing fill at stream crossings and seeding grass or planting trees will produce additional sediment in the short-term. Therefore, monitoring offers a rich opportunity to evaluate the effectiveness new management practices.

The spatial and temporal variability of precipitation intensity, duration, and frequency make it difficult to assess risks and evaluate the effectiveness of mitigation efforts. A major storm event may occur the year immediately following harvest or restoration, or there may not be one for 15 years. Therefore, it may take 15 years to realize the benefits of preventative actions taken today. Alternatively, restorative actions taken today could be destroyed by a major flood event next year. Likewise, the occurrence of major earthquakes that further destabilize an already unstable landscape, especially during unusually wet winters, is not predictable. The impacts of management activities are subject to normal climate variability and need to be evaluated against a background that recognizes this variability. For example, if a 100-year storm occurs during early monitoring, it should not necessarily lead to further restrictions on timber harvest. Likewise, if no significant storms occur in the near future, it should not lead to an increased rate of timber harvest.

When formulating policy in light of the issues of natural variability and lack of adequate data, two contrasting options emerge. A conservative approach to timber harvest would limit the rate of harvest until short-term effects of timber harvest and mitigation measures can be demonstrated by performance effectiveness monitoring, especially as influenced by site specific geologic conditions affecting mass movement and land surface erosion. A more aggressive timber harvest strategy would accept claims of the effectiveness of all mitigation measures as outlined in the Timber Harvest Plans (THP) and HCP and allow higher rates of harvest, while also acknowledging that timber harvest may negatively impact this unstable geologic setting with unpredictable climate.

Evaluating Science through Peer Review

For at least 200 years, scientists have been called upon to review the works of colleagues before the results of scientific studies are published in the technical literature. The system, known as peer review, is still considered a linchpin of scientific investigation (Altman 2002). Peer review is designed to identify weaknesses in study design, methodological errors in data collection and analysis, possible biases by scientific investigators, claims by authors that cannot be supported by the evidence they present, and other possible problems. Although peer review is considered to be an imperfect process by some scientists (see e.g., Rustum 1993, Garfield 1993), it remains the foundation for evaluating the validity of scientific findings before the works are published or used in formulation of policy by regulatory agencies.

Peer review follows a generally accepted process in which authors submit manuscripts to journals whose editors send the most promising ones to other experts (peers) in the appropriate disciplines to solicit their advice on the scientific merits of the works. The peers then check the legitimacy of all aspects of the work and make suggestions that the editors subsequently use in deciding whether to publish or reject a manuscript.

Peer reviews are generally conducted in one of three formats: open, blind, and double blind. In the open format, the author(s) of the paper and the peer reviewers are each aware of the others identity. In the blind format, the peer reviewers know the name(s) of the authors, but not vice versa. In a double blind review neither author(s) nor reviewers know the identity of the others.

The Panel conducted open peer review of key papers addressing issues related to timber harvest rates, sediment production, and flooding in the Freshwater, Elk, Bear, Jordan, and Stitz watersheds to evaluate the merits of works done and conclusions reached by several authors. The results of the reviews will aid the Board in understanding the strengths and weaknesses of the various papers and in identifying which papers are most credible for use in policy development.

The Relationship Between Science and Policy

In the past decade, scientists and science institutions have been increasingly called upon to contribute to public dialogue about management of federal forestland (Mills et al. 1998), as well as state and private forestlands. During the 1990s, scientists were increasingly involved in formulating policy for management of natural resources on federal lands. Policy related to management of habitat for spotted owls (USDA Forest Service 1992), habitat for anadromous fish (USDA Forest Service and USDI Bureau of Land Management 1994), late successional forests in the Pacific Northwest (Johnson et al. 1991), the Interior Columbia Basin (USDA Forest Service 1996), and the Tongass National Forest (Everest et al. 1997, USDA Forest Service 1997a, 1997 b, 1997c) has been developed by using various models for science-management collaboration. Although the models differ in some respects, an appropriate role for scientists in development of natural resources policy seems to be emerging.

The emerging science role focuses on assisting policy-makers in making science-based decisions (Mills et al. 2001) without advocating a particular policy outcome. What are science-based decisions? Mills et al. (2001) provides five criteria for science-based decision-making in formulation of natural resources policy:

- Focus the science on key issues and communicate it in a policy-relevant form.
- Use scientific information to clarify issues, identify potential management options, and estimate consequences.
- Clearly and simply communicate key science findings to all participants.
- Evaluate whether of not the final policy decisions are consistent with the science information.
- Avoid advocacy of any particular policy outcome.

All of these criteria are designed to maintain the credibility of scientists involved in policy issues and avoid "advocacy science". The final point regarding advocacy, however, is crucial because policy formulation is not science. Policies are formulated after decision-makers carefully consider a combination of scientific information, social and cultural values, and legal, financial, and political considerations. Also, policy recommendations made by scientists are not science. They are a combination of the scientific knowledge, experience, and personal values of the scientists involved. Because the personal values of scientists may differ on resource management issues, it is possible for experts in the same field to review scientific information and recommend very different policy outcomes. Advocacy of this type, especially divergent recommendations by experts using a common science base, tends to erode the credibility of scientists and negate their contribution to the decision-making process. Under these circumstances, policy makers, judges, and stakeholders have a difficult time discerning which experts are credible on the issue.

The Panel's focus in addressing the questions in the terms of reference was on acquisition, synthesis, and analysis of scientific information and on evaluating and communicating the probabilities, risks and consequences that are likely to be associated with proposed forest management actions. The Panel's findings are derived from peer review of reports of other scientists involved in this work. The Panel does not recommend that the NCRWQCB adopt any particular policy outcome. Instead, the Panel intends for the NCRWQCB to include the Panel's findings with other information to formulate regulatory policy in the five watersheds and to identify further information and analyses needed.

FINDINGS

QUESTION 1

Please review the provided documents, and any other relevant information, regarding calculation of appropriate rates of timber harvest that would not impede recovery from excess sediment loads and would not cause or contribute to exceedence of water quality objectives. Please discuss the technical strengths and weaknesses of the varying approaches described in some of these documents to address harvest rate and flood severity, as well as any other reasonable approaches to calculate a rate of harvest for each of the five watersheds that is protective of water quality, which considers natural and other anthropogenic sediment sources.

Background

The Panel was asked to review the provided documents and any other relevant information regarding calculation of timber harvest rates that will not impede recovery from excess sediment loads or the attainment of water quality objectives. Recovery is interpreted to mean a trend ensuring that a water body will be able to eventually support all designated beneficial uses of water and meet the water quality standards as outlined in the NCRWQCB Basin Plan. The Panel was also asked to discuss the technical strengths and weaknesses of different methods for calculating timber harvest rates in the five watersheds.

The current policy on turbidity as stated in the Basin Plan is that "turbidity shall not be increased more than 20% above naturally occurring background levels" so as not to impair beneficial uses or impede recovery of water quality. The Board's policy also states "allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof". The California Department of Forestry currently regulates timber operations in these five watersheds on a THP-by-THP basis that also takes into account the Sustained Yield Plan (SYP), the HCP, and supplemental watershed analyses.

The Panel acknowledges that rate of cut projected by a timber company may be chosen based on a variety of factors, for example company policy, demand for timber at the mill, traditional forestry practice of cutting when stands reach culmination of mean annual increment (Smith et al., 1997). Our focus was, however, on considerations of how rate of cut influences water yield and sedimentation.

Thinning or selection methods that maintain high levels of residual stocking (e.g., 2/3 of full stocking) are assumed to produce less sediment because considerable canopy cover is retained. These methods delay culmination of stands and maintain production of timber at near-maximum rates because, in highly productive forests on the West Coast, the curve of mean annual increment does not have a very sharp peak and thinning a stand broadens the peak. The implication is that production rates in thinned stands well past the point of culmination continue to produce wood at a very high rate for decades (Curtis and Marshall, 1993). However, for corporations where the mill is the profit center, timber may be harvested earlier than culmination based on board feet volume growth, because feeding the mill becomes more important than maximizing wood production. Thinning and delaying the final clearcut harvest in the highly productive redwood forest type should not markedly reduce the quantity or quality of wood produced. From a water quality standpoint spreading the cut among different watersheds so that cutting is not concentrated within one watershed over a short time will help reduce peak flows and sedimentation.

Mechanisms for Sediment Delivery

The rate at which sediment is produced and removed from a watershed is controlled by three factors (e.g., Knighton, 1998): the rate at which erodible material is produced by physical and chemical weathering of bedrock, the rate at which sediment is transported downslope by mass wasting or slope wash processes, and the rate at which sediment is removed from valley bottoms by fluvial processes. Wet and tectonically active areas underlain by weak rocks will produce large amounts of sediment even in the complete absence of human activity. Reid (1998b), for example, used climatic records to demonstrate that a five-fold increase in debris flows in a northern California study area could be attributed to an increased frequency of high-intensity storms during the late 1930s. Therefore, it is not a simple matter to distinguish the amount of sediment that would have been produced by natural processes, and particularly extreme natural events, from that produced as the result of land management activities such as timber harvesting in the watersheds of interest to the Panel.

An abundance of published scientific literature points to the role of timber harvest on increasing sediment production rates. Lewis (1998) suggested that the relationship between timber harvesting, sediment production, and sediment delivery is a complicated web that includes many feedback loops. Important factors include timber felling (which can increase soil moisture, decrease tree root strength, increase the likelihood of blowdown, and increase channel roughness through the addition of woody debris), yarding and skidding (which can compact soils, decrease infiltration rates, and increase runoff), road and landing construction (which can increase runoff as well as increase the likelihood of landsliding), burning (which can increase erodibility by creating bare ground and, in some cases, create hydrophobic soils that increase runoff), and site factors (such as geologic predisposition to landsliding regardless of land management).

In a paired watershed study of North and South Caspar Creeks, Lewis (1998) and Lewis et al. (2001) showed that timber harvesting during the 1970s increased the annual suspended sediment load at the South Fork weir by 212 percent. Subsequent data from individual drainages within the North Fork watershed, which were logged under conditions more representative of the California Forest Practices Rules of the 1990s, showed an 89 percent increase in summed storm loads relative to that predicted for undisturbed conditions, most of which was due to a single landslide. Data from all but one of the watersheds within the North Fork drainage suggested an increase in suspended sediment load following timber harvest, but downstream effects appeared to be small or absent because the sediment had not yet reached the downstream measurement stations. Lewis (1998) and Lewis et al. (2001) suggested that much of the suspended sediment increase attributed to timber harvesting was related to an observed increase in peak flow volume in the years immediately following timber harvest, which they expected to be short-lived. They further concluded that the effects of multiple disturbances within a watershed were approximately additive. Finally, they concluded that sediment increases could have been reduced by avoiding activities that degrade the banks of small channels and that sediment loads are affected as much by channel conditions as sediment delivery from adjacent hillsides.

Other studies have examined the relationship between timber harvesting and landsliding (or other forms of mass wasting) and found a positive correlation between the two (e.g., Furbish and Rice, 1983; Sidle et al., 1985; Pyles et al., 1998; Montgomery et al., 2000; Sidle and Wu, 2001). Other studies (e.g., Brardinoni and Slaymaker, 2001) suggest that modern logging practices produce no detectable increase in landsliding. The increase in landsliding is generally attributed to a combination of increased soil moisture and reduced root strength. Although soil moisture increases probably play an insignificant role in wet season landsliding, because the susceptible slopes are already saturated or nearly so, it may increase the temporal window during which slopes are susceptible to sliding (Sidle and Wu, 2001). Most studies of timber harvesting and landsliding have concentrated on clearcut harvesting, but data collected in Humboldt County on behalf of PALCO suggest that selective harvesting can also increase landslide activity (Pacific Watershed Associates, 1998a).

O'Connor (2002) developed a sediment budget for Freshwater Creek based on a combination of computer models and field observations. Sediment sources for the years 1988 through 1997 included streambank slides, soil creep, bank erosion, shallow landslides, deep-seated landslides, scour of tractor fill, harvest surface erosion, road-related landslides, and road surface erosion. He further attributed various fractions of each of these categories to background processes that would have acted even in the absence of human activity, legacy sources that exist as the result of prior logging practices, and management-related sources that contribute sediment even under modern forest practice rules.

Adequacy of the Existing THP-SYP-HCP Framework

The Panel considered each of the existing regulatory processes to determine if the existing framework could provide a means for ensuring recovery of beneficial uses. The first regulatory process considered by the Panel was THPs. However, because each THP is evaluated on an individual basis, it is not possible to assess the combined impact on water quality and thus THPs for areas within impaired watersheds continue to be approved. The cumulative effects considerations in the THP do not include a firm projection of additional near-term harvest plans, nor do they appear to offer assurances as to the proportion of a watershed to be disturbed within a given time period such as the next five or ten years. Further, assumptions in the THP that mitigations outweigh impacts leads to a conclusion that there need be no limit on rate of disturbance or the total proportion of disturbance of any given watershed.

The Panel then considered the SYP. One of the main goals is to maximize sustained timber production by ensuring that more timber is produced than harvested (California Department of Forestry, 2002). The SYP does rely on environmental documentation that considers potential impacts to wildlife habitat and water quality. However, because the SYP is based on ownership, it does not provide a means to assess the cumulative effects of timber harvest in any one watershed.

The HCP focuses on wildlife habitat conservation, in which water quality per se is by definition a secondary concern, and does not include an integral science-based monitoring component that fully addresses water quality. From our limited review it appears that the THP-SYP-HCP structure lack some of the key elements needed to move toward and assure attainment of water quality standards.

The Panel supports the general concept of watershed analysis to assess the cumulative impacts of timber harvesting as they relate to the NCRWQCB's mission. Watershed analysis is conducted on a scale appropriate for the assessment of cumulative impacts, which stands in contrast to the ownership-based SYP or narrowly focused THPs.

From the Panel's perspective, watershed analyses would need to have the following attributes to be an effective tool. Watershed analyses would at minimum: 1) be completed prior to the approval of THPs, 2) consider the rate of disturbance, 3) consider the proportion of the watershed to be disturbed in a given time period, and 4) consider the location of current and future THPs relative to slope, geology, landslide risk, and related site conditions. Further, because the analyses will require the application of scientific and technical judgement under conditions of wide uncertainty, they should be prepared by an independent, third party. The methodology, assumptions, and conclusions will need to be subjected to rigorous and independent scientific review.

This is particularly so if the analyses are to incorporate innovative but untested concepts such as the PALCO Mass Wasting Areas of Concern (MWAC) or other computer models to delineate areas of potential instability. Watershed analyses conducted in a manner that respects the disparate time scales upon which geologic processes and humans work would also be beneficial. The establishment of background rates, as discussed below, that take into account the magnitude and periodicity of geologic events that contribute sediment regardless of any land management activities would render the analyses more robust.

Assessment of Sediment Credit/Debit Analyses

The following discussion concerns the use of sediment "credits" and "debits". Sediment credits refer to future, planned reductions in sediment from mitigation measures, such as storm-proofing roads and removing Humboldt crossings. The notion is that reductions in sediment be credited against sediment increases (debts) from other timber harvest activities.

PALCO and CDF argue that more harvesting will lead to more recovery because their calculations show that the credits associated with mitigation exceed the debits associated with timber harvest. (Jeff Barrett, personal communication, 10/9/02; John Munn, personal communication, 10/10/02). However, mitigation activities such as the storm proofing, decommissioning, and proper abandonment of roads will, despite their probable long-term benefits, almost certainly have short-term negative impacts. A study of road removal in Redwood National Park (Madej, 2001) estimated that each mitigated stream crossing produced 50 m3 of sediment, which is about one-fifth of that which might have been produced had the mitigation not occurred. Unfortunately, short-term impacts such as these have not been included in the debit side of PALCO and CDF estimations. Furthermore, although mitigation activities may reduce the impact from previously improperly abandoned harvest areas the Panel questions the concept of whether these mitigations should be credits relative to a natural background rate of sediment production.

The Panel also questions the veracity of the extremely high estimates of credits associated with mitigation apparently calculated with worst-case assumptions. The Panel made efforts to seek out measurement-based studies that might support those high estimates, but was unable to find sufficient evidence in support of the values suggested by PALCO (cf., Madej, 2001; McCashion and Rice, 1983). Madej (2001) wrote that decommissioned stream crossings in Redwood National Park reduced sediment production by at least a factor of four, and possibly more, compared to that which might have been expected from untreated crossings. Completely decommissioning roads in the park reduced sediment production by a factor of three to ten compared to sediment production from untreated roads in an adjacent watershed. The decommissioned roads, however, still produced an average of 480 m3 of sediment per kilometer of road. Similarly, McCashion and Rice (1983) concluded that only about one-quarter of the erosion from forest roads in northwestern California can be mitigated using conventional engineering methods. The remaining three-quarters were attributed to site conditions and alignment choices that could not be changed. Finally, the Panel notes that some PALCO estimates of mitigation effectiveness are based on worst-case scenarios; for example, that every mitigated channel crossing would have completely failed and contributed a large amount of sediment to the watershed (PALCO, 2002). A more likely situation is that only some of the crossings would fail, that most of the failures would not have been complete (Best et al., 1995; Madej, 2001), and that some crossing which failed would not contribute the maximum amount of sediment. Thus, a 100% failure rate assumption will probably lead to overestimates of the amount of sediment that is actually saved. It is therefore the Panel's opinion that completely decommissioned roads should be expected to reduce long-term sediment production by a factor of not much more than four or five and that the sediment savings realized from the proper abandonment of roads is likely to be less.

Given the scarcity of scientifically robust studies that might reduce or constrain the uncertainty associated with potentially effective but untested mitigation techniques, one option would be for PALCO to test promising methods and validate their effectiveness through the use of carefully designed and executed monitoring programs. Paired watershed studies could shed considerable light on the effectiveness of road treatments and removal of Humboldt crossings. One approach to be considered is to limit harvest rates until the effectiveness of the promised mitigation approaches has been validated through such mitigation reliability performance monitoring. The alternative approach of permitting accelerated timber harvest rates based on the untested promise of mitigation strategies will, in the opinion of the Panel, lead to a significantly uncertain outcome in terms of downstream sedimentation and water quality standards being met.

Background Rates of Sediment Input

Assessing the impacts of human activities by comparing water quality, sediment production, or any other environmental variable to a naturally occurring background rate is an approach that seems intuitively attractive and logical. Background rates, however, are hard to define. Sediment production (and, consequently, turbidity) is a function of episodic tectonic uplift; bedrock type, including the influence of fracturing and folding; climate and weather, particularly precipitation; fire frequency; and human activities. Thus, sediment production and turbidity can be expected to vary considerably in space (i.e., among watersheds and within watersheds as a function of geology and topography) and time regardless of human activities. Background conditions are also likely to be episodic, with long periods of relative quiescence—lasting decades, centuries, or even millennia—punctuated by events of short duration but large magnitude. The further back one looks, moreover, the more uncertain the geologic record becomes and the more difficult it is to infer anything more than gross averages that fail to capture the episodic nature of watershed change. The result is that any rate or formula will ultimately be a product of professional and scientific judgment, made within a context of high variability and will not simply emerge from the data.

It became apparent during the Panel's work that the relevant working definition of background includes most of the 20th Century, a time during which Humboldt County watersheds were being heavily logged. Scientists do not know how late 20th century sediment production in Humboldt County watersheds compares to peaks in the geologic record, but the Panel is confident that it is above the baseline levels that existed between rare sediment-producing events before the advent of commercial logging. The NCRWQCB must decide whether this is an appropriate definition of background. More work is needed to document the historical water quality for the five streams at the time the standards were adopted and subsequent trends for each stream. Since the entire watershed has been disturbed at various times in the last 150 years, one option would be to establish background levels with respect to nearby minimally disturbed or reference watersheds.

One promising approach to developing water quality standards in such complex landscapes would rely on a relationship between suspended sediment (or turbidity) and stream discharge for less-disturbed watersheds that are otherwise similar to the five watersheds of concern. At the same time, suspended sediment-discharge rating curves could be developed for Freshwater, Elk, Stitz, Bear, and Jordan watersheds. Paired watershed analyses of shifts in the rating curves would help agencies separate significant increases of sediment due to timber harvest from those that would have occurred without human activities. Residents in the Freshwater Creek watershed have been collecting suitable data for just this type of analyses and PALCO has indicated a desire to begin similar water quality monitoring efforts. The Panel underscores the need to develop separate sediment rating curves for each of the five watersheds. The Jordan, Bear, and Stitz watersheds are not occupied by permanent residents but are more tectonically active and steeper and have experienced a notably different history of timber harvest.

Approaches to Calculation of Allowable Harvest Rates

In order to clarify its discussion on specific approaches to calculation of allowable harvest rates, the Panel has prepared the following summary of general approaches. The methods discussed below are models of watershed behavior and response to timber harvest. Such models seek to represent complex physical environmental systems as less complex numerical systems, to predict outputs, given inputs. In this case, inputs may include the area of forested land that is harvested or the rate of cut, for example, while outputs may include water yield or sediment yield. There are two general approaches to numerical modeling, and the models described below fall into both categories.

Empirical models represent environmental systems in terms of relatively simple regression-derived equations that relate inputs to outputs. They are not distributed, meaning that they produce output that carries a value for the whole system (e.g. sediment yield for a whole watershed). The equations contain constants and coefficients that are not directly related to physically measurable properties of the system. When developing an empirical model the emphasis is usually placed on obtaining the best possible fit between predicted and observed output. Much of the complexity of the environmental system is concealed within the 'black box' of the empirical relationships, which means that empirical models are less used in research environments where the primary focus is on understanding the internal processes and their interaction, rather than on getting exactly the "right" answer. Because of their simplicity and the fact that internal processes are not directly simulated, empirical models have relatively low data requirements and are easy to apply.

PBDMs usually represent environmental systems via differential equations where all the terms in the equations are measurable physical quantities (e.g. rainfall, soil erodibility, etc.). Their inputs and outputs are spatially distributed, meaning, for example, that soil erodibility must be calculated for all different soils in the watershed and separate values applied for all sub-watersheds. Also, sediment yield is calculated as a spatially varying amount in the sub-watersheds. When developing a PBDM, the emphasis is generally placed on having the most scientifically rigorous representation of the main physical processes and their interconnections. While accuracy of output is highly desired and sought after, PBDMs are generally more valued for accurately representing the internal workings of the environmental system than for producing the 'right' answer. Because of their complexity and the fact that all equations require physically measurable parameters, they have very high data requirements and are very unreliable where these data are not available.

As a general rule, empirical models are used in "application" environments where the emphasis is on getting the most accurate answer with minimal data collection, while PBDMs are used in "research" environments where large data collection efforts can be justified because of the insight into the internal behavior of the environmental system that is gained by running such a model. While PBDMs are conceptually more realistic and have the potential to be more powerful predictive models than empirical models, obtaining a more accurate answer from a PBDM is rare in complex environmental systems because there is almost never sufficient data to parameterize the model. In most settings, empirical models are more likely to be accurate.

The peak stream discharge approach and the Empirical Sediment Budget approach described below are examples of empirical models. The Modeled Sediment Budget approach incorporates a large number of both empirical and physically based distributed models. As an overall approach, it has many of the characteristics of a PBDM.

PEAK STREAM DISCHARGE APPROACH

The approach to allowable harvest rate calculation articulated by Mr. Munn of CDF is based primarily on a consideration of the influence of proposed timber harvest activities on peak stream discharge (Munn, 1/14/2002). It does not take into account sediment production or changes in the sediment transport capacity of channels that might result from harvest. During the Panel's discussion with him, Mr. Munn also indicated that the CDF approach to evaluating cumulative impacts is designed to maintain the current level of impact rather than promote the recovery of impaired watersheds. As such, this approach, administered by CDF, yields a high risk that current harvest rates will not achieve recovery of beneficial uses of water in the impaired water bodies.

MODELED SEDIMENT BUDGET APPROACH

The approach taken by Dr. O'Connor on behalf of PALCO was to develop a comprehensive sediment budget (O'Connor, 2002). The Panel reasons that the idea of developing a comprehensive sediment budget is in principle a good one that should be pursued over the long-term. Moreover, the sediment input categories used by Dr. O'Connor on behalf of PALCO appear to be useful with regard to the effects of timber harvesting on water quality (O'Connor, 2002). However, the reliance on complex models based on limited data calls into question some of the findings, especially when these findings disagree with data based on empirical sediment budgets. Model-based sediment budgets such as those proposed by Dr. O'Connor for the Freshwater watershed require large amounts of data and calibration relative to other potentially useful approaches. The WEPP model, for example, relies on very detailed site characteristics for small watersheds that require careful field measurements not available from secondary sources. The models used by Dr. O'Connor on behalf of PALCO are also very sensitive to the models used to calculate sediment transport rate and methods used to estimate the residence time of sediment stored in the channel. Predictions based purely on modeled results are subject to one to two orders of magnitude variation in estimated sediment transport rates depending on the rates of sediment transport and storage that are assumed.

The large number of categories (management sources, legacy sources, and background sources) and scarcity of empirical data required Dr. O'Connor to estimate the sediment input for eleven types of sources (soil creep, bank erosion and small streamside landslides, deep seated landslides, shallow landslides in harvest units, surface erosion of landslides, surface erosion in harvest units, erosion of tractor-filled channels, erosion of low order valley fill, road-related shallow landslides, surface erosion of roads, gullies and culvert-fill failures) using at least five different methods that range from field surveys to aerial photograph inventories to computer models. It is therefore very difficult to assess the degree of reliability or uncertainty associated with each sediment source estimate. The Panel questions, for example, whether soil creep truly accounts for an order of magnitude more sediment than harvest unit surface erosion and whether it is truly a background process. Likewise, it is difficult for the Panel to understand the logic behind classifying 40% of shallow landslides in harvest units as naturally occurring events. This is not to say that any given landslide would or would not have occurred in the absence of harvest, or that one could not have made a reasonably good estimate given enough time and money, but rather that it is impossible to evaluate the veracity of such claims from the information provided to us. The Panel also notes that soil creep and deep-seated landslides were interpreted as background and indeterminate sediment sources, respectively. One can easily argue that either might have been accelerated by timber harvesting, because it is physically plausible to infer that upslope harvesting increases the amount of water infiltrating into the slope. Therefore, one cannot infer, in the absence of supporting data, that deep landslides are never triggered by harvest-related practices.

Finally, the Panel notes that if Dr. O'Connor's sediment budget is accepted at face value, it shows that management-related sources produced 51%* more sediment than background sources between 1988 and 1997. This figure increases to 70% if legacy sources are added to the effects of recent timber harvesting, as they probably should, and even higher if some of the arbitrarily assigned background or indeterminate sediment sources are actually management-related. Although these percentages cannot be directly converted into an estimate of excess turbidity, they clearly imply that modern timber harvest practices implemented by PALCO still resulted in significantly increased sediment production in the Freshwater Creek watershed in the last few decades.

The Panel concluded that, although the Modeled Sediment Budget method has promise over the long-term, major problems exist that are inherent in the use of a complicated sediment budget approach to establish allowable timber harvest rates. For example, many qualitative judgments about sources of sediment are poorly supported by quantitative studies. Also, the quality and quantity of empirical data that are available or likely to become available over the short-term, particularly regarding the efficacy of proposed mitigation techniques, are key limiting factors.

EMPIRICAL SEDIMENT BUDGET APPROACH

The approach suggested by Dr. Reid of the Redwood Sciences Laboratory (Reid, 1998a & Reid, 2000), is also a sediment budget approach, but it is empirically based on observed differences between harvested and non-harvested areas. Each watershed is divided into a series of land classes. Reid initially used two classes: harvested and non-harvested. Each land class has an assumed background sediment production rate (tons/yr/mi^2). An empirical rate factor then quantifies the effect of harvest on sediment input. The rate factor is denoted generally as *L* hereafter (as used by O'Connor, Reid used the specific number 9.6). Based on the fraction of an area subject to harvest and fraction of sediment (as inferred from aerial photograph landslide volume estimates) from harvested areas, *L* can be estimated and used in a calculation to determine the allowable rate of timber harvest to sustain an impact relative to background less than a threshold ratio (Reid used 1.2 which amounts to a 20% increase in sediment based on the NCRWQCB Basin Plan policy that turbidity shall not be increased more than 20% above background levels). Important assumptions in this Empirical Sediment Budget approach as applied to Bear Creek are:

- A fixed recovery period exists, denoted *n*, during which sediment production is at the enhanced rate quantified by rate factor *L*. Following this period of *n* years, sediment production reverts back to the background rate. Reid used *n* = 15 years because that had been used in studies by Pacific Watershed Associates (Pacific Watershed Associates, 1998a, 1998b, 1999a, 1999b) in categorizing watersheds as harvested or not, even though she believed that 15 years was an underestimate of the true recovery time. If it is true that the recovery time is substantially greater than 15 years, this assumption will tend to overestimate the background landslide rate and produce higher allowable timber harvest rates.

- The sediment production is proportional to landslide volume observed on aerial photographs. This assumption will tend to overestimate allowable harvest rates because landslides are not the only process for increased sediment production due to timber harvest. Increased sediment production due to harvest-related sources other than landslides visible on aerial photographs has not been accounted for. Any overestimate is at least partially offset by an underestimate induced by interpretation of aerial photography. Aerial photograph inventories are known to underestimate the number of old landslides in heavily forested terrain, thereby overestimating the influence of recent timber harvest activities and, as a consequence, underestimating the allowable harvest rate (Pyles, 2000; Brardinoni and Slaymaker, 2001).

- Any increase in turbidity is equal to the increase in sediment production estimated from landslide volumes.

- Although the absolute rate of sediment delivery for each land class may be a function of weather

* O'Connor (2002), figure 10 lists the following percentages for sediment inputs over the Freshwater watershed from 1988-1997: 56% management, 37% background, and 7% legacy. This gives (56 - 37)/37 = 51% more or (56 + 7 - 37)/37 = 70% more if legacy effects are included.

and climate, the relative ratios for different land classes are constants independent of weather and climate. Stated another way, the rate factor, *L*, that quantifies relative increased sediment production from harvested areas is constant. Reid's strategy means that the total volume of sediment from both classes may be expected to increase during wet years, but a recently harvested area will contribute *L*, times as much sediment per unit area as a completely healed area - regardless of weather and climate. This assumption and the use of relative sediment input rates counters a principle criticism that Dr. Reid's estimates of increased landsliding on recently harvested land are biased because they are based upon data from unusually wet years.

A second, slightly more complicated, analysis for the North Fork Elk River was expanded to include the time-dependent effects of non-landslide sediment delivery in terms of annual proportion of canopy removal. This extension used land class rate factors adapted from the results of post-harvest sediment production from the Caspar Creek experimental watershed.

Dr. Reid kept the Empirical Sediment Budget approach simple by using three land classes:

- High hazard areas that will never be harvested but, even without harvesting may produce sediment at a rate above the background rate of lower hazard areas.
- Average to low hazard areas that were harvested more than *n* years ago, are completely healed, and produce sediment at background rates.
- Average to low hazard areas that were harvested less than *n* years ago, are not completely healed, and therefore produce sediment at rates above background.

One of the criticisms of Dr. Reid's approach to estimating landslide-derived sediment has been that it does not explicitly account for the proportion of the watershed that is declared unavailable for harvest because of high landslide hazards (Opalach 1998). Instead, it specifies the proportion of the total watershed sediment production that comes from high hazard areas. The Panel has re-derived Reid's equations for landslide-derived sediment delivery (see Appendix C) and found that the proportion of sediment from high hazard areas is clearly related to the proportional area of the high hazard zones. The allowable *n* year harvest proportion can be expressed equivalently as

$$N_T = \frac{(S_{RT} - 1)[(R_1/R_2)a_h + 1 - a_h]}{(L - 1)(1 - a_h)} \qquad (1)$$

or

$$N_T = \frac{S_{RT} - 1}{(L - 1)(1 - f_h)} \qquad (2)$$

in which S_{RT} is the allowable threshold sediment yield ratio (S_{RT} = 1.2 in Reid's calculations), *L* is the sediment production rate factor for recently harvested areas (*L* = 9.6 for Bear Creek in Reid's calculations), and fh is the proportion of sediment supplied by high hazard areas (0.9 for Bear Creek in Reid's calculations). R_1 and R_2 are, respectively, the background sediment production rates per unit time for the high-hazard areas and the lower hazard harvestable areas. a_h is the proportion of the watershed classified as high hazard and declared unavailable for harvest. N_T must be interpreted carefully because it is the proportion that can be harvested in an *n* year period of the proportion of watershed available for harvest. The proportion of the total watershed area that can be harvested in the same *n* year period without exceeding the threshold sediment production ratio is N_T (1 - a_h). Furthermore, N_T must be divided by *n* in order to calculate the single year allowable harvest rate.

Equations (1) and (2) are, as demonstrated in Appendix C, related to each other by the equation

$$f_h = \frac{a_h(R_1/R_2)}{1 - a_h + a_h(R_1/R_2)} \qquad (3)$$

Equation (3) shows that fh is a non-unique quantity that is controlled by a combination of the high-hazard area withheld from harvest and the ratio of background sediment production rates for high-hazard areas and harvestable areas. Thus, there are an infinite number of combinations of R_1, R_2, and ah that can give rise to any particular value of fh. Equation (3) reduces to $f_h = a_h$ for the special case of $R_1 = R_2$. The Panel does, however, note that Dr. Reid probably overestimated the value of *L* (9.6 for Bear Creek and 13.0 for North Fork Elk River) by including landslides resulting from timber harvest in low to average hazard areas as well as high hazard areas in which future logging presumably would not occur. In the studies (Pacific Watershed Associates, 1998a, 1998b, 1999a, 1999b) that Dr. Reid based her calculations on, the sediment production from low and high hazard areas that may be specifically excluded from harvest is not separated out when the volume of sediment from harvested areas is reported. Therefore, the rate factor *L* that Reid used is an aggregate from both low and high hazard areas. To calculate an allowable harvest on low hazard areas only using equations (1) or (2) requires that *L* be estimated for the low hazard areas. In Appendix C we explored the sensitivity to *L* and found that unless the logging rate increase factor *L* is reduced considerably from Reid's estimates of 9.6 or 13 down to values approaching 4 that the proportion of area available for harvest per year is not significantly increased.

Overall, the Panel found the Empirical Sediment Budget approach to be fundamentally sound and at a level of detail commensurate with the kinds and amounts of data that are available, or can be made available, in the near future. The field-based land class rate factors necessary to use this approach can be estimated from existing aerial photographs, publicly available geologic and geologic hazard maps, and published studies of watersheds such as Caspar Creek. The use of sediment production ratios, rather than the absolute rates, alleviates much of the difficulty associated with background rate estimation because it is generally easier to estimate one ratio of rates than two independent rates.

The Empirical Sediment Budget approach is suitable for use with an adaptive performance-based allowable timber harvest calculation. The calculations that Reid performed have been criticized for reliance on data from locations claimed not representative of the watersheds at hand. However, although these criticisms have merit, in many cases this was the best data available. PALCO consultants have justified THP requests based on model estimates of sediment production. Models of sediment production, although state of the art, have considerable uncertainty. Furthermore, the claims of effectiveness of mitigation measures are also uncertain and untested. A comprehensive monitoring program in the watersheds being harvested could be used together with the Empirical Sediment Budget approach developed by Reid and expanded in Appendix C to adapt allowable harvest rates in each watershed as the monitoring of sediment yields leads to refined estimates of the rate factors involved. This would address criticisms of both approaches by using data from the actual watershed being harvested. Policy makers setting initial allowable harvest rates need to weigh together the uncertainty in the initial rate factors and consequences in terms of downstream sedimentation and water quality, and economic impacts on the land owners (both timber and downstream residents).

The Panel suggests that the following steps be taken to refine the Empirical Sediment Budget approach to the point where it can be used by the NCRWQCB, other regulatory agencies, PALCO and other timber harvest entities to calculate timber harvest rates that will not impede the recovery of impaired watersheds.

First, conduct exploratory data search to determine the availability, preferably in digital format amenable to GIS analysis, of geologic maps, landslide hazard maps, landslide inventories, aerial photographs, and topographic maps.

Second, develop families of land class rate factors according to bedrock geology, geomorphology (e.g., inner gorge, swale, planar-convex slopes), and harvest methods (e.g., in terms of canopy removal percentages) for each of the five watersheds. Sediment production associated with roads should, if there are sufficient data, be considered as a separate category. The Panel strongly recommends that publicly available information be used to develop land class rate factors. In cases where the necessary information is the subjective and interpretive product of professional judgement, for example landslide hazard maps, the Panel further recommends that the NCRWQCB give strong preference to documents that have undergone rigorous and independent peer review. It would be instructive to compare the land class rate factors generated using alternative hazard zonation schemes such as the PALCO mass wasting avoidance strategy or other computer models. The first generation of estimates, however, should be based on publicly available and peer-reviewed maps rather than potentially useful but as yet untested sources.

Third, review the first generation of land classes and their rate factors to determine what additional information can be used to refine the classes, consolidating or expanding them as appropriate.

Fourth, calculations of initial allowable harvest rates be rigorously and independently peer reviewed.

Fifth, permitted timber harvests be subject to careful performance monitoring to measure and refine the reliability of mitigation measures and rate factors that have been used in the allowable harvest rate calculations.

Sixth, adapt and refine allowable harvest rates (upwards or downwards) based on the outcomes from performance monitoring measurements.

These suggestions are targeted at setting initial allowable harvest rates as well as longer-term allowable harvest rates based on performance monitoring.

QUESTION 2

What options are available (e.g. dredging, and modification of activities resulting in, or reducing, sediment delivery) that can be immediately implemented and will be effective in lessening the adverse flooding conditions and impacts to beneficial uses? Please discuss the potential benefits, limitations, and tradeoffs of these options for each watershed.

The Panel has identified two fundamental processes contributing to flooding problems and impacts to beneficial use of water: (1) a large increase in suspended sediment yield, and (2) a moderate increase in surface water runoff (Li and Carver, 1992, and Sommerfield et al., 2002). The available evidence suggests that flooding is primarily due to an increase in channel bed elevation due to aggradation. The inundation impact of flooding is related to the stage (water level height). Due to aggradation, the same inundation stage occurs with increased frequency (Cafferata and Scanlon 1998, Reid 1998b and 1999). A secondary factor is increased water yield, leading to an increased flow discharge from any given rainfall event.

Large Increase in Suspended Sediment Yield

Aggradation occurs when sediment supply from the watershed exceeds sediment transport capacity in the stream channel. [Please refer to page 14 where mechanisms for sediment production and delivery are discussed.] One of the principal triggers for aggradation is a decrease of gradient, which does occur in the lower portions of Freshwater Creek and the Elk River. Thus, mitigation of an aggradation problem requires either a reduction in sediment supply or an increase in stream transport capacity or storage capacity. Increasing storage capacity by dredging is a short-term solution that will likely be countered by subsequent delivery of sediment. A longer-term solution would be to reduce the sediment supply from the upper watershed. In addition to modifying the sediment system, roads, bridges and structures in the flood prone area may be raised to increase the river stage at which they can be used without inundation.

Moderate Increase in Surface Water Runoff/ Patterns of Peak Flows

Regarding peak flows and the pattern of peak flow, the scientific literature converges on two points (e.g., Anderson et al., 1976; Satterlund, 1972; Brooks et al., 1991; Reid, 1993; Luce, 1995; Ziemer, 1998; Wohl, 2000):

- The effect of timber harvest on the frequency of smaller peak flows depends on the sequence of storm events. If clear-cut watersheds experience a sequence of rain events one after another, with little time in between for soil moisture to decline, then the effect of timber harvest (including tree removal and roads) will be to increase the frequency of lower magnitude peak flows.
- The effect of timber harvest on larger peak flows is more tied to the effects of roads and compacted skid trails than to vegetation removal.

Studies show that redwood coast vegetation can intercept as much as half an inch of precipitation per rainfall event, and that increasing soil moisture levels in the fall can be accelerated by removing vegetation (Reid, 1999). Research by Jones (2000) on paired watersheds shows increased runoff in fall and spring from clearcut watersheds compared with vegetated watersheds.

Reduction in interception and transpiration as a result of vegetation removal offers a possible explanation for the observed pattern of increase flooding in the Elk and Freshwater drainages. Under this explanation a series of small rainfall events would increase soil moisture levels in clear-cut areas so that these areas would require less rainfall to become saturated compared with vegetated areas. As a consequence early storms would produce more runoff and have greater potential to cause flooding (Kittredge, 1948; Ziemer, 1998). The influence on storm runoff would be in proportion to the area that was clearcut recently. In addition, impervious surfaces such as roads or compacted skid trails and landings shed water much faster than fully vegetated areas.

Some research analysts have argued that peak runoff from clearcuts during high magnitude rainfall events is not affected by forest removal, because the size of the lost interception store is small relative to the total amount of water delivered in a large event. Thus, some hydrologists have dismissed the significance of interception, or its loss when the vegetation is removed by clearcutting (e.g., Patric, 1999). PALCO (1999) points out that the Elk River and Freshwater Creek watersheds are not being widely clearcut over short periods of time, as was the case for the often cited Caspar Creek experimental study. Also, PALCO notes that steep terrain is not being tractor-logged and clearcuts are being replanted, two steps that would quickly counter any increase in water and/or sediment production.

In a watershed where a high proportion of the area had been clearcut recently and where the road surface area including skid trails is substantial, the Panel believes there is a strong possibility that peak flows from early fall storms or from smaller storms would be increased to the point where flood frequency and magnitude was increased. In addition to canopy interception, forest cover significantly lowers soil moisture through transpiration. Forest removal or thinning will significantly increase soil moisture levels, potentially contributing to faster and larger amounts of runoff, and increasing pore-water pressures that are a trigger in the activation of some landslides.

Evaluation of Options to Address Flooding and Impacts to Beneficial Uses

As outlined in the terms of reference and noted on page 11 (the relationship between science and policy), the panel does not believe its role is to advocate specific options. We have outlined a number of potential options and sought to objectively evaluate them as positive or detrimental in terms of different attributes. We have not sought to add more detailed scores or values to the options as this would require additional investigation beyond the scope of the Terms of Reference, and individual values would vary from watershed to watershed. However, we have identified the actions that would need to be taken in order to calculate these values.

Once these values have been determined, the resulting framework can provide a methodology for evaluating mitigation options by deciding on a weighting for the attributes, and multiplying by the benefit or cost to determine a ranking of options. Depending on which attribute or group of attributes is given the greatest weight, different options will appear more or less attractive. For example, in the option and attribute matrix below (Table 3) selection of "speed of benefit" as the most heavily weighted attribute will probably result in dredging and raising infrastructure having the highest score on the matrix, whereas if "long-term benefit to water quality" is the most important attribute assessed then options that reduce the sediment yield will have the highest score.

Identification of which of those attributes should carry the most weight is a policy decision that requires value judgments from the participants in the planning process.

In considering possible short-term options to lessen the severity of flooding and impacts to beneficial uses, the Panel focused on five attributes: effectiveness (as defined by the amount by which flooding and turbidity is reduced), implementation speed (as defined by the time needed to achieve improvement), impact (as defined by the degree to which options cause short-term damage to water quality or habitat during implementation), initial cost, and recurrent cost.

Based on a review of literature, meetings with stakeholders, site visits, and discussions among its members, the Panel identified three categories of options (in no particular order) with a variety of specific options related to each: Increase Channel Transport Capacity, Reduce Sediment and Water Supply From the Watershed, and Other Measures.

Increase Channel Transport Capacity

DREDGING

The most immediate (short-term) option is to dredge the channel in Freshwater and Elk creeks from the point where flooding begins to the sea. The principal advantage of this approach is that it would immediately lower flood levels for a given flow. In addition it would increase water and sediment transport capacity, and could jump-start ecological recovery of the channel by removing fines and exposing spawning gravel.

However, dredging has many disadvantages and is an option that would fly in the face of current recommendations for watershed management and restoration. Principally, it would be treating the symptom rather than the cause of the problem, and would entail a large amount of medium term damage to the channel and riparian corridor, which would have a major negative impact on fish and other wildlife. Unless sediment supply is reduced at the same time, dredging will only be a short-term benefit, requiring repeated intervention and consequently high damage and costs. Benefits could be nullified in short order by one or a few major storms or debris flow events. Thus, the Panel sees this a high-risk strategy that would require further detailed study and cost benefit analysis before acceptance.

Reduce Sediment and Water Supply From the Watershed

DECREASE THE RATE OF TIMBER HARVEST

The second option is to decrease the rate of timber harvest until a threshold of recovery is reached. The anticipated benefits of the approach are that it would reduce risk of increased peak flows and therefore reduce risk of accelerated erosion from roads, harvest units, and landslides. The anticipated disadvantages are that its effects would not be immediate and that it would be costly in terms of reduced timber harvest revenues and their associated economic impacts.

REDUCE TRACTOR AND SKIDDER YARDING

The third option is to reduce tractor and skidder yarding by substitution of helicopter and cable harvest methods, thus reducing ground compaction and reduced infiltration capacity. Both methods are now being substituted frequently for ground-based logging in current operations. The anticipated benefit of the approach is that it would reduce surface runoff, which is in turn anticipated to reduce the risk of accelerated erosion. The anticipated disadvantages are that its effects would not be immediate and that it would be costly in terms of reduced timber harvest revenues and their associated economic impacts.

RIP PREVIOUSLY COMPACTED AREAS

The fourth option is to rip previously compacted areas, including skid roads with or without a concomitant decrease in harvest rate. The anticipated benefit of the approach is that it would increase infiltration and reduce surface runoff, which is in turn anticipated to reduce risk of accelerated erosion. The positive impact of this approach depends on the amount of compacted area available for ripping. The anticipated disadvantage is that it is likely to increase short-term erosion and sediment yield depending on on-site mitigation efforts.

IMMEDIATE REPLANTING OF CLEARCUTS AND SEEDING OF HIGHLY DISTURBED AREAS INCLUDING RIPPED LANDINGS, SKID TRAILS, AND DECOMMISSIONED ROADS

The fifth option intended to improve erosion control is efficient revegetation of areas disturbed by logging or road decommissioning. The Panel did not receive sufficient information on the replanting of clearcuts and seeding of disturbed areas to determine the potential of this option. Replanting of clearcuts with tree seedlings during the first post-cutting opportunity (within one year) helps reduce the area needing herbicide treatment and allows the natural revegetation process to go forward. Also, seeding grasses on ripped landings and skid trails and on decommissioned roads so that the grasses provide protection before the first big winter storm events has potential to mitigate the large sediment loads when heavy rains hit bare soil. PALCO has practiced both techniques with some success; however further fine-tuning of these efforts may have potential to significantly reduce the erosion potential. The anticipated disadvantages are that the fast-growing grass species may spread to regeneration areas, require subsequent herbicide treatments, and depending on the type of vegetation used, interfere with timber regeneration.

ROAD DECOMMISSIONING/WEATHERPROOFING

The sixth option is road decommissioning/weatherproofing. In the Panel's view, PALCO is currently doing an admirable job of maintaining, repairing and decommissioning roads. Accelerating the rate of decommissioning or proper abandonment, however, would more rapidly decrease the risk of erosion and sediment production in the affected watershed. The advantage of this method is that it addresses a very significant sediment source that is accessible and readily mitigated. The disadvantage is that there is likely to be a short-term increase in sediment production due to road reconstruction and the combined, immediate increase in sediment may be significant. In addition, benefits may be slow to accrue even under an accelerated decommissioning program.

STABILIZING LANDSLIDES

The seventh option is to stabilize landslides, particularly shallow slope failures that enter watercourses. Landslides are known to be a major sediment source in the area and are currently not mitigated. Possibilities include:

- Development of a program for prioritizing and stabilizing landslides as soon as they become apparent.
- Toe armoring and biotechnical stabilization of landslides (especially landslide toes adjacent to stream channels).
- Installation of horizontal drains in accessible landslides and redirection of surface water to reduce runoff and infiltration.
- Revegetation of landslide surfaces and affected riparian areas.

The advantage of this method is that it reduces risk of accelerated mass erosion from some sources that have not historically been mitigated. The disadvantage is that it will take some time to realize the benefits of this kind of sediment reduction, particularly from large landslides that are only episodically active. This can be expensive, especially if rock gabions or other structures are used to slow the rate that sediment enters streams at the base of slope failures. Moreover, control of deep-seated slope failure is unlikely.

Other Measures

PLACE INSTREAM WOODY DEBRIS IN UPPER AND MID-CHANNEL REACHES

Sediment deposition can be induced in the channel upstream of homes built on the floodplain by placing instream woody debris. This would have the advantage of trapping some sediment that would otherwise reach homes and may improve ecological function in some channels. However, in a system where sediment delivery exceeds transport capacity, structures will overfill and have little ecological benefit, or could even have a negative impact if gravel is buried beneath fine sediment. Also, large capital investments in structures are vulnerable to the next large storm/debris flow event.

CONSTRUCT SEDIMENT DETENTION BASINS BETWEEN THE MID CHANNEL AND FLOODPLAIN REACHES

It may be possible to construct detention basins at the break of channel slope upstream of the floodplain to trap sediment. The advantage of basins is that sediment could be trapped in a confined location and removed without damaging valuable habitat. The disadvantage of this mitigation measure is that such basins would require frequent maintenance (sediment excavation and disposal) and that land would have to be acquired for their construction. There would also have to be consideration of the sediment yield and provision for fish passage at low flows. Also, large capital investments in structures are vulnerable to the next large storm/debris flow event.

RAISE THE BRIDGES AND ROADS, AND BUILD TEMPORARY BERMS

The advantage of this measure is that it would immediately reduce the impact of floods on roads and infrastructure, raising the flood level required to cut off transportation and inundate property behind berms. The disadvantages of these measures are that they would be treating the symptom not the problem, and that further floodplain aggradation may necessitate additional raising of roadbeds. In addition there is a significant risk that structures on the floodplain may disrupt flood and sedimentation patterns, and induce further sedimentation.

Developing More Detailed Values for Beneficial and Detrimental Effects

A prototype matrix of options is listed in Table 3 with associated social, economic, and environmental benefits compared to the initial and longer-term expenses. The potential benefits to be gained by several of the options (e.g. avoiding ground-based skidding, ripping, and immediate planting) is unknown because data were not available to determine how much of each practice is already being done by PALCO.

The notes below outline the steps that could be taken to provide values or scores for the table. In some cases, local experience and management expertise may be sufficient to provide answers. However, the following suggestions may help in cases where there are high stakes and conflicting opinions.

Note that in many cases data or modeling approaches are common to several options and could be carried out in parallel. For example, assessing the effects of altered sediment and water yields on the downstream channel would require combined hydraulic, sediment transport, and erosion modeling (e.g. using HEC-RAS combined with HEC-6). However, the model would only need to be created once to be used to assess numerous scenarios.

TABLE 3: FRAMEWORK FOR EVALUATING BENEFITS OF POTENTIAL EROSION CONTROL OPTIONS

	SPEED OF BENEFIT		LONG-TERM BENEFIT		SHORT-TERM IMPACT			COST	
METHODS	A Flooding	B Water Quality	C Flooding	D Water Quality	E Water Quality	F Channel Habitat	G Riparian Habitat	H Initial	I Recurrent
1: Dredging	+	NONE	+	NONE	–	–	–	$	$
2: Reduce Harvest Rate	+	+	+	+	+	+	+	$	$
3: Reduce Ground-Based Logging	+	+	+	+	+	+	+	$	$
4: Rip Skid Roads	+	+	+	+	–	–	–	$	NONE
5: Road Decommissioning	+	+	+	+	–	–	–	$	NONE
6: Road Weatherproofing	+	+	+	+	–	–	–	$	$
7: Landslide Treatment	+	+	+	+	NONE	NONE	NONE	$	$
8: Place Instream Woody Debris	+	+	NONE	NONE	+	+ / –	+	$	NONE
9: Construct Sediment Trapping Basins	+	+	+	+	NONE	+	+	$	$
10: Raise Floodplain Infrastructure	+	NONE	+	NONE	NONE	NONE	NONE	$	NONE

+ BENEFICIAL EFFECT, – DETRIMENTAL EFFECT, +/– BENEFICIAL OR DETRIMENTAL EFFECT POSSIBLE, $ COST

1: DREDGING

A) Speed of benefit/flooding ▸ The benefit could occur as soon as dredging is complete. No additional data are required.

B) Speed of benefit/water quality ▸ Dredging will not affect the quality of water entering from upstream. No additional data are required.

C) Long-term benefit/flooding ▸ The degree to which dredging reduces flooding can be calculated using standard 1D hydraulic models such as HEC-RAS or MIKE-11 combined with flood frequency curves. The duration of the benefit depends on the sediment delivery from upstream compared with the sediment transport capacity of the dredged channel. An analysis of sediment deposition rate would be required to assess the life expectancy of the channel and to calculate the frequency with which additional dredging would be required (if necessary). Most of these data are available or can be gathered relatively easily.

D) Long-term benefit/water quality ▸ Dredging will not affect the quality of water entering from upstream. No additional data are required.

E) Short-term impact/water quality ▸ A literature review would be required to assess the impact of dredging on suspended sediment and turbidity in similar channel dredging operations, so as to evaluate the impact of dredging.

F) Short-term impact/channel habitat ▸ Dredging will have considerable short-term impact on channel habitat. A biological assessment of the dredged reaches would be required to determine the intensity and duration of the impact.

G) Short-term impact/riparian habitat ▸ Dredging is expected to have considerable short-term impact on riparian habitat. A biological assessment of the riparian corridor adjacent to the dredged reaches would be required to determine the intensity and duration of the impact.

H) Initial cost ▸ An estimate of the cost of dredging could be obtained from a contractor.

I) Recurrent cost ▸ An estimate of the cost of dredging should be obtained from a contractor.

2: REDUCE HARVEST RATE

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as harvest rate is reduced, and to increase over time, as compacted ground recovers and infiltration capacity increases, reducing runoff and erosion from the watershed and deposition and flooding downstream. A literature review should reveal typical rates of recovery for planning purposes. Monitoring of infiltration capacity and runoff in plot experiments will enable the actual rate of recovery to be measured and used as a basis for future planning.

B) Speed of benefit/water quality ▸ The benefit would be expected to start as soon as harvest rate is reduced, and to increase over time. The modified Reid model approach could be used to predict the change in sediment yield that would occur over time. Monitoring of suspended sediment discharge in paired watersheds or field plots will enable the effect to be measured and used as a basis for future plans.

C) Long-term benefit/flooding ▸ The modeling and field monitoring approach described in sections 2A and 2B can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced, as well as the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ The modified Reid modeling approach could be used to predict the benefit in water quality. Data for this are mostly available or can be obtained at little cost.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ No detrimental impact would be expected.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of reduced harvest rate should be obtained from a forest economist.

I) Recurrent cost ▸ An estimate of the cost of reduced harvest rate should be obtained from a forest economist.

3: REDUCE GROUND-BASED LOGGING

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as ground-based logging is reduced, and to increase over time, as compacted ground recovers and infiltration capacity increases, reducing runoff and erosion from the watershed and deposition and flooding downstream. A literature review would likely reveal typical rates of recovery for planning purposes. Monitoring of infiltration capacity and runoff in plot experiments will enable the actual rate of recovery to be measured and used as a basis for future planning.

B) Speed of benefit/water quality ▸ The benefit would be expected to begin to occur as soon as ground-based logging is reduced, and to increase over time, as compacted ground recovers and infiltration rates increase, reducing runoff and erosion. The hydrology data from 3A could be used as an input to an erosion model that would be used to predict the change in sediment yield that would occur over time. Monitoring of suspended sediment discharge in paired watersheds or plot experiments will enable the effect to be measured and used as a basis for future harvest plans.

C) Long-term benefit/flooding ▸ The modeling and field monitoring approach described in sections 3A and 3B can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Literature data on water and sediment yields under ground- and non-ground-based logging may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ No detrimental impact would be expected.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of reduced ground-based logging could be obtained from a forest engineer.

I) Recurrent cost ▸ An estimate of the cost of reduced ground-based logging could be obtained from a forest engineer.

4: RIP SKID ROADS

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as skid roads are ripped, and to increase over time, as compacted ground recovers and infiltration capacity increases, reducing runoff and erosion from the watershed and deposition and flooding downstream. A literature review would likely reveal typical rates of recovery for planning purposes. Monitoring of infiltration capacity and runoff in plot experiments will enable the actual rate of recovery to be measured and used as a basis for future planning.

B) Speed of benefit/water quality ▸ The benefit would be expected to begin to occur as soon as skid roads are ripped, and to increase over time, as compacted ground recovers and infiltration rates increase, reducing runoff and erosion. The hydrology data from 4A could be used as an input to an erosion model that would be used to predict the change in sediment yield that would occur over time. Monitoring of suspended sediment discharge in paired watersheds or plot experiments will enable the effect to be measured and used as a basis for future harvest plans.

C) Long-term benefit/flooding ▸ The modeling and field monitoring approach described in sections 4A and 4B can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Literature data on water and sediment yields from ripped and non-ripped skid roads may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ Road ripping would be expected to produce a small short-term increase in sediment yield, increasing turbidity. A literature review could reveal the typical magnitude of turbidity increases and duration of the impact.

F) Short-term impact/channel habitat ▸ Road ripping would be expected to produce a small short-term increase in sediment yield, impacting channel habitat. A literature review could reveal the magnitude and duration of typical sediment yield increases.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of skid road ripping could be obtained from a forest engineer.

I) Recurrent cost ▸ No recurrent costs are expected.

5: ROAD DECOMMISSIONING

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as roads are decommissioned, and to increase over time, as more roads are disconnected from the stream channel network, reducing runoff. A literature review would likely reveal typical recovery rates. Infiltration measurements and runoff monitoring from field plots could be used to measure the effects over time, as a basis for future planning.

B) Speed of benefit/water quality ▸ The benefit would be expected to start as soon as roads are decommissioned, and to increase over time, as more roads are disconnected from the stream channel network, reducing runoff, erosion and sediment delivery. A literature review would likely reveal typical recovery rates. Sediment yield monitoring from field plots should be used to measure the effects over time, as a basis for future planning.

C) Long-term benefit/flooding ▸ The literature and field monitoring approach described in sections 5A and 5B can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Data from 5A and 5B may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ Road decommissioning would be expected to produce a small short-term increase in sediment yield, increasing turbidity. A literature review could reveal typical expected values and durations.

F) Short-term impact/channel habitat ▸ Road decommissioning would be expected to produce a small short-term increase in sediment yield, impacting channel habitat. A literature review could reveal typical expected values and durations.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of road decommissioning should be obtained from a forest engineer.

I) Recurrent cost ▸ No recurrent costs are expected.

6: ROAD WEATHERPROOFING

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as roads are weatherproofed, and to increase over time, as more roads are disconnected from the stream channel network, reducing runoff and landslides. A literature review might reveal typical recovery rates. Runoff monitoring from weatherproof and non-weatherproof road plots could be used to measure the effects over time, as a basis for future planning.

B) Speed of benefit/water quality ▸ The benefit would be expected to start as soon as roads are weatherproofed, and to increase over time, as more roads are weatherproofed, reducing runoff, erosion and sediment delivery. A literature review might reveal typical recovery rates. Sediment yield monitoring from field plots should be used to measure the effects over time, as a basis for future planning.

C) Long-term benefit/flooding ▸ The literature and field monitoring approach described in sections 6A and 6B can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Data from 6A and 6B may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ Road weatherproofing would be expected to produce a small short-term increase in sediment yield, increasing turbidity. A literature review might reveal typical expected values and durations.

F) Short-term impact/channel habitat ▸ Road decommissioning would be expected to produce a small short-term increase in sediment yield, impacting channel habitat. A literature review might reveal typical expected values and durations.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of road weatherproofing could be obtained from a forest engineer.

I) Recurrent cost ▸ An estimate of the cost of road weatherproofing could be obtained from a forest engineer.

7: LANDSLIDE TREATMENT

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as landslide treatment commenced, and to increase over time, as more landslides are prevented and runoff and sediment yield from existing landslides is reduced. Calculation of speed of benefit would be difficult, and an estimation would have to be made from a literature review. Field monitoring should be carried out to provide data from future plans.

B) Speed of benefit/water quality ▸ The benefit would be expected to start as soon as landslide treatment commenced, and to increase over time, as more landslides are prevented and runoff and sediment yield from existing landslides is reduced. Calculation of speed of benefit would be difficult, and an estimate would have to be made from a literature review. Given the likely magnitude of costs, field monitoring should be carried out to provide data for future plans.

C) Long-term benefit/flooding ▸ An inventory of landslides could be carried out, and measurements of sediment and water delivery to the stream network made. This information can be used to provide water and sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Data from 7C may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ No detrimental impact would be expected.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of landslide treatment could be obtained from an engineering geologist, geotechnical engineer, or geomorphologist.

I) Recurrent cost ▸ An estimate of the recurrent cost of landslide treatment could be obtained from an engineering geologist, geotechnical engineer, or geomorphologist.

8. SEDIMENT TRAPPING - LARGE WOODY DEBRIS

A) Speed of benefit/flooding ▸ A small benefit would be expected to start as soon as large woody debris placement commenced, as sediment is trapped behind structures, allowing scour to occur downstream.

B) Speed of benefit/water quality ▸ A small benefit would be expected to start as soon large woody debris placement commenced, as sediment is trapped behind structures, allowing scour to occur downstream.

C) Long-term benefit/flooding ▸ The volume of sediment trapped by each structure could be predicted by a geomorphology consultant or fisheries biologist. This information can be used to provide sediment inputs to a combination of models that can be used to assess downstream flood impacts. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Data from 8C may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ Large woody debris could have either a positive or negative effect - channel habitat, by creating certain types of habitat but possibly inducing burial of spawning gravels. A sediment transport analysis and channel biological assessment would be required to assess the impacts.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of sediment trapping could be obtained from an engineering geologist, geomorphologist, or civil engineer.

I) Recurrent cost ▸ An estimate of the cost of sediment trapping could be obtained from an engineering geologist, geomorphologist, or civil engineer.

9. SEDIMENT TRAPPING - DETENTION BASINS

A) Speed of benefit/flooding ▸ The benefit would be expected to start as soon as sediment trapping commenced, as sediment delivery to the main channel network is reduced, allowing scour to lower the channel bed elevation and reduce flood levels. Hydraulic and sediment transport modeling of the basins and lower channel would be required to assess the speed of the benefit.

B) Speed of benefit/water quality ▸ The benefit would be expected to start as soon as sediment trapping commenced, as sediment delivery to the main channel network is reduced. Hydraulic and sediment transport modeling of the basins and lower channel would be required to assess the speed of the benefit.

C) Long-term benefit/flooding ▸ Data from 9A and 9B can be used as inputs to a combined hydraulic-sediment transport model. One-dimensional hydraulic modeling coupled with sediment erosion and transport models (e.g. HEC-RAS combined with HEC-6) can be used to predict the rate of channel scour or deposition that would occur if sediment and water yield from the watershed was reduced. Given these, it would also be possible to estimate the resulting channel bed elevations and flood frequencies.

D) Long-term benefit/water quality ▸ Data from 9B may be used to predict the long-term benefit on water quality.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ No detrimental impact would be expected.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of detention basins should be obtained from an engineering and construction company.

I) Recurrent cost ▸ An estimate of the cost of removing sediment from the basins and disposing of it could be obtained from an engineering and construction company.

10: RAISING FLOODPLAIN INFRASTRUCTURE

A) Speed of benefit/flooding ▸ The benefit would be expected to start on completion of construction.

B) Speed of benefit/water quality ▸ No benefit would be expected as the work would not affect the sediment yield from upstream.

C) Long-term benefit/flooding ▸ One-dimensional hydraulic modeling (e.g. HEC-RAS or MIKE-11) can be used to predict the rate reduction in flood frequency achieved by raising infrastructure.

D) Long-term benefit/water quality ▸ No benefit would be expected as the work would not affect the sediment yield from upstream.

E) Short-term impact/water quality ▸ No detrimental impact would be expected.

F) Short-term impact/channel habitat ▸ No detrimental impact would be expected.

G) Short-term impact/riparian habitat ▸ No detrimental impact would be expected.

H) Initial cost ▸ An estimate of the cost of raising infrastructure should be obtained from a civil engineer.

I) Recurrent cost ▸ No recurrent costs are expected.

Potential to Recover Beneficial Uses of Water

Because the fundamental problem can be attributed to an abundance of water and sediment, restoring the flux of water and sediment to a level that more closely resembles their pre-logging levels would increase the probability of restoring the beneficial uses of water in the long-term. If water and sediment yields are in balance with transport capacity, a self-sustaining system should develop again, with all the associated benefits in terms of water quality, flood frequency, and stream biological and physical function.

Although natural background levels of runoff, erosion and landslide activity are not known, the Panel believes the inevitable consequences of logging activities, even with the best mitigation efforts, are increased runoff, erosion and landslide activity. Therefore, while mitigation should form an important part of any effort it is not likely to achieve the desired levels of sediment reduction alone. A concurrent reduction in the harvest rate would likely increase the probability of long-term recovery. Reid (1999) has estimated the hydrologic recovery as a function of stand age. After 20 years, 56% recovery is expected; after 50 years, 89% recovery is expected; after 80 years, 100% recovery is expected. If timber is harvested over shorter time cycles, watershed impacts will be cumulative because recovery time will be interrupted by a new set of impacts. Therefore, the Panel suggests that PALCO develop and use a silviculture regime that uses thinning or partial cutting to maintain relatively long rotations.

QUESTION 3
What additional data or piece(s) of information, if any, will be useful in the future for refining approaches to address the above issues? This can include monitoring information, modeling exercises, etc.

The following steps may help the Board take actions appropriate to the current level of knowledge and move sequentially over time to buttress its science base.

Immediate period

The "Immediate Period" is defined as the period of time including the next few months. The following steps should be possible with a small amount of staff time, and should be seen as interim measures.

CLARIFYING THE DEFINITION OF "BACKGROUND LEVEL"

The current sediment standard in the North Coast Water Quality Control Plan states that turbidity must not be increased by more than 20 percent above natural background levels. The Panel, stakeholders, and some regulatory agencies are bothered by a standard that depends on defining "natural background" conditions. Natural is generally assumed to mean pre-settlement, and therefore pre-logging conditions. The NCRWQCB could decide now to set an interim definition of "Background levels" that recognizes the variability in response of geologic units to timber harvest activities. The interim definition would become more fully developed and formalized in the TMDL process and other Board actions; but some immediate clarification is needed. The Panel is concerned that other agencies' definitions will not meet the Board's mandate, and in fact, will frustrate the attainment of water quality standards. The Panel is especially concerned that any definition that progressively subsumes changing "legacy" sediment sources over time cannot serve as a baseline for achieving water quality standards.

Performance of this task is beyond the Panel's purview, but a good definition is essential to necessary regulations. The Panel recommends that the Board consider a definition that is based upon estimates of watershed performance under essentially undisturbed conditions, recognizing variation in geology, climate, fire, and mass wasting. While no single control watershed will serve to define undisturbed conditions, it would not be unreasonable to use the Headwaters drainage as a starting point. One approach that deserves investigation is to describe a new standard based on measurement of suspended sediment differences from a suspended sediment-discharge rating curve. Since turbidity or suspended sediment concentration vary considerably with water discharge, any background level should be defined with relation to discharge rate. In other words, it should take the form of a discharge v. sediment discharge or turbidity rating curve, with exceedence defined as deviation more than a prescribed percentage away from the line.

SETTING A "RATE OF TIMBER HARVEST" FOR THE FIVE WATERSHEDS

Any approach to setting rates of timber harvest should allow for adjustments over time based upon new information. But it is essential that corrective actions be started soon and not postponed awaiting research and monitoring that would take place over a period of years. In the Panel's opinion, it should be possible within this immediate time period to refine the Empirical Sediment Budget Approach along the lines suggested in Appendix C. Using this approach, it should be sufficient to set interim rates for each of the five watersheds. These rates then could be adjusted up or down as information and a more robust management structure evolve during the longer-term period described below. The Panel prefers this approach to one that would rely on the Modeled Sediment Budget Approach because of the uncertainties with each step in the detailed analyses.

Short-term (6 months to 2 years)

DATA AND ANALYSIS

In the short-term (e.g., 6 months to 2 years), it should be possible to collect and re-assemble information that already exists, but is not currently being used for decision support.

GIS

A number of useful data layers are now available and simply need to be re-projected to a common base and assembled for analysis. In the Panel's view, the NCRWQCB has the staff capabilities and computing resources to do this quickly (recognizing that other work may have priority); assistance from CGS and CDF as well as private stakeholders would be helpful. Considerable information is potentially available now from a number of organizations, but data-sharing, although begun, has not built a readily available set of reference material. The essence of the GIS work would be to help the NCRWQCB and its staff visualize and track sediment-causing impacts in the five watersheds. Appendix D of this report depicts some preliminary views, and a list of data layers that are available now, and gives some suggestions for further acquisitions from cooperators.

FIELD DATA

It would be desirable to initiate a limited set of field studies now, even though data might not be forthcoming for use in immediate decisions. Items noted during the Panel's field trip and discussions were:

- Longitudinal profiles and notation of streambed conditions. Some profiles exist, but they were prepared for fisheries purposes. There is considerable controversy about pulses of sediment. Do they exist? How large are they? How frequently do they move? Are they composed of fine or coarse sediment? How persistent are channel bed changes caused by these sediment pulses? Some of this dissention could be reduced by simple field surveys; other items would require more substantial inventories and monitoring.

- Core samples of streambed sediment could be taken to not only authenticate sampling of sediment depth, but possibly to help identify sediment sources by reference to the location of geologic features.

DIGITAL LIBRARY SERVICES

It is obvious to the Panel that a very large and growing body of literature, reports, maps, and memoranda must advise the decision process. Creation of a digital repository for key documents, as well as a web site to list and provide access to files, would be of great help.

Longer-term (next four or five years)

BACKGROUND LEVEL

The interim definition must be refined based upon consideration of long-term climatic and geomorphic episodic events, (e.g. floods, seismicity, tectonic uplift, fire).

This topic warrants formal scientific review, but the Panel would note that the final definition will not emerge from science alone, but come as a policy decision.

An early step would be to develop further monitoring data for the Headwaters, and/or other selected watersheds. Channel surveys and the development of discharge-suspended sediment rating curves are foremost among data needs. The importance of monitoring is already understood, and residents and companies are involved. Some excellent monitoring is underway, and the Board's reliance on monitoring will underscore the value of such efforts.

RATE OF DISTURBANCE

In the mid- to longer-term, watershed analyses and cumulative effects analyses, coupled with improved data should permit re-evaluation of the interim rates of cut. Evaluation could be timed to follow from new information, rather than a pre-set date; the interim rate might in any event be re-evaluated in four to five years.

WATERSHED AND STREAM CONDITIONS

Detailed mapping of Mass Wasting Potential has already been prepared by CGS in the form of maps and will be exposed to scientific review in the short run. Watershed Analyses will be improved and finalized during the short-term for at least some of the five watersheds.

- Sediment rating curves should be developed for watersheds with different geological characteristics and different land disturbance histories, to provide background conditions and to enable deviation from background level to be objectively demonstrated in the future.

- Monitoring of water and sediment runoff from roads, harvest units subject to different harvesting methods (e.g. tractor logging, cable logging), log landing areas, and landslides should be carried out to enable more accurate sediment budgets to be constructed. This work will also reveal the effectiveness of mitigation methods and allow for more rigorous identification of problem areas.

- Longitudinal profiles of the five streams, combined with geomorphic analysis of channel condition and sediment storage, would be helpful in identifying the current condition of the watershed and providing some insight into the future impact of the upper watershed and stream geomorphology on the lower channel and floodplain.

- Continued monitoring of on-site and near-site disturbances should be intensified.

IMPROVING THE SCIENCE BASIS FOR FUTURE ACTIONS

The Board's record of decision should be increasingly based upon peer-reviewed studies and documentation. Reliance on gray literature commonly leads to conflicting interpretation. The Panel recommends that if the Board adopts policies regarding background and rate of disturbance, it should upon adoption also initiate a process whereby the science basis for background and rate of disturbance is published and subject to peer review. This can be time-consuming, so the Panel recommends a three-step process as follows: 1) policy adoption, 2) formal publication and review, and 3) revision of the policy if peer review supports alternative interpretation.

CONCLUDING REMARKS

The Panel has addressed the three questions posed in the TOR using the literature, a site visit, meetings with stakeholders, and deliberations among Panel members. The Panel acknowledges the conflicting views of the residents, PALCO, and other stakeholders. For a number of reasons, scientists with the best of intentions contrast in their interpretation of cause-and-effect in the five watersheds being reviewed. In the North Coast watersheds of Humboldt County, the geology is complex, climate is variable, and hydrologic and geomorphic data are rarely of sufficient spatial and temporal resolution to answer key questions. The modeling efforts have not completely resolved the debate because of inherent uncertainties in those efforts. Cumulative watershed effects (CWEs) are difficult to recognize because CWEs are diffuse in space and time. Moreover, it is hard to pinpoint a specific process or place that is responsible for impacts to the sediment and water regime of a watershed. Nevertheless, the Panel believes that this report highlights the best available scientific information to clarify issues, identify potential management options, and estimate consequences. The NCRWQCB is left with the task of actually selecting management options to achieve their water quality goals.

The Panel wishes to express its appreciation to the NCRWQCB staff, to CONCUR, to the stakeholders, and to regulatory agency personnel with whom we met during the course of this investigation. Panel members have supplemented their own expertise by reviewing the printed materials supplied by all parties and through interviews and discussions during the 9–11 October 2002 site visit.

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Personal communication from Bill Kleiner and Dan Cohoon to CONCUR regarding concerns and interests of non-industrial timberland interests. October 22, 2002.

Personal communication from Bill Kleiner and Dan Cohoon to the Humboldt Watersheds ISRP on behalf of non-industrial timberland owners, farmers and timberland managers within the Freshwater and Elk Watershedd. November 1, 2002.

Examples of CGS reviews for THP that recommend modification of proposed mitigations, additional geologic input, deletion of protions of the plan or denial of a THP plan:

- THP 1-98-209HUM, AM #6
- THP 1-01-148-HUM
- THP 1-01-148-HUM (Focused)
- THP 1-01-218-HUM
- THP 1-02-106HUM
- THP 1-02-106HUM (Supplemental)
- THP 1-02-218HUM (First Review)

CGS/DMG Notes related to forest management:

- Note 45 - Guidelines for Engineering Geologic Reports for Timber Harvesting Plans
- Note 50 - Factors Affecting Landslides in Forested Terrain (To be updated 2003)
- Note 52 - Guidelines for Preparing Geologic Reports for Regional Scale Environmental and Resource Management Planning

APPENDIX A:

TERMS OF REFERENCE FOR THE PANEL

INDEPENDENT SCIENTIFIC REVIEW PANEL ON SEDIMENT IMPAIRMENT, FLOODING AND ASSOCIATED IMPACTS ON BENEFICIAL USES IN FRESHWATER, BEAR, JORDAN, STITZ AND ELK WATERSHEDS

Purpose

The North Coast Regional Water Quality Control Board (Regional Water Board) is convening an Independent Scientific Review Panel to address questions which will assist the Regional Water Board in fulfilling its mission to protect and restore sediment impaired beneficial uses of waters of the state in Freshwater, Bear, Jordan, Stitz and Elk watersheds in Humboldt County, CA, and to advise of interim physical actions that can be initiated in the short-term to fulfill this mission. Longer-term issues, including Total Maximum Daily Load (TMDL) development and implementation issues, will be addressed in a different process.

Background

On June 27th, the Regional Water Board unanimously approved a five-part motion which in part directed staff to "invite the members of the existing Convening Committee, plus representatives from Elk River, to assist Regional Water Board staff in finalizing an initial set of Terms of Reference (TOR) for an Independent Scientific Review Panel for the purpose of addressing any actions that can be initiated in the short-term to protect beneficial uses and reduce flooding in all five watersheds."

This motion builds upon earlier efforts to address these issues. On April 19, the Regional Water Board had directed its staff to pursue mediation, as an alternative to a lengthy legal process, in order to develop a locally constructed agreement that would provide for water quality protection, community protection, and timber harvesting needs. The Convening Committee was established to determine the appropriate structure and focus for the mediation process. The Committee consisted of representatives from the Humboldt Watershed Council, the Freshwater Working Group, the Environmental Protection Information Center, Pacific Lumber Company, several non-industrial timber interests, and Regional Water Board Staff[1], and was originally focused on issues and solutions in the Freshwater, Bear, Jordan and Stitz watersheds.

The Convening Committee met five times from May 30th to June 26th, and adopted the following mission statement to guide its efforts "to develop and agree on a set of interim measures, by August 31, 2002 aimed at protecting and restoring beneficial uses and to mitigate nuisance in the Freshwater, Jordan, Bear, and Stitz watersheds prior to TMDL development". One primary recommendation of the Committee was to establish an Independent Scientific Review Panel to provide guidance on a suite of possible interim options that could be used to protect beneficial uses and address flooding in the four watersheds.

During the four-week process, the Convening Committee reached an impasse on the framing of an initial set of questions to guide the Scientific Review. At the

1. The Regional Water Board's staff participated as consultants to the Convening Committee in order to assist the group in developing measures likely to be acceptable to the Regional Water Board, while maintaining the Regional Water Board's independent authority over measures or other actions that it will be required to approve.

June 27th meeting, the Regional Water Board directed staff to (1) initiate its own facilitated Scientific Review Process which would build upon the work on the Convening Committee and which would include Elk River and (2) invite the original members of the Convening Committee, as well as Elk River representatives, to assist the Regional Water Board staff in finalizing an initial set of Terms of Reference (TOR) for the proposed Scientific Review Panel.

This document is the final version of the TOR.

Issue Statement and Objectives

The Convening Committee originally recommended focusing on the following issues from which to derive questions for the Independent Scientific Review Panel's review and analysis:

- Sediment impairment/reduced channel capacity;
- Flooding/peak flows;
- Riparian/flood plain management;

and the impacts of each of the above on beneficial uses.

The Independent Scientific Review Panel's deliberations should be solution-oriented and will be used as a foundation for developing the package of interim measures. The Panel will undertake the following activities: (1) review and comment on current documents and reports that address the questions posed to the Independent Scientific Review Panel (2) identify what further information and analysis, if any, is necessary to assess these or other relevant questions, and (3) provide guidance on possible interim options that would address these issues.

In carrying out its work, the Independent Scientific Review Panel shall address the following issues and should consider time frames, natural sediment transport potential, existing infrastructure, development and alterations throughout the watersheds and sediment input rates from sources, including but not limited to natural sources, timber harvest and related activities, and road rehabilitation activities.

A. What options are available (e.g. dredging, and modification of activities resulting in, or reducing, sediment delivery) that can be immediately implemented and will be effective in lessening the adverse flooding conditions and impacts to beneficial uses? Please discuss the potential benefits, limitations and tradeoffs of these options for each of the five watersheds.

B. Please review the provided documents, and any other relevant information, regarding calculation of appropriate rates of timber harvest that would not impede recovery from excess sediment loads[2] and would not cause or contribute to exceedence of water quality objectives. Please discuss the technical strengths and weaknesses of the varying approaches described in some of these documents to address harvest rate and flood severity, as well as any other reasonable approaches to calculate a rate of harvest for each of the five watersheds that is protective of water quality, which considers natural and other anthropogenic sediment sources.

C. What additional data or piece(s) of information, if any, will be useful in the future for refining approaches to address the above issues? This can include monitoring information, modeling exercises, etc.

2. Recovery is interpreted to mean that the water body can support all designated beneficial uses of water and meet the water quality standards as outlined in the Basin Plan.

APPENDIX A

The following documents provide contextual information regarding beneficial uses of water, water quality objectives and prohibitions, and watershed-specific sediment sources, sediment impairment, and timber harvesting activities.

California Regional Water Quality Control Board, North Coast Region 1, Water Quality Control Plan (Basin Plan), including amendment adopted February 26, 1997.

North Coast Regional Water Quality Control Board. September 2000. Staff Report for Proposed Water Board Actions in the North Fork Elk River, Bear Creek, Freshwater Creek, Jordan Creek and Stitz Creek Watersheds.

North Coast Regional Water Quality Control Board. April 8, 2002. Executive Officer's Summary Report: Public Hearing for Consideration of Potential Requests for Report(s) of Waste Discharge for Timber Harvest Activities on and about Freshwater Creek, Bear Creek, Stitz Creek, and Jordan Creek.

North Coast Regional Water Quality Control Board. April 8, 2002. Executive Officer's Summary Report: Public Hearing for Consideration of Potential Requests for Report(s) of Waste Discharge for Timber Harvest Activities on and about Elk River.

Natural Resources Management Corporation, 1998. Stitz Creek Sediment Source Assessment and Sediment Reduction Recommendations.

Pacific Watershed Associates, 1998. Sediment Source Investigation and Sediment Reduction Plan for the North Fork Elk River Watershed, Humboldt County, California.

Pacific Watershed Associates, 1998. Sediment Source Investigation and Sediment Reduction Plan for the Bear Creek Watershed, Humboldt County, California.

Pacific Watershed Associates, 1999. Sediment Source Investigation and Sediment Reduction Plan for the Jordan Creek Watershed, Humboldt County, California.

Pacific Watershed Associates, 1999. Sediment Source Investigation and Sediment Reduction Plan for the Freshwater Creek Watershed, Humboldt County, California.

Pacific Watershed Associates. December 10, 2001. Memo: Road-related and non road-related erosion and sediment delivery to Clapp Gulch, Railroad Gulch, South Fork Elk River and lower mainstem Elk River (interfluves).

The following documents represent approaches proposed to date to evaluate timber harvest effects on flooding, and approaches to determining appropriate rates of harvest. These documents are presented in chronological order.

Reid, L. M. 1998 Calculation of Appropriate Cutting Rate in Bear Creek Watershed. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Barrett, J. 2000. Memorandum to John Sneed: Freshwater Flooding Analysis Summary. Pacific Lumber Company.

Reid, L. M. August 28, 2000. Calculation of Appropriate Cutting Rate in North Fork Elk River Watershed. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Lisle, T.E., L.M. Reid, and R.R Ziemer. September 15, 2000. Review of: Freshwater flooding analysis summary. Unpublished review prepared for California Department of Forestry and Fire Protection and the North Coast Regional Water Quality Control Board. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Lisle, T.E., L.M. Reid, and R.R Ziemer. October 25, 2000. Addendum: Review of: Freshwater flooding analysis summary. Unpublished review prepared for California Department of Forestry and Fire Protection. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Munn, J. R. December 20, 2000. Review of Issues Related to Sediment Production in the Addendum to the Redwood Sciences Laboratory's Review of Freshwater Flooding Analysis Summary. California Department of Forestry and Fire Protection.

Barrett, O'Connor, Salminen. August 6, 2001. Elk River Flooding Analysis Summary. Pacific Lumber Company.

Munn, J. R. January 14, 2002. Memorandum to Dean Lucke: Elk River Peak Flow Analysis. California Department of Forestry and Fire Protection.

White, A. February 1, 2002. Memorandum to Diana Henrioulle-Henry: Elk River Peak Flow Analysis. North Coast Regional Water Quality Control Board.

Reid, L. M. March 25, 2002. Comments concerning differences between analyses by Lisle et al. And by Mr. John Munn. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Munn, J. R. April 12, 2002. Memorandum to Dean Lucke: Response to Comments by Reid. California Department of Forestry and Fire Protection.

The panelists will be expected to review the above-mentioned documents. If panelists choose to review additional background information, any of the following documents will be made available upon request. Please note the below list is not exhaustive.

Anderson, J.K. Review of Elk River Flood Analysis Summary, October, 2001.

Cafferata, p. August 17, 2001. Preliminary Comments on PALCO Elk River Materials. California Department of Forestry and Fire Protection.

Conroy, B. December 1999. Masters Thesis: A Comparison of Rainfall Runoff Relations in Elk River, A Small Coastal Northern California Watershed. Humboldt State University.

Dunne, T., J. Agee, .S. Beissinger, W. Dietrich, D. Gray, M. Power, V. Resh, and K. Rodrigues. 2001. A Scientific Basis for the Prediction of Cumulative Watershed Effects. The University of California Committee on Cumulative Watershed Effects. University of California Wildland Resource Center Report No. 46.

FEMA/National Flood Insurance Program maps for Freshwater and Elk River.

Hart Crowser. November 2000. Geology and Stream Morphology, Bear Creek Sub-Basin, Lower Eel Watershed, Humboldt County, CA.

Klein, R.D., Review: Elk River Flood Analysis Summary, September 25, 2001.

Lee, Jonathan. A Multimetric Analysis of Benthic Macroinvertebrate Data Collected from Freshwater Creek Watershed (Humboldt County California) From 199401998.

Lisle, Reid, and Lewis. Review of Masters Thesis authored by Mr. William John Conroy: "A comparison of rainfall-runoff relations in Elk River, a small coastal northern California watershed." USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory

Marshall. G. January 11, 2002. Memo: Rapid Review of Engineering Geologic Conditions for Specific Timber Harvest Plans in the Elk River Watershed. Department of Conservation Division of Mines and Geology.

Montgomery, Dave. Peer Review of North Fork Cutting Rate by Dr. Leslie Reid.

Munn, J. October 2, 2001. Memo to Dean Lucke: Elk River Channel Assessment Report. Department of Forestry and Fire Protection

Munn, J. January 14, 2002. Memo to Dean Lucke: Responses to issues raised by North Coast Regional Water Quality Control Board, Jeffery Anderson, and Randy Klein about PALCO's Channel and Hydrology Assessment for the Elk River Watershed. Department of Forestry and Fire Protection.

North Coast Regional Water Quality Control Board. Rebuttal to proposed testimony submitted on behalf of Pacific Lumber Company in the matter of "Staff Report for Proposed Water Board Actions in the North Fork Elk River, Bear Creek, Freshwater Creek, Jordan Creek and Stitz Creek Watersheds."

North Coast Regional Water Quality Control Board. November 9, 2001. Review - August 2001 Elk River Flooding Document, Pacific Lumber Company, Humboldt County

O' Connor, M. June 28, 2000. Analysis of Erosion and Sedimentation and its Effects on Flooding in Freshwater Creek: Freshwater Creek Between Graham Gulch and Little Freshwater Creek.

O'Connor, M. November 5, 2001. Memo to John Munn: Response to Comments, Elk River Channel Assessment Report

Pacific Lumber Company. 1999. An Analysis of Flooding in Elk River and Freshwater Creek Watersheds, Humboldt County.

Pacific Lumber Company. Draft Freshwater Creek Watershed Analysis.

Pacific Lumber Company. January 2001. Freshwater Creek Watershed Analysis.

Pacific Lumber Company. January 31, 2000. Memo to Craig Anthony: Information Relevant to CDF's Moratorium in Elk River.

Pacific Lumber Company. December 12, 2001. Memo to Craig Anthony: Additional Materials for Freshwater Creek THPs.

Pacific Lumber Company. December 13, 2001. Memo to Craig Anthony: Peer Review of RSL's Analysis [of Freshwater Flooding Summary].

Pacific Lumber Company. September 12, 2001. Response to "Preliminary Comments on PALCO Elk River Materials by P. Cafferata, dated August 17, 2001."

Pacific Lumber Company. October 23, 2001. Memo: Response to CDF review of Elk River Preliminary Hydrologic Change Assessment.

Pacific Lumber Company. May 16, 2001. Pilot Turbidity Monitoring Project: Winter 2000-2001 Completion Report.

Pacific Lumber Company. Trend Monitoring results for Bear Creek, Stitz Creek, Jordan Creek, Elk River, and Freshwater Creek.

Pacific Lumber Company. Elk River and Freshwater Creek Thalwegs.

Pacific Watershed Associates. October 6, 1999. Memo to Ray Miller: Differentiation of "ASAP" and "High" Treatment Immediacy (priority) sites.

Pacific Watershed Associates. August 2000. Jordan Creek Channel Monitoring and Cross Section Surveys.

Pacific Watershed Associates. June 2000. Bear Creek Channel Monitoring and Cross Section Surveys.

Preston, L, D. McLeode, J. Schwabe, and PALCO Scientific Collectors. 1999 Juvenile Salmonid Index Sampling, Freshwater Creek, Humboldt County.

Reid, L.M. Review of the Final EIS/EIR and HCP/SYP for the Headwaters Forest Project, Appendix 4, Discussion of memo from PALCO concerning analysis of flooding in Freshwater. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Reid, L. M. Review of the Sustained Yield Plan / Habitat Conservation Plan for the properties of The Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Corporation, Appendix 4. The influence of cross-sectional changes on flood frequency, Freshwater Creek. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Reid, L. M. 1998. "Review of: Sediment Source Investigation and Sediment Reduction Plan for the Bear Creek Watershed" for the EPA and the NCRWQCB.

Reid, L. M. Review of: An analysis of flooding in Elk River and Freshwater Creek watersheds, Humboldt County, California (prepared by The Pacific Lumber Company, Scotia, California)"

Reid and Lisle. Review of Freshwater Watershed Analysis. USDA Forest Service Pacific Southwest Research Station, Redwood Sciences Laboratory.

Ricker, S. Study 1a1, Annual Report, Escapement and Life History Patters of Adult Steelhead in Freshwater Creek, California, 2000-2001.

Ricker, S. Study 2a6, Annual Report, Results of Juvenile Downstream Migrant Trapping Conducted on Freshwater Creek, California, 2001.

Salminen, E. October 23, 2001. Memo to Steve Horner: Response to CDF review of Elk River Preliminary Hydrologic Change Assessment.

Salminen, E. April 3, 2002. Memo to Steve Horner: North Coast Regional Water Quality Control Board comments on the Elk River Flooding Analysis.

Simpson, G. February 2002. Trench Investigation of Recent Sediment History Along the Elk River, Revision 1. Humboldt County, California. Prepared for Stoel Rives LLP.

U.S. Fish & Wildlife Service and California Department of Forestry and Fire Protection. 1999. Final Environmental Impact Statement/Environmental Impact Report and Habitat Conservation Plan/Sustained Yield Plan for the Headwaters Forest Project.

The University of California Committee on the Scientific Basis for the Analysis and Prediction of Cumulative Watershed Effects. July 1, 1999. Review of "An Analysis of Flooding in Elk River and Freshwater Creek Watersheds, Humboldt County, California "by The Pacific Lumber Company, March 1999.

The University of California Committee on the Scientific Basis for the Analysis and Prediction of Cumulative Watershed Effects. Letter to Andrea Tuttle, Director, CDF, "Re: PALCO Report on Flooding in Elk and Freshwater Basins"

Guiding Principles

This initiative, to be launched in August, will be guided by several key principles:

FAST TRACK SCHEDULE TO MEET

Given the Regional Water Board's direction to provide interim measures, the Independent Scientific Review Panel will be responsible for completing its review and analysis to provide recommendations in a time-sensitive fashion. To this end, stakeholder input on the following tasks will be taken by July 19th: Creating a refined set of questions for the Independent Scientific Review Panel; finalizing the selection criteria for the technical experts; and the completion of a list of technical experts for nomination to the Independent Scientific

Review Panel. The Panel is expected to produce a concise, final written report by mid-November with a presentation to the Regional Board to follow in December.

LEGITIMACY, ACCOUNTABILITY, NEUTRALITY

To ensure that the process is credible and results in advice useful to the Regional Water Board and stakeholders, it is essential that the Independent Scientific Review Panel's work be structured to foster legitimacy, accountability and neutrality. Accordingly, the Independent Scientific Review Panel process outlined below incorporates a handful of key elements—accountability to the Regional Water Board, joint scoping of questions to be addressed, and joint development of criteria to guide technical expert selection—that are intended to produce these results.

OUTCOME-FOCUSED

It is the Regional Water Board's intention to use Independent Scientific Review Panel review to produce concrete findings and recommendations regarding the issues, impacts to beneficial uses and potential responses. These recommendations will be included in a report that summarizes the Independent Scientific Review Panel's findings and deliberations, and suggests critical elements and concepts for consideration in developing a package of interim measures to protect and to restore beneficial uses in the watersheds.

It is anticipated that solutions that could arise from the requested analysis may raise significant public policy questions distinct from the scientific questions. These policy questions might include, among other things, issues such as "who pays" for the solution, versus "who caused or benefited from" the sediment source activity. Any such issues would in the end need to be addressed by the Regional Water Board and/or other agencies/stakeholder groups, as appropriate, as policy questions

Approach

PARTICIPANTS

Disciplines of Technical Experts. The Regional Water Board staff will recruit recognized technical experts who collectively can provide analysis and understanding in the following subjects:

- Hydrology, Hydraulics and Fluvial Geomorphology
- Aquatic Ecology/Fisheries Biology
- Civil Engineering/Water Quality
- Geotechnical/Slope Stability
- Restoration Ecology
- Forestry/Silviculture

RECRUITMENT CRITERIA

The following criteria will apply to all technical experts: 1) technical capability in their respective disciplines with ability to work across disciplines; 2) objectivity, as reflected by their willingness/ ability to integrate diverse viewpoints 3) ability to work collaboratively; 4) track record of science advising for environmental decision-making; 5) availability, 6) experience with evaluation of cumulative watershed effects in a forested setting, 7) proven track record of meeting deadlines, 8) experience with practical application and 9) broad acceptability by the shareholders, with final selection by the Regional Water Board staff. Regional Water Board staff will need to take into consideration the need for representation on all the subjects listed above in the final selection process.

PROCESS

The Independent Scientific Review Panel process is expected to begin in early August. The intent is to carry out a process that includes these steps:

- review current documents and reports;
- meet and confer with stakeholders, as feasible;
- meet face to face as a panel, one or more times as needed, to conduct their deliberations;
- conduct a site visit, as feasible;
- conduct a portion of the deliberation in a facilitated workshop format, open to the public, as feasible;
- review additional documents and conduct additional analysis, as needed; and
- convene a final ISRP meeting to present the findings and recommendations.

DELIVERABLE

The Independent Scientific Review Panel's primary deliverable will be a concise, final written report in response to the questions regarding water quality issues in these five watersheds, with recommendations of potential interim measures.

TIMING

The Regional Board's direction is that the Independent Scientific Review Panel's final report should be finalized and received no later than mid-November, 2002.

APPENDIX B:

ITINERARY FOR THE OCTOBER 9TH SITE VISIT TO FRESHWATER, ELK, AND BEAR CREEK

HUMBOLDT WATERSHEDS INDEPENDENT SCIENTIFIC REVIEW PANEL

8:00 AM	Panel discussion with residents (Grange Hall)
8:30	Panel discussion with PL (Grange Hall)
9:00	Drive to Howard Heights Bridge in Freshwater to examine flooding impacts and discuss opportunities for addressing flooding
9:30	Drive up Cloney Gulch to see sediment build up in non-populated watershed at a temporary fish trapping site.
10:15	Point out Freshwater pool on the way to visit monitoring station at Roloef's
11:00	Begin driving along back road up divide between Elk and FW. Stop at Vista #1 (Horse shoe) on Freshwater side to examine pre-HCP and post-HCP logging (includes an example of recent operation and an operation that is at least 1 year old)
12:00	Stop at road failure site located near second switchback
12:40	Brief stop at Vista #2 on Elk River side to get an aerial overview of the Elk River drainage
1:00	Lunch at Bridge Creek to see the channel, coarse substrate, road work, new bridge, geology
1:45	Stop at Wrigley Ranch to see gradient change. It is the first reach below and adjacent to PL property.
2:15	Brief stop at North Fork Bridge to see accreted channel and loss of fine sediment due to flooding.
2:30	Visit USGS gauging station to examine sediment build up.
3:00	Drive to Bear Creek
4:00	View mouth of Bear Creek from bridge, then drive up to the bridge on PALCO property and look at channel there.

APPENDIX C:

DERIVATION AND SENSITIVITY OF EMPIRICAL SEDIMENT PRODUCTION EQUATIONS

The empirical sediment budget approach is based on stratifying a watershed into land classes and applying rate coefficients that quantify the amount of sediment produced from each land class. The sediment production from a watershed can be represented as the sum of contributions from each distinct land class

$$S = \sum c_i A_i \qquad (1)$$

in which S is sediment production per unit area [$L^3/L^2/T$], A_i is the dimensionless fraction of area comprising land class i, and c_i a sediment production coefficient [$L^3/L^2/T$] for land class i. This approach uses different sediment input coefficients for different land classes, each of which is a logical subdivision of the landscape based on the physical processes governing erosion. It is quite general and can be tailored to account for the geologic, hydrologic, and geomorphic differences that exist within and among watersheds.

The land classes in equation (1) may represent areas a) underlain by specific geologic formations or soil types, b) characterized by specific geomorphic attributes such as swales, inner gorges, or convex-planar slopes, c) subjected to different management practices, or d) any combination of a, b, and c. The challenge is to divide the watershed into meaningful classes, each of which is broad enough to allow the field-based measurement of a significantly different sediment input coefficient. Definition of a large number of classes would require that an equally large number of coefficients be estimated from limited field data. The uncertainty arising from a large number of inputs, moreover, increases the uncertainty of the results. Definition of a small number of classes requires the estimation of fewer parameters. The result is that more data constrain each parameter and uncertainty is reduced, although differences within each class may be obscured.

Temporal changes in weather and climate complicate any quantitative estimate of sediment production, which is controlled in part by precipitation. The sediment production coefficients are therefore strongly dependent upon weather and climate, and it is useful to remove this effect by normalizing the sediment production rate relative to a background or reference rate. Using r_i [$L^3/L^2/T$] to represent the reference state sediment production coefficients for each land class, equation (1) becomes

$$R = \sum r_i A_i \qquad (2)$$

where R [$L^3/L^2/T$] is the reference sediment input rate. Dividing equation (1) by (2) gives

$$\frac{S}{R} = S_R = \sum (c_i \,/\, R)\, A_i = \sum w_i A_i \qquad (3)$$

in which S_R is the dimensionless sediment production relative to the reference state and w_i, are the normalized, and therefore dimensionless, sediment production coefficients.

One way to arrive at an acceptable timber harvest rate or land management option is to solve equation (3) for the A_i values that yield a normalized sediment delivery rate at or below some acceptable threshold value. The fractional area A_i corresponding to the harvested area land class, obtained from this solution, gives the maximum area that can at any time be impacted by harvest activities if the relative sediment production is to be kept below the target threshold level. Solution of this requires knowledge of the normalized sediment production coefficients, w_i, from each distinct land class representing the geologic and geomorphologic variability present in the area. In the empirical sediment budget approach these coefficients are estimated based on field measurements. With this general background, the calculations of sediment production and rate of harvest limitations that have been proposed by Dr. Reid are examined.

REID'S FIRST CALCULATION (REID, 1998A)

Dr. Reid calculates post-harvest sediment production using two classes: the fraction of area cut, N, and the remaining fraction that is left uncut, $1–N$. The fraction of area cut is defined as the area that has been harvested within the last n years (she used $n = 15$). Therefore, there is an n year recovery period built in to the calculation and, under a uniform sustainable harvest rate, the annual harvest rate is N/n. The sediment production coefficient for uncut or fully healed areas is the background rate R and the sediment production coefficient over the cut area is this rate multiplied by a factor L, i.e. LR. Equation (1) can therefore be written as

$$S = (1 - N)R + NLR \qquad (4)$$

The pre harvest conditions are simply background (i.e., $S = R$), so normalization of equation (4) by R yields

$$S_R = 1 - N + NL \qquad (5)$$

If the allowable relative impact is specified as a threshold (e.g., using a value of $S_{RT} = 1.2$ to be consistent with Reid), equation (5) can be solved for the threshold value of N to yield

$$N_T = \frac{S_{RT} - 1}{L - 1} \qquad (6)$$

The subscript T indicates an allowable threshold on S_R and the resulting threshold fraction of area N impacted over n years. This result was used for Reid's first calculation of allowable cut in the Bear Creek watershed (Reid, 1998a).

To estimate L, Reid relied on the numbers reported by Pacific Watershed Associates, (1998a), namely that 85% of landslide-derived sediment originates on the 37% of the area cut within the previous 15 years. This implies that 15% of sediment was derived from the 63% of the area not cut. Letting f represent the fraction of sediment derived from the cut proportion N,

$$fS = NLR \qquad (7)$$

for the cut proportion and

$$(1 - f)S = (1 - N)R \qquad (8)$$

for the uncut proportion of the watershed. Both R and S cancel when equations (7) and (8) are combined into a ratio, which can then be solved for L in terms of f and N. The result is

$$L = \frac{f / N}{(1 - f) / (1 - N)} \qquad (9)$$

Values of $f = 0.85$ and $N = 0.37$ yield a result of $L = 9.6$. Using this result and a value of $S_{RT} = 1.2$ in equation (6) gives an allowable n year cut of $N_T = 0.023$, or 2.3%, which corresponds to an annual rate of 0.15%.

INCLUDING THE EFFECT OF NO-CUT ZONES

The land class approach of equation (1), may be applied to the sediment production from two classes: a high-hazard area with the proportional area a_h and the remaining low-hazard proportional area $(1–a_h)$. The definition of high-hazard is open to debate. A conservative estimate might be all of the areas listed as high or very high hazard on a CGS landslide hazard map, whereas a liberal estimate might be those areas delineated by the PALCO mass wasting areas of concern (MWACs). Regardless of the definition used, however, the background sediment production for a two-class reference state is

$$R = R_1 a_h + R_2(1 - a_h) \qquad (10)$$

Reid's calculation did not explicitly distinguish the possibility of different background sediment production rates from these different areas, nor did it explicitly incorporate the proportion of the watershed that falls within the high-hazard class. Instead, Reid wrote (equation 5, Reid, 1998a) $R = 0.9R + 0.1R$ with the $0.9R$ intended to represent the sediment production from high hazard areas and $0.1R$ intended to represent the sediment production from the remaining area. For generality, the fraction of sediment production from the high hazard area is denoted as f_h. Thus,

$$R_1 a_h = f_h R \tag{11}$$

and

$$R_2(1 - a_h) = (1 - f_h)R \tag{12}$$

Combining equations (11) and (12),

$$\frac{R_1}{R_2} = \frac{f_h / a_h}{(1 - f_h) / (1 - a_h)} \tag{13}$$

This permits calculation of the different background sediment production rates for the high- and low-hazard areas. Equation (13) can also be used to calculate the fraction of sediment production from high hazard areas given the area fraction a_h and ratio of sediment production rates R_1/R_2, namely

$$f_h = \frac{a_h (R_1 / R_2)}{1 - a_h + a_h (R_1 / R_2)} \tag{14}$$

If no timber harvesting is allowed in the high-hazard areas, then the land class approach of equation (1) contains three classes: the high hazard zone with proportion a_h, the harvested fraction of the remainder $N(1 - a_h)$, and the unharvested fraction of the remainder $(1 - N)(1 - a_h)$. As before, N refers to the area harvested in the last n years and it is assumed that harvested areas are completely healed after n years. Therefore, the annual harvest fraction is N / n of the harvestable area, or $(N / n)(1 - a_h)$ of the total area. Again using L to denote the increase in sediment production from harvested area the sediment production is

$$S = R_1 a_h + R_2(1 - a_h)(1 - N) + R_2(1 - a_h)LN \tag{15}$$

The ratio of equation (15) to equation (10) is the relative increase in sediment production

$$S_R = \frac{R_1 a_h + R_2(1 - a_h)(1 - N) + R_2(1 - a_h)LN}{R_1 a_h + R_2(1 - a_h)} \tag{16}$$

which can be divided by R_2 to yield

$$S_R = \frac{(R_1 / R_2)a_h + (1 - a_h)(1 - N + LN)}{(R_1 / R_2)a_h + 1 - a_h} \tag{17}$$

Solving equation (17) for the allowable cut rate given a threshold S_{RT}, results in

$$N_T = \frac{(S_{RT} - 1)(R_1 a_h + R_2(1 - a_h))}{(L - 1)R_2(1 - a_h)} \tag{18}$$
$$\frac{(S_{RT} - 1)((R_1 / R_2)a_h + 1 - a_h)}{(L - 1)(1 - a_h)}$$

Now, using equations (11) and (12) to substitute for $R_1 a_h$ and $R_2(1 - a_h)$ in (16),

$$S_R = \frac{f_h R + R(1 - f_h)(1 - N) + R(1 - f_h)LN}{R f_h + R(1 - f_h)} \tag{19}$$
$$= f_h + (1 - f_h)(1 - N + LN)$$

Equation (19) is equivalent to Reid's (1998a) equation (7) and equation (17). Using (11) and (12) to substitute for $R_1 a_h$ and $R_2(1 - a_h)$ in equation (18), results in

$$N_T = \frac{(S_{RT} - 1)(f_h R + R(1 - f_h))}{(L - 1)R(1 - f_h)} \tag{20}$$
$$= \frac{(S_{RT} - 1)}{(L - 1)(1 - f_h)}$$

This is equivalent to Reid's (1998a) equation (8).

There are three dimensionless empirical parameters that enter in to this calculation:

- R_1 / R_2, the dimensionless ratio of background sediment production rate from high-hazard areas to that from low-hazard areas.
- a_h, the proportion of the watershed classified as high-hazard.
- L, the increase in sediment production due to logging on non high-hazard areas.

With these parameters equations (17) or (19) can be used to calculate the relative increase in sediment production, S_R, given the harvest impact area proportion N. The complementary relationship expressed in equations (18) or (20) can be used to calculate an allowable impact area proportion N_T given a threshold permissible relative sediment production rate S_{RT}. Furthermore, the parameters R_1 / R_2 and a_h can be combined into the single quantity f_h (equation 14), which is the fraction of background sediment produced in high hazard areas. Therefore, relative sediment production or allowable impact area proportion can be calculated using only f_h and L.

Reid's second calculation (Reid, 1998a equation 8) used this approach with $f_h = 0.9$, and $L = 9.6$. The result yields $N = 0.23$ and with $n = 15$ an annual allowable harvest $N/n = 0.015$ or 1.5%.

Some points that emerge from this derivation are:

- L is the increase in sediment production due to logging on non high-hazard areas. The value that Reid used, $L = 9.6$, was obtained from the first calculation that did not separate out non-high hazard areas, so may not be a good estimate for non-high hazard areas.

- f_h represents the fraction of sediment production from high hazard areas under reference (non-harvest) conditions. In this context, reference conditions are areas not logged in the n = 15 previous years. It is not clear whether the value of f_h = 0.9 that Reid used was for a combination of logged and reference areas or reference areas alone. It is, however, a very conservative estimate that will help to maximize the annual cut rate for low-hazard areas.

The data upon which the estimates of L = 9.6 and f_h = 0.9 are based (Pacific Watershed Associates, 1998a, 1998b, 1999a, 1999b) consists of landslide inventories derived from aerial photographs, with the estimated volume of sediment production associated with each landslide included in the total. The area harvested in the previous n = 15 years was delineated to obtain the sediment production from harvested areas. There is also in principle a delineation of high hazard areas (although this may not have been explicitly done yet). Therefore the information does in principle exist to delineate the watershed into four area classes and estimate the sediment production coefficients needed for proper application of a source area based sediment production calculation and allowable harvest. The primary input quantities required are listed in Table C1.

TABLE C1: QUANTITIES REQUIRED FOR SOURCE AREA SEDIMENT PRODUCTION CALCULATION

Area class	Area [L^2]	Sediment production [L^3/T]
Reference, low hazard	A1	S1
Reference, high hazard	A2	S2
Logged, low hazard	A3	S3
Logged, high hazard	A4	S4

The primary calculation inputs are then obtained as

R_1 = S2 / A2
R_2 = S1 / A1
a_h = (A2+A4) / (A1+A2+A3+A4)
L = (S3 / A3) / R_2

As an example, the Panel presents some of these calculations, loosely based on the Bear Creek Pacific Watershed Associates (1998a) report that Reid (1998a) used as her data source. The Pacific Watershed Associates report (1998a, page 18) indicates that 37% of the watershed was in a state of "recently" harvested (<15 year old harvested slopes) at the time of the 1996/97 storm. This report (table 5, page 19) gives sediment production volumes for recently harvested and older harvested slopes, and notes that 75% of the slides occurred on inner gorge hillslopes (high hazard areas). The report does not separate out the sediment production from high hazard areas, either recently or older harvested areas. With a geographic information system map of high hazard areas and sediment volume estimates from each landslide it is in principle simple to separate out the area and sediment production from the four possible area classes, namely reference low hazard, reference high hazard, logged low hazard and logged high hazard. Because the Panel does not have this information, estimates of these numbers have been used for illustrative purposes and to examine sensitivity.

The base data used for Bear Creek was:

Area Class	Area [mi^2]	Sediment Production [yd^3/interval]
Reference, low hazard	3.02	4020
Reference, high hazard	2.02	36180
Logged, low hazard	1.78	22850
Logged, high hazard	1.18	205650
Total	8.00	268700

The total 8 mi^2 area was divided in to high hazard and low hazard assuming a ratio of 0.4 (a guess for illustrative purposes; the exact value is not critical because the result is very insensitive to changes in this ratio). Then the area fraction of each that was logged was taken as 37%. Pacific Watershed Associates reported that this number applies to the whole area, but here, we assumed that the split is equal between low and high hazard areas.

The total sediment production of 286,700 yd^3 from the 1996/97 photo interval (reported by Pacific Watershed Associates) was split between logged and reference using Pacific Watershed Associates (1998a) table 5. These amounts were then split between high hazard and low hazard areas using a factor f_h = 0.9 (the same as Reid). The resulting derived empirical input parameters are:

R_1 = S2 / A2 17946 [yd³/interval/mi²]
R_2 = S1 / A1 1329 [yd³/interval/mi²]
a_h = (A2+A4) / (A1+A2+A3+A4) 0.4
L = (S3 / A3) / R_2 9.68

Note that L is the same as the value Reid obtained due to the assumption that the split between sediment production from high hazard and low hazard areas is 0.9 for both logged and reference conditions. With these values, the results for a sediment production threshold of S_{RT} = 1.2 are:

NT (by equation 20) 0.23
n 15
NT/n 1.54%

These results are the same as Reid obtained, verifying her procedure.

Sensitivity Analysis

The general sensitivity (equation 20) of the allowable annual cut, N_t/n, was evaluated with respect to variations in L and the lumped variable f_h, with results shown below. Recall that N_t is the proportion of the proportion of the watershed available for timber harvest; therefore, N_t/n must be multiplied by $(1 – a_h)$ in order to obtain the proportion of the total watershed area.

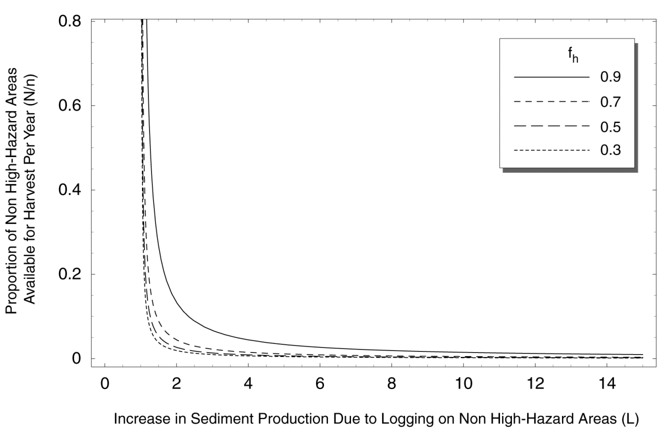


FIGURE C1: SENSITIVITY OF PROPORTION OF NON HIGH-HAZARD AREA AVAILABLE FOR HARVEST PER YEAR TO LOGGING RATE INCREASE FACTOR AND FRACTION OF SEDIMENT PRODUCTION FROM HIGH HAZARD AREAS

This sensitivity analysis shows that the allowable annual harvest rate, N_t/n, is somewhat sensitive to the proportion of sediment contributed by high-hazard areas, f_h, as long as the logging rate increase factor, L, is low to moderate (e.g., $L \leq 6$). As demonstrated in equation (14), f_h is a lumped variable that includes both the proportional high hazard area and the ratio of high- to low-hazard area background sediment production rates. The allowable annual harvest rate becomes much more sensitive to changes in f_h when $0.9 < f_h < 1.0$. It is the Panel's opinion, however, that those values are likely to be unrealistically high and would need to be justified by a well-documented monitoring program.

One result of the sensitivity analysis that may seem counterintuitive is that the allowable harvest rate increases as the proportion of the sediment being derived from high hazard areas increases. The explanation is that the more sediment that is derived from areas that will not be logged, the less sediment will be derived from the areas that may be logged.

Finally, it is noted that the allowable annual harvest rate is extremely sensitive to the logging rate factor L only for low to moderate values of L (depending on the value of f_h). The results are very insensitive to variations in L for the values used by Dr. Reid but, as previously mentioned, these estimates may be unrealistically high if they include the effects of timber harvesting in high hazard areas. Therefore, estimation of reliable values of L for different watersheds and geologic conditions will be a critical step towards the use of this model to calculate allowable timber harvest rates.

APPENDIX D:

BUILDING A GEOGRAPHIC INFORMATION SYSTEM TO STRENGTHEN DECISION SUPPORT

In the Panel's view, a relatively small amount of effort could bring together a considerable body of information for decision support. The purposes of this effort would be to:

- Evaluate trends and conditions in each of the five watersheds. GIS can help isolate features on a watershed-specific basis and help visualize the extent and location of problems.
- Compute conditions and changes in land management related to water-quality impacts. GIS can show the proportion of a watershed harvested or scheduled for harvest, and help measure and track changes.
- Help validate data from disparate sources by showing the degree to which new data comports with established reference layers such as USGS map and photographic products.

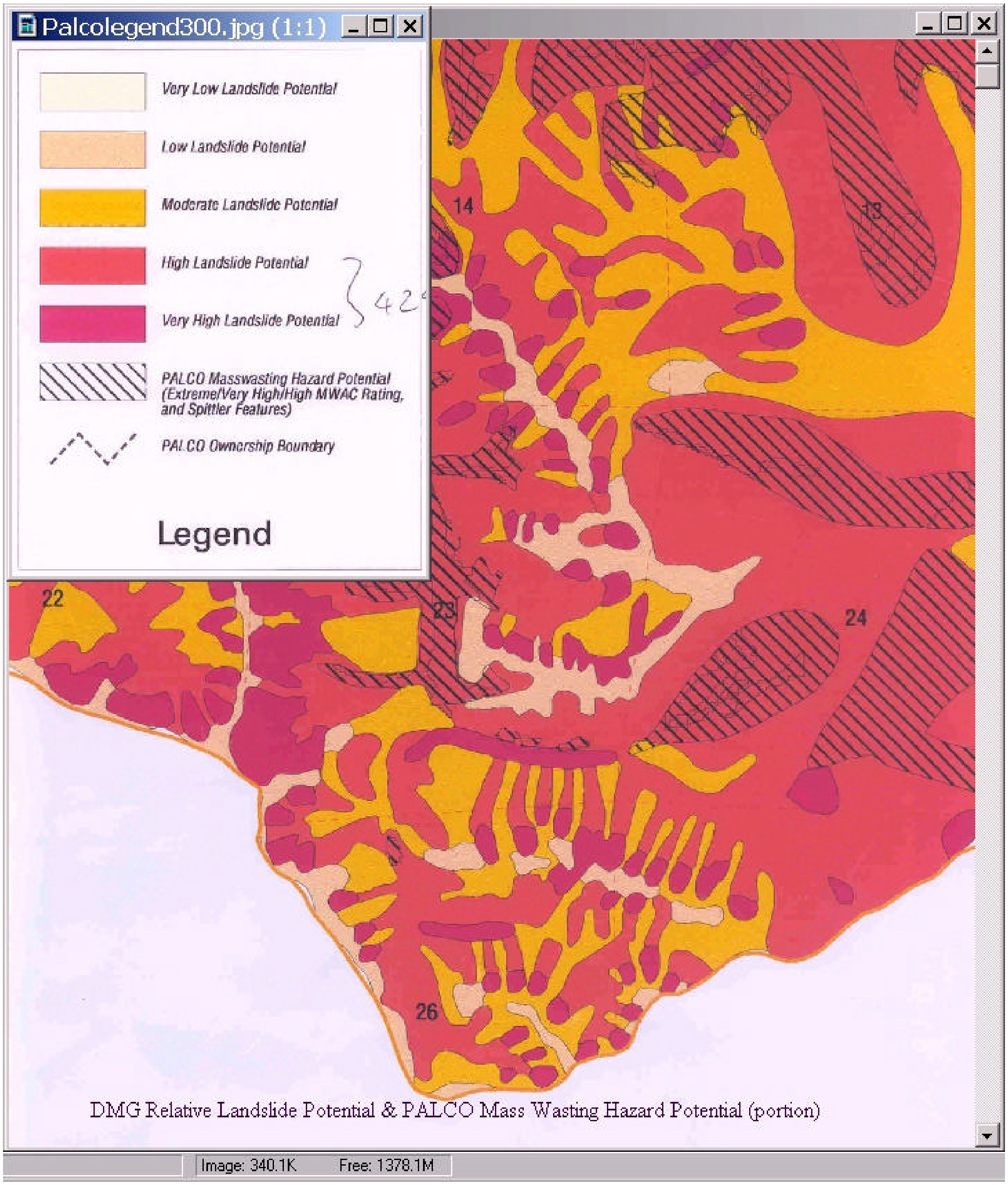
GIS can also serve as a basis for analysis to assist with implementing the sediment production calculations described in Appendix C. A watershed may be stratified into different land classes, such as low hazard, high hazard (e.g. as mapped by CGS or PALCO mass wasting areas of concern), recently harvested, recovered. Then observation and monitoring of sediment production can be used to establish sediment production coefficients for each class. Potential sediment production in each watershed containing proposed timber harvests can then be evaluated and used in planning timber harvests so as not to exceed sediment production limits. Within the GIS, the spatial sediment production measured by ongoing monitoring on areas treated with new mitigation strategies can be recorded and sediment production coefficients adjusted. In this way the GIS serves as a useful tool for documenting the reliability of mitigation strategies so that harvest rates can be adjusted once mitigation strategies have been proved effective through monitoring.

The Panel has compiled some GIS data working on its own, and with assistance from NCRWQCB staff and data from CGS and CDF. PALCO quickly provided a paper map in response to our request. In a GIS the following digital maps can now be viewed singly, or in combination:

- USGS 7.5 minute quadrangles (e.g. common topographic maps)
- USGS contour lines (alone) as an overlay to other data
- USGS roads
- USGS streams
- USGS panchromatic aerial ortho-photo quarter quads as an underlay
- DWR CALwater Planning Watersheds and watershed boundaries
- CDF-approved THPs covering 1990–2000
- CGS surficial geology and landslide potential for Freshwater Cr. Watershed (only)
- PALCO Mass Wasting Potential (made available to the Panel in paper map form only, but produced from the company's GIS)

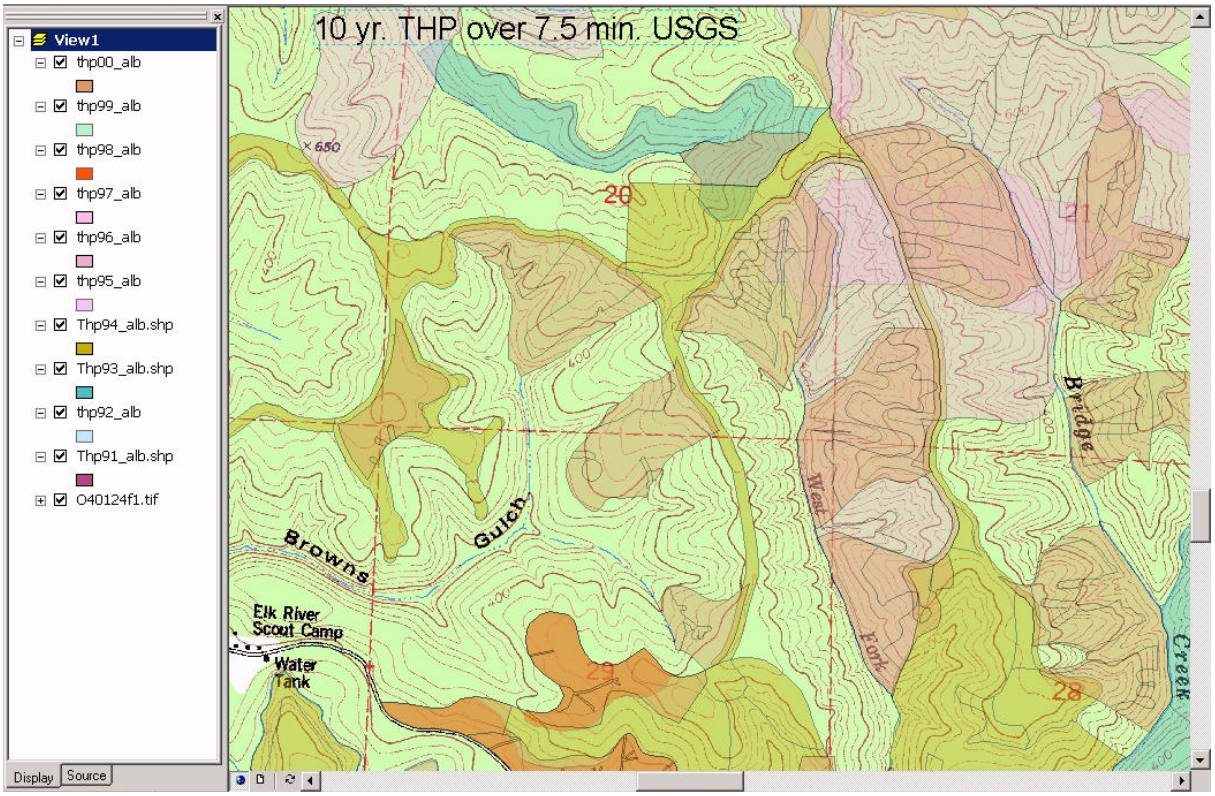
EXAMPLES OF GIS VISUALIZATIONS

The Panel was not charged to conduct, nor did it have the time or resources to conduct any analyses. However, the following examples of GIS applications prepared by the Panel may help illustrate how GIS can be of use to the Board in decision support.



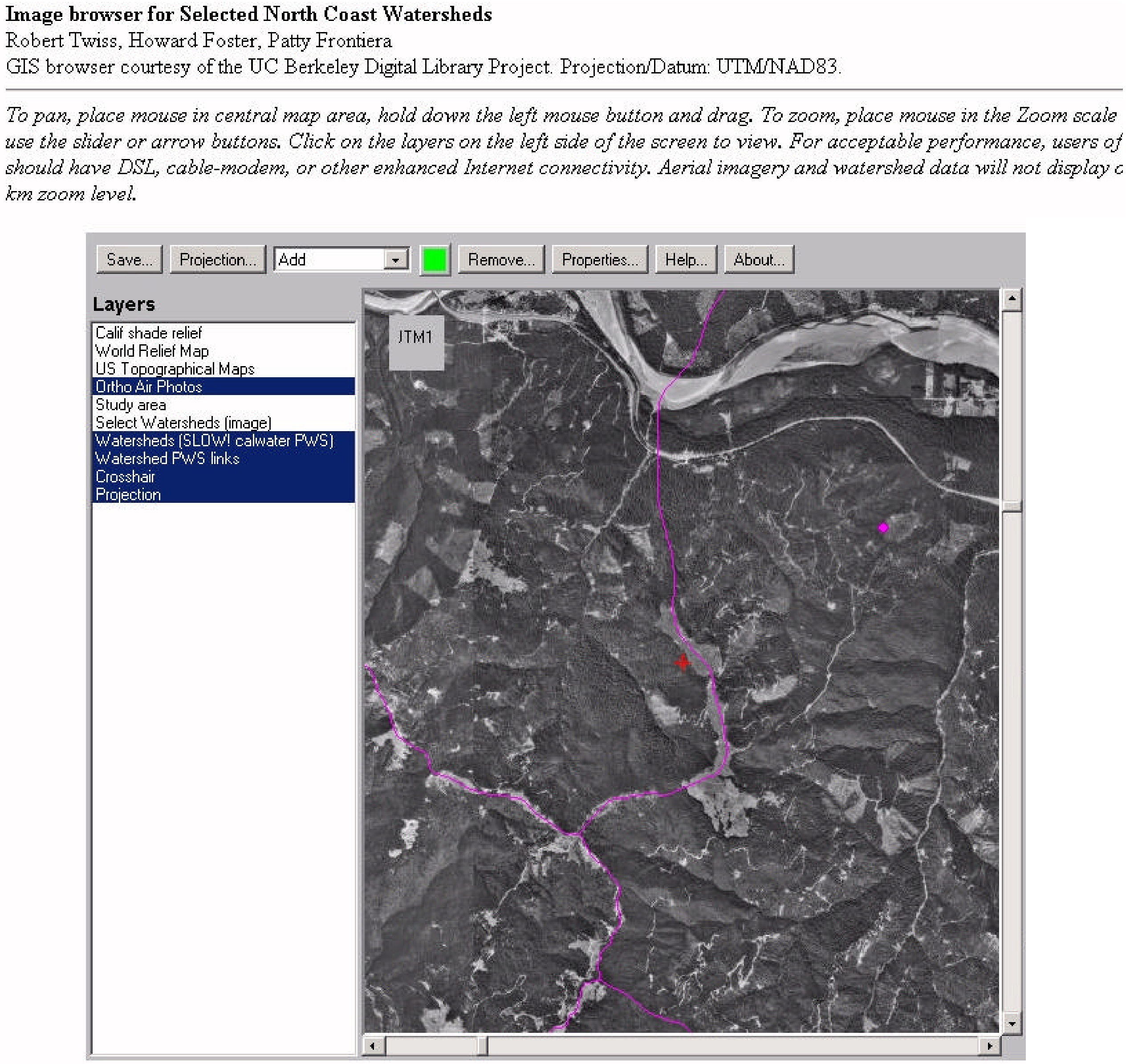
GIS EXHIBIT 1

In this image, PALCO mass wasting zonation is shown as crosshatched lines over the mass wasting map prepared by the California Geologic Survey (CDG CD 2002-06, August 2, 2002). This example covers only a portion of the Freshwater Creek watershed, but was selected as being a balanced representation of the relative coverage of the two classification systems for of the entire watershed.



GIS EXHIBIT 2

Timber Harvest Plans (THPs) from the years: 1990–2000 are shown as semi-transparent overlays to USGS 7.5 minute topographic maps; covering a sample area Northeast of the Elk River Scout Camp. The colored polygons representing the areas covered by THPs can also be draped over other maps and imagery, such as Mass Wasting Zonation, or aerial photography.



GIS EXHIBIT 3

This is a static image of an on-line Web-GIS display prepared by a member of the Panel (at: http://calsip.regis.berkeley.edu/northcoast/). It is presented as an example of how maps and imagery can be mounted for work over the internet. When working in the on-line browser, map layers can be added to the list in the upper left, and toggled on and off. The user can zoom out to get an overview or zoom down to see details, and the user can pan so as to "fly" around the region. This screen capture simply shows a portion of the Jordan Creek watershed boundary (in purple) over panchromatic ortho-photos on which recent harvest areas, landings, roads, and many other features can be seen. This tool could be useful for project work involving multiple organizations, and for communication with stakeholders and the public.