BOARD OF FORESTRY PILOT MONITORING PROGRAM: IN-STREAM COMPONENT

FINAL REPORT

Contract #8CA28103

VOLUME I

PROJECT PLANNING, IMPLEMENTATION, AND RESULTS

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EXECUTIVE SUMMARY

The in-stream monitoring component of the Board of Forestry (BOF) pilot monitoring program was a field test of some in-stream monitoring techniques. Other techniques might also be used in such a scheme but were not tested here. This pilot tested the feasibility of in-stream monitoring in remote areas, including problems of crew training and consistency, the ability to collect usable data given the variability of the medium sampled and the ability of the monitoring technique to detect a signal. Another component of the BOF monitoring program was a pilot demonstration of hillslope monitoring which was conducted in the same watersheds in locations close to the in-stream study reaches. That project is described in a separate publication (Tuttle, 1995). An additional goal was to improve the mechanism for implementing cooperative private-public field studies on private timberlands.

This project was limited to an evaluation of selected field assessment tools. It did not include a watershed analysis necessary to determine which monitoring techniques were the most appropriate or the level of effort needed to develop useful results for a real monitoring situation. Also, we were not asked to determine the resources at risk nor the root cause of the risk. For the reader, an example of a watershed analysis protocol which determines possible impacts to anadromous fisheries is titled "Coho Salmon Habitat Impacts: Qualitative Assessment Techniques for Registered Professional Foresters," and is available from the Department of Fish and Game, Environmental Services Division, Sacramento, California. In practical applications, a watershed analysis would be conducted to determine the techniques to be used and the location of the appropriate study reaches. The project designer or reviewer must decide whether or not a monitoring effort is necessary by: 1) identifying the problems within a watershed, 2) identifying relevant monitoring tools, and 3) determining which type of monitoring is appropriate (e.g., trend, baseline, implementation, effectiveness, project, validation, or compliance) (MacDonald et al, 1991; California Department of Fish and Game, 1994).

Techniques tested in the pilot included methods for evaluating fisheries habitat, sediment transport and deposition, stream temperature, shade canopy, macro-invertebrate composition, and stream channel reconnaissance. These protocols were chosen as among the most likely to detect changes in conditions that influence the quality of anadromous fish habitat.

The completion of this project represents the culmination of a cooperative effort between private landowners and agencies. Early stages of the project included significant efforts to reach consensus on study sites (selection and access) and site information. By the end of the second field season, landowner representatives and project field personnel were quickly addressing and resolving data collection and interpretation problems. A high degree of cooperation was achieved.

The most useful results of this effort indicate that:

1. A pre-project objective is necessary to focus efforts and interpret results.

2. Crews with limited natural resource background can be trained to deliver results, but some precautions must be taken.

3. Protocols have to be carefully chosen for the situation to be monitored; e.g., sediment and macro-invertebrate measurements are not useful data when collected in transport reaches or on armored channel beds, and temperature must be measured in areas critical to life history needs. Monitoring a combination of hillslope and in-stream parameters may provide a better understanding of resources at risk (including domestic water supplies) rather than relying on only one parameter.

4. Data acquisition costs are inversely proportional to the training and supervision of the study participants; e.g. inadequate training and supervision results in inconsistent implementation of field techniques, increased error rates in data entry, additional site visits for re-sampling, and increased efforts in preparing data files for analysis.

5. Training must prepare the survey crew for the range of conditions to be encountered in the study.

6. Error and range checking procedures for data entry and information analysis must be clearly identified and pertinent to the data anticipated in the study.

7. Macro-invertebrate sampling can be conducted quickly and consistently, and will provide meaningful biological results if pre-project objectives have been established. It appears to be an effective technique for assessing in-stream biological health.

8. Information analysis should be conducted with well documented and easy to use application software packages. Any custom or proprietary software should have data entry screens, error and range checking, and easily exported output files.

9. Selected monitoring parameters and protocols should be implemented in additional study reaches to further determine their limitations, ranges of acceptable values, and refinements.

10. Additional monitoring procedures and protocols should be selected and field tested to determine their utility in assessing watershed conditions on private timberlands.

11. Cooperative private-public field studies can be effectively conducted on private timberlands.

There is no "cook-book" for in-stream monitoring. The exercise of judgement is necessary in gathering information and generating meaningful results.

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PROJECT PLANNING, IMPLEMENTATION, AND RESULTS

I. Introduction

The Board of Forestry (BOF) established a Monitoring Study Group (MSG) to develop and facilitate implementation of a long-term program for monitoring the effects of timber operations as conducted pursuant to the BOF's Forest Practice Rules on the quality and beneficial uses of waters.

MSG determined that a two-year Pilot Monitoring Program (PMP) should be conducted prior to final design of the long-term program. The scope and objectives of the pilot monitoring program are identified in a report entitled, "Assessing the Effectiveness of California's Forest Practice Rules in Protecting Water Quality" (California State Board of Forestry, 1993). MSG determined that coldwater fisheries and domestic water supplies are the beneficial uses of water most sensitive to changes in stream conditions due to timber operations. The PMP included two parts: hillslope monitoring and in-stream monitoring. The goal of the PMP was to test and develop methods that can be used in a lont-term monitoring program. The hillslope component report was submitted by Tuttle (1995). An associated study dealt with geologic considerations for hillslope monitoring (Spittler, 1995). This paper reports on the in-stream component.

MSG also decided that the monitoring sites should be located within or adjacent to approved timber operations to facilitate legal access. The selected sites should also be clustered within selected watersheds to facilitate physical access and minimize travel time. Finally, the sites should be located within different parts of the State (western Sierra Nevada, Klamath Mountains, and north Coast Ranges) to provide opportunities to see differences in the various timber producing areas with their different environmental characteristics.

After considering a wide variety of monitoring parameters and techniques, MSG approved testing of several in-stream and nearstream parameters and techniques for evaluating current stream condition and long-term trends (residual pool volume or V^{STAR}, sediment transport and deposition, temperature, and macro-invertebrates). These parameters and techniques were selected because they appear to be:

- sensitive to effects of timber operations on the condition of domestic water supplies and coldwater fisheries,
- feasible for State agency personnel, professional foresters, and members of the public to utilize without excessive training and equipment,
- capable of providing reliable and reproducible data for land managers and agency decision makers, and
- representative of the condition of coldwater fisheries and domestic water supplies.

The California Department of Forestry and Fire Protection contracted with the Department of Fish and Game (Department) to conduct the instream component of the PMP. During the project, the Department tested and refined these parameters and techniques.

Selection of target watersheds and preliminary office screening of candidate timber harvesting plans (THPs) was coordinated through the Department and the California Department of Forestry and Fire Protection (CDF). THPs without an adequate number of acceptable sampling sites were deemed unsuitable for instream monitoring and screened from further consideration as a part of this project, in cooperation with other MSG members. The Department participated in field visits to make adjustments to the list of candidate sites, and, criteria and procedures were developed to select and relocate sampling sites.

Monitoring parameters (habitat types, sediment, and temperature) were selected by the MSG. The assessment techniques were selected based upon recommendations by a technical advisory team composed of Department technical specialists (James Harrington, Stephen Rae, Bill Snider, and Kris Vyverberg). Initial recommendations received a limited peer review that resulted in the deletion of one assessment technique (use of in-stream sediment capture boxes) and the addition of four techniques (macro-invertebrates, V-star, RASI, and D50). Frank Reichmuth, Chris Knopp (now with the U S Forst Service Lake Tahoe Basin Management Unit), and Elmer Dudik of the North Coast Regional Water Quality Control Board in Santa Rosa helped to refine the sediment sampling techniques. During the 1993 season, slope measurements techniques were added. A preliminary assessment of site descriptions following the 1993 season suggested that canopy measurements would be helpful in describing site conditions. Stand and canopy assessment techniques (by use of spherical densiometer, sighting tube, and Cruz-All) were added during the 1994 season. During implementation, suggestions generated periodically by field crew members, landowners, and observers were incorporated.

This report is divided into two volumes. Volume I introduces the project, describes the tasks and activities involved in initiating and completing the in-stream effort, and reports on the resultant findings and recommendations. Appendices in Volume I list candidate and evaluated sites, describe monitoring assessment techniques, and present data forms. Volume I also includes technical appendices presenting a training curriculum, describing the equipment and supplies appropriate for each technique, assessing the costs associated with implementing the different techniques, and database structure descriptions. Within Volume II are appendices listing data collected for each of the parameters monitored. Similar assessment efforts have been reported by others. For an example of a different report organization and structure, see Harrelson et al (1994).

II. Goals and Objectives

The purpose of the pilot monitoring program was to provide a substantive basis and analytical decision making process for implementing a monitoring effort. The objectives of the study were to:

1) develop procedures for selecting sample sites

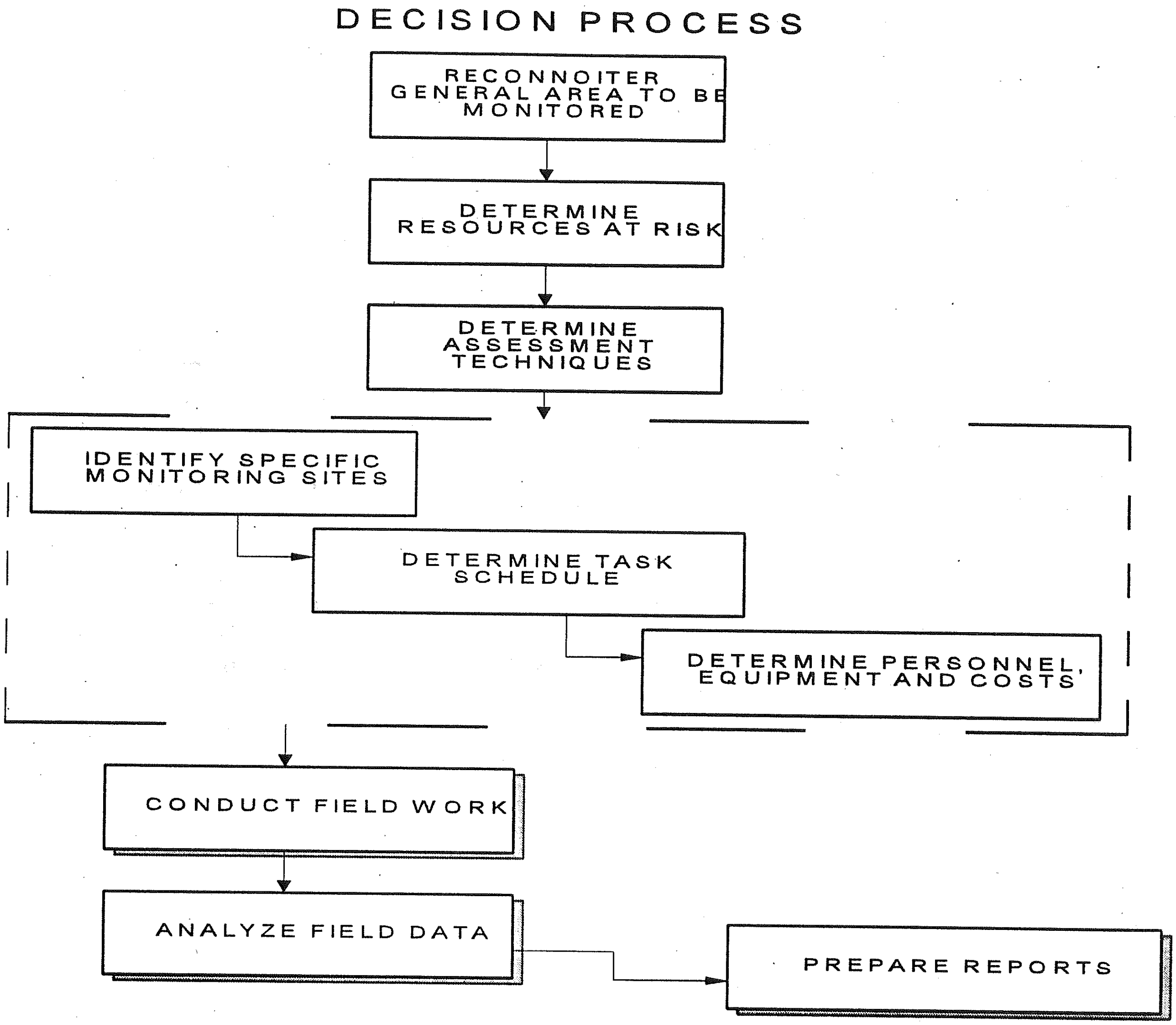
2) test procedures approved by MSG

3) develop field sampling protocols

4) develop training materials

Thus, the project extends earlier efforts of the Board of Forestry to assess the effects of timber harvest activities on private lands (California State Water Resources Board, 1987). The concept of 'Resource-at-Risk' (California Department of Fish and Game, 1994) was applied to focus on important parameters in a watershed and match the best monitoring techniques to measure changes in those parameters. The program then becomes an example of the generalized decision making process (diagrammed on following page).

The program paralleled efforts to produce 'how-to publications' recently initiated by other agencies (Washington Department of Wildlife, 1990; Flosi and Reynolds, 1991, 1994; MacDonald et al, 1991; Washington State Forest Practice Board, 1994; Hayslip, 1993; and USDA Forest Service, 1994). The current emphasis in issuing comprehensive field assessment guides was underscored



by revisions appearing soon after initial publications (Flosi and Reynolds, 1991, 1994; and Washington State Forest Practice Board, 1992, 1994).

The focus of the project was to assess the utility, applicability, and feasibility of implementing the selected assessment techniques. Each assessment technique was applied in all the stream reaches. Among those site selection and information management criteria evaluated were:

- methods for relocating study reaches on return visits
- minimum qualifications for reach components to be recognized as sample units
- sequence of parameters to sampled
- format and relationship of field data forms
- physical maintenance and analysis of information

Maintenance of information within a database management system was evaluated; consistency of observations within study reaches and among sampling sites was examined; and the effectiveness of field team training and the utility of a field training manual were assessed.

The study did not examine linkage between parameters measured in the stream and management activities conducted on the land. Analysis of collected information also did not extend to assessing variation among the sites. Similarly, behavior of one parameter against the behavior of others was not the focus of the pilot. Other questions remaining to be studied are the relationship between management activities and the observed variation in a parameter, and variation of a parameter among the sampling sites. The U.S. Forest Service has addressed these issues and has unpublished data on variation among parameters (Ken Roby, Plumas National Forest, pers. comm) and expressed reservations about whether the techniques work equally well under all conditions (Tom Lisle, Redwood Sciences Laboratory, pers. comm.). This study adds to that data, and in encouraging others to conduct similar projects, may result in a better understanding of the variability within selected parameters throughout their range.

III. Monitoring Parameters and Protocols

The parameters selected for monitoring were reported by several authors as appropriate in defining high quality in-stream habitat (Flosi and Reynolds, 1991, 1994; Knopp, 1993; USDA Forest Service, 1994; and Washington State Forest Practice Board, 1992, 1994). These authors conducted field studies that demonstrated the capability of different techniques to discriminate between the background variation of the parameter in the watershed and the change of the parameter due to land management activities. And, observed variations in a parameter may result from cumulative watershed effects rather than be linked to the application of individual land management practices at specific locations within the watershed (California State Water Resources Board, 1987; MacDonald et al, 1991; Dissmeyer, 1994; and California Department of Fish and Game, 1994).

Marking the Study Reach. Based on direction from MSG, each study reach was usually fixed first on the basis of proximity to timber harvest activities, suitability, and physical access. A permanent reach marker was placed in a secure spot not subject to removal by seasonal flows or land management activities. The distance and bearing to the start of the study reach was recorded. Photographs were taken of the permanent reach marker and its relationship to the upper edge of the study reach. See Appendix C for a detailed description of assessment techniques. Similar techniques are described by Harrelson et al (1994). All measurements were recorded in metric units on standardized data sheets (see Appendix D). A listing of equipment and supplies necessary for each assessment technique is included in Appendix G (Volume II).

Channel Typing and habitat Inventory. In-stream channel typing and a habitat inventory were conducted within the study reach as described in Flosi and Reynolds (1991, 1994) to quickly characterize the biological condition of streams (Barbour and Karr, 1993; Boechler and McAllister, 1992; Dissmeyer, 1994; Hayslip, 1993; MacDonald et al, 1991; Montgomery and Buffington, 1993; Reid, 1994; US EPA, 1990, and Washington State Forest Practice Board, 1992, 1994). Channel type units were consistent with the classification developed by Rosgen (1994) and implemented in a manner similar to the process outlined for coho salmon habitat assessment (California Department of Fish and Game, 1994). MSG decided that habitat type units defined as Level II in Rosgen (1992) and clarified for California by Flosi and Reynolds (1991, 1994) were appropriate to this study; higher levels would have provided information more detailed than required in this study. The application of subjective quality classes to describe channel types and habitat units followed techniques refined during the '208' study (California State Water Resources Board, 1987).

Preliminary habitat typing was conducted from the upstream end of the study reach down the stream until a sufficient number of habitat types were enumerated or 1000 m was traversed. For the study, the number of habitat types to sample was set at six pools, three riffles, and three runs in each stream reach. Habitat types were numbered consecutively from the bottom of the reach accoring to their category: P for pool, V for Run, R for Riffle. The lowest pool was P1, while the third riffle was R3. Once preliminary habitat typing was completed, sampling began at the bottom of the reach and proceeded upstream to reduce the possibility of sampling activities affecting subsequent sampling sites (Harrington, 1993a).

Site Descriptions. Site descriptions were developed for the in-stream channel, the near-stream corridor (Erman et al, 1977), and contiguous up-slope areas that could directly affect the study reach. Aerial photographs were consulted in planning site assessments and in developing descriptions. Conspicuous features (such as erodable bedrock, woody debris recruitment, and canopy) that may introduce sediments into the channel were noted (Boechler and McAllister, 1992; Flosi and Reynolds, 1991, 1994; O'Connor and Harr, 1994; and Rashin et al, 1993). Before sampling was initiated, a channel reconnaissance was conducted upstream from the upstream permanent reach marker for an arbitrary distance of 1000 m. If a channel branched with significant flow into more than one channel, the reconnaissance was conducted along all branches to an aggregate of 1000 m. Channel characteristics, current land practices, and evidence of historical land uses that may affect in-stream conditions were recorded. If problems were encountered during the initial site reconnaisance and assessment, the study reach was discarded and a new site selected which did not include similar problems. Problems encountered during sampling resulted in sampling stopping at that point. During early field assessment, observations were recorded within the study reach. The reconnaissance ended at any point where channel alterations (e.g., water diversion), channel events (e.g., crossing failure), or upslope features (e.g., landing failure) were present and may have introduced materials that would have overwhelmed the sampling techniques.

Habitat unit descriptions and the placement of transects, sampling sites, and channel features were recorded for pools and riffles (Flosi and Reynolds, 1991, 1994; Knopp, 1993, 1994; and Harrelson et al, 1994). Also identified was the source and amount of shade, dominant vegetation, bottom substrate, bank morphology and composition, obvious sediment sources, local disturbances, sidestream influences (including drainages or rivulets), or any other feature which may be of importance (Platkin et al, 1989; and Washington Department of Wildlife, 1990). Included within the site description of each sampled pool was a cross-sectional diagram (oriented as viewed from the bottom of the pool looking upstream), showing the bank slopes, riparian vegetation (overstory, midstory, and emergent), wetted edge of the pool, and any debris or rock formations present (Harrelson et al, 1994).

Sediment Movement. Sediment transport and the size of particles transported was reported as indicative of the quality of the stream by Kappesser (1992, 1993a, 1993b), Knopp (1993, 1994), and others. One measure of stream sediment as an indicator of stream condition was considered to be the distribution of particle size classes represented in a riffle (Flosi and Reynolds, 1991, 1994). The change in particle size distribution over time and through the reach catalogued the movement of sediment plugs or flushes through the system. The RASI, or the riffle armor stability index (the largest particle transported during bank full stage), was determined by measuring particle sizes in those riffles sampled for macro-invertebrates (Kappesser, 1992, 1993a, and 1993b). The particle size distribution of riffle materials were sampled according to the 'Wolman Pebble Count' method (Wolman, 1954) and particle size class distribution (D50) and Riffle Armor Stability Index (RASI) were calculated with custom application software created by Kappesser.

Sediment retention within a pool was measured according to the particular V^{STAR} technique developed by Chris Knopp (1993, 1994), based on earlier work by Lisle and Hilton (1991, 1992).

V^{STAR} (pronounced 'vee-star'), is the fraction of residual pool volume filled with fine sediment. The amount of annually mobile sediment retained within a pool is in a dynamic balance between upstream natural supply sources and the rapidity at which the sediments can move through the system (see the review by Flosi & Reynolds, 1995; and others). The fraction of pool volume filled with fine sediment was reported to be directly related to sediment supply and channel mobility (Lisle and Hilton, 1991; Knopp, 1994). Lisle and Hilton (1992) reported that V^{STAR} correlated well with scoured pool volume in channels with abundant sediment. Thus, fine sediment deposition was determined to be 'volume-related.' Additionally, minor variations between pools may result in local differences in sediment transport and deposition. That is, the size of the low energy zone that fills with sediment was proportionately larger in large pools than in small pools. However, in channels with limited sediment, V^{STAR} correlated with local stream gradient. Fine sediment content was determined to be 'jet-limited.' When the scouring mechanism is strong, filling ceased at moderate flows. And, variations in scour strength caused large pool-to-pool V^{STAR} variations. The V^{STAR} method was found to be practical in detecting and evaluating sediment inputs along stream channels. Again, according to Lisle and Hilton (1992) V^{STAR} measures the most active component of the sediment stored in a channel, quantifies a sediment-related effect on an important habitat component, and implements easily in small to moderate sized stream reaches. Fine pool sediments were distinguished from coarser substrates by being unarmored, distinctly finer than other bed materials, and easily penetrated by a metal rod.

Sediment deposits collected within study reach pools were measured by the V^{STAR} assessment technique developed by Lisle (Lisle and Eads, 1991; Lisle and Hilton, 1991; Hilton and Lisle, 1993; Lisle, 1993) and modified by others (e.g., Knopp, 1993, 1994). Data analysis was performed using the custom application software developed by Chris Knopp (1993, 1994), and revised by him several times during 1994 and 1995. Tom Lisle and Sue Hilton also provide custom software (Lotus™ templates) for calculating the V^{STAR} index (Tom Lisle, U S Forest Service Redwood Sciences Laboratory, pers. comm.).

Canopy. The effects of canopy coverage on stream temperature through shading and its contribution to stream nutrients through leaf-fall and generation of small and large woody debris has been reported (Plafkin et al, 1989; Flosi and Reynolds, 1991, 1994; MacDonald et al, 1991; and O'Connor and Harr, 1994). Erman et al (1977) measured canopy density and estimated temperature increases related to canopy openings following timber harvest activities. Shading decreases the penetration of sunlight to the stream surface within a forest stand. Therefore, stream temperature may be increased within stands due to increased insolation where canopy coverage has been removed. The canopy (both immediately above and adjacent to the stream) has been identified as the source of both nutrients and woody debris for the stream (Erman, et al, 1977; Flosi and Reynolds, 1991, 1994). Within the study reach, canopy coverage measurements were taken by use of the spherical densiometer (observation of shade intercepting subdivisions of reflected sky (Lemmon, 1956, 1957)) and sighting tube (overhead canopy line-intercept observation). An indirect measure of canopy coverage over sampled pools and riffles included basal area measurement by the Cruz-All (Bell and Dilworth, 1993). Portions of the sky blocked by the proximity and height of watercourse banks or ridgelines were also measured by observing adjacent hillside slopes with a clinometer.

The three canopy assessment techniques measured different physical parameters (line intercept - ocular tube; percent cover - spherical densiometer; and biomass - Cruz-All™) . In addition, the measured feature of the canopy for each technique occurred in different parts of the in-stream and near-stream environment. The ocular tube was used to record canopy intercepts along a transect directly over the thalweg in pools and riffles. The area monitored by the ocular tube is a line (of infinite thinness). The spherical densiometer was used to record the number of quadrants in the overhead sky that are either obstructed or not obstructed by a canopy. The area monitored by the spherical densiometer is an area reflected in the curved mirror that can be seen from the point of observation. The width of the observed area depends on the slope of the land or height of the canopy at increasing distances from the observer. The spherical densiometer measures a large area in flat terrain, and a relatively smaller area in rugged terrain (a function of image reflection from the curved mirror). In any case, the area of measurement extends beyond the channel boundaries, and, sometimes includes vegetation outside of the near-stream or riparian corridor. The Cruz-All™ measures trees with diameters exceeding specified angles, when viewed from a point. A small tree close to the observation point may encompass the same angle of incidence as a large tree further away. In any case, the size of the tree and the its angle of incidence are the criteria for recording rather than the location of the tree within either the in-stream or near-stream environment.

During canopy data collection, documentary photographs (35 mm color transparencies) were taken (MacDonald et al, 1991; and Harrelson et al, 1994). Unique features which may help explain a problem, a certain technique, or verify the specific sampling site were visually documented.

Temperature. Flosi and Reynolds (1991, 1994) and Barbour et al (1980), among others, have reported on the importance of temperature in defining the in-stream habitat. However, maximum and minimum temperature limitations are different for each organism in the stream at different times throughout the year (MacDonald et al, 1991). Temperature within the canopy over the stream and in the water was recorded in pools #1 and #6, and in each of the three riffles sampled for macro-invertebrates. Instantaneous measurements were obtained with handheld electronic sensors and mercury thermometers. Recording temperature sensors (Hobo™) were placed within pools #1 and #6 in fall 1993 and removed in late spring 1994. Instantaneous temperature measurements were also taken in the pools at the time of Hobo™ installation.

Macro-Invertebrates. The composition of a macro-invertebrate community has been reported as an indicator of the biological quality of in-stream habitat (Plafkin et al, 1989). The use of macro-invertebrate communities as a parameter validly assessing logging impacts has been established for some time, and has been demonstrated specifically for logging in California (Erman et al, 1977; Mahoney and Erman, 1984; and others). Macro-invertebrate sampling was completed prior to the initiation of other in-stream sampling in order to gather the mobile creatures that would otherwise evade collection nets once water disturbance began (Harrington, 1993a; and Hayslip, 1993). The California Stream Bioassessment Procedure (CSBP), developed by the Department closely followed the Rapid Bioassessment Protocol (RBP III) for benthic macro-invertebrates as outlined by the EPA (Environmental Protection Agency) (Plafkin et al., 1989), was used to determine macro-invertebrate assemblages. This procedure has been used successfully by the Department to detect point source pollution (Harrington, 1993b) and to establish evidence for Fish and Game Code 5650 water pollution cases (James Harrington, 1993c). Each year, 99 samples were collected. Physical habitat assessments were performed at each riffle using the EPA Physical Habitat Assessment Protocol - Level 1 (Hayslip, 1993).

Macro-invertebrate samples were identified at the Department's Water Pollution Control Laboratory (WPCL) to the lowest taxonomic level using Allen and Edmunds (1962); Brinkhurst (1986); Brown (1972); Edmunds et al (1976); Merritt and Cummins (1984); Pennak (1991); Stewart and Stark (1993); Weaver (1988); Wiggins (1977); and Usinger (1963). Macro-invertebrate sampling included the collection of three replicate samples at each of three riffles on each of the eleven stream reaches. Sub-samples of each sample were evaluated to determine a minimum sub-sample size that adequately represented the riffle. Specimens of each identified macro-invertebrate taxon was retained within the WPCL Sample Depository reference collection. Taxonomic lists, diversity index and bioassessment metrics (statistical indices) were generated for each of the samples. Each taxon was assigned to a functional feeding group consistent with Merritt and Cummins (1984) and additional unpublished information on regional aquatic macro-invertebrates (James Harrington, pers.

comm.). A diversity index value, as in Shannon and Weaver (1963), was calculated for each subsample.

IV. Criteria and Methods

Site Selection. Stream reaches were selected for their: 1) occurrence within target watersheds identified by the MSG, 2) association with Timber Harvest Plans (THPs) approved after 21 October 1991 with completion of harvest operations prior to the onset of field studies; and 3) exposure to at least one over-wintering period. The date 21 October 1991 was selected by MSG since BOF Rules significantly changed at that time. The study reach starting point was proposed for the upstream end at the highest elevation along the watercourse where materials could enter the stream from associated timber harvest operations. However, several study reach starting points were established at other locations due to site access constraints. Control reaches, or 'references', were not utilized for the PMP.

THP information was gathered by CDF and delivered to the Department in August 1993. Information on candidate sites was limited to approved THPs in CDF offices. The files did not contain sufficient information to determine if the potential study reach was physically accessible for the study, contained gradients outside of established limits (1-5%), or other site specific problems. MSG agreed that final site selection would occur following the review of additional information with the landowner, and a site visit. Landowners were asked to provide larger scale maps and aerial photographs to help in determining study reach gradients, and identifying access. During the site visit, the study reach was visited to identify access and channel entry points.

Despite the delayed start of the 1993 sampling period, a late, dry fall permitted all candidate sites to be sampled. At the end of fall, time was available to select a stream reach near Hilt that drained into the Klamath River. As no suitable sites were identified within the Scott River drainage, MSG added the Gualala River watershed. The addition enhanced sampling within the Coast Ranges.

The selected study streams were preliminarily stratified as definitely suitable, probably suitable, and questionably suitable (see Appendix A). Definitely suitable sites, according to landowner supplied materials, encompassed at least 1000 m of a 5% (or less) gradient stream reach downslope from a qualifying THP, possessed vehicular access, and were located in watersheds largely free from substantial in-stream or near-stream disturbances (dams, crossings, diversions, etc.) Probably suitable sites appeared to possess the previous features but warranted a confirming field review. File documentation on probably suitable sites was not sufficient to definitely determine their suitability. On the other hand, questionably suitable sites were supported by documentation suggesting that several qualifying features needed to be verified in the field. Unsuitable sites were rejected for varying reasons at different levels of review (see Appendix A). During early site evaluation, streams in the Gualala River watershed were added. Potential streams were eliminated from the study due to various physical factors including excessive gradient, excessive stream flow, excessive stream depth, inaccessibility, inadequate length of suitable reach, etc. Following discussions with property owners, examination of aerial photographs and small scale maps, and site visits, the number of selected streams was reduced to ten (total for three watersheds). There were no suitable streams initially identified in the Klamath River watershed that met selection criteria. Outside of the study criteria, one stream was selected in the Klamath River watershed in order to provide an additional opportunity for techniques assessment. The total number of selected study reaches was eleven distributed among four watersheds (see below).

STUDY REACHES

Mokelumne River Watershed/Sierra Nevada (Georgia-Pacific Corporation)

1	(M-01)	North Mill Ck
2	(SS-01)	South Solinsky
3	(S-01)	Sweetwater
4	(T-01)	Tiger Loop

Upper Klamath River Watershed/Siskiyou County (Fruitgrowers Supply)

5	(CC-01)	Cottonwood Ck

Gualala River Watershed/Mendocino County (Gualala Redwoods Corporation)

6	(D-01)	Doty Ck
7	(LC-01)	Log Cabin Ck
8	(NFG-01)	Little NF

Noyo River Watershed/Mendocino County (Georgia-Pacific Corporation)[1]

9	(NOY-01)	Lower NF Noyo
10	(UPC-01)	Upper Pudding Ck
11	(LPC-010	Lower Pudding Ck

([1] Pudding Creek lies immediately north of the Noyo River Watershed and flows directly to the Pacific Ocean.)

The length of study reach inventoried was the distance necessary to include six measurable pools (P), three measurable runs (R), and three measurable riffles (V). The inventory usually terminated just below the sixth pool. For a distance up to 1000 m upstream from the upper end of the study reach, in-stream and side-stream influences potentially affecting the in-stream environment were recorded.

Stream lengths in the reach that did not conform to sampling suitability criteria were not sampled and were designated as NC (non-criteria). Within the reach, the first six pools, first three riffles, and first three runs were sampled. Pools, riffles, and runs encountered after the first six, three, or three respective habitat types were not sampled, but were designated as NSP (non-sampled pools). Both NC and NSP units were assigned sequence units in the reach, beginning at the upstream end of the study reach. Sampling began on the downstream end of the study reach.

Analytical Techniques. Preliminary evaluations of 1993 data were performed by visual review of database records and spreadsheet displays. Custom spreadsheet and statistical templates (created by James Harrington at DFG's WPCL) were used to analyze macro-invertebrate information. Proprietary software was used for the analysis of temperature and custom application software for sediment (V-star, RASI, D50) information. The V-star software was written by Chris Knopp, USDA Forest Service, under temporary personnel assignment to the North Coast Regional Water Quality Control Board (Knopp, 1994). Gary Kappesser, Idaho Panhandle National Forests (USDA Forest Service), created the custom software IPNFRASI.EXE for determining RASI and D50 statistics and indices (Kappesser, 1993b), and assisted in the data analysis by commenting on study procedures and providing software revisions during 1994 and 1995 (Gary Kappesser, pers. comm.).

Personnel. The distribution of participants in the field survey crews and office support during the project were:

Department of Fish and Game	1993	1994
Permanent	3	3
Temporary	5	7
Volunteer	2	1
Cooperators		
Permanent	3	0
Temporary	1	0
Volunteers	0	2

V. Quality Assurance/Quality Control Methods

Field manuals were developed to describe techniques and field procedures. The manuals included step by step procedures for the implementation of each technique, as well as sample forms and instructions for data entry and analysis. During the course of the study, the manuals were revised to incorporate new techniques and revisions to existing practices.

Preliminary assessment of sample data was performed in the field while each feature was being sampled. Preliminary assessment also occurred late each field day during evening de-briefings, and following the field sessions in the office. Discrepancies, uncertainties, and errors were usually corrected by same day or next day re-sampling. Infrequently, re-sampling happened during site re-visits conducted following the close of the sampling schedule.

After breaks in the field schedule (or, with the addition of new crew members), anticipated data acquisition and recording problems were discussed prior to entering the stream reach. On-site training was conducted whenever techniques were modified. Identified discrepancies, uncertainties, and errors were discussed with the field crew as they were encountered.

The field supervisor periodically collected data in parallel with the field crews. Comparing results in the field provided immediate feedback on the adequacy of implementing established protocols. When necessary, focussed training was conducted to reinforce sampling skills.

The criteria used to determine the need for re-training or re-sampling were based on direct and indirect analysis of field data. For instance, incomplete erasures or strike-outs, or the omission of required entries on field forms warranted re-sampling. An undefined pool edge, omission of the pool length, or gap in the habitat unit sequence number were typical of errors usually caught before leaving the stream reach. Pool depth less than the riffle crest was an error generally caught during data entry. The criteria for suggesting data unacceptability is summarized below (with examples). Suggestions on how to obtain acceptable data are presented in parentheses. Alternative suggestions are numbered with the first being most preferable. Note that recovery from unacceptable data is not always possible.

1. Incomplete or erroneous data entry
   - edge of pool not defined
     (1: return to field, re-locate pool and transect, and re-sample; 2: review cross-sectional sketches and photographs to estimate pool edge; 3: re-sample entire pool)
   - stream reach or habitat unit identifier omitted
     (1: review habitat inventory form to determine which habitat unit matches data on the parameter field form, e.g. pool length, gradient; 2: review cross-sectional sketches and photographs)

- duplicate habitat unit identifier
  (1: review habitat inventory form to determine which habitat unit matches data on the parameter field form, e.g. pool length, gradient; 2: review cross-sectional sketches and photographs)
- last V^{STAR} data triplet has only one or two entries

  (1: locate missing data entry by examining data triplets to confim that first entry in each triplet increases, corresponding to increasing distance from start of transect, 2: locate missing data entry by examining data triplets to confirm that scour depth exceeds water depth; 3: determine that all data fields have been entered for the record; 4: revisit the reach and re-sample)
- two or more data entries in data field where only one entry is appropriate
  (1: during field work, ask field crew which entry was the later correction and obliterate the earlier incorrect entry; 2: while in the area, re-sample; 3: review cross-sectional sketches and photographs to determine correct entry; 4: revisit the reach and re-sample)

2. Information out of sequence
   - water depth exceeds pool depth
     (1: locate missing data entry by examining data triplets to confim that first entry in each triplet increases, corresponding to increasing distance from start of transect, 2: locate missing data entry by examining data triplets to confirm that scour depth exceeds water depth; 3: determine that all data fields have been entered for the record; 4: revisit the reach and re-sample)
   - transect or sample point distances not in sequential order
     (1: locate missing data entry by examining data triplets to confim that first entry in each triplet increases, corresponding to increasing distance from start of transect, 2: locate missing data entry by examining data triplets to confirm that scour depth exceeds water depth; 3: determine that all data fields have been entered for the record; 4: revisit the reach and re-sample)
   - habitat unit number omitted
     (1: review habitat inventory form to determine which habitat unit matches data on the parameter field form, e.g. pool length, gradient; 2: review cross-sectional sketches and photographs)

3. Information out of range
   - pool depth less than riffle crest
     (1: locate missing data entry by examining data triplets to confim that first entry in each triplet increases, corresponding to increasing distance from start of transect, 2: locate missing data entry by examining data triplets to confirm that scour depth exceeds water depth; 3: determine that all data fields have been entered for the record; 4: revisit the reach and re-sample)
   - water depth or pool depth exceeds length of penetration probe
     (1: determine that decimal point is in the correct location; 2: locate missing data entry by examining data triplets to confim that first entry in each triplet increases, corresponding to increasing distance from start of transect, 3: locate missing data entry by examining data triplets to confirm that scour depth exceeds water depth; 4: determine that all data fields have been entered for the record; 5: revisit the reach and re-sample)
   - canopy coverage in one quadrant varies by more than an order of magnitude from the average of the other three quadrants
     (1: review cross-sectional sketches and photographs; 2: re-sample)

- large sediment volume recorded in bedrock dominated reach
  (1: review site sketches, photographs, reconnaissance, and aerial photographs to determine presence of associated local sediment source; 2: re-sample)
- small sediment volume recorded in sediment dominated reach
  (1: review site sketches, photographs, reconnaissance, and aerial photographs to determine possibility of local flushing flows; 2: re-sample)

4. Data reconciliation not possible
   - field data form entries not consistent with habitat unit sketch (number or placement of transects or significant features, unit dimensions) or documentary 35 mm transparencies
     (Re-sample)
   - calculated stream gradient for a study reach different from the sum of the observed gradients for individual habitat units
     (Re-sample)
   - habitat unit description, notes, or photograph in one sampling period differs from comparable data from subsequent sampling period
     (1: if within the same season and sampling within the season is still possible, re-sample; 2: determine that the two data sets do not belong to different sites; 3: re-sample)
   - missing field data form
     (Re-sample)
   - illegible entries
     (Re-sample)
   - cryptic abbreviations
     (Re-sample)

In addition, procedures specific to assessment protocols facilitated both the maintenance of accurate measurements and the consistency of the measurements. Discussed below are examples of the more common procedures.

V^{STAR}. Quick visual estimates of pool and sediment volume were gathered by multiple penetration probe profiles. The location and estimates of pool depth and sediment layer width allowed adjustment of transect locations.

Temperature. Electronic and mercury sensors were paired to assess instantaneous sample accuracy. Due to the long response time and poor waterproof protection of the electronic sensors, mercury thermometers were used throughout most of the project for instantaneous sampling. Longterm temperature sampling was conducted with paired sensors in each of two pools per study reach. Sample comparisons were immediately performed in the field with re-sampling conducted until variations in instantaneous measurements were minimized.

Slope. Percent slope for the hillside extending from the edge of the in-stream channel to the top of the ridge was observed by use of the clinometer. Several observations by more than one observer were obtained for each location. Observations were made from points where the ridge was visible through any intervening trees. Where possible, observations with an Abney level were recorded and compared with clinometer readings. Data comparisons were immediately performed in the field with re-sampling conducted until variations were minimized.

Macro-invertebrates. The effectiveness of sampling was evaluated by selecting one jar at random from the set of samples for each study reach and identifying and enumerating all of the macro-invertebrates and comparing that determination with the 100 specimen sub-samples extracted from each sample jar. Based on the evaluation of the 1993 subsamples, the macro-invertebrates sub-sample was increased to 300 specimens for the 1994 collections.

Canopy. Qualitative descriptions and sketches of canopy strata were recorded by different field crew members and compared against data collected by use of spherical densiometer and sighting tube while still at the sampling site. Pairs of field crew members collected canopy data at the start of each study reach and whenever visually obvious changes in canopy were evident. Basal area estimates collected by use of the Cruz-All were concurrently gathered at the same site until crew members agreed. Comparisons of samples was immediately performed in the field with re-sampling conducted until variations were minimized. Following the field session, data was compared with documentary photographs. Data discrepancies or conflicts resulted in re-sampling during return field trips.

VI. Data Management System

Initial data management efforts focused on the design of standardized field data forms. Early designs were based on forms included in descriptive publications or provided by cooperators. These preliminary designs were tested and refined during field training exercises. Examples of final field data collection forms are presented in Appendix D.

Field team supervisors were responsible for maintaining supplies of blank forms and retaining completed forms. Daily team debriefings assessed the adequacy of each day's effort. Completed survey forms and associated field notes were deposited centrally at the end of the field season.

To reduce volume, forms were printed double-sided. Following problems with immersion, forms were printed on Rite-in-the-Rain® paper.

Separation of team members along the same stream reach sometimes resulted in multiple copies of the same data entry form for the same sampling site with different data. Form collation, comparison, and completion was originally scheduled for evening de-briefings, but usually occurred following each week's field surveys. Data irregularities sometimes were obvious when field forms for the entire reach were evaluated at the end of the week. Completed field survey forms and associated field notes were collated, reconciled, duplicated, and filed at a central location each week.

In order to determine if all sampling had been completed, cross-reference forms and databases referencing habitat unit codes, dates of field sampling, team members, and assessment techniques were designed and tested. Following the first field season, electronic database and spreadsheet files were designed and data was entered into them. Data entry was performed in the office.

Four duplicate sets of field data sheets were created and maintained in separate locations (two field supervisor vehicles, program supervisor office, and Sacramento). The original field data sheets were maintained in the project supervisor's office. Duplicate sets included cross-reference sheets, copies of portions of the THP and maps supplied by the landowner, and paper copies of electronic files.

Electronic files containing field data on fine sediment (V^{STAR}), RASI, D-50, canopy, temperature, habitat type, slope, and macro-invertebrates were created. The data files on V^{STAR}, RASI, D-50, and macro-invertebrates also served as the basis for input files for application software packages.

VII. Training

Field crew members participated in modular training exercises at the start of each field season. Each field assessment technique was performed by each crew member individually and in groups under the supervision of experienced professionals (1993) and permanent Department personnel (1993, 1994). The team creating the curriculum for participant training included Bill Snider, James Harrington, Kris Vyverberg, Stephen Rae, and Chris Knopp. Initial training on sediment sampling was conducted by Chris Knopp, macro-invertebrates (including channel typing and habitat inventories) by James Harrington, and near-stream influences by James Steele and Gaylon Lee. Stephen Rae, Kris Vyverberg, Frank Reichmuth, and Elmer Dudik assisted in 1993. For the 1994 season, Stephen Rae added training on canopy and slope assessment, photographic technique, and written documentation. Field training consisted of the instructor explaining and demonstrating the technique, followed by the crew members performing the technique under direct supervision. Immediately afterward, crew member groups performed the technique without supervision. The results of supervised and unsupervised efforts were assessed to determine whether data variation was due to improper technique. The cycle of supervised and unsupervised effort was continued until results were satisfactory.

The preliminary field manual was given to the field crew and cooperators during in-service and initial field training sessions. Portions of the field manual evolved into procedures reported in this study (see Appendices C, D, E, F, and H).

Following the initial training sessions in August and September 1993, field crew members were assembled and assisted in the preparation of written field procedures and revised data entry forms. At the completion of field surveys in 1993 and 1994, field survey crew members met again to refine the field procedures.

Periodic reviews of data sheets during each field season sometimes suggested that implementation could be improved. When necessary, field crew supervisors (John Hummel and Dave Richter) and the project supervisor (Stephen Rae) conducted focussed training at the study site before sampling was resumed.

Training materials developed in this study were included within the Watershed Academy presented in August and September of 1995 (see Appendix E).

VIII. Participants and Cooperators

To accomplish field surveys within project time constraints, field survey participants were limited to specialists and temporary personnel of the Department, and others subject to their direct supervision. Landowner representatives and personnel from other departments occasionally attended the surveys and assisted. Frequent replacement of temporary personnel in the field team was considered a satisfactory proxy for the periodic incorporation of volunteers from other sources. Personnel turnover provided an opportunity to assess the delivery of newly acquired technical skills to field survey participants. New participants were trained and placed within the field crews with minimal disruption. The cycling of field crew participants gave frequent opportunities to conduct training. Druing the training sessions, we oriented new participants as well as re-examined the skills of continuing field crew members. Survey team participation by members of the public was discouraged due to the tight schedule, physical restrictions at most sites, and legal access problems for non-agency personnel on private lands.

Surveys on private lands were made possible through the generous cooperation of the Georgia-Pacific Corporation, the Gualala Redwoods Company, and the Fruitgrowers Supply Company.

Cooperation from these companies included physical access, maps, aerial photographs, sharing of information, assistance in preliminary site planning, and field coordination.

Stephen Rae designed and revised data forms, and designed and maintained the electronic databases and spreadsheets. Chris Knopp created the application software for the analysis of V-star data. Chris Knopp and Elmer Dudik provided examples of the V-star penetration probe and in-stream particle measuring templates which were fabricated by both project personnel and commercial lathe operators. Robert Kasun, USDA Forest Service (Idaho Panhandle National Forests), provided the IPNFRASI.EXE software and documentation, as well as technical advice, for the assessment of particle size and sediment transport. Don Erman, UC Davis, advised on the level of statistical analysis, while Rob Titus (Department) assisted in performing the statistical tests.

Personnel recruitment began in April 1993. During the short time between contract authorization and the start of field work, just two temporary field assistants could be hired. Field surveys began with half of the temporary staff originally proposed. Two half-time temporary field assistants were assigned from the Department's Water Pollution Control Laboratory for the 1993 field season. The North Coast Regional Water Quality Control Board contributed one full-time temporary field assistant to help with consistency in V^{STAR} sampling for the 1993 season. Personnel recruitment occurred again prior to the 1994 season to replace separated temporary participants. Also, volunteers were periodically recruited to augment the field crew.

IX. Problem Identification and Resolution

During the project, field and office techniques were developed and refined. New procedures, forms, and tasks were created and implemented in response to problems. These categories of problems are summarized with the various means of resolving them. The problems encountered while evaluating techniques are grouped into categories in this section and linked with solutions developed during the study.

Reconciliation of Field Entries. Incomplete field data sheets frustrated the completion of site surveys. Difficulties arose in linking data sheets for different parameters sampling the same habitat unit. Vague location information and incomplete corrections resulted in loss of data and duplication of effort. Entries smudged following immersion were illegible. Incomplete erasures, strike-outs, erasures, and write-over corrections were difficult to interpret. Most ink entries either smeared or soaked through the paper.

Resolution:

1. Establish stream reach ID and habitat unit numbers.
2. Record reach and habitat numbers, date, and team members on each form.
3. Document each riffle and pool by photograph and site sketch.
4. Annotate scaled site sketches with transect and plot locations.
5. Use Rite-in-the-Rain® paper, or equivalent, for all forms.
6. Use pencil for all entries.
7. Use Magic Rub® erasers, or equivalent, for all corrections.
8. Clearly indicate corrections (remove, eradicate, completely black-out entry errors).

Habitat Unit Identification and Re-Visiting. During the same and subsequent site visits, survey team members lost time in locating and re-establishing reach and habitat unit locations.

Resolution:

1. Use bright orange or yellow flagging on branches/limbs overhanging study reach at start of each habitat unit. (Do not conflict with flagging already in use by the landowner).
2. With waterproof ink, annotate all flagging with habitat unit number (use standard abbreviations consistent with entries on forms).
3. Document each habitat unit and significant features by photo; establish permanent photo points for reach access points.
4. At the close of each site visit, prepare text description drawing upon sketches, diagrams, and photographs.
5. Maintain reach and habitat unit flagging throughout the term of the study, including data evaluation.
6. Establish GPS reference points corresponding to each study reach.

Quality Assurance/Quality Control. Many problems occur during field monitoring which must be solved in order to protect data integrity. In our study, lack of consistent QA/QC resulted in loss of data, incomplete field forms, duplication of effort, and site revisits. Either through misunderstandings regarding how to determine when a site visit was complete, or inadequate procedures for reconciling field data forms, several sites were re-visited and some parameters were resampled. After the field season, additional missing data was identified. Data entry quality assurance performed by different individuals varied widely in effectiveness. Many completed data files that had supposedly been checked for errors required extensive revision.

Resolution:

1. Assign specific field supervisor tasks for insuring that data forms are complete, linked, duplicated, and filed.
2. Perform survey data sheet evaluations each evening during the site visit prior to leaving the study reach.
3. Turn in field data sheets, exposed film, maps, and field notes to the monitoring supervisor at the end of each study reach visit.
4. Augment data entry training to include explanation of the information collected and how it will be evaluated.

Data Analysis. Although one purpose of the project was to determine how to conduct data analysis, significant uncertainties in procedure resulted in long delays in report preparation. Problems associated with data entry and validation became confused with those caused by poor record definition. The use of analytical techniques still undergoing revision forced transformation of data files through several different formats requiring several different software packages in a complex and time consuming sequence. For instance, the collection and analysis of V-star sediment data involved the following steps:

1. Data collection on field survey forms.
2. Data entry into Quattro Pro (*.WB1) spreadsheets.
3. Decision rejecting or modifying entries related to overhanging banks, submerged logs, or other significant features.
4. Production of printed copies of spreadsheets.
5. QA/QC (Comparison of spreadsheet entries against field forms).
6. Conversion of Quattro Pro spreadsheets to Excel spreadsheets.
7. Conversion of Excel spreadsheets to comma separated text (*.CSV) files .
8. Conversion of text files to V^{STAR} data (*.DAT) files.
9. Calculation of V^{STAR} indices.
10. Data entry of V^{STAR} indices into Systat input (*.SYS) files.

11. Calculation of Wilcoxon probability statistics.
12. Revision of Systat input file format.
13. Calculation of Freidman probability statistics.
14. Data entry into summary table.

An error in backup file creation caused considerable delay in data analysis. The 1994 data were entered into spreadsheets. At the end of the 1993 and 1994 seasons, all spreadsheet files were printed and duplicated. However, the data files for each stream reach had been named the same for both 1993 and 1994 data files, and during the duplication process, the 1994 files were overwritten by their 1993 counterparts.

Then, during the first calculations of the V^{STAR} index, the structure of the spreadsheet was found to be incompatible with the proprietary software. This was corrected by revising both the spreadsheet structure and the proprietary software. Also, encountered during proprietary software use were error messages resulting from the use of alphanumeric identifiers for each reach and pool. Each spreadsheet row was revised to replace reach and pool identifiers with numeric codes.

The original 132 files, including over 6000 rows of information, were revised to 22 files including about 660 rows. At every step of data entry, file reorganization, and testing, errors in file format were encountered. Typical errors included omission of complete information triplets, omission of one or two parts of a triplet, splitting of pools onto separate lines, and numerical errors (such as 137 for 1.7). Errors encountered during data analysis required reference to field sheets and frequent printouts. Also, file corrections required going back to duplicate files for back-up purposes, and to access readily revisible formats. Revisions to individual files to correct a single V^{STAR} data triplet could consume 15 minutes. Approximately 120 hours were devoted to V^{STAR} data file error checking. Half of this time was required a second time following loss of the 1994 backup files.

The cumulative pool V^{STAR} indices were entered into Systat input files in the format required by the Wilcoxon non-parametric statistical test. The information had to be entered into a second Systat input file with the different format required by the Freidman non-parametric statistical test.

Resolution:

1. Schedule redundant QA/QC to verify accuracy of data files.
2. Assess the possibility of performing index calculations and statistics within existing commercial spreadsheet packages.
3. Revise proprietary software and accompanying documentation to facilitate data entry and analysis (use commercial software when feasible).
4. Establish procedures for electronic data entry and analysis prior to data collection.

<u>Photographic Documentation</u>. Linking survey forms and reconciling entries was sometimes difficult if the actual location for collected data was not clear. Creating a record of each habitat unit was essential to writing text descriptions as well as interpreting vague or illegible entries on field forms. Comparison of written materials with photographic documentation frequently resolved ambiguities.. The cost of film and processing, as well as the convenience in viewing the final image , were less than the costs of revisiting the sampling sites.

Resolution:

1. Use color transparency film.
2. Document all habitat units and significant features.
3. Expose duplicates for each view.
4. Promptly label each exposed roll with site and date.

5. Limit each film roll to a single study reach.
6. Expose views on film in same order as habitat units in the field.
7. Maintain a log of roll number, frame number, and subject.
8. Promptly label each developed transparency with reach, habitat unit, and exposure date.

V^{STAR}. Variation in the inscribed markings on V^{STAR} penetration rods, their long length, and the wide variety of field sampling conditions resulted in data collection inconsistencies. The equipment to sample water and scour depths in the field is not commercially available. Machine shops experienced problems in economically producing V^{STAR} penetration probes in the time available prior to the start of field surveys. During sampling, clay layers, undercut banks, and partially submerged woody debris presented unique problems.

Resolution:

1. Provide a model penetration rod to the machinist during the bid process.
2. Require incised 1 cm rings, and stamped numbers and double incised rings at each 10 cm interval (consistent with the model rod).
3. Machine shorter penetration rods for submerged or overhanging situations.
4. Reposition the penetration rod when encountering impenetrable objects.
5. Carry waterproof flashlights to supplement existing light under dense canopies and overhangs.

Field Assessment Techniques. The field survey crews initially were not comfortable with adopted techniques. The first sample reaches contained channel features (bedrock dominance, undercuts and overhangs, and submerged logs) that were not included in training exercise. These sites and habitat units were revisited in order to obtain proficiency with field equipment and concurrence in techniques in the new situations.

Resolution:

1. Provide comprehensive assessment technique training for all participants prior to the starting surveys.
2. Design training to include the range of situations expected during the field surveys.
3. Conduct on-site technique evaluation at the start of each block of field surveys to determine consistency among participants.
4. Evaluate field survey sheets each evening for consistency, clarity, omissions.
5. Conduct daily de-briefings to discuss team member questions, solicit recommendations for study revision, identify field site problems, or equipment and supply needs.

Equipment. Some of the equipment and supplies initially acquired for the program warranted revision or replacement (for instance, Hobo sensor housings were subject to cracking). Difficulties in working in cool water forced equipment changes, while unique site problems warranted unusual remedies (e.g., use of waterproof flashlights to observe probe markings under overhanging banks). Some equipment failed during field surveys (electronic handheld temperature sensors).

During early survey efforts, expensive electronic temperature probes failed following exposure to water. Short probe lead lengths and inadequate meter sealing resulted in system short-circuits. Mercury release during breakage of hand-held thermometers was collected and deposited in approved hazardous waste disposal sites.

Resolution.

1. Include appropriate safety and adverse weather equipment, such as waterproof flashlights and insulated gloves.
2. Test field equipment and supplies for both integrity and ease of use prior to conducting field work.
3. Where possible, include cheaper manual sampling equipment as back-ups to more expensive electronic sampling equipment.
4. Provide suitable carrying cases for transportation and field use of equipment.

X. Results and Refinements

The technical advisory group initially estimated that field sampling at each stream reach would require the dedication of five to seven people for a two day period (approximately 120 hours). Based on that estimate, the review of ten streams in each of three watersheds should require approximately fifteen weeks. During the study, the time period to evaluate a stream reach initially took 120 hours and was finally shortened to 60 hours. The composition of the field team started with eight permanent and temporary staff and dropped later to three members. During the final days of field work in 1994, some field crews were composed entirely of temporary personnel.

Landowner representatives assisted at various times during initial site location, transportation of equipment and supplies, and information collection. The names of participants involved in field data collection are indicated on field data forms and field notebook pages. Sometimes participating and sometimes observing, the on-site supervisor is named on field data forms only when participating in data collection. And, the names of office support assistance do not appear on forms or analyses.

Printouts of data files are contained in the appendices. For instance, Appendix B includes descriptions of selected study reaches to illustrate how data collected in the field may be integrated into presentations. The appendices F-H contain lists of materials and costs (assessment technique equipment and supplies), and displays of database and spreadsheet structures for the maintenance of field data (database structures). The remaining appendices in the companion report (I-O) contain the field data collected at each study reach. Not all of the data collected in the field is presented in information summaries or referenced in the text of the completion report.

V^{STAR}. Stream sediment transport and deposition characteristics were assessed by direct measurement of sediment contained in pools. Difficulties encountered when stream reaches exhibited channel characteristics not presented in training included low sediment volumes in bedrock-dominated systems, undercut banks, and clay layers within pool sediments. Also, the V^{STAR} technique required careful placement of pool transects and penetration probe intercepts in order to adequately characterize uneven pool margins, differentiate submerged logs and protruding bedrock, and determine the riffle crest in bedrock-dominated systems.

Documentation on the V^{STAR} technique introduced the concept of the pool volume calculations that support the V^{STAR} index. However, little information was available on the V^{STAR} indices to be expected in our study reaches, or on the procedural problems that might be encountered while transforming data on the field sheets into information in the software input matrices.

Very low or very high V^{STAR} indices (e.g. $< .1$ or $> .6$) may suggest that a sampled reach contains pools that the V^{STAR} index was not created to assess (Chris Knopp, pers. comm.). Previous work by Lisle (1993) has shown that V^{STAR} is best suited for geologic types (such as soft sedimentary, weathered granite, or schist) that produce abundant fine sediment. A low index indicates the relative absence of sediment within the sampled reach. Because of inconsistencies in sampling technique or accuracy errors due to insufficient numbers of transects or penetration points, the error in establishing pool and sediment volumes may be within the range of error anticipated in sampling. Therefore, minor pool sediment volume changes would not be consistently documented. And the time necessary to better define the small sediment volumes in such a system may be not cost effective when producing statistically inconclusive results. Bedrock-dominated systems, especially at higher elevations similar to project sampling sites in the Mokelumne watershed, contain little sediment and, therefore, are not appropriate for V^{STAR} sampling (Tom Lisle, pers. comm.). Similarly, a high index indicates the abundance of sediment in the pool, some of which may not be annually mobile. The retention of sediment in pools for extended periods (over one year) violates one of the presumptive bases for the application of the V^{STAR} technique (Chris Knopp, pers. comm.).

Although the individual V^{STAR} pool indices vary differently between the years (the rank order of pools within a reach was not the same for both years), the cumulative V^{STAR} index for each reach was generally similar (see table below). Recent work by Lydgate (in prep.) has shown that V^{STAR} index means for reaches remained relatively constant over time, even over winters with widely varying amounts of precipitation. The differerences between reach indices for North Fork Gualala and Upper Pudding Creek for the two years may be due to various causes, such as sampling variability, changes in stream morphology during high winter flows, or errors in defining the sampled pools. Within Upper Pudding Creek, the reach index varied because the indices for pools #2 and #3 were so different (.718 to .333 and .917 to .547) even though the other four pools in the reach remained similar. In the North Fork Gualala, the second pool could not be relocated in 1994. The channel configuration at the point on the study reach that had been a pool in 1993 no longer fit the criteria for a pool in 1994. A similar situation occurred for pool #2 in North Fork Noyo. Due to the small number of samples and the lack of duplicate samples for each year, the data did not support statistical analysis.

On a stream by stream basis, the reaches were not statistically similar (rejection of the Wilcoxon hypothesis), suggesting that the pools are drawn from different populations. However, there is a general correlation for streams between the years. The wide variation in pool V^{STAR} indices suggests that pool conditions varied widely between the years. But the similarities in reach V^{STAR} indices suggest that the reaches have remained constant from year to year. Statistical values alone did not clearly explain the differences or similarities among the V^{STAR} indices. The experimental design of the project may not have been sufficiently rigorous to support statistical analysis. It is not clear whether the variation in V^{STAR} indices is due to changes in pool characteristics or inconsistencies in the implementation of the V^{STAR} assessment technique.

V^{STAR} STATISTICS

REACH	POOL	1993	1994
Mill Creek (01)			
	1	.1955213	.3161547
	2	.1495791	.196313
	3	.4938971	.45802
	4	.2687652	.278192
	5	.2005089	.1861816
	6	.2712666	.2001636
	CUMULATIVE	.305397	.3030242

V^{STAR} STATISTICS (continued)

REACH	POOL	1993	1994
South Solinsky (02)			
	1	.01333567	.1428161
	2	.1979925	.2362349
	3	.2565837	.1698099
	4	.08452155	.1274419
	5	.09752617	.0251736
	6	.008986321	.03727824
	CUMULATIVE	.1655494	.1309139
Sweetwater (03)			
	1	.5905287	.5274793
	2	.04633332	.1576168
	3	.1674344	.3095852
	4	.09360558	.223308
	5	.18022	.2075365
	6	.3319358	.266857
	CUMULATIVE	.2826613	.3079963
Tiger Loop (04)			
	1	.217446	.2598426
	2	.150666	.375072
	3	.2936586	.3054801
	4	.2759822	.2901529
	5	.1127036	.06536034
	6	.03933214	.07267012
	CUMULATIVE	.2445207	.2796495
Cottonwood Creek (05)			
	1	.1356677	.1543055
	2	.1002939	.2600699
	3	.3918412	.3267873
	4	.07012475	.1629361
	5	.4285386	.4063448
	6	.4774185	.3596402
	CUMULATIVE	.2669035	.2730712
Doty Creek (06)			
	1	.7692775	.9653478
	2	.7832745	.7237371
	3	.3724978	.8939687
	4	.9227914	.800998
	5	.7415679	.3202315
	6	.5323637	.6402791
	CUMULATIVE	.6807042	.6855087

V^{STAR} STATISTICS (continued)

REACH / POOL	1993	1994
Log Cabin Creek (07)		
1	.9974861	.8967695
2	.6018719	.5387506
3	.6193292	.495987
4	.4910737	.5500407
5	.6794398	.568596
6	.2981804	.3709038
CUMULATIVE	.5517839	.5467182
North Fork Gualala (08)		
1	.7813766	.575462
2	.7185743	[no data]
3	.8610223	.4850197
4	.6267875	.7563406
5	.7330312	.7681283
6	.6235489	.5595186
CUMULATIVE	.7822986	.5988714
North Fork Noyo (09)		
1	.9139923	.7745845
2	[no data]	[no data]
3	.7379233	.5881387
4	.6259677	.863876
5	.8212799	.9052639
6	.8253375	.5280138
CUMULATIVE	.7811962	.7629113
Upper Pudding Creek (10)		
1	.7528742	.801895
2	.7184489	.3326709
3	.9173683	.547437
4	.8883673	.4591272
5	.534776	.5025099
6	.8174666	.8791402
CUMULATIVE	.8003927	.5788854
Lower Pudding Creek (11)		
1	.5815554	.8769795
2	.478568	.4243935
3	.9489574	.8620564
4	.6860707	.7617994
5	.7957436	.6350127
6	.8755976	.8497863
CUMULATIVE	.6767046	.6233754

Coupled with the minimal visual changes in the reaches between 1993 and 1994, the small annual variation in reach V^{STAR} indices for ten of the eleven reaches suggests that measuring the amount of residual pool volume filled by annual sediment may be appropriate. For watersheds where the sediment deposits are annually mobile, the V^{STAR} assessment technique is a reliable means of measuring residual pool volume and sediment deposits.

Gradient. The water surface gradient of each study reach was first estimated by calculations based on data scaled from published topographic quadrangles. The calculated gradient was then corrected by direct measurements collected during habitat unit identification in 1993 (see following table). Sampling errors at Sweetwater Creek initially suggested gradients of 9 - 12% within pools; the reach gradient could not be calculated from field data sheets. In other in-stream studies, gradient has been calculated during bankfull flows (Gaylon Lee, State Water Board, pers. comm.).

REACH GRADIENT[1]

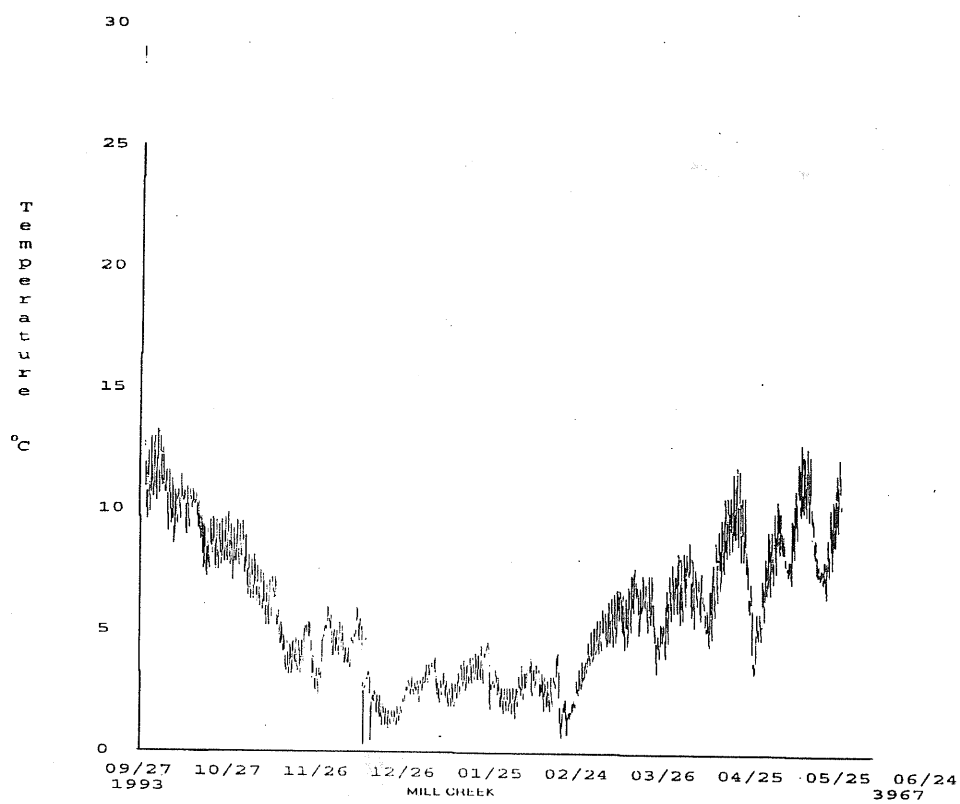
STUDY REACH	LENGTH	GRADIENT SCALED	GRADIENT ACTUAL
Mill Creek	305	4.5	2.9
South Solinsky	544	1.0	1.9
Sweetwater Creek	275	5.0	----[2]
Tiger Loop	628	5.0	4.0
Cottonwood Creek	381	1.0	0.9
Doty Creek	484	4.5	2.5
Log Cabin Creek	281	5.0	5.2
North Fork Gualala	244	0.5	1.4
North Fork Noyo	196	0.5	2.2
Upper Pudding Creek	345	3.0	1.2
Lower Pudding Creek	540	1.5	2.1

[1](Length in meters, scaled and actual gradient in percent)
[2](Excluded due to errors on field data sheet)

The calculation of stream reach gradients from published topographic sheets was corrected by actual measurements.

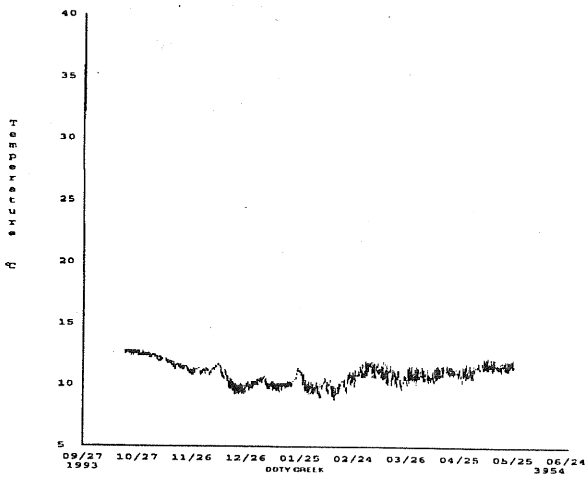
Temperature. Instantaneous water temperature measurements (reported in centigrade) from handheld sensors were consistent with data recorded by submerged recording sensors (Hobo™). Set with a sampling interval of 2.4 hours, the recording sensors were capable of maintaining measurements over a nine month period. However, 14 of the 44 submerged sensors did not record information (see table following graphs below). One of the four sensors and its waterproof housing in Tiger Loop was lost during the winter. The electronics or the battery in another sensor in Tiger Loop failed after setup and did not record any measurements. Fluid on the circuit boards of eight Hobo™'s apparently caused system failures. Operator error at sensor setup left four Hobo™'s set for a short duration (30 days or less) that primarily recorded office and vehicle storage temperatures before the units were placed into the streams. Recorded data from individual pools within a watershed are generally consistent (see temperature graphs in Appendix K). Due to the placement of sensors in fall 1993 and their removal in spring 1994, the hottest summer months were not measured.

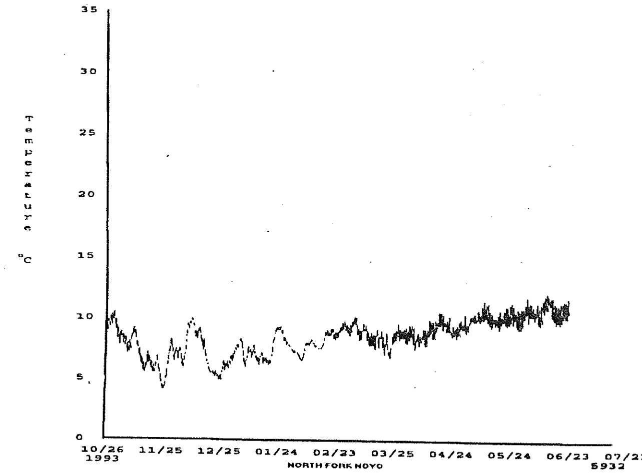
Measurements gathered from submerged recording sensors reflected seasonal water temperature fluctuations expected for the watersheds (Geiger, 1966). Study reaches in the Mokelumne River watershed experienced seasonal minima and maxima of approximately 0 - 12° (temperatures in degrees centigrade) (see graph below). Differences between the daily mimima and maxima for winter in the Mokelumne watershed varied from 0 to 2°, while spring mimimum and maximum readings differed by 9 to 12°. Low winter water temperatures were associated with low air temperatures and snow. A gradual increase in water temperature during the spring may be associated with the decreasing contribution of cold water from a melting snow pack being replaced by slightly warmer groundwater.

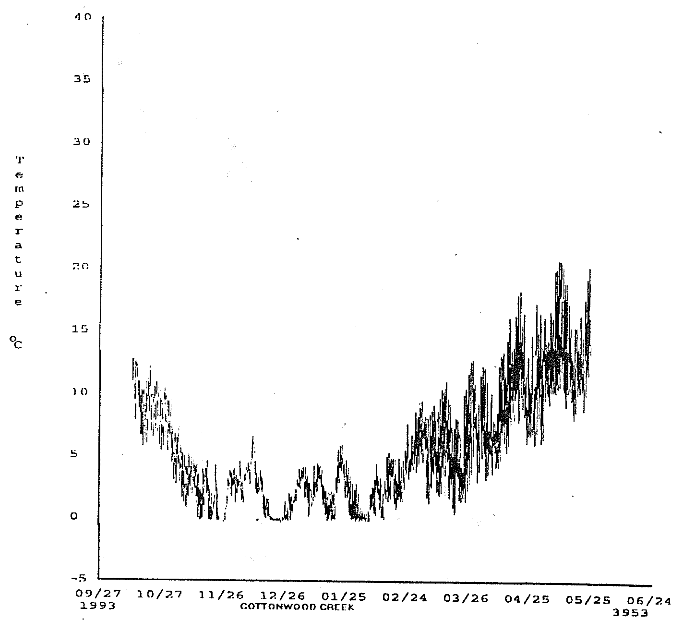


Temperature measurements along the North Coast (Noyo and Gualala River watersheds) reflect moderate coastal climates; that is, little diurnal minimum/maximum differences (2 to 5°) and little seasonal minimum/maximum differences (8 to 13°) (see graphs below). Minimum and maximum readings in the Noyo River watershed where stream canopy cover was less differed more in the spring (20°) than in the fall (5°). Water temperatures increased gradually during the spring. With more canopy cover in the Gualala River watershed, diurnal differences were typically less than 3°, and seasonal differences less than 5°.

Cottonwood Creek temperature measurements (lower winter and higher summer) reflected the cool winters and hot summers experienced in the interior of Northern California (see graph below). The difference between daily minima and maxima were more in pools having little canopy coverage (21°) than those with almost complete cover (5°.) Daily mimimum/maximum differences ranged from small (1 to 2°) to large (10°). The greatest daily differences occurred during early summer in a pool having little cover.







Instantaneous water temperature measurements agreed with recorded temperature measurements obtained from Hobo's. Hand-held instantaneous air temperature measurements generally reflected either the constancy of coastal climates or the diurnal fluctuations typical of interior climates (Barbour, Burk, & Pitts, 1980). During October 1993, air temperatures 1 m above the water surface at coastal sites were frequently within 3° of water temperatures. Summer air temperatures at all sites ranged from 5° to 15° higher than associated water temperatures. Air temperatures just above the water were more similar to air temperatures 1 m above the water at pools under dense canopies than at pools with less cover. With less cover, air temperatures increased and fluctuated more as distance increased from the water surface. Canopy coverage reduction could result in greater diurnal temperature fluctuations and extreme temperatures that could stress fish populations.

HOBO™ Results in Stream Reaches

Hobo™	Location	Period	Data Collected
3936	Mill Creek	9/29/93-5/25/94	Entire period
3951	Tiger Loop	9/29/93-5/25/94	Entire period
3952	South Solinsky	10/6/93-5/25/94	Entire period
3953	Cottonwood Creek	10/12/93-5/25/94	Entire period
3954	Doty Creek	10/21/93-5/25/94	Entire period
3955	Sweetwater Creek	-	None - Fluid build-up
3956	South Solinsky	9/27/93-10/4/93	Office temperature
3957	Lower Pudding Creek	11/6/93-6/29/94	Entire period
3958	North Fork Gualala	-	None -Fluid build-up
3959	Cottonwood Creek	9/28/93-5/25/94	Office temperature
3960	Mill Creek	9/28/93-5/25/94	Entire period
3961	Lower Pudding Creek	11/4/93-6/29/94	Entire period
3962	Cottonwood Creek	10/20/93-5/25/94	Entire period
3963	Doty Creek	10/23/93-5/25/94	Entire period
3964	Doty Creek	10/23/93-5/25/94	Entire period
3965	North Fork Gualala	-	None -Fluid build-up
3966	South Solinsky	9/27/93-10/4/93	Office temperature
3967	Mill Creek	9/29/93-5/25/94	Entire period
3968	North Fork Gualala	11/4/93-6/29/94	Entire period
3969	Lower Pudding Creek	11/4/93-6/29/94	Entire period
3970	Doty Creek	-	None -Fluid build-up
3971	Log Cabin Creek	10/21/93-5/25/94	Entire period
3972	North Fork Gualala	11/4/93-6/29/94	Entire period
3973	Tiger Loop	-	None - Sensor lost
3975	Tiger Loop	9/28/93-5/25/94	Entire period
3976	Sweetwater Creek	9/28/93-5/25/94	Entire period
3977	Cottonwood Creek	9/28/93-5/25/94	Entire period
3978	Sweetwater Creek	-	None - Fluid build-up
3979	South Solinsky	-	None - Fluid build-up
3980	Lower Pudding Creek	11/4/93-6/29/94	Entire period
3981	Log Cabin Creek	10/21/93-5/25/94	Entire period
3982	Sweetwater Creek	9/28/93-5/25/94	Entire period
3983	Log Cabin Creek	9/27/93-10/20/93	Office temperature
3984	Tiger Loop	-	None - Sensor failed
3985	Upper Pudding Creek	11/3/93-6/29/94	Entire period
3986	Upper Pudding Creek	-	None - Fluid build-up
3987	North Fork Noyo	10/27/93-6/23/94	Entire period
3988	North Fork Noyo	10/27/93-6/23/94	Entire period
3989	Log Cabin Creek	10/21/93-5/25/94	Entire period
3990	Mill Creek	-	None - Fluid build-up
5926	Upper Pudding Creek	11/3/93-6/29/94	Entire period
5927	Upper Pudding Creek	11/3/93-6/29/94	Entire period
5931	North Fork Noyo	10/27/93-6/23/94	Entire period
5932	North Fork Noyo	10/27/93-6/23/94	Entire period

Rachel E. Furman (Onset Computer Corporation, pers. comm.) suggested that fluid on the Hobo™ circuit boards is probably condensation rather than battery leakage. Other users have reported to Onset Computer Corporation, manufacturer of the Hobo™, that what originally appears to be battery leakage is actually condensation that has built up underneath the battery and corroded the battery temianls and the circuit board. The condensation and corrosion has resulted in battery failure and causes the sensor to stop recording prematurely. Condensation build-up may be avoided by placing desiccant packs in the submersible case. For long deployments, Onset Computer Corporation suggests the use of several desiccant packs.

The HoboTM recording sensors were reliable temperature monitoring devices when installed and maintained properly. In conjunction with handheld instantaneous thermometers or temperature sensors, the recording sensors provided long-term monitoring capabilities. However, temperature measurements should be collected during periods when temperature is a critical factor in the life history of the resource at risk. In this study, the sensors were installed after that period in 1993 and removed before that period in 1994.

Canopy. The three canopy assessment techniques measuring different physical parameters (line intercept, ocular tube; percent cover, spherical densiometer; and biomass, Cruz-All™) were implemented in 1994. In addition, the measured feature of the canopy for each technique occurred in different parts of the in-stream and near-stream environment. Canopy assessment techniques added to the project during the 1994 season (see table below); canopy sampling was not conducted in 1993. There was not sufficient time to return to study reaches in 1994 to use the three assessment techniques a second time.

AVERAGE REACH CANOPY COVERAGES

STUDY REACH	SPHERICAL DENSIOMETER[1]	SIGHTING TUBE[2]	BASAL AREA[3]
Mill Creek	97	25	357
South Solinsky	80	8	229
Sweetwater Creek	97	29	225
Tiger Loop	88	20	279
Cottonwood Creek	70	18	194
Doty Creek	99	29	395
Log Cabin Creek	98	30	386
North Fork Gualala	99	25	272
North Fork Noyo	91	21	308
Upper Pudding Creek	99	25	513
Lower Pudding Creek	95	23	231

[1](Spherical densiometer measures percent cover averaged over reach)
[2](Sighting tube measures percent cover directly over thalweg)
[3](Basal area measured in basal square feet)

The canopy coverage measured for the reach by the spherical densiometer was consistently higher than the canopy coverage measured by the sighting tube. The sampling field of the spherical densiometer covers 74° centered over the thalweg, while the sighting tube samples a line transect directly over the thalweg. There is no statistical significance in the variation in percent cover. The lower numbers from the sighting tube observations reflect occasional openings in the riparian cover directly over the channel. However, diurnal and seasonal sun angle changes may result in openings directly over the channel having less importance than the canopy coverage over the stream extending away from the water surface (the forest canopy through which the light must penetrate at different times and dates). The study was not designed to test the relationship among sun angle, openings directly over the channel, reach canopy coverage, and temperature. Since the temperature sensors were not recording during the hottest summer months, comparisons with temperature data can not be made.

RASI/D50. Information on annually mobile (D50) particles and pebble counts (200) was collected in 1993 and 1994 (see Appendix J). The average particle sizes calculated from the two counts are presented in the table on the following page. Data was subjected to the Wilcoxon and Kruskal-Wallis non-parametric statistical tests and linear regression.

There was a significant difference between the years (Wilcoxon) and between the reachs for both years (Kruskal-Wallis) for annually mobile particles. The 1994 data was slightly more non-normal than the 1993. Using the F-statistic on a regression of 1994 data on 1993 data, there was a highly significant linear relationship between the years (r^2 = .58). Particle size had decreased from 1993 to 1994. A pulse of coarse bedload sediment appears to have been moving downstream through the reaches (perhaps in response to a wet season following a period of extended drought).

However, there was no significant difference between the years (Wilcoxon) for particle sizes measured during the pebble count. There was a significant difference for particle sizes between the reaches for both 1993 and 1994 (Kruskal-Wallis). The 1994 data was very non-normal compared to the 1993 data. The regression of 1994 data on 1993 data was not significant (r^2 = .66). The fit along the line was better in smaller particle sizes but divergent in higher ranges.

Differences between D50 estimates in this study and those of others (such as Knopp, 1993) may be due to differences in sample site selection. Knopp and others sampled pools within representative reaches of watercourses while this study placed sample sites primarily on the basis of proximity to THPs. Whether the sites in this study adequately sample the eleven stream reaches can not be determined.

The assessment of annually mobile particles (D50) is straight forward and based on substantial literature. The D50 technique can be quickly and efficiently implemented in reaches where point bars or riffles are can be easily accessed. Less is know about RASI as the technique has not seen widespread use. There is less certainty in the application of the RASI procedure, and a need for significant professional judgement in the field. While the D50 technique is quantitative and correlates well with sediment column sieve samples, the RASI technique is more qualitative. The D50 technique is appropriate in most monitoring programs, but the RASI procedure additional testing before widespread implementation.

ANNUALLY MOBILE PARTICLES

	A	B	C	D	E	F	G	H	I	J	K	L
1						AVERAGE PARTICLE SIZE						
2									D50			200 COUN
3	REACH #	YR		RIFFLE #		POINT	STREAM		(mm)			(mm)
4						BAR						
5	M-01	93		R-01			X		78			86
6	M-01	94		R-01			X		27			60
7	M-01	93		R-02		X			84			89
8	M-01	94		R-02		X			26			71
9	M-01	93		R-03		X	X		87			61
10	M-01	94		R-03			X		29			90
11	SS-01	93		R-01			X		102			128
12	SS-01	94		R-01			X		53			262
13	SS-01	93		R-02			X		113			66
14	SS-01	94		R-02			X		75			88
15	SS-01	93		R-03		X			108			116
16	SS-01	94		R-03			X		50			124
17	S-01	93		R-01			X		67			102
18	S-01	94		R-01			X		23			154
19	S-01	93		R-02			X		74			77
20	S-01	94		R-02			X		32			90
21	S-01	93		R-03					71			119
22	S-01	94		R-03			X		32			196
23	T-01	93		R-01			X		87			151
24	T-01	94		R-01			X		41			128
25	T-01	93		R-02			X		84			121
26	T-01	94		R-02			X		33			147
27	T-01	93		R-03		X	X		86			110
28	T-01	94		R-03			X		44			161
29	CC-01	93		R-01		X			78			250
30	CC-01	94		R-01			X		25			217
31	CC-01	93		R-02		X			75			193
32	CC-01	94		R-02			X		19			171
33	CC-01	93		R-03			X		91			114
34	CC-01	94		R-03			X		24			282
35	D-01	93		R-01		X			76			38
36	D-01	94		R-01			X		27			35
37	D-01	93		R-02					76			50
38	D-01	94		R-02			X		23			33
39	D-01	93		R-03		X			79			22
40	D-01	94		R-03			X		24			38
41	LC-01	93		R-01		X	X		67			34
42	LC-01	94		R-01			X		17			59
43	LC-01	93		R-02					73			60
44	LC-01	94		R-02			X		22			44
45	LC-01	93		R-03					74			55
46	LC-01	94		R-03			X		19			44
47	NFG-01	93		R-01					81			40
48	NFG-01	94		R-01			X		47			41
49	NFG-01	93		R-02					84			19
50	NFG-01	94		R-02			X		47			39
51	NFG-01	93		R-03					92			37
52	NFG-01	94		R-03			X		35			37
53	NOY-01	93		R-01					61			29
54	NOY-01	94		R-01			X		22			20
55	NOY-01	93		R-02					60			28
56	NOY-01	94		R-02		X			24			22
57	NOY-01	93		R-03		X			59			32
58	NOY-01	94		R-03			X		25			26
59	UPC-01	93		R-01		X			77			37
60	UPC-01	94		R-01			X		16			35
61	UPC-01	93		R-02					80			51
62	UPC-01	94		R-02			X		25			38
63	UPC-01	93		R-03		X			83			40
64	UPC-01	94		R-03			X		24			37
65	LPC-01	93		R-01					83			40
66	LPC-01	94		R-01			X		25			25
67	LPC-01	93		R-02					79			33
68	LPC-01	94		R-02			X		28			29
69	LPC-01	93		R-03					68			37

Macro-Invertebrates. In this study, macro-invertebrate sampling techniques were assessed during fall 1993 and spring 1994. The Department hopes the CSBP will eventually be used state-wide to assess the effects of point and non-point source pollution and possibly in Aquatic Biological Criteria development as required by the Clean Water Act (U.S. EPA 1990). Widespread use of the CSBP will result in the collection of information from watersheds that can be easily compared and correlated. In the absence of a standardized collection scheme, the analysis of macro-invertebrates across and among watersheds would be constrained.

Evaluation procedures (metrics) used for the set of biological data collected for the project followed those developed by Fore and Karr (1994). The properties of a useful biological metric are: 1) its value should increase (or decrease) as human influence increases; 2) it must vary across the range of human influence; and 3) for similar locations or situations, metric scores must be close in value.

Information on land-use variables for streams and watersheds sampled for the project were not available. The measurements made in this project can be used to examine variability in metric scores within streams and differences in metric scores between streams. A properly constructed metric should vary in relation to changes in site conditions, provided that the linkages are well understood. The metric should not be highly variable among similar sites (Fore and Karr 1994).

In fall 1993, the coefficient of variation for taxa richness, diversity index, biotic index and EPT index for the 11 streams were below 27% and averaged 13%, 11%, 10% and 17%, respectively (Appendix N, Table 4). The low variation suggests that the samples were representatives subsets of the macro-invertebrate assemblages in the stream reach. In spring 1994 the values for taxa richness, diversity index, biotic index and EPT index for the 11 streams were higher (Appendix N, Table 1 and 2), but the coefficient of variation were similar to fall 1993. The coefficients of variation were below 21% and averaged 16%, 9%, 13% and 17%, respectively (Table 5). In spring 1994 there was no difference in the coefficients of variation generated for the 100 and 300 subsamples (Table 5 and 6) even though the metric values increased substantially (Appendix N, Table 2 and 3). The low coefficient of variation suggests that sample collection was conducted consistently; a small subset (100) was as representative of the macro-invertebrate fauna as was a larger subset (300). The coefficient of variation for the dominant taxa metric was consistently high averaging 39 and 36 for fall 1993 and spring 1994, respectively (Appendix N, Table 4 and 5).

Ranking streams from most degraded to most pristine using bioassessment metrics is at best an approximation. For comparison, data sets should have similar physical characteristics and differ primarily by the level of human influence. Potentially important abiotic factors which should be considered include elevation, aspect, stream size, gradient, watershed geology and flood history (Fore and Karr 1994). The design of this project did not include data collection in a way to support rigorous statistical analysis. However, based on the sum of the bioassessment metrics scores calculated for data collected in spring 1994, the 11 streams can be ranked in order reflecting a relatively simple to more complex biological condition (see the following table).

BIOLOGICAL CONDITION OF STUDY REACHES BASED ON MACRO-INVERTEBRATE FAUNAS

	Score	Reach
Group 1 (COMPLEX)		
	45	Upper Pudding Creek (Noyo Watershed)
	43	Sweetwater Creek (Mokolumne Watershed)
	39.5	Tiger Creek (Mokolumne Watershed)
	37	Noyo River (Noyo Watershed)
	35.5	Mill Creek (Mokolumne Watershed)
Group 2		
	31.5	Doty Creek (Gualala Watershed)
	29	Solinsky Crossing (Mokolumne Watershed)
Group 3 (SIMPLE)		
	21	North Fork Gualala River (Gualala Watershed)
	17.5	Lower Pudding Creek (Noyo Watershed)
	13.5	Cottonwood Creek (Siskiyou Watershed)
	12.5	Log Cabin Creek (Gualala Watershed)

Obviously, this ranking should be taken with a degree of caution. Without comparison to differences in habitat parameters, the biological significance of the groupings is not clear.

Subsampling 100 macro-invertebrates from a sample is recommended in the national RBPs (Plafkin et al 1989). The total number of macro-invertebrates in 11 samples examined ranged from 138 to 3950 with an average of 1140. Subsampling effected the metric values from 0 to 300% and the degree of difference was related to the difference in abundance (Appendix N, Table 7). In spring 1994, subsampling was increased to 300 to improve metric reliability. Metric values increased substantially (Appendix N, Table 2 and 3), but there was no difference in the coefficients of variation (Table 5 and 6). For 12 of the spring 1994 samples, there were less than 300 organisms. The lowest number was 134 but there was no noticeable effect to the metric value or variability.

A strong correlation could not be detected between bioassessment metric values and physical/habitat scores. This may be because the generalized visual evaluation was not quantitative or there was inconsistency in implementing the field procedures. The macro-invertebrate community appears to be more responsive to upstream influences than those in the immediate area. There were also inconsistencies between information indices generated for the streams visited in fall 1993 and spring 1994.

The bioassessment metrics taxa richness, diversity index and EPT index seem to be reliable indicators of biological conditions. The biotic index had low variability which is indicative of a useful metric, but may not be a relevant metric for forested streams since it was developed for an indicator of organic pollution. Dominant taxa had the highest variability and its usefulness may be questionable.

The effectiveness of the physical/habitat evaluation procedure originally recommended by the EPA (Plafkin et al. 1989) was not determined in this study. Low-level ocular physical assessment procedures may still be useful. In the future, these and other low-level ocular physical assessment procedures and revisions to the original EPA procedure should be evaluated.

Additional macro-invertebrate sampling could produce reference data sets for correlation of future studies. Also, the possible relationship between macro-invertebrate fauna and physical and biological features could be examined. Meanwhile, macro-invertebrate sampling provides a standardized means of assessing stream habitat quality under widely varying gradients, canopy coverages, and sediment regimes.

Multi-Parameter Comparison. No clear patterns emerge in comparing different canopy coverage data types (spherical densiometer, sighting tube, and basal area). The sum of the bioassessment matrix scores, when compared against other parameters, correlated poorly with gradient, canopy coverage, and V^{STAR}. High bioassessment scores occurred in reaches with both high and low V^{STAR} indices, different canopy coverages, and particle sizes. Low bioassessment scores also occurred in reaches with high and low V^{STAR} indices, different canopy coverages, and particle sizes.

Comparisons based on individual pool V^{STAR} indices were not attempted. According to Tom Lisle (pers. comm.), Chris Knopp (pers. comm.) and others, V^{STAR} is more an assessment of stream reach sediment storage in pools than a reliable indicator of individual pool status.

Other studies (e.g., Knopp, 1993) sampled pools within representative reaches of watercourses. V^{STAR} indices from these studies could be compared with other data from the same area that is obtained by representative sampling. In this study, sample site selection for all data was biased by the need to place study reaches in close proximity to THPs. In the absence of reference sites or data sets, whether the sites in this study adequately sample the eleven stream reaches can not be determined. Consequently, rigorous statististical analysis is also questionable as the in-stream sampling regime does not satisfy the need for representative samples.

Should statistical analysis suggest correlations between parameters, the meaning of the correlation would not be clear. Is there correlation between two parameters whose samples do not represent the real variation of the parameters for the watersheds? Are correlations among small numbers of samples misleading when the statisitical test are designed for larger data sets?

An analyis of the variation of different parameters should be designed to obtain multiple data sets in order to reduce the variance, and be based on representative sites to produce results useful in a management context.

Training. Temporary and permanent personnel participating in the project assessed the training they received. Comments primarily stressed the need to conduct short, field-oriented sessions in which each assessment technique was practiced in representative field sites. Participants identified the need to conduct small group training, expose participants to different field conditions in different watersheds, and use the field equipment and data forms that would be encountered in the project.

The need to address specific techniques in depth was also noted. Because the project included several techniques, participants experienced a modular curriculum in which techniques were addressed individually. Due to the complexity of selected techniques, participants requested multiple training experiences and group and individual feedback.

The concept of "set-piece" training was applied in this study. Set-piece training incorporates exercises in which the results are known to the instructor but not the participants before the session begins. Participant results are compared against already constructed data sets and information displays in evaluating training effectiveness. In some cases, multiple data sets may suggest the degree of variability to be expected in participant results. For certain parameters, such as temperature, examples may be obtained from texts (e.g., Geiger, 1966). In the absence of such comparative materials, the accuracy and consistency of participant results is difficult to assess.

The Department has defined a "Watershed Academy" concept for the training of watershed assessment techniques. Efforts in this project helped form the basis for several of the topics covered in the first offering of the academy (see Appendix E). By using a modular approach, the academy recognized the need to break down the assessment question into processes and techniques. Standardized curriculum materials may include: parameter descriptions and field techniques, data sheets and information analysis processes, photo documentation of field procedure, case study or set piece field sessions, and relationships among parameters and processes.

Data Management System. CDF is establishing an electronic database for the entry, maintenance, and analysis of information collected in the monitoring of THPs. Standardized data entry schemes and database structures facilitate the distribution of information among the agency, industry, and academic participants. DFG has established an electronic database linked to a GIS (geographic information system) for maintenance of stream habitat information. The capability of the DFG system to be a repository for habitat information collected in the monitoring of THPs has not yet been determined.

Data management starts with the data entry forms used in the field. And, the design of field forms depends on the parameters to be measured. But, the primary factor defining the format of information is the analytical technique to be used in assessing that information. For instance, the V^{STAR} application software requires the reporting of data in meters and centimeters for observations reported along transects oriented at right angles to the thalweg. Strict adherence to the data structure for the input matrix is necessary in order to perform the assessment. The database management system must be able to maintain and present the information in the required format for analysis.

GIS. The data management system must contain links to GIS and the field sites. Current studies rely primarily on the physical identification of study sites by map annotations or text descriptions. Such physical identification frustrates rapid site relocation, introduces error in subsequent identification of sampling sites, and reduces the effectiveness of comparing physical and biological parameters among the sites. The GIS is the electronic vehicle created to address these and other needs. A GPS (global position satellite) system receiver can produce accurate geographic coordinates in remote sites. The GPS readings provide the means to document access routes and sample sites. The use of GIS and rapid site relocation (GPS) allow prompt access to different data sets for a site as well as cut the costs of locating and revisiting stream study reaches.

Rapid creation and revision of graphical displays of information are possible with the GIS. GIS is also able to import information from different databases so long as the structure of the database and the information content of the entries is consistent with adopted standards. This project created database files for maintaining sample information but did not extend to linkages with a GIS.

XI. Implementation Recommendations

The pilot monitoring program should be followed by a series of efforts to continue applying assessment techniques within different watersheds. The initial bias of the project in restricting studies to sites associated with qualifying THPs may have resulted in not adequately sampling the spectrum of physical and biological features within the target watersheds. This bias may be reduced by: 1) selecting future study sites on a random basis, 2) not constraining sites on the basis of dates of approval of nearby THPs, and 3) selecting additional, alternative assessment techniques. Also, limitations imposed by the short term of the project may be addressed by subsequently establishing longer term studies that reduce the immediate effects of irregular events (such as catastrophic storms, drought, or short-term erosion related to ground disturbances).

The effectiveness of monitoring procedures should be tested within watersheds over extended periods. Such "demonstration watersheds" could anchor efforts to test new and revised assessment techniques, as well as provide opportunities to generate reference data sets. Long term monitoring in demonstration watersheds could also focus on possible linakges between management practices and resources at risk, so long as issues associated with mixed ownerships and monitoring continuity are addressed. Training efforts could be conducted within demonstration watersheds.

Additional effort should be focussed on determining the individual contributions of upslope management practices to in-stream systems. This project was able to note some of the obvious near-stream and in-stream sources of sediment and in-stream sites of management practices that may directly contribute to levels of parameters. However, paired sites or control (reference) points to determine the contribution of background noise were not included in the design of the project. Consequently, individual contributions of a practice or physical habitat factor (e.g., slope, bedrock instability, canopy coverage) could not be separated from the cumulative effects measured in the stream. In-stream monitoring should be implemented in conjunction with hillslope monitoring (a watershed assessment approach). The smaller variation expected in hillslope monitoring data may result in a greater possibility of detecting impacts from recent timber operations.

Linkages between the macro-invertebrate assessment and the evaluation of habitat factors could be better defined. The physical/habitat evaluation scores should be compared to the more quantitative habitat typing measurements. Bioassessment metric development is an iterative process and this data set should be further evaluated when information on abiotic factors, land-use measurements, and in-stream physical conditions are available. An index of macro-invertebrates tolerant to sedimentation may be a more appropriate metric. Although variability was not improved significantly, a 300 organism subsample is recommended in further macro-invertebrate sampling because it produces metric values (statistics)which may be more effective at detecting biological conditions of forested streams. Additional data on benthic macro-invertebrate assemblages would be helpful in future metric development. Spring sampling would be preferable and reference streams and conditions should be established in these watersheds to better evaluate the ability of metrics to indicate biological conditions of forested streams.

Future studies should continue to assess the appropriateness of using different techniques at different sites. Assessment techniques will continue to evolve, affecting ease of measurement, inherent variability, and sensitivity to detect change (MacDonald et al, 1991). The usefulness of techniques may be evaluated with respect to their capability to differentiate between in-stream and near-stream variations in a parameter. Also, each assessment technique and parameter must be evaluated to determine whether the observed variation is due to either specific processes (upslope or upstream, or historical) or random variation (background noise). If a parameter varies little throughout the watershed, it is not likely to be a sensitive indicator of on-site effects.

Modifications to published techniques or new processes defined in the project, and those associated with subsequent monitoring efforts, must be published to encourage their widespread use and evaluation by others in additional studies. Data sets from the validation of published or new techniques must also be published to serve as comparisons for future studies.

Pre-Planning. To design a monitoring effort, first evaluate and characterize the present conditions of the biological resources and other beneficial uses of interest (including water quality) within the watershed, locate hazards pertinent to those resources and uses, and estimate the level of risk from those hazards (California Department of Fish and Game, 1994). Next, survey to locate continuing and proposed land management activities that will add to the existing hazards, degrade habitat, or slow the natural rate of habitat recovery from prior impacts. For each problem identified, describe the hazard and risk, determine specific mitigation to reduce those hazards, and enumerate a monitoring program to evaluate the effectiveness of protection and mitigation measures in reaching the goal of protecting and enhancing fish and wildlife populations and other beneficial uses throughout the watershed. Appropriate pre-planning biological questions include:

1. What is the present condition of the habitat? Is there evidence of either direct or cumulative large scale change from watershed inputs (water, heat, nutrients, wood, and sediment)?

2. Are individuals of the species at risk present within the assessment area?

3. Are individuals directly vulnerable to any change in the five watershed inputs?

4. What is the habitat vulnerability to the five watershed inputs?

5. What is the stream channel response to the five watershed inputs?

6. How are the inputs routed to the stream reach?

7. What are the potential habitat changes in response to changes in each of the five watershed inputs? Where will the potential habitat changes be located? How do these potential habitat changes impact on critical components of the life history of species at risk?

Relevant pre-planning questions for water quality considerations include:

1. What are the locations of domestic water supplies that utilize surface flow from creeks or springs, or those using wells that derive from the underflow of a stream (i.e., those in close proximity to a watercourse and would have poor filtering through permeable gravels)?

2. Are these water sources at risk to advers impacts from rpoposed timber operations?

3. Do the domestic water supplies that could be impacted by timber harvest operations currently experience problems with water quality parameters such as turbidity, organics, odor, etc. (I.e., are there documented problems with the systems)?

4. What type of filtration systems do the domestic watersources utilize and can these systems be expected to handle impacts that can reasonably be expected to occur from timber harvest operations within the watershed (i.e., how vulnerable are the water systems to watershed inputs)?

5. What types of domestic water sources are present, who are the owners or responsible parties, how many connections exist, what are the storage capacities, and what is the pattern of demand on those systems?

Answering the project pre-planning questions (determining hazards and potential impacts) involves reviewing watershed processes, land management activities (from all sources), maintenance programs, road conditions, site preparation, emergency and exempt operations, and erosion control facilities. This analysis looks at how each aspect of the proposed land management activity can individually and collectively change the five input variables.

The category of monitoring selected depends on the information need. What question is being asked? The differences between monitoring types (trend, baseline, implementation, effectiveness, project, validation, or compliance) is based more on the monitoring need than on the type and intensity of the proposed land management activity (MacDonald et al, 1991). And, the monitoring types overlap.

Monitoring Issues. Based on the results of the analyses presented above, and in response to the refinements implemented during the conduct of the study, implementation recommendations are offered below for short-term monitoring efforts. Additional specific procedures for long-term monitoring projects are identified under each heading. Generally, short-term monitoring recommendations deal with project or site specific issues, while recommendations for long-tem monitoring focus on concept, procedure, data sets, and training.

The selection of monitoring parameters should be based on the watershed processes operating within the assessment areas, the significant biological issues in the watershed, and the beneficial uses at risk. Selected techniques should be easy to understand and implement, and for fish and wildlife issues, focus on changes in the habitat that affect the most critical aspect of the life history of the resource at risk. The monitoring program should be designed to be easily replicated on the same and similar sites. All parameters to be monitoried should be linked to management issues; unless such linkage is demonstrated, avoid monitoring that parameter.

1. Need to Monitor: Prior to initiating a monitoring effort, the project designer or reviewer should determine whether monitoring is appropriate. The questions of appropriateness apply equally to both short-term and long-term monitoring.

   Short-Term and Long-Term Monitoring

   A. Identify the resources at risk within the watershed and whether the project occurs in an area which may affect those resources.

   B. Identify whether monitoring tools exist to measure changes in the parameters affecting critical periods in the life history of targeted resources at risk, or established beneficial uses.

   C. Determine monitoring objectives (i.e., what is the management information need?).

2. Site Selection: A pre-project objective is necessary to focus efforts and interpret results. One way to perform pre-project planning is to conduct a watershed assessment. Selection of sampling sites should be based on the purpose of the study. Monitoring may be done by random or selected placement of temporary or permanent study sites. Management activity

effects may be monitored by placement of study sites in proximity to the area of activity. Monitoring should be conducted on sites sensitive to the resource at risk in order to better determine the linkages between physical changes and species responses oe effects on beneficial uses.

Short-Term Monitoring

A. Define the purpose of the study prior to selecting study reaches.

B. Conduct a field examination of available study sites prior to selecting assessment techniques.

C. Identify the resources at risk prior to selecting which physical parameters to monitor.

D. Determine whether the parameter that directly affects a critical component of the identified resource at risk can be monitored at the proposed study sites.

E. Rank potential monitoring sites according to resource at risk sensitivity and select the most sensitive sites for study.

F. Develop criteria for ranking the sensitivity of the resource at risk to habitat changes at different sites.

Long-Term Monitoring

A. Perform a watershed assessment to determine resources at risk and beneficial uses, parameters directly affecting critical components of life histories andwater quality, and study sites that optimize monitoring.

B. Determine permanent study reaches and sample sites with both long-term access and site integrity.

C. Integrate the assessment of private and public lands in monitoring studies.

D. Develop criteria for ranking the sensitivity of the resource at risk or other beneficial use to physical changes at different sites.

3. Training: Different levels of training and experience may result in the design of biased monitoring studies, selection of inappropriate parameters, and the inconsistent implementation of assessment techniques.

Short-Term Monitoring

A. Conduct standardized training. Focus study design training on watershed assessment; field procedures training on established assessment techniques. See Appendix E for a training curriculum example.

B. Distribute standardized technique descriptions. See Appendix C for a description of assessment techniques, including site selection techniques.

C. Deliver implementation training tailored to the needs of different participants.

D. Demonstrate standard techniques under controlled conditions. Incorporate set-piece examples with established data sets to both facilitate QA/QC and provide examples of information analyses and displays.

E. Adapt curricula to accommodate local conditions.

F. Develop a cadre of knowledgeable specialists available to design or comment on training curricula.

Long-term Monitoring

A. Modify watershed assessment curriculum to reflect changes in resource issues and assessment techniques.

B. Establish schedule for refresher training and new technique training for participants.

C. Establish a Watershed Academy for the standardized delivery of assessment concepts and field procedures.

D. Establish an electronic clearinghouse for information on techniques (both accepted and under review), current projects, current problems, data sets, and questions on monitoring. Consider a World Wide Web home page.

4. Techniques/Parameters: The need to improve existing technology, discard inappropriate technology, and develop new technology will continue. Documented procedures should be used for monitoring parameters that reflect

the quality of critical components of the habitat and beneficial uses. The capability to determine from a data set whether data variation is due more from changes in the site rather than from inconsistencies in assessment technique implementation has not yet been proven. The techniques should also reveal the relative contributions of recent and historical factors in order to differentiate between 'legacy' problems and issues related to current management.

Short-Term Monitoring

A. Select parameters that directly affect one or more critical components of the life history of a resource at risk or other beneficial use within the target watershed.

B. Select parameters for which assessment techniques have been previously used in similar watersheds or stream reaches.

C. Implement assessment techniques for which field procedures have been published and accepted by the professional community.

D. Provide justification for selection of parameters that do not directly affect a critical component of the life history of a resource at risk or othr beneficial use.

E. Implement the Rapid Bioassessment Protocol for macro-invertebrate faunal assemblage assessment within all monitoring studies. Include spring and fall sampling with 300 count subsamples.

F. Consider implementing the V^{STAR} protocol for sediment assessment within wadable streams having an overall gradient less than 4%. Do not use the V^{STAR} protocol in streams that are either bedrock dominated or include significant sediment deposits that are not annually mobile. Also, V^{STAR} should not be used in lithologies that do not produce moderate to high concentrations of ine sediments.

G. Implement the D50 technique for sediment transport assessment. In wadable streams, the technique may be used on either submerged or exposed sediments (riffles or point bars).

H. Select and implement canopy coverage assessment to establish cross-walks with forest stand inventory data and linkage with woody debris recruitment and water temperature.

I. Observe temperature within the stream in critical habitat areas for fish during critical time periods. Utilize submersible recording sensors for continuous records.

J. Generally, monitoring on higher gradient streams should focus on macro-invertebrates (Rapid Bioassessment), temperature, canopy coverage, and the recruitment of large woody debris.

K. Generally, monitoring on lower gradient streams should focus on sediment transport and storage (D50), residual pool volume filled with fine sediment (V^{STAR}), the recruitment of large woody debris, temperature, and canopy coverage.

Long-Term Monitoring

A. Conduct long-term studies to assess the accuracy of assessment techniques to monitor specific parameters under different site conditions, and

B. Implement the V^{STAR} protocol within additional, low gradient watersheds to better determine the physical factors limiting its usefulness, and site specific refinements that may be appropriate.

C. Implement the RASI protocol within additional watersheds to better determine its effectiveness.

D. Conduct paired tests to validate the relevance of reference, or control, data sets drawn from both spatially or temporally separated samples.

E. Implement the Rapid Bioassessment Protocol for macro-invertebrates within additional watersheds to produce additional reference data sets.

F. Determine additional biological parameters and assessment techniques for monitoring that focusses on vertebrate species.

G. Evaluate the effectiveness of vegetation analysis procedures for characterizing plant community structure within the riparian and near-stream corridor. Determine linkages between vegetation analysis procedures and forest stand (commodity-based) type mapping. Evaluate the linkage between canopy coverage data and recruitment of woody debris.

H. Evaluate the application of the Wildlife Habitat Relationships system within the riparian and near-stream corridor.

I. Publish the results of evaluating the effectiveness of assessment techniques.

5. Equipment: The use of expensive or fragile equipment and materials may introduce additional costs and time delays (for equipment and supplies used in the study, see Appendix F).

<u>Short-Term Monitoring</u>

A. Select field equipment that is relatively inexpensive to acquire or fabricate.

B. Select field equipment that are appropriate for use by field crews with varying levels of training and experience.

C. Avoid the use of equipment subject to breakage during normal use or that requires frequent or expensive calibration. Avoid the use of toxic or hazardous materials (e.g., mercury-based thermometers).

<u>Long-Term Monitoring</u>

A. Periodically re-examine the choice of equipment.

B. Revise and develop new equipment and assess its use in field trials.

C. Publish procedures involving the use of revised or new equipment.

D. Develop methods for "un-wadable" streams.

6. QA/QC: Adopt and adhere to a defined QA/QC process covering field surveys, data sheet evaluation, file management, data entry, data management, and information analysis. Establish ranges of acceptable values for field data and guidelines for minimum and maximum plots, transects, and sampling points. Assign specific responsibilities for tasks and procedures for reporting progress.

Short-Term Monitoring

A. Identify expected ranges for parameters to be measured in the field. Establish data ranges responsive to differences due to substrate, elevation, vegetation type, land use history, or other relevant factors.

B. Ensure that collected data falls within expected ranges, or provide explanation of why exceeding range limits is appropriate.

C. Prepare a list of tasks detailing each information handling step from field data collection, through data entry, electronic file creation, hard copy printing and storage, and backup procedures.

D. Prepare an explanation accompanying each field survey form and data analysis file (spreadsheet or database) that defines each entry.

E. Schedule daily reviews of field survey activities.

F. When necessary, revisit field survey sites promptly and reconcile field survey forms.

G. Ensure that all entries are complete and legible at the close of each field activity.

H. During data entry, manually check each data file against field survey sheets before proceeding to next set of forms.

I. Refine QA/QC procedures based on issues and concerns identified in each monitoring study.

Long-Term Monitoring

A. Establish data sets that can serve as reference or control sets for projects on similar sites.

B. Determine whether spatially or geographically separated reference or control sites are most appropriate for evaluating data set variability.

C. Establish linkages with GIS to facilitate data handling, information analysis, and reporting.

D. For the target watershed, identify parameters for which acceptable ranges do not exist. Establish data ranges responsive to differences due to geology, elevation, vegetation type, land use history, or other relevant factors.

E. Encourage the development of application software for data entry and analysis that incorporates necessary QA/QC.

F. Develop data entry validation procedures incorporating double entry or electronic comparison.

G. Distribute QA/QC procedures for peer review.

7. Data Analysis: Poorly defined and undocumented information analysis techniques typically are difficult to implement. Also, the resulting interpretation may be subject to challenge.

Short-Term Monitoring

A. Select only information analysis techniques that have been published in final form.

B. Select computer software that is either commercially available or, if custom, ready to implement. Require full documentation for custom software.

C. Avoid modified or custom analytical schemes that have not yet been peer reviewed or had results correlated with relevant comparative studies.

Long-Term Monitoring

A. Refine software and documentation for performing parameter assessments(e.g., stream sediment analyses by V^{STAR} and RASI/D50).

B. Develop uniform display and reporting of monitoring information.

C. Develop improved information analysis techniques.

D. Subject improved data analysis techniques to peer review.

E. Publish revised or new data analysis procedures, including custom application software.

8. Standardization: Information generated by studies with differing data collection protocols may not be comparable.

Short-Term Monitoring

A. Present techniques assessment to professional, technical, industry, and public audiences.

B. Establish data management procedures consistent with established database definitions.

C. Encourage monitoring efforts to determine ranges of parameters associated with site factors not adequately represented in previous studies.

Long-Term Monitoring

A. Promote the widespread sharing of information among interested parties.

B. Develop standardized curricula for each parameter and assessment technique.

C. Establish uniform database structures for the uniform reporting, storage, and management of information.

D. Facilitate the establishment of repositories for storage of monitoring information.

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APPENDIX A

FIELD SURVEY CANDIDATE SITE EVALUATION

Field Survey Candidate Site Evaluation - 1993/1994

Mokelumne River Watershed/Sierra Nevada

Accepted:

4-92-37-AMA-7	(North Mill Ck)
4-92-10-CAL	(South Solinsky)
4-92-45-AMA-8	(Sweetwater)
4-91-130-AMA-15	(Tiger Loop)

Rejected During Initial Screening:

4-90-105-CAL	Under Previous Timber Harvest Rules
4-91-81	Insufficient Information To Review
4-91-118-CAL	Small Landowner; Inadequate Time To Obtain Access Permission
4-91-131-CAL	Commercial Thinning/Sanitation Salvage
4-92-9	Insufficient Information To Review
4-92-14-AMA	Too High In Watershed; Insufficient Flow
4-92-46	Too High In Watershed; Insufficient Flow
4-92-77	Too High In Watershed; Reach Gradient Too Steep
4-92-78	Ridge-Top; Reach Not in Proximity
4-92-79	Significant Up-Stream Diversion; Presence of Cattle
4-92-86	Ridge-Top; Reach Not In Proximity
4-94-14	Timber Harvest Operations Still Underway
4-93-21	Timber Harvest Operations Still Underway
4-93-52	Timber Harvest Operations Still Underway

Rejected During Field Reconnaissance:

4-91-119-CAL-30	Could Not Locate Reach In Field
4-91-120-CAL-31	Insufficient Reach Length; Reach Gradient Too Steep
4-92-16-AMA	Insufficient Flows (Class III)
4-92-36-CAL	Commercial Thinning
4-92-44	Reach Too Deep For Safe Access
4-92-82	Too Far From Other Acceptable Reaches
4-92-83-CAL-16	Reach Too Deep For Safe Access

Scott River (Upper Klamath) Watershed/Siskiyou County

Accepted:

2-90-EX-122-SIS	(Cottonwood Ck)

Rejected During Initial Screening:

2-91-232	Rejected By Project Manager and CDF Contract Administrator
2-91-236	Rejected By Project Manager and CDF Contract Administrator
2-91-247	Rejected By Project Manager and CDF Contract Administrator
2-92-104	Rejected By Project Manager and CDF Contract Administrator
2-92-162	Rejected By Project Manager and CDF Contract Administrator
2-92-175	Rejected By Project Manager and CDF Contract Administrator
2-92-176	Rejected By Project Manager and CDF Contract Administrator
2-92-262	Rejected By Project Manager and CDF Contract Administrator
2-92-281	Rejected By Project Manager and CDF Contract Administrator
2-92-359	Rejected By Project Manager and CDF Contract Administrator
2-92-381	Rejected By Project Manager and CDF Contract Administrator
2-93-36	Rejected By Project Manager and CDF Contract Administrator
2-93-37	Rejected By Project Manager and CDF Contract Administrator
2-93-39	Rejected By Project Manager and CDF Contract Administrator

2-93-47	Rejected By Project Manager and CDF Contract Administrator
2-93-79	Rejected By Project Manager and CDF Contract Administrator

Rejected During Field Reconnaissance:

2-92-EX-039-SIS	Insufficient Reach Length

Gualala River Watershed/Mendocino County

Accepted:

1-91-482-MEN	(Doty Ck)
1-92-021-MEN	(Log Cabin Ck)
1-92-039-MEN	(Little NF Gualala)

Rejected During Initial Screening:

1-90-666-MEN	Under Previous Timber Harvest Rules
1-90-667-MEN	Under Previous Timber Harvest Rules
1-90-713-MEN	Under Previous Timber Harvest Rules
1-91-163-SON	Under Previous Timber Harvest Rules
1-91-181-SON	Under Previous Timber Harvest Rules
1-91-182-SON	Under Previous Timber Harvest Rules
1-91-184-SON	Under Previous Timber Harvest Rules
1-91-225-SON	Under Previous Timber Harvest Rules
1-91-356-SON	Under Previous Timber Harvest Rules
1-91-452-MEN	Too Far From Other Acceptable Reaches
1-92-289-MEN	Insufficient Flows; In-Lieu Practices

Rejected During Field Reconnaissance:

1-92-022-SON/MEN	Reach Too Deep For Safe Access

Noyo River Watershed/Mendocino County

Accepted:

1-91-443-MEN	(Lower NF Noyo)
1-91-380-MEN	(Upper Pudding Ck)
1-91-442-MEN	(Lower Pudding Ck)

Rejected During Initial Screening:

1-91-441-MEN	Insufficient Reach Length
1-92-078-MEN	Ridge-Top; Reach Gradient Too Steep

Rejected During Field Reconnaissance:

1-91-380-MEN	Access Road Within Stream Channel
1-92-055-MEN	Insufficient Number of Riffles And Runs; Inadequate Access

		Accepted	Initial Reject	Field Reject
Mokelumne River Watershed Sierra Nevada		4	14	7
Scott River (Upper Klamath) Watershed Siskiyou County		1	16	1
Gualala River Watershed Mendocino County		3	11	1
Noyo River Watershed Mendocino County		3	2	2
	Status Total	11	43	11
	Total Plans		==>	65

Sampled Sites - 1993/1994

PMP R_ID	Site Name	RF3RCHID (CU SEG MI)	PNMCD	Calwater_ID	GPS (UTM)
Mokelumne River Watershed/Sierra Nevada (Georgia-Pacific Corporation)					
M-01	North Mill Ck	18040012/414/1.44	6021276	-	10/720603/4647547
SS-01	South Solinsky	18040012/8/9.73	18040012004	-	10/734967/4252003
S-01	Sweetwater			-	10/722710/4263668
T-01	Tiger Loop	18040012/28/7.79	18040012012	-	10/725812/4266822
Scott River (Upper Klamath) Watershed/Siskiyou County (Fruitgrowers Supply)					
CC-01	Cottonwood Ck	18010206/27/9.4	18010206012	-	10/530678/4647547
Gualala River Watershed/Mendocino County (Gualala Redwoods Corporation)					
D-01	Doty Ck	18010109/108/1.79	830239924	-	10/453867/4296884
LC-01	Log Cabin Ck	18010109/109/0.00	830239925	-	10/454749/4296219
NFG-01	Little NF Gualala	18010109/107/0.00	830239923	-	10/455672/4294315
Noyo River Watershed/Mendocino County (Georgia-Pacific Corporation)					
NOY-01	Lower NF Noyo	18010108/29/3.14	PVA94051601	-	10/443057/4367092
UPC-01	Upper Pudding Ck	18010108/32/9.97	18010108018	-	10/442252/4369235
LPC-01	Lower Pudding Ck	18010108/32/7.28	18010108018	-	10/437638/4368703

APPENDIX B

FIELD SURVEY SITE (ACCESS AND DESCRIPTION)

Field Survey Site Access and Description Example

Sampled sites are described according to the following format. First, for each site the access route is identified from a prominent physical point readily located on a public map (ie, AAA or USFS forest map). Milepost markers on public roads are presented where appropriate. However, GPS (global positioning satellite) reference information (using the UTM, universal transverse mercator system) is presented for all intersections and other visually significant route markers once leaving public roads.

The site description includes four areas of coverage (surrounding area, near-stream, in-stream, and individual habitat units). The surrounding area description extends beyond the immediate riparian zone out to flats, ridges, and slopes generally visible from the site. The surrounding area description is not site-specific, but more regional or ownership specific. The near-stream description extends from the physical edge of the stream channel out to the apparent limit of influence of the forest canopy. The near-stream description characterizes the physical and biological features that obviously influence the stream through direct shading, leaf fall, exfoliation, etc., but does not include features within the watercourse channel. The in-stream description includes features within the watercourse channel, as defined by the point of highest flow. The remaining description (individual habitat units) is a sequential characterization of each habitat unit encountered in the study reach.

The individual habitat unit descriptions begin with a standard heading: sequence number in the study reach, unit type and sequence number of that type, length in meters, starting and ending points in the study reach (measured in meters from the start of the reach), and gradient for the individual unit. For instance, the following individual habitat unit heading may be decoded as:

Habitat Unit #3 - P-02 (14.1 m) (27.6 m - 41.7 m) (0.0%)
- -(Habitat Unit #3) sequence number 3 in the study reach
- -(P-02) pool number 2 in the study reach
- -(14.1 m) 14.1 m long
- -(27.6 m - 41.7 m) start point 27.6 m, end point 41.7 m from start of the study reach
- -(0.0%) 0.0% gradient in the habitat unit

Within the study, pools (P), riffles (R), and runs (V) are identified. Stream lengths in the reach that do not conform to sampling criteria are not sampled and are designated as NC. The first six pools, first three riffles, and first three runs are sampled. Pools, riffles, and runs encountered after the first six, three, or three are not sampled and are designated as NSP. Both NC and NSP units are assigned sequence units in the reach.

Site Description Example

<u>Access Route</u>.

Proceed on Highway 12 seven miles east from Napa to Moskowite Corner. At the intersection of Highway 128 and County Road 15, turn left (east) onto County Road 15. Proceed east on County Road 15 until the end of pavement (3.5 miles) (UTM 10-770403/6263168).

Zero the odometer at the end of pavement, as all subsequent mileage is measured from the start of the unpaved private road. Proceed to the locked gate marked 'Margo Properties - Gate #34.' Go through the locked gate and follow the dirt road to the north for 3.1 miles, until the three way intersection. Turn to the right (north) onto an unmarked dirt road. Proceed .4 miles to the double culvert crossing. Immediately after crosing the culverts, turn to the right ((east) and continue on the road paralleling the creek. Proceed .2 miles to the water truck access turn-around (wide area in the dirt road leading to the creek). The end point of the Owl Creek reach is the upstream side of the culvert crossing immediatelu upstream of the water truck access (UTM 10-790703/4464428). The sample reach extends upstream.

Site Description.

(Surrounding Area)
The topography of this volcanic bedrock dominated area is that of sharply incised canyons in moderately sloping foothills. The study reach starts at approximately 1100 feet in elevation. The canopy near this watershed is sparse (about 20%), consisting almost exclusively of digger pine (average overstory tree height= 15 m to 18 m). The overstory from the surrounding area provides little canopy coverage for the stream. The midstory is composed of chokecherry, madrone, christmas berry and green-leaf manzanita. Dominant understory and groundcover species typical of this area include buckbrush, whitethorn, chaparral pea, and introduced Mediterranean grasses. The surrounding area is primarily range land currentlu supporting cattle grazing. The hillslopes adjacent to the streambed are generally between 50% and 90% with several 80+% slopes on the right bank side in the lower reach.

(Near-Stream)
The dominant near-stream trees (average height 6 m), which provide a high percentage (40-60%) of the streambed canopy coverage, are box elder and arroyo willow. Mature cottonwoods (10 m - 15 m) are sporadically scattered throughout the reach. Various herbaceous and woody plants exist immediately adjacent to the watercourse, covering approximately 70% to 89% of the streambanks. These include young box elders, spice bush, mint, stinging nettles, Equisetum spp., mugwort, fireweed, dandelion, and grasses which are the dominant understory and groundcover species (average height=0.3m to 1.3m). The average basal area for the reach is 70 square feet. Closely cropped vegetation on the streambanks was noted at several habitat units. The lower habitat units of the reach (P-01 to P-03) have a relatively flat left bank and an extremely steep four to five meter incline on the right bank which levels off and extends into open grassland with little emergent vegetation. The upper habitat units (P-04 to P-06) exhibit the opposite with the left bank having the upslope of two to five meters, which levels off to grassland. The right bank is flat with the exception of the depression of the floodplain and a slight incline to the road which is 20m-40m away from the stream. Large granitic and sandstone boulders are present in, and around, the stream in the floodplain. Medium sized gravel and cobble are present above the left bank in the lower habitat units of the reach (P-01 to P-04) and above the right bank in the upper habitat units of the reach (P-05 and P-06). The percent canopy coverage varies widely from habitat unit to habitat unit (measurements are presented in Individual Habitat Units, below).

(In-Stream)
Sandstone slab formations are a dominant geomorphological feature of the stream bed and banks. The sedimentary bedrock lines most of the streambed and is not covered by transported sediments. Slab uplift, as well as natural deposition of large organic debris, correspond with pool formation. The reach is also characterized by low gradient riffles and long runs. The gradient of the study reach ranges between 0.0% to 2.0%. The average gradient for the entire reach is 1.2%. The stream channel profile is inverse trapezoidal and exhibits little incision. The average stream width is 5 m and the depth is 25 cm. Large granitic and sandstone boulders are scattered along the reach. Cobbles are scattered amongst the boulders and line the watercourse along the floodplain. The stream holds low amounts of organically derived sediment and debris. Several pools contain relatively small sediment deposits. Lower bank stability ranges between stable and moderately

unstable and disruptive pressures are evident. Cattle crossings through the stream are noted in several areas of the study reach. The instream vegetation consists of young willows, mint, Equisetum, mugwort, grasses, sedges growing in the cracks in the bedrock, several submerged mosses, filamentous algae, and *Nostoc* colonies. Differentiation between these understory and groundcover species and those of the near stream area is nearly impossible, as many species occur widespread in both areas. Aquatic snails are abundant throughout the reach.

(Individual Habitat Units)
There are eighteen individual habitat units reported for the reach. These units correspond to a total running length of 381.1m from the bottom of the reach (start) to the top (end).

Habitat Unit #1 - P-01 (13.6 m) (0.0 - 13.6 m) (0.0%)
P-01 is characterized by sedimentary slabs and a bedrock-lined substrate. Erosion of the bedrock formed the water channels at the head and tail of the pool. The upper left bank has some large rocks and a pile of woody debris in the pool just below two dead snag trees. The rest of the bank is uniform. The upper right bank has a large slab of bedrock defining that portion of the pool. The rest of the right bank is uniform. P-01 averages 6.0 m wide, 35 cm deep, a maximum pool depth of 52 cm, and a riffle crest of 12 cm. There is an 80% vegetative cover on the left bank and a 90% vegetative cover on the right bank. The pool is symmetrical and rectangular. Very little cobble, moderate amounts of decaying organic matter/debris, and a high percentage (85%) of canopy coverage from box elders characterize the pool. Box elders are the dominant midstory and understory species. With the exception of a small amount of debris in the upper left section, the pool is free of major disruptions. The 1994 measured length was 18.1 m.

Habitat Unit #2 - NC-01 (14.0 m) (13.6 m - 27.6 m) (1.5%)
This is a non-criterion site. The percent total canopy coverage measured was 50%. No other site-descriptive measurements were taken at any of the NC or NSP (non-sampled pool) habitat units.

Habitat Unit #3 - P-02 (14.1m) (27.6m-41.7m) (0.0%)
The field crew in 1994 determined that P-02 and P-03, which are directly adjacent to one another in the stream, should be measured and considered as one pool. The length measurement for the combined pool is be 19.6 m. P-02 averages 9.0 m wide, 43 cm deep, with a maximum pool depth of 60.0 cm, and a riffle crest of 15cm. An old cattle crossing is evident at the bottom of the pool. No sediment appears to be currently entering the water from the cattle crossing. The 1994 measured length of P-02 was 7.5 m (See Habitat Unit #4 for written description).

Habitat Unit #4 - P-03 (11.5 m) (41.7 m - 53.2 m) (0.0%)
Both P-02 and P-03 are characterized by sandstone bedrock substrate. The head and upper half of P-03 is defined by large uplifted slabs of bedrock and large root masses in the upper right portion of the pool. The tail of P-02 is defined by boulders and a collection of small woody debris. The left bank of both habitat units is fairly uniform. The right bank is bedrock defined and is a series of points and clefts in which sedges and other groundcover species grow. P-03 averages 6.6 m wide, 55 cm deep, with a maximum pool depth of 87.0 cm, and a riffle crest of 31.0 cm. The overstory at both habitat units is absent. Midstory is dominated by box elders, the understory by willows, wood rose, and young alders, and the groundcover by sedges, mugwort, mint, dandelion, fireweed, grasses, and Rumex. P-02 has a 0% vegetated left bank and a 70% vegetated right bank. P-03 has an 80% vegetated left bank and a 50% vegetated right bank. Canopy coverage is provided by midstory willows (65% for P-03 and 50% for P-02). Moderate amounts of decaying organic matter/debris line the bottom of both pools. A large sediment bar extends from the upper right portion of P-03 downstream through P-02. The lower portion of the sediment bar in P-02 is vegetated with grasses, Equisetum sp., and sedges. A portion of both pools flows to the right of the bar. Medium-sized boulders are scattered along the left side of P-03, terminating at the 1993

riffle crest for P-03 defined by boulders and woody debris on the left bank. P-02 is more dominated by assorted boulders and the large sediment bar than is P-03. The 1994 measured length of P-03 was 11.1m.

Habitat Unit #5 - NC-02 (24.1 m) (53.2 m - 77.3m) (0.5%)

Habitat Unit #6 - R-01 (12.3 m) (77.3 m - 89.6m) (2.0%)
Riffle #1 is characterized by exposed sandstone and shale bedrock substrate. The head of the riffle is defined by uplifted bedrock slabs. The left side of the riffle is exposed bedrock. Cobbles and little sedimentation are present on the right side of the riffle. The banks are 70%-80% covered with vegetation. A few overstory cottonwoods are present on both streambanks but provide no canopy coverage. Coverage appears minimal and is provided by midstory alders. Midstory box elders are present on the left bank, and oregon ash on the right bank. Groundcover species include Equisetum sp., hound's tongue, Artemisia menziesii, tall clover, and Osmorrhiza sp. A filamentous green algae covers submerged rocks. The 1994 measured length of R-01 was 10.6m.

Habitat Unit #7 - NC-03 (76.0 m) (89.6 m -165.6 m) (1.0%)

Habitat Unit #8 - V-01 (11.0 m) (165.6 m - 176.6 m) (0.0%)
Run #1 has a mean width of 2.9 m, mean depth of 57 cm, and a maximum depth of 76 cm.

Habitat Unit #9 - NC-04 (12.5 m) (176.6 m - 189.1 m) (2.0%)

Habitat Unit #10 - P-04 (10.3 m) (189.1 m - 199.4 m) (0.0%)
P-04 is defined by bedrock substrate with moderate amounts of sediment. The head of the pool is cobbled. The tail of the pool is bedrock. The left bank of the pool is relatively straight, rises 1.5 m and abruptedly rises to a vetical rock face. Three dead alders, flanked by sedges, are mid-pool on the left bank. The right bank of the pool is defined by a series of bedrock slabs which extend into the pool, creating a series of points and recessions. Sedges grow in the cracks in the bedrock. The right bank slopes gently for about 4 m, then flattens out. P-04 averages 4.1 m wide, 66 cm deep, with a maximum pool depth of 73 cm, and a riffle crest of 14 cm. The left bank vegetative cover is 40%, and the right bank is 20%. P-04 has 0.0% canopy coverage. Midstory oregon ash are scattered along both banks of the pool. Young willow, sedges, Equisetum sp., and fireweed are the dominant understory and groundcover species. Five small rocks are exposed in the mid-channel upper section and one large boulder just above the riffle crest on the left side of the channel. The gravel access road is 15-20 m from the stream on the right side.

Habitat Unit #11 - V-02 (12.1 m) (199.4 m - 211.5 m) (0.0%)
Run #2 has a mean width of 3.5 m, mean depth of 35 cm, and a maximum depth of 60 cm.

Habitat Unit #12 - NC-05 (41.2 m) (211.5 m - 252.7 m) (2.0%)

Habitat Unit #13 - P-05 (13.6 m) (252.7 m - 266.3 m) (0%)
P-05 is formed by raised bedrock slabs, several of which extend perpendicular to the current from the left bank. Erosional sediments line the bottom of the pool. A downed cottonwood and assorted woody debris have collected at the bottom of the pool. The left side of the pool is defined by intruding slabs of bedrock, in the cracks of which sedges grow. The left bank is a steep 6.0 m high rocky soil embankment which is sparsely vegetated with a few midstory alders and dead grasses. The right bank is a slightly elevated soil and cobble mix with some exposed gravels at the upper left of the pool and about 15 m to the right of the stream where the stream's floodplain exists. P-05 averages 5.8 m wide, 60 cm deep, with a maximum pool depth of 68.0 cm, and a riffle crest of 18.0 cm. A 40% vegetative cover exists on the left bank, and a 70% vegetative cover on the right

bank. The overstory is digger pine. The midstory is comprised of cottonwood, digger pine, and box elder, the last of which provides canopy coverage of about 20% of the pool. The understory is willow and spice bush, and the primary groundcover species are grasses, wood rose, thimble, mint, sedge, Ceanothus sp., fireweed, oregon ash, and Equisetum sp. A large granitic boulder and sandbar displace approximately 25% of the pool volume and are situated along the right side of the pool: the boulder at mid-pool, and the sediment bar immediately below the boulder. Several large boulders (1.5 m - 2 m wide) are in the lower right portion of the pool below, and adjacent to, the sediment bar. To the right of the large sediment bar is a backwater channel that is filled with organic debris. The 1994 measured length of P-05 was 14.6 m.

Habitat Unit #14 - NC-06 (52.9 m) (266.3 m - 319.2m) (1.0%)
The precise physical location of R-02 within NC-06 is not recorded. R-02, although listed as H.U. #17 (actually R-03) in the 1993 Habitat Inventory forms, is somewhere within the length of H.U. #14 (NC-06). R-02 measures 10.3 m in length (this length is accounted for in the running reach length of Habitat Unit #14). See HU #14 (portion) below for R-02 written description.

Habitat Unit #14 (portion) - R-02 (10.3 m) (not recorded) (not recorded)
Riffle #2 is characterized by cobbles lining both sides of the channel. Cobbles in the channel are marginally embedded (50% - 70% surrounded by fine sediment). Woody debris lies at the head of the riffle. Streambank vegetation provides greater than 90% coverage on both banks. Midstory box elders are present on both banks. Canopy coverage averages 30%. Groundcover species present include Equisetum sp., Carex sp., hound's tongue, and filamentous algae on rocks in the water.

Habitat Unit #15 - P-06 (15.4 m) (319.2 m - 334.6 m) (0.0%)
P-06 is bedrock dominated. The head of the pool is narrow and defined by eroded bedrock slabs and exposed rocks. Medium sized rocks line, and are exposed at, the lower portion of the pool. The bottom of the pool contains more cobbles than the upper portion. The left bank is quite uniform, with some bedrock slab and rocks in the upper corner of the pool. The right bank is less uniform, but is relatively straight. The pool is fairly symmetrical and rectangular. P-06 averages 6.4 m wide, 53 cm deep, with a maximum pool depth of 60 cm, and a riffle crest of 22 cm. Sediment load is moderate to high, much of which is organic. Canopy coverage is about 90%, provided by understory and midstory box elders, as well as willows. 50% vegetative cover exists on the left bank and 90% vegetative cover on the right bank. All vegetation strata are identical to that of P-05. A large granitic boulder sits at the bottom-right corner of the pool. Some medium-sized rocks are exposed in the middle-left and lower portions of the channel. An abandoned log landing extends from the left bank out 20 m along the entire length of the pool. Grasses and young willows on both sides of the pool have been heavily grazed. The gravel road is about 20 m from the stream on the right side. The 1994 measured length of P-06 was 15.9 m.

Habitat Unit #16 - NC-07 (9.1 m) (334.6 m - 343.7 m) (0.5%)

Habitat Unit #17 - R-03 (15.9 m) (343.7m - 359.6 m) (1.0%)
R-03 is characterized by soil and bedrock banks. The left bank is uniform and composed of soils and cobble. The right bank is bedrock and soil and forms a jagged point bar formation. Midstory and understory spice bushes, willows, and cottonwoods line the left bank. Several willows exist at the top and bottom of the right bank. Groundcover species on the right bank point bar include Veronica sp., Trifolium sp., Mentha sp., Lepidium sp., and Verbascum thlaspi. Percentage of canopy cover was not measured for R-03. Exposed rocks line both sides of the riffle, with a greater concentration in the lower portion of the unit. Habitat Unit #17 is listed incorrectly in the 1993 Habitat Inventory forms as R-02. See H. U. #14 for explanation.

APPENDIX C

ASSESSMENT TECHNIQUES

ASSESSMENT TECHNIQUES

The upstream limit of the study reach is usually fixed first on the basis of proximity to timber harvest activities, reach integrity, and physical access. A permanent reach marker is placed in a secure spot not subject to removal by seasonal flows or maintenance activities. The distance and bearing to the start of the study reach is recorded. Photographs are taken of the permanent reach marker and its relationship to the upper edge of the study reach.

The permanent marker is a four or six foot steel reinforcing bar. The bar is driven into upper bank soil and/or wedged between larger rocks until immovable. Placement near an obvious landmark or readily visible from the access is preferred. A four inch square brass tag is inscribed with reach identification information and fixed to the eye on the reinforcing bar with heavy wire. Florescent paint is sprayed on the bar and the tag. Measurements are metric and recorded on standardized data sheets (see Appendix D). A listing of equipment and supplies necessary for each assessment technique is included in Appendix G.

All macro-invertebrate sampling must be conducted prior to any other in-channel assessment is started.

Habitat Inventory.

Preliminary habitat typing is conducted downstream of the upstream permanent reach marker. Walking downstream, but not within the channel, each successive habitat unit is preliminarily identified and delineated with flagging. Preliminary habitat typing continues until six pools (P), three runs (V), and three riffles (R) are encountered and their lengths measured, or until 1000 m of study reach have been traversed. Identified pools, riffles, and runs that don't meet the criteria for sampling or are within the reach but in excess of the numbers needed (6,3,3) are indicated as non-criteria (NC). Reach portions that cannot be classified as a pool, a run, or a riffle are indicated as non-sampled (NS).

An in-stream, near-stream, and side channel reconnaissance is conducted upstream from the upstream permanent reach marker for 1000 m. If the channel branches with significant flow in more than one channel, the reconnaissance is conducted along all branches to an aggregate of 1000 m. Using a hip-chain to determine distance from the permanent reach marker, the observer records channel characteristics, current land practices, and evidence of historical land uses that may affect in-stream conditions. Observations center on the in-stream channel, include the near-stream corridor, and extend up-slope to include features that may introduce sediments into the channel or otherwise effect parameters to be measured. The reconnaissance is ended if channel alterations (ie., water diversion), channel events (ie., crossing failure), or upslope events (ie., landing failure) are present and may introduce materials or change parameter levels more than that expected from the associated land practices being monitored.

Information analysis is performed through the construction of species lists and metrics. The occurrence of certain species or groups of species is considered indicative of specific habitat types and conditions, as presented in the literature. analytical procedures included ANOVA (analysis of variance), and other statistics created specifically for the assessment of macro-invertebrates.

Channel Typing.

Once the preliminary habitat typing has been completed, sampling begins at the bottom of the reach and proceeds upstream. Habitat type units conform to Level II in Rosgen (1992) as clarified for California (Flosi and Reynolds, 1994). An upstream sampling direction reduces the possibility of sampling activities affecting subsequent sampling sites. Field crew members record the length and gradient of all the separate habitat units on the Habitat Inventory Form. The length is measured with a tape measure, and the gradient is measured with Abney level and stadia rod.

The gradient is determined by observing the percent gradient from unit downstream edge to upstream edge. An observer stands with their feet at water level holding the Abney level centered and balanced on the zero mark, while a cooperator holds the stadia rod with its base at water level directly in front of the person with the level. The cooperator holding the rod then informs the observer of their eye level height on the stadia rod, and marks the level with bright flagging. Next, the cooperator walks to the upstream edge of the habitat unit and places the bottom end of the stadia rod level with the surface of the water. The observer remains at the downstream edge of the habitat unit with their feet level with the surface of the water. The observer looks for the flagging on the stadia. The cooperator may assist in locating the flagging by pointing with a hand and extended finger. The observer centers the bubbles within the Abney level, then aligns the black lines in the level with the eye-level mark on the rod and reads the gradient off the percent scale. Typically, a recorder accompanies the observer and the cooperator and records data on the Habitat Inventory Form.

Length and gradient are recorded for each habitat unit in sequence from the downstream edge of the reach to the upstream edge of the reach. During gradient observation, any necessary adjustments are made to habitat type identification and unit upstream/downstream limit determination. Units designated as NC or NS are measured only for length and gradient. For all pools, riffles, and runs, the average width and depth are measured. Several widths and depths are observed by direct measurement by use of stadia rod or V* penetration rod.

Upon sampling the last habitat unit or encountering the 1000 m distance, the downstream end of the study reach is determined. A permanent marker is set similar to the upstream permanent marker.

Site descriptions are recorded for pools and riffles to indicate the placement of transects, sampling sites, and channel features. Pool and riffle site descriptions include significant plant species in the overstory, midstory, understory, and groundcover, and the average height of each layer. Also identified is the source and amount of shade, dominant vegetation, bottom substrate, bank morphology and general area composition, obvious sediment sources, local disturbances, sidestream influences (including drainages or rivulets), wildlife, or any other feature which may be of importance. Included within the site description is a cross-sectional diagram drawn from the bottom of the pool looking upstream, showing the bank slopes, riparian vegetation (overstory, midstory, and emergent), wetted edge of the pool, and any debris or rock formations present.

An areal diagram of each pool and riffle portrays the orientation of the habitat unit, major habitat features, location of significant vegetation, and sites of diagram cross-sections, transects, and sampling sites. Drawn to scale on a grid, the diagram correlates distance measurements and is documented with photographs. Pool features include: riffle crest, top of pool, wetted area of the pool, sediment/cobble bars, debris and rock formations in and out of the water, streambanks, nearby vegetation in the riparian corridor, emergent vegetation, and the area over the pool which is covered by tree canopy (labeled). One of the most important aspects of these drawings are the locations of the transects, as these as well as photographs may be used to explain questions arising in the V* data forms. All transects should be drawn as accurately as possible at the correct distances in the pool and show important features such as rocks or logs. The diagram also should reflect overhang and undercut banks, submerged or emergent logs, and rocks which define the pool but whose contribution to pool volume is difficult to determine.

Information analysis includes the incorporation of habitat data within site descriptions, and the correlation of changes in site parameters with changes in the macro-invertebrate fauna. During preliminary evaluation of site data, habitat typing documentation (field forms and photographs) facilitates the linkage of field data forms whose headers are not complete.

V-star (Pool Sediment).

Pool sediment sampling is conducted after the completion of downstream macro-invertebrate sampling. V-star (V*) measures the relative quantity of fine sediment in pools. The V-star sampling technique is a way to measure the sediment load in a particular pool between the armor layer on the bottom and the surface of the water. The following discussion is adapted from Knopp (unpublished, 1994).

The riffle crest measurement is used to determine the residual depth of a pool, and residual volume of a pool (the volume or depth of a pool, including sediment, filled to the brink of spilling). The riffle crest is found usually in an irregular arc at the transition between the lower edge of the pool (end of 0% gradient portion) and the riffle or next inventroy unit below the pool. The pool's lip, or riffle crest, is determined by measuring the depth of water at the deepest part of the pool's outflow. If the deepest section is indistinct, then a series of 4 to 6 measurements should be taken along the crest arc, and these averaged to estimate the pool's riffle crest depth. If the deepest section of the channel is obvious, then determine the riffle crest depth with one or two direct measurements. If the riffle crest occurs in loose, fine sediment, then the measurement must be taken to the bottom of the sediment. Probe the pool tail gravel above and below the apparent riffle crest to estimate the location of the actual buried riffle crest. Four to 6 measurements should be taken. However, the riffle crest should occur on the hard scoured channel, in which case the measurement rod should not be forced into the gravel.

Transects are located to define the morphology and sediment deposited in the pool. Find the most representative locations by initial probing with the V* penetration rod. A tape is used to determine the overall pool length and provide a reference for the cross sections. The meter tape should be anchored to the head and tail of the pool. The tape should be left in place while the cross sections are measured. A minimum of 4 transects are required for each pool. More complex pools may require 8 or more transects. Cross sections are defined with a second tape stretched at right angles to the longitudinal tape or a stadia rod laid perpendicular to the lengthwise tape. If the pool is curved, measurements are taken in distinct segments (the lengthwise tape is always straight, but may be in several sections at successive angles).

Penetration rod sampling is at variable intervals of about 0.5 meters so as to measure approximately 10 points across the pool. All measurements start from the same stream bank. Sample points include depth changes in the cross section and as necessary to best define the pool's sediment cross-section. Unusual or peculiar site characteristics are recorded on the areal diagram.

Each measurement along a transect defines the center of a measurement cell defined by 3 numbers; distance from the bank, water depth, and depth to the bottom of the scoured pool from the surface of the water. The cell extends halfway to the next transect (unless a different proportion is specified during data analysis program execution). The cells associated with the first and last transects extend to the start or end of the pool. If the pool narrows at the head or tail, transects should be placed near the ends to minimize measurement error. The largest volume in the pool occurs where the residual depth is greatest. Errors in shallow sections are relatively unimportant.

Therefore, place transects to minimize errors resulting from the data analysis program area algorithm and to emphasize water and sediment volumes.

Sediment collected in a pool is measured by probing the pool bottom with a steel rod at several points along several transects . The rod is pushed into the sediments by hand until the firm resistance of the scoured channel (the armor layer) is encountered. The armor layer at the bottom of the sediment column is typically at the limits of rod penetration by hand. Intermediate layers can sometimes be felt, but they should be ignored if the rod can be firmly pushed through. If clay is encountered, the penetration should stop at the depth of the clay. Clay can be easily recognized, both by feel and by the residue it leaves on the V* rod. Unlike the resistance of the scoured layer, clay yields slowly but retards rod penetration. After extraction, traces of clay remain on the rod and in the inscribed lines and numbers. Buried wood fragments typically are penetrated by the rod but rod removal is difficult. Wood fragments yield slowly to determined penetration and do not leave material on the extracted rod. Sometimes the rod encounters a rock laying in the sediment but above the scour depth. If a scour depth is grossly less than the two adjacent, another penetration may be placed close by on the transect to determine if the resistance is local and not the anticipated bottom layer.

Measurements are taken through the bank above and away from the surface of the water to a point where the pool depth is less than the riffle crest depth. There often arises the situation in which there is zero water depth, but the probe can still reach water which lies under the surface. This water,and sediment, is considered to be in the pool up to the point where the water measured under the sediment is less than the riffle crest depth.

Undercut banks are difficult to measure. Direct measurements can be made by probing through the bank or using a shorter V* penetration rod. If neither of these two options are feasible, measure the horizontal distance of the undercut with the rod, and estimate the water and pool depth by placing the rod in at an angle, measuring the water and pool depth, and then subtracting what was estimated to be the distance gained by placing the rod at an angle. Note that in pools where the undercut volume is insignificant, then no measurement (direct or estimated) may be necessary.

Information analysis is performed by running the custom application software written by Chris Knopp (1994). The software produces a V-star index for each sampled pool within the stream reach and an index for the entire reach. The software exports a data file which is run through DesignCad-2 for creation of pool transect cross-section diagrams.

Canopy.

Direct canopy measurements are taken by use of the spherical densiometer (observation of shade intercepting subdivisions of reflected sky)(Lemmon, 1956,1957) and sighting tube (overhead line-intercept observation). An indirect measure of canopy coverage includes basal area measurement by the Cruz-All. See Bell and Dilworth (1993) for the mathematical basis for canopy measurements. Portions of the sky blocked by the proximity and height of watercourse channels or ridges are measured by observing adjacent hillside slopes.

The spherical densiometer, a small hand held-device, is a mirrored lens with twenty-four equal-area etched squares on a concave mirror (model A). The lens is set into a wooden carrying case with hinged lid and small bubble level. The etched squares form a grid delineating a plot of the area over a sampling site. The observer levels the densiometer and notes the squares that include canopy. Care must be taken to keep the device at waist level in front of the observer, but without introducing the shadow of the observer into the sampled area. Each square is visually divided into four sections, thus creating a total of 96 sampling quadrants. Recorded average numbers are corrected in the office by applying the appropriate ratio (N x .96 or N x 1.04). The .96 factor is applied when closed squares are counted, the 1.04 factor when open squares are counted.

The presence of any living plant material within the sampling quadrant constitutes a 'hit' and is counted. Each of the intercepted or empty quadrants are counted and recorded onto the data sheet. For relatively open canopies, the intercepted quadrants may be quickly counted. Within closed canopies, counting the open quadrants is easier. The number of quadrants counted and whether they were 'open' or 'closed' is noted. At each sampling site, observations are taken in four opposite directions (facing upstream, turning to the right, facing downstream, and turning right again). The first observation is always taken facing upstream, and all subsequent readings proceed to the right (clockwise). Since the observations are a measure of density, the four samples should be taken directly over the same spot by the observer rotating around the densiometer. A series of observations is taken for each pool starting at five meters above the top of the pool, at the top of the pool, in the middle of the pool, at the bottom of the pool, and five meters below the bottom of the pool. All observations should be taken in the center of the stream channel. At the 95 per cent probability level, Lemmon (1956) showed that average measurements of the same overstory area can be expected to be within $\pm$2.4 per cent of the mean. For more discussion on the spherical densiometer, see Lemmon (1956,1957).

The sighting tube, another small hand-held device, is a PVC 'L' containing mirrors, and two levels. The sighting tube is used to obtain a point-intercept measure of canopy directly overhead of the middle of the stream channel. The observer views the canopy through the mirrors within the tube, while leveling both horizontally and vertically. A set of wire crosshairs and a dot on a mirror permits the observer to maintain the level and observe at a specific point. When these dots are centered on the horizontal axis, the crosshairs in the sighting tube show the point directly above the observer's head. Depending on the available light, the observer may be able to note both an intercept and the species of tree seen. Under lower light levels and where footing is uncertain, a recorder may note the intersept and determine the species. These measurements are taken at five meters above the pool, half way to the top of the pool, at the top of the pool, at two places equidistant between the top and middle of the pool, at the middle of the pool, at two places equidistant between the middle and bottom of the pool, at the bottom of the pool, half way between the bottom of the pool and five meters below the bottom of the pool, and at five meters below the bottom of the pool. Again, the observer should stand in the center of the stream channel.

Basal area (standing crop of trees) is measured by the use of the Cruz-All. A small, hand-held die-cut aluminum plate attached to a string, the Cruz-All has slots of different widths cut through it which represent four size classes. A tree is noted as being within one of the four size classes (5, 10, 20, and 40) if it is wider than the class in question but narrower than the next larger class. A valid sample is taken when the Cruz-All is held a set distance away from the eye of the observer (the length of the string attached by the manufacturer to the Cruz-All) and the observer rotates about a fixed spot. The observer then compares the trunk (at DBH) of each tree visible from the sampling site through the Cruz-All openings. The observer does not move in order to better see tress located behind others. Trees hidden behind other trees are not recorded. The Cruz-All is kept above the same spot for all samples at a single site. Observations are taken at the top, middle, and bottom of each pool.

The canopy coverage which results from sun interception by ridgelines and channel sides is measured as the hillslope on the right and left banks (looking upstream). Slope is estimated by use of a clinometer, a small hand held device which measures both percent and degree angles. The observer holds the clinometer near an eye and looks upslope to a point at an equal height above the ground surface. By looking at the point with the uncovered eye, and centering the line in the

Macro-Invertebrates.

As stated earlier, work in riffles should be completed before sampling in any section has begun. It is important to sample for macro-invertebrates before performing RASI (riffle armor stability index) sampling so as not to disrupt the fauna to be sampled, or their habitat. Each riffle unit used for biological assessment must be approached from downstream and no portion of the riffle walked on until all sampling is completed.

The California Stream Bioassessment Procedure (CSBP) closely follows the Rapid Bioassessment Protocol (RBP III) for benthic macroinvertebrates as outlined by the U.S. Environmental Protection Agency (EPA) in Rapid Bioassessment Protocols for use in Streams and Rivers EPA/444/4-89-001 (Plafkin et al, 1989) and has been used successfully by CDFG to detect point source pollution. The CSBP has been used to determine impacts of fish hatchery effluent (organic pollution) to the receiving waters of the Hot Creek Hatchery, Mono County (Harrington, 1993a) and to establish evidence for pollution cases involving Fish and Game Code 5650.

The three riffles in each monitoring reach are sampled for macro-invertebrates starting at the downstream riffle. Three transects are selected by choosing three numbers using a random number table and locating those numbers along a graduated metric tape placed on the bank along the length of the entire riffle.

Starting from the downstream transect, macro-invertebrates are collected by placing a D-shaped kick-net (0.8 mm mesh) on the substrate and disturbing a 30 x 60 cm section upstream of the kick-net. Cobbles are picked up and scrubbed by hand under water in front of the net. Three locations are sampled along the transect and combined in the kick-net. In riffles with well graded substrate, the three locations are at the side margins and the center (thalweg) of the stream. In complex riffles, locations are altered to include all habitats such as leaf-packs, in-stream vegetation and woody debris. The contents are placed in a tray and large organic material is removed by hand while carefully inspecting for clinging organisms. The remaining material is placed in a plastic jar, labeled and filled with 70% ethanol.

Samples are submitted to the Department's Water Pollution Control Laboratory (WPCL) in Rancho Cordova along with a Chain of Custody (COC) card and stored in the WPCL Sample Depository (according to established CDFG Laboratory Quality Assurance Procedures) until processing.

Physical habitat assessments are performed at each riffle using the Physical Habitat Assessment Protocol - Level 1 as outlined by EPA Region 10 (Hayslip, 1993). Habitat parameters 1 through 4 (bottom substrate - percent fines, instream cover, embeddedness and velocity/depth) are considered primary condition factors and scored numerically between 0 and 20 within four categories from poor to optimal condition. The entire riffle is evaluated with emphasis on the substrate along the transects. The remaining habitat parameters (channel shape, pool/riffle ratio, width to depth ratio, bank vegetation protection, lower bank stability, disruptive pressures and zone of influence) are considered secondary and tertiary parameters and are scored numerically between 0 and 15 and 0 and 10, respectively within four categories from poor to optimal condition. The evaluation is performed over a larger stream area, primarily in an upstream direction where conditions have the greatest impact on the riffle community being sampled.

In the laboratory, sample jars are removed from the WPCL Sample Depository, opened and the contents placed in a gridded (5 cm^2) white enameled tray. The sample material is then evenly distributed on the bottom of the tray. For the 1993 collections, 100 macro-invertebrates are removed from randomly chosen grids. The remainder of the sample material is redeposited into the sample jar and returned to the WPCL Sample Depository.

Macro-invertebrates are identified to lowest taxonomic level using Allen and Edmunds (1962); Brinkhurst (1986); Brown (1972); Edmunds et al (1976); Merritt and Cummins (1984); Pennak (1991); Stewart and Stark (1993); Weaver (1988); Wiggins (1977); Usinger (1963). Specimens of each taxon of identified macro-invertebrates are placed in individual glass vials and maintained within the reference collection in the WPCL Sample Depository.

Data Analyses include the creation of taxonomic lists, diversity indices, and bioassessment metrics. Statistics are generated for each of the samples using a custom application (template) developed in Micosoft Excel®. Functional feeding groups are assigned to each taxon using Merritt and Cummins (1984) and other unpublished information on regional aquatic macro-invertebrates. The evaluated bioassessment metrics include:

Species Richness: total number of genera and/or species present.

Modified Hilsenhoff Biotic Index: the index (based on Hilsenhoff (1987)), summarizes family level tolerance values ranging from 0 to 10, increasing as water quality decreases. The Hilsenhoff Biotic Index was developed for eastern states, so Plafkin et al (1989) recommends modification to tolerance values for western species.

Percent Contribution of Dominant Taxon: ratio of numerically dominant taxon to the total number of organisms.

EPT Index: total number of distinct taxa within the insect orders Ephemeroptera, Plecoptera and Trichoptera.

A diversity index value, such as in Shannon and Weaver (1963), is calculated for each subsample. Means and coefficients of variation for the biotic metrics are calculated for each riffle using the Systat® application software. Multivariate statistical procedures (cluster and principal component analysis) and graphical analysis is also performed using the Systat® software. The analyses identifies populations of macro-invertebrate assemblages and determines relationships between biotic and physical parameters.

Riffle Armor Stability Index.

The riffle armor stability index (RASI) is determined by measuring particle sizes in the riffles used for macro-invertebrate sampling. The particle size distribution of materials in the riffle are sampled according to the 'Wolman Pebble Count' (Wolman, 1954). Our procedure is drawn largely from Kappesser (1992, 1993a, 1993b).

Two hundred sampling sites are arranged in transects perpendicular to stream flow. Particles are measured at approximately equal intervals across each of the transects. Transects are distributed at equal intervals from the top to the bottom of the riffle. There is no set number of transects per riffle or points per transect. However, transects should include the top, middle, and bottom of the riffle. Points should include the entire width of the riffle (bankfull edge to bankfill edge). Once the interval between points is established, the location of each point may be fixed by laying a stadia rod along the transect. The interval between sample points on a transect should be consistent for all transects throughout the riffle.

At the sampling point, a finger is extended vertically down into the sediment at the bottom of the water column. The first particle encountered is measured. Particle size is tallied within size classes: 1 (<2 mm), 2 (2 - 4 mm, 3 (4 - 8mm), 4 (8 - 16 mm), 5 (16 - 32 mm), 6 (32 - 64 mm), 7 (64 - 128 mm), 8 (128 - 256 mm), 9 (256 - 512 mm), 10 (512 - 1024 mm), and 11 (>1024 mm). The first 200 particles are counted. A flexible, transparent plastic ruler may be used to directly measure the particle size.

Information analysis is performed by use of custom application software created by Kappesser (1992, 1993a, 1993b). The software produces an index number, the riffle stability index, for the study reach.

D50.

The estimate of the largest particle size moved in the stream is based on measuring thirty (30) of the largest particles encountered in a fresh bar or other depositional area. Since only recently moved particles should be sampled, particles that are embedded, differ in color from most of their peers, or support epiphytic growth or attachments, should be discarded. The depositional feature is searched thoroughly to locate and measure the largest particles that appear to have been recently moved.

Depositional areas may occur in different locations in the stream (point bars, central bars, or behind constrictions. The downstream portion of the point bar should be sampled. For each particle sampled, then intermediate axis is measured and recorded to the nearest millimeter. A flexible, transparent ruler may directly measure the particle size. The intermediate axis is the axis defining a circle which is the smallest through which the particle may fit. Obviously, a shorter axis allows only a portion of the particle to pass, while a larger axis passes the particle in several orientations.

Information analysis is performed by use of custom application software created by Kappesser (1992, 1993a, 1993b). The software determines the maximum sediment size transported by the study reach.

APPENDIX D

FIELD DATA FORMS

List of Forms

Habitat Inventory Form (1-1)

Pool/Riffle/Run Diagram (2-1)

RASI "D" Index (3-1)

Stream Bioassessment (5A)

Canopy Measurements

HABITAT INVENTORY FORM

page #___of___

DFG IN-STREAM PMP STUDY DATA FORM 1-1

Date ___/___/___ Stream Name ____________________ T___ R___ S___

REFERENCE POINT UTM N___ E___

Surveyors____________________

Channel Type_____ Reach #_____ Time_____ Air T°_____ Water T°_____ Flow _____

Habitat Unit Number							
Habitat Unit Type							
Side Channel Type							
Mean Length							
Gradient (%)							
Mean Width							
Mean Depth							
Maximum Depth							
Depth Pool Tail Crest							
Stream Shelter Value (1 to 4)							
% Unit Shelter [redacted]							
% undercut banks							
% swd (d<12")							
% lwd (d>12")							
% root mass							
% terrestrial veg.							
% aquatic veg.							
% white water							
% boulders							
% bedrock ledges							
Percent Total Canopy >30cm							
Right Bank dominant type*							
% Right Bank vegetated							
Left Bank dominant type*							
% Left Bank vegetated							

* **Bank composition types:** 1. bedrock/rock 2. boulder 3. cobble/gravel 4. bare soil 5. grass 6. brush 7. trees

Unit #	Comment

POOL / RIFFLE / RUN DIAGRAM
DFG IN-STREAM PMP STUDY DATAFORM 2-1

Date: ____________ Crew Members: ____________

Reach Number: ________ ____________

Riffle/Run/Pool Number: ________ ____________

Stream: ________ Scale 1 cell = ________

RASI "D" Index

DFG IN-STREAM PMP STUDY DATA FORM 3-1

Stream: ____________________

Date: ____________________

Crew Members: ____________________

Reach Number: __________

Riffle Number: __________ Dist. ______

Depositional Measurements (30), Use fresh depositional feature. Point Bar ___ Stream ___

Pebble counts accros Riffle (200)

<2mm	2 - 4mm	5 - 8mm	9 - 16mm	17 - 32mm	33 - 64mm	65 - 128mm	129 - 256mm	257 - 512mm	513 - 1024mm

PILOT MONITORING PROGRAM
DFG-IN STREAM COMPONENT

STREAM BIOASSESSMENT

DATA FORM 5A \PMP_01:\FORMS\MACRO.001 (3 MAY 1994)

STREAM REACH ____________ WATERSHED ____________________ SAMPLE ID ____________

RIFFLE # __________ DATE ____________ TIME ____________ WPCL # ________

WATER TEMP (°C) __________

RIFFLE LENGTH (M) __________

TRANSECT INTERSECT

#1 (M.CM) ________

#2 (M.CM) ________

#3 (M.CM) ________

CREW MEMBERS

____

____

____

____

HABITAT ASSESSMENT PARAMETERS
(FILL IN AFTER FIELD DATA REVIEW)
(REFER TO HANDOUT FOR DEFINITIONS)

1. BOTTOM SUBSTRATE ___
2. INSTREAM COVER ___
3. EMBEDDEDNESS ___
4. VELOCITY / DEPTH ___
5. CHANNEL SHAPE ___
6. POOL / RIFFLE RATIO ___
7. WIDTH / DEPTH RATIO ___
8. BANK VEGETATION ___
9. LOWER BANK STABILITY ___
10. DISRUPTIVE PRESSURES ___
11. ZONE OF INFLUENCE ___

COMMENTS ____

____

____

____

____

CHAIN OF CUSTODY

	RELEASED BY	RECEIVED BY	DATE
COLLECTOR	____________	____________	________
TRANSPORTER	____________	____________	________
TRANSPORTER	____________	____________	________
TRANSPORTER	____________	____________	________

Canopy Measurements

Stream: ____________________
Date: ____________________
Reach Number: ____________________
Habitat Number: ____________________

Crew Members: ____________________
____

SHERICAL DENSIOMETER

Location	Readings				Open/Closed (O/C)
Top + 5m	____	____	____	____	____
Top	____	____	____	____	____
Middle	____	____	____	____	____
Bottom	____	____	____	____	____
Bottom + 5m	____	____	____	____	____

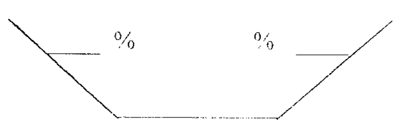
SIGHTING TUBE

Top + 5m ____
____
Top ____
____
____
Middle ____
____
____
Bottom ____
____
Bottom + 5m ____

BASAL AREA (CRUZ - ALL)

	Top	Middle	Bottom
5			
10			
20			
40			
Total			

HILLSIDE SLOPE (Looking Upstream)



APPENDIX E

IMPLEMENTATION TRAINING

IMPLEMENTATION TRAINING

I. IMPLEMENTATION TRAINING CONCEPT

Use of the studied assessment techniques depends on how well they can be implemented. The program has presented a process for deciding which techniques may be useful in different areas. The training to facilitate the use of the assessment techniques then focusses on the decision making process. The following training curriculum is based upon the Watershed Academy core course and technical field module presented during August and September of 1995.

Within the context of watershed assessment, participants are presented with basic concepts involving the physical and biological features creating the unique setting of each watershed. Physical factors are presented as they define the habitat of the biological resource of interest. To describe such habitats, participants are introduced to the life histories of species targeted for management. Within the description of the life history, the physical factors that exert major influence during periods when the species is vulnerable are detailed. Then, the possible relationship between upslope and upstream activities and resultant downstream habitat changes are better clarified.

The watershed academy is a structured approach to presenting the basics of watershed assessment. The core course is the foundation for later emphasis on specific techniques or physical parameters, depending upon the interest of the participant. The subsequent technical field module is designed around specific field assessment techniques and information analysis systems.

Managers responsible for resource recommendations and those designing field monitoring projects can increase their conceptual and technical competency by attending the core course and relevant technical modules. Field crew members or data keyers may more appropriately attend only the technical module (or, a portion of the field course). The breadth of training necessary can be based on the degree of responsibility for planning and managing the monitoring effort.

II. WATERSHED ACADEMY

A) ***<u>Core Course</u>***

Day One, Afternoon Session: Begin at 1300 hrs.

Welcome
<u>Mr. Jim Steele - DFG</u>

1) **Introduction**
<u>Instructor: Mr. Norm Benson - CDF</u>

- general course overview
- course objectives
- expectations of participants
- ground rules and housekeeping matters

2) **Authorities for Watershed/Cumulative Effects Analyses**

<u>Instructor: Mr. Jim Steele - DFG</u>

- California Environmental Quality Act
- California Endangered Species Act
- Fish and Game Code

<u>Instructor: Mr. Frank Reichmuth - NCRWQCB</u>

- Porter-Cologne
- water quality standards and basin plan objectives
- Federal and State anti-degradation policy

<u>Instructor: Mr. Pete Cafferata - CDF</u>

- Forest Practice Act
- Board of Forestry rules

3) **General Overview of the Watershed Analysis Process**
<u>Instructor: Mr. Michael Furniss - USFS</u>

- watershed definition
- resource assessment to determine present watershed condition
- identify hazards and evaluate resource risk
- develop avoidance, mitigation or restoration measures
- monitoring and feed-back loops

Day One, Casual Evening Get-to-Know Each Other and Barbecue: Begin at 1800 hrs.

Day Two, Morning Session: Begin at 0800 hrs.

4) **Biological Resources to Be Considered**

4a) **Fish Biology and Life History**

Instructor: Dr. Terry Roeloffs - HSU Foundation

- species identification
- life history requirements
- habitat quality relative to the five watershed input products
- how fish interface with physical parameters and their habitat
- human impacts on fish populations
- limiting factors
- fish habitat sensitivity
- sampling techniques and tools

4b) Aquatic Amphibian Biology and Life History
Instructor: Mr. Brad Valentine - CDF

- species identification
- life history requirements
- habitat quality relative to the five watershed input products
- how amphibians interface with physical parameters and their habitat
- limiting factors
- amphibian habitat sensitivity
- sampling techniques and tools

4c) Benthic Macroinvertebrates
Instructor: Mr. Jim Harrington - DFG

- stream ecology
- benthic macroinvertebrate diversity and function
- benthic macroinvertebrate identification
- benthic macroinvertebrate habitat sensitivity
- sampling techniques and tools

Day Two, Afternoon Session: Begin at 1300 hrs.

5) Watershed Process Theory

5a) Hydrology
Instructor: Mr. Randy Klein - HSU Foundation

- processes affecting water delivery to stream systems
- baseline flow and peak flow
- rain-on-snow events
- surface versus sub-surface flow
- estimating flood flows
- human impacts on hydrology and how have they impacted fish populations
- sampling techniques and tools

5b) Fluvial Geomorphology
Instructor: Dr. Bill Trush - HSU Foundation, Mr. Randy Klein - HSU Foundation

- stream bedload material particle size in relationship to flow and land use
- stream processes as a continuum
- linking hydrology to sediment transport

- watersheds at high risk to large storm events
- stream crossings and how they affect fish populations
- stream channel morphology, structure and function
- sampling techniques and tools

5c) Riparian Function
Instructor: Dr. Bill Trush - HSU Foundation

- definition of riparian areas and how they are formed
- key riparian functions: shading, bank stability, sediment storage, LWD
- riparian stand structure and composition
- riparian function relative to watershed input products, aquatic habitat, fish and amphibians
- riparian stand structure relative to stream channel condition during over-flow events when fish and amphibians need high flow escape cover
- riparian habitat sensitivity
- sampling techniques and tools

Day Three, Morning Session: Begin at 0800 hrs.

5d) Water Quality
Instructor: Mr. Gaylon Lee - SWRCB

- beneficial uses needing protection
- water temperature
- other physical water parameters that can affect biological resources
- sampling techniques and tools

5e) Geology
Instructor: Mr. Tom Spittler - DMG

- underlying bedrock geology as an indicator of significant erosion hazard
- hillslope processes
- dominant types of mass wasting features
- what constitutes high risk sites and locating them
- sampling techniques and tools

5f) Soils
Instructor: Mr. Michael Furniss - USFS

- surface erosion (sheet, rill, gully) from hillslopes
- surface erosion from roads, landings, residential sites, agricultural operations, mining operations, and other human activities
- soil productivity in relation to erosional processes and timber operations
- what constitutes soil-related high risk sites and how are they located
- sampling techniques and tools

Day Three, Afternoon Session: Begin at 1300 hrs.

5g) Watershed Processes
Instructor: Dr. Bill Weaver - HSU Foundation

- overview of watershed processes
- nature and types of driving forces causing watershed change
- watersheds naturally and artificially in-and-out of phase
- natural disturbance regimes: droughts, floods, fires and storms
- disturbance recurrence intervals - what's normal and what's important
- watershed sensitivity and response to annual and extreme events
- linking hillslope and stream channel processes
- stream channel morphology, structure and function
- five watershed input products: sediment, water, heat, large woody debris, nutrients
- routing of watershed input products to and through the stream system
- erosion, sediment delivery, storage and yield: the sediment budget
- sediment flux and sediment routing from headwaters areas to floodplain to estuary
- sampling techniques and tools

Day Three, Evening Session: Begin at 1930 hrs.

Instructor: Dr. Bill Trush - HSU Foundation

- fish habitat formation and alteration relative to the five watershed input products
- basin scale perspective
- sampling techniques and tools

Instructor : Mr. Brad Valentine - CDF

- baseline conditions, standards and thresholds against which to evaluate impacts from timber operations
- avoidance, mitigation, restoration and enhancement concepts in the context of watershed assessments

Day Four, Morning Session: Begin at 0800 hrs.

6) Gathering Available Information and Office Review Techniques
Instructor: Mr. Gary Stacey - DFG

- information sources and their location
- historical information from local or regional experts and various publications
- information regarding past and present land management activities
- information regarding natural conditions and events
- interpreting information used in the watershed analysis process
- reliability, limitations and resolution factors for information used in the watershed analysis process
- knowing when to ask for help from an expert

7) Determining Existing Stream Channel Form, Physical Attributes and Condition
Instructor: Mr. Tim Curtis - DFG

- stream order
- stream channel classification and typing
- stream habitat inventory including riffle-pool-flatwater ratios, canopy coverage, riparian zone site descriptions, large woody debris presence and recruitment

potential, and qualitative assessment of pool infilling and spawning gravel imbeddedness
- data management

8) Risk Assessment/Risk Analysis/Cumulative Effects

8a) Biological Parameters
Instructor: Mr. Jim Harrington - DFG

- benthic macroinvertebrate population structure as indicators of fish habitat condition, water quality and general watershed health
- concepts of bioassessment and biological criteria
- use of the California stream bioassessment procedure
- importance of reference conditions and the eco-region approach

Day Four, Afternoon Session: Begin at 1300 hrs.

Instructor: Dr. Bill Trush - HSU Foundation

- riparian habitat sensitivity
- aquatic habitat sensitivity
- fish sensitivity
- cumulative effects analysis for aquatic systems
- determining present rate of recovery from past impacts

8b) Physical Parameters
Instructor : Dr. Bill Weaver - HSU Foundation

- watershed "value" in regional salmonid habitat conservation and recovery strategy
- assessment of "key" watersheds, sub-basins, areas and sites
- determining representative stream reaches for use in conducting field analyses
- limiting factors and physical parameters for analysis
- sources of human-caused perturbation in watershed function
- watershed sediment risk assessment
  - conducting a watershed assessment
  - common sources of accelerated erosion and sediment yield
  - evaluating risk of future erosion
  - watershed and stream channel sensitivity to change
  - sediment routing pathways and efficiency
  - relationship between past and present natural events, land management practices, and erosion and sediment delivery
  - example results and findings
- avoidance, prevention, mitigation and restoration to minimize hazards
  - cost-effectiveness evaluation
  - implementation measures
- primary and secondary changes to watershed input products caused by land management practices
- cumulative effects analysis for physical processes
- determining degree, persistence and rate of recovery from past impacts

Day Four, Evening Session: Begin at 1930 hrs.

8c) Synthesis - Providing a Linkage between Watershed Assessments and Development of THPs, NTMPs and SYPs
Instructor: Mr. Jim Steele - DFG, Mr. Pete Cafferata - CDF

- limits of methodologies used versus conclusions reached
- reaching conclusions regarding resources at risk
- reaching conclusions regarding present watershed and stream habitat conditions, and present recovery rate from past impacts
- making decisions regarding proposed practices, impact avoidance, mitigation measures, restoration and enhancement activities
- incorporating watershed assessment results into the required cumulative effects analysis
- identifying appropriate practices and mitigation measures to be incorporated into the THP, NTMP or SYP

9) Record of Decision
Instructor: Mr. Tom Hoffman - CDF

- documentation of how agency decisions are reached
- basis for decision
- official responses

Day Five, Morning Session: Begin at 0800 hrs.

10) Monitoring

10a) Theory
Instructor: Mr. Gaylon Lee - SWRCB

- knowing why, when and what to monitor
- three types of monitoring: implementation, effectiveness and project
- establishing monitoring objectives and constraints
- sampling and statistical design
- establishing monitoring parameters
- determining sensitivity to management activities being monitored
- compiling results and interfacing with subsequent land management activities

10b) In-Stream
Instructor: Mr Stephen Rae - DFG

- site selection
- field assessment techniques
- quality assurance/quality control
- data management
- conclusions

10c) Hillslope
Instructor: Mr. John Munn - CDF

- site selection

- field assessment techniques
- quality assurance/quality control
- data management
- conclusions

11) Data Management
Instructor: Mr. Paul Veisze - DFG

- evaluating data submitted as the basis for reaching conclusions and developing proposed land management activities as described in a THP, NTMP or SYP
- information repositories (e.g. DFG's databases) and how to access them
- linkage to a GIS and the value in doing so

12) Course Evaluation
Instructor: Mr. Norm Benson -CDF

- instructor evaluation
- course evaluation
- participant evaluation (test)

Day Five, Course Ends at 1200 hrs.

B) ***Field Module***

Day One, Afternoon Session: Begin 1300 hrs.

Welcome

1) Preparation for Watershed Assessment and Evaluating Cumulative Effects

Discussions on tasks and decisions to be undertaken prior to conducting fieldwork.

- selecting an area for assessment
- preparing for assessment
- storm history
- air photo analysis
- review of fisheries data pertaining to habitat and fish presence
- review of temperature data
- field assessment: tools and techniques
- treatments: prescriptions, estimating costs, prioritizing
- peer review of assessments and prescriptions
- assessment reporting
- implementation: design and layout, contracting, logistics, specifications and performance
- monitoring and documentation
- implementation reporting

Day Two and Day Three, Morning and Afternoon Sessions: Begin 0800 hrs

2) **Field Assessment Techniques**

a) Hands-on exercises on hillslopes and in streams emphasizing issue identification, sampling site selection, parameter and assessment technique selection, and technique implementation. Problems anticipated during technique implementation, and their prossible resolution, are covered.

- Hillslope Issues

-problem recognition
-fill slope instabilities
-landing instabilities
-hillslope landslides
-stream-side landslides
-stream crossings
-road surface drainage
-surface erosion

-inventory procedures (hands-on techniques)
-data forms and categories
-site identification
-site location
-volume estimates
-treatment prescriptions
-production and cost estimates
-cost-effectiveness evaluation
-site sketches

-In-Stream Issues

-problem recognition
-sediment input to pools and spawning areas
-residual pool volume and sediment transport
-reduced shade canopy and increased water temperature
-effects of water flow
-reduction in large woody debris and channel simplification
-changes in nutrient cycling

-inventory procedures (hands-on techniques)
-V^{STAR}, RASI, D50
-bank-full discharge, fluvial geomorphic processes
-channel typing, habitat typing, large woody debris inventory
-rapid bioassessment of benthic macro-invertebrates
-shade canopy and temperature

b) Participants are divided into small groups (4-7) to facilitate group discussion and participant-instructor dialogue, to reduce equipment and supply demands, and to minimize habitat disruption. The groups undergo concurrent training, cycling among the concurrent sessions. Groups assigned to hillslope issues spend a half-day on problem recognition followed by a half day on inventory procedures. Groups assigned to in-stream issues cycle through each of four quarter-day sessions, then rejoin for a session on shade canopy and water temperature. The concurrent sessions are:

(Hillslope)
1) hillslope problem recognition
2) hillslope inventory procedures
(In-Stream)
3) V^{STAR}, RASI, D50
4) bank-full discharge, fluvial geomorphic processes
5) channel typing, habitat typing, large woody debris inventory
6) rapid bioassessment of benthic macro-invertebrates
7) shade canopy and water temperature

Day Four: Begin 0800 hrs

c) Synthesize results of field assessments relative to cumulative effects; develop mitigation measures, alternatives, and recommended treatment/restoration options.

All groups return for on-site facilitated discussions at key locations to examine evidence of cumulative effects, to determine watershed recovery rates relative to cumulative effects and potential impacts from future practices, and to develop mitigation measures, alternatives, and treatment/restoration options. Field demonstrations focus on completed hillslope practices (road upgrading, storm proofing, and road closures).

Day Five: Begin 0800 hrs

d) Application of Field Assessment Techniques Prior to Operations.

At a different site, the entire group reviews a proposed timber harvest operation and assesses associated hillslope and in-stream issues. A facilitated exercise to demonstrate the application of watershed assessment techniques, this wrap-up session provides an opportunity to examine a proposed project and its site, identify issues and develop resolutions, and compare workshop recommendations with plan components.

Discussions explore the usefulness of assessment techniques within different watersheds, re-entry problems, cost effectiveness of proposed mitigation measures, and presence or absence of cumulative effects prior to operations.

Day Five, Course Ends at 1200 hrs.

APPENDIX F

ASSESSMENT TECHNIQUE EQUIPMENT AND SUPPLIES

ASSESSMENT TECHNIQUE EQUIPMENT AND SUPPLIES

V^{STAR}

- Equipment
  - V^{STAR} penetration probe - 2 m (3) — (custom fabrication)
  - V^{STAR} penetration probe - .7 m (3) — (custom fabrication)
  - level or transit
  - measuring tape - 50 m
  - measuring tape - 10 m
  - stadia rod - metric (2)
  - waterproof flashlight
- Software
  - spreadsheet — (Excel™)
  - V^{STAR} index calculator — (custom application)
- Supplies
  - waders
  - insulated, waterproof gloves (without fingers)
  - flagging
  - field data forms

Riffle Armoring Stability Index and D50

- Equipment
  - size class templates - (many) — (custom fabrication)
- Software
  - index calculator — (custom application)
- Supplies
  - plastic rulers - metric (many)
  - field data forms

Temperature

- Equipment
  - recording, submersible sensors — (Hobo's by Onset)
  - handheld electronic sensors
  - handheld mercury thermometers
- Software
  - sensor download and data storage — (Boxcar by Onset)
  - (including special serial cable)
  - (including additional serial port, if necessary)
- Supplies
  - submersible sensor housings
  - steel reinforcing bar - 2 m
  - hose clamps - 1 "
  - hose clamps - 2-1/2 "
  - socket screwdrivers to fit hose clamps
  - mallet - 2 lb - short handle
  - nylon rope
  - field data forms

Habitat Inventory and Channel Typing
- Equipment
  - level or transit
  - measuring tape - 50 m
  - measuring tape - 10 m
  - stadia rod - metric (2)
  - waterproof flashlight
- Supplies
  - field data forms

Slope
- Equipment
  - clinometer
  - compass
- Supplies
  - field data forms

Macro-Invertebrates
- Equipment
  - stadia rod - metric (2)
  - measuring tape - 50 m
  - D-net - long-handled
  - sieve set
  - white enamel pan
  - plastic alcohol-proof sample containers - 500 ml
- Supplies
  - field data forms
  - random number table
  - absolute alcohol
  - tweezers
  - waders
  - insulated, waterproof gloves (without fingers)
  - alcohol resistant marking pen

Canopy
- Equipment
  - spherical densiometer
  - sighting tube
  - basal area estimator
    - (Cruz-All)
    - (Sighting prism)
    - (Relaskope)
  - compass
  - clinometer
  - measuring tape - 50 m
  - range finder
- Supplies
  - field data forms

APPENDIX G

COST ANALYSIS

COST ANALYSIS

The following cost analysis assumes that equipment, software, and supplies are acquired separately for each protocol. The costs for equipment and supplies is for equipping that one field crew. Software costs assume a Windows 3.1 PC. Consumable equipment and supplies (recording temperature sensors, flagging, etc) is for conducting the monitoring of one stream reach of six pools, three riffles, and three runs.

	Equipment ($)	Software ($)	Supplies ($)	Hours
V^{STAR}				
Field data collection	500	-	5	12
Data entry		150		6
Data analysis	-	450	-	12
RASI-D50				
Field data collection	10	-	5	6
Data entry	-	150	-	6
Data analysis	-	-	-	3
TEMPERATURE				
Field data collection	600	-	50	9
Data entry	-	100	-	1
Data analysis	-	-	-	1
HABITAT INVENTORY				
Field data collection	300	-	5	8
Data entry	-	-	-	2
Data analysis	-	-	-	2
MACRO-INVERTEBRATES				
Field data collection	400	-	140	10
Data entry	(lab)	(lab)	(lab)	(lab)
Data analysis	(lab)	(lab)	(lab)	(lab)
(Cost varies for data entry and analysis - our cost was $150 per riffle)				
CANOPY				
Field data collection	350	-	5	6
Data entry	-	-	-	3
Data analysis	-	-	-	3

APPENDIX H

DATABASE STRUCTURES

DATABASE STRUCTURES

The following fields were created to maintain information collected during the implementation of the monitoring parameters according to the protocols described in this study.

V^{STAR}

Data

1 Stream ID
2 Reach Number
3 Pool Number
4 Transect #
5 Pool Riffle Crest
6 Transect Distance From Head of Pool
7 Pool Length
8 Weight Up (weighting value to upstream transect; typically 50%)
9 Weight Down (weighting value to downstream transect; typically 50%)
10 Sample Point Distance From End of Transect
11 Water Depth
12 Scour Depth

(10, 11, 12 concatenated for multiple sample points on each transect)

Information

1 Stream ID
2 Reach Number
3 Pool Number
4 Pool Volume
5 Pool V^{STAR} Index
6 Cumulative Reach V^{STAR} Index

RASI and D50

1 Stream ID
2 Reach Number
3 Riffle Number
4-33 Depositional Measurements
34 Average Depositional Measurement
35 Pebble Count - Size Class I
36 Pebble Count - Size Class II
37 Pebble Count - Size Class III
38 Pebble Count - Size Class IV
39 Pebble Count - Size Class V
40 Pebble Count - Size Class VI
41 Pebble Count - Size Class VII
42 Pebble Count - Size Class VII
43 Pebble Count - Size Class VIII
44 Pebble Count - Size Class IX
45 Pebble Count - Size Class X
46 RASI Index
47 D50 Index

Temperature

Information -

1 Stream ID

2 Reach Number
3 Date
4 Habitat Unit Number
5 Temperature - Air (handheld)
6 Hobo Number
7 Downloaded Data File Name (submersible recording sensor)

Habitat Inventory and Channel Inventory

1 Stream ID
2 Reach Number
3 Date
3 Habitat Unit Number
4 Habitat Unit Type
5 Mean Length
6 Gradient
7 Mean Width
8 Mean Depth
9 Maximum Depth
10 Riffle Crest
11 % Unit Shelter
12 % Undercut Banks
13 % Small Woody Debris
14 % Large Woody Debris
15 % Root Mass
16 % Terrestrial Vegetation
17 % Aquatic Vegetation
18 % White Water
19 % Boulders
20 % Bedrock Ledges
21 % Total Canopy
22 Right Bank Dominant Vegetation Type
23 % Right Bank Vegetated
24 Left Bank Dominant Vegetation Type
25 % Left Bank Vegetated

Slope

1 Stream ID
2 Reach Number
3 Habitat Unit Number
4 % Slope (right side looking upstream)
5 % Slope (left slope looking upstream)

Canopy

1 Stream ID
2 Reach Number
3 Habitat Unit Number
4 Distance from Head of Unit
5 % Cover - Upstream Quadrant (spherical densiometer)
6 % Cover - Right Quadrant (spherical densiometer)
7 % Cover - Downstream Quadrant (spherical densiometer)
6 % Cover - Left Quadrant (spherical densiometer)

8 Sighting Tube Hit/Open
9 Stand Basal Area
10 Number of Canopy Layers