The Garcia River Instream Monitoring Project

Final Report to

California Department of Forestry and Fire Protection

April 2001

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For
Mendocino County Resource Conservation District

With Baseline Conditions Reported by:
McBain and Trush
O'Connor Environmental
Ridge to River
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Photo by Rixanne Wehren

DEDICATION
TO
MICHAEL MAAHS

On March 11, 2000, Michael Maahs was killed in a fishing accident at sea. Michael served as the Garcia River Watershed Project Manager for the Mendocino County Resource Conservation District for over seven years. His project management skills were responsible for seeing this and other projects through in a manner respected by landowners as well as his peers and colleagues. He cared about fisheries and watershed health and understood the issue from many sides -- as a commercial fisherman, from his decades of experience trouncing around creeks as a youthful trout fisherman, as a scientist, and as a concerned human being. He will be greatly missed. This document is dedicated to his life and accomplishments in the Garcia River Watershed.

ACKNOWLEDGMENTS

The Garcia River Instream Monitoring Project was implemented based on an instream monitoring plan written in 1998 by Forest Soil and Water (Dr. Fred Euphrat and Kallie Kull), along with O'Connor Environmental (Dr. Matt O'Connor) and East-West Forestry (Tom Gaman). The Mendocino County Resource Conservation District and its staff and subcontractors arranged landowner access to 12 tributaries, negotiated compromises between the Plan and the budget, and implemented the plan during 1998 and 1999. Linda Vance of UC Davis established the sample plots and study reaches, cross-sectional and thalweg profiles, and collected water temperature and canopy data. Dr. Matt O'Connor, O'Connor Environmental, completed the large woody debris inventory with the assistance of Charlotte Morrison Ambrose and Louisa Morris. Mr. Michael Maahs and the Salmon Trollers Marketing Association carried out the spawning survey. Mr. Darren Mierau, McBain and Trush, completed the assessment of gravel composition and permeability, and Teri Jo Barber, Ridge to River, carried out the Sediment Transport Corridor investigation. Dr. Tim Lewis and David Lamphear of the Forest Science Project provided a detailed analysis of the water temperature data collected in 1999.

Report writing began in early 2000, with Michael Maahs and Teri Jo Barber co-authoring the first draft of the final report. Since Michael's accidental death earlier this year, Teri completed the first draft, incorporated editing suggestions, and produced the final report. The spawning survey of Garcia River tributaries was the last of those designed and supervised by Fisheries Biologist Michael Maahs, whose work has been referenced in many of the rivers and streams of Mendocino County. Mapping and GIS services were provided by Suzanne Lange of CDF and Rixanne Wehren, Cartographer with Coast GIS.

Comments on the first draft of the Garcia River Instream Monitoring Project were received from CDF's Pete Cafferata and John Munn, Craig Blencowe, consulting forester and MCRCD Board Member, Dr. Matt O'Connor of O'Connor Environmental, and Chris Surfleet of Mendocino Redwood Company. Additional words of advice were obtained from Michael J. Furniss of the USFS, Pacific Northwest Research Station (formerly Six Rivers National Forest), Dr. Tim Lewis, EPA (formerly Director of the Forest Science Project), David Hines, Fisheries Biologist for the National Marine Fisheries Service (formerly Campbell Timberlands Management), and Charles Crayne of the MCRCD. As promised, in October 2000, the second draft was circulated to landowners participating in the monitoring program or granting access, and to Friends of the Garcia (FROG) with a 30-day comment period. No comments were received.

EXECUTIVE SUMMARY

The Garcia River Instream Monitoring Project was a pilot cooperative project that documented current channel conditions and established baseline monitoring data for a North Coast timber-producing watershed with anadromous fish. The project was conducted in two phases. The first phase was a watershed assessment and instream monitoring plan (1997-1998), and the second was implementation of the instream monitoring plan (1998-1999). The objective of the project was to document current instream channel conditions in Garcia River tributaries that could serve as a baseline, which could later be revisited to determine the effectiveness of California's Forest Practice Rules in protecting salmonid habitats. The utility of the Instream Monitoring Project is intended to develop with time, as monitoring stations are revisited and information is collected and compared to that collected in the baseline inventory. In this way, trends may be identified to indicate whether channel conditions are improving or declining, both within and among the surveyed tributaries.

Twelve sub-basins within the Garcia River (Figure 1) were monitored. Parameters measured included water temperature, gravel composition, gravel permeability, large woody debris (LWD), channel cross-sections, thalweg profiles, riparian canopy and shading, sediment transport corridors, a spawning survey, and to a very limited degree, turbidity. Five separate contractors conducted the sampling for these parameters. Four plots were established for the 12 tributary reaches, with plot length defined by estimated bankfull width. Spawning survey information was the only information available to characterize the population levels of Garcia River salmonids. Out-migrant trapping of juvenile fish would have provided a better indication of current habitat conditions, but available funding was not sufficient for this level of monitoring.

Water temperature data was collected at the upper and lower ends of study reaches, and a complete set of data was collected from mid-May to mid-October 1999 in flowing water to reflect average water conditions. Maximum weekly average mean and maximum weekly average maximum summer water temperatures were determined for each tributary. Maximum weekly average temperatures (MWATs) exceeding 17.4^{o} C, calculated with the highest 7-day moving average of maximum daily temperatures, were found on 6 of the 12 tributaries monitored. All of the six coastal tributaries were below this threshold. A recently developed MWAT model developed for predicting presence/absence of coho salmon based on temperatures in thermal refugia was applied to the data set. The model predicted coho in all the coastal tributaries evaluated, while none of the inland tributaries were predicted to have coho present. Canopy cover data was found to be correlated with maximum water temperatures ($r^2 = 0.60$ for all 12 tributaries). Average Garcia River canopy density was found to be 64%, while average shading determined with a Solar Pathfinder was reported as 71% in July.

Spawning gravel composition and gravel permeability was measured in 10 of the 12 tributaries. The relationship between permeability and the bulk samples explained 45% of the variability ($r^2 = 0.45$), with the remainder of the variability hypothesized to be due the packing of substrate particles. The basin average for percent fines (<0.85 mm) was found to be 8.2% utilizing the dry sieving method. Earlier work in the Garcia River watershed produced a much higher average for fine sediment with wet sieve data (for example, the Garcia TMDL lists the percentage as 20.6% with wet sieve data). Mean gravel permeabilities were approximately 3,000 cm/hr, with means for the various tributaries ranging from approximately 1,700 to 5,000 cm/hr. These values are generally considered to be in the lower portion of the moderate range for permeabilities. It was concluded that permeability showed the potential to define variability in spawning gravel quality with better resolution and lower cost than McNeil bulk samples—but the relationship between permeability and egg survival has yet to be established and quantified.

For the Garcia as whole, LWD loading was estimated to be 385 m^3/ha (compared to an average of 220 m^3/ha in second growth redwood/Douglas-fir watersheds, and 1,200 m^3/ha for old growth stands). Over half the LWD was found in accumulations or larger jams; approximately 60% was redwood and 25% hardwood. Most LWD was sound and mildly weathered and about 25% of the pieces were pool related. The recruitment rate was estimated to be 3.7 m^3/ha/yr, compared to 5.3 m^3/ha/yr documented at North Fork Caspar Creek. The recruited wood was a mix of hard and softwood classes with average diameters smaller than 0.5 meters. In contrast, long-lasting, geomorphically significant instream pieces are most often redwood with large diameters.

Sediment transport corridors (STCs) are visible corridors allowing sediment to enter stream channels and provide linkages to current sediment generating mechanisms on hillslopes. STCs were evaluated for the plots located within the 12 tributaries. Delivery potential, restoration priority, and possible machine restoration were rated. Most of the surveyed STCs were road and crossing related landslides and gullies. Many were failed crossings that diverted tributaries down roads, and most sites were judged to be inaccessible to heavy equipment due to crossings being washed out.

Spawning surveys were continued in the Garcia basin. Approximately 29 km (18 mi) of the upper mainstem and 12 of its tributaries were surveyed, for a total of 134 km (83 mi). No live coho or coho carcasses were observed during the winter of 1998-1999. Approximately two steelhead redds/mile and about one live fish/mile were observed. Turbidity measurements were attempted with a very low budget approach. Spawning surveyors collected grab samples at established cross sections, but there were difficulties in relating stage to discharge and the sample size in individual tributaries was very small. Because of these problems, little can be concluded regarding turbidity.

A schedule for re-evaluation of the 12 tributary reaches is included. It is suggested that parameters including LWD loading, channel cross-sections, and thalweg profiles be remeasured following geomorphically significant flood events, while other parameters such as water temperature, fish surveys, and turbidity be measured more frequently.

To determine how forest practices are related to changes in channel conditions, addition of the BOF’s Hillslope Monitoring Program in the 12 study reaches of the Garcia River Instream Monitoring Project is recommended. Without this added component, the baseline may be used to determine whether channel conditions are trending toward target conditions, which would reflect on the Forest Practice Rules as a whole. But to connect impacts of timber operations, problems documented with hillslope monitoring need to be traced to channels. Without this understanding, it will be difficult to identify changes in the FPRs that are needed to prevent adverse impacts to downstream channels.

Several recommendations for future cooperative projects are provided. These include: 1) utilizing hillslope monitoring in watersheds with instream monitoring reaches to relate upslope impacts to instream channel conditions, 2) gaining full landowner access prior to project implementation, 3), collecting data so that measurement units are comparable to numeric targets set by agencies, 4) defining an acceptable rate of change toward targets for selected parameters prior to instream monitoring—not after, 5) monitoring the fish themselves to estimate populations, and 6) providing more feedback to landowners regarding techniques and locations for controlling sediment entry.

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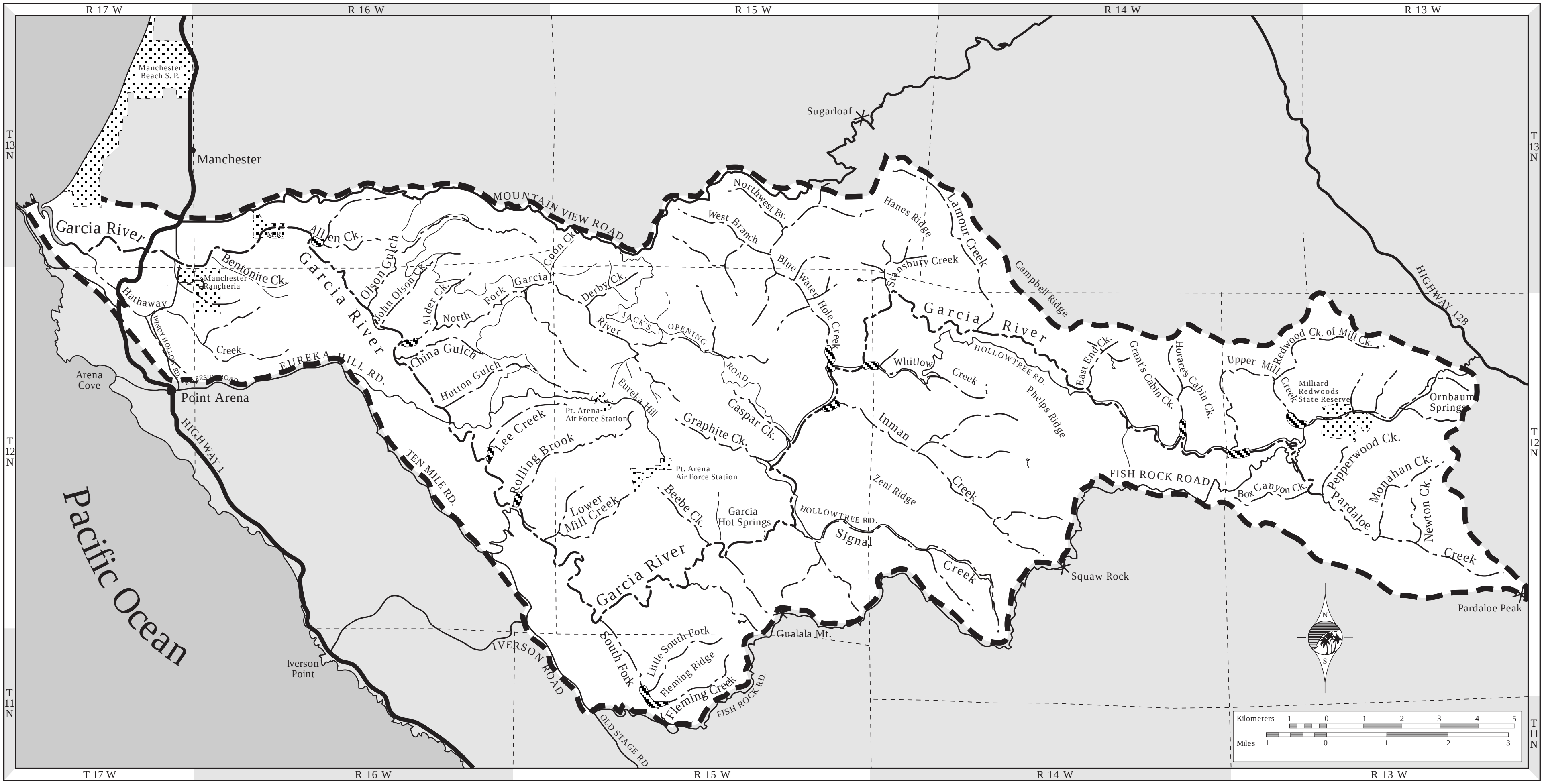
Study site map to reaches and plots (L. Vance)

These individual reports are not included in the Final Report. The reports in bold print, as well as this document, are either provided online at the Board of Forestry and Fire Protection's Monitoring Study Group website (www.fire.ca.gov, click on Board of Forestry and Fire Protection, click on Monitoring Study Group), or will be in the near future. For additional information on the project, contact Pete Cafferata, CDF, Sacramento, at pete_cafferata@fire.ca.gov.



Garcia River Watershed

Mendocino County, California

Figure 1: instream monitoring reaches

Map source materials: USGS 1:100,000 topographic quadrangle Point Arena, Calwater Hydrologic Planning Unit maps, Garcia River Watershed Enhancement Plan work site maps, Blue Waterhole / Stansbury Subbasin Stabilization Project location map, local informants.

Legend

- Garcia River
- creeks
- highway
- paved roads
- secondary roads
- watershed boundary
- ✱ peaks
- Eureka Hill landmarks
- ● towns
- ownership boundaries
- Township & Range
- instream monitoring reaches

Rixanne Wehren
Cartographer

INTRODUCTION

This report documents results of a cooperative Instream Monitoring Project on the Garcia River, conducted by the Mendocino County Resource Conservation District (MCRCD) on behalf of the California Department of Forestry and Fire Protection (CDF). This pilot Instream Monitoring Project compliments the Board of Forestry and Fire Protection's (BOF's) Hillslope Monitoring Program. Taken together, the instream and hillslope components form the BOF's Long-Term Monitoring Program, which is charged to assess the effectiveness of the Forest Practice Rules (FPRs) in protecting the beneficial uses of water following timber harvesting activities on non-federal lands in the state.

Preliminary investigations were funded by CDF and agency partners in the early 1990s to determine how to monitor whether FPRs protect anadromous fishes (Knopp, 1993; BOF, 1993; Tuttle, 1995; Rae, 1995; Spittler, 1995). The Garcia River Watershed was chosen to implement the pilot instream monitoring project because the cooperative landowner-agency monitoring outlook appeared conducive. Additionally, anadromous fish issues are a significant concern in the Garcia River basin. Coho salmon have not been observed in the Garcia River basin since their population was estimated at seven to nine adults basin-wide in 1997, while coho continue to be observed in other Mendocino County watersheds (Maahs, 1999).

Site-specific investigations were accomplished in three phases, allowing the development of the final Garcia River Instream Monitoring Project (GRIMP): 1) collection of existing data regarding water quality and fish utilization, 2) preparation of a watershed assessment, and 3) utilization of these materials to develop a long-term Instream Monitoring Plan. Collection and processing of instream monitoring data began in 1998 and continued through 1999.

The following specific objectives were stated in the Garcia River Instream Monitoring Plan: "<u>The primary objective of the this plan is to test the capability and effectiveness of the California Forest Practice Rules to protect determined beneficial uses, in this case, the salmonid fishery of the Garcia River.</u> A secondary objective is to create a long-term monitoring data set whereby the Garcia River can be compared to other neighboring rivers in the development of a regional standard. The third, and perhaps most important objective, is to understand the Garcia River watershed and reduce its overall sediment load through adaptive management" (Euphrat et al., 1998).

The Garcia River Instream Monitoring Project selected 12 permanent study reaches in second and third order tributaries on managed forestlands where access was granted to establish baseline habitat conditions. Selection of monitoring parameters and experimental design were guided by the Watershed Assessment and Cooperative Instream Monitoring Plan for The Garcia River by Forest Soil and Water (Euphrat et al., 1998). Within each study reach, three or four sample "plots" were established. Each of these plots was 250 feet to 400 feet in length. Sampled monitoring parameters included channel morphology (cross sections and longitudinal thalweg profiles), large woody debris (LWD) and potential LWD recruitment, canopy and shading, stream temperature, spawning gravel composition and permeability, spawning surveys, sediment transport corridors, and to a very limited extent, turbidity.

Two experimental design approaches have been recommended by the authors as a means to compare the baseline conditions established during the 1998-99 GRIMP with results of subsequent monitoring. The first approach is to compare baseline instream conditions to “target instream conditions” recommended in the Garcia River Water Quality Attainment Action Plan (California Regional Water Quality Control Board, 1998) or new targets as they are developed. Target conditions were developed over the course of the Garcia River TMDL (total maximum daily load) issued by EPA to control the introduction fine sediments to the river. A second recommended approach is to associate instream conditions with FPR-related hillslope disturbances. The linkage or “cause and effect” approach lets landscape conditions traced to the channel lead to the determination of whether and to what extent FPRs change instream conditions. This second approach requires further investigation of hillslope conditions and should direct investigators to the practices producing channel degradation.

Testing California’s FPRs for capability and effectiveness at protecting salmonids is a complex task. Recently, a consensus group of specialists termed the Scientific Review Panel concluded that the FPRs do not ensure protection of anadromous salmonid populations (SRP, 1999). Taking the fish out of the equation and framing the question around habitat makes the test difficult to administer using this instream monitoring plan because: (1) CDF’s hillslope monitoring component did not coincide geographically with this instream monitoring project, such that linkages from recent timber operations to the channel remain unknown in the Garcia River (Poff, 1996). (2) A recent Hillslope Monitoring Program summary states in its conclusions that the effects of upslope conditions on channel conditions were not tested (BOF, 1999). (3) The instream conditions measured in Garcia River tributaries reflect “legacy”conditions (pre-forest practice rules) as well as post-modern FPR conditions, but post-modern FPR activities (the ones being tested) cannot be easily or accurately extricated from legacy conditions (Knopp, 1993). (4) Without identifying causal links and tracing their path to channel conditions, we are left with assessing the net instream measured channel condition against channel form targets that oversimplify "adequately protected salmonid habitat" (SRP, 1999; Michael J. Furniss, USFS-Six Rivers National Forest, Eureka, personal communication; Dr. William Trush, Humboldt State University, Arcata, CA, personal communication). (5) Effectively protecting threatened species implies achieving a sustainable population, but sustainable population sizes are not currently known (SRP, 1999).

Establishing baseline conditions for a long-term monitoring data set according to the instream monitoring plan was accomplished. A variety of problems were encountered while attempting to implement the plan, most being consequences of issues that did not fully arise until after implementation had begun, such as landowner access and budget constraints. The issue of landowner access was especially thorny, because one landowner directly experienced a situation in which data collected as a result of allowing government employees on the land was used against them. In order to gain access, a preliminary agreement entrusted MCRCD to "code" tributaries instead of associating commonly recognized names. Even with the privacy agreement, one large industrial landowner refused access. Eventually, the landowners that participated in the project allowed the coded tributaries to be descrambled.

Private landowners should be involved early on in setting up the monitoring program, in the selection of unbiased organizations and personnel gathering data, establishing conditions on how the information will be utilized, and whether and to what extent data will be made available to the public. With involvement comes care, pride and overall improvement to the quality of the project.

BACKGROUND INFORMATION

PREVIOUS INVESTIGATIONS INTO MONITORING CALIFORNIA'S FPRS

Prior to the Garcia River Instream Monitoring Plan, several investigations were funded by CDF, along with the North Coast Regional Water Quality Control Board (NCRWQCB) and the California Department of Fish and Game (DFG), to determine how best to monitor the effects of Forest Practice Rules on salmonids and other beneficial uses of water quality (Knopp, 1993; BOF, 1993; Lisle, 1993; Rae, 1995; Tuttle, 1995; Spittler, 1995; Dresser, 1996). These documents describe different suites of indicator variables appropriate to the task. For example, the need for monitoring a combination of hillslope and instream parameters was clearly stated in the recommendations in BOF (1993) and Rae (1995), yet this was not incorporated into the Garcia plans. Knopp (1993) categorized upslope watershed conditions as index, moderately disturbed, or highly disturbed, and used ANOVA (Analysis of Variance) to test the sensitivity of a suite of instream monitoring variables to the upslope disturbance classes. Conclusions stated that differences in instream conditions measured in "legacy" watersheds (highly disturbed in the pre-modern FPRs era) were not significantly different than conditions measured in highly and moderately disturbed watersheds, indicating these legacy effects are long-lasting and do exert some control on channel conditions found today.

BOF 's Hillslope Monitoring Program

In 1999, an interim report summarizing data collected from 1996-1998 as part of BOF 's Hillslope Monitoring Program was written (BOF, 1999). One hundred fifty timber harvesting plans (THPs) were sampled statewide, with 46 from within Mendocino County. An office review, a field review of on-site conditions, and an evaluation of Rules were conducted for each THP. Results for California as a whole were summarized by roads, logging operations, landings, watercourse crossings, watercourse and lake protections zones (WLPZ), and large erosion events (BOF, 1999). The BOF and CDF's Hillslope Monitoring Program is ongoing, but does not include a component that ties hillslope conditions to instream conditions monitored. The interim results from the BOF report are briefly summarized in the following paragraph.

Data collected as part of the Hillslope Monitoring Program has shown that roads and their associated crossings have the greatest potential for sediment delivery to watercourses. "Major departures were assigned when sediment was delivered to watercourses or when there was a substantial departure from the Rule requirements. Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule)." Problems were identified at about 40% of the evaluated crossings. Common deficiencies included fill slope erosion, culvert plugging, scour at the outlet, and diversion potential. Similarly, a substantial percentage of road-related rule requirements had poor implementation ratings, but generally had less impact on water quality than poorly implemented crossing Rules. Road Rules most frequently cited for poor implementation were waterbreak spacing and the size, and number and location of drainage structures. For both roads and crossings, implementation of FPRs that specify design, construction, and maintenance needs improvement. Erosion problems noted on randomly selected skid trails and landings were much less frequent and produced much lower impacts to water quality. Average canopy and ground cover remaining following harvesting in WLPZs were found to exceed Rule requirements (greater than 70 and 85%, respectively). Erosion events originating from current timber operations in WLPZs were found to be rare.   Overall, erosion problems related to timber operations were almost always associated with improperly implemented Rule requirements.

As stated above, the Hillslope Monitoring Program results, however, do not allow conclusions to be drawn about whether the existing FPRs are providing properly functioning habitat for aquatic species, since evaluating the biological significance of the current Rules is not part of this program. Sample size and confidentiality of data preclude the ability for the public to associate site-specific findings to discrete watersheds or subwatersheds. The authors recommend a Garcia-specific study associating hillslope conditions with instream conditions and forest practices.

PREVIOUS GARCIA RIVER INVESTIGATIONS

Garcia River TMDL

The Garcia River was determined by EPA (Environmental Protection Agency) as impaired by non-point source sediment in 1998 (U.S. Environmental Protection Agency, 1998). EPA had previously funded a sediment source analysis from the work of Forest Soil and Water and O'Connor Environmental (PWA, 1997). Key elements needed to develop the Garcia River Watershed Water Quality Attainment Strategy were the reestablishment of the Watershed Advisory Group (WAG), a data gathering process, a limiting factors assessment, and a sediment source analysis (Mangelsdorf and Lundborg, 1997). In December 1998, the North Coast Region of California Water Quality Control Board adopted Resolution 98-66 to its North Coast Basin Plan, thereby establishing a TMDL (Total Maximum Daily Load) for sediment and a sediment reduction strategy for the Garcia River. On September 21, 2000, the State Water Quality Control Board approved the amendment, thereby placing Garcia's TMDL and Attainment Strategy into the North Coast Region's Basin Plan (see further information about the Garcia River TMDL at http://www.swrcb.ca.gov/rwqcb1/download/GarciaActionPlan.pdf).

Garcia River Limiting Factors Assessment

In October 1996, the North Coast Regional Water Quality Control Board (NCRWQCB) began meeting with agency and timber industry personnel to develop a limiting factor assessment. Stream habitat and fisheries information was sorted by subdivisions of the basin based on CALWATER planning watersheds. A four-volume set of information was distributed to a ten member Limiting Factors Assessment Team composed mainly of agency personnel. In March 1997, this group met to discuss the available data and to develop an office-based "limiting factors" assessment. The group discussed issues such as stream temperature, pool volume, gravel quality, large woody debris, migration barriers, flow rates, competition for water, channel geometry for maintaining gravel, pool cover, canopy, predation, food availability, and poaching, as well as population controlling factors such as carrying capacity versus productivity. A second meeting in April 1997 resulted in a report listing the factors in the freshwater environment that were likely to be limiting to salmonids by planning watershed within the Garcia basin (Mangelsdorf, 1997). A list of Target Conditions is reported in Attachment B of California Water Quality Control Board's Resolution 98-66 amending the North Coast Basin Plan (California Water Quality Control Board, 1998). A report titled "Reference Document for the Garcia River Watershed Action Plan for Sediment" provides clarification on how the numeric targets were obtained. References are made to research in the literature and to government agencies with respect to instream conditions preferred by coho, chinook salmon, and steelhead. Similar conclusions drawn by multiple researchers that quantify instream conditions were used to set the numeric target conditions adopted by the NCRWQCB. In the current report, discussions regarding limiting factors and target conditions are presented in the section entitled "Revisiting the GRIMP Objectives."

Garcia River Watershed Assessment

The MCRCD agreed to prepare a watershed assessment for CDF pertaining to portions of the basin having inadequate analysis, especially for geologic composition and dominant soils. Watershed assessments prepared by industrial timberland owners for a large portion of the basin as part of their draft Sustained Yield Plans (SYPs) were expected to be available. An additional goal was to select third or fourth order tributaries where comprehensive instream monitoring would be used to test the effectiveness of California's FPRs. The NCRWQCB and major landowners were expected to cooperate in this assessment effort.

The MCRCD Scope of Work called for the development of a watershed assessment using the mass wasting, surface erosion, and synthesis modules from the Washington State Department of Natural Resources assessment manual entitled Conducting Watershed Analysis Version 3.0 (Washington Department of Natural Resources, 1995). The remaining five modules were to be completed by a team of agency personnel. The final aspect of work included development of an instream monitoring plan.

Forest Soil & Water (FSW) was awarded the contract in April 1997. The FSW proposal called for a "Level I" watershed assessment, as described in the Washington Forest Practice Board's manual. This "office-level" approach utilized aerial photos, geologic maps, existing data, and reports to conduct the watershed assessment. Fieldwork was limited to areas that could not be interpreted from maps, photos, or existing reports.

Access issues developed early in the assessment because industrial timber companies were reluctant to allow access to their lands or data due to concerns that certain members of the FSW team might be hired by an environmental organization to review their company's Sustained Yield Plan. Timberland owners also wanted a guarantee that they would have an opportunity to review the MCRCD documents before they became final. These concerns were addressed in a meeting between the consultant, the MCRCD, and timber company representatives in May 1997.

In November 1997, FSW submitted a draft report and presented findings to the Garcia River WAG. The draft plan was modified based on comments from the WAG, public agencies, and timber industry representatives, and the final Watershed Assessment and Cooperative Instream Monitoring Plan for The Garcia River (Euphrat et al., 1998) was approved by the MCRCD in March 1998.

The mass wasting and surface erosion modules provide estimated historic erosion and sedimentation rates. Aerial photos from 1965, 1978, and 1996 covering 12 CALWATER planning watersheds were examined and identified mass wasting sites were classified as shallow rapid landslides, debris torrents, and persistent deep-seated landslides according to size classes. Aerial photo analysis identified 447 mass wasting sites. Of these, 85% were shallow rapid slides, 11%

were debris torrents, and 4% were persistent deep-seated features. The analysis suggests mass wasting rates decreased significantly after 1978.

The surface erosion module provided development of rough estimates of past and present road and skid trail erosion for the Garcia River watershed. The assessment relied heavily on a Geographic Information System (GIS) that was developed and maintained by CDF from existing THP maps. This GIS was used to compute the length of road in each planning watershed and then to estimate erosion potential based on inherent erodibility of parent material, protection from erosion provided by vegetation and road surfacing materials, and the proportion of roaded area that delivers drainage and sediment to stream channels. A similar method was used to estimate erosion for skid trails. Natural background levels of erosion were also estimated and included in estimates of total surface erosion in the Garcia River basin. Estimated erosion rates and methodologies for determining surface erosion in the basin are provided in Euphrat et al. (1998).

Garcia River Instream Monitoring Plan

History and Development

The Garcia River Instream Monitoring Plan (GRIMP) was developed by Forest Soil and Water to guide implementation of a pilot project for instream monitoring that would compliment CDF's Hillslope Monitoring Program. "The primary objective of this plan is to test the capability and effectiveness of the California Forest Practice Rules to protect determined beneficial uses, in this case, the salmonid fishery of the Garcia River" (Euphrat et al., 1998). Establishing a baseline condition and long-term database of uniform protocols across ownerships and assisting landowners with cost-effective sediment reductions were secondary objectives.

Landowner Issues

The GRIMP was designed to be a cooperative effort between landowners, agencies, and the MCRCD; it was imperative to get landowner support for the project, not just for access to monitoring sites, but also by incorporation of GRIMP protocols into their own monitoring programs. During the development of the GRIMP, it was realized that each landowner was using its own set of monitoring protocols and that the data sets were rarely compatible. Landowners were invited to participate in a series of meetings to discuss access, monitoring protocols, and data collection/ distributions issues. The first of these meetings was conducted in March 1998, a period of transition in the Garcia basin during the sale of Louisiana-Pacific Corporation and Coastal Forestlands, Inc. timberlands, which made access commitments uncertain. Key issues of concern to landowners were the use of raw data and preventing uninterpreted data from being distributed to the general public. At this meeting "coding the data" was agreed by those present as a technique that would satisfy data-privacy concerns of landowners while still affording the ability to publish findings and make them available to the public.

To alleviate landowner concerns, agreements were written to insure that data, when released, would not be linked to collection sites. This condition satisfied landowners, CDF, and environmental groups. Soon, LP (now Mendocino Redwood Company), GP (now Hawthorne Timber Company managed by Campbell Timberland Management), and the Maillard Ranch granted access. However, Pioneer Resources (the new owners of the Coastal Forestland property) did not. Eventually all the landowners participating in the project agreed to allow the tributary codes to be descrambled (see Table 1).

At the first meeting of the landowners, MCRCD, and FSW, there was little agreement on any issue. Concerns were raised that assessing the effectiveness of the FPRs through an instream monitoring program was not feasible. It was agreed that the current project could only document baseline conditions, and future measurements would be required to determine long-term trends related to FPR effectiveness. However without investigating links between channel conditions and upslope timber harvests, the task of assessing the effectiveness of FPRs may have been oversimplified.

Subcontracts for Implementation

The Garcia River Project Manager, Michael Maahs, acted as primary coordinator for the GRIMP. Most fieldwork was conducted by resource professionals who had considerable expertise with the selected monitoring protocols—without additional training. Five separate contractors were hired by the MCRCD to implement monitoring parameters listed in the GRIMP.

Selection of Tributaries for Monitoring

The GRIMP called for establishing study reaches in 12 Garcia River tributaries. The plan recommended Mill, Grant's Camp, Whitlow, Stansbury, Blue Waterhole, Inman, Signal, Graphite, and Fleming Creeks, Rolling Brook, and the North and South Forks of the Garcia River (see map, Figure 1). However, Signal, Graphite and Stansbury Creeks were not included in the final study reaches because the landowner would not allow access and Stansbury Creek was too remote to make monitoring practical. Study reaches in Pardaloe, Lee and Allen Creeks were established to replace these streams.

The GRIMP called for temperature monitoring on a slightly different set of 12 Garcia River tributaries: Horace's Cabin (also known as Grant's Cabin) Creek, Larmour Creek, Whitlow Creek, Stansbury Creek, Inman Creek, Signal Creek, Graphite Creek, Beebe Creek, SF Garcia, Fleming Creek, Rolling Brook, and the North Fork of the Garcia River. Access exclusion eliminated Signal, Beebe, Whitlow, and Graphite Creeks, as well as Blue Waterhole (during 1998). In addition, temperature monitoring in Pardaloe and Mill Creeks, which was expected to be conducted by the Mendocino County Water Agency, did not occur in 1998. The MCRCD Board of Directors decided 12 tributaries would be monitored for the full compliment of habitat conditions. The final list of 12 tributaries were Mill, Pardaloe, Horace's (or Grant's) Cabin Creek, Blue Waterhole, Inman, Whitlow, Lee, Fleming, Allen, Rolling Brook, and the North and South Forks of the Garcia River (Figure 1). North Fork Garcia and Rolling Brook were not monitored in the spawning survey because access would have required crossing the Garcia mainstem on foot during high flows. In addition, Rolling Brook and Lee Creek were deleted from the gravel component due to budget limitations.

Selection of Habitat Conditions for Monitoring

The GRIMP (Euphrat et al., 1998) offered the following list of candidate habitat conditions for monitoring and their utility in measuring fishery values (Table 2). Budget limitations required focusing on a refined subset. Those omitted included V*, summer fish counts, aerial photography, and dissolved oxygen monitoring. Other protocols were only partially completed, such as spawning substrate data collection in 10 of the 12 study reaches, and turbidity. The indices presented in **BOLD** were measured over the sampling period beginning in August 1998 and ending in fall 1999.

Table 1. Garcia River tributary names and corresponding codes.

Tributary Code	Tributary Name
1	Whitlow Creek
2	Lee Creek
3	North Fork of the Garcia River
4	Mill Creek
5	Pardaloe Creek
6	Horace’s/Grant’s Cabin Creek
7	Allen Creek
8	Inman Creek
9	South Fork of the Garcia River
10	Blue Waterhole Creek
11	Fleming Creek
12	Rolling Brook

Table 2. Summary of Planned Measurement Parameters and Fisheries Values.

Class	Index	Measurement	Fishery Value
Water quality			
	turbidity	suspended sediment, sources	incubation, rearing
	dissolved oxygen	oxygen saturation	incubation, rearing
	temperature	heat, oxygenation	incubation, rearing
Gravel quality			
	percent fines	substrate composition	spawning, incubation, emergence
	permeability	interstitial flow	spawning, incubation, emergence
Channel			
	cross-section	bed mobility, transport	juvenile rearing
	V*	pool depth	summer refugia
	LWD	stream complexity	summer, winter rearing/refuge
	thalweg profile	bed complexity	summer, winter rearing/refuge
Riparian			
	canopy	shade, allochthenous food	juvenile rearing/food
Causal mechanism			
	STCs	sediment sources	sedimentation over habitat
	turbidity	suspended sediment sources	incubation, rearing
Fish productivity			
	spawning survey	escapement	productivity
	summer fish counts	utilization of habitat	productivity, age class

HABITAT CONDITIONS MONITORED

STUDY REACHES

Study reaches within the 12 selected tributaries were chosen by the contractor hired for channel morphology work to be representative of managed timberlands and accessible for monitoring. Study reaches are mapped within the basin on Figure 1. Plot ends and cross-sections were marked with a combination of flagging, metal tags, and driven painted rebar, expected to endure for long-term relocation. The meander length criterion was difficult to apply to the third order streams selected because they are controlled more by bedrock than by alluvial deposits that generally form meanders. As such, a length equivalent to 20 bankfull widths was substituted as the criterion for desired length of a study reach.

CHANNEL MORPHOLOGY

Longitudinal thalweg profiles were measured over the length of each plot in all study reaches, recording relative elevations along the deepest parts of the channel. This technique captured rises and falls in elevation characteristic of pools and riffle crests. Graphs of these profiles provide a visual representation of the bed in terms of elevational changes along the channel length (thalweg profile) or width (cross-sectional profile). Cross sections were taken at a frequency of at least one per plot to measure channel complexity and the rise and fall of thalweg, bed, bars, banks, and floodplain. Longitudinal and cross section profiles are presented as a channel morphology unit.

WATER TEMPERATURES

Stowaway™ temperature data loggers recorded water temperature at half-hour intervals. Temperature loggers were calibrated at room temperature before deployment to insure that variability was within the manufacture’s specifications (less than 0.5 degrees Celsius). These units were installed at both the upper and lower ends of study reaches. The contractor also recommended a temperature monitoring site in the mainstem Garcia River, as well as at least one air station. Only the mainstem station was implemented. Due to the complexities in gaining access and in contract negotiations, only five tributaries were monitored for summer water temperature in 1998, beginning in mid-August. A complete set of 12 tributaries were monitored for summer water temperature from mid-May to mid-October in 1999.

RIPARIAN CANOPY AND SHADING

Two different measurement techniques were recommended in the GRIMP to measure canopy and shading. The Solar Pathfinder was recommended as a means of determining the total amount of solar radiation blocked by vegetation or topography (referred to as shade in this document). To measure the amount of overhanging vegetation, or canopy cover, a spherical densiometer was recommended. For each of these instruments, measurements were recommended at the beginning, middle and end of each plot, for a total of 12 readings per study reach. Canopy was measured on only five tributaries in 1998, ceasing as the autumn leaves began to fall. All 12 creeks were monitored in 1999 by mid-August before leaf-fall.

LARGE WOODY DEBRIS AND RECRUITMENT TREES

Assessing the amount of large woody debris (LWD) was a major component of the GRIMP. Large wood (logs and root wads) within the wetted channel width create suitable fish cover, increase channel complexity, store and route spawning gravel, act as streambed grade control structures, and stabilize stream banks. To assess the amount of wood in streams, the GRIMP specified implementing the protocol described in the Timber Fish Wildlife manual (Shuett-Hames et al., 1994) in sample plots.

Because recruitment of new LWD into the channel is important, the GRIMP also recommended assessing the rate at which new LWD is recruited into the stream channel over time. To conduct the assessment of recruitment trees, the GRIMP recommended using the Washington Forest Practices Board (WFPB, 1995) methodology that called for on-the-ground assessment, as well as use of aerial photography. An assessment methodology developed by the Fish, Farm and Forests Communities Forum (Taylor, 1998) was also reviewed.

A meeting between landowners, CDF, MCRCD, and the LWD Contractor occurred where the various protocols were discussed. As a result of this meeting, a modified version of the WFPB protocol was adopted. Other competing protocols had desirable elements such that a hybrid protocol was developed at this meeting. Due to budget considerations, only the on-the-ground assessment of potential recruitment trees was conducted in conjunction with the LWD assessment. In addition to the WFPB approach, riparian stand assessments were also conducted according to California Wildlife Habitat Relationships (WHR) criteria (CDF, 1988). So while many features of recommended protocols were adopted, the final LWD survey incorporated features from other protocols to satisfy the objectives of landowners, the surveyor, CDF, and MCRCD representatives.

Riparian stand condition evaluation included 170 feet of horizontal distance from each streambank. The proportion of conifer to hardwood was reported for this zone, as well as whether the canopy cover was dense or sparse. For the LWD survey, the minimum size of wood counted required a midpoint diameter of 4 inches (10 centimeters). Data reported included whether the wood measured was redwood, other conifer or hardwood; a log, rootwad, or log with rootwad; in a single piece, an accumulation of up to 10 pieces, or a jam composed of more than 10 pieces; and whether the wood was freshly recruited, sound, or decayed. Other comments indicated the input mechanism, the manner in which stability was afforded against downstream forces, and whether the wood was associated with pools.

SPAWNING GRAVEL COMPOSITION AND PERMEABILITY

Two methods were recommended in the GRIMP to assess and monitor the quality of the spawning gravel. One method involved determining particle size distributions in the subsurface spawning gravel substrate, while the other method measured gravel permeability. A meeting was held in Fort Bragg in April 1999 with the MCRCD, Garcia River landowners, and the contractor to demonstrate the permeability pump and discuss sampling protocols. After considerable negotiations over protocols and budget, gravel condition measurements began in mid-May and were completed by the end of June 1999. For budgetary and logistical reasons, these measurements were completed on only 10 of the 12 tributaries.

TURBIDITY

The GRIMP specifically recommended hiring a helicopter or plane to conduct overflights during rainstorm events to locate turbidity sources. This would have included color airphoto sets of the entire basin. In addition, a collection of grab samples was recommended where various MCRCD cooperators could collect samples at gauged sites to make simultaneous flow and turbidity data available.

Due to budget limitations and foreseen long winter shadows, no aerial overflights were conducted. Secondly, information collected by such aerial surveys was not considered to be comparable or helpful in evaluating long-term changes without relating the observed conditions to streamflow discharge.

As plans for spawning surveys were being developed, it was apparent that grab samples could be collected during winter months at little to no extra cost to the project in the course of the spawning survey. To conduct this work, staff gauges were to be installed in each study reach. Spawning surveyors carried with them numbered sample bottles that they filled by: (1) submerging to approximately two-thirds the depth of the water column, and (2) tipping to allow water entry into the bottle. This was to be done at the time they encountered the staff gauges so that water stage could be recorded at the same time. Once samples were collected and sample bottle number recorded on spawning survey data sheets, the bottles were submitted to the MCRCD. Turbidity was determined with a Hach Portalab Model 16800 Turbidimeter.

It was originally intended that spawning surveyors would also determine current velocity at staff gauges where the stream profile had been determined. With known velocities, cross-sections, and staff gauge heights, stream flow could be estimated for each sample. With enough trips to the Garcia River at different flow conditions, a useful stage-discharge relationship (discharge rating curve) could be developed for estimating streamflow discharge for any gauge height. Staff gauge installation at measured cross sections, however, was incomplete when the spawning surveyors completed their fieldwork.

Ultimately, the level of commitment to turbidity monitoring was insufficient to produce a useful product. In this case, creativity and over-optimism spawned a partial effort that was doomed by lack of budget, lack of volunteers, and problems in the stream gauging plan.

SEDIMENT TRANSPORT CORRIDORS (STCs)

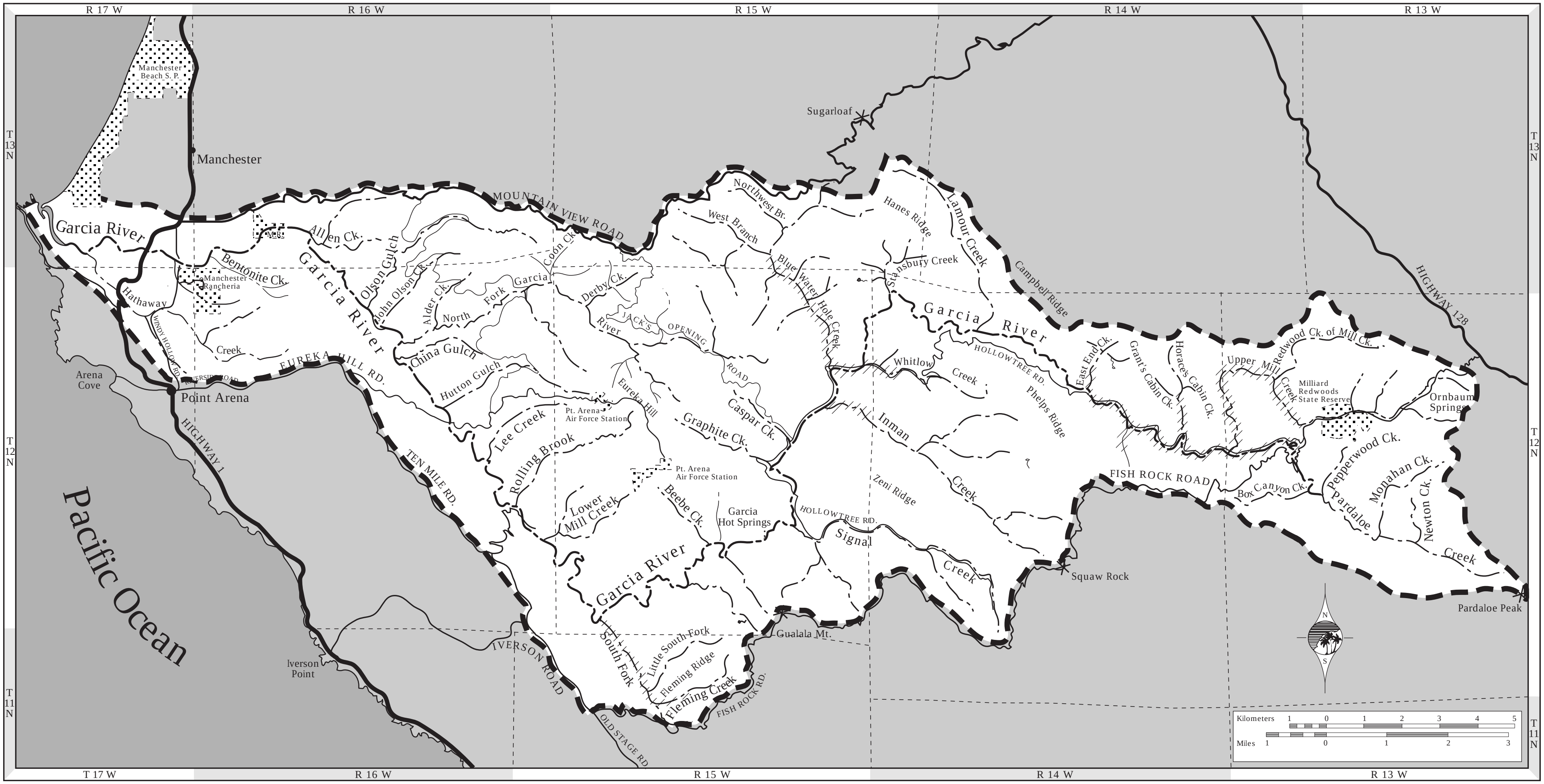
Sediment delivery pathways linking hillslope conditions, erosion source areas, and sediment entering a stream channel were considered in the GRIMP to be an important means of evaluating sediment production from erosion related to forest practice activities. This protocol offered the only link between forest practices and channel conditions in the Instream Monitoring Project. While sediment deposition signals were not always present, features such as landslides, gullies and bank failures were frequently identified as STCs. The lack of deposits can be partially explained in that second order tributaries are often transport reaches, not depositional reaches.

ANADROMOUS FISH PRODUCTIVITY

The GRIMP recommended that past fish stock assessment be continued. The two primary data sets available were salmon and steelhead spawning surveys, as well as late summer/early fall standing crop assessment utilizing electrofish surveys. Electrofishing was not pursued due to concerns of potential damage to fish. A spawning survey over much of the basin was conducted (see Figure 2). Data from some important spawning grounds, such as upper Inman Creek, Signal Creek and the North Fork Garcia could not be obtained due to landowner access issues.

The survey began in early December 1998 and continued through March 1999. Spawning surveys were not conducted on the North Fork, Rolling Brook, and Inman Creeks because they required crossing the mainstem Garcia by foot under unsafe winter flow conditions. Surveys were not conducted on Allen Creek because the landowner did not want conditions reported for fish, and Lee Creek, due to lack of spawning gravel.

Spawning survey results are reported by area. This was required by the permit obtained from National Marine Fisheries Service (NMFS), which specified that any data must be submitted to NMFS and the distribution of fish reported. Special permission was granted by landowners to conduct these surveys. This survey was the last of several spawning surveys developed and supervised by Michael Maahs in the Mendocino County area.



Garcia River Watershed

Mendocino County, California

Figure 2: Spawning Survey reaches

Map source materials: USGS 1:100,000 topographic quadrangle Point Arena, Calwater Hydrologic Planning Unit maps, Garcia River Watershed Enhancement Plan work site maps, Blue Waterhole / Stansbury Subbasin Stabilization Project location map, local informants.

Rixanne Wehren
Cartographer

SUMMARY OF BASELINE CONDITIONS MEASURED

A wide variety of habitat data was collected during the GRIMP implementation, the results of which are presented in the original reports prepared by the subcontractors hired by the MCRCD (see the list of these reports in the Table of Contents). Figure 1 shows the tributaries monitored in the Garcia River Basin. Figure 2 shows the extent of the spawning surveys, which in some cases excluded tributaries that required crossing on foot in high flows, and in other cases extended beyond the established study reaches. This chapter summarizes habitat conditions by monitoring element and attempts to coalesce results to generalize the basin wide condition. The analyses presented build on contributions by the subcontractors.

SAMPLE REACHS AND PLOTS

The sampled 12 tributaries include Horace's Cabin, Mill, Pardaloe, Fleming, Allen, Lee, Inman, Whitlow and Blue Waterhole Creeks, Rolling Brook, and the North and South Forks of the Garcia River (Figure 1). Streams are represented by codes; see Table 1 for corresponding tributary names. There are four surveyed plots per stream reach in all tributaries but one, where there are three plots. Table 3 provides a descriptive summary of each monitored tributary's drainage area, calculated stream length and bankfull width based on the San Francisco Region's Channel Geometry relationships (Dunne and Leopold, 1978; Linsley et al., 1975), measured plot lengths and widths, summed plot lengths (reach lengths) and variation in measured and estimated bankfull widths. Estimations of bankfull width were made from channel geometry tables in Dunne and Leopold (1978) to evaluate differences in the field estimates of bankfull width made by subcontractors Vance and O'Connor. These differences of opinion are discussed further in the QUALITY ASSURANCE AND QUALITY CONTROL section. Strahler stream orders are presented in Table 4.

Table 3. Plot and Reach Size in Surveyed Tributaries of Garcia River and Variations in Bank Full Widths.

Tributary code #	Drainage Area (acres)	Drainage Area (ha)	Plot length (m)	Reach length (m)	R Stream Length (m)	R % stream length (plots)
1	1221	494	87	351	3320	10.48
2	573	232	70	278	2108	13.28
3	6554	2652	111	445	9098	4.88
4	4846	1961	144	579	7591	7.59
5	5626	2277	173	692	8302	8.34
6	684	277	119	477	2345	20.3
7	862	349	39	156	2694	5.79
8	5481	2218	98	391	8173	3.6
9	2768	1120	117	467	5443	8.6
10	4750	1922	113	451	7500	6.03
11	667	270	118	474	2310	20.43
12	1690	684	112	446	4035	11.1

Tributary	Bankfull Width Estimates			# bankfull widths per plot, reach		
code #	by S1(m)	by S2 (m)	by R (m)	plot S1	reach S1	plot S2
1	4	11.4	26.8	21.8	88	8
2	4	11.4	21.3	0	70	6
3	9	29.8	15.2	12.3	50	4
4	6.5	13.1	27.1	22.2	89	11
5	6.5	17.2	32.3	26.6	106	10
6	6.7	7.5	21.6	17.6	71	16
7	4.3	21.3	11	9.2	36	2
8	7.4	15.4	16.2	13.2	53	6
9	6.7	10.9	21.3	17.5	70	11
10	9.1	15.2	15.2	12.4	50	8
11	6.2	9.5	23.2	19.1	76	12
12	4.9	17.2	27.7	22.8	91	7

S2 = based on measurements by Matt O'Connor

S1 = based on measurements by Linda Vance

R = based on average channel dimensions for drainage area in San Francisco Region,
annual rainfall = 30" (Dunne and Leopold, 1978)

Study reaches consist of three to four clustered sample plots, with a target representation of a 15% sampling intensity on each surveyed tributary. The desired statistical approach was to create a stratified, systematic sampling of plots (experimental units) within the population of managed forestlands within the Garcia River Basin. All parameters were to be applied uniformly to multiple plot samples. The goal of this sampling plan was to produce a quantitative "snapshot" of current conditions in representative tributaries to provide a baseline for long-term monitoring (Euphrat et al., 1998). Plots can be located for remeasurement from permanent benchmarks placed at the lower end of plots or at cross-sections that are out of flood-prone areas, increasing the probability of relocation following a flood event with 30 to 100 years recurrence interval. Plot lengths ranged from 39-173 meters (128-568 feet), with plot and interplot distances increasing with drainage area.

CHANNEL MORPHOLOGY AND POOL DEPTHS

Longitudinal thalweg profiles and cross-sections were used to characterize channel morphology for 1998-1999. It was assumed that comparison of thalweg profiles from the same sites over several years would identify trends toward overall channel degradation or aggradation, or degradation in some locations and aggradation in others.

Tributary pools were identified from longitudinal thalweg profiles and depths were calculated from changes in measured elevations. In Table 4, a pool was considered present where there was a drop in elevation of at least one foot relative to the highest elevation measurement occurring downstream. Elevational change was determined to be the residual pool depth. Pool length is proportional to the length of stream in each thalweg profile plot, and is then summarized as the mean of the 4 plots. This method compares the Numeric Target of pools occupying 40% of stream length, which was established during the Garcia River TMDL for 3rd order streams, to the Garcia tributary data. Three streams in the data set met this target. Pool data from the 12 tributaries is summarized by depth in Tables 4 and 5.

Table 4. Proportion of stream length occupied by pools deeper than 1 foot.

Stream #	Strahler Stream Order	Plot 1	Plot 2	Plot 3	Plot 4	Average
1	3rd	0.25	0.16	0.4	0.57	0.29
2	2nd	0.05	0.14	0.09	0.34	0.16
3	4th	0.36	0.3	0.28	0.3	0.31
4	3rd	0.55	0.3	0.23	0.73	0.45
5	3rd	0.36	0.36	0.3	0.47	0.37
6	2nd	0	0.09	0.2	0.09	0.1
7	2nd	0.09	0.06	0.23	0	0.1
8	3rd	0.36	0.27	0.56	NA	0.4
9	3rd	0.28	0.19	0.22	0.19	0.22
10	3rd	0.33	0.35	0.38	0.56	0.41
11	2nd	0.27	0.28	0.52	0.2	0.32
12	3rd	0.31	0.08	0.13	0.3	0.21

Table 5. Number of pools, pools/mile and cumulative number of pools per mile, by pool depth, for the 12 Garcia River study reaches.

Pool Depth Range (ft)	*Total # of Pools*	*Total # Pools/Mile*	*Cumulative Pools/Mile*
0.6-1.0	60	20.3	51.2
1.1-1.5	31	10.5	30.8
1.6-2.0	33	11.2	20.3
2.1-2.5	13	4.4	9.2
2.6-3.0	6	2.0	4.7
3.1-3.5	4	1.4	2.7
3.6-4.0	1	0.3	1.4
4.1-4.5	2	0.7	1.0
4.6-5.0	0	0.0	0.3
5.1-5.5	0	0.0	0.3
5.6-6.0	1	0.3	0.3
Total	151		

WATER TEMPERATURE

The baseline condition was sampled to obtain a general condition of flowing water and care was taken to assure no stagnant pools were measured. Deep holes were ignored so as to reflect average conditions, not cool refugia. Daily minimum, maximum, and average temperatures for the upstream and downstream ends of each study reach from May through October 1999 were determined. Weekly average mean and weekly average maximums were produced from the data set. Seven-day moving averages of daily average temperatures and seven-day moving averages of daily maximum temperatures were also determined.[1]

Salmonid growth and feeding are related to water temperature in a feedback loop. Therefore, determining salmonid impacts from temperature are best estimated in the context of site-specific

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[1] The Forest Science Project, associated with the Humboldt State University Foundation in Arcata, CA, utilized a macro-program to analyze the raw data set.

temperature conditions (SRP, 1999). The most obvious effect of elevated light and temperature conditions is increased primary production (algal growth) and increased secondary production (invertebrates) which provide more feeding opportunities (Hicks et al., 1991). A change from diatom-based food webs of well-shaded allochthenous streams to filamentous green algae prominent in warmer autochthenous waters promotes a change in first level consumers toward grazers, which drift more often and thus increase opportunities for foraging for drift-feeding salmonids. However, water temperatures may increase to the point that they become problematic by way of increasing susceptibility to disease, reduced metabolic efficiency in converting food to growth, altering the competitive balance between warm and cold water fishes such that warm water fishes are better able to compete for food and cover, or in tributaries, by increasing temperatures in mainstem habitats.

Preferred temperatures have been reported for chinook, coho, and steelhead as 12-14, 12-14, and 10-13 degrees Celsius, respectively. Upper incipient lethal temperatures were reported for these species as 26.2, 26-28, and 23.9 degrees Celsius (Bjornn and Reiser, 1991).

Analytical Methods

The term Maximum Weekly Average Temperature (MWAT) has been commonly used recently to express water temperature that can reduce salmonid health or cause an avoidance behavior for areas with excessive temperatures. Care is required in comparing reported MWAT temperatures because MWAT has been calculated by several methods, including: daily temperatures averaged over the week and the maximum of these is recorded, which produces a relatively low temperature estimate; daily maxima are averaged and recorded, which yields a relatively high temperature; and seven-day moving averages of daily maximum or average temperatures are determined. Examples of the differing formulas include:

MWAT (Mangelsdorf, 1997)
Average daily temperatures for seven days, extract maximum values, reported weekly.
MWAT here is calculated by averaging daily temperatures and reporting the maximum of the daily averages over the week. No reference is made as to whether dominant or refugia conditions are measured.

MWAT (Hines and Ambrose, 2000)

Peak daily temperatures extracted and recorded daily as 7-day moving average daily maximum (7DMADM). MWAT here is calculated by taking the maximum daily temperatures and using a moving average of these peaks over 7-days. Refugia conditions are measured (i.e., at the bottom of deep pools).

MWAT (Friedrichsen, 1998)

The highest temperature reading of the week extracted and reported weekly. No reference is made as to whether dominant or refugia conditions were measured.

The results of several pre-existing water temperature data sets from Garcia River tributaries were expressed as MWAT values by Mangelsdorf (1998). The 1999 temperature data for the Garcia River from the GRIMP provides both averaged weekly temperatures that are comparable to this data, as well as a 7DMADM (see Table 6). These data refer to an MWAT threshold of 17.4^{o} C for coho salmon (Mangelsdorf, 1997). Other reported thresholds include 16.8 and 18 degrees Celsius, reported by NMFS and USFWS (1997), and Brungs and Jones (1977), respectively.

In examining a recent application of MWAT (here 7DMADM, after Hines and Ambrose, 2000) for coho refugia, it appears that an MWAT value of 17.6^{o} Celsius may be the upper limit of coho tolerance in thermal refugia. In other words, if peak temperatures exceed 17.6^{o} for more than one day in cool water pool refugia, coho are predicted to be absent due to the combination of intensity and frequency of exposure. In coastal basins within Mendocino County, Hines and Ambrose used the 7DMADM (MWAT) interpretation defined above to explain coho absence from tributary streams having coho elsewhere in the basin with no barriers preventing access. Hines and Ambrose hired a statistician to analyze their data, who used a recently revived statistical method, Akaike Information Criterion (otherwise known as AIC), to predict coho presence/absence in streams from their dataset.

AIC compares multiple, competing, mathematical models to predict presence or absence of animal populations based on physical attributes that quantify habitat values. The AIC technique computes an arithmetic number value for each model and the lowest of these scores identifies that model best able to predict presence or absence (Hilborn and Mangel, 1997). AIC has been successfully used to predict presence or absence in wild owl and fish populations over the last few years (Dr. Howard Stauffer, USFS Pacific Southwest Research Station, Arcata, CA, personal communication).

Table 6. Weekly average mean and weekly average maximum temperatures versus threshold water temperatures for the Garcia River tributaries, summer, 1999.

	Maximum Weekly Average Temperatures (MWATs)								
Tributary Code #	Weekly Maximum	Date	Weekly Averages	7DMADM Daily Max Temps	Date	7DMA Daily Ave Temps	Threshold MWATs		
	(deg C)		(deg C)	(deg C)			(deg C)		
1 ds	24.7	7/16/1999	20.11	24.87	7/15/99	20.11	16.8	17.4	18
2 ds	14.79	8/29/1999	14.14	14.84	8/30/99	14.28	16.8	17.4	18
3 us	14.6	9/10/99	13.5	14.67	9/13/99	13.68	16.8	17.4	18
4 ds	20.09	7/16/1999	17.92	20.09	8/29/99	18.3	16.8	17.4	18
5 ds	26.57	7/16/1999	21.81	26.59	7/16/99	21.85	16.8	17.4	18
6 us	18.4	7/16/99	16.8	18.45	8/30/99	17.2	16.8	17.4	18
7 us	14.7	8/30/99	14.0	14.68	8/30/99	14.01	16.8	17.4	18
8 us	25.13	7/16/1999	20.98	25.18	7/15/99	20.98	16.8	17.4	18
9 ds	15.54	8/27/1999	14.3	15.56	8/30/99	14.52	16.8	17.4	18
10 us	24.6	7/16/1999	20.75	24.67	8/28/99	20.91	16.8	17.4	18
11 ds	14.19	8/27/1999	13.49	14.24	8/30/99	13.65	16.8	17.4	18
12 ds	15.43	8/27/1999	14.0	15.45	8/30/99	14.28	16.8	17.4	18

ds = downstream reach; us = upstream reach

Downstream reaches were used unless there was missing data or anomalous factors.

In the MWAT application, the AIC method was used to evaluate several habitat models to identify which combination of temperature metrics best predicted coho presence or absence. The 7DMADM water temperature model yielded the highest probability in explaining coho absence (Hines and Ambrose, 2000). Several threshold MWAT temperatures were examined for utility in the model. The resulting 7DMADM temperature model predicts coho absence when the number of days that water temperature exceeds each of six MWAT temperature thresholds (19.6°, 18.3°, 17.6°, 16.8°, 15.9°, and 15° Celsius) is greater than the number of days predicted by the model for presence.

Summer temperatures in Garcia River tributaries were compared with the coho presence/absence temperature model provided by Hines and Ambrose (2000). The number of exceedence-days in the model, for each threshold, is given in Table 7 and Figures 3 and 4 for the Garcia River tributaries evaluated. It is important to note that the temperature probes were not installed at maximum pool depths to capture refugia, as did Hines and Ambrose. Data for the Garcia reflect average water conditions and the maximum temperatures recorded over the summer weeks are reported, not thermal refugia found in deep pools.

Table 7. Water temperature duration thresholds for Garcia River tributaries based on seven day moving averages of maximum daily temperatures.

	Threshold temperature values (after Hines and Ambrose, 2000)					
Celsius scale	15	15.9	16.8	**17.6**	18.3	19.6
Fahrenheit	59	60.62	62.24	**63.68**	64.94	67.28
Total days = 84[2]	Number of days 7DMADM temperatures exceed thresholds					
(June 11th through Sept 2nd						
coho model	38	17	6	**1**	0	0
Garcia #1us	84	84	84	**83**	80	57
Garcia #2 ds	0	0	0	**0**	0	0
Garcia #3 us	0	0	0	**0**	0	0
Garcia #4 ds	80	78	73	**61**	24	5
Garcia #5 ds	84	84	84	**84**	84	84
Garcia #6 us	81	79	39	**16**	3	0
Garcia #7 us	0	0	0	**0**	0	0
Garcia #8 us	84	84	84	**84**	84	81
Garcia #9 ds	12	0	0	**0**	0	0
Garcia #10 us	84	84	84	**84**	84	82
Garcia #11 ds	0	0	0	**0**	0	0
Garcia #12 ds	10	0	0	**0**	0	0
ds = downstream reach; us = upstream reach						
downstream reaches were used unless there was missing data or anomalous factors						

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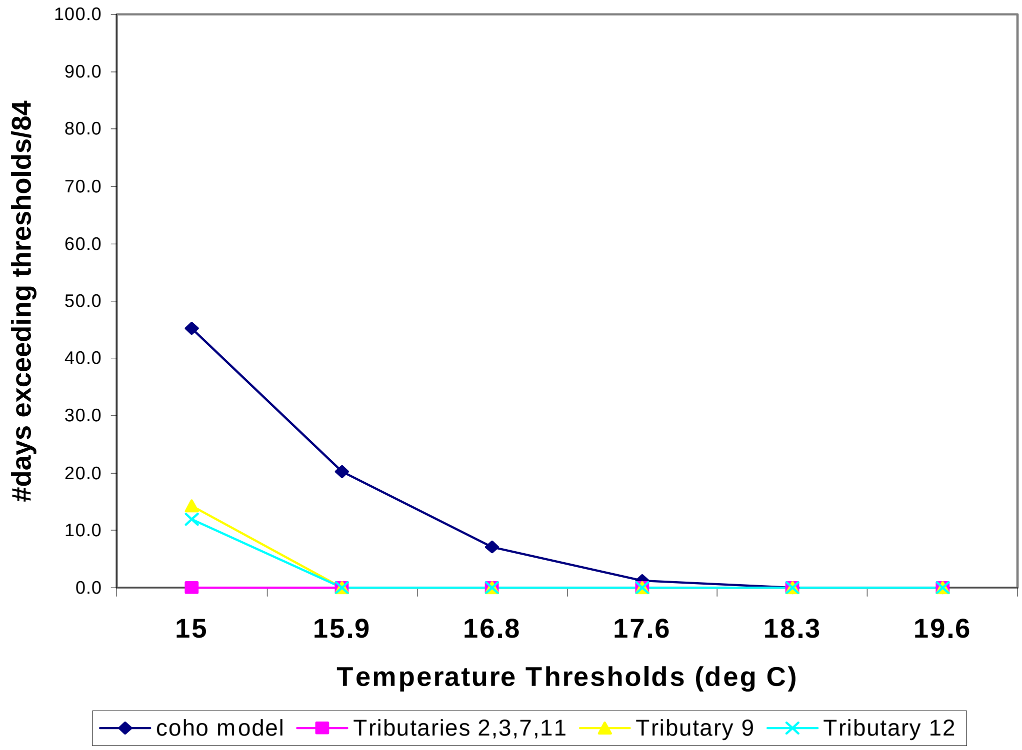
[2] In the Hines and Ambrose (2000) model, data was included from the start of the 24th week of the year through the end of the 35th week (David Hines, NMFS, Santa Rosa, CA, personal communication.

Figure 3. Coastal Tributaries
MWAT temperature data from 84 days of summer



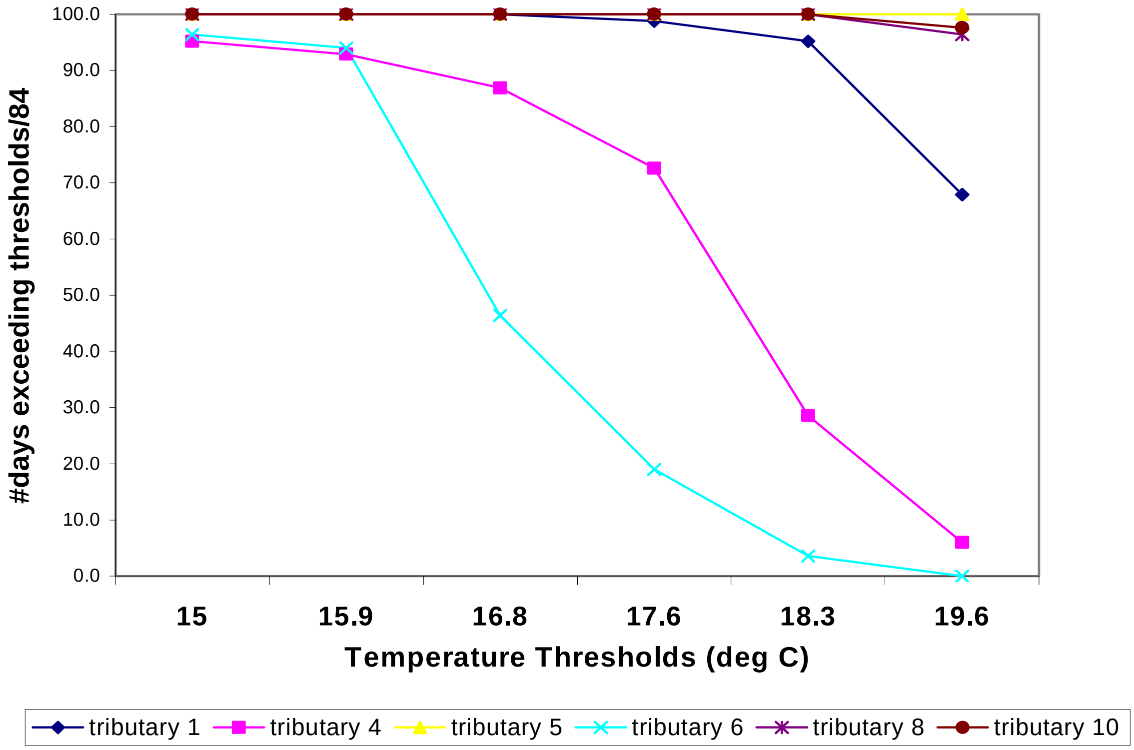
Results

Seven-day moving averages of the daily maximum temperatures for each tributary were determined from the data set. The data were compared to the 7DMADM MWAT threshold of 17.6 degrees Celsius (63.68 degrees Fahrenheit). The 7DMADM MWAT model suggests that a stream which warms to greater than 17.6 degrees Celcius (63.68 degrees Fahrenheit) more than one day during the summer will be coho-absent.

Figure 3 graphically displays the results for the coastal 7DMADM model from Mendocino County coastal creeks (Hines and Ambrose, 2000) as a backdrop on the coastal half of the Garcia River basins. The temperature data for the inland tributaries were also graphed (Figure 4), but without the model shown.

Figure 4. Inland Tributaries

MWAT temperature data from 84 days of summer



Figures 3 and 4 refer to the number of days water temperature exceeded MWAT thresholds. Several thresholds were provided because there are several threshold values in the literature that describe preferred water temperatures. Coastal streams are all within five miles of the coast, and are all tributaries that enter the river's north-northwest trending fault-line exhibited on basin maps of the Garcia River resembling a southern "dog-leg" which culminates in the South Fork Garcia (see map Figures 1 and 2). In contrast, inland tributaries enter the Garcia River at least 10 miles from the coast and are generally out of the fog-belt generating the cooler coastal climate.

Coho absence based upon temperature was not predicted for any of the six coastal tributaries, but none of these streams presently have any coho (Maahs, 1998). All inland streams exceeded the coho temperature tolerance limits predicted by the 7DMADM. No MWAT temperature tolerances for steelhead were examined, but stream temperature does not appear limiting for these fish in that the highest adult steelhead densities were observed in inland Garcia River tributaries.

Conditions that Explain Water Temperature

Water temperature is known to fluctuate over a 24-hour period with changes in air temperature and solar insolation. For example, recent work by Lewis et al. (2000) has shown that stream temperatures vary to a large extent depending on distance from the coast. Geographic position factors are largely surrogates for air temperature. Water temperatures were also found to increase with increasing distance from the watershed divide and with increasing drainage area. Factors that affect water temperature also include shading, channel width to depth ratios and, perhaps, upslope soil temperature effects on runoff and groundwater inputs (Brosofske et al., 1997). The IMP did not include soil and air temperature measurement. Air temperature data for the general region, however, is available from NOAA for weather stations located at Navarro, Booneville, Yorkville, and Point Arena, and can be found at the following website:

http://www.ncdc.noaa.gov

Canopy closure was tested in relation to water temperature and a correlation was found that explains most of the variation in water temperature. This analysis is described more thoroughly in the Riparian Canopy and Shading section that follows.

RIPARIAN CANOPY AND SHADING

Stream canopy and shade were measured with both a spherical densiometer and the Solar Pathfinder in each of the twelve monitored tributaries. Both methods provided long-term monitoring information that was useful in assessing changes in the amount of sunlight reaching the stream channel. As a means to establish an overall estimate of canopy in the basin, the density and closure (from spherical densiometer readings) estimates for each of the 12 study reaches was averaged, resulting in mean basin density and closure estimates of 64, and 52 percent, respectively. Similarly, the averaged Solar Pathfinder readings indicated that the proportion of solar radiation blocked from reaching the stream channel in 1998-99 was 72, 72, 71, 75, and 82 percent, for months May, June, July, August, and September, respectively. Basin averages may be more appropriate than data for individual tributaries, since the goal of the GRIMP is to develop habitat baseline conditions to document instream habitat changes with respect to time and land use practices. However local shade is certainly one important condition driving water temperatures recorded in individual tributaries. Where study reaches are not subject to canopy alteration by land management actions, changes observed through time will provide needed information regarding canopy recovery rates in the Garcia River watershed.

The results of restoration activities should not be confused with results of forest practices. For example, CCC and citizen volunteers have planted trees in many Garcia River watershed riparian locations (Craig Bell, habitat restorationist, Gualala, CA, personal communication). Additionally, the EPA's 319H restoration program grants have facilitated restoration of legacy condition problems in many locations within the basin, including some within the 12 surveyed tributaries.

We examined whether changes in stream temperature were related to densiometer or Solar Pathfinder readings. For this analysis, simple linear regression was used to determine the correlation between canopy and stream temperature. This included a comparison of the following two stream temperature indicators: (1) the maximum temperature reading observed over the summer, and (2) the maximum weekly average of daily maximums, with three canopy indicators: (A) percent closure, (B) percent density (both of these from densiometer readings), and (C) portion of solar radiation blocked from reaching the stream (from Solar Pathfinder readings). Of these comparisons, the regression between maximum stream temperature and percent canopy closure measured with the spherical densiometer gave the highest R-squared value ($r^2 = 0.60$, Figure 5).

The temperature report written by the subcontractor notes that stream # 6 had unusually warm temperatures, even in winter months, and postulated that there is a warm ground-water source near the mouth of the stream. Stream #3 was probably influenced oppositely by surfacing of cold ground water in the area of the temperature monitoring device. With streams 3 and 6 removed from the regression analysis as outliers, the correlation between maximum stream temperature and percent canopy closure was improved to an R-squared of 91% (Figure 6). One of the outlier basins removed was coastal and the other was inland, thereby balancing the effect of removing both outliers.

Certainly coastal fog has a cooling influence on water temperature for streams within that zone. We placed a limitation on the "coastal climate influence" roughly equal to eight miles measured perpendicularly from the coastline. There are several miles between the six western-most tributaries monitored, which we considered coastally influenced, and the other six more inland tributaries.

In comparing the difference between predicted and measured values for inland versus coastal streams, inland tributary measurements averaged 0.7 degrees Fahrenheit higher than predicted values while coastal stream measurements averaged 0.7 degrees cooler than predicted values. In other words, inland streams, for the same canopy coverage, averaged 1.4 degrees (F) warmer than coastal streams. The slope and intercept reported in the regression equations of Figures 5 and 6 define a predictive relationship between maximum summer stream temperatures and canopy closure measured by spherical densiometer in 1999. Solar radiation data collected with the Solar Pathfinder were not sufficiently analyzed by the surveyor nor MCRCD, but the data remain available for further analysis.

Figure 5. Maximum Water Temperature on Canopy Closure on Garcia River Streams 1999

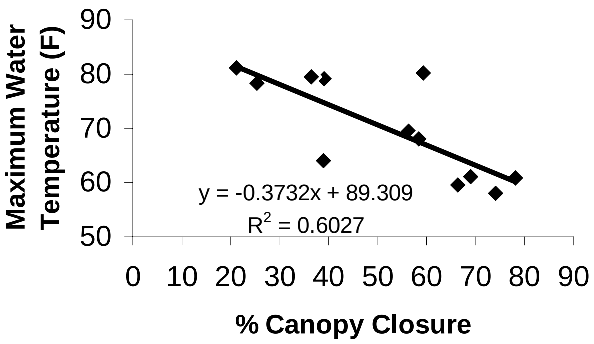
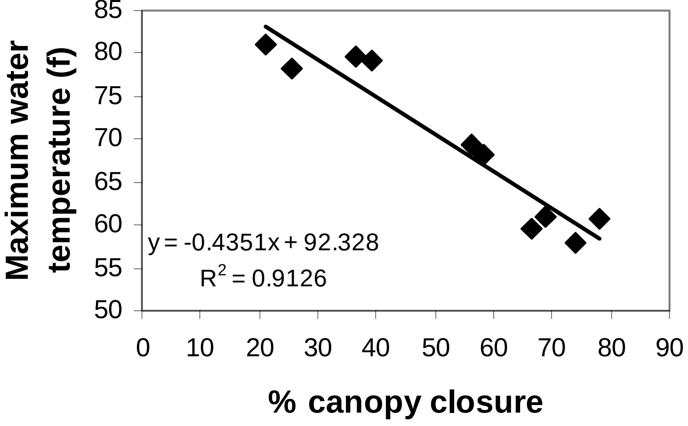


Figure 6. Maximum Water Temperature on Canopy Closure on 10/12 Garcia River Streams 1999



LARGE WOODY DEBRIS

There are a variety of ways to summarize the quantity of wood in the Garcia River tributaries for future comparison. One way is to simply determine the density of LWD pieces. For example, the total length of stream surveyed for LWD was about 4,340 meters, in which there were 1,620 pieces of LWD, for an average of one piece of wood every 2.7 meters. The mean diameter of the LWD can also be calculated. In this study the average diameter was 0.40 meters. A decrease in either the number of pieces or in the average diameter of the pieces of wood could be a reason for concern. Alternatively, an increase in the average diameter of LWD or an increase in the density of LWD pieces could provide evidence of improving watershed conditions. Trends would be less certain where one factor had increased while the other decreased, which can be overcome by using the volume of wood per length of stream, or volume of LWD per unit of area. In this survey, the mean volume of LWD in Garcia River tributaries was estimated at 385 cubic meters per kilometer or, alternatively, 279 cubic meters per hectare.

Variation in the amount of LWD between the studied tributaries was high. Two streams, in particular, had relatively low LWD volumes of 69 and 43 m^3/ha, while three streams had more than 500 m^3/ha. This extreme variation between streams indicates that all of the study streams must be surveyed in future years if any overall watershed comparison is made. There are a host of other comparisons that would be interesting and informative, such as the proportion of pieces meeting a specific diameter classification (e.g., greater than 0.5 meters), or the proportion of pieces, which were classified as fresh, sound or decaying.

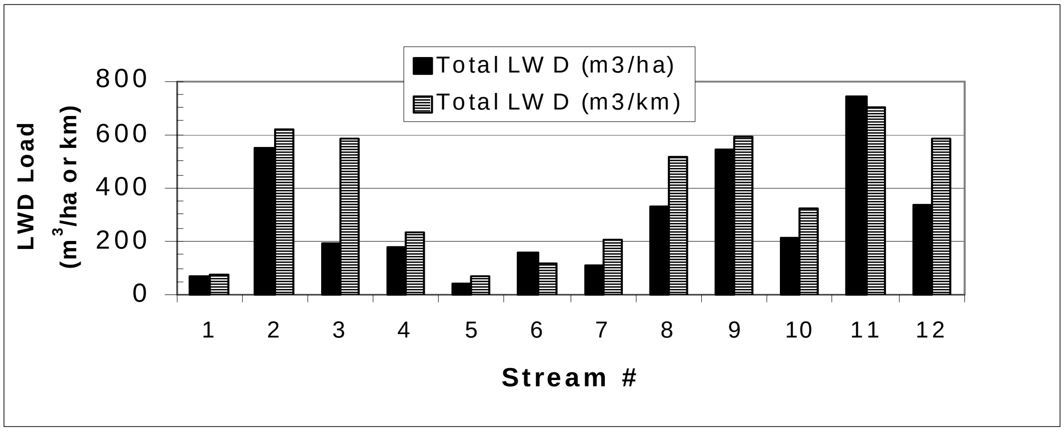
Table 8 shows that most LWD pieces were logs and over half of these were in accumulations or larger jams. Approximately 60% of the LWD was redwood and 25% was hardwood. Just 7% of the LWD was reported to be “fresh”, in the channel one year or less. Most LWD was sound and mildly weathered. The input mechanism could not be determined for 80% of the LWD. Nine percent was reported as input through bank erosion, and 4% each had input by windthrow, mass-wasting, and restoration mechanisms. Nearly one-third of the LWD was partially buried, either in the channel or on terraces, over 40% were pinned by boulders or other LWD, and just 10% appeared to be unconstrained by the channel. Another 10% was rooted into the bed or banks. Only 7% of the LWD had diameters of one meter or larger, which indicates they were legacy pieces. Approximately 25% were pool-related and half of these pools were thought to be formed by the LWD (O’Connor, 2000).

The units of measure most commonly used to compare LWD abundance among streams in the coastal redwood region are volume of LWD per unit area and volume of LWD per length of stream. Figure 7 reports this information by tributary (O'Connor, 2000).

Table 8. Summary of LWD attributes expressed as a proportion of the total number of LWD pieces surveyed in all four plots comprising each survey reach (O'Connor, 2000).

Stream #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
LWD Type													
Log (no rootwad)	0.71	0.90	0.83	0.74	0.89	0.68	0.71	0.51	0.87	0.68	0.83	0.59	0.75
Rootwad (no log)	0.02	0.02	0.01	0.20	0.04	0.00	0.02	0.33	0.02	0.04	0.04	0.00	0.06
Log with rootwad	0.28	0.08	0.16	0.07	0.06	0.32	0.27	0.16	0.11	0.28	0.13	0.41	0.19
Enhancement	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.02
Jam Status													
Single Piece	0.57	0.85	0.10	0.57	0.60	0.51	0.48	0.62	0.36	0.22	0.24	0.37	0.46
Accumulation	0.43	0.06	0.33	0.13	0.40	0.49	0.52	0.38	0.37	0.45	0.47	0.39	0.37
Jam (> 10 pieces)	0.00	0.09	0.57	0.30	0.00	0.00	0.00	0.00	0.27	0.33	0.29	0.25	0.18
Species Class													
Redwood	0.24	0.93	0.71	0.63	0.38	0.18	0.53	0.89	0.69	0.82	0.74	0.56	0.61
Other conifer	0.22	0.01	0.04	0.35	0.36	0.46	0.05	0.04	0.13	0.09	0.09	0.01	0.15
Hardwood	0.48	0.05	0.24	0.02	0.23	0.37	0.42	0.07	0.17	0.09	0.13	0.43	0.23
Unknown	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.04	0.00	0.01
Relative Age Class													
Fresh	0.07	0.01	0.03	0.39	0.00	0.12	0.08	0.07	0.04	0.01	0.04	0.01	0.07
Sound, weathered	0.69	0.63	0.89	0.54	0.64	0.46	0.44	0.87	0.75	0.90	0.68	0.84	0.69
Significant decay	0.24	0.36	0.07	0.09	0.36	0.42	0.48	0.05	0.21	0.09	0.29	0.15	0.23
Input Mechanism													
Undercutting	0.26	0.02	0.04	0.17	0.00	0.00	0.08	0.16	0.03	0.05	0.03	0.23	0.09
Windthrow	0.00	0.01	0.00	0.35	0.04	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.04
Mass Wasting	0.00	0.00	0.00	0.00	0.11	0.18	0.00	0.05	0.00	0.15	0.00	0.01	0.04
Management	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.22	0.05	0.01	0.09	0.00	0.04
Unknown	0.74	0.97	0.94	0.46	0.83	0.81	0.92	0.56	0.90	0.80	0.87	0.75	0.80
Stability													
Root system in bank	0.21	0.04	0.06	0.07	0.04	0.23	0.17	0.29	0.05	0.06	0.03	0.14	0.12
Pinned by other LWD/boulders	0.36	0.31	0.80	0.30	0.38	0.37	0.27	0.35	0.56	0.54	0.24	0.54	0.42
Buried in channel or terrace	0.33	0.55	0.08	0.46	0.43	0.25	0.39	0.29	0.29	0.30	0.21	0.26	0.32
No evidence of stability	0.10	0.09	0.06	0.17	0.15	0.16	0.17	0.07	0.10	0.09	0.07	0.03	0.11
Legacy LWD													
Diameter >= 0.5 m	0.10	0.19	0.11	0.30	0.30	0.19	0.15	0.36	0.22	0.25	0.29	0.22	0.22
Diameter >= 1.0 m	0.02	0.05	0.03	0.15	0.04	0.02	0.03	0.25	0.02	0.06	0.08	0.05	0.07
Pool Association													
Assoc. with Pool < 3 ft deep	0.05	0.00	0.41	0.17	0.04	0.04	0.11	0.00	0.11	0.15	0.19	0.01	0.11
Assoc. with Pool > 3 ft deep	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.15	0.01	0.02	0.04	0.00	0.02
Forming Pool < 3 ft deep	0.03	0.04	0.06	0.11	0.02	0.09	0.18	0.00	0.26	0.14	0.21	0.00	0.09
Forming Pool > 3 ft deep	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.24	0.04	0.01	0.07	0.00	0.03
No Pool Association	0.91	0.96	0.52	0.63	0.94	0.88	0.71	0.62	0.58	0.46	0.48	0.99	0.72

Figure 7. Large Woody Debris Abundance as Volume per Units Area and Length (O'Connor Environmental, 2000)



Data collected from North Coast streams classified as "old growth" and "second growth" report LWD per kilometer of stream. The median value for second growth streams is approximately 220 cubic meters per kilometer, while from old growth streams the value is about 1200 cubic meters per kilometer. Figure 7 indicates that LWD in Garcia tributaries is far less abundant than that found in old growth watersheds. For the Garcia as a whole, LWD loading was estimated to be 385 cubic meters per kilometer compared to an average of 220 cubic meters per kilometer in other second growth watersheds. In comparison to average abundance of LWD in second growth watersheds, the majority of the Garcia River tributaries have more LWD.

Recruitment rate is the natural process by which LWD is incorporated into streams. Recruitment rate of LWD into the channels from the watersheds was estimated to be 3.7 cubic meters per hectare per year, compared to 5.3 cubic meters per hectare per year documented at North Fork Caspar Creek (O'Connor, 2000). The larger the diameter of wood recruited, the more likely it will remain against the forces of downstream transport and decay. Diameters of freshly recruited LWD were less than 0.5 meters in mixed hardwood and softwood tree types (Table 9). The small diameter of the reported freshly recruited wood will not replace the longlasting, geomorphically significant pieces seen in streams forming deep pools and routing spawning gravels. Large woody debris is entering these systems at a relatively rapid rate, although it is comprised of multi-species and is of smaller dimension than the longer lasting old-growth redwood seen in persistent pools in the South Fork of the Garcia, Mill Creek, and other tributaries (O'Connor, 2000). An increase in recruitment rate and an increase in diameter of LWD in the channel would generally be indicative of channel recovery. But input mechanisms yielding intensive recruitment of LWD are often viewed as negatives, as in the case of input by landslide or streambank erosion due to the volume of fine sediments associated.

Table 9. Size, volume, species class and input mechanism for "fresh" LWD (O'Connor, 2000).

Stream#	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Average Diameter (m)	0.13	0.16	0.24	0.16	0	0.28	0.26	0.22	0.41	0.20	0.24	0.26	0.23
Total Volume (m^3)	0.26	0.13	5.55	1.12	0	4.57	2.26	1.44	18.6	0.45	2.04	0.61	3.08
Fresh LWD Species (proportion of total LWD)													
Redwood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.01	0.01	0.01	0.01
Other conifer	0.00	0.00	0.01	0.35	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03
Hardwood	0.07	0.01	0.01	0.02	0.00	0.12	0.08	0.04	0.01	0.01	0.03	0.00	0.03
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fresh LWD Input Mechanism (proportion of total LWD)													
Undercutting	0.05	0.01	0.01	0.00	0.00	0.02	0.02	0.04	0.01	0.00	0.02	0.01	0.01
Windthrow	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Mass Wasting	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.04	0.00	0.01	0.00	0.00	0.01
Management	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Unknown	0.02	0.00	0.01	0.02	0.00	0.04	0.06	0.00	0.01	0.01	0.01	0.00	0.01

SPAWNING GRAVEL COMPOSITION

Particle Size Distribution of Subsurface Bulk Sampling

Trends in the proportion of fines in spawning gravels can be used as an indicator of overall FPR effectiveness. TMDLs have targeted reducing the proportion of the bed occupied by fines smaller than 0.85 and 6.5 mm (U.S. EPA, 1998). In the Garcia, the subcontractor sieved streambed gravels into particle sizes smaller than 128, 64, 32, 16, 8, 5.6, 4.0, 2.8, 2.0, 1.4, 1.0, 0.85, 0.5, 0.25, and 0.125 mm. They focused on the cumulative percent finer than 0.85 and 8.0 mm to characterize the baseline condition, to predict survival to emergence of fry from redds built in these gravels, and suggest their use in detecting changes in gravel composition over time. Unfortunately, only the 0.85 mm and smaller size fraction is directly comparable to the TMDL targets. This size class is also quite useful in that it allows survival to emergence of salmonid eggs to be predicted.

Table 10. Summary of Gravel Particle Size Distribution for 10 Garcia River Tributaries, 1999 (McBain and Trush, 2000).

Cumulative percent finer than 0.85 mm for each tributary bulk sample

	BULK SAMPLE												*95% Conf Int*		
Tributary Code	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***ý***	***s***	***S.E.***	***Lower***	***Upper***	***CV (s/ý)***
Tributary-1	8.8%		8.5%	9.6%	9.8%	11.9%	12.2%	7.4%		9.7%	1.8%	0.7%	8.1%	11.4%	18.1%
Tributary-3	9.4%	11.1%	6.9%	13.7%	8.2%	9.7%				9.8%	2.4%	1.0%	7.4%	12.3%	24.1%
Tributary-4	12.4%	8.6%	9.7%	6.3%			7.7%	8.0%		8.8%	2.1%	0.9%	6.5%	11.0%	24.2%
Tributary-5	5.3%	8.3%	10.6%	10.2%	11.8%	7.7%	4.8%	8.7%		8.4%	2.5%	0.9%	6.4%	10.5%	29.4%
Tributary-6						3.7%	5.9%	5.0%		4.9%	1.1%	0.7%	2.1%	7.7%	23.2%
Tributary-7	12.1%	8.3%	19.0%	9.2%	12.0%	8.4%	12.0%	7.5%	8.7%	10.8%	3.6%	1.2%	8.0%	13.5%	33.2%
Tributary-8	5.5%	6.6%	7.6%	5.8%		5.2%	5.3%	5.7%		6.0%	0.9%	0.3%	5.1%	6.8%	14.7%
Tributary-9	9.4%	9.9%	9.6%	9.1%	8.0%	14.0%	11.8%	9.0%		10.1%	1.9%	0.7%	8.5%	11.7%	19.0%
Tributary-10			4.6%	5.3%		6.0%	11.1%	8.5%		7.1%	2.7%	1.2%	3.8%	10.5%	38.0%
Tributary-11	11.3%		5.3%	6.7%	5.5%	5.5%	3.5%	2.0%		5.7%	2.9%	1.1%	3.0%	8.4%	51.7%

Cumulative percent finer than 8.0 mm for each tributary bulk sample

	BULK SAMPLE												*95% Conf Int*		
Tributary Code	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***ý***	***s***	***S.E.***	***Lower***	***Upper***	***CV (s/ý)***
Tributary-1	40.4%		30.4%	25.0%	41.1%	24.5%	23.4%	32.2%		31.0%	7.4%	2.8%	24.2%	37.8%	23.9%
Tributary-3	34.9%	44.9%	29.4%	25.0%	35.0%	25.9%				32.5%	7.4%	3.0%	24.7%	40.3%	22.8%
Tributary-4	42.7%	29.3%	41.3%	43.9%	20.9%	26.3%	38.2%	38.9%		35.2%	8.5%	3.0%	27.4%	42.9%	24.3%
Tributary-5	42.7%	36.4%	41.2%	49.3%	35.3%	39.2%	28.5%	30.2%		37.9%	6.8%	2.4%	32.2%	43.5%	17.9%
Tributary-6						39.9%	44.3%	31.2%		38.5%	6.7%	3.8%	21.9%	55.0%	17.3%
Tributary-7	41.0%	36.5%	50.9%	41.9%	31.3%	34.2%	44.9%	39.6%	36.5%	39.6%	5.9%	2.0%	35.1%	44.2%	14.9%
Tributary-8	36.0%	55.8%	53.8%	38.6%	86.2%	33.8%	67.3%	29.6%		50.1%	19.5%	6.9%	33.3%	67.0%	38.9%
Tributary-9	45.3%	42.3%	18.4%	32.3%	35.6%	24.6%	21.4%	18.8%		29.8%	10.6%	3.7%	21.0%	38.7%	35.5%
Tributary-10			31.9%	25.6%		34.3%	45.7%	41.6%		35.8%	8.0%	3.6%	25.9%	45.7%	22.2%
Tributary-11	38.3%		33.5%	39.3%	31.1%	19.1%	42.0%	43.6%		35.3%	8.4%	3.2%	27.5%	43.0%	23.8%

Gravel particle size composition for fractions finer than 0.85 mm and 8.0 mm are shown for the 10 tributaries evaluated in Table 10. Results indicate that 4.9-10.8% of spawning gravels were composed of fines smaller than 0.85 mm in diameter (the mean for all tributaries was 8.2%, with 95% confidence interval ranging from 5.9% to 10.4%); and 29.8-50.1% of spawning gravels were composed of gravel sizes smaller than 8.0 mm (dry sieve data).

Variability in the samples as characterized by the 95% confidence intervals shows that some tributaries had consistent gravel size distributions while others were wider ranging. The composition of spawning gravels at individual sites showed considerable variability indicating that gravel sizes are different even across the same riffle.

Recovery of channel conditions could be demonstrated if mean proportions of fines in gravels attenuate with time. Increasing variability around the mean increases the range in confidence interval such that in highly variable tributaries, a very strong recovery must be in place before the reduction in gravel sizes is significant enough to cause the mean to fall outside the confidence interval. That is, the significance of any trend in cumulative percent finer from this size class should be interpreted in relation to the variability among samples from the same tributary. The degree of variability among gravels from the same tributary may be so high as to preclude the ability to determine any trend in the improvement of gravel composition for beneficial uses. Detectability could be improved by increasing sample size.

The difference in results obtained from sieving a gravel sample into its size-classes while wet or after drying is on the order of 10%. For this study, gravel was air-dried on tarps after removal from the streambed. No moisture was obviously present on any particles as sieving began. Gravel composition results previously reported in other studies are frequently based on gravel that is sieved immediately after removal from the bed and which has an appreciable mass of water adhering to particles. The mass of the water is incorporated into the mass reported by weight in each size class and, as a result, direct comparison from one data set to another is reasonable only if both data sets were sieved under equivalent moisture conditions. Alternatively, Shirazi and Seim (1979) quantified the water gained by wet-sieved gravel so that wet sieved gravel volumes can be multiplied by a correction factor (different for low, medium, and high density rock) to estimate the volume of the same gravel dry. Garcia gravel was quantified by weight, not volume, but for gross comparisons Table 11 below, reproduced from Shirazi and Seim (1979), may suffice. These correction factors are offered for a moderately dense rock type. For a more precise comparison, correction factors can be established directly by measuring the mass of wet and then dry particles for each size class in the field. It should be noted that dry sieving avoids the errors and bias that is added by the presence of water, so the less certain wet values should be converted to dry values, rather than converting from dry to wet values.

Table 11. Water Gained in a Wet Gravel Sieving Process (Shirazi and Seim, 1979)

Sieve Sizes (mm)	Gram Water Gained Per Gram Dry Gravel	Correction Factor Applied To Wet-Sieved Gravel
256	NA	NA
128	NA	NA
64	.02	.96
32	.02	.96
16	.03	.93
8	.04	.9
4	.06	.86
2.8	.08	.82
1.4	.11	.78
1	.12	.76
.85	.13	.74
.5	.18	.69
.25	.25	.61
.125	.35	.52

Biological Link

Elevated proportions of fines in spawning gravel have been shown to impair permeability of gravel, which in turn, decreases dissolved oxygen levels, increases carbon dioxide levels, and traps fry in their nest. An alternative approach to characterizing the biological integrity of spawning gravel is to measure directly the permeability they provide. The permeability measurement is faster, less energy intensive, and has potential for replacing the bulk sample measurements used widely in the

Pacific Northwest and Northern California. Therefore we measured both gravel composition and permeability in the same places in an attempt to correlate the two and begin testing whether or not permeability can substitute for bulk samples and also correlate to survival-to-emergence from the redd. Table 12 interprets gravel composition and quality in terms of the proportion of fry able to incubate and successfully emerge from a gravel redd composed of measured gravel composition and measured permeability (data for coho salmon were not available).

The EPA-SWRCB numeric target for fines <0.85 mm is 14%, assumed to be determined with the wet sieve technique. Assuming that the difference in results obtained from sieving a gravel sample into its size-classes while wet or after drying is on the order of 10% and the mean reported for the Garcia tributaries examined in the GRIMP is 8.2%, then as a whole, the basin is over the target value. Additionally, based on the reduction in survival caused by inhibiting emergence of chinook salmon reported by Tappel and Bjornn (1983), all tributaries surveyed in the Garcia would presently impair chinook survival (Table 12). Although the Garcia does not support chinook, this concept could be reasonably extended to coho or steelhead (McBain and Trush, 2000).

GRAVEL PERMEABILITY

The challenge of extrapolating the biological significance of fine sediment is even greater than detecting trends in gravel composition. For this reason, the alternative approach of gravel permeability was conceived as a more direct reflection of pore space clogging. A limited test of permeability's utility was conducted as part of the GRIMP. Permeability measurements in themselves reduced variability and improved the detection of differences compared to gravel composition as percent fines. This was partially due to the ease of making permeability measurements, which led to substantially increasing sample size at a minimal cost. While a predictive correlation between percent fines and permeability was obtained in the Klamath basin, permeability was not as good of a predictor of fines in Garcia River tributaries. The relationship between permeability and the bulk samples (using both 32 mm and 0.5 mm size fractions combined) explained 45% of the variability ($r^2 = 0.45$), with the remainder of the variability hypothesized to be due to the packing of substrate particles.

Mean permeability (cm/hour) was obtained for each tributary by averaging 5-10 replicates per site and then averaging each site for one representative permeability value per tributary (Table 13). Each site's measurement of inflow rate (ml/s) was corrected for water temperature using a viscosity correction factor and then converted to cm/hour. Detection of a change in mean permeability would require the future mean to fall outside confidence bands. Representative basin permeabilities from 1999 ranged from 1708-5002 cm/hour and 95% confidence bands generally ranged from 1000 to 2500 cm/hour around each tributary's mean (Table 13). Both gravel composition and permeability are highly variable between and among tributaries. This makes discerning change problematic because management related differences are obscured by the large range of natural variability.

Permeability can also predict survival to emergence from the redd for coho or chinook (after Tagart (1976) and McCuddin (1977), respectively). With the exception of tributary #6, all predictions of survival to emergence from permeability indicated more fry would emerge than predictions based on gravel composition (Table 12).

Table 12. Percent survival of Salmonid Eggs to Emergence from the Redd based on Tappel and Bjornn (1983) and Tagart (1976) and McCuddin (1977) – from McBain and Trush (2000).

	PERCENT FINE SEDIMENT			***PERMEABILITY***		
	estimated chinook survival (%)			***estimated chinook survival (%)***		
	mean	***lower 95% CI***	***Upper 95% CI***	***mean***	***lower 95% CI***	***Upper 95% CI***
Tributary-1	0	0	35	29	18	35
Tributary-3	0	0	41	33	27	37
Tributary-4	13	0	72	43	31	49
Tributary-5	0	0	39	28	18	33
Tributary-6	34	0	64	29	23	33
Tributary-7	0	0	21	29	20	34
Tributary-8	4	0	53	40	25	47
Tributary-9	20	0	63	37	27	43
Tributary-10	15	0	58	43	36	47
Tributary-11	0	0	41	31	20	37

Table 13. Mean Permeability Measured in Spawning Riffle/Pool Tails in Garcia River Tributaries (McBain and Trush, 2000)

Mean Permeability for each pool-tail site (cm/hr)

	POOL-TAIL SITE												***95% Conf Int***		
Tributary Code	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***ý (trib)***	***s***	***S.E.***	***Lower***	***Upper***	***CV (s/ý)***
Tributary-1	2,185	2,941	1,669	2,214	513	455	1,090	4,001		1,883	1,219	431	864	2,902	0.65
Tributary-3	2,855	3,113	2,414	1,021	2,632	3,057				2,515	778	317	1,699	3,332	0.31
Tributary-4	3,835	3,883	3,785	8,952	8,748		4,050	879		4,876	2,930	1,108	2,166	7,586	0.60
Tributary-5	3,876	1,304	1,231	2,349	1,922	767	1,183	1,031		1,708	1,012	358	862	2,554	0.59
Tributary-6			2,381	761	1,782	2,011	1,974	2,575		1,914	635	259	1,248	2,580	0.33
Tributary-7	1,872	3,743	1,240	598	1,638		1,800	3,014	983	1,861	1,047	370	986	2,737	0.56
Tributary-8	2,826	4,884	2,859	2,006		2,710		8,496		3,964	2,421	988	1,422	6,505	0.61
Tributary-9	734	2,660	2,676	1,034	4,325		2,239	1,438		2,158	1,227	464	1,023	3,293	0.57
Tributary-10	7,268	4,756	7,955	6,157	982	4,300	4,784	3,817		5,002	2,183	772	3,177	6,828	0.44
Tributary-11	1,608		1,313	1,651	4,754	3,238	5,006	5,614		3,312	1,822	688	1,627	4,997	0.55

Mean Permeability for each bulk sample site (cm/hr)

	POOL-TAIL SITE												***95% Conf Int***		
Tributary Code	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***ý (trib)***	***s***	***S.E.***	***Lower***	***Upper***	***CV (s/ý)***
Tributary-1	1,830	359	3,642	2,849	734	303	732	5,152		1,950	1,778	629	463	3,437	0.91
Tributary-3	4,500		1,699	265	1,832	2,954				2,250	1,579	706	434	4,066	0.70
Tributary-4	4,253	1,622	2,208	12,575	9,023		1,383	812		4,554	4,520	1,708	374	8,734	0.99
Tributary-5	4,967	1,396	559	1,246	571	866	1,714	761		1,510	1,456	515	293	2,727	0.96
Tributary-6			3,027	671	873	2,500	2,246	2,501		1,970	964	394	958	2,981	0.49
Tributary-7	552	4,179	337	792	1,092		2,018	3,637	963	1,696	1,460	516	476	2,917	0.86
Tributary-8	2,043	2,376	1,672	1,161		5,611		2,229		2,515	1,578	644	859	4,171	0.63
Tributary-9	1,503	2,551	1,830	1,797	2,448		1,468	2,048		1,949	426	161	1,555	2,343	0.22
Tributary-10	5,616	7,917	11,075	2,050	779	2,497	2,161	1,922		4,252	3,618	1,279	1,227	7,277	0.85
Tributary-11	1,224		2,781	3,652	4,213	8,122	5,388	8,722		4,872	2,747	1,038	2,331	7,412	0.56

TURBIDITY

Attributes

Turbidity is a promising monitoring parameter that is capable of documenting upslope sediment delivery in the short term (Beschta, 1981; Furniss, 1999). Turbidity measurements must be reported together with discharge at the time of sampling because turbidity naturally rises during storms when stream discharge rises. Reductions in optical clarity (turbidity) caused by suspended sediments result from both eroded particles transported from upslope and re-suspension of bedload sediments. Turbidity levels caused by upslope disturbances that exceed background levels by 20% are in violation of the North Coast Basin Plan developed by NCRWQCB. Additionally, turbidity and suspended sediment concentration values for lethal and sublethal doses have been established quantitatively for several species of salmonids (Noggle, 1978; Newcombe and MacDonald, 1991). The downside of turbidity monitoring has been the expense of setting up monitoring stations that can be sampled during high peak flows. Adequate sampling intensities have usually meant remote, automatic sampling equipment utilizing a randomized sampling design programmed to trigger the sampler (Lewis and Eads, 1998). Alternatively, grab samples can be taken by humans if transportation to the sites is achievable on short notice in extreme weather conditions.

Limitations

Due to prohibitively high estimated costs and remote study reaches, turbidity was not selected as an official measurement parameter for the Garcia River IMP. Gravel monitoring, LWD, cross-sections, thalweg profiles, and water temperature appeared more cost-effective than turbidity when compared to the large funding requirements of programs like the Caspar Creek Watershed Study's turbidity/suspended sediment concentration monitoring system (Henry, 1998; Lewis, 1998). Technical opinion by USFS Pacific Southwest Research Station (PSW) Redwood Sciences Laboratory research staff indicated that this level of investment would be required to obtain unbiased turbidity results. Lower-technology grab sample approaches failed to satisfy statistical and hydrological constraints necessary in formulating quantitative relationships needed to predict turbidity from stream discharge. The USFS PSW's list of required turbidity sampling components includes automatic pumping samplers run by battery power and statistical sampling programs, floating boom intakes, continuously recording turbidimeters, and other costly components (for further details, see the PSW's website at www.rsl.psw.fs.fed.us).

Recently, however, a successful low-technology grab-sample program in Freshwater Creek (Humboldt County) mentored by Dr. Leslie Reid of the USFS-PSW enabled a low-cost application to succeed in meeting statistical and hydrological requirements, indicating turbidity can be affordable, and user friendly. This program is in place and working, and is contracted to Salmon Forever, a local grass-roots salmon recovery organization.

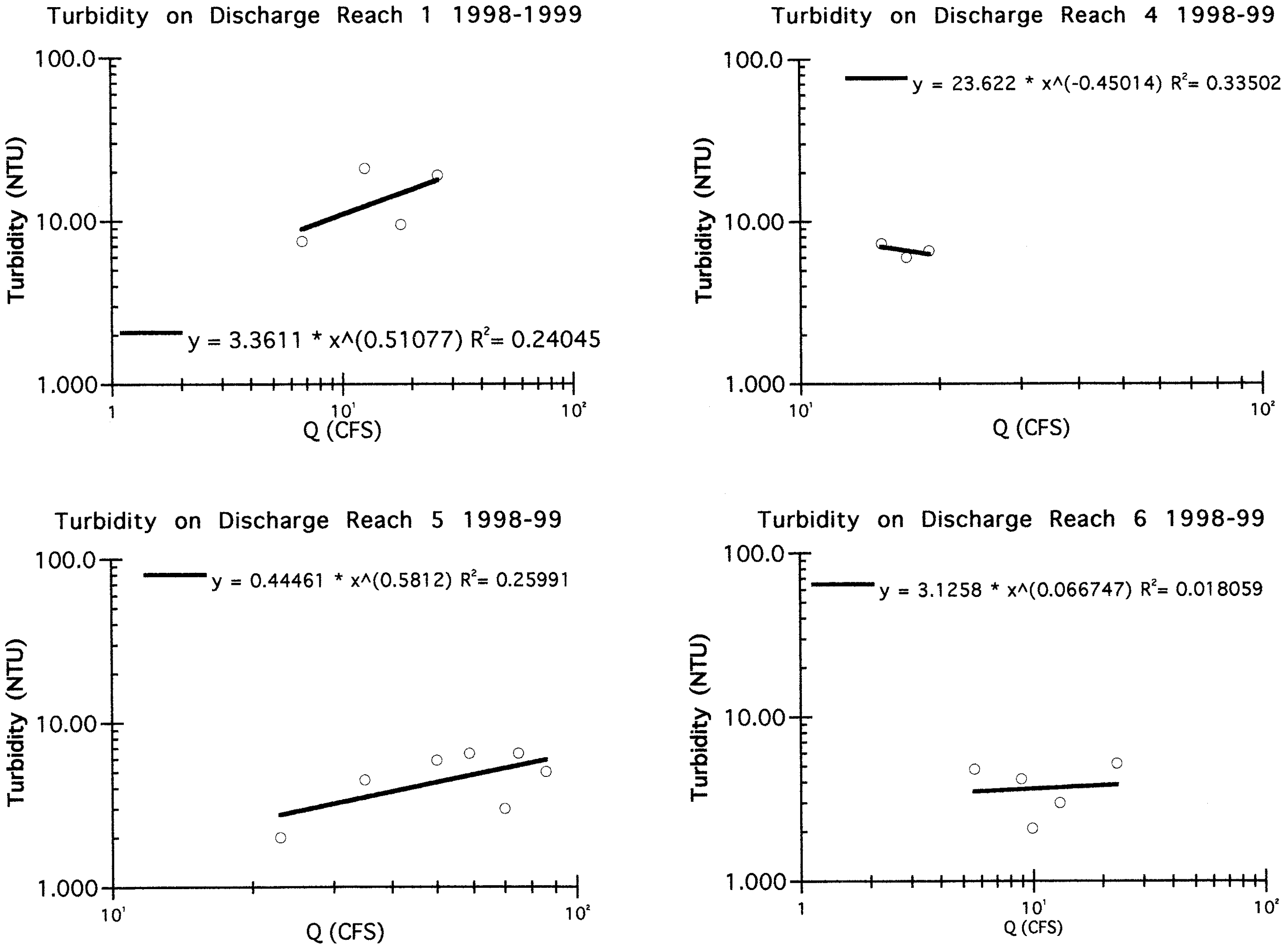
Results

An attempt at measuring turbidity was undertaken in a combined effort by MCRCD staff, the spawning surveyors, and the cross-section surveyor in Garcia River study reaches. As a result of a partial financial committment, efforts were not led by a single entity, but rather tasks were shared among contractors whose primary tasks were not turbidity monitoring. The data reported are sparse and were not nearly as frequently measured as would have occurred under a committed turbidity program. Turbidity rating curves were developed for survey streams 1,4,5,6,8,9,11 and the mainstem (see Figures 8, 9, and 10). The number of samples utilized in these relationships was very low, ranging from 3 to 7 on each tributary, which is generally considered an insufficient number of samples from which to make a regression analysis. While the number of data points is low, these data can be built upon in further studies, so long as discharge (or stage height) and turbidity values are collected at the same time and reported together such that discharge levels can be related to the turbidity sample. Correlation coefficients ranged from 2-93%, suggesting a poor predictive relationship due to the extremely low number of samples measured in each creek (see Figures 8, 9, and 10).

Turbidity monitoring provides a signal of upslope and instream sediment transport. It has utility in evaluating water quality with the NCRWQCB’s 20% over background standard. The link between turbidity and biology to lethal and sublethal doses is quantified in the literature for juvenile coho, steelhead, and chinook in laboratory studies. Elevated turbidity at sublethal levels for long periods of exposure abrades gills and lessens the ability to feed over winter, thus reducing a fish’s chance to grow to critical smolt length enabling successful ocean competition and for returning as an adult to spawn (Dr. William Trush, Humboldt State University, Arcata, CA, personal communication). Therefore, turbidity and supporting variables are recommended as parameters for measuring whether FPRs are conserving anadromous fisheries habitat. Future monitoring activities should place a high priority on the use of turbidity and discharge measurements.

Ideally, baseline conditions with highly significant predictive correlation coefficients would have been produced as part of the GRIMP. The baseline relationship could then be compared to subsequent monitoring results to determine whether the quantity of suspended sediments are increasing or decreasing with additional management activities. Recovery would be indicated by a consistent trend of decreasing suspended sediments/turbidity with discharge. The baseline turbidity measurements made in 1998-99 were limited by low sampling frequency and by simplified measurements of cross-sectional area and velocity. Improving accuracy in these measurements would help to refine predictive relationships between turbidity and discharge.

Figure 8. Garcia River Turbidity Rating Curves, For Study Reaches 1,4,5,and 6



Turbidity on Discharge Reach 1 1998-1999

Turbidity on Discharge Reach 4 1998-99

Turbidity on Discharge Reach 5 1998-99

Turbidity on Discharge Reach 6 1998-99

Figure 9. Garcia River Turbidity Rating Curves, For Study Reaches 7,8,9, and 11

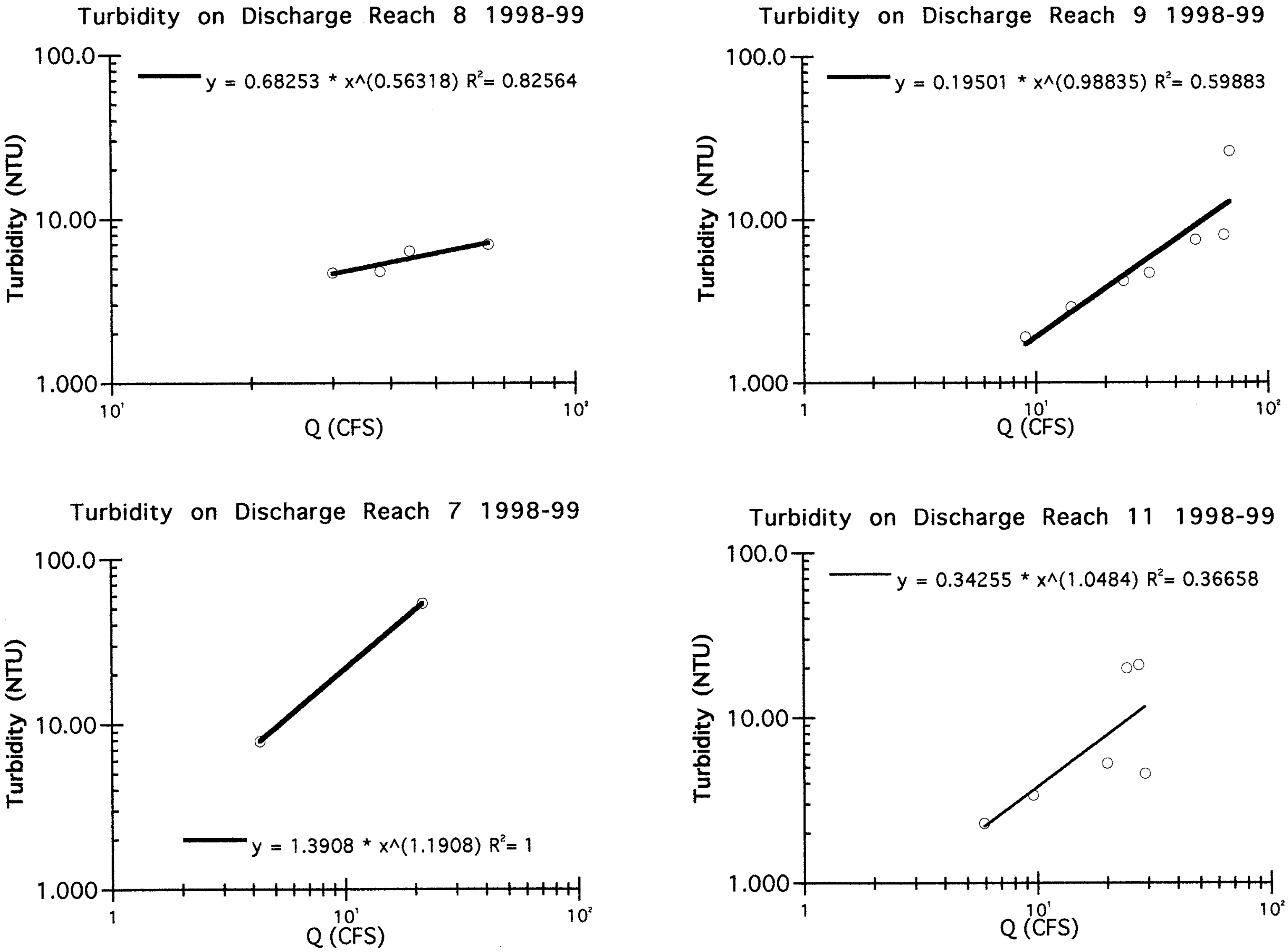
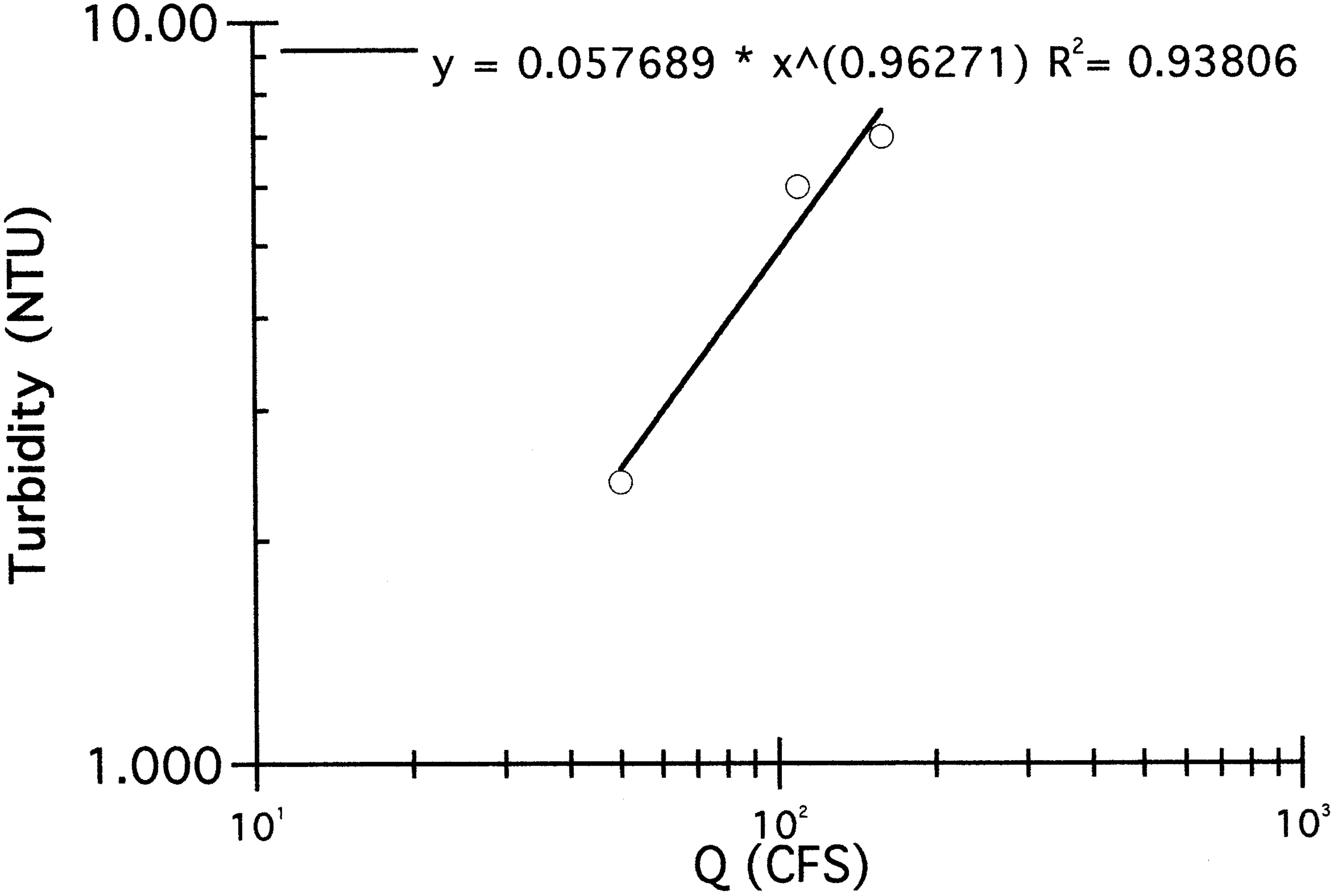


Figure 10. Mainstem Garcia River Turbidity on Discharge 1998-99



SEDIMENT TRANSPORT CORRIDORS

Of 138 sediment transport corridors (STCs) identified in Garcia River surveyed streams during the winter 1998-99, there were 38 gullies, 26 landslides, 26 bank failures, one in-channel headcut, and 47 natural tributaries (Barber, 1999). Natural tributaries can be considered STCs since they process water, sediment, and sometimes fish. Management related STCs include landslides and gullies if a trigger-source can be identified. Background rates of landsliding are beneficial for watershed condition because they provide an input of LWD and coarse sediment needed for spawning habitats. Of more concern, are human-induced, controllable STCs, such as road related landslides and road diversion gullies, which were found to be abundant on the landscape.

Management Related STCs

For evaluating FPR effectiveness it is appropriate to focus on STCs caused by timber management-related activities. Identifying the source of these STCs is crucial. When STCs were traced to a location where a source could be identified, watercourse crossings, ditch relief culverts, and inadequate water bars were found to be the most common cause. Therefore, it is logical to further focus on these road and landing-related STCs (Table 14). The timberlands where these features were documented are owned and managed by a variety of landowners, and are used to access industrial timberlands, small private timberlands, hunting lands, and ranchlands. Many of the roads were constructed prior to the implementation of the Z'Berg-Nejedly Forest Practice Act in 1974. Some fraction of road-related STCs identified in 1998-99 resulted from improper implementation of more recent road-related FPRs. Timber harvesting activities were not the only cause of management related STCs. For example, some streambank failures appeared to be caused by grazing impacts.

Table 14. Road and Landing Related Sediment Transport Corridors in Garcia Tributaries (Barber, 1999).

Stream #	Gullies	Landslides	Streambank Failure
1	1	2	2
2	0	1	1
3	0	0	0
4	1	0	0
5	9	2	1
6	3	2	0
7	0	0	0
8	7	1	1
9	3	1	1
10	11	2	0
11	1	1	0
12	2	0	0
	38	12	6

STCs identified as definitively having management related sources were all caused by changes in redistributing water by roads. All road-related STCs were unnatural landscape voids eroded by moderate and chronic gullying or severe, episodic landsliding. STCs related to other management activities were not discernable to the surveyor. Expected downstream effects include an increase in the volume of fine soil particles and colluvium (non-rounded hillslope rock particles) contributed to streams over and above background levels. These are sediments with no appreciable benefits for downstream habitat (e.g., spawnable gravel). Road related STCs totaled 34 of 38 gullies, 11 of 26 landslides, 5 of 26 bank failures, and 0 of 1 in-channel headcut, for the basin as a whole. Of the 91 non-tributary STCs encountered, 55% were road-related. Seventy percent of the landslides and gullies documented were road-related.

No “Humboldt Crossings” (i.e., stream crossings built by filling channels with logs and soil, thereby risking failure that can move large volumes of sediment downstream) were noted.

However, smaller first order crenulations still commonly drain into inboard ditches, which divert the water to crossings, resulting in gullying at the outlet or failure of the road fill. Improvements to standard practices over those used in "the legacy era" are readily apparent. Perhaps the most disturbing of the legacy era's road practices are older culvert installations with shot-gun outlets that impede or prevent up or downstream fish migration, and crossings that directly or indirectly divert natural watercourses down the roads and onto hillslope locations when plugged.

ANADROMOUS FISH PRODUCTIVITY

The 1998-1999 Garcia River spawning survey report identified four steelhead spawning-run strength indicators. These consisted of: (1) the number of steelhead observed per mile of spawning survey, (2) the number of redds observed per mile of stream, or total redd area, (3) steelhead carcass counts, and (4) peak live steelhead counts. The number of steelhead carcasses found during spawning surveys is very low relative to the number of fish that spawn, and therefore, provides little useful information. Peak live counts could provide a reasonable index for the spawning populations, but only if the amount of stream surveyed each year is similar or, ideally, the same streams are surveyed each year. In the past, because of access conditions, there has been considerable change between years in which streams were surveyed, as well as the length of survey segments.

To determine a baseline condition for the steelhead run on the Garcia River, one could simply refer to the results of the 1998-1999 survey where 1.2 live fish per mile of spawning survey were observed, or alternatively, where 6.3 redds per mile of stream were observed (Maahs, 1999). A single year of spawning data, however, does not account for variability between years and provides a very limited basis for establishing a baseline condition. Two other recent years of spawning survey data are available for sections of the Garcia River, these being 1995-1996 and 1996-1997 (Maahs, 1996; 1997). For those two years, the number of live steelhead observed per mile of stream survey, for the February - April period, was 3.3 and 3.6, respectively, while the number of redds per mile was 12.2 and 13.4, respectively. Therefore, the average baseline indicator for the Garcia River steelhead run would be 2.7 live steelhead per mile of survey, or alternatively, 10.6 redds/mile of stream, stated as a 3-year average.

An alternative baseline is the total redd area for the February through April survey period. For example, in 1998-1999, there was an estimated 297 sq. meters of redds constructed in survey areas. Although only a single example was found in an initial review of the literature regarding the amount of area utilized by a female steelhead for spawning purposes (Shapovalov and Taft, 1954), this approach could be used to estimate the steelhead population. Shapovalov and Taft (1954) observed a single 60 cm female steelhead construct redds over a 60 sq. ft. area, which is equal to about 5.5 sq. meters, suggesting that about 53 female steelhead spawned in the 297 sq. meters of redd area surveyed within the Garcia River watershed.

The 1995-1996 and 1996-1997 Garcia River steelhead abundance indices can be compared to steelhead abundance in two other Mendocino County coastal streams: Caspar Creek and Ten Mile River (Maahs, 1996; 1997). Spawning surveys in the much smaller Caspar Creek watershed found 1.1 live steelhead observed per mile of survey in both these years, with redd densities nearly identical at 4.5 and 4.6 per mile for the same two years, respectively. For tributaries of Ten Mile River, live steelhead counts were 0.26 and 0.29 per mile in 1996 and 1997 and redd densities were 3.3 and 11.3, respectively. This limited information suggests that the steelhead run in the Garcia River is relatively strong compared to other Mendocino County streams.

No coho salmon were found in two out of three years that spawning surveys were conducted in the Garcia River watershed. While these surveys did not occur throughout the watershed, they did cover many of the areas coho would be expected. In 1996-1997, the total coho population within five of the major Garcia River tributaries was estimated to be between 7 and 9 fish (Maahs, 1997). These population counts indicate that the Garcia River coho run is in a very precarious state and is on the brink of extinction, if it has not already occurred.

Finally, any use of spawning information as a baseline must also consider that angling regulations were changed starting in the 1998-1999 season. In prior years, sportsman could keep up to two steelhead per day, but starting in the fall of 1998, all steelhead caught by sportsmen had to be released. The impact of this change on the 1998-1999 run, as well as future runs, may be difficult to quantify, but there should be an increase in the proportion of the steelhead run which is able to reach its spawning grounds. This regulation, besides resulting in the release of hooked steelhead, has also significantly reduced the total fishing effort (Marty Scribner, North Coast Angler, Fort Bragg, CA, personal communication). Future steelhead spawning abundance estimates should take into account the effect of this reduced fishing pressure whenever a reference is made to abundance indices developed for years prior to the 1998-1999 spawning run.

Besides spawning survey information, little other information is available to characterize the population levels of Garcia River salmonids. The MCRCD investigated the utilization of outmigrant traps to estimate the population of salmonid smolts, but this was determined to be unfeasible within the budgetary constraints of the GRIMP and landowners were unwilling to take on this expense. Currently, there are few funding sources available to conduct fish monitoring and assessment work, and unless there are significant increases made to state agencies or other entities, even the continuation of spawning surveys in the Garcia River is unlikely to occur.

SUMMARY OF HABITAT CONDITIONS MONITORED

Table 15 summarizes the baseline monitoring data collected on the Garcia River tributaries in 1998-99.

Table 15. Summary of baseline conditions for Garcia River tributaries, 1998-1999.							
Study	Bed	Woody	Gravel Quality		STCs	Shading	Canopy
Reach	Gradient	Debris	% Fines	Permeab.	% Road	July Data	Density
		Volume	dry-sieved	(cm/hr)	Related	(%)	(%)
		(m^3/ha)	(<0.85 mm)				
1	1.9	69	9.7	1883	60	64.5	56.5
2	5.9	553	n/a	n/a	67	88.8	82.1
3	1.1	197	9.8	2515	0	63.9	50
4	0.9	179	8.8	4876	2	81.5	60.6
5	1.2	43	8.4	1708	70	58.9	31
6	3.7	159	4.9	1914	29	76	72.5
7	2	112	10.8	1861	0	76.5	73.4
8	0.9	333	6	3964	55	60.7	52.7
9	1.6	543	10.1	2158	57	69.9	78.8
10	2.2	213	7.1	5002	75	47.1	33.8
11	2.4	741	5.7	3312	33	83.2	88.1
12	2.9	335	n/a	n/a	17	83.5	84.4
Study	**Water Temperature Data, deg F**					**Habitat**	**Fish**
Reach	**Peak Temp**	**MWAT**	**MWAT**	**MWAT-- 7 Day**	**MWAT -- 7 Day**	**Pools/mi**	**Steelhead**
	Recorded	**Weekly**	**Weekly**	**Moving Daily**	**Moving Daily**	**>2 ft Deep**	**Redds/Reach**
	1999	**Max**	**Ave**	**Max Temp**	**Ave Temp**		**Mile**
1 ds	79.2	76.5	68.2	76.8	68.2	40.4	3
2 ds	59.6	58.6	57.5	58.7	57.7	6.3	0
3 us	58.6	58.2	56.3	58.4	56.6	19.8	NA
4 ds	69.4	68.2	64.3	68.2	64.9	36.5	12.6
5 ds	81.1	79.8	71.3	79.9	71.3	12.7	22
6 us	66.3	65.2	62.2	65.2	63	11.1	42.4
7 us	59.4	58.4	57.2	58.4	57.2	0	NA
8 us	79.5	77.2	69.8	77.3	69.8	18	0.9
9 ds	61.1	60	57.7	60	58.1	22.6	16.5
10 us	78.3	76.3	69.4	76.4	69.6	27.3	4.6
11 ds	58	57.6	56.3	57.6	56.6	26	22.2
12 ds	60.8	59.8	57.2	59.8	57.7	7.9	NA
ds = downstream reach; us = upstream reach							
Downstream reaches were used unless there was missing data or anomalous factors.							

Large woody debris loading was found to be highest in tributaries 11, 2, and 9. The percentage of fine sediment found in stream gravels was lowest in tributaries 6, 11, and 8. Gravel permeabilities were highest in tributaries 10, 4, and 8. Shading and canopy were highest in tributaries 2, 12, and 11. Water temperatures were lowest in the coastal tributaries 11, 7, 3, 2, 12, and 9. Deep pool frequency was highest in tributaries 1, 4, and 10. Steelhead redd density was greatest in tributaries 6, 11, and 5.

REVISITING THE MONITORING OBJECTIVES

PURPOSE OF THIS SECTION

The goals and objectives of any monitoring project should be periodically reviewed to determine whether, and to what extent, its objectives can be met (MacDonald et al., 1991). A critical examination of this project toward meeting its objective is appropriate at this point. This section (1) reintroduces the study objective in light of the past, present and future; (2) investigates the benefits and limitations inherent to numeric target-conditions assessment; and (3) underscores the conclusions of preliminary, pilot and related projects, which suggested that valid conclusions about influences of Forest Practice Rules cannot be drawn until on-the-ground hillslope conditions are tracked downhill to the instream tributary study-reaches sampled under the GRIMP.

GARCIA RIVER WATERSHED IMP OBJECTIVES

“The primary objective of this plan is to test the capability and effectiveness of the California Forest Practice Rules to protect determined beneficial uses, in this case, the salmonid fishery of the Garcia River. A secondary objective is to create a long-term monitoring data set whereby the Garcia River can be compared to other neighboring rivers in the development of a regional standard. The third, and perhaps most important objective, is to understand the Garcia River watershed and reduce its overall sediment load through adaptive management” (Euphrat et al., 1998).

Instream and hillslope disturbances resulting from forest practices have been linked to adverse conditions in the freshwater habitats of salmonids. “Legacy” era conditions (pre-Z’Berg-Nejedly Forest Practice Act of 1973) are widely cited as the cause of dramatic increases in soil erosion on hillslopes and sedimentation of rivers (Hagans and Weaver, 1987; Cafferata and Spittler, 1998), as well as other manifestations in rivers in California and the Pacific Northwest. Linkages between forest practices and aquatic dysfunction are acknowledged by ecologists, geomorphologists, loggers, foresters, environmentalists, regulatory agencies, and the public. The experimental design put forth in the GRIMP assumes that these legacy-era disturbances largely generated the conditions observed in 1998 and 1999, when baseline conditions were monitored. The notion that present channel conditions are largely controlled by the legacy era disturbances was reported by Knopp’s (1993) findings in several North Coast watersheds. Present-day Forest Practice Rules have greatly improved on-the-ground methods used to access and harvest timber.

Timely efforts by the North Coast Regional Water Quality Control Board compiled many references from the research literature and have reported them in the form of numeric targets for instream conditions supporting optimal salmonid reproductive success (NCRWQCB, 2000). These targets are useful in evaluating the Garcia River baseline condition in relation to optimal instream conditions. The Garcia River Instream Monitoring Project was designed to determine if the FPRs are now providing adequate protection of salmonid habitat through the use a set of uniformly applied habitat measurements over time.

Determining whether FPRs can or do control whether a stream trends toward or away from target conditions will be difficult or impossible to answer unless broad assumptions or expanded efforts to link current channel conditions with hillslope conditions are made.

LINKING CONDITIONS INSTREAM TO CONDITIONS UPSLOPE

Pilot projects are an investment made to provide preliminary, practical guideposts prior to implementation of a full-blown project. Another useful application is to critically evaluate whether the project will meet its intended goal based on the initial design once initial monitoring data is obtained (MacDonald et al., 1991). However, it appears that at least one of the recommendations made by several studies was not incorporated into the GRIMP. An early report on FPR effectiveness monitoring by the Board of Forestry's Monitoring Study Group clearly recommended that instream monitoring coincide with upslope monitoring to link disturbances with instream effects (BOF, 1993). The instream monitoring component conducted by Rae (1995) concluded that a combination of hillslope monitoring along with instream monitoring would improve the understanding of how upslope activities affect channel conditions. It seems to this author to be critical that local hillslopes be examined in order to determine whether and to what extend the application of FPRs controlled problematic hillslope conditions resulting from timber harvesting activities. Yet this sort of assessment was omitted in the design of the Garcia River Instream Monitoring Plan.

The current Hillslope Monitoring Program traces timber harvest disturbances downhill to the receiving waterways, but does not determine downstream channel and habitat conditions. The BOF's Hillslope Monitoring Program interim report (BOF, 1999), not surprisingly, concluded, "Recent timber operations cannot be linked to current instream channel conditions based on results from the Hillslope Monitoring program because the project evaluated FPR effectiveness on hillslopes, not in the stream channels."

So without an upslope monitoring component within the subwatersheds sampled linked to instream conditions, results of Garcia River instream monitoring will be limited to comparisons of: 1) long-term trend data collected in the Garcia River basin, and 2) instream target conditions set by the North Coast Regional Water Quality Control Board. The latter approach is straight forward and useful for monitoring trends in channel conditions toward or away from the ideal channel condition. However this approach alone reflects an unsubstantiated assumption that post-1974 FPRs have a controlling influence on instream habitat conditions. In fact, this assumption was refuted by Knopp (1993). Without an effort to describe localized hillslope conditions adjacent to monitoring reaches, this target based analysis approach can tell us nothing about how, if, where, or when forest practices or FPRs control channel conditions.

It is questionable whether the Forest Practice Rules can be evaluated from the channel without exploring linkages to hillslope disturbances (Michael J. Furniss, USFS, Six Rivers National Forest, personal communication). The channel receives and interprets the entirety of watershed processes, delivered from all directions from the present as well as the past, natural and forest-practice related impacts alike. If forest practices of today are to be singled out for their effect on channel conditions, then some effort must be made to isolate them relative to the other forces that act on the channel. These forces include legacy conditions, natural background conditions, and the effects of non-compliance with FPR requirements.

Extracting Present FPR-based Activities from Past, "Legacy Era" Conditions Prior to FPRs

Extracting present conditions from the past is important in that the GRIMP objectives focus on effects of present timber harvest activities, rather than those from the legacy period. It is a difficult undertaking, but if seriously considered, then perhaps a "space-for-time substitution" on landscapes is a practical solution for the separation of legacy and present conditions (Dr. Tim Lewis, Forest Science Project, Arcata, CA, personal communication). This would require an investigation into the sub-watersheds of the Garcia River tributaries monitored to establish timber-harvest histories and their year of occurrence. The ultimate objective would be to relate the instream conditions monitored with a period of timber harvest history. This is important to discern whether the instream conditions are a result of legacy conditions only (no timber harvest for approximately 100 years), or those resulting from timber harvest activities before the modern Forest Practice Rules were enacted (no timber harvest since the passage of the Z'Berg-Nejedly Forest Practice Act of 1973), or the result of timber harvest since the mid-1970's. Then a reorganization of the data into these groups would enable an analysis group-by-group to indicate whether instream conditions have improved as a result of improved timber harvest practice rules. Even with considerable effort, however, the sample size of each group may be too small to glean a result. If that strategy is employed, then reviewing the basin history described in The Garcia River Watershed Enhancement Plan (Monschke and Caldon, 1992) is recommended reading. Timber harvest records could be examined from the records located in CDF offices.

THE USE OF INSTREAM NUMERIC TARGETS CONDITIONS TO ASSESS FPRS

Channel form-related indices that identify healthy stream habitat have been adopted by NMFS, and PACFISH (reported in Reid and Furniss, 1998) and by the NCRWQCB (Mangelsdorf, 1997). Achieving the recommended target habitat conditions in the Garcia and other salmon and steelhead rivers may be essential to increase the population of sustainable anadromous fisheries. If this were to be the intended mechanism with which to evaluate conditions in Garcia River tributaries, than this goal would have been clearly stated in the Garcia River Instream Monitoring Plan, but it was not. Data gatherers and analysts would have been encouraged or required to collect data and state their findings in the same numeric units used in quantifying the numeric targets. In this way, comparisons to the numeric targets would have been straight forward.

Several of the instream features measured during the baseline GRIMP are, however, comparable to the numeric targets, or, healthy stream indicator conditions. Comparing the existing baseline condition to the targets will help to evaluate the current habitat quality in the various Garcia tributaries. Future monitoring measurements should reveal positive trends toward these ideals or negative trends away from them. Positive trends would suggest FPRs are working and negative trends would suggest they are not working, but exceptionally large storm events will complicate this process (Madej, 1999).

If the FPRs are beneficial in reducing limiting factors on salmonid productivity, then fish productivity would be expected to improve (assuming that freshwater habitat conditions are currently limiting anadromous fish populations). The NCRWQCB and a team of technical specialists representing local, state, and federal agencies identified potential limiting factors for subbasins in the Garcia River watershed. They are as follows (Mangelsdorf, 1997):

Tributary	**Potential Limiting Factors**
North Fork	**Poor access, embededdness, pool depth, pool frequency, LWD, fine sediment**
Lee	**Pool depth, pool frequency**
Inman	**High temperature, limited pool depth, pool frequency, LWD, fine sediment**
Pardaloe	**High temperature, pool depth, pool frequency, instream complexity, fine sediment**
Rolling Brook	**Limited pool depth, pool frequency, fine sediment**
South Fork	**Access, pool depth, pool frequency, instream complexity, fine sediment**
BlueWaterhole	**High temperature, pool depth, pool frequency, fine sediment**
Fleming	**Access, pool depth, pool frequency, fine sediment**
Whitlow	**Pool depth, instream complexity**

Fine Sediment Targets: Current and target conditions for sediment were identified by the NCRWQCB as follows for the Garcia River TMDL (Mangelsdorf, 1998):

- For stream gravel percent fines <0.85 mm in Class I watercourses, the present condition was determined to be 20.6% (wet sieve) with the target set at 14%.
- The present conditions for fines <6.5 mm were estimated to be 45% and the numeric target was set at 30%.

These are useful targets for effectiveness monitoring. While the TMDL does not state whether targets were quantified for dry or wet sieved gravel, a review of the data used to develop the target clearly indicates that the target refers to wet sieve data. As stated previously, dry sieving methods are more accurate, but indicate a smaller proportion of fines than the same gravel sample sieved wet, which includes water weight. Wet sieving is more common because no time is required for drying the gravels.

Other Targets: The NCRWQCB refers to threshold sedimentation levels for several instream conditions, which may be useful in evaluating the sediment-related baseline or future conditions. Too little large woody debris indicates reduced habitat quality, but no threshold levels were quantified. While no numeric target was stated, instream summer water temperatures should not exceed the preferred range for anadromous fish growth: 12-14, 12-14, 10-13 degrees Celsius for chinook, coho, and steelhead, respectively (Mangelsdorf, 1997).

Parameter	**Habitat Impact**
Embeddedness > 25%	Spawning is limited
Sediments <0.85mm B diameter[3] >14% of riffle	Embryo development is limited
Sediments <6.5mm B diameter > 30% of riffle	Fry emergence is limited
Average pool depth < 4 feet	Rearing is limited
Average pool frequency < 40%	Rearing is limited
Average V* > 21%	Channel stability is limited
Average D_{50} particle size < 69 mm	Channel stability is limited

Statistical Considerations: Unbiased conclusions are most appropriately developed if acceptable rates of change toward targets are stated clearly and early in the process (definitely prior to any subsequent monitoring). If data analysis concludes that acceptable rates of change in the target directions are met, then the FPRs could be determined adequate at conserving fish habitat. However, natural fluctuation or variation could be mistaken for a trend toward or away from targets that have nothing to do with FPR effectiveness (Dr. Howard Stauffer, USFS Pacific Southwest Research Station, Arcata, CA, personal communication).

Complicating Factors:

(1) The desired numeric target conditions are not entirely known for the suite of parameters measured under the IMP (such as LWD).

(2) Schools of thought are divided as to whether healthy habitat form or healthy watershed function is needed by salmonids. The concept of dynamic equilibrium suggests that undesirable forms of habitat are part of the larger sequence of events that sustain salmonids over time across landscape mosaics and food-chain substitutions.

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[3] The B axis is the intermediate axis on a pebble, the A axis has the widest diameter.

(3) Meaningful points of knowledge about what makes habitat inaccessible or inhospitable include some items that do not have targets and were not considered as potentially limiting candidates, including:
   - road-related migration barriers
   - high and unnatural levels of predation
   - lack of off-channel habitat for refuge from high winter storm flows
   - duration and frequency of exposures to high water temperature and/or turbidity
   - cumulative watershed effects

(4) Some limiting factors are instream signals of unidentified disturbance upslope. Without implementing a hillslope monitoring component within the same watershed as the instream component, tracking the effects of FPRs from source to signal is not feasible. Some of the driving variables and biological links thought to be controlled by FPRs include:
   - road-related hydrological connections that deliver a high proportion of fines via gullying/landsliding/chronic surface erosion
   - depleting the riparian corridor, which increases water temperatures by solar exposure
   - harvesting trees in the riparian corridor or on the hillslope that would have been recruited to instream locations, generating accumulations of large woody debris and instream cover
   - destruction of off-channel habitat by utilizing heavy equipment in riparian zones

What is a Healthy Fishery?

An old-timer from Oregon once said that it doesn’t require an extensive monitoring program to determine whether a healthy salmon fishery exists. What is required is simply modest olfactory sensors in the nose because a healthy fishery smells of rotting fish carcasses in spawning season. On that basis along with a more technical fishery report (Maahs, 1999), it can be said that the Garcia coho fishery is not presently healthy, nor has it been for a number of years. However the steelhead fishery appears strong in the Garcia. There has not been a precise or quantitative description of a healthy fishery, however (SRP, 1999).

DISECTING THE PRIMARY OBJECTIVE AND CREATING HYPOTHESES

The objective statement can be used as a broad hypothesis that is divisible into smaller alternate hypothesis components for testing through direct experimentation, results of past experimentation, and by logical argument (Platt, 1964). Or, if the hypothesis were restated as “the FPRs work and allow fisheries recovery," then, the following decision table might be utilized (Dr. Fred Euphrat, Forest Soil and Water, Healdsburg, CA, personal communication).

Population of salmonids	FPRs are effective	FPRs are ineffective
Decrease	Unknowns in control of fish	FPRs may be at fault
Increase	FPRs allow watershed processes to support fish	FPRs irrelevant, unknown factor improves fishery

Smolts are Better than Spawners at Indicating Watershed Health

Spawning adult counts represent both watershed and ocean productivity. A better test of a watershed's ability to produce healthy fish would be survival from incubation to a 1+ smolt length of 18 cm for steelhead. Smolt fitness is a primary watershed-controlled limiting factor, in that a steelhead smolt smaller than 18 cm in length is less likely to return as an adult to spawn (Dr. William Trush, Humboldt State Univ., Arcata, CA, personal communication). Testing watershed conditions with respect to average smolt length requires an outmigrant trap measuring smolt length, or, perhaps, using scale samples from spawning adults to indicate how large smolts are at outmigration to the ocean. This metric provides a logical mechanism whereby the entirety of channel conditions is measured by smolt length. While this would not identify how FPRs impact channel conditions, it would address how well the watershed is producing fish. Without direct measures of fish production, we must assume that the combined elements of the GRIMP are a suitable proxy for evaluating fish conditions (Dr. Fred Euphrat, personal communication). This is a substantial assumption.

Ocean and Climatic Factors Beyond Control of the Forest Practice Rules

Certainly there is a major problem with either (or both) the freshwater or ocean conditions currently affecting salmon and steelhead. Coho salmon have not been found in the Garcia River basin for several years and have been decreasing in many California North Coast basins, as corroborated by the recent listings under the federal Endangered Species Act. Steelhead have also been recently listed in some basins, but appear stronger in the Garcia. There is evidence supporting the concept that ocean conditions, a large and mostly unknown influence, may be controlling distribution or limiting these fish in this portion of their range (Mantua et al., 1996; Francis, 1993; Beamish and Bouillion, 1993; Anderson, 1995). One hypothesis is that a cyclic division between the Alaska and California currents determines whether the northern or southern ranges of salmon are productive, but not both (Pearcy, 1992). Thus there remains a possibility that ocean conditions or some other factor is controlling anadromous fish populations over and above watershed conditions. If so, even ideal freshwater habitat conditions in each of the life stages might not bring the fish back to sustainable populations. However, when and if ocean currents reverse to favor the southern ranges (10-40 year cycles), then watershed processes and disturbance rates could become primary limiting factors (if they are not already).

CONCLUSIONS OF ANALYSIS FOR THE PRIMARY OBJECTIVE

It appears unlikely that instream experimental design will be able to test the effects of the FPRs from the channel unless target conditions are used, a useful but oversimplified notion with several assumptions. Instead, testing whether the FPRs are protecting the anadromous fishery should be linked to an upslope monitoring program to fairly and accurately determine what works and what does not. Without this upslope component, the connection between upslope activities and instream conditions remain unknown.

FACTORS COMPLICATING THE PRIMARY OBJECTIVE

While conceptually simple, the primary GRIMP objective requires understanding, distributing, and quantifying the effects of timber harvest practices on instream conditions that limit anadromous fishes. This leads to underlying difficulties that include: (1) upslope disturbances caused by timber harvest activities have not been traced, or linked, directly to habitat in the channel; (2) exactly what habitat features protect the anadromous cold-water fishery, and exactly what watershed processes maintain them is not entirely understood; (3) "legacy" era disturbances dominate current channel conditions in highly and moderately disturbed channels (Knopp, 1993); and (4) whether habitat conditions, watershed function, or ocean conditions are primary limiting factors has not been determined.

SECONDARY OBJECTIVES

A Data Set for Long Term Instream Monitoring

Baseline conditions should be reexamined for a variety of objectives. Data resulting from the instream monitoring program will be freely available to the public, public agencies, industrial timberland owners, etc. It will provide opportunities for comparative research with other streams in the region, and will allow further research for any imaginative researcher with interest in this area.

The Garcia River Conditions as a Regional Standard

The regional standard concept was introduced as a means to compare rivers in terms of their instream conditions (Dr. Fred Euphrat, personal communication). The conditions in the Garcia are not ideal and how these conditions could be used as a reference to other streams has not been identified.

Reducing Overall Sediment Loads through Adaptive Management

This objective requires an approach for implementation that has not been clearly identified. Perhaps the first step is to provide landowners with a list of items to address--that are meaningful and feasible (Dr. Fred Euphrat, personal communication). As a starting point, it is recommended that landowners inspect their roads during or just after substantial rainstorms to determine the adequacy of road drainage structures and the ability of stream crossings to provide for fish passage (Weaver and Hagans, 1994).

QUALITY ASSURANCE AND QUALITY CONTROL

INTRODUCTION

The Quality Assurance and Quality Control component of the project was included to ensure that data collection efforts were implemented as envisioned by the Instream Monitoring Plan (IMP). A secondary role was to encourage reevaluation of the ability of the experimental design to determine whether the IMP and its data will meet its objectives. A discussion of the practical limitations of the IMP is presented in the previous section entitled “Revisiting the GRIMP Objectives.”

DATA COLLECTION

Quality assurance recommendations set forth in the GRIMP by Euphrat et al. (1998) included a sampling framework in designated stream reaches and listed the desired qualifications of the staff implementing the sampling. The procedure employed by the MCRCD consisted of: (1) hiring qualified resource professionals to collect the data; (2) using explicit contract language to facilitate communication of mutual expectations regarding fees, protocol and task, level of precision required, and deliverable products; (3) hiring a Quality Assurance/Quality Control Hydrologist to insure IMP data would meet the needs of a long-term monitoring program; and (4) relying on the Garcia River Project Manager to manage each subcontract. For each of these roles, the MCRCD hired independent subcontractors having at least a masters level education and/or considerable experience.

The Quality Assurance Hydrologist’s duties included: coordinating activities with the MCRCD’s Garcia Project Manager, organizing a panel to select and refine recommended protocols, meeting with subcontractors to affirm field methods prior to data collection, and reviewing draft subcontractor reports. Identification and review of protocols and field methods prior to data collection was considered a priority. Intentions of the subcontractor were to be approved by the Project Manager and Quality Assurance Hydrologist prior to any data collection, but this was not always accomplished.

Subcontractors for each protocol were asked to attend two meetings prior to gathering data to establish consensus in: (1) selection and refinement of the parameter protocol, and (2) agreement on the proper field methods. Meetings were initially targeted to include consulting watershed specialists, but this was found to be problematic to schedule with available funding. Attendees included the subcontractor (often a specialist), neighboring landowners (industrial and non-industrial timberland owners), the Project Manager, and the Quality Assurance Hydrologist. Together, this group invested approximately half a day to identify and/or edit a proposed protocol, gain more complete understanding, and accept a unified protocol for implementing the parameter in question across ownerships. A smaller group invested a second half-day to work through field methods to be employed during data collection. This day also improved efficiency by introducing subcontractors to the location of the streams and their best access points.

The team approach to preliminary acceptance of protocols and field methods proved to be a wise quality assurance procedure. This preliminary review substantially reduced field costs over those expended to determine the status of contracted work, facilitated identifying and resolving gray areas before implementation began in the field, helped to maintain good relations with the subcontractors, and was more successful in conveying the intent behind each protocol task than the contract language. This was especially true where subcontractors had an interest in the monitoring effort that went beyond compensation, such as an applied interest in the data.

QUALITY REVIEW OF THE DATA

The Quality Assurance Hydrologist targeted a 25 percent sample of subcontractor work for quality control review, amounting to three of 12 survey reaches. The goal of this review was to observe whether or not subcontractor work met the terms of the contract and the goals of the IMP. An effort was made to identify the sample randomly to get a representative, unbiased view of contracted fieldwork to grade quality and identify problems.

Study Reach Establishment

Problems identifying reach and plot boundaries were anticipated, and contract language was developed to avoid a poor selection by requiring submittal of maps identifying each study reach and a timeline for work agreed to by the Project Manager before implementation. However, a full set of study reach maps was not received until after the contract term expired, which denied their utility for other subcontractors and left evaluation by the MCRCD or others out of the question. A considerable amount of the survey work was completed before the “preliminary site visit” was made with the subcontractor. The subcontractor did not wait for approval for monitoring sites and located them assuming approval.

Upon examining the first plots, issues were raised by the Quality Control Hydrologist to the Contract Manager that plots were too narrow to allow channel migration during the study and that bankfull widths were not estimated properly, which had impacts on the plot length criterion.

Longitudinal and Cross-Sectional Profiles

Determining bankfull width in the field is generally acknowledged as difficult on the North Coast, and fundamental differences of opinion existed. The survey subcontractor consistently identified much narrower bankfull channels than did the LWD subcontractor, with the Quality Control Hydrologist somewhere in between the two estimates. A San Francisco based regional estimate of bankfull width was applied from tables in Dunne and Leopold (1978) to further evaluate the estimates of bankfull width, both on the plots themselves and on the criterion of establishing reach lengths equivalent to 10 or 20 bankfull widths (see Table 3). This information indicated all of the survey subcontractor's estimates and most of those by the LWD subcontractor were too narrow. One result of a narrow cross-section was that in one tributary, original cross-sections intended to represent a width equal to three bankfull channels had endpoints that were wetted by a bankfull event. The site with the narrowest width was corrected, but the problem generally persists in most study sites. Thalweg and cross-sectional profiles did not fully satisfy sample design, generally accepted methods for long term channel monitoring, or the terms set forth in the contract in that:

(1) Multiple plots were individually shorter than recommended to satisfy statistical and hydrological assumptions (20 bankfull widths), but when summed, the overall reach length went beyond 20 bankfull widths. Because plots were not continuous nor connected, hydrological and statistical assumptions based on the 20-bankfull width sample were not met. A request to link the plots by a single measure of gross elevation change was not provided for most streams.

(2) The minimal cross-section widths may not accommodate flooding and/or channel migration.

(3) Soil benchmarks used to establish elevations recorded at rebar pins are likely to fluctuate, which means the benchmark elevations cannot be relied on to determine streambed aggradation/degradation, either in cross-section or thalweg profile.

(4) Truly permanent monuments, such that reach and plot relocation can be expected in five to 20 years, was generally not achieved (this was partially corrected by the MCRCD staff).

(5) Staff gauges were located at a distance from cross-sections, which precluded their use for gauging stream flows.

Secondary, less serious deficiencies included: (1) a lack of “closing the loop” on thalweg profiles negated the ability to provide an estimate of measurement errors, such that real geomorphic scour or aggradation is recognizable from that error (Madej, 1999; Harrelson et al., 1994; Scott McBain, McBain and Trush, Arcata, CA, personal communication); and (2) no installation of flagging at regular intervals, so that the same positions within the plot could be measured separately by each following parameter’s subcontractors. Negotiations with the subcontractor were initiated, but without additional payments, the subcontractor was unwilling make corrections.

As a result, the MCRCD Board of Directors withheld partial payment of invoiced work and used these funds to install more permanent monuments for elevational benchmarks outside flood-prone areas. These monuments are ½ inch rebar in 4-foot lengths driven into the soil and capped with yellow plastic. Distance, azimuth, and elevation to the first thalweg measurement were measured at most of these points. These are the minimum procedures recommended by Harrelson et al. (1994) that were referenced by Euphrat et al. (1998) and by Scott McBain (personal communication). The MCRCD’s follow up efforts were courtesy of EPA’s Garcia River restoration implementation program and will correct some elements of the cross-section and thalweg profiles and improve plot relocatability. However, without completely resurveying and linking all plots in terms of elevation and distance, some cross-section and thalweg profile data may be unusable in comparing initial surveys with later ones.

Canopy and Shading

Reports for five tributaries were completed in late summer 1998, but the remaining creeks were not measured until the return of the leaves in 1999. A single sampling season would have afforded a more uniform sampling condition at baseline measurement (which is usually an assumption of baseline measurements). In this case, we have assumed that no changes in independent variables affecting canopy and shading occurred between summer 1998 and summer 1999.

Water Temperature

Initial sampling began in August 1998, after most summer water temperatures had already peaked. All data loggers were redeployed in May through October 1999. Air temperature loggers were recommended by the subcontractor but were not implemented. The two-year data set may be useful in estimating general variability of non-peak water temperatures. Other than this utility, the 1998 effort may be insignificant in establishing baseline conditions and perhaps the late start should have deterred the investment.

Large Woody Debris

Various LWD protocols were examined and discussed in a pre-data collection meeting. The selected protocol borrowed from a combination of methods from the Fish, Farm and Forests Communities Forum Field Protocols Handbook[4], from previous Caspar Creek LWD studies (O'Connor and Ziemer, 1989; Surfleet and Ziemer, 1996), and from procedures utilized by Mendocino Redwood Company and Campbell Timberlands Management, Inc. (formerly Georgia-Pacific Corp.) industrial forestland managers. This survey also incorporated riparian stand classification elements from the Washington Department of Natural Resources' Watershed Analysis Riparian Function Module (WDNR, 1995), along with the California Department of Fish and Game's Wildlife Habitat Relationships (WHR) vegetation classification system. The data and report includes an inventory of the existing LWD over 10 cm in diameter and 2 meters in length, and a recruitment estimate based on the density of "fresh wood" presumed to have had 0-3 years residence time in the channel.

The subcontractor for this work also recommended that if the LWD data is analyzed in terms of volume per unit area, the unequal area of sample plots will require a statistical data transformation using a ratio estimator (O'Connor, 2000). LWD is traditionally expressed as volume per unit area of stream channel or by weight per length of stream channel. The bankfull width identified and utilized by the LWD subcontractor was consistently and considerably wider than that estimated by the subcontractor who established the cross-section measurements, illustrating the degree of variability of this measurement and its dependence on the individual's methodology for determining bankfull stage (Table 3).

Spawning Surveys

Spawning surveys were conducted from the first week in December 1998 through the fourth week in March 1999 in tributaries and some portions of the mainstem Garcia River. No coho redds, live coho, or coho carcasses were observed during the survey. However, the literature indicates that adult coho spawn in late fall and early winter in their southern zone and coho salmon were identified in Mendocino County tributaries in November 1998 (Jerry Wall, Salmon Restoration Association, Fort Bragg, CA, and Charlotte Morrison-Ambrose, NMFS, Santa Rosa, CA, personal communication). This raises the possibility of coho activity in the Garcia in November, prior to the onset of the survey.

No redds of any kind were found during the first week in December, suggesting that either there was no coho activity prior to December, that redds built by coho before the survey were washed out prior to the first week in December, or that coho tributaries were not sampled. In any case, future surveys should begin in early fall so that no potential coho activity is overlooked.

Gravel Quality in Bulk Samples and Permeability

Initially, all gravel measurements were to be made in abandoned salmonid redds because redd construction is known to alter the composition of fines in spawning substrate. McNeil bulk gravel composition results are notoriously variable, indicating the GRIMP would benefit from as many bulk samples as possible to accurately represent the mean proportions and variability of gravel size classes. The subcontractor for these measurements worked with the Project Manager and Quality Assurance Hydrologist to estimate the most efficient sample size that accurately represented the sample population within the available budget. This evaluation showed that when the constraint of sampling abandoned redds was included, an insufficient number of sample sites were generated. Instead of mixing spawned gravel sites with non-spawned gravel sites, a decision was made to exclude spawned sites from the primary data set to limit expected variation.

Permeability samples were to be taken at any known redd site located in the study, but this element was not implemented due to time constraints, despite the fact that gravel sampling took place well after salmonid emergence, and in most tributaries, spawning sites were still evident by streambed features and flagging left by spawning survey crews. These omissions took place even though it was discussed in pre-data-collection meetings, and the Quality Assurance Hydrologist was present during much of the data collection.

Analysis of bulk gravel data from the Garcia River tributaries indicated lower percent intergravel fines than was expected from a river basin impaired by excessive fine sediments. This is due to differences resulting between processing dry-sieved samples and wet sieved samples. Dry-sieved GRIMP baseline gravel results cannot be directly compared with wet-sieved results produced from previous studies, due mostly to water weight gained with wet sieving.

Measurement variability is best controlled by sieving dried gravels to remove the mass attributable to water, without requiring correction. The literature suggests using air or oven drying in a laboratory, sorting into size classes by passing the sample through a series of sieves, and weighing

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[4] See the Fish, Farm and Forests Communities Forum web page at www.humboldt.edu/~fffc.

each size class's collection. The subcontractor's budget (and that of the entire GRIMP) precluded transporting gravel samples to a laboratory, but considerable effort was made to ensure that all samples were air-dried by spreading the samples uniformly on separate tarps and turning them such that all sides were exposed to the sun, heat, and air. Samples prepared in this manner appeared dry, and no particles adhered to one another upon sieving. Once dry, the entire sample was weighed and its weight entered on a field form for that sample. This was followed by sieving and weighing of each size class. A final sum of weights by size class was compared to the initial sample weight to test for gross gain or loss in mass. The argument remains, however, that some water weight may have remained in the "dry" samples. If so, the intergravel percent fines reported would reflect both fines and water, such that the true and unknown net fraction of fines alone would reflect an even lower percent than those reported.

Turbidity Sampling

Turbidity was not formally adopted into priority parameters intended to be included in the GRIMP. Nonetheless, its value as an immediate response variable was recognized. A preliminary attempt at turbidity measurement was made by MCRCD staff and members of the spawning survey crew during winter 1998-99, with the loan of a turbidometer from the Mendocino County Water Agency. Problems that unfolded included: (1) staff gauges were not always located at cross-sections, resulting in limited gauge height data to relate to water samples, and (2) as winter progressed and high flows were encountered, five staff gauges washed out or were so damaged that gauge heights could not be determined. On one tributary, the staff gauge was too short and was overtopped in high flows, while on another, the staff plate was not installed until February. Even with these problems, the resulting turbidity and flow data was informative. But a quantitative investigation requires sampling in high flow conditions where a discharge rating curve is maintained. A greater commitment in effort would be required to deliver a successful turbidity monitoring program, yet it is perhaps the signal most appropriate to the needs of this study.

Sediment Transport Corridors

The STC survey was the only parameter utilized in the GRIMP capable of linking cause and effect. This parameter and protocol were introduced by Forest Soil and Water (Euphrat et al., 1998). The only previous reports or reviews of the procedure known to have occurred are in the personal experiences of Dr. Euphrat and Dr. O'Connor. Difficulties quantifying STCs and repeating this survey were expected.

Quantifying STC length, width, and depth from the field observations is needed to obtain volume estimates for eroded material. Accuracy within an order of magnitude is likely from the existing data, but finer precision will not be available until more accurate field measurements can be made. This may be achieved by having a team of two in the field, rather than one, and by more carefully accounting for width and depth variations in individual STCs.

Sediment delivered to a fish-bearing channel is one of the most obvious impacts on the stream. When roads alter topographic and subsurface drainage patterns, fresh scars can appear on the landscape that are recognizable as STCs – usually gullies and landslides. Although not included in the STC protocol, the STC analysis could have included density of gullies, landslides, bank failures, and tributaries, perhaps stratified by road density in the plot or sub-watershed.

Repeatability of this survey may not be a problem, even if individual STCs are not relocated. The protocol is similar in nature to the LWD survey, where the particular pieces of wood may not be relocated due to washing out or burial by sediment, but an increase or decrease in wood per mile, or a change in rate is discernable. In contrast, relocatability suggests that a future person or team repeats the survey from plot 1 through plot 4, attempting to locate those STCs found initially to determine whether they are visible and whether their length, width, and depth has increased or decreased. STCs may not be relocated due to healing and revegetating or lack of experience in the surveyor. There was a definite trend towards identifying more STCs with experience.

STC density and rate of development may be more informative than precise estimates of the volume of sediment they deliver. If so, it would be more useful to determine whether the density of STCs increases with time than an effort to relocate each STC identified in 1999.

Pebble counts

In response to public comments during the review of the draft GRIMP, pebble counts were added to the list of parameters to be monitored, and this sampling work was conducted during spawning gravel quality sampling. However, this data has not been analyzed and was submitted as raw data only because the analysis was not specifically included in the original scope-of-work.

CONCLUSIONS FROM QUALITY ASSURANCE METHODS

Recovery from unacceptable methods is not always possible, and the GRIMP experience suggests that it is far more productive, efficient, and realistic to work out problems before they are implemented rather than attempting to solve them later. Pre-data collection investments in Quality Assurance were highly effective at solving problems before surveyors began field work and presumably saved money. Consensus building at each stage reduced probabilities of future contesting of data, fostered support and goodwill among diverse landowners, and maintained good relations with subcontractors. Most importantly, many issues were resolved before they became problems. Critical personnel should attend a scooping meeting to review experimental design and meet to compare and contrast protocol options. Attendees should include representatives from the sponsoring organization, contracting organization, and subcontractors. In the field, a separate meeting should include these same individuals as well as field people collecting the data. Consensus building between those involved increased understanding of expectations such that fewer surprises resulted, thereby avoiding potential problems both for protocol development (office setting) and protocol implementation (field setting). In the one problematic contract, no such preliminary meeting took place.

Contractual Methods

A signed written contract can clarify mutual expectations of tasks, deliverable products, and compensation. It is the main source of documentation and leverage for resolving disputes. If contract language is carefully articulated to clearly convey deliverables, and if the contract is revisited to ensure its applicability throughout its life, then problems can be taken care of through arbitration, mediation, or in court. This does not necessarily assist in fixing poor quality data. The 10% withholding provision is useful when additional expenses are required for corrective work. The primary problem encountered in implementing the GRIMP was failure by subcontractors to carry out some portion of the scope-of-work specified in contract, although in some cases, the task descriptions were not as clear as they should have been. Once the work was completed, subcontractors were unwilling to go back and collect missing data or refine their work. Problems with property access and starting GRIMP implementation later than expected exacerbated this situation by forcing decisions to allow subcontractors to use short-cuts to keep progress at a reasonable pace.

Field Methods

When conflicts arise, they should be worked out in the field as soon as possible to the satisfaction of the Quality Assurance person. Utilizing the Quality Assurance person as a field technician can also conserve resources for both the subcontractor and contracting organization. However, it may be unrealistic to expect this person to fully project himself/herself into both roles unless sufficient field time is allocated to successfully undertake both tasks.

Resolving Problematic Issues - Whose Role?

Contracts are typically negotiated and administered by the Project Manager. This person takes the lead when dealing with the subcontractor over tasks described in the contract. When the Quality Assurance role is assigned to a different individual, the responsibility for resolving problems resides somewhere in between. If direct negotiation between the Quality Assurance Hydrologist and the subcontractor is inappropriate, some mechanism must be included to illuminate and solve problems so that the investment in identifying problems is not wasted. If issues are raised but not addressed, funds spent to ensure quality are wasted in the mildest case. In the worst case, the integrity of the program is at risk. Whether the QA/QC representative is empowered to remedy problems or not, he/she should document all problems in writing when they are first identified and, if necessary, forward them up to all rungs in the ladder empowered to negotiate the contract. If verbal communications fail, the written document stating the problem provides a record of when the problem was brought to the subcontractor’s attention and the measures proposed for resolution.

COSTS IN DEVELOPMENT AND IMPLEMENTATION

BUDGETED AND ACTUAL EXPENSES

The dollar amount of the contract between CDF and the MCRCD for developing and implementing the Garcia River Instream Monitoring Project totaled $173,880. The budgeted expenses and actual costs are detailed in Table 16. Upon completion, the project was over budget in Establishing Plots and Surveying Profiles, Quality Assurance/Quality Control, and Project Management. The approximate dollar amount extended to this project from other sources is $9000.00, funded mostly through EPA's 319H Garcia River restoration implementation project.

Table 16. Estimated and Actual Expenses for IMP Development and Implementation.

Task	Budgeted Expense ($)	Actual Expense ($)
Develop Instream Monitoring Plan	33779	33733
Establish Plots and Survey Profiles	20453	21420
Water Temperature	7174	7174
Riparian Canopy	2808	2808
Large Woody Debris	15075	15075
Spawning Survey	9998	10000
Sediment Transport Corridor	3500	3500
Gravel Quality	36678	36687
Quality Assurance and Control*	5829	9315
Project Management**	15905	11788
Overhead	22680	19988
Equipment		2393
TOTAL	173879	173881
* included some aspects of project management		
** approximate over-budget expense not paid by CDF		9000

BEST PARAMETER PERFORMANCE

Riparian Canopy and Water Temperature

Riparian canopy and water temperature were the most cost-effective measurement parameters. Water temperature is dependent on canopy in smaller streams and is a biological link that shows the importance of canopy closure/shading in cooling stream waters. As baseline parameters, both are simply quantified and understood, and for utility in fisheries assessment, canopy closure and maximum temperature are useful data metrics. The models developed by Hines and Ambrose (2000) successfully predicted coho absence from elevated stream temperatures according to duration and magnitude of exposure in cool water refugia. Therefore, canopy and temperature are biologically significant parameters that can be affected by forest practices along the WLPZ (watercourse and lake protection zone). Harvesting the riparian canopy reduces stream shading, potentially elevating stream water temperatures and increasing duration of elevated stream water temperatures, which can be used to predict the absence of one threatened anadromous fish species within its range.

Sediment Transport Corridors

Sediment transport corridors identified links between road disturbances and hillslope erosion. Surveys of second and third order tributaries revealed that fine sediment eroded from upslope locations was usually either flushed from the tributary and transported to the mainstem, or was mixed into the bedload substrate so that its presence was not observed. Quantitative measurements used to obtain baseline data and subsequent monitoring could be improved. Most critical and recurring STCs were road crossing diversions, ditch relief drainage structures, waterbar outlets, and roadway diversions.

Large Woody Debris Recruitment Rate

The species and recruitment rate of wood entering the system was a sub-element of this parameter, but may be the most important parameter linking watershed process to ideal habitat form features that can be directly controlled by the FPRs. That is, because we believe juvenile and perhaps adult salmonids rely on the cover and pool features created by LWD, it is important to know if we are building our in-channel wood or causing depletion. Determining only fresh recruitment species and rate would substantially reduce costs by quantifying only freshly down wood by species and volume. However this would omit pre-existing LWD in relation to the habitat present.

Gravel Quality and Permeability

Gravel measurements and analysis were the most costly elements of the GRIMP. Bulk gravel samples are notoriously costly to measure and require many samples because of variability, so this was not surprising. However, the gravel permeability protocol that directly measures the rate at which water passes through spawning gravel took much less time and was relatively inexpensive. Permeability measurement has a potential to replace the more laborious McNeil technique that requires removing one cubic foot of gravel and then determining its particle-size distribution. The link between stream biology and particle size is the clogging of gravels by fines that prevents the flow of water through the gravel. Permeability is a more direct measurement of these phenomena. However, its utility awaits further testing to determine criteria for predicting survival-to-emergence, a concept that has already been quantified for percent fines. Sampling permeability alone is an emerging goal if survival-to-emergence can be predicted directly by permeability.

Channel Morphology via Longitudinal Thalweg and Cross-sectional Profiles

The longitudinal thalweg profile is best used to investigate trends of channel aggradation, downcutting, and pool filling. Cross-sections are useful for identifying the relationship between the bed, banks, and floodplains. It is difficult to determine the cost-effectiveness of these factors individually because they were budgeted and invoiced together. Costs could be reduced without sacrificing data integrity by measuring one or two cross-sections per plot. Longitudinal profiles are classic elements of a stream survey and can be used to produce a great deal of graphical information about bed elevations and channel complexity (i.e., more “bumps” mean more complexity and more diverse habitat).

PREPARING A COST EFFECTIVE, REALISTIC MONITORING PROJECT

All parameters could have been implemented at less cost if a staff of employees were trained by specialists and then conducted measurements for $15-$20 per hour. Instead, highly skilled resource professionals were generally compensated between $20 and $40 per hour for this work. Using lower cost technicians would have allowed measurements of additional parameters such as V* or a committed turbidity measurement effort. Tradeoffs in quality of data are anticipated but not known.

Project Management requires a larger budget than was allotted, by about 25%. Perhaps a reduction in overhead budget could reasonably be reapportioned to project management. Participating in collaborative, pre-protocol meetings with project managers, landowners, technical peers, and other concerned parties prevented problems as opposed to attempting time consuming and less effective resolutions, thereby reducing project management time. Reexamination of project objectives in light of the plan and parameters cannot happen too often.

FUTURE MONITORING AND STUDY MAINTENANCE

FUTURE MONITORING

Monitor Hillslope Conditions in Hydrologic Units Sampled Under the GRIMP

To adequately answer the primary objective of the GRIMP, hillslope and instream conditions should be monitored in the same hydrologic unit. Moreover, disturbances identified in the hillslope component should be traced to the channel where any physical changes to the receiving channel could be reported. When a change in the physical condition is related to salmonid requirements, then a biological link connects the source with the signal and the problem. Without these links, possible conclusions regarding FPR effectiveness over time cannot reveal where the problems lie.

Because instream baseline conditions have been established, a hillslope component can now be applied to the Garcia River in subwatersheds where aquatic conditions were monitored under the GRIMP. The BOF's hillslope monitoring procedures have been well developed, tried, and tested, so that its protocols are well defined. Hillslope monitoring should be conducted in the hydrologic units of the GRIMP as soon as possible to establish hillslope baseline conditions, and then remeasured following THP operations in each of the hydrologic basins. In particular, hillslope monitoring for FPR effectiveness should be conducted following significant stressing storm events.

Link Harvest Related Disturbances to Measured Instream Conditions

Causal mechanisms thought to begin with timber harvest-related activities (such as road construction) go through a series of linkages before affecting fish-related beneficial uses in the channel (such as accumulation of fines in spawning gravel, reduction in fry feeding due to chronic turbidity, filling of pools, and reducing available off-channel habitat by roading a flood plain). The GRIMP has established baseline conditions for some fish habitat indicators, but did not consistently establish their links to causal mechanisms due to a lack of explicit recommended methodologies, and a separation of instream from upslope monitoring. However, the potential still exists to determine these links to instream parameters if the project is expanded to include monitoring of upslope activities in the monitored subbasins and tracking process mechanisms to the receiving channel downstream. The GRIMP has identified several streams that would serve as ideal locations to conduct simultaneous hillslope and instream monitoring.

The objectives of future monitoring could include:

1. Determine long-term trends in the measured habitat parameters.
2. Link beneficial fish uses with channel conditions, and channel conditions with upslope disturbances, and upslope disturbances with forest practices, and forest practices with FPRs.
3. Quantify the range of ecologically acceptable watershed disturbances.
4. Determine whether the application of FPRs effectively limits watershed disturbances to the level established in (3).

Plan for Use of Target Conditions and Measure Parameters by Same Methods and Units

The Garcia River can now be used as a baseline data set for testing FPRs, as the measured habitat conditions are reevaluated in the future. Continued monitoring of instream parameters without upslope monitoring will test instream conditions against target conditions identified as beneficial for the fishery. Some such targets were identified by the NCRWQCB in its TMDL process (U.S. EPA, 1998), as well as NMFS and Pacfish (reported in Reid and Furniss, 1998). If this is the desired plan for analysis, then all future monitoring should measure conditions in the same units as they are expressed in the targets. Whether a few or the entirety of parameters measured are selected in answering the monitoring question, a directional trend toward fish-friendly targets and acceptable rates of improvement for each parameter should be determined before another round of data is collected. Identifying the acceptable direction and rates of trends ahead of time will enable unbiased conclusions to be drawn (Dr. Howard Stauffer, personal communication).

STUDY MAINTENANCE

In visiting stream reaches and plots over the last two years, it became clear that more than one marker is needed for each plot and that, while flagging is the most visible marker, it is quite temporary in nature. Flags and driven rebar were the contracted methods for establishing reaches and plots boundaries. We suggest that all reaches and plots be revisited in the very near future to apply “flashers” or aluminum tree tag markers at each end of the reach and in plot boundaries. Cement monuments with an inset steel carriage bolt are also desirable to facilitate relocation by a magnetic detector (Scott McBain, personal communication; Harrelson et al., 1994).

It would be advisable to examine study reaches one to two years after establishment to insure markers can be relocated based on study reach maps and written descriptions. Someone other than the person who originally installed the study reach should conduct this task to insure accuracy and utility in maps and descriptions. The ability to relocate study reaches, plot boundaries, and benchmarks is essential if all or some of the IMP parameters are to be revisited. The objective of this task would be to either confirm that plot boundaries can be identified, or to remedy situations onsite so that plots and study reaches can be relocated in perpetuity or at least in the next round of monitoring.

Remeasuring Schedule to Encapsulate Change in Watershed Conditions

For LWD and channel morphology, conditions are unlikely to change in a significant manner until a 30-year to 100-year storm is experienced (Euphrat et al., 1998). Other parameters change more quickly. The GRIMP recommends a remeasuring schedule based on a time-scale that reflects the expected rate of change for each parameter. A conceptual framework for developing a re-monitoring schedule is presented in Table 17, based on a table which was included in the Instream Monitoring Plan (Euphrat et al., 1998). It is suggested that parameters such as LWD loading, channel cross-sections, and thalweg profiles be remeasured following geomorphically significant flood events, while other parameters such as water temperature, fish surveys, and turbidity be remeasured seasonally and/or annually. A precise remeasurement schedule remains to be developed for the Garcia River watershed.

Table 17. Time scale of watershed response: potential remeasurment schedule (after Table 5-3, Euphrat et al., 1998).

Condition Measured	Seasonal Response	Annual Response	Management Response	Geomorphic Event Response (>30 yr)
Turbidity	x	x	x	
Temperature	x	x	x	
Gravel composition		x	x	
Gravel permeability		x	x	
Cross-section profiles			x	x
Longitudinal thalweg profiles			x	x
Riparian canopy	x	x	x	
Large woody debris			x	x
Sediment transport corridors	x	x	x	x
Fish surveys	x	x	x	

CONCLUSIONS[5]

A COMPREHENSIVE BASELINE OF INSTREAM CHANNEL CONDITIONS WAS ESTABLISHED

The baseline conditions identified by this monitoring program describe many features of Garcia River tributaries, including: water temperature, riparian canopy and shading, pool depth and frequency, spawning gravel composition and permeability, LWD loading, spawning adults, and sediment transport corridors. Although coho salmon appear to be virtually gone from the basin, the steelhead population in the Garcia watershed appears to be strong relative to other streams in Mendocino County (Maahs, 1999). Large woody debris is entering these systems at a relatively rapid rate, although it is composed of multi-species and is of smaller dimensions than the longer lasting old-growth redwood seen in persistent pools in the South Fork of the Garcia, Mill Creek, and other tributaries (O'Connor, 1999).

Water temperatures in the coastal tributaries were adequately cool so that coho presence is predicted based on temperature alone. Riparian canopy was well-correlated to water temperatures, corroborating the concept that a decrease in canopy increases water temperatures. The correlation between canopy and water temperature in the Garcia River basin is credited to Project Manager Michael Maahs, who had just plotted the data on the last day prior to his untimely death in March 2000.

Permeability monitoring was tested to describe spawnable substrate. This method may replace the more costly and more variable bulk sampling done throughout the region if a reliable relationship between permeability and salmonid egg survival to emergence can be developed (McBain and Trush, 2000). Currently, permeability can be considered an index of gravel quality. Another new protocol, the STC (sediment transport corridor), was tested in this program. This procedure tracks hillslope disturbances from their source and identifies some consequences in the stream. The STC procedure was the only sediment-related parameter that linked management-related sources to a channel signal. STC identified problems linked to forest practices were mostly road-related diversion gullies and landslides (Barber, 1999).

The author summarized the baseline data collected during the Instream Monitoring Project for Board of Forestry and Fire Protection's Monitoring Study Group (MSG) in June 2000. The presentation brought excellent reviews and commendations by the diverse group. It appears that the public, industrial timberland owners, and the resource agencies see long-term value in this project, where there was an intensive baseline collection of instream conditions within multiple tributaries of a single river basin. This is further reflected in the dollars contributed by EPA for this purpose. As a result, the MSG made a firm recommendation to CDF to explore avenues to: 1) follow through on future monitoring to identify trends, even if upslope linkages are not identified; 2) provide funding for this future monitoring, 3) act on recommendations to revisit the plot boundaries in the field and increase the permanency of markers to ensure that plot boundaries may be relocated, and 4) determine hillslope linkages.

HILLSLOPE CONDITIONS WERE NOT INVESTIGATED

Hillslope conditions and forest practices were not evaluated as to their effects on channel condition. Instream conditions reflect responses to watershed processes working on landscapes created in both the present and the past, and they reflect both natural and management related disturbances. Separating the effects of the Forest Practice Rules from past and present, and from hillslope to channel in the watershed mosaic requires focusing on how timber harvest effects are routed to the channel and how they effect the fish. Therefore by omitting a hillslope investigation tied directly to the channels monitored, the present GRIMP is unable determine the effects of timber harvest practices on instream conditions.

Except for the Sediment Transport Corridor Component, the GRIMP did not establish linkages from channel conditions monitored to activities on hillslopes where forest practices most often occur. Therefore this report recommends an additional investment in Garcia River watershed hillslope monitoring to determine the nature and extent to which upslope disturbances are connected to the channel and to relate in-channel effects to needs of the fish.

Without the hillslope link, monitoring instream trends, particularly toward or away from "target channel conditions," will be the practical approach to experimental design used to determine whether the Forest Practice Rules are effective at conserving the coldwater fishery in the Garcia. This requires assumptions in that: (1) instream conditions are controlled by FPRs--but this assumption is refuted by Knopp's (1993) work; (2) target channel conditions represent those

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[5] Please also see the following section, Recommendations, for a concise list of conclusions.

desired by salmonid fishes; and (3) watershed processes control fish productivity--but this assumption ignores the significance of ocean conditions during most of the fish's life, from smolt to adult.

Monitoring fish themselves is problematic because they respond to channel and watershed conditions as well as ocean conditions, predation, disease, etc. Yet, if we do not monitor the fish we lose the most important indicator of fish health, the fish! We must admit that we are not conscious of everything that affects salmonids (Reid and Furniss, 1998). Food web dynamics involved with instream temperature and turbidity may play a greater role than previously credited (Sommarstrom, 1997; SRP, 1999). Finally, Knopp (1993) concluded that legacy disturbances continue to dictate channel conditions of today in moderate or highly disturbed watersheds, which suggests that the current FPRs cannot control instream channel conditions (particularly in regard to coarse sediment and LWD loading). If so, then restoration from legacy conditions, improvements in grazing and agricultural practices, etc., will be required before stream channel conditions in the Garcia can be controlled by application of Forest Practice Rules. Some such work has been undertaken.

SURVEY PLOTS AND STREAM REACHS ARE SMALLER THAN PLANNED

Unfortunately, the plot boundaries were set by the first subcontractor, without input from MCRCD or its staff, or anyone else. While avenues to keep this from happening were incorporated into the contract language, the deficiencies brought forward by the Quality Control Hydrologist were ignored by the sub-contractor and the project manager. So, narrow plot boundaries persist which are not permanently benchmarked. Disconnected plots with several hundred feet between plots remain without measurements describing the elevation gained between the upper end of one plot and the lower end of the next. This may impart a statistical problem, in that the samples (plot lengths) may be too small to yield sound conclusions.

Therefore, recommendations include extending plot widths to valley walls, initiating plot and reach reconnaissance to more permanently mark each plot and reach, and an investigation into whether the plot layout is hydrologically and statistically valid. Further, it is recommended that future studies either empower the quality control person to negotiate with the surveyors to ensure the work meets the goal, or to merge the quality control position with contract manager.

Since the tributary codes have been released, each tributary has a baseline collection of its own to allow independent monitoring in the future. Further, THPs from the past and present can be utilized to interpret findings in the channel, and linkages between hillslope conditions and the channel can be made by any individual with legal access to the land.

RECOMMENDATIONS

(1) The goals, objectives, and baseline data of the GRIMP should be reviewed by a multi-disciplinary review team that includes a statistician, hydrologist/geomorphologist, fisheries biologist, and a forester.

(2) A list of pertinent literature that identifies previous work in FPR effectiveness monitoring should be developed for use with future projects. This should include reports documenting preliminary investigations evaluating FPR effectiveness monitoring.

(3) Monitoring of instream conditions should be linked to hillslope monitoring within the same sub-watershed to identify and establish critical linkage mechanisms between upslope activities and channel response.

(4) Future monitoring should include habitat measurements for each numeric target, with field methods equivalent to those recommended by the numeric target providers. Measurement units should be duplicated by the monitoring parameter so that comparisons are as straight forward as possible.

(5) Landowner access requirements should be finalized before project implementation begins.

(6) If data privacy constraints prevent achieving an objective, either the objective should be revised or the privacy constraint must be lifted.

(7) No objective should be planned without also creating a procedure for implementation.

(8) The reasons for not implementing recommendations from a preliminary investigation should be explained.

(9) A position or committee should be established to regularly check progress toward achieving objectives.

(10) Continue spawning surveys annually.

(11) Follow Table 16 for remeasuring channel conditions.

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