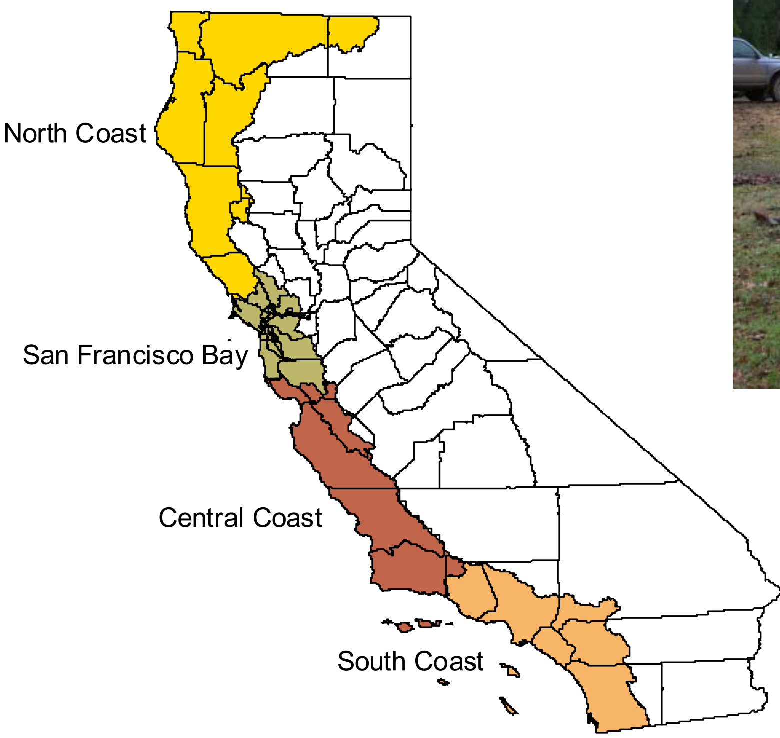
CALIFORNIA COASTAL SALMONID RESTORATION MONITORING AND EVALUATION PROGRAM

Interim Restoration Effectiveness and Validation Monitoring Protocols

March 2003



California Department of Fish and Game
The Resources Agency
State of California

Development of these monitoring protocols was made possible by funding from the Fisheries Grant Restoration Program's Salmon Steelhead Trout Restoration Account through the recommendation of the California Coastal Salmonid Restoration Grants Peer Review Committee.

PREFACE

In 2001, the California Department of Fish and Game (DFG) contracted for the development of interim effectiveness and validation monitoring protocols. They were completed in March 2003. The protocols are intended to measure the effectiveness of efforts to improve and conserve coastal watersheds, streams and anadromous fish habitat. The interim protocols are presented in this manual. They are being made available to qualified investigators for use with proposed and/or completed restoration projects in coastal California watersheds. Additional field tests will help refine and improve these protocols on an adaptive basis. In coordination with these efforts, the Fisheries Restoration Grants Program made additional grants to:

- Complete monitoring protocol development;
- Field test all effectiveness and validation monitoring protocols;
- Complete a data management support system;
- Provide training in protocol usage;
- Develop statistical sampling designs for statewide coastal monitoring;
- Begin testing the implementation procedures for a comprehensive restoration effectiveness monitoring program.

By the spring of 2005 it is anticipated that the Department will have formalized the implementation, effectiveness, and validation monitoring protocols and incorporate them into an updated *California Salmonid Stream Habitat Restoration Manual*.

ADDITIONAL INFORMATION

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CAUTION: This report and the protocols contained within it are currently in a draft form. The report is undergoing scientific review and may be substantially revised. The protocols have received some field testing but more is planned. Readers desiring further information should contact the Principal Investigators:

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CONTENTS

Part I. Monitoring Fish Habitat Restoration Projects

Part I provides interim protocols for monitoring fish habitat improvement projects throughout coastal California within the current or historic ranges of anadromous salmonids. They include:

- Qualitative protocols for implementation and effectiveness monitoring of all projects types;
- Quantitative protocols for monitoring instream, riparian, and road projects.

These protocols are applicable only to physical and chemical components of instream habitat and riparian vegetation.

Part II. Validation Monitoring Of Watershed Restoration: Guidelines for California Coastal Watersheds

The California Department of Fish and Game supports watershed improvements in coastal regions to assist in anadromous salmon and steelhead trout population recovery. To date however, no validation monitoring protocols have been developed for evaluating the response of salmon and steelhead to coastal watershed restoration efforts. This report is the first step in developing those needed validation monitoring protocols. This report includes:

- A review of existing biological monitoring programs;
- A list of program objectives and considerations for the design of a validation monitoring program;
- Conceptual models of the biological responses to restoration actions.

Part II is organized around stream and watershed features that are the subject of restoration actions. Topics include riparian condition, channel morphology, large woody debris, sediment, and water quality parameters, including turbidity, nutrients, dissolved oxygen and water temperature.

Part III. Validation Monitoring of Watershed Restoration in California

Validation monitoring protocols for assessing the response of salmon and steelhead populations to coastal watershed restoration have been developed, and a report describing these protocols is under preparation. Part III is a draft copy of that report, which describes draft validation monitoring protocols for measuring:

- Juvenile salmon and steelhead condition and fitness;
- Juvenile salmon and steelhead abundance and population size;
- Salmon and steelhead smolt production;
- Adult salmon and steelhead escapement.

Each of the three parts of this report contains a table of contents specific to its subject matter. An Appendix is also provided following Part III, which lists watershed restoration action categories, objectives of these actions, and validation monitoring criteria.

This page provided for your notes:

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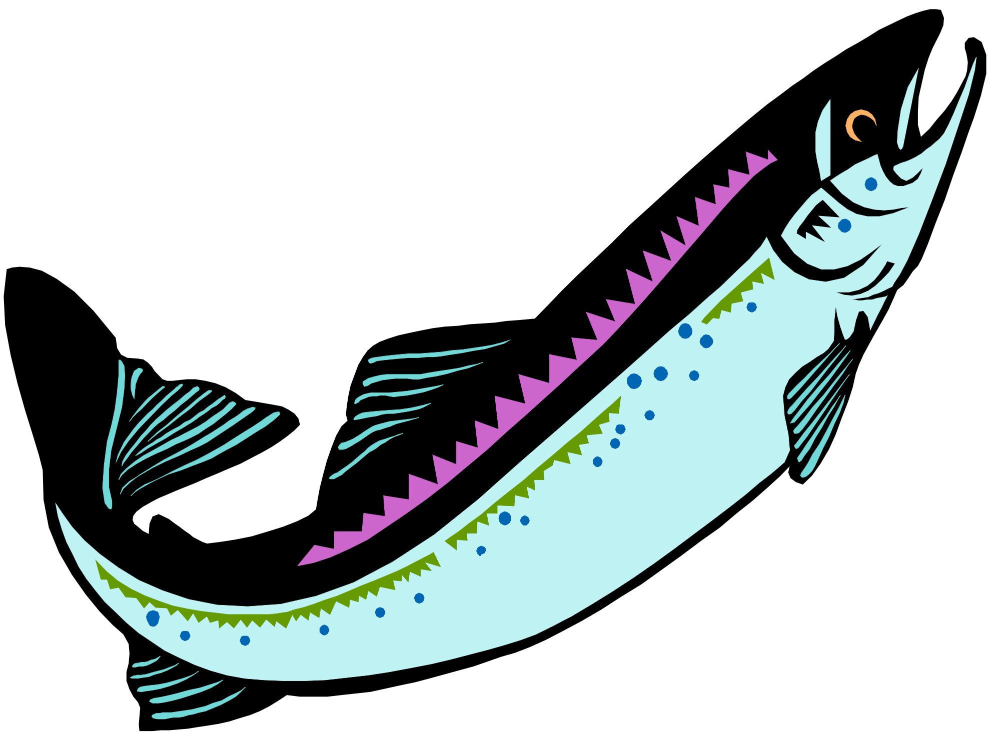
Part I.

MONITORING FISH HABITAT RESTORATION PROJECTS



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Draft Final Report to the Department of Fish and Game
Contract Manager: Barry Collins
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INTRODUCTION

The California Department of Fish and Game's (DFG) coastal anadromous fish habitat restoration program is a multi-million dollar a year competitive grants program that has been in place for over 20 years. Every year numerous proposals are received and evaluated by a DFG team and a citizen's advisory panel. The funding sources for the program include the state general fund, several state bond measures and federal funds. The level of funding varies from year to year. The primary source of information on the program and restoration project design is the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998), referenced as the DFG Manual in this report, and the yearly call for proposals.

The purpose of this report is to provide protocols for monitoring DFG-funded fish habitat restoration projects. It has been developed by the University of California's Center for Forestry in collaboration with DFG biologists and with oversight and review by numerous scientists and practitioners. Protocols for effectiveness monitoring of all projects at a qualitative level, and protocols for quantitative monitoring of in-stream, riparian, and road projects are included in this report. Recommendations for establishing and implementing a restoration monitoring program, including developing monitoring objectives and establishing specific study designs, will be made in an accompanying report in January 2003.

PROJECT DESCRIPTIONS

There are over 30 different types of fish habitat restoration projects funded by DFG for coastal watersheds. A tabulation of project types, including their goals and measures of effectiveness, is provided in Appendix A. Not all project types are carried out every year and over time there has been a gradual shift in emphasis from instream habitat restoration to restoration of watershed processes that benefit anadromous fish. In many cases, more than one project or project type may be done at a site or within a stream reach.

- *Fish passage projects* are geared toward improving the movement of anadromous fish through stream systems or preventing fish from entering manmade facilities. An example of a preventative project is a fish screen on an irrigation ditch. An example of a passage improvement project is a fish ladder. Design criteria for some of these projects are contained in the DFG Manual, especially in Volume 2, Part X.

- *Instream habitat restoration projects* are undertaken to create better conditions for one or more fish life stages, e.g., spawning or rearing habitat. They vary in complexity from the simple placement of a log in a stream, to completely reconstructing a degraded stream reach. Detailed guidelines for planning and executing these projects are in the DFG Manual, Volume 1, Parts VI and VII.

- *Streambank stabilization projects* involve instream work aimed at preventing erosion. The DFG Manual provides detailed guidelines for many of these projects. It also provides methodology for assessing potential hydraulic effects of instream structures. Sophisticated projects may require extensive engineering design work.

- *Land use control projects* seek to relieve stresses on streams and/or watersheds by changing management practices. An example would be the use of fencing to prevent livestock access to streams. An example of an agreement on riparian management (exclusionary fencing and planting) is provided in the DFG Manual.

- *Vegetation management projects* include controlling vegetation (e.g., removing exotic plants) or planting vegetation (e.g., riparian restoration). Most have the common goal of improving the ecological functions of riparian communities. Controlling vegetation encroachment in stream channels is done to increase fish habitat availability, especially spawning gravel. A new Manual chapter on riparian restoration (Volume 2, Part XI) is currently in preparation.

- *Streamflow management projects* are often intended to benefit both fish and riparian communities. A common example is the setting of instream flow requirements below dams or diversions. In the context of restoration, streamflow management may include procurement of water rights. There are no standard design criteria in the DFG Manual for these project types.

- *Upland erosion control* and *gully repair projects* are aimed at reducing sediment delivery to streams. A variety of methods may be employed. Gully repair is covered in detail in the DFG Manual. Some projects would require engineering design expertise. Fuels management projects intended to reduce the risk of fire and consequent erosion would require the input of a forester or vegetation ecologist.

- Over the past few years, the majority of grant funding has gone to projects involving the *upgrading or obliteration of rural roads*. A new chapter is currently being finalized to deal with these projects (Volume 2, Part IX).

TYPES OF MONITORING

Monitoring is the process by which information is gathered and evaluated to increase our certainty about ecological events, trends or outcomes. There are several types of monitoring being conducted in California and elsewhere in the Pacific Northwest. Most of these can be categorized as implementation, effectiveness, validation, or trend (Ice et al. 1996).

- *Implementation monitoring* is usually defined as an evaluation of whether or not a specific action occurred as planned. A variant called compliance monitoring is used to evaluate if an action meets regulatory standards. Implementation monitoring provides baseline information before and immediately after a project occurs.

- *Effectiveness monitoring* is defined as an evaluation of whether or not the properly installed or implemented action is having the desired effects. If the action is having undesirable effects, this should be revealed through effectiveness monitoring.

- *Validation monitoring* has typically been defined as the evaluation of a model's accuracy in predicting events or performance (MacDonald et al. 1991). Recent discussions of validation monitoring have focused on the evaluation of whether or not organisms are responding in a positive way to restoration treatments (Botkin et al. 2000). In the context of stream restoration, validation monitoring would focus on the responses of instream life to restoration activities.

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- *Trend monitoring* is the evaluation of ecological or environmental changes over time, usually over a rather broad geographic area, such as a large watershed or bioregion. Over an extended time period, trend monitoring should detect whether or not the status of watersheds and/or associated organisms is improving or degenerating.

For the restoration grant program, the objectives of DFG are to answer the following questions through monitoring:

1) Are fish habitat restoration projects being carried out as proposed?

2) Assuming proper installation, are restoration projects having the intended beneficial effects on habitat?

3) Are fish and other aquatic organisms responding in a positive way to the restoration treatments?

These three questions may be addressed through implementation, effectiveness and validation monitoring. This monitoring may be tiered to trend monitoring, which is commonly done on a regional scale (Kaufmann et al. 1999; Reeves et al. 2001). This report is solely concerned with implementation and effectiveness monitoring. DFG is also funding the development of validation monitoring protocols for the fish habitat restoration program through Humboldt State University. In the future, a program for integrating the proposals contained herein and Humboldt State's work with a regional trend monitoring effort may be developed.

As the first step in developing implementation and effectiveness monitoring tools for DFG, all relevant public agency monitoring programs in California, Oregon and Washington were reviewed. From this review, exemplary approaches were identified. Of particular interest were a review of monitoring protocols conducted in Washington State (Johnson et al. 2001) and Oregon's effectiveness monitoring program (Lacy and Thom 2000; Jacobsen and Thom 2001).

The approach and monitoring protocols provided herein are intended for use throughout coastal California, within the current or historic ranges of anadromous salmonids, wherever fish habitat restoration projects may be undertaken. They are applicable only to the physical and chemical components of habitat and to riparian vegetation. No biological monitoring tools for fish or other aquatic life are provided. These will be provided by the validation monitoring project now underway at Humboldt State University.

These protocols have been developed for use in a comprehensive monitoring program intended to generate and disseminate information that can be used to improve current restoration practices and ultimately the DFG restoration program itself. In order for this to occur, specific, testable questions need to be developed and answered using monitoring data. Results of these monitoring studies need to then be incorporated into the DFG restoration program. Recommendations on developing a comprehensive monitoring program will be contained in a separate report to be submitted to DFG in January 2003.

MONITORING APPROACH

MONITORING LEVEL

The selection of a monitoring level determines the degree of detail with which monitoring will be carried out and consequently, the costs and expertise required (Table 1).

Table 1: Effectiveness Monitoring Process Matrix (adapted from Dissmeyer, 1994)

Level	Questions or Issues	Quality of Data for Decision Making	Skill Levels	Amount of Data Collected	Streams Eval-uated	Time to Decision on Effectiveness
Level 1	Screen projects for an obvious yes or no on effectiveness	Qualitative data and observation. Obvious good or bad recognized, large uncertainty	One or two trained professionals with knowledge and experience and a technician	Small to moderate amount	Many	A few hours to one or two days to a week
Level 2	Effectiveness of projects on high value streams	Qualitative and quantitative data. Moderate amount of precision. Moderate uncertainty	Two professionals trained in hydrology, fisheries, habitat, invertebrates plus technicians	Moderate to large amount	Many	Two weeks to a month
Level 3	High value resources at stake, produce information to modify practices	Quantitative data, limited qualitative data. Good precision to detect significant impacts, minor uncertainty.	Professionals in statistics, hydrology, fisheries, invertebrates, channel geomorphology plus technicians	Large to very large amount-extensive data management system needed.	Limited number	Two to three months for individual projects, watershed studies require one to three years.
Level 4	Understand cause and effect, modify practices	Quantitative data, very little qualitative data. Good precision to detect small changes. Very minor uncertainty.	Same as level 3, but many are likely to be researchers	Very large amount-extensive data management system.	Very limited number	Two, three or more years.

Until the present time, DFG monitoring has mainly consisted of formal and informal staff evaluations. These evaluations have been conducted as part of project progress reviews or completion reports. Approximately 10 percent of all projects are monitored each year at a level between 1 and 2. In addition, some monitoring is funded every year by the grant program. Research-level monitoring (i.e., level 3-4), has not been funded by the grant program nor has it been undertaken by DFG. During the course of developing this report, DFG biologists determined that effectiveness monitoring should be done with both qualitative (level 1) and quantitative (level 2-3) methods, depending on the monitoring objective. The protocols included here provide for monitoring of all projects at level 1 (qualitative) and a subset of projects at level 2-3 (qualitative and quantitative).

MONITORING STRATEGY

The principle goal of DFG is to determine if restoration projects are improving habitat conditions for anadromous fish. Effectiveness criteria for all project types were developed by surveying staff from DFG and other agencies. These criteria were then reviewed and confirmed by a Science Review Panel. The resultant criteria are presented in Appendix A. After development of effectiveness criteria, physical and biological (in the case of riparian vegetation) indicators (i.e., quantitative or qualitative parameters) were formulated. Qualitative and quantitative protocols for measuring parameters were then formulated based on professional judgment and the literature and field-tested. These protocols will be used in the context of a monitoring program yet to be developed by DFG. Below, we provide guidelines for an overall approach to monitoring. These will be expanded further and discussed in more detail in a future report.

Generally, the monitoring strategy should include implementation and qualitative effectiveness monitoring for all projects and quantitative effectiveness monitoring of some individual projects, categories of projects, and a few small watersheds.

Single Project Effectiveness Monitoring

Specific restoration projects should be monitored for effectiveness using quantitative methods in situations where the potential risks to the resources in case of failure would be unacceptable. An example would be a project in a particularly sensitive location such as a fish passage improvement in critical salmonid habitat. Candidates for single project effectiveness monitoring should be determined during the yearly proposal review process.

An example of a single project effectiveness study is provided in Kondolf et al. (1996). The methods and level of effort involved with single project monitoring should be commensurate with the risk posed to the resource. Level three and four monitoring protocols are most likely to be needed for high value projects.

Project Categories Effectiveness Monitoring

In project category monitoring, projects are grouped according to specific criteria and monitored before and after project implementation. Effectiveness judgments are rendered on groups of projects as a whole rather than on individual projects. Monitoring information collected is lumped together to determine whether categories of projects are effective.

Two different project groupings are recommended. Projects with similar goals can be monitored across differing environmental settings using appropriate statistical design. For example, instream habitat improvement projects can be monitored throughout coastal California to determine how effectiveness varies by region. This approach is modeled in part on the restoration effectiveness monitoring program in Oregon (Lacy and Thom 2000). DFG has also done this with a qualitative monitoring approach (Hopelain unpublished). The objective of this monitoring is to determine if specific goals such as riparian habitat improvement, or fish habitat improvement, are being generally met or how performance varies due to environmental conditions.

Projects using different types of treatments to meet similar objectives can also be grouped to determine effectiveness. For example, projects using rip-rap may be compared to those using bioengineering for bank protection (Shields et al. 2000). This can be done either across different environmental settings or with a controlled experiment.

The focus of this monitoring approach should be determined by a list of critical questions developed by DFG and stakeholders. Once critical questions are formulated, the appropriate grouping(s), study objectives, and study design(s) can be developed. Category monitoring can vary from year to year and may be incorporated into the grant proposal process where proposals to do specific monitoring studies can be solicited.

Monitoring using this approach should use the level 2-3 quantitative protocols described here. These protocols have been tested in the field to determine their applicability to specific types of restoration projects. Field-testing consisted of repeated use of protocols in three different areas, northern Humboldt/Del Norte Counties, southern Humboldt County and central Mendocino County. Modifications to improve their validity and reliability have been made and are incorporated in the protocol descriptions.

Small Watershed Effectiveness Monitoring

The third type of effectiveness monitoring should be conducted at the small watershed scale. This should be done in cases where a large proportion of a watershed or stream system will be subject to restoration. In basins selected as demonstration areas, monitoring should be done at the site, stream reach and small watershed scales simultaneously. At the present time, this type of restoration effectiveness monitoring is not being done in California, although there are a few examples of experimental small watershed studies such as Caspar Creek (Ziemer 1998).

Guidelines for designing a small watershed monitoring plan are included here (See appendix F). A case study applying these guidelines was conducted at the University of California, Hopland Field Station in Mendocino County. The goal there is to monitor watershed-level effects of upland erosion control projects on streamflow and sediment transport and storage. As such, the case study may not be directly applicable to other watersheds where there are different restoration objectives. Since every watershed is different, and restoration objectives and activities will vary by watershed, each watershed monitoring project must have a specific study design.

MONITORING TIMING

All projects should have a minimum of before and after qualitative monitoring to ensure that they are properly implemented. Qualitative effectiveness monitoring should also be done for all projects, using protocols described below (photographic records and completion report checklists). Projects in categories selected for quantitative monitoring should be subject to baseline data collection before implementation. For watershed monitoring, it is desirable to have one to several years of pre-implementation data.

The timeframe for post-implementation effectiveness monitoring will vary by project type and will depend on specific monitoring plan design. In many cases, the first phase of effectiveness monitoring should be done in conjunction with implementation monitoring. It should then be repeated after stressing climatic or streamflow events. The timeframe for monitoring each project type is discussed in the protocol descriptions.

MONITORING PROTOCOLS

Definitive protocols for documenting restoration project locations (Appendix B) and for photographic monitoring of restoration projects (Appendix C) have been created and field-tested. These should apply to all restoration projects and their use should improve current inconsistencies in project documentation. In addition, a protocol for implementation monitoring of all projects has been developed (Appendix D). This is intended to confirm that projects were correctly designed and installed. It would replace procedures currently used by DFG contract managers that are inconsistently applied.

Protocols for two different levels of effectiveness monitoring have been developed: qualitative (level 1) and quantitative (level 2-3). Qualitative protocols described here are to be applied to every DFG funded project (Appendix D). A smaller subset of projects, chosen for evaluating a specific monitoring objective, would be monitored by the quantitative methods described here.

QUALITATIVE PROTOCOLS

Qualitative monitoring should be applied to every project involving physical environmental changes. Qualitative monitoring would address both implementation and effectiveness of projects. Qualitative monitoring has two components: photographic records and field evaluation checklists. These protocols have been tailored for each project type and are based on general effectiveness criteria (see Appendix B and D).

For project evaluators to use the qualitative monitoring approach, they must provide specific objectives and effectiveness measures. For each project type, the checklists require a summary judgment on the project (Was it properly implemented or not? Was it effective in achieving objectives or not?). They also require recommendations for remedial actions or improvement. Monitoring should be performed by DFG staff and/or restoration practitioners after training in protocol use.

Repeated photographs and field evaluations provide the basis for before and after comparisons and for detecting effectiveness over time. These data can be used to report on overall program accomplishments, as has been done recently in Oregon (Malecki and Riggers 2001). Reports on individual projects can be used to assess the need for remedial actions.

QUANTITATIVE PROTOCOLS

Quantitative protocols for measurement of in-stream habitat, riparian vegetation, and upland erosion control projects (primarily road treatments) are included here. These protocols will apply to most but not all types of projects funded by DFG (see Table 2). Additional protocols for monitoring effectiveness of other project types will be developed during the next grant year. Descriptions of all quantitative protocols are included in Appendix E. Protocols are intended for use by trained professionals, either DFG staff or contractors.

Table 2: Project Types and Applicable Protocols

Project Types	**Quantitative Protocol(s)**
Fish Passage *(Fish Screens, Fish Ladder, Channel Modification, Barrier Removal,*	To be developed. Some will be based on DFG stream crossing guidelines (see

Barrier Modification)	DFG Manual, Section X). Many projects in this category will be critical projects requiring specific monitoring plans.
Instream Habitat Improvement *(Install Structures, Install Gravel, Remove Structures, Construct Channel/Breach Dikes)*	Instream protocols (longitudinal profiles, cross-sections, etc., and habitat unit monitoring).
Streambank Stabilization *(Deflect Streamflow, Bioengineering, Armoring)*	Instream protocols (longitudinal profiles, cross-sections, etc., and habitat unit monitoring).
Land Use Control *(Exclude Grazing, Install Watering Sites, Grazing Management, Conservation Easements)*	Riparian protocols.
Control Vegetation *(Remove Exotic Plants, Plant Vegetation, Reduce Vegetation Encroachment)*	Riparian protocols and instream protocols.
Riparian Planting *(Plant Vegetation, Alter Composition)*	Riparian protocols.
Restore Flows *(Obtain Water Rights, Manage Flows)*	To be developed. Probably some form of instream flow incremental method or other hydrologic modeling coupled with stream gauging.
Slope Stabilization or Erosion Control *(Soil Engineering, Bioengineering, Upland Fuels Management)*	Upland erosion control protocols in part (will depend on specific project). Other protocols to be developed.
Gully Repair *(Channel Modification, Bioengineering, Armoring)*	Upland erosion control protocols in part (will depend on specific project). Other protocols to be developed.
Road Upgrading and Decommissioning *(Road Surfacing, Drainage Improvements, Partial Decommissioning, Full Road Decommissioning)*	Upland erosion control protocols.

Instream Habitat Protocols

There are two quantitative protocols for instream projects. One is an adaptation of DFG's habitat typing procedures called habitat unit monitoring. The other would involve longitudinal profiles, substrate measurements, temperature monitoring and other methods that are not dependent on habitat classification. Habitat unit monitoring should be used at the project site and stream reach scales. It can provide a somewhat coarse level of information on general habitat changes. The more rigorous quantitative methods would apply to projects involving changes in stream geomorphology, temperature and/or substrate where more detailed information is desired. They may be applied to specific critical projects or in statistical designs evaluating different treatments within a specified range of environmental conditions or across a range of environments. Instream quantitative methods are presented as a "tool box" of appropriate protocols. The choice of method should depend on the specific nature of the project(s) to be monitored and study objectives. For example, for some purposes, cross-sections alone may be the ideal tool for monitoring effectiveness (Kondolf and Micheli 1995). In other situations, a more complete set of monitoring tools may be needed.

Riparian Protocols

The approach to quantitative assessment of riparian projects is based on using well-established sampling methods (transects and plots) to monitor vegetation changes over time. The primary focus is on changes in cover (i.e., biomass and structure) and community composition. Five different methods are recommended, depending on the community types involved (forest or shrub versus herbaceous) and scale of the treatment. These methods would generally be used at the stream reach scale because that is the typical scale for riparian restoration projects. As with other quantitative methods, they would be applied in statistical designs aimed at evaluating effectiveness of different treatments or environmental effects on treatment effectiveness.

Upland Erosion Control Protocols

Two quantitative methods are presented for upland erosion control (mainly road-related restoration or remedial actions). One is based on the existing DFG method for planning and prioritizing these projects (Part X of the Manual). That method has been adapted for use as a monitoring tool. The second method is based on Madej (2001) and would apply to quantitative studies of restoration effectiveness after stressing climatic events. Quantitative protocols for some types of upland erosion control projects (fuels management, gully control, engineered slopes) have not yet been developed and would depend on specific project characteristics.

DATA MANAGEMENT

A detailed description of the data management system developed for this monitoring program is included in Appendix G. It builds upon and is complementary to existing DFG data management systems, especially the California Habitat Restoration Data Base (CHRPD) and the habitat typing database.

Data collection forms have been developed for all qualitative and quantitative protocols. Data forms and instructions for completing them are included in each protocol description (See Appendix B, C, D, and E). Where possible, these are based on existing DFG forms currently in use for restoration project assessment, habitat typing and other purposes. Data collection forms are all linked to data management systems generally in use at DFG.

When fully operational, this monitoring program will generate a large amount of qualitative and quantitative data including field data sheets, checklists, photographs and maps. Quality control and assurance procedures for these data will be developed during the next grant year. Procedures will include training, field auditing of data collection procedures and if possible, repetition of sampling by different field crews. Procedures for minimizing data entry errors made transferring quantitative data from field sheets to computer data files will be established. These will include training, and automatic and manual data checking.

DATA ANALYSIS AND REPORTING

At this time, it is not possible to foresee what analysis procedures will be used to evaluate qualitative and quantitative data. The protocols and data management system presented are flexible enough to accommodate any form of statistical analysis. Analysis must be based on questions to be addressed. DFG will convene a Scientific Advisory Panel to assist in formulating questions and developing the approach to be used to address them. It is likely that qualitative data on implementation and effectiveness will be compiled and analyzed for the purpose of summarizing DFG's restoration program accomplishments, as has been done for the State of Oregon (Malecki and Riggers 2001). Quantitative studies will be subjected to more rigorous statistical analysis.

Work products, especially statistical analyses, should be subject to scientific peer review prior to public release. This provision should be incorporated into any monitoring contracts. Watershed monitoring should be overseen by a technical advisory committee competent in the relevant disciplines. Such committees are routinely established for watershed planning projects funded by DFG, CALFED and other agencies in California.

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APPENDICES

APPENDIX A: PROJECT TYPES, OBJECTIVES AND EFFECTIVENESS MONITORING CRITERIA

Table 1: Fish Passage

<table>
<tr><td><u>Fish Ladder</u>
Objectives: Improve fish passage by circumventing barrier; improve accessibility to habitat</td><td rowspan="4">Effectiveness Criteria:
Area of habitat made accessible
No unforeseen adverse effects on habitat such as incision or channel instability or sedimentation
Increased attraction flows during migration periods (for barrier modifications)</td></tr>
<tr><td><u>Channel Modification</u> (e.g. build step pool approach to culvert, back flooding weirs
Objectives: Improve fish passage by modifying natural channel; improve accessibility to habitat</td></tr>
<tr><td><u>Barrier Removal</u> (e.g. logjam modification, barrier blasting):
Objectives: Improve fish passage by eliminating natural barrier; improve accessibility to habitat</td></tr>
<tr><td><u>Barrier Modification</u> (e.g. culvert baffles, repositioning, size upgrade)
Objectives: Improve fish passage by modifying human caused barrier; improve accessibility to habitat</td></tr>
<tr><td><u>Fish Screens</u>
Objectives: Prevent fish passage into stream reaches or man-made facilities to protect them from entrainment and/or mortality</td><td>Effectiveness Criteria:
No unforeseen adverse effects such as incision or channel instability.</td></tr>
</table>

Table 2: Instream Habitat Restoration

Install structures *(e.g. install boulder/ log/ rootwad structures)* Objectives: Increase cover, habitat complexity, instream habitat types	*Effectiveness Criteria:* • Project improves targeted habitat parameters within the project reach • Project does not impair natural movement of LWD, substrate or nutrients downstream • No unforeseen adverse effects on habitat features, substrate, channel geometry or fish passage • Project increases amount of suitable spawning habitat at specified flows
Install gravel Objectives: Increase spawning habitat	*Effectiveness Criteria:* • Increased amount of suitable spawning habitat at specified flows • No unforeseen adverse consequences such as gravel migration or scouring, pool filling, net loss of primary pools over reach
Remove structures (e.g., remove concrete riprap, remove dams) Objectives: Increase stream interaction with floodplain; increase habitat complexity	*Effectiveness Criteria:* • Stream re-establishes and maintains properly functioning geometry and pattern, in relation to Rosgen stream type • No unforeseen adverse erosion or sedimentation or channel instability • Increased quality of the immediate and adjacent instream habitat units, riparian vegetation and substrate • Stream regains access to formerly abandoned floodplain
Construct channel/ breach dikes *(e.g., reconnect stream to floodplain, construct side channels, remove floodplain roads or levees)* Objectives: Improve stream interaction with floodplain; increase habitat complexity; increase habitat types; improve flood control.	*Effectiveness Criteria:* ♦ Channel re-establishes and maintains properly functioning geometry and pattern, in relation to Rosgen stream type • Stream regains access to formerly abandoned floodplain • Peak flows do not cause adverse erosion or sedimentation, and/or peak flows are reduced • Increase in number, area and types of instream habitat units • Increased riparian vegetation, reduced fine sediment, and reduced water temperature • No reduction in the diversity and quality of instream habitat units over time through a broad range of stream flows

APPENDIX A: PROJECT TYPES, OBJECTIVES AND EFFECTIVENESS MONITORING CRITERIA

Table 3: Streambank Stabilization

<table>
<tr><td><u>Deflect streamflow</u> (e.g., install deflectors)
Objectives: Increase streambank stability by reducing stream power at erodible surfaces</td><td rowspan="3">Effectiveness Criteria:
• Reduced bank erosion
• Improved channel geometry e.g., reduced width/depth ratio
• Reduced fine sediment in reach
• Increased riparian vegetation</td></tr>
<tr><td><u>Bioengineering</u> (e.g. install willow baffles/brush mattress/ stake, resloping and revegetating cut banks)
Objectives: Increase streambank stability by protecting erodible surfaces with organic matter (living or dead)</td></tr>
<tr><td><u>Armoring</u> (e.g., install rock armor)
Objectives: Increase streambank stability by protecting erodible surfaces with inorganic matter (rock)</td></tr>
</table>

Table 4: Land Use Control

<table>
<tr><td><u>Exclude grazing (e.g. fencing)</u>
Objectives: Reduce livestock or wildlife access to stream and riparian zone; decrease contaminant input to stream</td><td rowspan="4">Effectiveness Criteria:
• Livestock and/or wildlife successfully excluded from riparian zone and stream
• Increased riparian vegetation
• Increased riparian connectivity
• Increased bank stability
• Improved channel geometry e.g., reduced width/depth ratio
• Reduced fine sediment in reach
• Improved water quality
• Others as appropriate for conservation easements</td></tr>
<tr><td><u>Install watering sites</u>
Objectives: Reduce livestock access to stream and riparian zone; decrease contaminant input to stream</td></tr>
<tr><td><u>Grazing management</u>
Objectives: Manage riparian pastures to reduce impacts to riparian vegetation and stream banks</td></tr>
<tr><td><u>Conservation easements</u>
Objectives: Reduce stresses due to land uses</td></tr>
</table>

Table 5: Control Vegetation

<table>
<tr><td>Remove exotic plants (e.g. remove noxious weeds/plants, non-native blackberries)
Objectives: Directly eliminate exotic plants from riparian community</td><td rowspan="3">Effectiveness Criteria:
• Reduced relative abundance of exotic plants
• Increased relative abundance of native plants
• Increased native plant species richness
• Reduced barren ground
• Increased riparian canopy cover
• If clearing encroachment is involved, reduced vegetation within bankfull channel
• If clearing encroachment is involved, increased availability of spawning gravels</td></tr>
<tr><td>Plant vegetation
Objectives: Increase native plant species composition</td></tr>
<tr><td>Reduce vegetation encroachment into channel
Objectives: Increase available instream fish habitat</td></tr>
</table>

Table 6: Riparian Planting or Management

<table>
<tr><td>Plant vegetation
Objectives: Increase shading to stream; increase LWD inputs to stream; increase nutrient inputs to stream; increase stream bank stability</td><td rowspan="2">Effectiveness Criteria:
• Riparian tree composition meets planting or management objectives
• Increased riparian canopy cover
• Advancement in riparian successional stage from grass-shrub to forest
• Increased riparian corridor continuity and patch size</td></tr>
<tr><td>Alter composition (e.g. promote conifers)
Objectives: Increase shading to stream; increase LWD inputs to stream; increase nutrient inputs to stream; increase growth of conifers</td></tr>
</table>

Table 7: Restore Flows

Obtain water rights Objectives: Improve stream flows to benefit fisheries and riparian communities	*Effectiveness Criteria*: • Increase low flows, achieve natural peak flow regime • Decreased water temperature during low flows • No adverse changes in downstream stream flows
Manage flows Objectives: _Improve stream flows to benefit fisheries and riparian communities	

Table 8: Slope Stabilization or Erosion Control (including road cut and fill slopes)

Soil engineering *(e.g. toe protection)* Objectives: Use engineering practices to reduce erosion/stream sedimentation; increase slope stability	*Effectiveness Criteria*: • Reduced likelihood of slope failure • Decrease in soil erosion from site • Decreased sediment load near site during peak flow events • If planting involved, reduced bare ground • If a large portion of a watershed is treated, reduced sediment yields
Bioengineering *(e.g. mulching, planting, seeding)* Objectives: Use living and dead organic matter to reduce erosion/stream sedimentation; increase slope stability	
Upland fuels management *(e.g., understory thinning, brush removal)* Objectives: Reduce the potential for sedimentation as a result of catastrophic fire	*Effectiveness Criteria:* • Reduced fire hazard • Reduced fire incidence • No significant increase in erosion rate

Table 9: Gully Repair

<table>
<tr><td><u>Gully modification</u> (e.g. new channel construction, pond and plug)
Objectives: Decrease erosion and stream sedimentation by changing gully grade and cross-section</td><td rowspan="3">Effectiveness Criteria:
• Improved channel geometry e.g., reduced width/depth ratio
• No offsite adverse effects on downstream channels
• Reduced erosion and sediment yield
• Reduced flood flows in gully
• Increased vegetation cover</td></tr>
<tr><td><u>Bioengineering</u> (e.g. brush/rock mattress, vegetation planting
Objectives: Use living and dead organic matter as obstructions to reduce the rate of head-cutting and incision</td></tr>
<tr><td><u>Armoring</u> (e.g. rip-rap)
Objectives: Use inorganic matter as obstructions to reduce the rate of head-cutting and incision</td></tr>
</table>

Table 10: Road Upgrading or Decommissioning

Road surfacing Objectives: Use rock, chip seal and/or asphalt to reduce surface erosion	*Effectiveness Criteria*: • Reduced erosion rate from road surface • Reduced sediment yield in immediately adjacent watercourses • If a large portion of a watershed is treated, reduced sediment yield
Upgrading *(e.g. outsloping, installing rolling dips, boulder riprap, and energy dissipaters, removing berms, installing detention basins and check dams, upgrading stream crossing, revegetation)* Objectives: Use improvements in road drainage and stream crossings to reduce erosion and potential stream sedimentation; reduce risks of crossing failures; reduce hydrologic impacts of roads on streams	*Effectiveness Criteria*: • Reduced erosion rate from road surface • Reduced number or probability of road related slope failures • No offsite adverse effects on erosion or sedimentation • Improved stream discharge regime in immediately adjacent watercourses • If a large portion of a watershed is treated, reduced actual sediment yield • If a large portion of a watershed is treated, improved stream discharge regime
Full road decommissioning *(e.g. removing crossings, excavating fill, removing drainage structures)* Objectives: Obliterate all evidence of road; decrease road access; decrease road density	*Effectiveness*: • Reduced number or probability of road related slope failures • Reduced erosion from site • Increased infiltration rate on road surface • Reduced sediment yield in immediately adjacent watercourses • No offsite adverse effects on erosion or sedimentation

APPENDIX B: PROTOCOL FOR DOCUMENTING RESTORATION PROJECT LOCATIONS

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APPENDIX B: PROTOCOL FOR DOCUMENTING RESTORATION PROJECT LOCATIONS

PROTOCOL DESCRIPTION

The locations of restoration projects must be consistently and accurately documented to enable implementation and effectiveness monitoring. This protocol describes methods for documenting project location, as well as locations of project features. The procedures for documenting locations of sampling points for monitoring are described within each protocol description.

DOCUMENTING PROJECT LOCATION

Restoration project locations can be described as linear, extensive, or occupying a single point. The point or set of points used to define the project location are known as the project coordinates. The protocols for defining project coordinates for point, line and polygon project types are slightly different.

Single point locations

Projects that occupy only a single point location on a stream include fish ladders and screens, and individual in-stream structures or barriers. Projects in upland locations, such as road upgrading or erosion control may also occupy a single point and are not necessarily located in or near a stream.

Projects at points will be described by a single latitude and longitude coordinate recorded in decimal degrees, with notation of projection system. The watershed name will be noted for upland projects. Stream and watershed names will be noted for stream projects. In the event that projects are in unnamed watersheds or on unnamed streams, the next larger named stream or watershed will be used.

Linear projects

Projects that involve planting or managing riparian vegetation, restoring flows, multiple instream structures, slope stabilization and road resurfacing or decommissioning are linear in nature. Restoration projects that combine a number of project types along a stream reach may also be considered linear.

Linear projects will be described by beginning and end points (upstream and downstream ends for stream related projects) and the linear distance between. The location of the project will be documented by recording the latitude and longitude at the beginning and end points of the project in decimal degrees (noting projection system) as measured with a GPS. The length of the project will be recorded in stream distance along the centerline of the stream for stream related projects or road length for road related projects. Watershed name will be noted for upland projects. Stream and watershed names will be noted for stream projects.

Extensive projects (polygon shaped)

APPENDIX B: PROTOCOL FOR DOCUMENTING RESTORATION PROJECT LOCATIONS

Extensive projects such as grazing management and fuels treatment occupy a land area that can be described as a polygon. Extensive projects will be described by their corner points and the estimated area contained within them. The location of corner points will be documented by recording the latitude and longitude in decimal degrees as measured with a GPS. The area of the project in acres will also be calculated, if it is not already available in project files.

Determining project coordinates

Project coordinates may be determined using the following methods. All these methods of coordinate location should be used together to compensate for the inherent weaknesses in each individual method. Coordinate positions generated using each method should be compared to coordinate positions estimated from other methods and differences noted. The most basic method of determining the coordinates of a project is to locate the project on a topographic map and back calculate the coordinates (latitude and longitude) using map measuring devices.

A second method uses a handheld GPS unit to identify project coordinates. This method may provide more precise coordinate locations than mapping, depending on the terrain and quality of the GPS unit. It may not be possible to determine location using a GPS unit on steep north facing slopes, and in these instances it will be necessary to rely on the skill of the surveyor to accurately locate their location on the map.

A third method of determining project coordinates is to determine their bearing and distance from known reference points. The use of bearings and distances is intended to be a useful field method to relocate coordinates, not a method of determining latitude and longitude for project coordinates. However in settings where the GPS unit cannot be relied upon, the use of bearings and distances may be used to assist in determining location on the map.

Determining project distances

Distance and lengths of projects should be determined for projects that are linear or extensive in nature. Distance of single point projects from known reference points may also need to be determined. Distances may be estimated in many ways including pacing, tape measures, string box distances, vehicle odometers, map measurements, GPS units, GIS analysis, etc. Because recorded distances may vary between methods, it is essential to record which method or combination of methods was used in locating each point. For example, the length of a stream reach as measured using a stringbox in the field can be quite different than the length as derived from a map or GIS system.

Recording locations for single point projects that are not on actively used roads require the greatest degree of accuracy since these will be the most difficult projects to relocate in the field. Latitude and longitude of single point locations determined via map estimates or GPS units may not be adequate. Therefore, single points should also be located relative to known reference points, as discussed below.

Monumenting project coordinates

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Single points, beginning and end points, and corner points will be monumented with permanent markers in areas that are not likely to be disturbed (above the 100-year floodplain for stream related sites and out of the way of graders and brushing machines on roads). There are multiple ways to establish permanent markers. The easiest method is to affix an aluminum tag to an existing, durable feature such as a large tree (>12 inches dbh), boulder, rock outcrop, bridge, building, etc. If no existing feature is available or suitable then a marker will have to be established. An inexpensive and easy method of establishing permanent markers is to use a three foot length of 1/2" outside diameter rebar driven into the ground 2 to 2.5 feet deep. An aluminum tag stamped or inscribed with the project name and coordinates, date installed, organization responsible, and other appropriate information should be affixed to the marker.

In areas that are not likely to be disturbed, a six-foot length of white PVC pipe (1/2" inside diameter) should be slipped over the exposed rebar to make relocating the marking point easier. Brightly colored flagging should be tied to the marker and on nearby vegetation. The same information recorded on the aluminum tag should also be written on the PVC pipe. A detailed description of each permanent marker will be recorded on the data sheet. The description should include the type of marker (tree, boulder, fencepost, etc.) and characteristics of the marker (diameter of tree and species, size of boulder, color of fencepost, etc.).

The proximity of each project coordinate marker to permanent reference points should be determined. Permanent reference points include durable landmarks such as bridges, parking lots, buildings, trees, and rocks above the 100-year floodplain. The distance and bearing of each permanent marker from one of these reference points will be recorded on a data form so that reference markers that are affected by disturbances can be re-located in the future.

Permanent markers should also be affixed to reference points. On trees, these will be square aluminum tags with bearing and distance to associated markers. For rocks, these should be square aluminum tags attached to the rock with epoxy.

Data to be submitted to DFG

The location data form includes watershed, stream name (for stream related projects), USGS quadrangle and legal description (TRS), written descriptions and photos of the project coordinates and permanent reference points, contact information for landowners and relevant agencies, access information, and a site sketch.

The location of permanent markers at points, project beginnings or ends, and polygon corners will be accurately plotted on a large-scale site map and 1:24000 quadrangle. Directions, including distance and bearing from the nearest access point road, trail, bridge, stream tributary, and reference point to each monumented location marker will also be included. Latitude and longitude will be provided for every project coordinate, permanent reference point and permanently marked project features.

DOCUMENTING PROJECT FEATURES

APPENDIX B: PROTOCOL FOR DOCUMENTING RESTORATION PROJECT LOCATIONS

Linear projects may consist of multiple project features along a stream or road system. Stream related linear projects may involve multiple in-stream structures, locations for planting or managing of riparian vegetation, or bank stabilization sites. Road projects may include multiple locations of slope stabilization, drainage improvements, contouring, or decommissioning. Extensive projects may also have discrete project features such as locations with particular types of fuels treatment or discrete pastures for riparian fencing.

Projects that are linear or extensive but do not have discrete sub-project locations (such as a length of road resurfacing or a reach of stream reconstruction) are not required to document separate project feature locations.

Projects with multiple features will have each feature documented for subsequent relocation and monitoring. Locations and descriptions of all project features will be recorded as follows:

Numbering project features

For stream related projects, each project feature such as fish ladder, barrier, or instream structure will have a unique ID number assigned to it. Numbering will be sequential from downstream to upstream and reflect as-built conditions. For road-related projects, each project feature such as culvert replacement, rolling dip or outsloping section will have a unique ID number assigned to it and be numbered sequentially from beginning to end. For extensive projects, discrete project locations such as pastures or treatment areas will be assigned a unique ID number. Contiguous areas should have sequential numbers.

Feature location markers

A feature location marker should be established for each project feature, where feasible. Stream related features should be monumented on the left or right stream bank above the 100-year floodplain. These reference markers should be clearly visible to observers standing in the channel. Permanent reference markers for road related features should be visible from the road surface. For extensive projects, markers should be easily located by surveying from project corners.

Feature locations that are very close together, less than 15 feet apart, or are near features from similar past projects should have individual project feature location markers. For some large projects, such as a road projects with many rolling dips and drains on the same section of road, affixing a permanent marker at each feature may not be feasible. In these cases, feature location should be recorded (e.g. 1.2 road miles from starting project coordinate marker).

Monumenting feature locations

The same protocols used to monument project coordinate locations will be used to monument feature locations.

If it is necessary to monument a feature location, but not possible to place a permanent feature marker because of a high probability of disturbance (i.e. in-stream or landslide projects), relative locations should be documented using the "two-pin method" described in the DFG manual (Appendix L). This standard surveying technique establishes the feature location by triangulation from the two reference markers that are out of the potential disturbance zone. Having two reference markers will also be useful for relocating either of the reference markers if one becomes lost or damaged.

DATA TO BE SUBMITTED TO DFG

The location data form includes: date markers installed, description of marker, name of person installing marker, associated structure ID numbers, bearing and distance information from project markers to reference points, photos of the marker/reference point, and a site sketch. Permanent markers and reference points will be accurately plotted on a large-scale site map and 1:24000 quadrangle.

REPORT FORMAT

Data from the field data sheets will be entered into the DFG database and a field ready report will be printed. The field ready site location report will be part of a package prepared for the monitoring crew that will include the following additional items: transportation map for driving portion of trip, topographic map with parking location and project site included, site sketches, photographs of project coordinate markers, project feature markers, and permanent reference points, GPS unit with pre-programmed way points for relevant features, and combinations or keys to any locked gates.

APPENDIX B: PROTOCOL FOR DOCUMENTING RESTORATION PROJECT LOCATIONS

INSTRUCTIONS FOR COMPLETING THE SITE LOCATION DATA FORM

FRONT SIDE OF DATA SHEET

General Information- section 1

1) **Date-** Enter the day's date: mm/dd/yy
2) **Surveyors-** Enter the names of the survey crew
3) **Stream Name-** Print in the name of the stream. For unnamed streams, enter the name of the stream to which it is tributary.
4) **Project ID-** Print in the project identification number assigned to this contract by the Department of Fish and Game.
5) **Watershed Name-** Enter the name of the watershed where the project is located.
6) **USGS Quadrangle(s)-** Enter the name(s) of the 7.5 minute USGS quadrangle where the project is located.
7) **Legal Description-** Enter the township, range and section(s) where the project is located.
8) **GPS Unit ID-** Enter the serial number or other identifying number for the GPS unit being used to determine locations on this project.
9) **Camera ID-** Enter the serial number or other identifying number for the camera being used on this project.

Contact Information for Project- section 2

10) **Name-** Enter the name of a contact person for each entity listed in the leftmost column. Landowner refers to the person or organization that owns the land on which the project is located. Lead agency refers to the agency providing funding or technical leadership for the project. Contractor refers to the person or organization that has received the grant from the lead agency to carry out the work. Crew 1 and 2 refers to the last two teams of surveyors that have conducted monitoring or assessment work at this location.
11) **Affiliation-** Enter the name of the organization that each contact person works for or represents.
12) **Address-** Enter the address of the organization that each contact person works for or represents.
13) **Phone-** Enter the business telephone or cell phone number for each contact person.
14) **Email-** Enter the email address for each contact person.

Gates and Access- section 3

15) **Gate combo or key required?-** Enter the combination to any gates on the access road for this project, or note that a key is required and provide information on how to acquire this key for future survey crews.
16) **Landowner permission required?-** Enter whether or not prior permission from the landowner (or road owners leading to the project) is required to access the project. If permission is needed from someone other than the landowner, enter the contact information for that person.
17) **Access Hours-** Enter the hours that the road leading to project or the project area itself is open to access. For example, some timber companies close their gates at 5 pm.

Driving Directions to Parking Site- section 4

18) **Driving Directions-** Record detailed driving directions to the parking site where the project is accessed from. Start driving directions at the nearest highway or major marked road, include: exit names, street names, directions to turn, distances in miles and tenths from the odometer in the vehicle, useful landmark descriptions and locations, and a detailed description of the parking spot.

Photo of Parking Site – section 5

19) **Photo Number-** Enter the frame number displayed on the camera for each photograph.
20) **Photo Bearing-** Enter the compass direction that the camera is facing, use azimuth readings and note whether the compass is reading magnetic north (MN) or true north (TN).
21) **Description of Photo Point-** Describe the location of the point where the photograph is being taken from, include important features or landmarks.
22) **Description of Scene-** Describe the scene in the photograph, include important features or landmarks.

Parking Site Location – section 6

23) **Waypoint Name-** Enter the waypoint name used in the GPS unit to mark this location.
24) **Latitude-** Enter the latitude displayed on the GPS unit. If no GPS unit is available or unit does not function, measure the latitude of the location using a map. In either case record the method used to determine latitude.
25) **Longitude-** Enter the longitude displayed on the GPS unit. If no GPS unit is available or unit does not function, measure the longitude of the location using a map. In either case, record the method used to determine longitude.

BACK SIDE OF DATA SHEET
General Information- section 7

26) **Date-** Enter the day's date: mm/dd/yy
27) **Surveyors-** Enter the names of the survey crew.
28) **Stream Name-** Print in the name of the stream. For unnamed streams, enter the name of the stream to which it is tributary.
29) **Project ID-** Print in the project identification number assigned to this contract by the Department of Fish and Game.
30) **Compass Type-** Record whether your compass provides bearings based on 'True North' or 'Magnetic North' by circling the appropriate category . If your compass has the declination set use 'True North', if your compass does not have a declination setting or you have not set it, use 'Magnetic North'.

Navigation Data- section 8

31) **Point Name-** Enter the name of the point used to denote this location. The point name is structured code consisting of the point type followed by the point number. The possible point types are listed in the table at the bottom of the data sheet. Point numbers are assigned sequentially *within* each point type category, but not sequentially *between* point type categories. For example, the first point is likely to be the DP1 (Departure Point 1); the next point may be CP1 (Corner Point 1); followed by CP2 (Corner Point 2); and then BM1 (Benchmark 1). Feature Marker point types are different, they are simply assigned the same number as was originally assigned to the feature itself during the design phase or first monitoring effort. Project features are numbered sequentially from downstream to upstream for in-stream projects and from beginning to endpoint on road projects.
32) **Description of Point-** Describe the physical setting of the point and the type of marker used, e.g. red metal fencepost, 15 inch dbh spruce, 4' diameter rock with rebar inserted, etc. Use specific details when possible, such as tree species, size of rock, color and type of fencepost, slope angle, aspect, nearby landmarks, etc.
33) **Waypoint Name-** Enter the waypoint name used in the GPS unit to mark this location.
34) **Latitude-** Enter the latitude displayed on the GPS unit. If no GPS unit is available or unit does not function, measure the latitude of the location using a map. In either case record the method used to determine latitude.
35) **Longitude-** Enter the longitude displayed on the GPS unit. If no GPS unit is available or unit does not function, measure the longitude of the location using a map. In either case, record the method used to determine longitude.
36) **Bearing to Point-** Enter the bearing to the current point from the previous point in degrees from 0-360. Note if your compass reads Magnetic North or True North at the top of the page.
37) **Distance to Point-** Enter the distance from the previous point to the current point in feet.
38) **Measure Method-** Enter the method used in the previous 'Distance to Point' measurement. For example: tape measure, rangefinder, map distance, pacing, ocular estimate, etc.
39) **Photo Number-** Enter the frame number displayed on the camera for each photograph.
40) **Photo Description-** This is a photograph of the current point taken from the direction from which the point will be approached in the future. Describe features visible in the photograph that will help a subsequent observer re-locate this point, e.g., landmarks, distinctive trees, soil type, etc.

SITE LOCATION DATA SHEET

Site Location Data Sheet

Date____________________ Surveyors_______________ Stream Name________________________
DFG Project ID #_______________________ Watershed Name_____________________
USGS Quadrangle(s)______________________ Legal Description (TRS):__________________________
GPS Unit ID #_______________ Camera ID #______________________

Contact Information for Project

Entity	Name	Affiliation	address	phone	email
Landowner					
Lead Agency					
Contractor					
Crew 1					
Crew 2					

Gates and Access:

Gate combo or key required?
Landowner permission required?
Access hours

Driving Directions to Parking Site (include landmarks, roads and distances)

Photo of Parking Site, if necessary.

Photo Number	Photo Bearing	Description of Photo Point	Description of Scene

Parking Site Location

Waypoint name	Latitude	Longitude

Site Sketch

Site Location Data Sheet, Backside

Date___________ Surveyors_____ Stream Name________________________

DFG Project ID_______________________ Compass Type (circle one) **True North** -or- **Magnetic North**

Navigation Data (Brg and Dist are from previous point to current point, 0 and 0 at departure point)

Point name	Description of point	Waypoint Name	Latitude	Longitude	Bearing to point (AZ)	Distance to point (feet)	Measure Method	Photo Number	Photo Description

Point Types

SP	Single Point, project coordinate	RP	Reference Point, permanent	BM	Benchmark
EP	End Point, project coordinate	DP	Departure Point, parking spot	XP	Cross Section end point
CP	Corner Point, project coordinate	NP	Navigation Point, used to navigate to other	WP	Witness Point, to locate photopoint
FM	Feature Marker	OP	Other Point, explain	PP	Photopoint

APPENDIX C: PROTOCOL FOR PHOTOGRAPHIC MONITORING

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APPENDIX C: PROTOCOL FOR PHOTOGRAPHIC MONITORING

PROTOCOL DESCRIPTION

Compared to collection of extensive quantitative data, implementation and effectiveness monitoring using photographs tends to be relatively quick and easy. Photographic evidence of change in a project area is often readily apparent to a broad audience without in-depth data gathering, analysis, and report writing. A good photo sequence documenting project change is thus literally worth 1000 words, or more.

However, careful photographic techniques must be employed to monitor site and reach level changes. For example, to be effective, sequential photos must be taken from identical locations with identical methods over time. This is made possible by the establishment of permanent photopoints at specific sites. In addition, photos must be taken from strategic locations and at times chosen to maximize the possibility of showing changes in project conditions.

ASSUMPTIONS

Photo monitoring will be done on every DFG funded restoration project in order to aid in qualitative assessment of restoration effectiveness.

- Effectiveness of projects can be judged in part based on photo documentation of project effectiveness criteria. Achievement of some effectiveness criteria will be apparent from visual records while achievement of others may not. Photos will be taken in locations that maximize the probability that visible effectiveness criteria will be documented.

- Photos will be taken by different people at different times. Pre and post project photos will probably be taken by project contractors or DFG contract managers. Later photos will probably be taken by DFG staff during qualitative evaluation visits (in conjunction with qualitative checklists).

- Photo sequences will not be used for quantitative measurements but should be of sufficient detail and quality to enable retrospective evaluation of projects.

PHOTOGRAPH TYPES

Implementation, effectiveness, general location, and spot photos are suggested. <u>General location photos</u> are taken at key places throughout the project site including the start and end points of a project and the permanent markers that denote them. Key places include landmarks such as side channels, tributaries, nearby roads, road intersections, bridges, buildings, trails, fence posts, trees or other identifiable features.

<u>Implementation photos</u> record key steps in completing the project as well as the mitigation measures taken to prevent construction related impacts. The purpose of implementation photos is to determine if projects were correctly implemented, structures have been aligned correctly and are in good condition, and that project mitigation measures were applied. Photos of structure installation or removal, planting or clearing, or road work help document the actions taken for future evaluators. Photos should also be taken of measures that mitigated project impacts such as stream diversions, erosion control measures, and vegetation protections or stockpiling.

APPENDIX C: PROTOCOL FOR PHOTOGRAPHIC MONITORING

Effectiveness photos are taken to help observers qualitatively judge the effectiveness of the project at meeting its objectives. Photos should be taken at locations that will facilitate evaluation of how well the project met effectiveness criteria. Only some of these criteria will be visually apparent and only in some locations. Likewise, effectiveness is not likely to be properly evaluated until some time after the implementation work has been completed.

Spot photos are individual photos that depict project or treatment effectiveness, or the lack thereof. These may be associated with a pre-treatment photo, but can still be used to make a point or to show something in greater detail that was not anticipated prior to project implementation. They may also be photos that show greater detail than the overall before and after photo sequence of the larger scene.

The following tables list the photographs to be taken to facilitate implementation and effectiveness monitoring for each project type. Effectiveness and implementation criteria are listed for each project type. Location and types of photos to be taken are listed for each criterion. The photo sequence should include pre- project photos taken of the project area before the project is implemented, post-project photos taken directly after project implementation, and post-project photos taken during subsequent effectiveness monitoring, all from the same photo point.

Table 1: Fish Passage – Implementation/ Effectiveness Photos

Projects: Fish ladders, channel modification, barrier removal, barrier modification

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Properly installed inlets and outlets	Photos taken from directly downstream and directly upstream of future passage structure at elevation of structure	Photos taken from directly downstream and directly upstream of passage structure looking through it
Proper culvert/bridge alignment	Photo taken from above and from side looking at location where new structure will be installed	Photo taken from above and from side of culvert/bridge slope. Culvert photos should show culvert inlets and outlets relative to the vertical and horizontal distance from the channel bottom. Photo of pool at base of structure
Area of habitat made accessible	Photo of conditions causing fish barrier Photo of habitat above barrier	Photo of location of previous barrier Photo of habitat above previous barrier
No unforeseen adverse effects on habitat such as incision, instability or sedimentation	Photos of channel conditions taken from mid-channel upstream of barrier, downstream, and at barrier	Photos taken from mid-channel of channel upstream of barrier, downstream, and at previous barrier
Increased attraction flows during migration periods (for barrier modifications)	Photo of attraction flow at barrier during migration	Photo of attraction flow at previous barrier during migration

Table 2: Instream Structures – Implementation/ Effectiveness

Projects: Install structures, install gravel, construct channel/breach dikes

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Properly installed structures/Structures in good condition/ Structure integrity preserved/ No undesirable channel changes or bank erosion	Photos taken from mid-channel looking upstream and downstream from each future structure location and photo taken from either right or left bank looking down upon future structure location.	Photos taken from mid-channel looking upstream and downstream from each structure location and photo taken from either right or left bank looking down upon structure.
Increase in targeted habitat units	Habitat at future location of each structure	Habitat formed by each structure (pool, shelter, undercut banks, gravels, side channels, etc.)

Table 2b: Instream Structures – Implementation/ Effectiveness Photos
Projects: Remove structures

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Properly removed structures/ No undesirable changes or bank erosion / Increased riparian vegetation /Increased channel/floodplain connectivity	Photos taken from mid-channel looking upstream and downstream from structure and photo taken from either right or left bank looking down upon structure and the adjacent habitat.	Photos taken from mid-channel looking upstream and downstream from previous structure location and photo taken from either right or left bank looking down upon previous structure location.
Increase in targeted habitat units	Habitat at location of each structure	Habitat formed by structure removal (pool, shelter, undercut banks, gravels, side channels, etc.)

Table 3: Streambank stabilization – Implementation/ Effectiveness Photos
Projects: Deflect streamflow, bioengineering, armoring

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Properly installed structures / Structures in good condition/ Structure integrity preserved	Photos taken from opposite bank and mid-channel looking across channel to where structure is to be placed.	Photo taken from opposite bank and mid-channel looking across channel at the structure. Photo taken from the bank with the structure looking down upon the structure.
Reduced bank erosion/ Improved channel geometry/ Increased riparian vegetation	Photos of channel upstream and downstream of future structure location. Photo of channel at future structure location from opposite bank.	Photos of channel upstream and downstream of structure. Photo of channel at structure location from opposite bank.

Table 4: Land use – Implementation/ Effectiveness Photos
Projects: Exclude grazing, install watering sites, manage grazing, conservation easements

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Properly installed structures *(fences, troughs) /* Structures in good condition/ integrity preserved.	Photos taken of future structure locations	Photos taken of structures.
Livestock/wildlife effectively excluded	Photo of animal impacts on riparian zone/channel	Photos at same locations Photo of fence line showing vegetation use/trampling on each side.
Increased riparian vegetation/ riparian connectivity/ Increased bank stability/ Improved channel geometry	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]
Improved water quality	Photo of water clarity (including algal blooms and other indications of nutrient loading) within future project reach (from above channel at low flow)	Photo of water clarity within project reach (from above channel at low flow)

Table 5: Vegetation Control – Implementation/ Effectiveness Photos
Projects: Remove exotic plants, plant vegetation, reduce vegetation encroachment into channel

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Project properly installed/Planting survival/Reduced exotic plants/ Increased native plants/ species richness	Photos where plantings/removals will occur	Photos at same location after treatment
Reduced barren ground	Photo of areas of bare ground	Photo at same location after treatment
Increased riparian canopy cover/ Reduced vegetation within bankfull / Increased availability of spawning gravels (if clearing encroachment involved)	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]

Table 6: Riparian Planting or Management – Implementation/ Effectiveness Photos
Projects: Plant vegetation, alter vegetation composition

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***

Project properly installed/ Planting survival/ Advancement in riparian successional stage from grass-shrub to forest	Photos where plantings/removals will occur (from opposite bank)	Photos of project plantings/removals at same location (from opposite bank)
Increased riparian canopy cover / Increased riparian corridor continuity and patch size	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]	Photos taken from mid-channel of riparian vegetation on left bank, right bank, channel upstream, channel downstream, and overhead [upstream of project reach, throughout project reach, and downstream of project reach]
Riparian tree composition meets planting or management objectives	Permanent photo plots in areas of future treatment site	Permanent photo plots after treatment

Table 7: Restore Streamflow – Implementation/Effectiveness Photos
Projects: Obtain water rights, manage flows

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Project properly installed	Photo of location where structure/practice to restore water will be implemented	Photo of structure/practice where water flow restoration is occurring
Increased low flows, flows achieve natural peak flow regime	Photo of streamflow/channel throughout future project reach (from mid-channel) during low flows and high flows	Photo of streamflow/channel throughout project reach (from mid-channel) during low flows and high flows
No adverse changes in downstream flows	Photo of streamflow/channel downstream of future project reach (from mid-channel) during high and low flows	Photo of streamflow/channel downstream of future project reach (from mid-channel) during high and low flows

Table 8: Slope Stabilization – Implementation /Effectiveness Photos
Projects: Soil engineering, bioengineering, upland fuels management

Implementation/ Effectiveness Criteria	***Pre-project photos***	***Post project photos***
Project structures or treatments are properly installed, implemented or applied.	Photos of locations of future project structures or treatments, if any	Photos of project structures or treatments, if any
Reduced likelihood of slope failure	Photos of areas of slope failure	Photos of same areas after treatment
Decreased soil erosion and sediment delivery from site	Photos of areas with soil erosion and sediment delivery occurring	Photos of same areas after treatment

Decreased sediment load near site during peak flow events/ No significant increase in mass wasting and sediment delivery from treated area	Photos of areas where sediment from project area delivers to channel (ditch, culverts, channel)/ Photos of channel immediately downstream from potential sites of sediment delivery	Photos of same areas after treatment
If planting involved, reduced bare ground and increase in deep rooted vegetation.	Photos of bare ground/Photos of future planting locations	Photos of plantings/ground cover
Reduced fire hazard/reduced fire incidence	Photos of areas of high fire hazard	Photos of same areas after treatment

Table 9: Gully Repair – Implementation/Effectiveness Photos
Projects: Gully modification, bioengineering, armoring

Implementation/ Effectiveness Criteria	*Pre-project photos*	*Post project photos*
Project structures properly installed	Photos of location where structures will be installed	Photos of project structures if any.
Cause or source of gullying is removed	Photos of conditions causing gully formation, or of flows in gully.	Photos of same areas after treatment
Improved channel geometry / No offsite adverse effects on downstream channels / Reduced erosion and sediment yield/ Increased vegetation cover	Photos taken of channel (from mid channel) upstream of project reach, throughout future project reach, and downstream of project reach)	Photos taken of channel (from mid channel) upstream of project reach, throughout project reach, and downstream of project reach)
Planting survival and effectiveness	Photos where plantings will occur	Photos of same areas after treatment

Table 10: Road Upgrading or Decommissioning – Implementation/ Effectiveness Photos
Projects: Road surfacing, upgrading, and decommissioning

Implementation/ Effectiveness Criteria	*Pre-project photos*	*Post project photos*
Project structures or treatments properly installed	Photos of future project structure or treatment locations, if any.	Photos of project structures or treatment, if any.
Reduced erosion rate from road surface/ Reduced runoff and/or increased infiltration rate on road surface	Photos of road surface to be treated	Photos of same areas after treatment
Reduced sediment yield/ Improved stream discharge regime in immediately adjacent watercourses	Photos of areas where sediment /water delivers to channel (road surface, ditch, culverts, gullies, channel, etc.)	Photos of same areas after treatment

Reduced sediment delivery from road-related slope failure	Photos of probable slope failure	Photos of same areas after treatment
No offsite adverse effects on erosion or sedimentation	Photos taken of channel (from mid channel) upstream of project reach, throughout future project reach, and downstream of project reach)	Photos taken of channel (from mid channel) upstream of project reach, throughout project reach, and downstream of project reach)
Planting survival	Photos where plantings will occur	Photos of plantings

TIMING

Sequential photographs must be taken over time in order to show changes in site conditions. The timing and number of photos needed for an effective photo sequence depends on the project type. At minimum, photos should be taken at three different times, before project implementation, directly after project implementation, and again at a later date appropriate to the particular project. This later date for photographing effects depend on the project type and goals.

Project Goal: Improve fish passage by modifying or removing barriers
Effectiveness Photo Timing: Periods of adult fish migration, typically at highest flows and periods of juvenile fish migration, typically at lower flows.

Project Goal: Improve instream habitat by installing or removing channel structures
Effectiveness Photo Timing: After stressing events most likely to produce responses. Some desired effects such as scouring of channel fill deposits and gravel filling behind a structure may occur during relatively small events, depending on bed material size. Testing of structure resiliency may only occur during higher flow events, such as the 10-year flow.

Project Goal: Stabilize streambanks by installing armor, bioengineering, or deflectors
Effectiveness Photo Timing: After stressing events most likely to produce responses, based on the design criteria.

Project Goal: Restore riparian vegetation through planting or thinning, elimination of exotic or encroaching plants; and land use control through riparian fencing, grazing management or conservation easements
Effectiveness Photo Timing: After adequate plant establishment and growth should occur given site conditions and local climate. Photos should be taken within two to three years in locations where vegetation grows vigorously and three to five years elsewhere. Projects involving riparian plantings should be photographed during the growing season when full foliage is present. Follow up photos should be taken during the same part of the growing season.

Project Goal: Improve instream flows through obtaining water rights or managing flows
Effectiveness Photo Timing: At the periods of highest and lowest flows

Project Goal: Control erosion, stabilize slopes, or repair gullies by soil engineering, bioengineering, or armoring

Effectiveness Photo Timing: Most photos should be taken at the same time as implementation photos. Photos documenting differences in flow in gullies due to project work should be taken during the rainy season.

Project Goal: Upgrade or decommission roads by surfacing or decompacting (respectively), installing drainage and erosion control structures, upgrading or removing crossings, stabilizing or excavating unstable fills and performing erosion control and revegetation treatments.
Effectiveness Photo Timing: After the first stressing storm event. Photos should be repeated on a yearly basis for at least five years, and after large runoff events. For road upgrading projects, it is important to take monitoring photos prior to road repair work that might be done during normal or storm maintenance activities and would cover up or alter the treatment site.

FIELD SAMPLING

For projects with many project features, such as a road improvement or decommissioning projects with multiple stream crossings, rolling dips and areas of regrading, or extensive projects such as riparian plantings, it may not be necessary to establish photopoints at each project feature. In this case, photo sampling may be necessary and both representative and unique project sites can be selected for monitoring. Some sites may not be "photogenic" and monitoring efforts should be focused on sites where views are both representative and interesting.

For linear riparian projects, a minimum of 25 photos along a photo transect is suggested. Photos taken every 100 feet along the channel will amount to about 25 photos per half mile of stream. A transect should be established from project start to end point along which photos are taken from mid-channel if possible. Photos may need to be taken from banks opposite to project work in very narrow channels. Photo points should be monumented with permanent markers if possible. If this is not feasible, distance along the transect relative to an established starting point should be recorded using a string box or tape. For projects larger than a half mile in length, a minimum of 25 photos should be distributed throughout the project reach. These can be located at intervals longer than 100 feet or at strategic project locations. Strategic locations include areas with good views, such as from the top of a large boulder. For more in-depth guidance on effective photography of vegetation see Hall (2002).

For long extensive road projects, photo points should be established at a minimum of 30 percent of treated sites. Larger features where changes are more readily detected are recommended for photo documentation.

Sampling is not recommended for in-stream projects. Instead, photos of every in-stream structure should be taken. For additional guidance on effective photography of sediment and erosion control projects see Lewis et al (nd).

ESTABLISHING PHOTO LOCATIONS

The location of the camera when taking a photograph or photo series is known as the photo point. Photo points should be established for each project at the locations described in the tables above. The best locations for photo points are easily identified areas that allow a clear view of the project feature. These include points above the project looking down on it, or from mid-channel looking at channel banks.

Sometimes a good photo point can be developed by brushing and clearing vegetation in the field of view. Elevated sites that will not be obscured by vegetation extend the longevity of a photo point. The location chosen should be useable for at least 5 to 10 years.

Another element of a successful photo point is the availability of permanent landscape features in the photo background. Including permanent features allows the observer to confirm that subsequent photographs have been taken in the same location and of the same subject, even if drastic changes have occurred. Cross-valley photographs, where visibility permits, can be used because of their inclusion of landscape features.

ESTABLISHING PERMANENT MARKERS FOR PHOTO POINTS

Where feasible, a permanent marker should be established for each photo point. Permanent markers facilitate relocation of photo points for subsequent photographs. In stable settings, fence posts, rebar or other permanent markers can be placed in the ground to mark the location of the camera during photography. A metal label and flagging should be attached to the marker with the project number, photo point number, and date.

In some cases, the best vantage points for capturing relevant site characteristics may be within the channel or in areas prone to disturbance such as road surfaces, landslide run-out zones, and unstable stream banks. Permanent markers established in these areas are vulnerable to disturbance and may not be useful for relocating the project area in future years. In these cases, permanent markers may be attached to nearby objects such as fences, bridges, or trees. The location of these markers is known as the witness point, the point from which the photo point can be located. Directions from the witness point to the photo point should be recorded on the photo data sheet.

For some projects, such as riparian planting or instream structure installation along an entire stream reach, it may not be feasible to install many permanent markers. In these cases, photo locations should be described as distances from a known point using a string box. Known points can include project coordinates or nearby landmarks.

DOCUMENTING PHOTO POINT LOCATIONS

Photo point locations must be clearly documented in order to allow subsequent visitors to relocate points and take effective photographs. Photo and witness point locations should be recorded on the photo monitoring data sheet. Locations should be described as distances and bearings from other known points such as the project coordinates or other permanent landmarks.

For photo transects taken along a stream channel, relative distances between points measured in feet with a hip chain or tape should be recorded. For photos along driveable roads, the mileage between photo points should be recorded. Points that are closer together than 0.1 miles (the smallest reading on an odometer) should be recorded by pacing or a hip chain.

Witness and photo points should be numbered and marked on a site map (ideally a 1:3,000 scale DOQQ) and also drawn on a site sketch on the data sheet. The sketch map should contain readily identifiable landmarks that can be used to locate the photo point.

TAKING PHOTOS

Photographs may be taken using print, slide, or digital technology. Use of a high-resolution digital camera (greater than two mega pixels) is recommended to ensure high quality prints. Cameras with electronic stamps that automatically record date and time, film speed, and aperture for each photograph facilitate easier data storage and retrieval.

When framing the photo, incorporate other fixed landscape features in the shot, where feasible, to help orient the observer in subsequent years. Use features such as large or unique trees or stumps, boulders, fences, buildings, road intersections, and the horizon to identify the framing. In addition, make sure your pre-project view considers the treatment that is proposed for the site. That is, if the site calls for a large excavation of soil for a decommissioned stream crossing, make sure you will have the entire excavation area in the field of view. It is a common mistake to take the photo of the pre-project scene that does not reflect what the site will look like after the treatment, and significant parts of the treatment are not visible in the photo.

Photographs should be framed to capture the expected “area of influence” and not just the project component expected to cause changes. For example, photos of an in-stream structure designed to develop a pool should include the area that is expected to scour and the resulting gravel bar immediately downstream. This area is likely to be far larger than the actual structure. Likewise, photos of channels after structure installation should show adjacent reach features rather than just structures.

Typically, wide-angle lenses (up to 28mm) will give the best overall photos of restoration sites. Wider lenses may cause visible curvature or “fish-eye” distortion. Digital photos can be “stitched together to produce wide views, but the seams are often visible (as blurred lines) and the photos may end up as long, narrow prints. Zoom lenses on analog cameras can be used to provide the best possible framing of a scene. Zoom lenses on point-and-shoot or digital cameras do not have markings of the lens setting, and therefore cannot be easily recreated. In this instance, it is often best to set the lens at maximum wide angle and take the picture. Photos (or color copies of photos) taken during the previous round of photography should be brought to the field when re-taking the photographs at the next point in time. The photo data sheet with comments listed should be used to identify photo point locations.

Each photograph should contain a scale element such as a vehicle, person, meter board, or white board depending on the type of project. Vehicles make handy scale elements for large road projects. Meter boards are preferable for projects in low vegetation such as herbaceous or meadow vegetation. For stream related projects, a six-foot long stadia rod or other measuring item can be used. An erasable white board and marker can be used within the photo frame to identify the site within the photograph.

For projects that are not focused on improving vegetation, a lopper or a machete should be used to cut back vegetation and improve the photo.

The best time to take photos in heavily vegetated areas is on overcast days, or early or late in the day. This is not as important on grassland and open woodland sites. Trees and other large vegetation cast shadows and create light and dark patches that mask details and result in excessive contrast. Direct overhead sun will also cause glare and high contrast, making it difficult to distinguish detail in the picture. Areas of bare-ground such as road surfaces and slide scarps, often appear as bright white areas with no detail. If photographs of bare ground are taken on sunny days in exposed areas, they should be done in the morning or evening before sun hits the site and shadows become too strong. Subsequent photographs should be taken at about the same time of day and season as the previous photographs, if possible. In most cases, analog cameras should use high-speed film, and employ shutter speeds of 1/60 second or faster. A tripod or monopod should be used to take photos in extremely low light settings.

DOCUMENTING PHOTOGRAPHS

The importance of clearly documenting photos cannot be overemphasized. Detailed information about each photograph should be recorded on a photo data sheet. Information recorded should include the day and time of each photo, photo point number, frame, roll, and camera number, lens, photographer, direction, subject, distance between camera and subject, and height of camera above the ground. If shooting more than one photo at the same point, each photo should have a unique number to distinguish it. If a zoom lens is used, the lens setting should be recorded. Finally, descriptive text of the location of the photo point (e.g. taken looking north from on top of a 3' diameter fir stump at edge of the stream channel) should be included on the photo data sheet.

For photos taken in a forested setting, the direction of photograph should be noted using a compass bearing. For photos on stream channels, direction should be denoted as upstream, downstream, left bank, right bank, or overhead. Photo point number and photo direction should also be indicated by an arrow on the sketch map of the site.

Notes describing important elements of the subject are helpful for interpreting photographs. For example, tension cracks observed on a road fill that may not be visible in the photo should be noted to help monitor this process over time.

ANALYSIS AND STORAGE OF PHOTOGRAPHS

Digital images of each site can be stored along with other data collected for the site. Typically, at least one digital CD backup of the photos should be made and stored in a secure location. The digital information from the photo point data sheet can be stored on a database. All of this information can then be linked to a GIS map of the area to aid in spatial analysis. Printouts and exchange of data can occur at any point with digital information stored in this manner.

Clearly marked and identified print photos should be stored in project files along with the photo data sheet, sketch, and map of photo point locations. Archival photo storage sleeves should be used for all physical media. All photos should be labeled with information that will allow future monitoring personnel to clearly recognize their origin and location. Access to these photographs in a useable form is essential to allow subsequent photos to be taken in the correct locations.

REFERENCES

Hall, Frederick C. March 2002. *Photo Point Monitoring Handbook*, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report, PNW-GTR-526.

APPENDIX C: PROTOCOL FOR PHOTOGRAPHIC MONITORING

Lewis, David J.; Tate, Kenneth W.; Harper, John M., no date. *Sediment Delivery Inventory and Monitoring; A Method for Water Quality Management in Rangeland Watersheds*. University of California, Division of Agriculture and Natural Resources, California Rangelands Research and Information Center. ANR Publication 8014. 14 pages.

INSTRUCTIONS FOR COMPLETING THE PHOTO MONITORING DATA FORM – INDIVIDUAL FEATURES

General Information- section 1

1) **Date-** Enter the day's date: mm/dd/yy
2) **Surveyors-** Enter the names of the survey crew.
3) **Stream/Watershed Name-** Print in the stream name or watershed name. If unnamed, provide name of stream or watershed to which it is tributary.
4) **Project ID-** Print in the project identification number assigned to this contract by the Department of Fish and Game.
5) **Feature Number-** Enter the ID number(s) of the restoration feature(s) that is/are the subject of the photograph.
6) **Weather-** Enter a brief description of the weather at the time when the photographs were taken.
7) **Compass Type-** Record whether your compass provides bearings based on 'True North' or 'Magnetic North' by circling the appropriate category. If your compass has the declination set use 'True North', if your compass does not have a declination setting or you have not set it, use 'Magnetic North'.
8) **Point Name-** Enter the photo point or witness point name, which should have location details recorded on the Site Location Data Sheet, including driving directions to the site.

Photo point Location- section 2

9) **Marker Type and Location Description-** Describe the physical setting of the photo point or witness point and the type of marker used, e.g. red metal fencepost, 15 inch dbh spruce, 4' diameter rock with rebar inserted, etc. Use specific details when possible, such as tree species, size of rock, color and type of fencepost, slope angle, aspect, nearby landmarks, etc.
10) **Bearing and Distance from Landmarks-** Enter the bearing to the current point from the landmark or witness point in degrees from 0-360. Enter the distance from the landmark or witness point to the current point in feet.
11) **Comments-** Describe the location of the photo point or witness point where the photograph is being taken from, include important features or landmarks.

Witness and Photo Point Sketch- section 3

12) **Sketch-** Draw a simple map of the area including the subject of the photos (project feature), witness point, photo points and notable landmarks. Write in the names of points on the map; include distances and bearings between points on the map where possible.

Photo Record- section 4

13) **Camera ID-** Enter the serial number or other identifying number for the camera being used on this project.
14) **Film Speed-** Enter the speed of the film you are using. Write 'digital' if you are using a digital camera.
15) **Photo Point Number-** Enter the number of the photo point from which the photo was taken. Photopoints are numbered sequentially as they are designated.

16) **Time-** Enter the time that each photo was taken in military time notation (24 hour clock). It is not necessary to record time if the camera you are using automatically records date and time for each photograph, i.e. 'date back' cameras.
17) **Camera Bearing and Position-** Enter direction that camera is facing in degrees (0-360), then describe the location of the point where the photograph is being taken from, include important features or landmarks.
18) **Lens (mm)-** Enter the focal length of the lens used to take the photograph in mm. For cameras with a zoom lens it may only possible to determine the focal length at the extremes of the zoom range, i.e., fully wide angle or fully telephoto. Therefore on these zoom cameras you will have to use either the full wide or full telephoto settings and record the corresponding focal length, which is usually printed on the rim of the lens.
19) **Roll Number/Frame Number-** Enter the film roll number for each photograph taken followed by the frame number displayed on the camera. For digital cameras do not enter a roll number.
20) **Subject/Comments-** Describe the scene in the photograph, include important details about the subject of the photo. For example, "fine sediment deposit upstream of cabled log in center of photo" or "incision below culvert outlet at bottom of photo."

PHOTO MONITORING DATA SHEET – INDIVIDUAL PROJECT FEATURES

Photo Monitoring Data Sheet - Individual Project Features

Date_________ **Surveyors** **Stream Name**________________________
Project ID______________________ **Feature #:** _________________
Weather_________________ **Compass Type** (circle one) True North -or- Magnetic North

Photopoint Location

	Point Name	Marker type and Location description	Bearing & Distance from Landmarks	Comments
Witness Point				
Photopoint 1				
Photopoint 2				
Photopoint 3				
Photopoint 4				

Witness and Photopoint Sketch **

** Please attach a site map with witness and photo points marked

Photo Record Camera ID #_____________________ Film Speed______________

Photo Point #	Time	Camera Bearing and Position	Lens (mm)	Roll # / Frame #	Subject/comments

APPENDIX C: PROTOCOL FOR PHOTOGRAPHIC MONITORING

INSTRUCTIONS FOR COMPLETING THE PHOTO MONITORING DATA FORM- MULTIPOINT/MULTIFEATURE

General Information- section 1

1) **Date-** Enter the day's date: mm/dd/yy
2) **Surveyors-** Enter the names of the surveyors
3) **Stream/Watershed Name-** Print in the stream name or watershed name. If unnamed, use the name of the stream or watershed to which it is tributary.
4) **Form No.-** Enter in the form number. Number the forms sequentially beginning with "01" on the first page and "02" on the second page and so on.
5) **Project ID-** Print in the project identification number assigned to this contract by the Department of Fish and Game.
6) **Camera ID-** Enter the serial number or other identifying number for the camera being used on this project.
7) **Weather-** Enter a brief description of the weather at the time when the photographs were taken.
8) **Direction of Travel-** Circle 'Upstream' or 'Downstream' for the direction in which you are walking while taking pictures. If this is a road describe the direction of travel using a logical method, this may be cardinal directions on the compass or for windy or loop roads start and end points or references to landmarks.
9) **Film Speed-** Enter the speed of the film you are using. Write 'digital' if you are using a digital camera.

Information for each photograph- section 2

10) **Feature Number-** Enter the ID number(s) of the restoration feature(s) that is/are the subject of the photograph.
11) **Photo point Number-** Enter the number of the photo point from which the photo was taken. Photo points are numbered sequentially as they are designated.
12) **Reference Point or Monument Name-** For non-monumented photo points enter the reference point name (from the Site Location Data Sheet) that is being used to measure relative distance from. For monumented photo points enter the Photo point monument name, which should have location details recorded on the Site Location Data Sheet.
13) **Distance from Reference Point-** Enter the distance from the reference point to the current photo point, in feet or miles depending on the scale of project.
14) **Roll Number/Frame Number-** Enter the film roll number for each photograph taken followed by the frame number displayed on the camera. For digital cameras do not enter a roll number.
15) **Lens (mm)-** Enter the focal length of the lens used to take the photograph in mm. For cameras with a zoom lens it may only be possible to determine the focal length at the extremes of the zoom range, i.e., fully wide angle or fully telephoto. Therefore, on these zoom cameras you will have to use either the full wide or full telephoto settings and record the corresponding focal length, which is usually printed on the rim of the lens.
16) **Photo Point Location-** Describe the location of the point where the photograph is being taken from, include important features or landmarks.
17) **Direction of Photograph and scene description-** Enter direction that camera is facing in degrees (0-360) then describe the scene in the photograph, include important details about the subject of the photo. For example, "fine sediment deposit upstream of cabled log in center of

photo" or "incision below culvert outlet at bottom of photo." Note whether bearing is based on true north or magnetic north.

PHOTO MONITORING DATA SHEET – MULTIPOINT/MULTIFEATURE

Photo Monitoring Data Sheet - Mulitpoint/Multifeature

Form____of _____

Date__________ Surveyors___________ Stream/Watershed Name ________________________

Project ID____________________ Camera ID______________ Weather___________

Direction of Travel (circle one): Upstream or Downstream; or Other____________________ Film Speed:_______________

Feature Number	Photopoint Number	Reference Point or Monument Name	Distance from Reference Point	Roll Number/ Frame Number	Lens (mm)	Photopoint Location (site description)	Direction of Photograph and scene description

APPENDIX D: IMPLEMENTATION AND QUALITATIVE EFFECTIVENESS MONITORING

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PROTOCOL DESCRIPTION

The California Department of Fish and Game's (DFG) coastal anadromous fish habitat restoration program is a multi-million dollar competitive grants program that has been in place for over 20 years. From 1998 to 2001, over 345 projects were funded, totaling $14.5 million.

Despite current attempts to track project success, it remains difficult to develop a comprehensive overview of the success of the program at meeting its goals. Better and more comprehensive implementation and effectiveness monitoring of salmonid restoration projects is needed to allow informed decision making about the program by agency staff, legislators, and the public.

This protocol is intended to allow compilation of implementation and effectiveness information for all DFG funded projects and so permit a general evaluation of program effectiveness. It consists of two parts: a series of checklists to be completed based on field observations and a method for photographing project sites. Repeated photographs and field evaluations provide the basis for before and after comparisons and for detecting effectiveness over time. These data can be used to report on overall program accomplishments, as has been done recently in Oregon (Malecki and Riggers 2001). Reports on individual projects can be used to assess the need for remedial action.

Effectiveness monitoring can occur at a wide range of precision and effort levels. This protocol is designed to monitor effectiveness at a qualitative level. Using this protocol, a large number of qualitative observations are made to evaluate whether or not a project has reached its goals. Information is collected when a visually obvious effect is present or absent. By including few or no measurements of parameters, the amount of time taken to monitor each project is minimized. This allows the number of projects monitored to be maximized.

The monitoring checklists are provided below. The photo monitoring protocol is described in Appendix C. Use of the photo monitoring protocol in photographing pre-project and post-project conditions is critical to successful use of the checklists. Answering many of the questions depends on the use of successive photos taken over time to judge effectiveness. These protocols should be used in tandem to assemble the needed effectiveness information.

Successful use of this protocol also depends on availability of adequate pre-project information. This information should be available from project applications, contracts, and completion forms as well as pre-treatment checklists and project photographs. Monitoring checklists were created using existing DFG forms as a starting point. Storage and retrieval of pre-project and implementation information will need to be improved to allow easy access for monitoring.

RESTORATION OBJECTIVES AND EFFECTIVENESS CRITERIA

This protocol applies to all project types. Specific forms have been developed to evaluate each of the ten project types in relation to their associated effectiveness criteria (See Appendix A). Questions asked on the forms reflect the implementation and effectiveness criteria developed by a panel of DFG staff and restoration practitioners.

The basic questions to be answered using this protocol are:

- Was the project properly implemented or not?
- Was the project effective in achieving objectives or not?

Project evaluators conducting the monitoring must provide the specific objectives and effectiveness measures for each individual project assessed. These should be developed based on project documentation and guidelines provided below.

For each project type, the checklists require a summary judgment of excellent, good, fair, or poor on the project. They also require recommendations for remedial actions or improvement and suggestions for timing of return monitoring visits. Forms are designed to be completed within a few hours on one or several visits to the project.

ASSUMPTIONS

- Implementation and qualitative effectiveness monitoring will be done on every DFG funded restoration project involving physical environmental changes.
- Monitoring will be performed by DFG staff and/or restoration practitioners after training in protocol use.
- Implementation monitoring will be done immediately after project implementation.
- Effectiveness monitoring will be conducted at a later time depending on project type.
- Each project feature installed will have at least one specific objective documented in project files in order to allow evaluation of effectiveness.
- Project evaluators will have access to photographs and project files to take with them on site visits.

TIMING

Some information will be collected before project implementation in order to allow comparison to post project conditions and effectiveness. This information will include pre-project photos (See Appendix C) and pre-treatment checklists. For example, prior to installation of instream structures, data collection would document current habitat conditions (habitat type, maximum depths, visual observation of substrate type) and would include corresponding photos to illustrate these conditions. The pre-treatment checklist would be then be used during later monitoring to help judge effectiveness of the project.

Implementation monitoring will be done immediately after project implementation. Timing of effectiveness monitoring visits will depend on the specific project objectives. Since projects often have many features that are expected to show impacts at different times, not all questions included in the checklist may be answered during the same visit. The primary objective of each project should dictate timing. Examples are fish passage questions that are pertinent at high flows, or re-vegetation success questions that may require several seasons before answers are evident. Effectiveness forms also contain questions asking how well projects withstood high flow or stressing events that may not occur for many years after project implementation. Therefore, it is likely that more than one visit will be required to evaluate effectiveness of all project features.

Project Goal: Improve fish passage by modifying or removing barriers
Effectiveness Visit Timing: Periods of fish migration, typically at highest flows.

Project Goal: Improve instream habitat by installing or removing channel structures
Effectiveness Visit Timing: After stressing events such as 10-year recurrence interval storms

Project Goal: Stabilize streambanks by installing armor, bioengineering, or deflectors
Effectiveness Visit Timing: After stressing events such as 10-year recurrence interval storms.

Project Goal: Restore riparian vegetation through planting or thinning, elimination of exotic or encroaching plants; and land use control through riparian fencing, grazing management or conservation easements
Effectiveness Visit Timing: During the growing season when full foliage is present, three to five years after project implementation to allow adequate time for success of plant establishment and growth.

Project Goal: Improve instream flows through obtaining water rights or managing flows
Effectiveness Visit Timing: At the periods of highest and lowest flows

Project Goal: Control erosion, stabilize slopes, or repair gullies by soil engineering, bioengineering, or armoring
Effectiveness Visit Timing: After stressing events such as 10-year recurrence interval storms.

Project Goal: Upgrade or decommission roads by surfacing, installing drainage and erosion control structures, upgrading or removing crossings
Effectiveness Visit Timing: During the rainy season after the first large storm event.

PROTOCOL DESCRIPTIONS

The first step required to conduct monitoring is collection of all available pre- and post- project information. Information should include:

- Project application and assessments
- Project contract
- Environmental permits and mitigation measures required
- Site Location Form including how to find the project and the location of permanent markers of project coordinates and photo points
- Pre-treatment checklists
- Available pre-project, implementation, and post-project photos

Next, determine the number and type of project features to be monitored based on the assembled information. A checklist is needed to assess each individual project feature. For example, an in-stream project may include four instream structures, a fish ladder, bank stabilization work, and two areas of riparian planting. In this case, a total of seven checklists will be needed, including four in-stream checklists, one fish passage checklist, one bank stabilization, and two riparian planting checklists. Locate the project using information on the Site Location Form. Complete the checklists. Take follow up photographs at the established photo points.

To choose the correct checklist for monitoring, the overall goal of the project or feature must be identified. Identify the goal from the following list:

1. Fish Passage
2. Instream Habitat Restoration
3. Stream Bank Stabilization
4. Land Use Control
5. Vegetation Control
6. Riparian Management/Planting
7. Stream Flow Restoration
8. Slope Stabilization including road cut and fill slopes
9. Gully Repair
10. Road Upgrading and Decommissioning

Collect one form for each project feature. Once the correct number and type of forms has been collected, complete the portions of the Summary Sheet on project information, location, and problem being addressed. For implementation checklists, select project practice. For effectiveness checklists, select the effectiveness criteria on which the project will be judged from those listed, or supply others as appropriate.

In the field, complete as many questions on the checklist as possible. Each effectiveness checklist contains questions for a wide range of effectiveness criteria, not all of which will apply to that specific project. This is to allow compilation of information on unintended effects of the project, either positive or negative.

After all the questions on the checklist have been addressed, complete the last portion of the Summary Sheet evaluating overall project success. Make recommendations for any needed repairs and the timing for the next monitoring visit.

Reporting and Analysis

Completed summaries and checklists will be entered into a monitoring database. Reports generated as a result from this database will allow evaluation of the effectiveness of the overall restoration grant program as well as effectiveness of individual projects or project types. However, it is possible some effectiveness criteria may not be easily evaluated in a qualitative manner. Some checklist questions may routinely be answered as “Don’t Know” due to project complexity or lack of pre-project information. Compilation of information indicating that achievement of specific objectives is unknown should be considered a useful part of qualitative effectiveness monitoring. For example, if it is not possible to evaluate the ability of in-stream projects to improve channel substrate, this may indicate the need for a quantitative study of substrate effects. Inability to answer many effectiveness questions may also point to the need for improvement in storage and access to project records, implementation documentation, or the specification of objectives in the project application.

INSTRUCTIONS FOR COMPLETING THE QUALITATIVE MONITORING DATA FORMS

IN THE OFFICE

SUMMARY SHEET

1) **Project ID # -** Enter project identification number assigned to this contract by the Department of Fish and Game
2) **Project Feature # -** Enter project feature number assigned during the project planning and implementation phase.
3) **Date of visit-** Enter the day's date: mm/dd/yy
4) **Project Feature Description** (Pre-treatment) – Describe briefly the project feature that will be installed at this location, such as boulder weirs containing 3 large boulders, willow stake plantings of 100 stakes at bankfull, etc.
5) **Watershed Name-** Enter the name of the watershed.
6) **Stream Name-** Enter in the name of the stream If unnamed, use named stream to which it is tributary.
7) **Evaluator Name/Title/Agency -** Enter the names of the person(s) conducting the monitoring visit.
8) **Problem Statement** (Effectiveness) **-** Identify the original problem (s) the project was designed to correct in this section. This information should be found in the project application. There may be multiple problems such as unstable banks, degraded instream habitat and/or intolerable water temperatures.
9) **Project Type** (Implementation) – Chose the appropriate project or feature type from the list supplied with that checklist. If the project type is not listed, check other and describe the treatment.
10) **Project Description** (Implementation) – Write a brief description of the overall project, project features, and goals.
11) **Project Objective** (Effectiveness) - Chose the appropriate project objective from the list supplied with that checklist. If the project or objective type is not listed, check other and describe the project objective.
12) **Specific Objectives** (Effectiveness) - Write in any specific objectives of the project found in the project application. Examples of specific objectives include increasing the number of primary pools or expanding willow cover within the project reach. Identifying the specific objectives of the project is critical to correct use of these forms. The possibilities for evaluating effectiveness are increased if the objectives are detailed and specific.
13) **Effectiveness Criteria** (Effectiveness) - Identify the criteria by which the project will be considered effective and check all appropriate boxes. Additional effectiveness criteria should be tailored to the project and its objectives. Write these in the "Other" section. For example, if a project is intended to increase the number of pools in a reach, increased pool number would be the effectiveness criterion. If a project is intended to reduce stream temperature by increasing riparian shade, then reduced stream temperature and increased riparian shading would be the appropriate criteria.

IN THE FIELD

14) **Checklist completion** (Pre-treatment)- Answer all the checklist questions it is possible to answer using a combination of observations, project plans, and rudimentary measurements.

15) **Checklist completion** (Implementation and Effectiveness) - Answer all the checklist questions it is possible to answer using a combination of observations, photos, and pre-project and implementation information. Possible answers are:
    - **Yes** When a project has completely met an implementation or effectiveness criterion, circle the answer YES.
    - **Partially** When a project has substantially met an implementation or effectiveness criterion, but has not completely met it, circle the answer PARTIALLY.
    - **No** When a project has not even partially met an implementation or effectiveness criterion, circle the answer no.
    - **DK = Don't Know** When questions cannot be answered with the available information, please circle DK for Don't Know. Questions might be relevant to project objectives, but not answerable with available information. For each question answered DK, please make a recommendation on the cover sheet about how to get the needed information or when to revisit the project in order to answer the question.
    - **NA = Not Applicable** When questions are not relevant to a particular project or feature, please circle NA for Not Applicable. Questions which address effects which are apparent at a site even though they were not an objective of the project should be answered with a Yes, Partially, or No, rather than NA. This will allow unintended effects to be documented. Please refer to project objectives listed in the summary before answering NA.
    - **Comments** A number of implementation or effectiveness questions require further information to be provided. Please provide it in the comment section.

SUMMARY SHEET

16) **Overall Implementation** After completing the implementation checklist, provide an overall judgment on project implementation.
17) **Overall Effectiveness** After completing the effectiveness checklist, provide an overall judgment on project effectiveness at this point in time.
18) **Recommendations** If maintenance or improvements to this project are needed to help it meet its objectives, please write your recommendations here.
19) **Objective for next visit/ Date for next visit** If some important information was not available due to timing of this monitoring visit, please make a recommendation of when a return visit would be necessary to gather this information (e.g., high flows for fish passage projects, two-three years from now for planting projects)

Pre-Treatment Checklist for Instream Habitat Restoration Projects

Project ID #:___________________Project Feature #:_______________Date:___________

Project Feature Description (complete one checklist for each feature):______________________

____

____

Instream projects:

What is the current habitat type?	☐ *pool* ☐ *riffle* ☐ *flatwater* ☐ *DK* ☐ *N/A*
Photo Documentation: Take photo of current habitat type.	***Photo #:***

Estimate percent of instream shelter and list the two dominant instream shelter components.	☐ *0-20%* ☐ *20-40%* ☐ *40-60%* ☐ *60-100%* *#1 shelter component:* *#2 shelter component:*
Photo Documentation: Take photo of current instream shelter conditions.	***Photo #:***

What is the maximum water depth? Where is the maximum depth located?	☐ *1-2'* ☐ *2-3'* ☐ *3-4'* ☐ *4-5'* ☐ *5-6'* ☐ *6+'* ☐ *upstream* ☐ *downstream* ☐ *LB* ☐ *RB*

What is the dominant substrate type?	☐ *sand* ☐ *silt/clay* ☐ *gravel* ☐ *cobble* ☐ *boulder*
Photo Documentation: Take photo of substrate.	***Photo #:***

Is there currently fine sediment deposition (FSD)? If yes, is FSD located upstream or downstream of proposed project?	☐ *Yes* ☐ *No* ☐ *upstream* ☐ *downstream*
Photo Documentation: Take photo of FSD.	***Photo #:***

Is there currently a fish barrier?	☐ *Yes* ☐ *No*
Photo Documentation: Take photo of fish barrier.	***Photo #:***

Channel Modification projects:

Is there evidence of recent scouring or flooding on floodplain?	☐ *Yes* ☐ *No* ☐ *DK* ☐ *N/A*
Photo Documentation: Take photos of evidence of disturbance on floodplain or document lack of disturbance on floodplain.	***Photo #:***

Other Information:

Describe any potential problems that could occur due if the project is implemented (for example: bank erosion, downstream damage, filling in of pools, negative impacts on channel, etc).

If possible, complete cross-sections upstream and downstream of proposed location of project feature.

Attach all necessary photos, including general overview photos of the project area.

Pre-Treatment Checklist for Riparian Planting Projects

Project ID #:___________________Project Feature #:_______________Date:______________

Project Feature Description (complete one checklist for each feature):_____________________

____

____

Planting projects:

What is the current percent cover of riparian vegetation within the project area?	☐ 0-20% ☐ 20-40% ☐ 40-60% ☐ 60-80% ☐ 80-100%
Photo Documentation: Take photos of current riparian cover conditions.	Photo #:

What is the current percent cover of riparian vegetation shading the stream channel within the project area? Estimate or densiometer reading?	☐ 0-20% ☐ 20-40% ☐ 40-60% ☐ 60-80% ☐ 80-100%
Photo Documentation: Take photos of current riparian cover conditions.	Photo #:

What vegetation types are present within the project area? Estimate the percentage the area covered by each. What percentage of the area is barren?	☐ deciduous/hardwood _______% ☐ conifer _______% ☐ shrubs _______% ☐ herbaceous ______% ☐ barren ______% total = 100%
Photo Documentation: Take photo of current species composition.	Photo #:

Determine the length of stream bank that is either barren or sparsely vegetated.	Right Bank - linear feet of barren or sparse vegetation ☐ 0-50' ☐ 50-100' ☐ 100-300' ☐ 300-500' ☐ 500+ Left Bank - linear feet of barren or sparse vegetation ☐ 0-50' ☐ 50-100' ☐ 100-300' ☐ 300-500' ☐ 500+
Photo Documentation: Take photos of current stream bank conditions.	Photo #:

Is there a significant number of seedlings or sprouts of the species to be planted currently within the project area?	☐ Yes ☐ No
Photo Documentation: Take photos of current seedling conditions.	Photo #:

How many seedlings/stems will be planted within the project area?	# of seedlings/stems:_________
How much ground cover/seeds will be planted within the project area?	Seed coverage:_________

Implementation Monitoring Checklist #1 /Project Goal - Fish Passage

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________
Watershed:__________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:_________________

Project type *(choose one)*:

- ☐ Fish Ladder
  - ☐ step and pool
  - ☐ Denil Ladder
  - ☐ Alaskan steeppass
  - ☐ other: ____________________
- ☐ Culvert/Barrier Modification
  - ☐ build step pool approach to culvert
  - ☐ back flooding weirs
  - ☐ culvert baffles
  - ☐ Washington baffles
  - ☐ steel-ramp CMP baffles
  - ☐ culvert repositioning
  - ☐ culvert size or form upgrade
  - ☐ culvert replacement with bridge
  - ☐ other: ____________________________
- ☐ Barrier Removal
  - ☐ log jam removal or modification
  - ☐ beaver dam removal or modification
  - ☐ waterfalls and chutes - blasting
  - ☐ landslide removal or modification
  - ☐ other: ____________________________
- ☐ Fish Screen
- ☐ Other: ______________________________
____

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Crossing/ladder/screen installation

Is the crossing/ladder/screen properly installed and functioning?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Refer to Manual, Part X for guidance.

Is the crossing/ladder/screen properly aligned in relation to the channel?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Culverts should be aligned with the axis of the channel (thalweg), bridges should be aligned perpendicular to this axis.

Culvert/ladder installation

If the crossing is a culvert/ladder, is it positioned at the proper slope (at the slope of the channel)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: The culvert should not cause a break in channel slope.

If the crossing is a culvert/ladder, is the approach adequate for fish passage?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: See Manual, Part X for guidance.

If the crossing is a culvert/ladder, is the exit adequate for fish passage?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: See Manual, Part X for guidance.

Bridge installation

If the crossing is a bridge, is it positioned at the proper channel elevation?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Bridges should be positioned above the channel floodplain.

Fish exclusion

If a fish screen was installed, is it preventing fish access?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the species and age classes prevented access in comments below.

Area of habitat made accessible

If the crossing/ladder/bridge is successful, will it make habitat accessible to fish that was not previously accessible?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the number of miles made accessible and species of fish in the comments below.

Avoiding unforeseen adverse effects

Did the crossing/ladder/screen installation avoid negative impacts to the channel?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Potential impacts can include changes in natural channel bed and banks due to excavation and construction.

Condition

If project is a structure, is the structure in good to excellent condition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (stranded out of channel) but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Comments:

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident. Pieces may have shifted slightly, erosion cloth is visible, wire fence material visible, one or tow anchor pins or cables loose but structure is still intact. Structure is generally as designed.

Effectiveness Monitoring Checklist #1 **Project Goal – Fish Passage**

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:_________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)*:

- Fish Ladder: Improve fish passage by circumventing barrier; improve accessibility to habitat
- Culvert/Barrier Modification*:* Improve fish passage by modifying human caused barrier; improve accessibility to habitat
- Barrier Removal: Improve fish passage by eliminating natural barrier; improve accessibility to habitat
- Fish Screen: Prevent fish passage into stream reaches or man-made facilities to protect them from entrainment and/or mortality
- Other: ________________________________
  ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- Habitat made accessible
- Area of newly accessible habitat: ________
- No unforeseen adverse effects on habitat such as incision or channel instability or sedimentation
- Increased attraction flows during migration periods (for barrier modifications)
- Other: ________________________________

Overall Effectiveness: Excellent Good Fair Poor N/A

Recommendations:

Date for next visit: ____________Objective for next visit:_____________________________

Checklist

Streamflow during periods of migration

Does the flow through the crossing/ladder/removed barrier appear to permit passage by target species at all life stages?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: This will require monitoring at times when flows may pose a constraint to fish passage.

Did hydrologic modeling accurately predict streamflow conditions?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Manual Part 10 and project application.

Area of habitat made accessible

Has the crossing been successful in providing access to habitat previously inaccessible?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the number of miles made accessible and species of fish in the comments below.

Were fish observed above the crossing/ladder/removed barrier?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note species and age of fish in comments below.

Were fish observed below the crossing/ladder/removed barrier?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Please note the species and age of fish if known in comments below.

Avoiding unforeseen adverse effects

Did the project avoid negative changes to channel width or depth (widening or incision)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points. Changes in channel width or depth may be observed as signs of recent erosion, scouring or deposition that were not present before installation.

Did installation of any structures avoid impairment of natural movement of LWD, substrate or nutrients downstream?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Culverts, bridges and ladders may be overwhelmed by sediment or large woody debris from upstream.

Stressing events

Did the crossing/ladder/screen pass the design flow without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the flow event. In most cases the design flow is the 100 year precipitation event.

Did the crossing/ladder/screen pass large woody debris without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the flow event. In most cases the design flow is the 100 year precipitation event.

Comments:

Implementation Monitoring Checklist #2 **Project Goal – Instream Habitat Restoration**

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________
Watershed:_________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:_________________

Project type *(choose one)*:

- ☐ Install structures
  - ☐ boulder weir
  - ☐ boulder/log combo constrictor
  - ☐ log weir (plunge)
  - ☐ cover root wads
  - ☐ gabion weir
  - ☐ other: ____________________
- ☐ Install gravel
- ☐ Remove structures
  - ☐ remove stream bank stabilization (rip rap)
  - ☐ remove dams
  - ☐ other: ___________________________
- ☐ Construct channel/ breach dikes
  - ☐ reconnect stream to floodplain
  - ☐ construct side channels
  - ☐ remove floodplain roads or levees
- ☐ Other: ______________________________
____

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

In-stream Structure Condition

Is the installed structure in good to excellent condition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (stranded out of channel) but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Comments:

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident. Pieces may have shifted slightly, erosion cloth is visible, wire fence material visible, one or tow anchor pins or cables loose but structure is still intact. Structure is generally as designed

Effectiveness Monitoring Checklist #2 **Project Goal – Instream Habitat Restoration**

<u>Summary</u>

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:_________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)*:

- ☐ Install structures: Objectives - Increase cover, habitat complexity, instream habitat types
- ☐ Install gravel: Objectives - Increase spawning habitat
- ☐ Remove structures: Objectives –
  - ☐ Increase stream interaction with floodplain
  - ☐ Increase habitat complexity
- ☐ Construct channel/ breach dikes: Objectives –
  - ☐ Improve stream interaction with floodplain
  - ☐ Increase habitat complexity
  - ☐ Increase habitat types
  - ☐ Improve flood control
- ☐ Other: ________________________________

____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Project improves targeted habitat parameters within the project reach
  - ☐ instream habitat units
  - ☐ riparian vegetation
  - ☐ substrate
  - ☐ spawning habitat
- ☐ Stream re-establishes properly functioning geometry and pattern
- ☐ Stream re-establishes access to formerly abandoned floodplain
- ☐ Reduced peak flows, or peak flow impacts
- ☐ Other: ________________________________
- ☐ Other: _________________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________ Objective for next visit: ____________________________________

Checklist

Instream habitat (pools, riffles and shelter) within project reach

Did the project create desired habitat such as new pools or riffles, backwaters, side channels, undercut banks, etc)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Please circle all habitat types created.

Did the project lead to an increase in instream shelter?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: DFG Manual, Part III and project application.

Did the project increase pool depth downstream?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: DFG Manual, Part III. Estimates should consider maximum, not average pool depth.

Channel pattern

Did the project lead to changes in channel pattern, sinuosity, slope or cross-section that are in the direction of re-establishing natural stream conditions for the Rosgen channel type?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: DFG Manual Parts III and VII and project application.

Did the project successfully re-establish access to the floodplain for flood flows?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect after peak flow events and look for evidence of flood height such as debris or scour lines.

Fish passage

Does the project appear to have successfully removed a barrier to fish passage?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note species and age class.

Fish use

Were any salmonids or redds observed in the project area?

☐ ***Yes*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note species and age class.

Sedimentation patterns

Did the project successfully re-establish beneficial sedimentation processes?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Deposition or scouring may occur.

Did the amount of fine sediment increase upstream from the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Did the amount of fine sediment increase upstream from the project?

Did the project reduce the amount of fine sediment in downstream pools or riffles?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the project lead to an increase in floodplain deposition or size upstream?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Compare upstream channel and floodplain width before and after project.

Did suitable spawning gravel increase due to the project?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: See Manual for guidance on appropriate spawning gravel sizes and flows

---

Avoiding unforeseen adverse effects

Did installation or removal of structures/gravel avoid reductions in the diversity and quality of instream habitat units?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points (natural or artificial grade controls) for signs of scouring, pool filling, or net loss of primary pools over the reach.

Did installing or removing the structures/gravel avoid undesirable substrate changes?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points (natural or artificial grade controls) for signs of gravel migration, erosion, or sedimentation.

Did installing or removing the structures avoid creating a fish passage barrier?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points (natural or artificial grade controls).

Did installation of structures avoid impairment of natural movement of LWD, substrate or nutrients downstream?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points (natural or artificial grade controls).

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is the 100-year precipitation event.

Comments:

Implementation Monitoring Checklist #3 **Project Goal – Streambank Stabilization**

Summary

Project ID #:______________________Project Feature #:__________ Date of visit:____________________

Watershed:___________________Stream:____

Evaluator name: _________________Evaluator title:___________________Agency:___________________

Project type *(choose one)*:

- ☐ Streambank stabilization structures
  - ☐ boulder riprap or bank armor
  - ☐ boulder wing-deflectors
  - ☐ log cribbing
  - ☐ log bank armor
  - ☐ log wing-deflector
  - ☐ boulder/log deflector
  - ☐ tree revetment
  - ☐ gabions
  - ☐ Other: _____________________
- ☐ Bioengineering
  - ☐ live vegetative crib wall
  - ☐ native material revetment
  - ☐ willow wall revetment
  - ☐ brush mattress
  - ☐ willow siltation baffles
  - ☐ resloping and revegetating cut banks
  - ☐ Other: _____________________
- ☐ Other: ____________________________

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Summary

Construction

Was the project installed in accordance with approved design standards?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Structure Condition

If project is a streambank stabilization structure, is the structure in good to excellent condition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (stranded out of channel) but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

---

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident. Pieces may have shifted slightly, erosion cloth is visible, wire fence material visible, one or tow anchor pins or cables loose but structure is still intact. Structure is generally as designed.

Comments:

Effectiveness Monitoring Checklist #3 **Project Goal – Streambank Stabilization**

<u>Summary</u>

Project ID #:______________________Project Feature #:__________ Date of visit:___________________

Watershed:___________________Stream:____

Evaluator name: _________________Evaluator title:___________________Agency:__________________

Problem Statement:

Project type and objective *(choose one)*:

- ☐ <u>Deflect streamflow</u>*:* Increase streambank stability by reducing stream power at erodible surfaces
- ☐ <u>Bioengineering</u>: Increase streambank stability by protecting erodible surfaces with organic matter (living or dead)
- ☐ <u>Armoring</u>*:* Increase streambank stability by protecting erodible surfaces with inorganic matter
- ☐ Other: ________________________________
  ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Reduced bank erosion
- ☐ Improved channel geometry, reduced width/depth ratio
- ☐ Reduced fine sediment in reach
- ☐ Increased riparian vegetation
- ☐ Other: ________________________________
- ☐ Other: ________________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: _____________Objective for next visit:______________________________________

Checklist

Planting Survival and Conditions

If a planting project, was survival adequate?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Survival should equal or exceed 50 percent, depending on the site.

Is the growth and vigor of planted vegetation acceptable?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Unacceptable growth and vigor would be indicated by low foliage density, stunted height and yellow or mottled leaf coloration.

Riparian cover

Did the project lead to an increase in riparian cover?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Where (on banks, over channel, on floodplain)? (circle locations) Which layer of riparian cover (herbaceous, shrub, or tree) increased? (Circle layers}

Bank angle and stability both at and downstream from project

Did the project reduce bank erosion in the project reach?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the project reduce the amount of exposed streambank soil?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the project cause a change to a more stable bank angle?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect banks in and near project area to determine what is a naturally stable bank

---

Channel cross-section both at and downstream from project

Did the project cause a desirable change in channel width or depth?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: A successful project may reduce the width/depth ratio at the treatment site.

Instream substrate immediately adjacent to and downstream from project

Did channel substrate composition change for the better as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Make observations on coarsening of substrate due to reduced fine sediment input or scouring.

Did the project lead to reduced amount of instream fine sediment deposition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect nearby pools and riffle crests.

Avoiding unforeseen adverse effects

Were adverse impacts on downstream bank stability avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***

DK *N/A*

Note: Note any signs of recent erosion, scouring or deposition.

Was project effectiveness affected by factors from outside the project's area of influence?	*Yes* *Partially* *No* *DK* *N/A*

Note: Projects may be overwhelmed by sediment from upstream landslides, or be helped by changes in land use upstream.

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?	*Yes* *Partially* *No* *DK* *N/A*

Note: Note the magnitude of the event. In most cases the design flow is at least the 100 year precipitation event.

Comments:

Implementation Monitoring Checklist #4 **Project Goal – Land Use Control**
Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________
Watershed:__________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:________________

Project type *(choose one)*:

- ☐ Exclude grazing (*fencing)*
- ☐ Install watering sites
- ☐ Grazing management *(Manage riparian pastures)*
- ☐ Conservation easements
- ☐ Other: ______________________________

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:______________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note:

Were any deviations designed to improve the project?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note:

Condition

If project is a structure (e.g. fencing or troughs), is the structure in good to excellent condition?*

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (fencing in wrong location) but it may be in excellent structural condition

---

Were potential threats to or problems with the project successfully avoided?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note:

Performance

Did the project successfully achieve the desired land use control?

□ ***Yes*** □ ***Partially*** □ ***No*** □ ***DK*** □ ***N/A***

Note: Inspect project area for signs of undesirable animal or human use.

---

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident.

Comments:

Effectiveness Monitoring Checklist #4 **Project Goal – Land Use Control**

Summary

Project ID #:______________________Project Feature #:_________ Date of visit:___________________

Watershed:___________________Stream:____

Evaluator name: _________________Evaluator title:___________________Agency:__________________

Problem Statement:

Project type and objective *(choose one)*:

- ☐ Exclude grazing (*e.g. fencing):* Objectives - Reduce livestock or wildlife access to stream and riparian zone; decrease contaminant input to stream
- ☐ Install watering sites: Objectives - Reduce livestock/wildlife access to stream and riparian zone; decrease contaminant input to stream
- ☐ Grazing management: Objectives - Manage riparian pastures to reduce impacts to riparian vegetation and stream banks
- ☐ Conservation easements: Objectives - Reduce stresses due to land uses
- ☐ Other: ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Livestock and/or wildlife successfully excluded from riparian zone and stream
- ☐ Other land use successfully prevented
- ☐ Increased riparian vegetation
- ☐ Increased riparian connectivity
- ☐ Increased bank stability
- ☐ Improved channel geometry
- ☐ Reduced fine sediment in reach
- ☐ Improved water quality
- ☐ Other: ________________________________
- ☐ Other: ________________________________

Overall Effectiveness:	☐ Excellent	☐ Good	☐ Fair	☐ Poor	☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Performance

Did the project successfully achieve the desired land use control?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect project area for signs of undesirable animal or human use.

Riparian vegetation

Did riparian cover increase as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Where (on banks, over channel, on floodplain)? Circle all that apply. Note most prominent species:

Did riparian connectivity increase as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Bank angle and stability

Did the project reduce bank erosion in the project reach?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the project reduce the amount of exposed streambank soil?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did it cause a change to a more stable bank angle?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect areas in or outside project area for evidence of naturally stable bank

Channel cross-section

Did the project cause positive changes to channel width or depth?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: A successful project may produce a reduced width/depth ratio.

Instream substrate immediately adjacent to and downstream from project

Did the project reduce the amount of fine sediment in the stream?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect pools and riffle crests.

Did substrate composition change for the better as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Look for signs of coarsening, due to reduced fine sediment input.

Water quality (turbidity, nutrient pollution, temperature)

Did water quality improve as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: A successful project should have less pronounced signs of impairment than before the project

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?

 Yes ***Partially*** ***No***
 DK ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is the 100 year precipitation event.

Was project effectiveness affected by factors from outside the project's area of influence?

 Yes ***Partially*** ***No***
 DK ***N/A***

Note: Projects may be overwhelmed by sediment from upstream landslides, or be helped by changes in land use upstream.

Comments:

Implementation Monitoring Checklist #5 **Project Goal – Vegetation Control**

Summary

Project ID #:_____________________Project Feature #:_________ Date of visit:__________________

Watershed:__________________Stream:____

Evaluator name: _________________Evaluator title:__________________Agency:__________________

Project type *(choose one)*:

- ☐ Remove exotic plants *(e.g. remove noxious weeds/plants, non-native blackberries)*
- ☐ Plant vegetation *(e.g. native species)*
- ☐ Reduce vegetation encroachment into channel

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Project implementation

Was the project done in accordance with approved design?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note:

Comments:

Effectiveness Monitoring Checklist #5 **Project Goal – Vegetation Control**

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:__________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)*:

- ☐ Remove exotic plants*:* Directly eliminate exotic plants from riparian community
- ☐ Plant vegetation: Increase native plant species composition
- ☐ Reduce vegetation encroachment into channel: Increase available instream fish habitat
- ☐ Other: ______________________________ ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Reduced relative abundance of exotic plants
- ☐ Increased relative abundance of native plants
- ☐ Increased native plant species richness
- ☐ Reduced barren ground
- ☐ Increased riparian canopy cover
- ☐ If clearing encroachment is involved, reduced vegetation within bankfull channel
- ☐ If clearing encroachment is involved, increased availability of spawning gravels
- ☐ Other: ________________________________
- ☐ Other: ________________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Native plants

Did abundance of native riparian species increase as a result of the project?

Note: Where (on banks, over channel, on floodplain)? Circle all that apply.

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Did native plant species richness increase as a result of the project?

Note: Where (on banks, over channel, on floodplain)? Circle all that apply.

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Exotic plants

If the project involved controlling exotics, did the project reduce the abundance of exotic plants?

Note: Where (on banks, over channel, on floodplain)? Circle all that apply.

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Barren ground

Did the amount of barren ground in the project area decrease as a result of the project?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Vegetation removal within bankfull channel

Did the project reduce the amount of vegetation within the bankfull channel?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Did the project increase the availability of spawning gravels?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Instream substrate

Did the project change the distribution or area of channel bedforms (i.e., was sediment mobilized as a result of the project?)?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Did instream sediment composition change for the better as a result of the project?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Avoiding unforeseen adverse effects

If the project involved vegetation removal, did it avoid any undesirable downstream channel changes or bank erosion?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

If the project involved vegetation removal, did the removal of vegetation avoid adverse effects on stream shading?

Note:

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Was project effectiveness affected by factors from outside the project's area of influence?	☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Projects may be overwhelmed by seed sources delivered from upstream vegetation.

Comments:

Implementation Monitoring Checklist #6 Project Goal – Riparian Planting or Management

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:_________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Project type *(choose one)*:

- ☐ Planting vegetation
- ☐ Altering vegetation composition
- ☐ Other: ____________________

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:_______________________________

Checklist

Project implementation

Was the project done in accordance with approved design? — ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project? — ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed? — ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts? — ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Comments:

Effectiveness Monitoring Checklist #6 Project Goal – Riparian Planting or Management

Summary

Project ID #:____________________Project Feature #:________ Date of visit:__________________

Watershed:_________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)*:

☐ Plant vegetation: Increase shading to stream; increase LWD inputs to stream; increase nutrient inputs to stream; increase stream bank stability

☐ Alter composition *(e.g. promote conifers):* Increase shading to stream; increase LWD inputs to stream; increase nutrient inputs to stream; increase growth of conifers

☐ Other: ______________________________
____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

☐ Increased riparian canopy cover

☐ Increased riparian corridor continuity and patch size

☐ Advancement in riparian successional stage from grass-shrub to forest

☐ Riparian tree composition meets planting or management objectives

☐ Other: ______________________________

☐ Other: ______________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A Recommendations: Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Planting Survival and Conditions

If a planting project, was survival adequate? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Survival should equal or exceed 50 percent, depending on the site.

Is the growth and vigor of planted vegetation acceptable? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Unacceptable growth and vigor would be indicated by low foliage density, stunted height and yellow or mottled leaf coloration.

Riparian Vegetation

Did riparian cover increase as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Where (on banks, over channel on floodplain)? What layer (herbaceous, Shrub, or tree)*? (Circle all applicable)*

Is vegetation enhancing bank stability? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the species composition of the riparian community change for the better as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note species favored by project. Note any increase in exotic species.

Was the change anticipated? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Has the seral stage of the riparian community advanced as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Has riparian corridor continuity increased as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Large wood recruitment

Has future large wood recruitment potential increased as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Stream shading

Has stream shading increased as a result of the project? | ☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is the 100 year precipitation event.

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Projects may be overwhelmed by sediment from upstream landslides, or be helped y changes in land use upstream.

Comments:

Implementation Monitoring Checklist #7 **Project Goal – Restoring Streamflows**

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:__________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Project type *(choose one)*:

- ☐ Obtain water rights
- ☐ Manage flows
- ☐ Other: ____________________

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:_________________________________

Checklist

Project implementation

Was the project done in accordance with approved design?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Comments:

Effectiveness Monitoring Checklist #7 **Project Goal – Restoring Streamflows**

Summary

Project ID #:______________________Project Feature #:_________ Date of visit:___________________

Watershed:___________________Stream:____

Evaluator name: _________________Evaluator title:___________________Agency:__________________

Problem Statement:

Project type and objective *(choose one)*:

☐ Obtain water rights: Improve stream flows to benefit fisheries and riparian communities

☐ Manage flows: Improve stream flows to benefit fisheries and riparian communities

☐ Other: ________________________________
____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

☐ Increase low flows, achieve natural peak flow regime

☐ Decreased water temperature during low flows

☐ No adverse changes in downstream stream flows

☐ Other: ________________________________

☐ Other: ________________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________ Objective for next visit: ____________________________________

Checklist

Streamflow above and below project reach

Did the project change streamflow within the targeted range of flows?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: This requires inspection during periods of targeted flows (high or low).

Are the changes in flow having the intended effect on fish habitat?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Desired effects may include increased pool depth or increased wetted width during low flows.

Water temperature

Did water temperature change for the better as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Vegetation cover within bankfull channel

Did the project permanently reduce the amount of vegetation within the bankfull channel?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Instream substrate

Did the project change the distribution or area of channel bedforms (i.e., was sediment mobilized as a result of the project?)

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did instream sediment composition change for the better as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Avoiding unforeseen adverse effects

Did the project avoid undesirable downstream channel or bank erosion?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect downstream to next natural or artificial grade control. Look for signs of recent erosion or scouring.

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Projects may be overwhelmed by sediment from upstream landslides, or be helped by changes in land use upstream.

Comments:

Implementation Monitoring Checklist #8 Project Goal – Slope Stabilization or Erosion Control
Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________
Watershed:_________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:_________________

Project type *(choose one)*:

- Soil engineering
  - retention walls
  - toe protection
  - other: _________________
- Bioengineering
  - mulching, planting, seeding
  - other: _________________
- Erosion control
  - installing detention basins and check dams
  - waterbars
  - removing soil/spoils
  - other: _________________
- Upland fuels management
  - understory thinning
  - brush removal
  - other: _________________
- Other: ____________________

APPENDIX D: IMPLEMENTATION AND QUALITATIVE EFFECTIVENESS MONITORING

Project description:

Overall Implementation: □ Excellent □ Good □ Fair □ Poor □ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:_____________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the project avoid any short-term increases in soil erosion or sediment production?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect pools in affected watercourses for signs of recent deposition. Note areas of barren soil due to equipment operation or clearing.

Condition

If project involves a structure, is the structure in good to excellent condition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Fuels Management

If the project involved fuels management, did the project reduce fuel loading in the treated area?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Reduced fuels are evidenced by reduced vegetation cover, separation between tree crowns or between tree, shrub and herbaceous layers (reduced ladder fuels), and reduced amount of dead vegetation.

---

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident.

Comments:

Effectiveness Monitoring Checklist #8 Project Goal – Slope Stabilization or Erosion Control

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________
Watershed:__________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)**:

- ☐ Soil engineering: Use engineering practices to reduce erosion/stream sedimentation; increase slope stability
- ☐ Bioengineering: Use living and dead organic matter to reduce erosion/stream sedimentation; increase slope stability
- ☐ Upland fuels management: Reduce the potential for sedimentation as a result of catastrophic fire
- ☐ Other: ______________________________ ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Reduced likelihood of slope failure
- ☐ Decrease in soil erosion from site
- ☐ Decreased sediment load near site during peak flow events
- ☐ If planting involved, reduced bare ground
- ☐ If a large portion of a watershed is treated, reduced sediment yields
- ☐ Reduced fuel levels
- ☐ Reduced fire hazard
- ☐ Reduced fire incidence
- ☐ No significant increase in erosion rate
- ☐ Other: ______________________________
- ☐ Other: ______________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:______________________________

Checklist

Slope stability

Did the project maintain slope integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Determine if there are any persistent or new signs of instability such as tension cracks within the road bench, cut bank, fill slope and 100 ft. buffer below road.

Did the project eliminate causes of slope instability such as concentrated runoff?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect the affected areas such as road bench, cut bank, fill slope and 100 ft. buffer below road.

Did the project increase the stability of the slope for the near future?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Does the slope appear to be stable a reasonable period of time? Inspect the road bench, cut bank, fill slope and 100 ft. buffer below road.

Erosion and sedimentation

Did the amount of barren ground in the project area decrease as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Has the project avoided increasing erosion from the site?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Look for evidence of rilling, dry ravel and soil pedestals on bare ground, and note proximity to streams

---

Did the project decrease soil erosion from the site?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect the affected areas such as road bench, cut bank, fill slopes for signs of rilling or soil pedestals.

Did the project reduce sediment delivery to streams?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Planting Survival and Conditions

If a planting project, was survival adequate?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Survival should equal or exceed 50 percent, depending on the site.

Is the growth and vigor of planted vegetation acceptable?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Unacceptable growth and vigor would be indicated by low foliage density, stunted height and yellow or mottled leaf coloration.

Did the project lead to desirable changes in vegetation cover (increase or decrease)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note vegetation layer with increased cover (herbaceous, shrub, tree). Circle all that apply.

Fuel Loading

Has post-implementation fuel loading remained constant since treatment?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Note changes in fuel loading that occurred since implementation e.g., increased shrub or grass cover due to reduced tree canopy.

Has the long-term risk of catastrophic wildfire been reduced?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Estimate duration of effects.

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is at least the 100 year precipitation event.

Did the project area maintain resource values during a wildfire?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Note the date and magnitude of the event.

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Projects may be damaged by soil failures upslope.

Comments:

Implementation Monitoring Checklist #9 **Project Goal – Gully Repair**
Summary

Project ID #:_____________________Project Feature #:_________ Date of visit:___________________
Watershed:__________________Stream:____
Evaluator name: ________________Evaluator title:__________________Agency:_________________

Project type *(choose one)*:

- ☐ Gully modification
  - ☐ new channel construction
  - ☐ other:________________
- ☐ Bioengineering
  - ☐ brush/rock mattress
  - ☐ vegetation planting
  - ☐ other:________________
- ☐ Armoring with inorganic matter
- ☐ Other: ___________________
- ☐ Check dams
  - ☐ redwood board checkdam
  - ☐ brush and rock checkdam
  - ☐ post brush checkdam
  - ☐ tree checkdam

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Were any deviations designed to improve the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Condition

If the project involves structures or bioengineering, are these in good or excellent condition?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (stranded out of channel) but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Gully Remediation

Was the cause of the gully formation removed?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Gully may reform unless drainage or land management practices that led to gully formation are addressed.

---

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident.

Comments:

Effectiveness Monitoring Checklist #9 **Project Goal – Gully Repair**

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:__________________

Watershed:_________________Stream:____

Evaluator name: ________________Evaluator title:_________________Agency:_________________

Problem Statement:

Project type and objective *(choose one)*:

- ☐ Gully modification: Decrease erosion and stream sedimentation by changing gully grade and cross-section
- ☐ Bioengineering: Use living and dead organic matter as obstructions to reduce the rate of head-cutting and incision
- ☐ Armoring: Use inorganic matter as obstructions to reduce the rate of head-cutting and incision
- ☐ Other: _______________________________ ____

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Improved channel geometry e.g., reduced width/depth ratio
- ☐ No offsite adverse effects on downstream channels
- ☐ Reduced erosion and sediment yield
- ☐ Reduced flood flows in gully
- ☐ Increased vegetation cover
- ☐ Other: _______________________________
- ☐ Other: _______________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:____________________________________

Checklist

Gully dimensions

Did the project halt the enlargement of the gully (either laterally or longitudinally or both)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Success for some projects means the width, depth and length of the gully are equal to or less than they were before the project.

Did the project decrease gully size (either laterally or longitudinally or both)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Success for some projects means the size of the gully has decreased due to deposition

---

Planting Survival and Conditions

If a planting project, was survival adequate?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Survival should equal or exceed 50 percent, depending on the site.

Is the growth and vigor of planted vegetation acceptable?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Unacceptable growth and vigor would be indicated by low foliage density, stunted height and yellow or mottled leaf coloration.

Vegetation cover

Did vegetation cover in the gully increase as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Has there been a decrease in the amount of exposed soil as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Channel cross-section

Did the project cause positive changes to channel width or depth?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: A successful project may produce a reduced width/depth ratio.

Sedimentation

Has downstream sedimentation been reduced as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect depositional areas at breaks in slope and pools immediately downstream from gully confluences with other streams.

Avoiding unforeseen adverse effects

Have adverse effects on downstream channels been avoided?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect downstream bank stability to the nearest control point.

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is the 100 year precipitation event.

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Projects may be overwhelmed by upslope soil movement.

Comments:

Implementation Monitoring Checklist #10 Project Goal – Road Upgrading/Decommissioning

Summary

Project ID #:____________________Project Feature #:_________ Date of visit:____________

Watershed:_________________Stream:____

Evaluator name: _______________Evaluator title:_________________Agency:___________

Project type *(choose one)**:

- ☐ Road surfacing
- ☐ Upgrading
  - ☐ outsloping and ditch removal
  - ☐ installing rolling dips
  - ☐ boulder riprap
  - ☐ install ditch relief culverts
  - ☐ downspout/energy dissipaters
  - ☐ removing berms
  - ☐ installing ditch relief culverts
  - ☐ sidecast and fill removal
  - ☐ upgrading stream crossing
  - ☐ mulching/revegetation
  - ☐ other: ___________________________
- ☐ Road decommissioning
  - ☐ ripping/decompaction of the road surface
  - ☐ construction of cross-road drains
  - ☐ partial outsloping
  - ☐ complete outsloping
  - ☐ landing excavations
  - ☐ stream crossing excavations
  - ☐ fill/spoil removal
  - ☐ Other: ____________________

*For projects involving upgrading stream crossings on fish-bearing streams, use checklist #1 Fish Passage.

Project description:

Overall Implementation: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommendations:

Date for next visit: ____________Objective for next visit:______________________________

Checklist

Construction

Was the project installed in accordance with approved design standards?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note:

Were any deviations designed to improve the project?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Note the nature of the deviations and reasons they were made in comments below.

Short-term impacts

Were mitigation measures applied and followed?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Mitigation measures should be specified in the application and any associated permits (1600 agreements, ACOE 404 permits, NMFS consultations)

Were mitigation measures effective in reducing short-term impacts?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note:

Culvert/bridge installation

Is the culvert/bridge properly installed and functioning?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Refer to Manual, Part X for guidance.

Is the culvert/crossing properly aligned in relation to the channel?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Culverts should be aligned with the axis of the channel (thalweg).

Is the culvert positioned at the proper slope (at the slope of the channel)?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: The culvert should not cause a break in channel slope.

Culvert/Crossing removal

Was channel excavated to correct shape and slope?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Refer to Manual, Part X for guidance.

Condition

If the project involves structures such as riprap, basins or dams, are the structures in good or excellent condition?*

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Consider structure condition only. Do not include functional aspects in this category. The structure may not be functioning (stranded out of channel) but it may be in excellent structural condition.

Were potential threats to or problems with the project successfully avoided?

☐ *Yes* ☐ *Partially* ☐ *No* ☐ *DK* ☐ *N/A*

Note: Inspect excavated crossings and downslope areas for signs of instability.

Avoiding unforeseen adverse effects

Did the crossing/ladder/screen installation avoid negative impacts to the channel?

□ ***Yes*** □ ***Partially*** □ ***No***
□ ***DK*** □ ***N/A***

Note: Potential impacts can include changes in natural channel bed and banks due to excavation and construction.

Comments:

* Condition of structure: Excellent = Structure is intact and structurally sound, Good = Structure is intact and generally sound but some wear is evident. Pieces may have shifted slightly, erosion cloth is visible, wire fence material visible, one or tow anchor pins or cables loose but structure is still intact. Structure is generally as designed

Effectiveness Monitoring Checklist #10 Project Goal – Road Upgrading/Decommissioning
Summary

Project ID #:____________________Project Feature #:________ Date of visit:____________
Watershed:_________________Stream:____
Evaluator name: ________________Evaluator title:_________________Agency:___________

Problem Statement:

Project type and objective *(choose one)**:

- ☐ Road surfacing: Use rock, chip seal and/or asphalt to reduce surface erosion
- ☐ Upgrading: Use improvements in road drainage and stream crossings to reduce erosion and potential stream sedimentation; reduce risks of crossing failures; reduce hydrologic impacts of roads on streams
- ☐ Full road decommissioning**:** Obliterate all evidence of road; decrease road access; decrease road density
- ☐ Other: ______________________________ ________________________________

*For projects involving upgrading stream crossings on fish-bearing streams, use checklist #1 Fish Passage.

Specific objective:

Effectiveness Criteria *(Choose all that apply)*:

- ☐ Reduced erosion rate from road surface
- ☐ Increased infiltration rate on road surface
- ☐ Reduced erosion from site
- ☐ Reduced sediment yield in immediately adjacent watercourses
- ☐ Reduced number or probability of road related slope failures
- ☐ No offsite adverse effects on erosion or sedimentation
- ☐ Improved stream discharge regime in immediately adjacent watercourses
- ☐ If a large portion of a watershed is treated, improved stream discharge regime
- ☐ If a large portion of a watershed is treated, reduced sediment yield
- ☐ Other: _______________________________

Overall Effectiveness: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A
Recommendations:

Date for next visit: ____________Objective for next visit:____________________________

Checklist

Planting Survival and Conditions

If a planting project, was survival adequate?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Survival should equal or exceed 50 percent, depending on the site.

Is the growth and vigor of planted vegetation acceptable?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Unacceptable growth and vigor would be indicated by low foliage density, stunted height and yellow or mottled leaf coloration.

Vegetation cover

Did vegetation cover in the treated area increase as a result of the project?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note:

Infiltration rate

Did the project increase the permeability of soils on the former road surface, including cut and fill slopes?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Compare treated to untreated road surfaces.

Erosion on road surface or slopes

Did the project reduce surface erosion on the road surface including cut and fill slopes?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: There may be increased turbidity after the first winter storm.

Did the project reduce sediment delivery from the road surface to nearby streams?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: There may be increased turbidity after the first winter storm.

Drainage patterns

Did the project remove the hydrological impacts from the road/former road on the stream system?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Drainage is no longer captured and re-routed by the road surface or ditches.

Turbidity in runoff from site

Did the project reduce turbidity in runoff from the site (from the road surface, stream crossings, or ditches)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: There may be increased turbidity after the first winter storm.

Slope stability

Did the project increase the stability of cut and fill slopes or adjacent natural slopes?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No***
☐ ***DK*** ☐ ***N/A***

Note: Determine if there are any persistent or new signs of instability such as tension cracks or rills, wheel ruts and gullies, or signs of erosion such as rain splash pedestals and gullies.

Did the project eliminate unstable manmade slopes such as road cut and fill slopes?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Determine if there are any persistent or new signs of instability such as tension cracks or rills, wheel ruts and gullies, or signs of erosion such as rain splash pedestals and gullies.

Were potential future instabilities eliminated?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Avoiding unforeseen adverse effects

Did the project avoid causing adverse effects on erosion or sedimentation rates?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Did the culvert/crossing avoid causing negative changes to channel width or depth (widening or incision)?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Inspect channel upstream and downstream to next control points. Changes in channel width or depth may be observed as signs of recent erosion, scouring or deposition that were not present before installation.

Did installation of any structures avoid impairment of natural movement of LWD, substrate or nutrients downstream?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note:

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Culverts, bridges and ladders may be overwhelmed by sediment or large woody debris from upstream.

Stressing events

Did the project withstand high flows or precipitation without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the event. In most cases the design flow is the 100 year precipitation event.

Did the culvert/bridge pass large woody debris without damage to its integrity?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Note the magnitude of the flow event. In most cases the design flow is the 100 year precipitation event.

Was project effectiveness affected by factors from outside the project's area of influence?

☐ ***Yes*** ☐ ***Partially*** ☐ ***No*** ☐ ***DK*** ☐ ***N/A***

Note: Projects may be overwhelmed by upslope soil movement.

Comments:

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

E-1: Habitat Unit Monitoring Procedures

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INTRODUCTION

Assessments of a suite of instream physical habitat characteristics, collectively known as habitat typing, are commonly used for planning stream management and restoration activities in California. Virtually every instream restoration project funded by the California Department of Fish and Game (DFG) is based on the findings of habitat typing using accepted DFG protocols (Flosi et. al. 1998). A variant of this type of methodology is currently used in the state of Oregon for assessing effectiveness of fish habitat restoration projects (Jacobsen and Thom, 2001). Because of its widespread use in California, there is a strong incentive to utilize habitat typing as an effectiveness monitoring tool.

However, many elements of the habitat typing procedures used by DFG lack repeatability because of their subjectivity and flow dependency. This subjectivity has long been recognized by DFG and others and is the reason that the method has not been widely used for monitoring.

For example, the heart of the methodology, habitat unit classification, appears to be inconsistent between observers and flows. Roper and Scarnecchia (1995) found that even well-trained crews differed in habitat unit classifications by 20-30% or more at the same flow. Riffles were most consistently classified, while pools and glides were more often confused. In a separate study, Azuma and Fuller (1995) found that the largest discrepancies occurred with habitat types of the greatest length, generally fast water habitats, especially riffles. Estimates of total lineal distance of each habitat unit on the same stream routinely varied by 50% between observers. Kaufmann (1999) reported that percent pool values based on habitat classification varied almost as much between visits as among streams.

In general, the fewer habitat unit types used to classify habitat, the greater the consistency between observers. Azuma and Fuller (1995) found that by aggregating the 24 habitat classifications into 3 (pools, riffles, and runs) the coefficient of variation between observers was reduced from 0.75 to 0.36. Even with fewer habitat classification categories, they concluded that a 50 percent loss of a particular habitat type would be required before change could be detected as significant.

Because of this variability in habitat classification and other parameters within the habitat typing methodology, it was clear that modifications of current DFG habitat typing methodology were needed to produce a useful method for effectiveness monitoring. This habitat monitoring protocol describes changes made in consultation with the literature, practitioners, and DFG staff. The primary modifications made included deletion of parameters particularly subject to observer bias or flow, decreasing the number of habitats classified, and adding flow independent channel measurements and methods for monumenting and relocating restoration structures.

GUIDELINES FOR USE OF THE HABITAT MONITORING PROTOCOL

The habitat monitoring protocol presented here is recommended when basic quantitative and qualitative measures of restoration effectiveness are desired for instream, bank stabilization and canopy cover restoration activities. This protocol was designed to yield conclusions with a moderate amount of precision at a low to moderate expense and be applicable across a wide range of channel types and restoration methods. Because of its general nature it can be applied without addressing specific sampling or study design issues. However, data collected without an objective driven study design and statistical sampling methodology constitute case studies and cannot be extrapolated beyond the sampled reach or compared to other locations. It is preferable to use these protocols within the context of an objective driven study design.

The types of questions that can be answered through use of this protocol include, but are not limited to: 1) how long do instream structures last, 2) do instream structures change habitat unit classifications, i.e. change riffles to pools, 3) do local maximum depths and residual pool depths change after installation of instream structures, 4) do bank stabilization treatments reduce the amount of bare banks after treatment and for how long, 5) do reach level average channel geometry parameters such as width to depth ratios, or thalweg position change in restored stream reaches, 6) does reach level average substrate size change after restoration activities are completed 7) does canopy cover over the channel change in response to riparian planting projects, and 8) does maximum tree diameter change in the riparian area due to restoration activities. There are also qualitative estimates of instream cover, pool tail out substrate composition, fine sediment deposition in pools and sequential photographs of each restoration structure from which to make qualitative conclusions regarding the effectiveness of restoration activities.

This habitat monitoring protocol specifically does not address technically difficult restoration effectiveness parameters such as: velocity refugia, turbidity, suspended sediment concentrations, effectiveness of upslope restoration activities, fish passage or assessment of spawning habitat quality or quantity. This is because there are no reliable indicators for these parameters that can be inexpensively collected. In particular, there has been extensive research which indicates that there are no robust measures of spawning habitat quality that can be collected at low to moderate expense commensurate with the other protocols in this methodology (Sylte 2002, Bunt and Abt 2001, Kondolf 2000, McBain and Trush 2000).

When detailed, quantitative results are needed for individual parameters such as spawning habitat quality or quantity, more intensive protocols and a good study design are required. More intensive methodologies include: permanently monumented and surveyed longitudinal profiles and cross sections, V-star, bulk sampling of substrates, more intensive and location specific pebble counts, stereo photography of substrate, intergravel permeability assessment, electronic temperature monitoring, suspended sediment concentration values, continuous turbidity monitoring and a wide variety of existing methodologies that can be tailored to specific monitoring objectives (Johnson et al. 2001, Bain and Stevenson 1999, MacDonald 1991, and others). Use of quantitative and intensive protocols requires that a sampling regime be prescribed in the context of an overall study design. No generic study design can be predetermined for monitoring the wide range of restoration activities currently being implemented in a wide range of settings.

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

Restoration Objectives and Effectiveness Criteria

The primary objectives for the majority of DFG fisheries program in-stream restoration projects include:

- Increasing cover, habitat complexity, and instream habitat types
- Increasing spawning habitat
- Improving stream geometry and reduced width to depth ratios
- Increasing streambank stability
- Improving flood control

The principal parameters used to monitor effectiveness of instream restoration projects are habitat units, residual pool depth and frequency, shelter, canopy cover, channel geometry, and bank erosion. The effectiveness criteria that each parameter relates to are listed below.

Parameter: Frequency, length and percentage of pools, riffles, flatwater and dry habitat units
Effectiveness Criteria:

- Increased quality of immediate and adjacent instream habitat units
- Increased amount of suitable spawning habitat at specified flows
- No unforeseen adverse effects on habitat features

Parameter: Residual pool depth and pool tail substrate class
Effectiveness Criteria:

- Project improves pool habitat within the project reach
- Reduced fine sediment in reach
- No net loss of primary pools

Parameter: Shelter type and percent shelter
Effectiveness Criteria:

- Project improves shelter within the project reach

Parameter: Canopy cover and dominant canopy size and type
Effectiveness Criteria:

- Increased riparian vegetation cover
- Reduced water temperature

Parameter: Channel width and depth
Effectiveness Criteria:

- Improved channel width to depth ratio
- Stream re-establishes and maintains properly functioning geometry and pattern
- Stream regains access to formerly abandoned floodplain
- No unforeseen adverse effects on channel geometry or fish passage

Parameter: Bank erosion
Effectiveness Criteria:

- Reduced bank erosion

- Improved channel geometry and reduced width to depth ratio
- No net increase in erosion or sedimentation, or channel instability

ASSUMPTIONS

The following assumptions were used in developing the habitat monitoring protocol:

- Monitoring will be done by different observers over time
- Methods must be efficient and relatively inexpensive.
- Methods should be capable of detecting changes of 50 percent or greater change in frequency or size of habitat units. This level exceeds observer variability and is characteristic of the expected magnitude of changes.
- Methods must be suitable for monitoring effectiveness of a wide range of instream projects in a wide range of channel conditions and types.

Therefore, monitoring protocols must be robust to observer bias and variations in flow and relatively easy and inexpensive to implement.

TIMING

Sampling will be carried out before and after restoration practices are implemented. The first survey of in-stream conditions will be conducted during the low flow season prior to construction, usually between May and September. Timing should not be dependent on measured flows since many streams are un-gauged.

The restored stream reach should be resurveyed during the first low flow season following the first high flow season after construction. Conditions and recommendations for remediation, if necessary, should be noted at this time.

After the first season, the restored stream reach, or a sub-sample, should be re-visited every three to five years at the minimum and after any ten to twenty year recurrence interval event on the nearest gauged stream. Otherwise, re-surveying should be in accordance with applicable study objectives and sampling designs.

Resurveys should be conducted at a similar season (month) and flow to the original survey.

PROTOCOL DESCRIPTION

The habitat monitoring protocol presented below is applicable to reach-level in-stream restoration projects. These types of projects typically include the following practices:

Instream Structures
- Projects proposing habitat improvements using boulder, log, or rootwad structures
- Projects proposing habitat improvements by installing gravel in channels
- Projects proposing habitat improvements by removing in-stream structures such as dams and riprap and breaching dikes

Streambank Stabilization
- Projects proposing to protect streambanks with deflectors, armoring, or bioengineering

FIELD SAMPLING

For this methodology, the study reach is defined as the area extending from below the influence zone of the downstream most restoration structure/activity to above the influence zone of the upstream most restoration structure/activity. The influence zone refers to the area around each restoration structure/activity where changes in geomorphic processes or vegetation patterns are likely to occur, such as scour or aggradation of the bed, sorting of substrate, retention of LWD, stabilizing or destabilizing channel banks, increasing canopy cover over the channel, etc.. There are likely to be parts of the stream that have not received restoration treatments within the study reach and data are also recorded in these areas.

An important component of monitoring changes from instream projects is the ability to relocate installed instream structures and habitat units. This is difficult using current DFG habitat typing methods. DFG's current protocol compounds errors in distance by tallying the cumulative lengths of proceeding habitat units to determine current location. Location errors accumulate at distances further from the start point.

To improve accuracy, this survey is conducted using relative distances from known points. The location of every habitat feature and structure observed along the stream is recorded relative to the starting point and other permanent landmarks rather than from the previous channel unit. By using this method, it should be possible to relocate habitat units, restoration structures, and other notable features using only a string box, accompanying description data, and photographs. Relative locations are likely to be plus or minus 20 to 100 feet between observations depending on length of the survey reach and the number of obstructions in the channel.

Information needed before surveying

Locations and descriptions of all installed or proposed structures should be presented to the monitoring survey team prior to the initial survey. A site sketch map with distances between structures and an accompanying summary report of the design and intended function of each structure should be included in the 'packet' presented to the monitoring team. Proposed locations of all structures should be flagged along the stream and each structure should have a unique ID number assigned to it. Numbering should be sequential from downstream to upstream.

Conducting the stream survey

Each stream survey should begin at an easy to locate, permanent landmark on the downstream end of the surveyed reach. Bridges, roads, parking lots, power lines, and tributary junctions in non-alluvial settings can be used as the starting point. A photograph and detailed description of the starting point, along with explicit directions for getting there should accompany the data sheet. If no permanent landmark is convenient, a permanent point can be established (see site location protocol).

- Tie off the string from a string box (hipchain) at the beginning point of the survey and set the counter to zero
- Proceed up the thalweg of the channel conducting habitat monitoring. Parameters measured are described below. Record the location of habitat unit breaks, landmarks, and restoration structures at the distance indicated on the string box counter. Record structure type according to the DFG structure type codes in the DFG Manual (section VIII page 18-20). Do not reset the string box to zero at each habitat unit break.
- Describe on the data sheet notable permanent features within view of the channel as they are encountered along with the distance reading at that point. Examples of notable features include large snags within the riparian zone, buried LWD protruding from the streambank, large mid-channel boulders, trails crossing the creek, tributary junctions and human debris such as vehicles and structures.
- Take photographs of notable features and structures and record photograph information on the data sheet.
- Split stream survey reaches into sub-sections at un-mistakable permanent landmarks such as bridges, electric transmission lines, or occupied buildings. Describe and photograph these features and their distance from the last permanent reference point. Reset the string box to zero for the new section.

Documenting photographs

Photographs taken at channel transects, unvegetated banks, and at restoration structure sites should include a stadia rod for scaling purposes. The following will be recorded for each photograph: relative distance station, frame number, position of photo point within the channel, direction the camera is pointing relative to the channel, and the type of photograph being taken as restoration structure, channel transect, landmark, or opportunistic. Opportunistic photos of fish in a pool or unique vegetation should include a description of the feature being captured (See accompanying data sheet). Focal length of the camera lens should be recorded in the photo notes.

HABITAT MONITORING PARAMETERS

The parameters measured during the habitat monitoring survey are described below.

Habitat units are recorded as riffles, flatwater, or pools. Dry units are noted as a separate habitat type. Side channels are noted where they enter the main channel using the distance displayed on the hipchain. However, no further data are recorded on the side channel unless it received restoration treatments. Notes on the field form should make it clear which channel was surveyed as the 'main channel' and which was called the 'side channel'.

Maximum depth of water is recorded for all habitat units. A maximum depth measurement is also recorded within the estimated zone of influence of each in-channel restoration structure, both before and after installation. The measurement should be taken in the area that is geomorphically influenced (scoured or filled) by the structure. The distance along the channel from the reference point for each maximum depth point is recorded.

Maximum pool depth and residual pool depth are measured with a stadia rod. Residual pool depth is the maximum depth of water in the pool minus the depth of water recorded at the crest of the pool tail out. For intermittent channels where the maximum depth of water in a pool associated with a restoration structure may be below the tail crest depth, the following method must be used. One observer stands midway between the deepest part of the pool and the tail crest with a hand level and records readings for elevation from a stadia rod held by a second observer at the deepest part of the pool and at the surface of the tail crest. Residual pool depth in this case is the difference in elevation between the maximum pool depth and the tail crest surface. This allows measurement of the scour or lack thereof associated with restoration structures in intermittent streams.

For fine sediment deposition in pools, determine whether or not there is an area greater than six square feet of fine sediment deposition present. This may indicate an abundance of fine sediment in the system and may be affected by local scour and fill effects from restoration structures.

Pool-forming mechanisms are recorded for each pool encountered. Pools will be designated as natural or caused by restoration. Pool forming mechanisms include large woody debris (LWD), rootwad, boulders, bedrock, live trees, and stream confluences[1].

Mean width of habitat units is recorded only when fish sampling will be done for validation monitoring to associate fish density with habitat area.

- Record widths of habitat units on the same subsample of units that will be sampled for fish density. Width will be recorded at 25 percent, 50 percent and 75 percent of the length of the habitat unit.
- Units to be sampled for fish and width will be flagged at the upper and lower end of the habitat unit and labeled with habitat unit number and type.

Shelter rating is recorded for pools and flatwater units for a target fish three inches in length. The 'Shelter Value' and 'Percent cover' estimates are recorded using current DFG habitat typing methods. However, instead of recording an estimate of the percent cover contributed

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[1] Current DFG habitat typing methods designate all pools that encompass more than 60% of the wetted channel width as mid-channel pools. However, no information is recorded on mechanisms forming these pools making it impossible to determine the relative importance of boulders, LWD, bedrock, and other geomorphic elements (natural or restoration related) (Kaufmann et al. 1999).

by each cover type to the total cover, the three most extensive cover elements are recorded in order of relative cover contribution.

Dominant substrate is recorded in the pool tail out using an ocular estimate based on the Wentworth scale, already in use by DFG.

Unvegetated banks are recorded. Approximate average height, composition, and position (left or right bank) of unvegetated banks is recorded as is the beginning and ending distance relative to the reference point.

Restoration structure location is recorded. The location point is the edge of the structure farthest upstream. Each structure is classified using structure type codes from the DFG Manual (section VIII, pages 18-20). Condition codes including missing, functional, needs repair, or buried are assigned to each structure.

Transects are established at equally spaced intervals along the study reach, 200 feet is recommended. The initial transect should be placed randomly at some distance less than 100 feet from the start point and out of the influence zone of engineered structures such as bridges, which may occur at the start point of the survey. Distance between transects should be measured using a string box. Since it is important that transects be representative of average reach level conditions, transects may be placed closer or further apart depending on the characteristics of the channel, length of study reach, project objectives, and the judgment of the field crew. A minimum of 5 transects should be collected in short reaches (<500 feet), with a goal of at least 11 transects in most reaches. Additional transects may be placed above, below and/or within the influence zone of specific restoration structures depending on monitoring objectives. For example, a cluster of transects near wing deflector type structures or willow baffles would provide quantitative data on the effectiveness of these structures in decreasing channel width and/or increasing thalweg depth.
At each transect:

- Lay out a level tape across the channel and measure bankfull channel width.
- Subtract 1 foot from the width and divide the distance into 10 equally spaced stations.
- Using a stadia rod, record depth from the stretched tape measure to the streambed at each station. The first station is always one foot from the left edge of the tape (not the zero point where depth is always zero.)
- Record the distance from the left bankfull line (zero on the tape measure) to the left edge, right edge and maximum depth within the wetted channel Also record depth and substrate type at these points.
- Record point samples of surface substrate class at each of the 10 stations. Use the Wentworth scale as currently used in DFG habitat typing.
- Record information on the largest living tree within a 50-foot radius of each end of the transect. Trees are classified as broadleaves or conifers. Tree diameter is recorded using the following diameter classes: less than six inches, six inches to one foot, one to two feet, two to three feet, three to four feet, and over four feet. The purpose is to inexpensively monitor the successional status of riparian species. Increases in maximum tree diameters and gradual conversion to conifer dominance may be a restoration objective.

- Record canopy cover using a convex spherical densiometer at each transect by standing in the centerline of the channel. Use methods described in Appendix M of DFG Salmonid Habitat Restoration Manual (Flosi et al. 1998). Estimate the percent of the canopy cover provided by evergreen versus deciduous vegetation.
- Take a photograph from the middle of the channel facing downstream using the wide angle setting on zoom cameras, and record the lens focal length (mm) in the photo description notes.

During subsequent visits, all transects should be resurveyed and should be located as near to the original survey location as possible. Additional transects may be added to the survey reach in the future as desired, but no survey locations should be dropped. Use the stringbox distance, transect photos and site notes to relocate previously surveyed locations.

Water and air temperature are recorded every time a new data sheet is used. Although it is difficult to obtain useful temperature information from spot temperature measurements, data may be compared to nearby recording thermographs and analyzed accordingly.

DELETIONS FROM CURRENT DFG HABITAT TYPING METHODS

Pool tail embeddedness

Pool tail embeddedness is not recorded because it is subject to observer bias. According to recent studies and our review, making consistent estimates of cobble embeddedness between observers is difficult. Sylte (2002) found that since embeddedness is a result of a combination of physical processes, predicting embeddedness with any one variable is not feasible given the current level of understanding and measurement methods. Additionally, the scientific review panel for this project concurred on elimination of the embeddedness parameter because of the difficulty in obtaining consistent estimates between observers (Science Review Panel July 24, 2002).

Bank composition and cover

Bank composition and extensive vegetation data are not recorded here. Detailed data on riparian vegetation composition should be collected using the riparian monitoring protocols.

Mean depths

Mean depth of each habitat unit is not recorded. Mean depth measurements are flow dependent and subject to greater variability between observers than single point max depths.

Substrate sampling

Substrate sampling has been reduced because changes in substrate quality and quantity cannot be accurately portrayed using habitat typing procedures (Kondolf 2000). Substrate data collected will consist of ocular estimates of substrate type in pool tail outs, presence of fine sediment deposits in pools and modified pebble counts (Wolman 1954) at stream transects. These data may be sufficient to detect *gross* changes in substrate in pool tail outs, fine sediment within pools and average substrate composition at the reach level.

No information on changes in substrate quality or quantity such as percent fines, extent of suitable spawning gravels, permeability, surface and sub-surface substrate composition, suitability for particular fish species or life stages, will be collected as part of the basic habitat monitoring methodology. Simple and inexpensive methods to measure these components of channel substrate are not currently available. To reach conclusions on these parameters, more intensive quantitative methods should be used with a specific study design. See Bunte and Abt (2001) for a guide to use of intensive substrate sampling methods, objectives, and guidelines.

SUBSEQUENT SURVEY

The monitoring team will have a 'packet' of information on all subsequent monitoring surveys so that particular structures and features can be re-located and assessed. The packet will contain the following items:

- A 'stream schematic', which is a graphical display of the location of all habitat units, restoration structures, landmarks, photopoints and channel dimensions displayed according to their linear distance from the start point of the survey.
- Data sheets and comments from past surveys.
- An album of photographs recorded for the stream reach in past years, keyed to distances from the starting point, camera position, photo orientation and photo notes.
- Printouts of cross-sections from past surveys.

IDENTIFYING THE CORRECT PROTOCOL TO USE

Additional in stream quantitative protocols should be considered part of a "tool box" of protocols used in effectiveness monitoring. More intensive methods may be added on to the basic habitat monitoring protocols, substituted for protocols within the basic methods or used on their own. In general, more rigorous quantitative methods should be used to evaluate fine scale changes in stream geomorphology, temperature and/or substrate. The choice of protocols will depend on the specific nature of the project(s) to be monitored and study objectives. For some purposes, cross-sections alone may be the ideal tool for monitoring effectiveness (Kondolf and Micheli 1995). In other situations, the full range of monitoring tools may be needed.

Habitat monitoring should be used at the project site and stream reach scales to provide a coarse level of information on general habitat changes in response to restoration activities. It may be applied at the site or reach level to evaluate different treatments or in a statistical design to assess effectiveness of project types across a range of environments.

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INSTRUCTIONS FOR COMPLETING THE HABITAT MONITORING DATA FORM

FRONT SIDE OF DATA SHEET

General Information- section 1

1) **Date-** Enter the day's date: mm/dd/yy
2) **Stream Name-** Enter in the name of the stream. If unnamed, use named stream to which it is tributary.
3) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
4) **Stream Section-** Enter the stream section number beginning with 1 for the lowermost portion of the survey reach. Stream sections refer to divisions of the survey reach at distinct, permanent landmarks.
5) **Form No.-** Enter in the form number. Number the forms sequentially beginning with "01" on the first page and "02" on the second page and so on.
6) **Surveyors -** Enter the names of the surveyor crew.
7) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
8) **Water Temperature-** At the beginning of each page, record the water temperature to the nearest degree Fahrenheit. Water temperatures are taken in the middle of the habitat unit, at a depth <1 foot.
9) **Air Temperature-** At the beginning of each page, record the air temperature to the nearest degree Fahrenheit.

Habitat and Restoration Structure Data – section 2

Data recorded for all habitat units or restoration structures

10) **Habitat Unit # or Structure #-** For data about habitat units, enter the habitat unit number. Record the habitat unit numbers in sequence, beginning with "001" at the survey start. For data about in-stream or bank stabilization structures, enter the structure number. If numbers were assigned to the structures in the design drawings, use these. If structures were not pre-numbered, assign numbers to each structure in sequence, beginning with "R001" at the first structure encountered at the downstream end of the survey reach. All restoration structure numbers should begin with an "R" to avoid confusion with habitat unit numbering.
11) **Habitat Type-** Determine the type of habitat unit and enter the appropriate habitat type code. Pool = P, Riffle = R, Flatwater =F, Dry =D. If you are recording data about a restoration structure, draw an arrow down through the column to indicate that the restoration structure occurs in the previously recorded habitat type. Multiple restoration structures may occur in a single habitat unit.
12) **Structure Code-** Determine the type of restoration structure, referring to project description if available. The codes for each type of restoration structure are found in section VIII, pages 18-20 in the DFG Manual.
13) **Structure Condition-** Record condition of the structure. Refer to the attached code sheet for categories and codes.

14) **End Distance-** Record the distance as displayed by the running total on the stringbox at the upstream end of each habitat unit or restoration structure.
15) **Max Depth of Water-** Enter the measured maximum depth for each habitat unit or within the influence zone of each restoration structure, in feet. If the restoration structure has not yet been built, record the max depth of water within the area likely to be influenced by the structure.
16) **Distance at Max Depth-** Record the distance as displayed by the running total on the stringbox at each measured maximum depth.

Data recorded for pool and flatwater habitat units only.

17) **Shelter Value-** Enter the number code (0-3) that corresponds to the dominant structural shelter type that exists in the unit (Part III- Instream Shelter Complexity).
18) **Percent Unit Covered-** Enter the percentage of the unit occupied by the structural shelter.
19) **1st element-** Enter the two-letter code for the most extensive cover type in the unit. Refer to the attached code sheet for categories and codes.
20) **2nd element-** Enter the two-letter code for the second most extensive cover type in the unit. Refer to the attached code sheet for categories and codes.
21) **3rd element-** Enter the two-letter code for the third most extensive cover type in the unit. Refer to the attached code sheet for categories and codes.

Data recorded for pool habitat units only.

22) **Pool Former-** Enter the geomorphic element that caused the pool to form in its current location. If it is unclear what formed the pool or there appear to be multiple elements responsible for the pool formation, record 'UN' for unclear or 'MU' for multiple with the available codes. Where it is possible to identify the pool forming element, record whether the element is natural or due to restoration by putting a hyphen after the pool forming element and recording "N" for natural or "R" for restoration. For example, a pool formed by a naturally occurring piece of LWD would be recorded as LW-N. Refer to the attached code sheet for categories and codes of pool forming elements.
23) **Residual Pool Depth-** This is a calculated field arrived at by subtracting the depth at the pool tail crest from the maximum pool depth, recorded in feet. For pools where the water level is below the pool tail crest *and* a restoration structure is present, calculate residual pool depth by subtracting the elevation at the pool tail crest from the elevation at the deepest part of the pool using a stadia rod and a hand level, also recorded in feet.
24) **Pool Tail Substrate-** Enter the two letter code for the dominant substrate composition of the tail-out for all pools. Refer to the attached code sheet for substrate categories and codes.
25) **FSD >6 sq. ft.-** This refers to the presence or absence of contiguous patches of fine sediment deposition greater than 6 square feet in the bottom of a pool. Record 'Y' for yes if a patch of at least this size is present and 'N' for no if not present.
26) **Comments-** Add comments that are important to each habitat unit or restoration structure. For restoration structures comment on: whether or not the structure appears to be accomplishing the intended function, notes on condition of structures including any repairs that need to be made, and describe any unintended side effects of structures if apparent, etc.

Photographs and Landmarks – section 3

27) **Distance-** Enter the distance as displayed by the running total on the stringbox at the location where the picture is taken.
28) **Feature Code (TR, LM, RS, OP)-** Enter the code for the type of photograph being taken. TR = photos taken at transects, LM = photos taken of distinctive landmarks, RS = photos taken of restoration structures, OP = opportunistic photos of interesting features observed during the survey, e.g., fish, predators, exemplary habitat, etc.
29) **Cam. Pos. (RB, LB, MC)-** Enter the code for the location within the stream channel where the photograph was taken from, i.e., camera position. RB = right bank, LB = left bank, MC = mid channel.
30) **Cam. Facing (UP, DN, LB, RB)-** Enter the code for the direction that the camera is facing. UP = upstream, DN = downstream, LB = left bank, RB = right bank.
31) **Photo #-** Enter the frame number displayed on the camera for each photograph.
32) **Description –** Describe the salient features of the scene being photographed and add any site notes that might help in relocation of the photo point in the future.

Bank Erosion – section 4

33) **Start D-** Enter the distance as displayed on the stringbox at the downstream end of the un-vegetated bank.
34) **End D-** Enter the distance displayed on the stringbox at the upstream end of the un-vegetated bank.
35) **LB/RB-** Enter the unvegetated stream bank, left bank or right bank.
36) **Ht.-** Enter the approximate average height of the un-vegetated bank.
37) **Substrate-** Enter the two- letter code for the dominant substrate composition of the un-vegetated bank. Refer to the attached code sheet for substrate categories and codes.

BACK SIDE OF DATA SHEET-TRANSECTS

38) **Stream Distance-** Enter the distance displayed on the stringbox at the transect location.
39) **Bankfull Width-** Enter the estimated bankfull width of the stream channel at the estimated bankfull line, in feet.
40) **LB/RB Largest Tree Diameter-** Enter the diameter class of the largest tree within a 50 foot radius of the left and right endpoints of the transect. Refer to the attached code sheet for diameter categories and codes.
41) **Broad or Conifer-** Record whether the largest trees on the left and right banks are conifer or broadleaf.
42) **Percent Total Canopy -** Enter the percentage of the stream area that is influenced by the tree canopy. The canopy is measured at the center of the channel using a convex spherical densiometer (Appendix M in DFG Manual).
43) **Percent Deciduous -** Estimate the percent of the total canopy consisting of deciduous trees.

44) **Percent Evergreen -** Estimate the percent of the total canopy consisting of evergreen trees.
45) **Comments-** Record evidence of recent geomorphic change and a description of transect location to help in relocating the transect in future.
46) **Station-** Each transect has 10 equally spaced stations where depth and substrate are recorded, these are pre-numbered. In addition, the left and right edges of the water and the max depth are recorded if they do not fall on one of the 10 equally spaced stations.
47) **Distance-** The distance between stations is calculated by subtracting 1 foot from the bankfull width and dividing that number by 10. The first station is always at 1 foot from the left edge. Distance to, each subsequent station is calculated by adding the distance between stations to the distance at the current station.
48) **Depth** – Enter the depth reading from the stretched horizontal tape measure to the bed of the channel, in feet.
49) **Substrate-**Enter the size class of bottom substrate at each of the distance stations. Refer to the attached code sheet for categories and codes.
50) **LEW-** Enter the distance from the left edge of the transect to the left edge of water in the channel. Also record depth and substrate at the left edge of water.
51) **REW-** Enter the distance from the left edge of the transect to the right edge of water in the channel. Also record depth and substrate at the right edge of water.
52) **Max Depth-** Enter the distance from the left edge of the transect to the deepest point in the channel (the thalweg). Also record depth and substrate at this location.

Cover elements	code
undercut bank	UB
SWD (<12")	SW
LWD (> 12")	LW
Root Mass	RM
Terr Veg	TV
Aqua Veg	AV
Bubble Curtain	BC
Boulders	BO
Bedrock Ledges	BE

Pool Former	code
LWD	LW
Boulder	BO
Bedrock	BE
Rootwad	RW
Lateral scour	LS
Multiple	MU
Unclear	UN
Live Tree	LT
Large Human Debris	LH

Pool Former Cause	code
Restoration	R
Natural	N

Photo Codes	code
Landmark	LM
Restoration	RS
Opportunistic	OP
Transect	TR

Substrate	code
Silt/clay	SL
Sand (<0.08")	SA
Gravel (0.08-2.5")	GR
Sm. Cobble (2.5-5")	SC
Lg. cobble (5-10")	LC
Boulder (>10")	BO
Bedrock	BE

Location	code
Right Bank	RB
Left Bank	LB
Mid Channel	MC
Upstream	UP
Downstream	DN

Structure Condition	code
Proposed	PR
Good	GD
Needs Repair	NR
Missing	MI
Buried	BU
Partially Failed	PF

Largest Tree Diameter Classes (dbh)	code
< 0.5 feet	0
0.5-1.0 feet	1
1.1-2.0 feet	2
2.1 - 3.0 feet	3
3.1-4.0 feet	4
4.1-5.0 feet	5

HABITAT MONITORING DATA SHEET

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

Date:____________ Stream Name:________________________________ Project ID:__________________ Stream Section:______ Form______

Surveyors:_______________ Start Time__________ Water Temperature:____________ Air Temperature________________

Habitat and Restoration Structure Data

All Habitat Units and Restoratation Structures							**Shelter Data - Pool and Flatwater Units**					**Pool Data**			
Habitat Unit # or Structure #	Habitat Type	Structure Code	Structure Condition	End Distance	Max Depth of Water	Distance at Max Depth	Shelter Value	% unit covered	1st element	2nd element	3rd element	pool former	residual pool depth	pool tail substrate	FSD >6 sq.ft.

Photographs and Landmarks

Distance	Feature Code (TR,LM, RS, OP)	Cam. Pos. (RB,LB, MC)	Cam. Facing (UP, DN, LB, RB)	Photo #	Description	Distance	Feature Code (TR,LM, RS, OP)	Cam. Pos. (RB,LB, MC)	Cam. Facing (UP, DN, LB, RB)	Photo #

Bank Erosion

start D	end D	LB/RB	ht.	substrate	start D	end D	LB/RB	ht.	substrate	start D	end D	LB/RB	ht.	substrate

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

Stream Distance	Bankfull Width	LB largest tree diameter	Broad -or- Conifer	RB largest tree diameter	Broad -or- Conifer	Percent Total Canopy	Percent Deciduous	Percent Evergreen	Comments				
Station	1	2	3	4	5	6	7	8	9	10	LEW	REW	MAX Depth
Distance													
Depth													
Substrate													

Stream Distance	Bankfull Width	LB largest tree diameter	Broad -or- Conifer	RB largest tree diameter	Broad -or- Conifer	Percent Total Canopy	Percent Deciduous	Percent Evergreen	Comments				
Station	1	2	3	4	5	6	7	8	9	10	LEW	REW	MAX Depth
Distance													
Depth													
Substrate													

Stream Distance	Bankfull Width	LB largest tree diameter	Broad -or- Conifer	RB largest tree diameter	Broad -or- Conifer	Percent Total Canopy	Percent Deciduous	Percent Evergreen	Comments				
Station	1	2	3	4	5	6	7	8	9	10	LEW	REW	MAX Depth
Distance													
Depth													
Substrate													

Stream Distance	Bankfull Width	LB largest tree diameter	Broad -or- Conifer	RB largest tree diameter	Broad -or- Conifer	Percent Total Canopy	Percent Deciduous	Percent Evergreen	Comments				
Station	1	2	3	4	5	6	7	8	9	10	LEW	REW	MAX Depth
Distance													
Depth													
Substrate													

Stream Distance	Bankfull Width	LB largest tree diameter	Broad -or- Conifer	RB largest tree diameter	Broad -or- Conifer	Percent Total Canopy	Percent Deciduous	Percent Evergreen	Comments				
Station	1	2	3	4	5	6	7	8	9	10	LEW	REW	MAX Depth
Distance													
Depth													
Substrate													

E-2: Quantitative Protocols for In-stream Sampling

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INTRODUCTION

The objective of this protocol is to monitor the effectiveness of projects intended to change stream channel geomorphology, substrate or temperature.
These protocols will be applied to the following studies:

1) Quantitative analysis of individual critical projects.
   - Statistical analysis of the effectiveness of project types across a range of environmental conditions.
   - Statistical analysis of the effectiveness of a range of project types within specified environmental conditions or across a range of environmental conditions.
   - Long term watershed monitoring.

In all instances, it is mandatory that specific study designs be developed. The protocols therefore, represent only one part of these study designs. Other aspects include study objectives, sampling intensity, and analysis methods to be used.

PROTOCOL DESCRIPTION

EXISTING DFG METHODS

Protocols for conducting long profile and cross section surveys using differential leveling are well documented and have been used in many studies (Harrelson et al. 1994). DFG has developed its own protocols for these procedures that are similar to those described by Harrelson (1994).

DFG methods for measuring long profiles include recording bed elevation every five feet along a three-hundred-foot-long tape measure staked down the channel thalweg, and recording lateral offset from the tape measure to the channel thalweg. At the upstream-most stake and at each stake along the tape measure where the tape changes angles the bearing of the tape measure is recorded using a sighting compass. An optical automatic level and a stadia rod are used to determine bed elevations along the profile. Grade breaks and other features that occur between five foot stations are also recorded at the nearest station to which they occur. The upstream and downstream endpoints of the long profile are located at monumented cross sections.

Cross section endpoints are monumented using rebar stakes. Current DFG methods for conducting cross section surveys use two foot stations for elevation measurements. Elevations are recorded starting at the left bank and working to the right bank, grade breaks that occur between stations are recorded at the station where they occur.

MODIFICATIONS TO DFG METHODS

There are two aspects of the current DFG survey methods that need modification to improve their utility for monitoring: 1) methods for navigating to and relocating monumented survey points such as cross section endpoints and benchmarks; and 2) sampling design for installing channel cross sections within the area of influence of restoration structures.

Methods to relocate permanent points

1) Record driving directions from known points (roads, bridges, towns, etc.) to parking place or departure point, e.g. 3.2 miles from Clear Creek Bridge on Blueslide road, turn out is on south side of road with a four foot diameter redwood snag at east edge of turnout. Mark route on 1:24000 USGS quadrangle.
2) Record distance and bearing to benchmark(s) from departure point. Describe specific departure point and benchmark. It is most consistent and accurate to use a sighting compass for this task and record azimuth using Magnetic North, not True North. Distances can be measured with a tape measure or range finder and should be accurate to within five feet. For example, "from west sign-post on bulletin board at parking lot proceed 354 feet at 270 degrees to a five foot diameter sandstone boulder, this benchmark is marked with a piece of rebar epoxied in a drilled hole on top of the boulder."
3) Take a photograph of the benchmark and surrounding area from the departure point or en route to the benchmark if it is not visible from the departure point.
4) Establish rebar permanent points with a three foot long, 0.5 inch diameter piece of rebar driven 1.5 feet into the ground for cross sections at a suitable location (clear terraces, minimal visual obstructions, etc.). Where possible, a four-foot long, 0.5 diameter piece of white PVC pipe should be placed over the rebar with brightly colored flagging affixed to it. Permanent points should be above the 100-year floodplain if possible. The uppermost cross section for a long profile survey should be located 20-50 feet upstream of the upper-most restoration structure.
5) Record bearing from LB pin to RB pin using a sighting compass.
6) Record bearing and distance to LB pin from known point, usually benchmark.
7) Repeat steps 4-6 for other monumented cross sections.
8) For long profiles, record upstream and downstream-most point of each restoration structure along the tape measure and record type of structure or unique ID of structure, if available.
9) Record locations of departure points, permanent points, benchmarks and other relevant features on 1:24000 quadrangle as accurately as possible, if necessary draw a rough site sketch to record relative locations of relevant objects, permanent points and departure points.

Strategy for installing cross sections

Generally cross sections are installed using permanent endpoints (Harrelson et al. 1994). However, many restoration structures are designed to move in the channel over time. The intentional or un-intentional movement of structures over time within the stream channel may make monumented cross sections less useful than floating cross sections for monitoring effectiveness of restoration structures over 5-20+ year time periods.

Therefore, in addition to monumented cross sections at the upstream and downstream endpoints of the long profiles we suggest temporary cross sections at restoration structures.

The objectives for monitoring individual restoration structures are to: 1) document maximum depth of scour caused by each structure; 2) calculate approximate pool volumes; and 3) record patterns of sediment deposition/scour in relation to location of restoration structures. These objectives relate to the general goal of instream restoration structures which is, usually, to create scour in the stream bed (summer rearing habitat) or create obstructions that cause decreased water velocities and result in fine sediment deposition (winter velocity refugia). Another common goal for instream restoration structures is to modify streambed substrate composition, usually to improve the quality of or recruit spawning gravels.

The following methods are presented to measure streambed scour and sediment composition. First, a sub-sample of restoration structures within a reach must be selected. Sample selection is based on the following assumption:

It is assumed that the ‘population’ of structures being sub-sampled consists of all DFG funded restoration structures, not just the population of structures at each reach. Furthermore the ‘population’ of structures is stratified by type of structure, e.g. boulder weir, boulder cluster, wing dam, etc. Using this stratification the ‘effectiveness’ of each type of structure can be compared with other structures and potentially evaluated in terms of overall cost effectiveness. Therefore the selection of restoration structures to be sampled will have to be part of a larger study plan that has a target number of each type of structure to be sampled.

Cross sections at restoration structures

Four cross sections will be measured at each structure selected for sampling. One will be located at the upstream most point of the restoration structure, one at the deepest point of scour caused by the structure, one at the downstream extent of influence of the structure (pool tail out), and one midway between the downstream most cross section and the one at the deepest scour point. The distance station along the long profile will be recorded for each cross section.

The endpoints for these cross sections should be located at bankfull height on the streambank. The endpoints of the cross sections will have the elevation recorded using a stadia rod and automatic level. However, the depths across channel will be recorded using a stadia rod with the cross section tape measure as a reference. Not using the auto level for the cross sections will increase production speed, without a significant decrease in accuracy. As with the monumented cross sections, depths will be recorded every two feet. At each depth measurement substrate class should be recorded using one of the seven categories described in the habitat typing protocol.

In subsequent years, the cross sections will be placed at the points described above (upstream point, deepest scour, end of influence, midway), although these points may be in different places than they were during the previous set of measurements as the structures and streambed adjust over time. Changes in position will be apparent relative to the long profile distances and elevations of endpoint pins for the cross sections.

Substrate stereo-photo monitoring

A meter square quadrat with a 20 cm grid of strings will be placed on the bed of the stream at the downstream most cross section of each sampled structure as described above. The quadrat will be placed on the bed at six-foot intervals across the cross section. At each placement a pair of photographs of the substrate and quadrat will be taken. The camera should be placed as directly over the quadrat as possible to minimize distortion. The photographs should be taken 6 inches apart horizontally. A polarizing filter will be used to minimize glare off of the water. The photographs can then be analyzed using a stereoscope. The goal of this protocol is to be able to compare substrate composition at pool tail outs over time and make inferences about spawning suitability.

It may be possible to conduct more detailed digital analysis of the photographs to determine percent cover by substrate class or other parameters.

Stream Temperature

Automatic recording thermographs will be used to monitor changes in stream temperature over time. MWAT will be the metric used for analysis. Numerous protocols exist for siting thermographs and analyzing the data (Forest Science Project, among others).

E-3: Quantitative Protocols for Riparian Monitoring

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INTRODUCTION

Riparian zones play important roles in maintaining suitable instream condition, and in providing desirable habitat for anadromous fish. Riparian vegetation provides instream shading and cover, promotes bank stability, enhances physical channel features, provides large wood recruitment, filters sediment, dissipates flow energy, and serves as a major source of nutrients to support instream fauna and flora. Most riparian restoration projects are intended to improve one or more of these functions.

The time period over which riparian vegetation responds to restoration varies with the plant community type (herbaceous, shrub or tree) and the functions targeted for restoration. For example, the response of an herbaceous or shrub riparian community to reduced grazing pressure may be quite rapid. Conversely, it may take decades for a restored riparian forest to produce large woody debris. This temporal dimension has a strong bearing on developing an appropriate monitoring approach.

Plant species diversity and cover in restored riparian areas tends to increase as stabilization occurs and plant succession progresses. Most projects include planting or seeding of native herbaceous and/or woody species to accelerate vegetation establishment, or use various plant materials for bioengineered streambank structures. Monitoring usually includes assessment of survival rate of such plantings. Regardless of the approach, successful riparian projects will stabilize degraded sites. Instream characteristics may also respond to increases in riparian vegetation over time; moving from wide shallow channels with steep eroding cutbanks and high summer water temperature, to more fish-friendly stable channels that are narrower, deeper, have lower water temperature, and well-vegetated banks (Elmore and Beschta 1987). These physical changes are critical in restoring function and sustainability to aquatic habitats.

Monitoring in riparian areas can be perplexing and difficult due to the relatively small size and mosaic pattern of plant community types, and the continual readjustment to disturbance encountered in riparian settings (Winward 2000). Stands may range from a few square feet in size to several acres. Any one section of a stream is usually composed of numerous, repeating stands of community types determined in part by local soils and water table features. The inherent variability in riparian areas does not prevent the development of effective monitoring procedures, but it must be recognized.

The vegetative structure of riparian zones can also vary between sites and must be accounted for in a monitoring approach. Methods that are appropriate to monitor sites dominated by low growing, herbaceous species may not be appropriate or feasible on sites dominated by large shrubs and trees. The “tool box” for monitoring riparian zones, therefore, should include several options that can be selected based on site condition, initial vegetation structure, and the expected vegetative response to restoration over time. In some cases, initial monitoring methods will require subsequent modification if the dominant vegetation structure changes following restoration from low growing grasses to complex communities with multi-layered canopies. Different combinations of the methods described in this narrative can be used to address such changes over time. The types of riparian restoration projects funded by DFG are also a key consideration in selection of appropriate methods.

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

PROTOCOL OVERVIEW

RESTORATION OBJECTIVES AND EFFECTIVENESS CRITERIA

The primary objectives for the majority of DFG fisheries program riparian restoration projects include:

- Promoting bank and floodplain stability
- Increasing effective shade on the channel
- Reducing exotic species
- Increasing native riparian species' abundance
- Enhancing long-term recruitment of large woody debris
- Increasing the structural diversity of riparian communities.

Based on the above objectives, the two principal parameters that can be used to monitor effectiveness of riparian restoration projects are vegetation cover and species composition. The effectiveness criteria for each parameter are listed below.

Parameter: Vegetation Cover (by life form or species)

Effectiveness Criteria:

- Reduced bank erosion or increased bank stability
- Increased riparian cover
- Reduced barren ground
- Reduced vegetation within bankfull channel (for projects aimed at reducing encroachment)
  - Advancement in riparian successional stage and structure from grass-shrub to forest (i.e., increased structural diversity)
- Increased riparian corridor continuity and patch size

Parameter: Species Composition

Effectiveness Criteria:

- Increased relative abundance of native plants
- Increased native plant species richness
- Reduced relative abundance of exotic plants
- Riparian tree composition meets planting or management objectives

Secondary effects of improved riparian conditions on channel geometry or stream temperature can be assessed using instream protocols.

The protocols presented below are recommended for collecting data on these parameters. The specific methods used, and the sampling design must be prescribed in the context of an overall study design. No generic study design is appropriate for riparian restoration monitoring.

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

ASSUMPTIONS

- Monitoring will be done by different observers over time, and therefore, must be robust to observer bias.
- Monitoring will be conducted between May and September in conjunction with instream and upland monitoring where appropriate. Attempts will be made to monitor each riparian site at the same time of year to reduce the effect of seasonal variability. Timing will depend in part on plant phenology, streamflow, and access issues.
- Agency staff, experienced consultants or practitioners who are trained in riparian sampling methods will conduct quantitative monitoring.
- Quantitative monitoring will be applied to assess relative effectiveness of different approaches for achieving specified objectives or variation in effectiveness for one or more approaches across a range of environmental conditions.
- Quantitative protocols are applicable mainly to reach level riparian restoration projects.
- Methods must be efficient, repeatable, and relatively low cost.
- At a minimum, methods are designed to detect a 50 percent or greater change in cover or composition of riparian community types in response to restoration.

TIMING

Sampling will be carried out before and after restoration practices are implemented. The first survey should be conducted during the low flow season prior to implementation.

The restored stream reach or floodplain area should be resurveyed during the first low flow season following the first high flow season. Conditions and recommendations for remediation, if necessary, should be noted at this time.

Subsequent sampling will depend on specific study objectives and sampling design. Sampling after stressing events (e.g., 1997 storms) should also be carried out to obtain data on riparian response. In most cases, it will take several years to determine the response of riparian vegetation to restoration, whether the prescription is planting or changes in land management.

PROTOCOL DESCRIPTIONS

Protocols presented below are applicable to the following project types:

Vegetation Planting

- Projects proposing vegetative restoration within the immediate vicinity of the channel
- Projects proposing vegetative restoration in patches within a project site

Altering Composition of Riparian Vegetation

- Projects aimed at changing the composition of riparian forests usually to increase conifer stocking

Vegetation Control

- Projects proposing removal of exotic vegetation in or near the channel
- Projects proposing to reduce vegetation encroachment within the channel

Land use Management

- Fencing, grazing management, and/or conservation easements
- Other land use management

These project types represent the majority of riparian restoration projects undertaken with funding from the DFG fisheries restoration program. Of over 400 projects funded by the program in the past 15 years, 70 percent involved planting of hardwoods, willow or conifers and 20 percent involved fencing or livestock exclusion to allow vegetative recovery (Robin Carlson, personal communication).

The main objectives of these projects are to increase stream shading, thereby reducing water temperature and to increase bank stability by increasing vegetative cover. Projects may be undertaken in both shrub/tree and herbaceous dominated systems. Secondary objectives may include enhancing recruitment of large woody debris or increasing the diversity of riparian vegetation. These secondary characteristics generally require a long time period to develop and will not often be feasibly monitored within the current structure of the restoration grant program.

The recommended approach for effectiveness monitoring includes use of line intercept transects along stream banks (longitudinal transects) and/or across streams and associated floodplains (cross channel transects). One or both of these methods may be used in a monitoring prescription based on the project type and objectives. These will be accompanied by measurement of instream shading by riparian canopy and use of permanent photopoints. Where possible, aerial photographs may be used. In cases where restoration of primarily herbaceous vegetation communities is proposed (e.g., meadow restoration), methods may have to be modified to a point intercept approach. Line intercept is most appropriate for shrub- and tree-dominated systems. These represent the majority of the fisheries program riparian restoration projects.

LONGITUDINAL TRANSECTS

Longitudinal transects are primarily used to assess changes in bank cover, riparian continuity, and changes in species composition at or near bankfull. Longitudinal transects are established along both banks along the entire reach proposed to be treated. Pre-project and post project data are collected as described below. The line intercept method is used to estimate bank cover by species or genus and by height class

These data allow calculation of the percent cover on each bank by vegetation type or species or by barren ground or other features, such as restoration structures. Effectiveness of bank treatments will be related to the proportion of the bank length that is vegetated by species or lifeforms (tree, shrub, herbaceous) targeted for restoration.

Field Sampling Method

- Describe and/or monument the starting point for the longitudinal transect. Distance from a bridge, road, parking lot, or other landscape feature is useful in relocating the starting point. Tie this point into other monitoring activities if possible.

- From the monumented starting point, establish the line intercept transect along the left bank of the channel. This is done with a string box (hipchain) or tape measure. The line should intercept the permanent riparian vegetation closest to the channel bankfull line (i.e., the "green line" according to Winward (2000). The line intercept may be at, below or above bankfull depending on the location of permanent vegetation at that particular site. If no vegetation is present, the transect should follow the bankfull elevation on the bank.

- Walk along the channel bank making ocular estimates on the dominant plant form, genus (or preferably, species), and percent cover within three height class categories (less than 3 feet, 3 to 15 feet, and over 15 feet). These data are recorded in distances measured along the string box. It may be necessary to repeat the line more than once to capture relevant data in a complex, multi-storied riparian vegetation community.

- Repeat for the right bank.

CROSS CHANNEL TRANSECTS

The way in which cross channel transects are used will vary with project type. For projects proposing to increase riparian cover on the floodplain, line intercept transects are established perpendicular to the channel starting at the bankfull limit on either or both sides of the stream, depending on the treatment. For projects proposing to increase or decrease riparian cover within the bankfull channel, line intercepts are placed perpendicular to the channel from bankfull elevation to bankfull elevation. In some cases, transects fully spanning the channel and floodplain on both sides of the stream will be required. The number of transects to be used and the transect interval should be established with a specific study design. For transects across floodplains, they extend 50 feet from the bankfull channel boundaries away from the channel on either or both of the left and right banks. This coincides with the response zone that has the most influence on shade canopy and bank stability along the channel. The same data are collected for cross channel as for longitudinal transects. The positions of cross channel transects are geo-referenced to the longitudinal transect. Additional data collected on cross channel transects include mid-channel measurements of effective shade.

Field Sampling Methods

- Establish the location of each cross channel transect in relation to the longitudinal transect.

- For floodplain assessments, establish a 50-foot transect with a tape from the bankfull out into the floodplain (at a right angle to the channel). Run the tape over or under vegetation, keeping it perpendicular to the channel (slope distance, not horizontal distance).

- Stand mid-channel in line with the tape. Take four photographs; downstream, left bank and right bank, and overhead at that point. Reference the photograph numbers on a field data sheet to track location.

- Stand mid-channel (in the same place as photopoints) and take four readings with a spherical densiometer to estimate instream shading. Sum the measurements and multiply by 1.5, to estimate percent canopy cover shading the channel.

- Collect line intercept data starting at bankfull (at the beginning of the tape). Identify and record the linear extent of vegetation by genus or species and percent cover for each of three height classes along the transect.

- As required, relocate the tape to the opposite bank and repeat the data collection process.

For assessments of in-channel vegetation, the methods are identical but the transect spans the channel, not the floodplain. A single line should be used for full spanning cross sections. In cases where only in-channel vegetation is assessed (e.g., projects clearing encroachment), the position of the transect(s) will depend on the specific project.

TREATMENT AREA TRAVERSES

In some cases, riparian restoration projects involve treatments concentrated on plots such as grazing exclusions, plantings on eroded sites, exotic plant eradications, etc. Longitudinal transects may not be appropriate in this case to assess effectiveness due to the lack of vegetative continuity and/or dense herbage. In cases where it is possible to navigate over or through vegetation, a simplified line intercept may be used to gather vegetation cover data in treatment areas. This protocol applies to those projects when it is <u>not</u> possible to establish a line intercept due to density of vegetation. The perimeter of the treatment area is surveyed using standard traversing. Vegetative cover by height class is estimated visually as the observer walks around the perimeter.

Field Sampling Method

1. Establish a perimeter line around the vegetation patch using flagging.

2. Using a string box [hipchain], record the length of each side of the polygon.

3. At each polygon corner, record the angle between the sides.

4. Estimate the vegetation cover by height class within the patch.

PLANTATION SURVIVAL ASSESSMENT

Survey techniques for evaluating the survival of planted stock on forestlands are well established (Stein 1992). The methods recommended here are appropriate for evaluating project areas that are polygons with a relatively uniform distribution of single stem seedlings. They will provide information on survival and vigor. These methods are not appropriate for projects where seedlings are planted randomly or in clumps. Nor are these methods appropriate for evaluating survival of herbaceous plantings, willow baffles, willow mattresses, or similar projects. Those are best evaluated with line intercept methods.

Field Sampling Method

- Determine the extent of the project area(s). The project area(s) should be one or more distinct polygons mapped out on an aerial photograph or site map. Using GIS, a planimeter, or a dot grid determine the area(s) of the planted polygon(s) in acres.

- Calculate sample size. Once the area has been determined for each polygon, the required number of 1/100 acre sample plots to survey is determined. The following guidelines are suggested: if the polygon is less than 30 acres, 2 percent of the area should be sampled. If the area of the polygon is greater than 30 acres 1 percent of the area should be sampled. In any event, a minimum of 5 sample plots should be surveyed. If the polygon is less than 0.25 acres, the entire area should be searched for seedlings.

  Example: The project area is a 10 acre polygon. Two percent of ten acres is two tenths of an acre (10 acres*0.02 = 0.2 acres). Therefore, twenty 1/100 acre plots will be required to survey ten planted acres.

- Determine locations of sample plots within the project area polygon(s). The plots need to be equally distributed throughout the project area. First, divide the number of acres in the project area by the number of plots that will be surveyed (calculated in step 2). This will give you the portion of an acre that each plot represents. Multiply this number times the square feet in one acre: 43,560. Then calculate the square root of the result to provide a value in lineal feet. This will be the distance between lines and between plots on the line.

  Example:

  10 acres to be sampled=20 plots to sample
  10 acres/20 plots = 0.5 acres per plot
  0.5 acres x 43,560 square feet = 21,780
  square root of 21,780 = 147.5 feet between plots and lines

- After the distance between plots and lines has been determined, these lines and plot locations are drawn onto the appropriately scaled map. All lines must be parallel to each other and the first line should be inset from the polygon boundary by one half the calculated distance between plots and lines (147.5/2 = 73.8 feet). After drawing the grid on the map, determine the distance and bearing to the first plot from a recognizable reference point (i.e. bridge, tributary junction, large snag, etc.)

- Locate plots in the project area. The first step is to locate the reference point used on the map or air-photo. After this has been located, navigate to the first plot location using the bearing and distance calculated from the map or air-photo. After recording data for the first plot, navigate to all successive plots with a compass set to the bearing of the lines drawn on the map or air-photo. All distances between plots and lines must be slope corrected.

- Collecting data on the plot. After locating the plot center, measure out a distance of 11.4 feet due north. Search the plot in a clockwise direction for seedlings until arriving back at the due north starting point of your search. For every seedling within 11.4 feet of plot center record *species* and *vigor class* (live, dead, or dying). Record any observations regarding obvious causes of death (browsing, desiccation, competition, etc.) or other relevant observations in the comments section for the plot, not for each seedling.

- These data may be used to calculate: average number of trees per acre by species across all plots, percent of live versus dead seedlings observed and percent of plots with at least one live seedling.

EVALUATION OF FOREST COMPOSITION

This method is appropriate for project types intending to change the composition of riparian forests, often to increase the relative abundance of conifers in hardwood-dominated stands. Techniques for evaluating species composition in forest lands are standardized (Bell and Dillworth 1998). The methods recommended here are appropriate for evaluating project areas with tree species providing the majority of canopy cover. They will provide information on the average number of trees per acre by crown class and species and the average diameter of trees by species and crown class within the project area. It is assumed that most projects intending compositional changes will occur within 100-150 feet of the bankfull channel.

Field Sampling Method

- Determine the extent of the project area(s). The project area(s) should be one or more distinct polygons mapped out on an aerial photograph or site map. Using GIS, a planimeter, or a dot grid determine the area(s) of the planted polygon(s) in acres.

- Calculate sample size. Once the area has been determined for each polygon, the required number of 1/10 acre sample plots to survey in the polygon is calculated. A sample of two percent of the project area should be sufficient if stands are relatively uniform, more samples may be required for extremely heterogeneous stands. A minimum of 5 sample plots should be surveyed.

  Example: The project area is a 150 foot wide riparian corridor that is 1 mile long and occurs on the both the left and right banks. So (150 feet x 5,280 feet = 792,000 square feet) which is equivalent to 18 acres (792,000 square feet/ 43,560 square feet in an acre = 18 acres). And two percent of 18 acres is 0.36 acres, so there should be 4 1/10 acre plots surveyed in each riparian corridor (left and right banks) for a total of 8 plots in the project area.

- Determine locations of sample plots within the project area polygon(s). The plots need to be equally distributed throughout the project area. Assuming that a long narrow riparian corridor is treated, only one 1/10 acre plot will fit within the width of the corridor (1/10 acre plots are 75 feet in diameter and most projects will probably occur within 100-150 feet of the channel). Thus plots will be placed down the centerline of the riparian corridor at equal distances throughout the treated area.

  Example: Continuing with the example cited above, 4 plots would be placed in each riparian corridor (left and right banks) at equal distances along the 1 mile long treated reach. So, 5,280 feet /4 plots = 1,320 feet spacing between sample plots. And the plot centers would be located at 75 feet from the bankfull elevation of the channel in the 150 foot wide treated riparian area. This sample size may not be sufficient if forest conditions are highly variable, this determination must be made on site by a qualified professional.

- Locate plots in the project area. Following the spacing guidelines calculated above, proceed through the project area and locate the first plot, measure it and proceed to the next plot. The first plot should be located 100 feet from the end of the treated area.

- Collecting data on the plot. Measure out a distance of 37.2 feet due north from the plot center (plot radii must be slope corrected using a correction table). Measure all trees on the plot greater than 4.5 feet tall, proceed in a clockwise direction until arriving back at the due north starting point of your search. For every tree on the plot record *species*, *diameter at breast height (dbh) and crown class.* Record *height* and *live crown ratio* for two trees on each plot if volume calculations are desired for project objectives, distribute measurements across all species and crown classes throughout the survey (multiple plots).

- Collect data on tree regeneration in a $1/100^{th}$ acre plot nested within each $1/10^{th}$ acre plot. Measure out a distance of 11.4 feet due north from plot center. Count all tree seedlings that are less than 4.5 feet tall. Proceed in a clockwise direction until arriving back at the due north starting point of your search. For every tree seedling on the plot record *species.*

- These data will provide information on: average number of trees per acre by species and crown class, average diameter of trees by species and crown class, regeneration per acre by species. These in turn, may be used to estimate approximate volumes using height, LCR and diameter data for each species and crown class, and the future species composition of the stand.

ESTIMATING CANOPY AND SPECIES DIVERSITY (OPTIONAL)

In occasional instances where data on development of species or canopy height diversity are desired, a fixed area plot or releve technique is recommended. These would rarely be objectives for fish habitat restoration projects. Data collected in plots would include cover by species by height class and dominant species by height class. In addition, all plant species falling within plots are identified and tallied. The data provides information on foliar height diversity and species diversity. Generally, plots should be of a diameter that is appropriate to the vegetation type and located at the mid-point of cross channel transects on either side of the stream (i.e., at 25 feet along the transect) to estimate diversity in the vicinity of the stream. For larger project sites, plots may be needed at other locations as well. Again, the number of plots and their distribution should be determined through a specific study design and cannot be specified a'priori.

AERIAL PHOTOGRAPHY (OPTIONAL)

Aerial photographs can be extremely valuable for monitoring vegetative response to restoration. They are useful in identifying the boundaries of both herbaceous and woody vegetation communities, for stratifying sites, and for documenting study locations. They can also help identify features and disturbances that are not apparent from the ground. Species, size class and density can be determined in many cases from aerial photographs. Their value and use, though, should be determined by project size, objectives, and required scale. They are most effective at the small watershed level, and in open areas where the understory and overstory canopies are discernable from the air. Therefore, their use should be decided on a case-by-case basis.

IDENTIFYING THE CORRECT PROTOCOL TO USE WITH A RIPARIAN PROJECT

Study objectives will drive the selection of monitoring methods. For example, if a study is intended to determine the effectiveness of different restoration treatments in producing shade on the channel, it may be adequate to just collect densiometer data, without the need to collect vegetation transect data. For studies with more complex objectives, several of the methods presented above may be needed. Also, different methods may be needed at different stages of a study. Table 1 below provides guidance on the choice of protocols.

Table-1, Protocols recommended by project/study objectives

Project/Study Objectives	Recommended Protocols
Increase channel shading	Mid-channel densiometer measurements, cross channel transects
Increase bank cover	Longitudinal transects
Increase riparian corridor continuity	Longitudinal transects and/or aerial photographs
Diversify vegetation composition	Cross channel and longitudinal transects and possibly canopy and species diversity plots
Increase riparian corridor width	Cross channel transects
Reduce vegetation encroachment to channel	Cross channel transects
Reduce exotics	Longitudinal and cross channel transects Treatment area traverses if vegetation cannot be penetrated
Increase riparian canopy and species diversity	Canopy and species diversity plots
Alter composition of riparian tree components	Forest composition plots

Increase recruitment of LWD	Forest composition plots

Some monitoring of riparian vegetation may be done solely to gauge survival rates of vegetation planting. These methods vary according to vegetation life form, tree, shrub and herbaceous. In addition they vary on the ability of monitors to penetrate the vegetation for monitoring purposes. Protocols recommended for vegetation survival projects/studies are listed in Table 2.

Table-2, Planting survival protocols recommended by planting life form

Planting Life Form	Recommended Protocols
Tree seedling survival rates	Plantation survival assessment
Herbaceous planting survival rates	Point intercept herbaceous assessments
Shrub planting survival rates	Linear transects OR treatment area traverses depending on vegetation characteristics

REFERENCES

Bell, J.F. and J.R. Dillworth. 1998. Log Scaling and Timber Cruising. Cascade Printing Company. Corvallis, Oregon

Elmore, W and R.L. Beschta. Riparian areas: Perceptions in management. Rangelands: Vol 9, No. 6, December, 1987. Pg 260-265.

Stein, W.I. 1992. Regeneration surveys and evaluation. *In* Reforestation practices in southwest Oregon and northern California. *Edited by* Stephen D. Hobbs, Steven D. Tesch, Peyton W. Owston, Ronald E. Stewart, John Tappeiner II, Gail E. Wells. Forest Research Laboratory, Oregon State University. Corvallis, Oregon.

INSTRUCTIONS FOR COMPLETING THE LONGITUDINAL RIPARIAN SURVEY DATA FORM

General Information- section 1

1) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
2) **Date-** Enter the day's date: mm/dd/yy
3) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
4) **Crew-** Enter the names of the survey crew.
5) **Stream Name-** Enter in the name of the stream. If unnamed, use named stream to which it is tributary.
6) **Start Point-** Describe the location at which the survey began, using permanent reference points if possible.
7) **Survey Direction**- Circle the direction of travel taken by surveyors during data collection.
8) **Streambank**- Circle the stream bank being surveyed.

Line Intercept Vegetation Data – section 2

9) **Start Distance-** Enter the distance displayed on the stringbox at the location where the vegetation begins at a particular cover type and density.
10) **End Distance-** Enter the distance displayed by the running total on the stringbox at the location where vegetation of a particular cover type and density changes to a different type and/or density.
11) **Cover Type-** Enter the type of vegetation found at that section of the line intercept to the species level if possible.
12) **% Cover-** Enter the percent cover for the cover type found on the section of the line intercept. Percent cover should range from 5 to 100 percent.
13) **Comments-** Enter any comments that explain the cover type or vegetation found on the line intercept. Identify the location as measured on the stringbox at which associated cross-channel transects are done.

14) **<3 foot height class-** Fill out the line intercept data in this column for all vegetation found between the ground level and three feet above the ground.
15) **3-15 foot height class-** Fill out the line intercept data in this column for all vegetation found between the ground level and three feet above the ground.
16) **>15 foot height class-** Fill out the line intercept data in this column for all vegetation found between the ground level and three feet above the ground.

LONGITUDINAL RIPARIAN SURVEY DATA FORM
(facing page)

Longitudinal Riparian Survey at Bankfull

Project ID:________________

Date:_______ Start Time_________ Crew:____________ Stream:__________________________

Start Point___________________ Survey direction (Upstream or Downstream)

Streambank: **(Left or Right)**

0-3 ft height class				**3-15 ft. height class**				**>15 ft. height class**				
Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover	Comments

*Record location of transects in comments section

INSTRUCTIONS FOR COMPLETING THE CROSS CHANNEL TRANSECT DATA FORM

General Information- section 1

1) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
2) **Date-** Enter the day's date: mm/dd/yy
3) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
4) **Crew-** Enter the names of the survey crew.
5) **Stream Name-** Enter in the name of the stream. If unnamed, use named stream to which it is tributary.
6) **Longitudinal Station-** Enter the distance from the start of the longitudinal survey at which the cross channel transect is done.
7) **Canopy Cover Mid Channel**- Enter the reading on a densiometer from mid channel. Take four different readings.

Transect Vegetation Data – section 2

8) **Recruits: Conifer/Hardwood-** Enter the number of tree seedlings found along the transect.
9) **Bank Material-** Describe the composition of the bank at the beginning of the transect as silt, clay, sand, gravel, cobble, boulder, or bedrock
10) **Eroding**- Enter Y if the channel bank at the beginning of the transect appears to be actively eroding. Enter N if it does not.
11) **Start Distance-** Enter the distance displayed on the stringbox at the location where the vegetation begins at a particular cover type and density.
12) **End Distance-** Enter the distance displayed by the running total on the stringbox at the location where vegetation of a particular cover type and density changes to a different type and/or density.
13) **Cover Type-** Enter the type of vegetation found at that section of the line intercept to the species level if possible.
14) **% Cover-** Enter the percent cover for the cover type found on the section of the line intercept. Percent cover should range from 5 to 100 percent.
15) **Comments-** Enter any comments that explain the cover type or vegetation found on the line intercept. Identify the location as measured on the stringbox at which associated cross-channel transects are done.

16) **<3 foot height class-** Fill out the transect data in this column for all vegetation found between the ground level and three feet above the ground.
17) **3-15 foot height class-** Fill out the transect data in this column for all vegetation found between the ground level and three feet above the ground.
18) **>15 foot height class-** Fill out the transect data in this column for all vegetation found between the ground level and three feet above the ground.

19) **Left Bank-** Enter vegetation transect data for the channel's left bank in this section.
20) **Right Bank-** Enter vegetation transect data for the channel's right bank in this section.

21) **Cross Channel-** Enter vegetation data for the transect across the channel in this section (this section would be completed only when vegetation clearing to improve spawning gravels is done.)

CROSS CHANNEL TRANSECT DATA FORM
(facing page)

Cross Channel Transect

Project ID: __________
Date:_______ Start Time_________ Crew:____________ Stream:__________________________
Long station:______ Canopy Cover Mid Channel (%)______ ______ _______ ______

LEFT BANK

Recruits (#) Conifer_____ Hardwood________ Bank Material__________ Eroding (Y/N)____________

<3 feet height class				3-15 feet height class				> 15 feet height class				Comments	
Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover		

CHANNEL

Recruits (#) Conifer_____ Hardwood________ Bank Material__________ Eroding (Y/N)____________

<3 feet height class				3-15 feet height class				> 15 feet height class				Comments	
Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover		

RIGHT BANK

Recruits (#) Conifer_____ Hardwood________ Bank Material__________ Eroding (Y/N)____________

<3 feet height class				3-15 feet height class				> 15 feet height class				Comments	
Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover	Start Dist	End Dist	Cover Type	% Cover		

INSTRUCTIONS FOR COMPLETING THE TREATMENT AREA TRAVERSE DATA FORM

General Information- section 1

1) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
2) **Date-** Enter the day's date: mm/dd/yy
3) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
4) **Crew-** Enter the names of the survey crew.
5) **Start Point Description-** Describe the point at which the treatment area traverse is started. This should be described in reference to locations along longitudinal transect or permanent reference points if any.

Treatment Polygon Measurements – section 2

6) **Polygon Side #-** Enter the number of the side of the polygon measured on this line.
7) **Start Distance-** Enter the start distance of this polygon side on a stringbox or tape.
8) **End Distance-** Enter the reading on the stringbox or tape after traversing to the end of the polygon side
9) **Angle From Start**- Enter the angle as read on a compass from the end point back to the start point at the beginning of the polygon side.

Treatment Polygon Drawing – section 3

Draw a sketch of the treatment polygon labeling the polygon sides measured.

Cover Estimate within Polygon - section 4

10) **Cover Type-** Enter the type of vegetation found within the treatment area to the species level if possible.
11) **% Cover-** Enter the percent cover for the cover type found within the treatment area. Percent cover should range from 5 to 100 percent.

TREATMENT AREA TRAVERSE DATA FORM

(facing page)

Treatment Area Traverse

Project ID: _________

Date:_____________ Start Time__________ Crew:______________

Start Point Description:____

Treatment polygon measurements

Polygon Side #	Start Distance	End Distance	Angle From Start

Treatment polygon drawing

Cover estimate within polygon

<3 feet		**3-15 feet**		**> 15 feet**	
Cover Type	% Cover	Cover Type	% Cover	Cover Type	% Cover

INSTRUCTIONS FOR COMPLETING THE SEEDLING SURVEY DATA FORM

General Information- section 1

1) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
2) **Date-** Enter the day's date: mm/dd/yy
3) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
4) **Crew-** Enter the names of the survey crew.
5) **Stream Name-** Enter in the name of the stream. If unnamed, use named stream to which it is tributary.
6) **Polygon #-** Enter the location number of the treatment polygon.
7) **Start Point Description-** Describe the point from which the seedling survey began. This should be described in reference to permanent reference points if any.

Seedling Survey Data – section 2

8) **Plot #-** Enter the number of the plot where the data is collected.
9) **Species-** Enter the species of the seedlings found on the plot.
10) **Vigor-** Enter all possible vigor classes for seedlings of each species, live, poor health and dead.
11) **Tally**- For each species and vigor class, enter the number of seedlings found on that plot as a dot tally.
12) **Comments**- Enter any pertinent comments on the seedlings found in that plot.

SEEDLING SURVEY DATA FORM

(facing page)

Seedling Survey

Date:____________ Start Time__________ Crew:_____________ Stream:____________________
Project ID:_____________ Project Name:_______________ Polygon #:_________
Start Point Description:____

Plot #	Species	Vigor	Tally	Comments

Vigor Class = Live, Dead, Poor health

INSTRUCTIONS FOR COMPLETING THE FOREST COMPOSITION DATA FORM

General Information- section 1

1) **Project ID-** Enter in the project identification number assigned to this contract by the Department of Fish and Game.
2) **Date-** Enter the day's date: mm/dd/yy
3) **Start Time-** At the beginning of each page, enter the time in military time notation (24 hour clock). This should be the time that water temperature is recorded.
4) **Crew-** Enter the names of the survey crew.
5) **Stream Name-** Enter in the name of the stream. If unnamed, use named stream to which it is tributary.
6) **Location**- Enter identifying information on the specific plot location, typically distance and bearing from previous plot or fixed reference point.
7) **Start Point Description-** Describe the point at which the forest plot transect is started. This should be described in reference to permanent reference points if any.

1/10th Acre Plot Data – section 2

8) **Plot #-** Enter the number of the plot where the data is collected.
9) **Species-** Enter the species of each tree found in the plot
10) **DBH-** Enter the diameter at breast height to the nearest inch of each tree found in the plot.
11) **Crown Class-** Enter all the crown class of each tree in the plot as seedling, sapling, intermediate, co-dominant, or dominant
12) **LCR**- Enter the live crown ratio of each tree as the percentage of the height of the tree covered in live crown (optional)
13) **Height**- Enter height of the tree as determined by a clinometer to the nearest height class (optional).

FOREST COMPOSITION DATA FORM

(facing page)

Forest Composition Plots

Date:____________ Start Time__________ Crew:_________ Stream:_______________
Project ID:_____________ Project Name:____________ Location:______________
Start Point Description:____

1/10th acre plot #: ________

Species	DBH	Crown Class	LCR	Height

1/100th acre plot

Species	Seedlings

Crown Class = Seedling, Sapling, Intermediate, Co-Dominant, Dominant
LCR = live crown ratio, percentage of height occupied by foliage

E-4: PROTOCOLS FOR MONITORING THE EFFECTIVENESS OF UPLAND EROSION CONTROL RESTORATION PROJECTS

DRAFT-SUBJECT TO REVIEW AND FIELD TESTING

March 24, 2003

William Weaver, Richard Harris and Susan Kocher

CAUTION: These protocols have not received scientific peer review nor have they been adopted for use by the Department of Fish and Game. They will be subjected to review and field testing over the next year. For further information, contact Barry Collins, California Department of Fish and Game, (707) 725-1068 or bcollins@dfg.ca.gov

TABLE OF CONTENTS

INTRODUCTION

The main goals of conducting upland restoration are to reduce or minimize the delivery of sediment from managed areas in a watershed and, to the extent feasible, to restore natural hydrologic functioning to the drainage network. The main sediment-related objectives of upland restoration are to reduce erosion and sediment delivery (including fine sediment) from managed areas and to reduce the risk and magnitude of potential sediment input.

Monitoring activities centered on these objectives can be designed to evaluate the effectiveness of restoration practices on a process-by-process basis (e.g. surface erosion control), on a site-by-site basis (e.g., a single stream crossing) or on a project-by-project basis (e.g., and entire road upgrading project). Many techniques to measure erosion and sediment delivery have been developed in practical tests and scientific studies over the past several decades. These procedures range from observational, semi-quantitative techniques to fully quantitative practices that measure processes and rates.

Restoration of upland watershed areas may also be aimed at restoring the natural hydrologic functioning of the treatment area. This can include restoring the natural flow paths for surface runoff, increasing infiltration and interception of precipitation, and restoring a more natural rate and volume of runoff on upland hillslopes and in low order stream channels. Monitoring the nature and magnitude of hydrologic processes can be done using a number of the well tested and frequently applied techniques.

Monitoring Erosion and Sediment Delivery

Restoration projects aimed at erosion and sediment control are focused on arresting four processes, surface erosion, gully erosion, channel erosion, and mass wasting (landsliding). Each of these processes can be evaluated independently, in relation to a specific erosion control practice (such as mulching). Similarly, they can be evaluated collectively to determine the effectiveness of a general restoration practice in controlling erosion and sediment delivery (e.g., stream crossing decommissioning). In the latter case, the practice of excavating and treating decommissioned stream crossings can be evaluated in respect to each of these four processes.

The most common sediment control practices employed in road upgrading or road decommissioning projects focus on: 1) reducing the amount of runoff that is delivered to stream channels, 2) preventing road-related mass wasting that would otherwise deliver sediment to streams, 3) preventing or minimizing sediment delivery from erosion processes such as surface erosion, rilling and gullying, 4) reducing the threat of episodic erosion, and 5) reducing the volume of erosion that is likely to be delivered to streams when an episodic failure occurs.

Erosion and Sediment Delivery

Monitoring the effectiveness of road upgrading and decommissioning projects is as simple as monitoring surface erosion, gully erosion, channel erosion and mass wasting, as a combined suite of processes, at specific work sites. For example, at decommissioned stream crossings, excavated side slopes can be monitored for surface erosion, gullying and mass wasting processes. The exhumed stream channel can be monitored for bank erosion and channel down cutting. The combined results yield a determination on the effectiveness of stream crossing decommissioning at that site.

In practice, the level of detail needed to determine restoration effectiveness will vary by project. Methods can be considered to fit into four different levels, ranging from qualitative observations (Level 1) to fully quantitative (Level 4). Qualitative methods (Level 1) include walking surveys and ocular estimates of sediment production and delivery. Semi-qualitative methods (Level 2) include monumented photopoints, mapping of processes and flow paths, semi-quantitative estimates or measurements of erosion, mass wasting and channel enlargement. Simple quantitative techniques (Level 3) include tag-line cross sections of stream channels and direct measurements of sediment production and delivery from disturbed areas. Fully quantitative measurements (Level 4) are typically too expensive to be useful for monitoring and so are beyond the scope of this document.

This suite of monitoring techniques is described below. Others not described here may also be used for monitoring upland restoration projects with proper testing and validation.

Fine Sediment Delivery

Each of the four erosion processes results in the generation of fine and/or coarse sediment. Only a portion of this sediment is delivered to the stream channel network, and it is this sediment that should be the target of upland restoration projects. Coarse sediment production and delivery is typically monitored by measuring voids left in treated areas by erosion processes or mass wasting that have moved sediment from hillslopes and delivered it to stream.

Surface erosion moves and delivers mostly fine sediment (clay, silt, fine sand). Eroded sediment does not move long distances unless transported by rills, gullies or other concentrated flow channels (e.g., road ditches). Bare soil areas deliver chronic fine sediment to streams without leaving visually obvious voids. Sediment delivery requires direct connection of bare areas with streams or flow channels (rills, gullies, ditches, etc.). Volumes of chronic sediment input are often comparatively small during each delivery event. However, cumulative watershed volumes and site volumes can be very large when large portions of the watershed are habitually disturbed.

The most effective measures for controlling fine sediment delivery include: 1) minimizing bare soil areas, 2) covering (mulch or revegetation) bare soil areas, 3) dispersing runoff, 4) increasing infiltration, and 5) disconnecting flow paths between bare soil areas and receiving waters so that fine sediment is not transported and delivered to streams. Most techniques used to reach these objectives are one-time measures. That is, once they are achieved through effective project implementation and are adequately documented, they are not likely to naturally degrade or change. Therefore, these techniques are typically evaluated only once at the conclusion of the restoration project, perhaps in full winter conditions. In high visibility situations, properly designed turbidity and/or suspended sediment monitoring can be employed through time to document the integrated effectiveness of the five restoration measures in controlling fine sediment delivery.

Reducing the Risk and Magnitude of Potential Sediment Input

Roads are one of the most frequently identified locations for preventable or correctable erosion and sediment delivery problems in upland areas. Road upgrading techniques are available to make stable, well located roads as "storm-proofed" and resilient to large storms and flood flows as possible by minimizing the risk of episodic erosion and sediment yield. These include increasing the capacity (size) of drainage structures used in stream crossings. The magnitude of potential stream crossing failures can also be reduced by eliminating diversion potential at the crossing site and by reducing the volume of the crossing fill when it is upgraded. Road decommissioning projects, including stream-crossing excavation, when properly designed and implemented, eliminate the risk of classic crossing failures (washouts) and the volume of sediment that could have been eroded and delivered to the stream channel.

The effectiveness of risk reduction measures, and of measures which reduce the potential magnitude of sediment delivery event, is often not easily monitored over short time periods. This is because the hydrologic events and erosion processes that are needed to stress the projects are episodic and event-related. Thus, it may be years before the effectiveness of a restoration project is fully “tested”. For this reason, effectiveness monitoring is typically accomplished through long term monitoring not tied to the actual restoration project. Instead, implementation monitoring is employed to assure that the project was implemented correctly, and maintenance monitoring is used to track the types and frequencies of problems that develop at road upgrade sites over long time periods. This type of monitoring requires sound record keeping by the land manager, landowner or maintenance staff.

Hydrologic Restoration

The hydrologic effects of watershed development and construction practices have been well documented. Roads, developments, and other managed areas often disturb the natural hydrologic regime by increasing runoff volumes, decreasing interception and infiltration, and altering peak and base flow characteristics of surface flow. Compaction increases runoff volumes and rates, grading and cutting into hillslopes brings soil water to the surface and increases runoff, roads collect and divert runoff to small streams that now carry more flow volume and “flashier” peak flows than they did in an undisturbed state.

One of the goals of upslope restoration is to reduce the effect of land management on rainfall-runoff relationships in the watershed. This can be accomplished through reducing compaction and increasing infiltration of precipitation. Increasing infiltration reduces the peak or “flashiness” of runoff that occurs in response to rainfall events. With less direct surface runoff, rill and gully erosion will be reduced. Finally, reducing soil compaction increases the rate of revegetation, and allows vegetation to intercept and reduce the amount surface runoff.

Many upland restoration projects, such as road decommissioning, involve practices that decompact the soil surface, by tilling or mechanical disaggregation, or by excavating and replacing compacted material. Roads are often one of the main sources of compacted soils in a watershed, and decompacting old roads is one way to reduce the volume of runoff that occurs during storm events.

Infiltration can be monitored directly or indirectly by fairly simple methods. One method monitors runoff from managed or formerly compacted sites. Another monitors soil infiltration rates in storms or by using simple infiltration tests that allow a more controlled analysis. Other sophisticated monitoring methods and analytical procedures are available for documenting rainfall, infiltration, runoff, hydrologic response and sediment transport associated with restoration sites, streams and upland watershed areas. Some of these methods are described below.

Restoration Objectives and Project Types

The primary objectives for upland restoration projects include:

- Preventing or reducing sediment delivery (trapping sediment before it is delivered to streams)
- Reducing risk of episodic erosion and sediment delivery
- Reducing chronic erosion and delivery of fine sediments from disturbed areas
- Reestablishing natural drainage patterns
- Restoring natural runoff and infiltration rates

The following types of projects account for most of the DFG-funded upland restoration projects:

Slope Stabilization or Erosion Control

- Projects conducted using engineering or bioengineering practices to reduce erosion/stream sedimentation and increase slope stability
- Projects conducted to reduce upland fuels through understory thinning or brush removal techniques in order to reduce the potential for sedimentation as a result of catastrophic fire

Gully Repair

- Projects using new channel construction or pond and plug techniques to decrease erosion and stream sedimentation by changing gully grade and cross-section
- Projects using bioengineering techniques such as brush/rock mattresses or vegetation planting to reduce the rate of head-cutting and incision
- Projects using armoring or rip-rap to reduce the rate of head-cutting and incision

Road upgrading and decommissioning

- Projects to improve road surfacing to decrease erosion and stream sedimentation
- Projects to upgrade roads including road drainage improvements (disconnection and dispersion using outsloping, critical dips, and rolling dips), stream crossing upgrades (culvert upsizing, conversions to armored fills, arches and bridges), treatment of road-related landslides, relocation
- Projects to permanently or temporarily decommission roads including stream crossing excavation, landslide treatment, road drainage improvement, decompaction and revegetation, restoration of rock pits, spoil disposal sites and other developed areas.

Effectiveness Criteria

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

The parameters that can be used to monitor the effectiveness of upland restoration projects include 1) sediment delivery, 2) infiltration rate, 3) runoff or flow and 4) risk of road and stream crossing failure and associated episodic sediment delivery. Erosion rate is not a viable parameter, just as erosion control per se, is not an objective of fisheries-related restoration. Rather, the specific objective of such projects is the control and prevention of anthropogenic sources of sediment delivery. The effectiveness criteria for each parameter are listed below.

Parameter: Sediment delivery

Effectiveness Criteria:
Reduced surface erosion on connected surfaces
Increased vegetative cover on connected surfaces
Reduced rates of rill erosion on connected surfaces
Reduced delivery from gullying
Reduced channel erosion
Reduced delivery from mass wasting
Reduced hydrologic connectivity between roads and streams
Increased dispersion of surface runoff
Increased infiltration
Reduced turbidity and sediment transport in natural stream channels

Parameter: Episodic road and stream crossing failure and mass wasting

Effectiveness Criteria:

Stream crossings, including culverts, are designed for the 100-year flow
Culverts have a low plugging potential
Stream crossings have no diversion potential
Slopes (fillslopes and excavated sideslopes) leading to streams are stable
Excavated stream crossings have stable longitudinal profiles
Excavated stream crossings have stable side slope profiles
Potential lands sites have a lowered risk of failure and sediment delivery

Parameter: Infiltration and flow

Effectiveness Criteria:
Reduced surface runoff
Increased dispersion of surface runoff
Increased infiltration
Increased vegetative cover and interception
Reduced connectivity between roads and streams
Reduced rates of runoff (peak flows, and time to peak) to stream channels

The protocols listed and briefly described below are recommended for collecting data on these parameters.

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

PROTOCOL DESCRIPTIONS

Assumptions

- Monitoring will be performed by different individuals through time, even at the same restoration and monitoring site. The measures and techniques used for monitoring upland sites must be clear, unambiguous, straightforward and yet robust to observer bias.

- Agency staff, consultants or trained technicians will conduct the quantitative monitoring.

- Most active monitoring will be conducted during the winter runoff period, from November to March. Certain parameters (such as road runoff) are runoff-dependent and must be collected during moderate- and high-intensity precipitation events.

- Monitoring and evaluation of reduced risk for road upgrade projects must be performed in combination with maintenance monitoring and record keeping. Any maintenance activities that document erosion events or result in repair or modification to the original "restoration" work must be documented.

- Monitoring methods must be efficient, repeatable and relatively low cost.

- Methods must be capable of identifying changes in parameters and measures of effectiveness criteria of approximately 20 percent or better.

Timing

Pre-treatment site data must be collected for each monitoring site prior to restoration work. If water quality is to be part of the monitoring project, pre-treatment runoff and sediment data should be collected a minimum of one runoff season prior to restoration treatment; preferably longer. Implementation monitoring data should be collected at the completion of the restoration work or prior to the occurrence of winter rains, whichever occurs first.

Effectiveness monitoring protocols can be divided into two types: 1) techniques which document processes as they occur (such as runoff, sediment transport and turbidity measurements) and 2) physical measurements which may be taken at restoration sites after one or more rainfall and runoff events (or seasons) have concluded (such as rill and gully erosion measurements).

Process measurements at road treatment sites (e.g., turbidity samples or discharge measurements) must be taken during storm and runoff events, when water and sediment is being generated and transported within the restoration project site. Feature measurements are typically taken following significant runoff events, or following one or more runoff seasons. During the first two runoff seasons, both process and feature measurements will likely be taken several times. Research elsewhere has shown the first two runoff seasons exhibit the greatest amount of change in newly restored upland sites. Subsequent sampling will be dependent on the size of runoff events that occur, and the number of similar events that have already been sampled.

Timing is also critical in relation to documentation and monitoring associated with maintenance work that is performed at restoration sites. Maintenance of restoration projects during the winter period can mask the true performance of restoration practices that were employed at a site, and if records of activities are not kept, the effectiveness of the project elements cannot be accurately evaluated. It is recommended that monitoring projects include a maintenance documentation component whereby those conducting repairs to projects provide a simple documentation of the problems and a description of the repairs that were performed.

PROTOCOL DESCRIPTIONS

There are many tested protocols available for monitoring erosion and sedimentation processes that vary in complexity, cost and rigor. The specific protocols presented below are suitable for monitoring: 1) surface erosion, 2) channel and gully erosion, 3) mass wasting and 4) runoff and infiltration. The protocols should be customized for the particular application based on study objectives, required accuracy and site-specific conditions.

Trained and experienced personnel will be responsible for the selection and application of the appropriate monitoring techniques within the context of a study design. Consequently, some general and specific knowledge of the protocols by users is assumed. The protocols are more fully described in a variety of publications and case study reports, and these can be investigated in the literature, researched through internet and library searches or developed in consultation with trained field geologists, hydrologists, and erosion control specialists.

1. Surface Erosion

Surface erosion is caused by raindrop impact and by relatively unchanneled water flowing over bare soil during and after rainstorms. The recommended monitoring approach documents and tracks erosion rates, the aerial extent of bare soil areas subject to surface erosion, and the delivery of eroded sediment to nearby stream channels.

1A. Photography and photo points

Photography can document successful revegetation of bare soil areas or conversely, their persistence. Percent vegetation cover is a surrogate measure for surface erosion rate. Scaled photos can be used to show the formation of soil pedestals and the development of a lag or natural armor indicative of surface erosion. Vertical photos of various scales can show features ranging from surface texture changes to vegetation cover and canopy increases. Photography is occasionally used for quantitative surface erosion studies (e.g., defining changes in bare ground) but is more often used for qualitative monitoring. Road upgrading work is usually not as photogenic as road decommissioning.

Field Sampling Method

1. Establish permanent photopoints using techniques described in Appendix C.
2. Photograph comprehensive views of restoration sites both before and after treatment. Recommended views include:

   a. Decommissioned (ripped) road surfaces,
   b. Reshaped road surfaces
   c. Upgraded stream crossings (especially new fillslopes),
   d. Excavated sediment stored upstream from culvert inlets
   e. Excavated stream crossings
   f. Newly established spoil disposal sites
   g. Sites of excavated mass wasting.
3. Take photos from an oblique vantage point to the project work, with reference points (stumps, trees, fences, etc.) clearly visible in the scene. Slightly elevated photopoints, relative to the subject, are preferable.
4. Take vertical photos from low-level platforms, such as a weather balloon 100 feet above the ground. These can be used to provide a more spatially correct "map view" of a restoration site, and to track changes in vegetative cover and bare areas through time.
5. Establish monuments (such as rebar) on the ground surface for close-up views of surface erosion through time. Take photos perpendicular to the ground, including at least one, preferably two, monuments and a graduated scale of known length. This allows subsequent photos to be reframed and for tracking the same scene through time.
6. Take similar close up photos of representative bare areas in different micro-settings (e.g., cutbanks, fillslopes, road surfaces, ditches, etc.) to identify visual differences in surface erosion through time.

If quantitative measurements are required, enlarged photos with scales included can be digitized to yield the numerical increase in surface armor that develops in each setting through time. Similarly, photos of mulched areas can be taken to document the gradual decomposition of mulch, re-exposure of bare areas and invasion of vegetation over time.

1B. Mapping exposed contributing bare soil areas

Hydrologically connected bare soil areas may deliver runoff and sediment to stream channels and other biologically sensitive habitat (e.g., wetlands) and are therefore prime targets for restoration. Unsurfaced roadbeds, cutbanks and ditches are common types of connected bare soil area. Other bare areas might include landslide surfaces, quarry sites, stream banks, construction sites and agricultural fields.

Monitoring focuses on the area of exposed soil connected to the stream or other water body receiving protection. The size and condition (bare, not bare) of the area contributing runoff and eroded soil to stream channels can be documented and monitored through a variety of techniques, including field estimates, sketch maps, field measurements, mapping on low level aerial photos, instrument surveys and random sampling studies. The contributing area is likely to change (shrink) dramatically when the restoration work is first performed and bare areas are disconnected from the stream system, and then to change only gradually in response to revegetation, natural armoring or other processes or treatments (mulching, surfacing, etc.). A monitoring protocol should be selected that addresses the restoration objective (e.g., reducing contributing area or reducing the area of exposed soil).

Field Sampling Methods

1. Select the monitoring methods to be used based on study objectives.
2. Measure the contributing area, or measure an analog (such as road length), prior to restoration treatment.
    a. Measurements can be made using pace, tape, hip chain, or a survey instrument.
    b. Areas can be calculated by taking average spatial measurements, by mapping on aerial photos, by mapping on scaled low-level vertical photos, or from detailed instrument surveys (level, plane table, theodolite, or total station) of the small contributing subwatershed areas. They can also be estimated using random sampling or aerial grids that identify areas as being "in" or "out" of the contributing area adjacent to the restoration site. Sampling reduces the measurement requirements, but lowers the accuracy of the aerial measurement.
3. Remeasure the contributing area following restoration treatment using the same measurement technique.
4. Map and measure the area of exposed bare soil within the contributing area. Exposed non-erodible bedrock and lag deposits of stony materials are not considered subject to surface erosion. Bare soil areas can be estimated, measured, sampled, mapped or surveyed using the same techniques described for measuring contributing areas (above).
5. Remeasure the area of exposed soil after treatment using the same measurement technique.

1C. Surface lowering monitoring (pins, caps, bridges)

Surface erosion results in an overall lowering of the surface of the bare soil area that is being eroded. This lowering may be relatively uniform, if erosion occurs largely by raindrop impact or sheet erosion, or it may be more localized and concentrated if rilling is the predominant surface erosion mechanism. Quantitative techniques for measuring surface erosion include fixed surface lowering plots where the surface elevation is accurately and precisely surveyed and resurveyed over time to track soil loss using pins, caps or rigidly monumented measurement frames (bridges).

These quantitative monitoring techniques for surface erosion can provide excellent spatial information on erosion processes. Erosion rates can be tracked through time at the locations where the pins and measurement devices have been installed. However, to extend the erosion rate data to larger contributing areas, it is important to first develop and implement a carefully planned random or gridded sampling scheme. Pins can be used to give localized information on erosion rates and are useful for developing generalized information about changing erosion rates, but their real utility lies in the ability to make estimates of erosion rates and sediment movement across broader areas.

Pins and similar monitoring devices provide real local data about soil erosion on bare soil areas. Combined with sediment collection and trapping methods, erosion and sediment delivery can be quantified and tracked for specific restoration areas and managed settings. A large number of pins are typically required to provide a meaningful estimate of surface lowering. Used on a large scale, such measurement techniques may be time consuming, labor intensive and, therefore, relatively costly to install and maintain. They also require considerable effort for continued data collection and analysis for an erosion process that may be relatively transitory (a few years) on all but the most erodible restoration work sites. Clearly, extensive use of erosion pins, caps and bridges should be carefully evaluated prior to the initiation of large-scale projects.

Field Sampling Methods

1. Develop a valid sampling scheme for the use of pins, caps or other surface lowering monitoring devices.
    a. The sampling plan can range from obtaining quantitative measures of surface lowering at a particular site location, to out-placing a representative number of pins on bare soil areas, to developing a statistically valid sampling plan so that erosion data can be extrapolated to other similar areas within the restoration site or to groups of restoration sites within the same watershed.
2. Install monitoring devices following treatment according to the sampling plan.
    a. Pins are typically less than 0.25" diameter and up to 12" to 18" long. Diameter and length can be modified according the depth to which pins must be inserted to obtain a solid, unmoving position. Welding rod works well in most soils with a loam texture. Hard substrate may require the use of shorter, thicker pins (such as 0.25" rebar) that can be hammered into the ground. Pins are inserted vertically into the ground to a depth below the zone of freezing and frost heave, and below the level of loose, comparatively uncompacted soil material that may exist immediately following restoration work. Measure the exposed length of pin at intervals to record surface erosion and lowering. Measure pins on the same side (or sides) each time to ensure that measurements are comparable.
    b. Caps typically consist of 3" to 4" diameter thin, round metal disks anchored onto the soil surface by a long nail (the nail is inserted through the cap prior to installing the cap on the soil surface). Lids from opened "tin" cans are inexpensive and work well when secured to the bare soil surface with a 4" to 5" nail. The nail holds the cap in place and the cap protects the underlying soil from raindrop impact and surface erosion. Both caps and pins are placed according to the designed sampling plan. Caps do not need to be removed for measurement, because soil pedestals will develop underneath.
    c. An erosion bridge consists of a rigid cross beam spanning two vertical supports that have been anchored into the slope. The vertical supports typically consist of 0.25" to 0.5" rebar pounded at least 2' into disturbed soil of the restoration site; deep enough so they will not move when slight pressure is applied to them or when freezing causes soil heaving. The rigid vertical supports (rebar end stakes) are placed 3' to 5' apart, and a rigid cross bar with a graduated scale is placed on top of the rebar end-stakes. The cross beam is graduated from one end, and measurements are taken at known intervals or points along the beam vertically down to the soil surface. Use a level bubble on the graduated vertical measurement rod or ruler to ensure precision. Alternately, depth measurements can be taken perpendicular to the ground surface (rather than vertically), but the same measurement methodology must be used each time the site is remeasured. Notch the cross beam at the beginning end so that it is placed in exactly the same location on the rebar stake each time measurements are taken. Repeat

measurements from time to time to record down-wearing and surface erosion directly beneath the bridge.

3. Take initial measurements prior to the first rainfall and runoff event. Early measurements from erosion pins and the erosion bridge may show soil compaction as well as soil erosion. Caps will more accurately show soil erosion and surface lowering in the early part of the first rainfall season. Care should be exercised with all methods to avoid disturbing the site (foot traffic) and altering erosion rates or runoff patterns reaching the sites from upslope.

1D. Sediment transport and delivery (traps, basins and troughs)

Quantitative techniques for measuring surface erosion include bounded plots (where plots are bounded with impervious barriers to isolate them from external runoff) and unbounded plot measurements. The objective is to collect all runoff and/or sediment delivered to the reservoir during runoff events. These devices monitor sediment transport or delivery rather than soil erosion. Some portion of the eroded soil reaches the trough or basin, and the remainder is stored locally on the hillslope between the plot and the basin. Collection troughs can also be mounted at the base of bare hillslopes, in ditches, at culvert or cross-drain outlets and at other locations where runoff is channeled and discharged. If poorly located, designed or installed, small sediment retention basins, traps or depressions may be overtopped and fail leading to the loss of all or most of the data collected. Proper design, construction, and regular maintenance (measurement and cleaning) are required if sediment retention basins are to remain functional.

Field Sampling Methods

1. Identify strategic locations where troughs, traps or basins can be installed to collect eroded materials as they leave a restoration site. Sediment retention devices can be installed on-site or in adjacent locations and connected to runoff channels with small diameter (e.g., 6”) flexible pipe.
2. Construct (excavate) sediment collection structures with sufficient capacity to accommodate the expected sediment discharge. Alternatively, purchase a small sheet metal stock-watering trough or other regularly shaped collection device that can be installed onsite or in a nearby adjacent downslope location. Construct each sediment collection device with a designed outflow spillway that will be stable and have sufficient capacity under the anticipated discharge.
3. Install baffling devices in the settling basin between the point of inflow and the outflow spillway such that flow velocities in the stilling “pond” are strictly minimized and sediment deposition is maximized.
4. Measure sediment collected. Settling basins can be lined with a flexible, impermeable liner that can be emptied to measure deposited sediment. Sediment can be analyzed for both volume and size fraction. Alternatively, a regular grid of deposition pins can be inserted in the bottom of unlined basins and progressive deposition can be monitored as the pins are buried. Once the basin is 50% full of sediment, it should be excavated and pins re-inserted in the bottom to begin another measurement period.
5. Take spot grab samples of turbid outflows and conduct laboratory analyses of suspended sediment concentrations.

1E. Measurement of rills

Rills (channelized erosion channels smaller than one square foot in average cross sectional area) are the most visibly conspicuous feature of rapid surface erosion, especially on long or steep, bare slopes. This type of slope is common on upland restoration sites where roads have been upgraded or decommissioned. Rills are also conduits for transporting eroded soil from surface erosion processes occurring on immediately adjacent bare soil areas. This eroded sediment is rapidly and efficiently transported in rills to downslope areas and into nearby gullies and stream channels. Simple mapping and measurement of rill dimensions (length, width and depth) provides a crude estimate of surface erosion rates, but this measurement is difficult to reproduce and accurately track through time. More repeatable measures of rill erosion can be obtained through monumented traverses and cross sections or with monumented, scaled photos of rilled slopes.

Field Sampling Methods

1. Establish permanent photo monitoring points to document the development and growth of rill systems on recently disturbed hillslopes as described in protocol 1A, above.
2. Place erosion bridges (see monitoring protocol 1C, above) roughly on contour to span one or more rills and monitor cross sectional growth through time.
3. Install erosion pins (see monitoring protocol 1C, above) within or adjacent to rills. Measurements can be taken relative to these fixed points to document rill widening and deepening through time.
4. Install contoured, monumented traverses on larger slope areas to monitor rill density and rill cross sectional dimensions. Pound 3' rebar into the hillslope to a depth of 2' in straight rows roughly on contour at approximately 5' intervals. Stretch a metal tape between the rebar monuments and at every location a rill is encountered to make measurements. This produces an accurate measure of rill density as well as a documented record of rill growth through time. A regular grid of monumented traverses can be developed on a hillslope to allow a rough estimate of total rill volume.

2. Gully and Stream Channel Erosion

Gullies are defined as newly developed "channels" that are at least one square foot in cross sectional area. Anything smaller is called a rill, and is evaluated utilizing surface erosion monitoring protocols. Some gullying is natural, but most gullying is associated with land management practices. Roads, construction sites, residential development and agricultural activities are all common land management activities that lead to concentrated runoff and increased gully erosion. Common features include gullies developed on long bare hillslopes (such as tall road cut banks where rills have merged to take on the dimensions of a gully), gullies at culvert outlets, gullies wherever runoff from a managed or disturbed area has been collected, diverted and released (such as ditched or bermed areas), gullied (washed out) stream crossings, and gullies formed by diverted streams.

Two main processes make gullies especially damaging to receiving streams and water bodies. First, gullies themselves are often large sources of sediment and they are very efficient at delivering the eroded sediment to downslope stream channels. Secondly, gullies are very efficient transporters of water and sediment that is delivered to them, and they, in turn, transport these erosion products to streams. For example, runoff and fine sediment delivered to a gully head from an insloped road and ditch system is usually transported to a downslope stream channel very quickly and efficiently. Thus, gullies are sources of eroded sediment and they are "connectors" that transport sediment from managed areas (e.g., roads) to receiving stream channels.

Treatments for gullies typically consist of either removing flow from the gully, or hardening the gully (with structures, armor or vegetation) so the flow will not continue to erode and enlarge it. The effectiveness of both these restoration treatments can be monitored over time.

The monitoring objectives of most gully control and gully restoration projects is to determine how restoration treatment has altered gully processes, including: 1) enlargement (widening, deepening and head cut advancement), 2) discharge, and 3) sediment delivery to receiving waters.

Stream channel erosion consists of both stream bank erosion and channel down cutting (bed erosion). It may be either natural or human-caused, and locally it may be the result of flow deflections and/or mass movement of the adjacent hillslope. Unless there is an obvious obstruction or bend in the channel, it is often difficult to determine the true cause of bank erosion.

Monitoring channel erosion in upland watershed areas is similar to monitoring gully erosion. The main processes are abrasion of the channel banks and slow retreat of the bank, or episodic collapse or failure of slopes that are undercut by channel erosion processes. These processes are similar to gully widening, and the same monitoring tools can be applied (gullies are, in essence, newly developing stream channels). Channel down cutting is monitored by tracking the elevation of the channel bed or thalweg, just as in gully bed monitoring. Monitoring may need to occur at the project site, as well as in reaches immediately downstream in case there are unintended channel responses to the restoration work that has been undertaken.

2A. Visual observations and photography

The simplest gully and channel monitoring consists of visual observations and photographic techniques. If structures or vegetation are employed to control gully or channel erosion, both the functioning of the structures and the occurrence of discrete erosion features can be visually and photographically monitored. Qualitative monitoring of gully erosion can document bank collapses, head cut migration and downcutting as indicators of gully enlargement. The water that flows to or within the gully is the ultimate cause of the erosion, and this too can be visually monitored through time for observable changes in discharge. Permanent photo points can be used to record changes in gully dimensions, including head cutting and bank failure, and revegetation and stabilization of the bed and banks through time.

Visual techniques for monitoring stream channel erosion include: 1) Descriptive analysis of increased bed/bank resistance or flow reduction (inferred effectiveness, such as armoring of channel bed or banks), 2) High flow observations of post-project channel behavior and project performance, and 3) Counting of sites of active bed and bank erosion. Overall project performance during high flow or stressing conditions can be monitored through the use of permanent photopoints. These same sites can then be monitored by using "targeted" limited-view photos of the bed and banks both before and after high flow events.

Finally, scaled photos can be taken showing close-up views of specific gully and channel features, such as the bed material, eroding banks and headcuts before and after high flow events. Photography is occasionally used for quantitative studies as well.

Field Sampling Methods

1. Document gully features (headcuts, nickpoints, eroding banks, channel widths and other features) descriptively and through the use of sketch maps. Locations should be permanently identified with markers and stationing so that maps and observations can be accurately relocated for future monitoring (See Appendix C). The beginning location of monitoring should be monumented (e.g., using rebar) at the top or the bottom of the gully section or channel reach being monitored and measurements taken up- or down- the feature from the monument point.
2. Establish photopoints at strategic locations to document changes in critical elements of gullies and stream channels, before and after restoration treatment and following flow events. These sites include headcuts, internal nickpoints, vertical or oversteepened banks, the channel bed and any locations where structures, vegetation or other restoration treatments will be applied. Be sure to include reference points in the framing of each photo. The best photo monitoring views of gully banks and eroding stream banks are typically taken from slightly downslope or downstream and oblique to the feature of interest. The channel bed and the top of the channel/gully bank should be visible, as well as one or more reference points for orientation. For gullies, the best shots are those which include oblique views of the most likely points of change, including undercut banks, gully bed nickpoints, the gully headcut(s) and the gully bed.
3. Establish monuments (such as rebar) on the ground surface for close-up views of erosion, deposition, or vegetation on the channel/gully bed.
4. Take photos perpendicular or obliquely to the bed. Include at least one, preferably two, reference points and a graduated scale of known length in each photo. This allows subsequent photos to be reframed and thereby portray the same scene through time.
5. Take similar monumented close up photos of various, representative channel beds, headcuts, banks and other areas of potential change to identify visual erosion and deposition through time.
6. Measure and calculate pre- and post-treatment contributing areas for gully systems where treatment is designed to reduce gully discharge. Use area measurement protocols described for quantifying surface erosion connectivity (see monitoring protocol #1, above).

2B. Gully bank and channel bank erosion and retreat (erosion pins and monument stakes)

Changes in gully dimensions can be quantitatively monitored with erosion pins (in the steep or vertical banks) and monumented stakes (around the exterior) that are used as reference points. Monitoring points may be regularly, randomly or non-randomly selected along an entire gully, or along a reach of eroding stream. Pins and stakes are also an excellent, cost-effective way to monitor head cut migration.

Erosion pins installed on unstable or eroding channel or gully banks are subject to complete loss during periods of episodic or rapid bank retreat or collapse. In situations where this is the dominant process, it is preferable to use monumented stakes placed back from the top edge of the stream bank or gully wall. These serve as reference points from which to measure and document episodic bank erosion and gully widening.

Field Sampling Methods

1. Identify sampling locations. Individual bank or gully erosion sites can be monitored without sampling. Long stream reaches that experience relatively uninterrupted bank erosion or long gullies may need to be sampled. Sample sites may be selected randomly along the reach or at regular intervals along a longitudinal transect. All headcuts should be monitored for advancement. Similarly, most or all internal nickpoints exceeding a predetermined height should be monitored for migration rates and changes in physical dimension (depth). Non-random sampling methods will yield results for the sampled sites, but may not provide a statistical basis for extrapolation to the reach as a whole.

2. Install erosion pins in settings where surface erosion or shallow failures (<6”) of the soil surface are expected to occur. They should not be used in locations where large block failures (typically caused by undercutting and bank collapse) are expected. They should be installed individually and in groups as per surface erosion protocol l C (see above).

3. Install monumented stakes along the top edge of the gully or eroding stream, far enough back to be out of the limits of potential bank failure and collapse. Install stakes at regular intervals along the top of the bank, either in one or more straight lines or in an irregular aerial pattern at an equal distance from the top edge. The closer the spacing of the stakes, the more accurately you will be able to monitor the location and magnitude of bank erosion or collapse.
    a. Stakes can be composed of a variety of materials, but 3’ - 0.25” rebar, driven at least 2’ into the ground, is ideal. Stakes should be exposed above the surface sufficiently to locate them in the future, and driven into the ground deep enough so that they are not easily moved or disturbed. Wooden stakes can be used but are more susceptible to disturbance. Mark the stakes so that they are easily visible (unless your project area is subject to vandalism) and number them so that you can track of each stake independently. Produce a sketch map of the stake locations and gully or eroding stream bank.

4. Install one or more reference stakes, located even farther back than the stake line, in areas where extreme bank retreat is possible.

5. Measure from a known point marked (with paint) on the stake out to the ground surface at the top edge of the bank. Mark this point with an erosion pin. The compass orientation of this measurement line should be recorded. The measurement line should be approximately perpendicular to the bank at that location. Erosion pins may be installed at regular one-foot intervals along this line, beginning with the one pin located at the top edge of the bank. In this manner, the next person returning to remeasure the distance to the stake can rapidly determine if the bank has retreated. The marked line will also insure measurements are taken along the exact line originally measured.

6. Remeasure stake distances at intervals determined by the occurrence of significant storms and runoff events. This should be done at least annually.

2C. Gully/channel bank retreat and changes in channel/gully bed erosion (tag line cross sections)

A tag line consists of monumented endpoints (usually rebar) with a level line (usually a taut wire or string line) stretched between them at the time of measurement. Measurements are taken vertically down from the line to the ground surface, and the distances are recorded as data pairs (horizontal distance from the end stake, vertical distance down from the line to the ground surface). In this manner tag lines can be used to measure bank retreat as well as changes in bed elevations (erosion or deposition). Tag lines become less accurate the longer the cross section becomes, due to the natural sag in the line. They are best employed where cross sections are less than about 30 feet. End points must be securely embedded in the ground so the line can be cinched tight to minimize sag.

If tag lines are longer than about 30 feet, the line sag can be accurately “reproduced” and calculated (and therefore subtracted) for each measurement point along the tag line by employing a line tension gage. Each time the tag line is reinstalled, the line is cinched until the same tension is reached. In this way, the original line sag is duplicated. Line sag can be approximately calculated by surveying the maximum deflection at the midpoint of the tag line and then developing a proportional relationship of sag versus horizontal distance from the beginning (zero point).

Tag line cross sections provide a complete cross sectional view of gully or channel changes at any selected point along a gully or small stream channel. Tag line cross sections may not reflect other points along the developing gully. A number of tag line cross sections may be required to present a realistic picture of gully or channel change over time. The more tag lines that are installed, the more accurately they will represent actual channel and gully changes.

Field Sampling Strategy

1. Select the sampling plan to be used for the installation of tag line cross sections. Tag lines may be installed at specific locations to record dimensional changes at that location,

or they may be placed at regular intervals or at random locations, depending on the study design. Perhaps the most common technique is to install tag lines in the middle of representative reaches of the gully or channel, and to assume the changes recorded at that location portray changes along the entire reach. Observations will either confirm or refute this assumption.

2. Install monumented endpoints using 0.5" to 0.75" diameter rebar pounded at least three feet into the ground and protruding no more than 1' above ground. The longer the span of the tag line, the larger the rebar and the deeper or more secure the rebar must be set. If necessary, rebar can also be strengthened by anchoring in concrete. Spikes in large trees, metal fenceposts and other secure monuments can also be used for monumented endpoints.
    a. Monument endpoints must be installed at the same elevation, so that the taut line stretched between them is level and vertical measurements taken from the line accurately portray ground elevations.
3. Cut a notch using a hacksaw, on the backside of one monument rebar. A line stretched between the rebar endpoints, through the notch, should be level. Check with a line level. When the line is level, cut the notch in the opposite rebar. The notches should be used to relocate the taut line each time measurements are taken from the tag line. In this manner, the tag line can be precisely reinstalled each time measurements are taken, and then removed between measurement periods.
4. Stretch a tape between the endpoints and take measurements with the left rebar endpoint representing the zero location or starting point (left and right are always determined when looking downhill or downstream). Take vertical measurements down from the line and record data pairs as distance and elevation.
5. Take measurements along the tag line wherever there are significant changes in elevation or slope inclination (breaks-in-slope). Record comments on any particular points that warrant description, such as edge of channel, edge of bar, thalweg, top of bank, etc.
6. Remeasure tag lines after significant runoff events and after observations suggest changes have occurred. Tag lines should be measured at least once each year, preferably following the winter runoff period.

2D. Gully and channel morphology (topographic surveys)

Topographic surveys can be conducted in a variety of forms and levels of detail. Complete topographic surveys are complex and technically difficult, and are probably not appropriate for most simple monitoring projects. Depending on access to the site (for survey equipment) and on the scope or size of the project area, these surveying techniques can be slow and labor-intensive. Survey equipment is expensive and surveying and data reduction techniques are highly technical. They are better suited to research level investigations.

Simple auto-level surveys can document changes in the channel bed and banks of the gully or stream channel. These less intensive applications of surveying for monitoring include: 1) longitudinal profiles of the channel or gully thalweg to document downcutting, 2) maps of the top edge of the gully including headcut(s) or the top edge of an eroding stream bank to document bank erosion or gully widening, or 3) cross sections of gullies or stream channels to monitor changes in cross sectional dimensions. Perhaps the most straightforward and elegant method for monitoring stream channel changes is the use of surveyed channel cross sections and profiles which can be resurveyed to quantitatively document progressive channel changes.

Field Sampling Strategy

1. Select the type of monitoring that is most appropriate to the objectives of the monitoring project.
2. Establish endpoints (upstream and downstream, or left bank and right bank, respectively) outside the expected area of change so that subsequent surveys will have common, unchanged points against which topographic changes can be compared. One or more additional reference points should also be surveyed to tie all survey points together to a common relative elevation benchmark (absolute elevations are typically not required for monitoring surveys).
3. Monument reference points using standard rebar or other permanent markers that are immobile. Because of the need for strict vertical and horizontal control, it is common for survey monuments or reference points to be fixed in concrete or on another immovable object (bedrock, tree or boulder).
4. Survey longitudinal profiles down the thalweg. The profile survey should include all major slope breaks, headcuts, nickpoints, and other significant features.
5. Install and measure cross sections from stable ground on the left side of the channel/gully to stable ground on the right bank. All major or significant slope breaks should be identified and described. To tie the cross sections into the longitudinal profile, a common point should be taken in both surveys at the thalweg. The choices for the location of cross sections are the same as described for tag line cross sections (see protocol 2C).

2E. Water (stage recorders, pressure transducers, data loggers, weirs, current meters)

Flow entering and leaving a restoration site can be monitored through time to determine the effects of restoration on runoff characteristics. For example, flow can be measured at the entrance and exit of a gully system, both before and following restoration work, to determine the effectiveness of restoration in reducing gully-forming discharges. Flow from intense rainfall and runoff events can also be measured at various points along a road system (e.g., in ditches and at culvert outfalls) to determine the effectiveness of restoration in dispersing and reducing road-related runoff. Stream flow can be measured upstream from a work site to identify the magnitude of runoff events that is triggering stream bank erosion. Finally, while several flow prediction methods are employed for determining peak discharges at culvert inlets for the 50- and 100-year discharge, actual hydrographs can be measured during storm events to monitor the effectiveness of stream crossing upgrade techniques.

Runoff and stream flow are measured by a number of techniques, depending on the magnitude of the discharge. In streams, the most common techniques employ current meters to measure flow velocities through a fixed cross section, thereby producing discharge measurements [cross sectional area X flow velocity]. Once a stage/discharge relationship has been developed for a cross section location, stage can be measured or recorded to produce a continuous record of stream flow. Stage is measured using a fixed, graduated staff gage and can be continuously monitored using water level recorders or pressure transducers in concert with data loggers or strip chart recorders.

Flow in smaller channels (e.g., gullies, ditches or culvert outlets) can be measured using similar devices, provided flow depth is sufficient and cross sections are stable. In addition, flow can be measured in a bucket or other container, over a known time interval, to produce the discharge value (volume/unit time). Flow also can be recorded by running the discharge through a calibrated weir and attaching a stage recorder to monitor water surface elevations through time. Similarly, flow can be diverted into a large container (such as a stock trough) and stage/discharge recorded as it exits through a weir with a known discharge calibration curve.

Perhaps the simplest techniques for measuring discharge are the most practical for use in most restoration monitoring projects. The most important requirement is that the technique be reproducible and that it produces a value that is sufficiently accurate to satisfy the monitoring objectives. Typically, on-site changes in flow that result from upland restoration work will need to show only gross changes in flow volumes and peak flow values. For example, dewatering a gully should show changes in discharge of 50% or more.

The specific methods suitable for designing, installing and collecting scientifically valid discharge measurements are contained in numerous texts and field manuals for hydrologic monitoring. They are not fully described here. The collection and analysis of hydrologic data must conform to these basic, commonly accepted scientific methods if the information is to be useful in monitoring the effectiveness of upland and small stream restoration projects. These standard operating procedures should be consulted prior to developing a hydrologic monitoring project or installing any flow monitoring equipment.

Field Sampling Method

1. Select the method of discharge measurement that is appropriate for the monitoring objectives and the expected flow volumes. In general, higher discharges associated with streams will require the use of current meters and stage recorders. Lower discharges associated with upland restoration sites, such as those involving road runoff, will employ small weirs, collection basins and simple bucket measurements.
2. Install flow measurement stations at locations appropriate to the study design. Flow volumes and rates should be monitored at points of connectivity along the road using techniques appropriate for the expected discharge of runoff and sediment from upland restoration sites. This may entail the use of small weirs, sediment collection basins, grab sampling, or other techniques. For example, most runoff along a road alignment is expected to occur during precipitation events and this data is likely to be most accurately measured using buckets and other collection methods. Runoff that occurs during periods when sampling crews are not present should be collected and measured utilizing impermeable basins and storage devices, where possible. These should be measured and emptied at regular and frequent intervals.
3. Measure stream discharge in cubic feet per second for in-stream monitoring at each sample station using standard stream gauging techniques such as the area-velocity method. Install a staff gauge at each measurement station and record stage each time a

discharge measurement is collected at this station. Convert stage height values to discharge values using a stage-discharge relationship developed after the collection of sufficient flow data.

2F. Sediment discharge (turbidimeters, suspended sediment sampling, sediment retention basins)

Sediment discharge is the ultimate measure of the effectiveness of erosion control work on upland restoration sites. Measures of sediment discharge taken before and after restoration work provides a rapid evaluation of the benefits of the project. Techniques for measuring project-level sediment flux include a variety of devices that trap and store the transported sediment as well as dynamic measurement techniques that measure sediment being transported in the water column. Regardless, sediment-monitoring techniques employed for most restoration monitoring projects should be simple, yet accurate enough to meet project objectives. Highly sophisticated techniques should be avoided unless required by the specific study design. Using these techniques is often costly and requires advanced analytical skills.

Sediment discharge can be measured at the same sites as runoff. The most common locations and techniques for collecting and monitoring sediment flux at upland restoration sites have already been described under the surface erosion protocol (protocol 1D). For gullies, sediment discharge can be measured at or near the gully mouth. If conditions are appropriate, sediment traps can be prepared to collect sediment that exits the gully or a reach of the gully. Similarly, traps and flow monitoring equipment can be installed at the entrance to the gully, to document changes that have occurred as a result of restoration work. Monitoring sediment and water outflows is informative when well performed but may be cost-prohibitive in all but the most favorable sites where access for vehicles and construction of simple settling basins can be employed to reduce costs.

Specific methods suitable for designing, installing, collecting, and analyzing highly quantitative and scientifically valid sediment flux measurements must conform to basic, commonly accepted scientific methods if the information is to be useful in monitoring the effectiveness of upland and small stream restoration projects. These standard operating procedures should be consulted prior to developing a sediment-monitoring project or installing any monitoring equipment. Methods include highly technical procedures requiring skill, scientific knowledge, and experience. Such as traps, grab sampling (during runoff events), turbidimeters, suspended sediment samplers, and/or bedload samplers. Method descriptions are contained in numerous texts and field manuals for water quality and sediment monitoring and so are not fully described here. In addition, these techniques may require the simultaneous collection of water discharge data in order to develop total discharge and flux rates. Some additional clarification is included in the protocol for infiltration monitoring (see below).

Field Sampling Method

1. Select the method of sediment measurement appropriate for the monitoring objectives and expected volumes. Sediment monitoring for gullies and small channels is best conducted using simple techniques. The most common locations and techniques for

collecting and monitoring sediment flux at upland restoration sites have already been described under the surface erosion protocol (protocol 1D). These techniques (including traps, basins and troughs) also work for gullies. They can be scaled to meet the requirements of the specific monitoring site, depending on the volume of water and sediment expected to reach the collection site.

2. Locate monitoring sites at the entrance and exit of the gully to be monitored. Monitoring sediment inflows provides information on the amount of sediment being delivered to and routed through the gully. Monitoring sediment outflows provides information on the amount of sediment being generated by continued erosion within the gully. Together, this gives a clear picture of sediment production and delivery from gullies, and can provide excellent information on the effectiveness of gully restoration projects.

3. Mass wasting (landsliding)

Road construction, spoil disposal, water diversions, grading and timber harvesting may directly trigger mass wasting or increase landslide movement. Common types of landslides range from large rotational and translational landslides and earthflows, to large and small debris slides, to small slumps. In general, the smaller the landslide, the more easily it can be prevented or controlled. Landsliding is an episodic process, with most slope movement occurring in response to precipitation events or seasonal changes in groundwater conditions. Most landsliding and sediment delivery occurs during large magnitude storm events, with the largest storms producing the greatest frequency and size of landslides.

Landslide monitoring is a technical and academic topic that has received much attention in the scientific literature. Many techniques have been written up and described offering a suite of possible monitoring practices if the project objectives call for more quantitative methods. For most restoration projects, landslide monitoring is designed and conducted to document landslide activity before and after restoration treatments have been implemented. Although it may be a simple process to document landslide movement, it is usually a complex process to predict landslide movement and to understand why a landslide moves.

Most restoration projects will involve fairly straightforward techniques for controlling or reducing landslide movement. These typically involve: 1) revegetation, 2) excavation aimed at taking weight off the unstable slide so it will slow or stop moving altogether and 3) buttressing to support the base of a landslide as a counter-balance to the sliding mass above it. Monitoring will confirm whether slope movement continues.

The most fundamental monitoring technique for mass wasting is to visually identify and map new scarps, cracks or other indications of landslide activity. Permanent photo points can document relative slope movement provided the scenes are clearly and accurately reproduced each time photos are taken. Simple monitoring, such as measuring the distances between objects that are on the slide and fixed objects that are known to be on nearby stable ground, can be used to add some measure of quantification to rates of slope movement.

The most common quantitative techniques for landslide monitoring are stake lines and reference grids. Stake lines (with stakes at known locations) installed across the slide surface graphically show displacement when movement occurs. Reference grids of stakes on the slide mass allow for monitoring of movement and internal deformation. These are the most straightforward methods for monitoring landslide movement. The most sophisticated techniques involve surveying, which provides research-grade information on landslide movement. However, using surveying techniques and equipment requires training. Similarly, the use of data loggers to develop continuous records of slope movement, and drilling and the use of subsurface monitoring techniques (such as inclinometers) should be confined to special situations that involve scientific research or the potential for downslope injury or property damage.

3A. Visual observations, mapping and photography

The simplest type of landslide monitoring consists of visual observations, mapping and photographic techniques. Identifying the occurrence of new scarps, cracks or other signs of soil mass wasting are clear indications of continued slope movement. They can be noted by mapping the features (this is especially useful if maps exist showing the location of original "pre-restoration" landslide scarps), or by photographing the scene with fixed reference points and describing the location and magnitude of mass wasting features (cracks and scarps). Oftentimes, small cracks and scarps signifying new or renewed slope instability may not be clearly visible in scene-scale photos, and repeated narrative descriptions, sketch maps and/or close-up photos (with scales) may be more useful.

Most road-related landslide restoration sites are those where spoil material was originally pushed over the edge onto a steep slope and the material has since become visibly unstable. Other work sites may consist of larger areas of instability associated with spoil disposal sites (such as a rock pit waste site) or streambank landslides. Maps and photos showing the spatial location of developing landslide features can be combined with physical measurements of the length and height of scarps and cracks to portray a "picture" of the location and magnitude of mass wasting features that can be tracked through time.

Field Sampling Method

1. Identify mass wasting and related features (crown and lateral scarps, internal scarps and slump blocks, cracks, leaning trees, springs, etc.) and document in writing and through the use of sketch maps.
2. Establish photopoints at strategic locations that comprehensive views of restoration sites both before and after treatment. The best views of landslide sites are those depicting:
    a. Excavation sites where landslide masses have been removed and slopes have been "unloaded."
    b. Areas open and free from obstructing vegetation for the next five years after vegetation has grown up on the treated surface.
    c. For road related landslides, sites on one side or the other looking obliquely across the landslide surface near the headscarp or from the road surface. It is important to capture the crown scarp and upper part of the lateral scarps in the photo, if possible, as these will be the first locations where renewed slope movement is likely to occur.

   d. For stream bank landslides, sites from the opposite side of the stream or from the channel bottom looking obliquely upstream or downstream at the unstable slope as it enters the stream channel.
3. Establish permanent points on the ground surface to show how slope displacement has altered the vertical or horizontal relationship between the points. Set up monuments into the ground on either side of a scarp, or former scarp. Photos and measurements of the changing distance and elevation between the two monuments can be used to portray the magnitude of slope movement.
4. Install permanent monuments (preferably rebar) at photopoints and label with a unique identification number so that photos and descriptions of landslide features can be linked to a specific monument with both compass direction and distance.
5. Take photographs. Be sure to include relocatable reference points in the framing of each photo. Consider the following types of photos:
   a. Vertical photos from low level platforms, such as a weather balloon 100 feet up to provide a more spatially correct "map view" of a site, and to track changes in vegetative cover and bare areas through time.
   b. Scene photos from sites that show the full extent of the work site before and after the stabilization work.
   c. Headcuts, internal nickpoints, vertical or oversteepened banks, the channel bed and any locations where structures, vegetation or other restoration treatments will be applied.
   d. Close-up views showing movement of mass wasting. Include monuments (such as rebar) in photos to facilitate reframing of subsequent photos and comparison over time. Take similar monumented close-up photos of various, representative landslide features and other areas of potential change. These photos portray slope movement before and after restoration treatment.
6. Rephotograph points after restoration treatment and following large magnitude storm events that trigger slope movement.
7. If quantitative measurements are required, enlarge and digitize photos with scales to portray changes in the dimensions of scarps and distance of lateral slope movement.

3B. Slope movement (monument stakes, stake-lines and grids)

Monumented stakes, stake lines and reference grids, the three most common "low-tech" landslide-monitoring techniques, are established on and adjacent to the landslide or former mass-wasting feature. By repeated measurement of reference points on the slide to reference points on stable ground outside the landslide, the location, magnitude and rate of slope movement can be quantitatively documented and tracked. Reference grids, established by pounding stakes or rebar into the slide surface in a regular grid (or other alignment) can document movement of various points on a larger landslide feature, one that has more than one internal block.

All these methods focus on repeatedly measuring and tracking the distance between monumented points on a landslide and monumented points on the adjacent stable ground outside the zone of instability. Measurements can be made using tapes or electronic distance measurement devices, provided they have sufficient precision and accuracy. Tape measurements have a resolution of an inch or less, but repeatable accuracy of perhaps 6 inches, depending on the total length being measured, topography, and vegetative cover and density.

Field Sampling Method

1. Identify monument stake locations and collect stake materials. Monument stakes usually consist of 4' to 5' rebar pounded at least three feet into the ground surface and sprayed with fluorescent paint or another marker to identify their location.
2. Install stakes along the top margin of the landslide, outside of the zone of existing or potential instability (outside stake). In areas where extreme bank retreat is possible, install one or more reference stakes, located even farther back than the outside stake. A second monumented stake, or multiple stakes, should be installed on the landslide surface (inside stake) directly downslope from the outside stake. The objective is to have the stakes in-line with the direction of movement or potential movement of the landslide mass.
    a. Measure the distance between the two opposing stakes and record this distance each time the monitoring is conducted.
    b. For lateral margins of the landslide, stakes should be installed on stable ground at fixed intervals, with two stakes on the outside for every stake on the inside. It is preferable for inside and outside stakes to be at a significant angle to each other, rather than directly opposite each other, so the greatest possible downslope component is recorded when small incremental movements occur. The measurements on each inside stake are then taken from two outside stakes, and a simple triangulation can be used to measure the component of downslope movement.
3. Install horizontal stake lines across a landslide surface approximately perpendicular to the direction of likely landslide movement. Stakes should be installed in a straight line across the slide mass, with at least two stakes on each separate landslide block (if the slide has discrete internal slump blocks) so that the movement of each block can be independently tracked over time. Spacing of the stakes can be regular or not, and the spacing is often dependent on the size of the slide, the visibility of the stake locations and the number and size of internal landslide slump blocks. For a 100 foot wide landslide, stakes might be installed every 10 or 20 feet across the inside of the slide area. Finally, for every stake line there should be at least two stakes on stable ground outside the lateral margins of the slide mass on each side of the slide, to ensure that one or both reference points are outside the margins of instability. The compass orientation of each stake line should be recorded and a sketch map of the lines and individual stakes should be included in the data collection.
    a. When establishing the stake line, a tight wire or cord is stretched between the endpoints and a tape measure is stretched along the same line (so that distance from the endpoint can be measured to locate each stake). A plumb bob on a fish line is looped over the wire and dangled over the tight line. Stakes are installed immediately below the plumb bob, at selected locations along the line. The stakes are located according to the distance along the tight line, beginning with the zero point at the left endpoint (left when looking in the downslope direction).

   b. Each time a re-measurement is to be taken, the displacement of stakes on the stake line is recorded. The same tight line is stretched between end points, the plumb bob is dangled from the wire and tape and the movement distance from the plumb bob to the stake in the ground is measured on the ground surface. It is preferable to insert an erosion pin at the location of the plumb bob each time a measurement is taken. That way, changes can be visually tracked at each visit and a decision can be made on whether or not to conduct the measurement.

4. Install vertical stake lines directly up- and down-slope on the slide surface. Install stake lines perpendicular to the horizontal lines described above. Locate reference stakes outside the zone of existing or potential instability above the crown scarp and distances are measured from these upper, stable monuments.
5. Establish reference grids by installing a regular or irregular grid of monument stakes on the landslide surface. Install an irregular grid by setting stakes at desired locations on the slide and then surveying their location using an auto level, theodolite or total station. In contrast, install a regular grid by setting stakes at the intersection of the predetermined grid pattern. Remeasure both grids by resurveying the location of each inside monument stake. The survey data will show how much movement, if any, has occurred at each stake location on the landslide.
6. Document locations of stakes. Stakes should be well marked, mapped, photographed, and individually labeled for future identification. It is important to track individual stakes as they move down the slope. Failure to mark each stake with a unique tag will make future interpretation of the measurements difficult, especially if some stakes are lost, removed, or vandalized.
7. Measure initial distances along monument stakes, stake lines and grids using tapes or survey instruments (auto level, theodolite, or total station with EDM). The more sophisticated survey equipment requires technical training in field survey methods and data analysis techniques.
8. Remeasure annually at minimum, as well as after significant storms or visible slope movement events.
9. Maintain stake lines by removing brush to allow for an unobstructed view of the measurement corridor.

3C. Slope movement (topographic surveys, extensometers, inclinometers and data loggers)

The most sophisticated techniques for monitoring landslide movement involve surveying (total station or auto-level) of landslide topography (including reference stakes on and off the landslide), and continuous monitoring of surface and subsurface slope deformation. Surface deformation is monitored using a recording data logger and a taut wire between stable ground and a fixed point on the unstable mass. When the stake on the slide moves, the data logger records the time and distance moved. In this manner, a temporal record of slope movement can be compared to precipitation or other variables that might play an important part in triggering slope failure. Drill holes and vertical inclinometers or other deformation indicators can also be used to continuously monitor internal slope movement.

These techniques are typically beyond the capability of all but research-level studies. They allow a much higher resolution of movement monitoring.

1. Determine the type (internal and/or external) and level of continuous monitoring required to satisfy the monitoring objectives.
    a. Ask for assistance from trained geologists or engineers as circumstances warrant (e.g., if life or property issues are involved).
2. If continuous monitoring of external or internal slide movement is required, contact a geologist or engineer familiar with the technical protocols for these methods. Effective methods can be as simple as:
    a. A stretched, weighted wire and pulley system linked to a stage recorder. As the landslide moves the wire plays out, turning the pulley on the chart recorder and tracking the timing and magnitude of slope movement with a pen trace on the chart.
    b. Other logging equipment can be employed, such as digital data loggers and potentiometers that send a signal to the data logger that is proportional to the length of the wire that has played out as the landslide moves downslope.
3. Install reference points on the slide surface so markers can be resurveyed intermittently during the course of the monitoring project. This will allow clear definition of both topographic changes and landslide movement rates (see monument grid protocol #3B, above).

4. Runoff and Infiltration

Projects such as road decommissioning often involve practices that decompact the soil surface, disperse runoff and/or divert runoff to locations where it no longer flows directly into stream channels. These restoration practices act to reduce storm water runoff and to lower peak flows and flashy discharge from impervious developed areas.

Compacted soils are decompacted by tilling or mechanical disaggregation, or by excavating the compacted material and replacing it without renewed compaction. Roads are one of the main sources of compacted soils in a watershed, and decompacting old roads is one practice that reduces the volume of runoff that occurs during storm events. Similarly, road upgrading typically includes treatments designed to “disconnect” the impervious road surface from the natural stream channel network, such as the installation of rolling dips, ditch relief culverts, road shaping (outsloping) and other treatments.

The objective of the monitoring is to identify changes in surface runoff and infiltration resulting from upslope restoration practices. Monitoring infiltration and changes in runoff can take several forms, none of which need to be complicated or sophisticated. One way is to monitor runoff from formerly compacted areas. Another way is to monitor soil infiltration rates in storms or by the use of simple infiltration tests that allow for a more controlled analysis. Finally monitoring revegetation of formerly compacted surfaces is an indirect way to monitor the expected reduction in runoff associated with decompaction efforts undertaken during restoration.

4A. Mapping contributing areas

Monitoring hydrologically connected bare and compacted areas, or hillslope areas whose runoff has been artificially diverted into a stream channel, involves measurement of the spatial dimensions and condition of the contributing lands. The simplest measurement technique for road-related runoff and connectivity is to directly measure the length of road and/or ditch delivering runoff and fine sediment to the stream channel. More detailed measurements can include spatial mapping from topographic maps, aerial photos or complete topographic surveys.

Hydrologically connected bare soil areas (unsurfaced roadbeds, cutbanks and ditches) may deliver sediment to stream channels and other biologically sensitive habitat (e.g., wetlands) and are therefore prime targets for restoration. Other bare areas include landslide surfaces, quarry sites, stream banks, and agricultural fields.

The size and condition (bare, not bare) of the area that is contributing runoff and eroded soil to stream channels can be documented and monitored through a variety of techniques, including field estimates, sketch maps, field measurements, mapping on low level aerial photos, instrument surveys, and random sampling studies. The contributing area is likely to change (shrink) dramatically when the restoration work is first performed and bare areas are disconnected from the stream system, and then to change only gradually in response to revegetation, natural armoring or other processes or treatments (mulching, surfacing, etc.). A monitoring protocol should be selected based on the objective of the monitoring (e.g., qualitative evaluation of changes in contributing area, or (alternatively) the quantitative assessment of the reduction in the contributing area and the subsequent reduction in exposed soils within this area).

Field Sampling Methods

1. Select the type of monitoring desired to characterize or quantify the contributing area and the exposure of soils subject to surface erosion (qualitative or quantitative).
2. Measure the contributing area, or measure an analog (such as road length), prior to restoration treatment.
    a. Measurements can be made using pace, tape, hip chain, or a survey instrument.
    b. Areas can be calculated by taking average spatial measurements, by mapping on aerial photos, by mapping on scaled low-level vertical photos, or from detailed instrument surveys (level, plane table, theodolite, or total station) of the small contributing subwatershed areas. They can also be estimated using random sampling or aerial grids that identify areas as being “in” or “out” of the contributing area adjacent to the restoration site. Sampling reduces the measurement requirements, but lowers the accuracy of the aerial measurement.
    c. Selection of the appropriate measurement technique for monitoring contributing areas will depend on the objective of the monitoring project.
3. If desired, classify and measure the contributing sub-areas according to their potential to generate runoff (compacted, paved, vegetated, etc) and deliver fine sediment (bare, protected, vegetated, etc.) to the stream system.
4. Remeasure the contributing area following restoration treatment using the same measurement techniques and intermittently thereafter if conditions change.

4B. Photography and photo points

Qualitative, visual evidence of increased infiltration and reduced runoff is often readily observable and can be mapped and photographed following a restoration project in which decompaction efforts have been successfully undertaken. Mapping can trace runoff paths that leave the work site during storm events, and these paths can be characterized as contributing to streams or re-infiltrating. Monumented oblique and vertical photography can be used to document surface conditions, surface texture, and revegetation through time.

Photography and direct observation can be an effective monitoring tool for areas that have been outsloped, waterbarred, drained, mulched, planted and/or decompacted. Road upgrading work is usually not as photogenic as road decommissioning projects and is therefore somewhat less amenable to photo monitoring.

Field Sampling Methods

1. Establish permanent photopoints to provide comprehensive views of restoration sites and to document rates of runoff and infiltration both before and after treatment.
2. Select photo point sites to show treatments designed to disperse surface flow, increase infiltration and reduce surface runoff
    a. Include ripped road surfaces, outsloped roads, filled ditches, cross-road drains, former ditch relief culvert sites and drainage dips.
    b. Upgraded stream crossings or disconnected gullies reducing the length of contributing ditches and road surfaces.
3. Monument photo points. Although unmonumented photos can document specific processes that might not have been predicted prior to treatment, they do not facilitate relocation of photo points and so do not show change over time.
4. Take photos from established permanent photo points. Include the following photo types:
    a. Close-up views showing compacted and decompacted surfaces through time taken perpendicular to the ground, including at least one, preferably two, monuments and a graduated scale of known length. The use of monuments (such as rebar) allows subsequent photos to show change over time.
    b. Close up views of cutbanks, fillslopes, road surfaces, and ditches to identify visual differences in runoff and infiltration capacity.
    c. Oblique ground photos to document and monitor effectiveness of reshaped road surfaces, rolling dips and ditch relief culverts. Include reference points (stumps, trees, fences, etc.) in the scene. Slightly elevated photopoints relative to the subject are preferable and those showing the ditch and road surface during winter storm runoff are often the best as pre- and post-treatment changes in runoff rates are often clearly visible.
    d. Vertical photos from low-level platforms, such as a weather balloon at 100 feet elevation, to provide a more spatially correct "map view" of a site, and to track the change in vegetative cover and bare areas through time.
5. Observe and take photos of opportunity during significant rainfall and runoff events.
    a. Document overland flow from restoration sites and the delivery of runoff and eroded sediment to stream channels. Note lack of runoff from post-treatment

restoration sites (e.g., ripped or decompacted areas) through direct observation of surface conditions.

4C. Precipitation and infiltration studies

Rainfall that does not infiltrate into the soil will run off to lakes, ponds or streams. Frequently, one of the goals of upland restoration work is to reduce the rate and volume of runoff that is generated from managed lands, so that it more closely approximates natural conditions. By reducing runoff, sediment delivery is also reduced. Monitoring rainfall and runoff in upland areas can be accomplished by documenting rainfall volumes and rates, the rate and volume of runoff or infiltration, or both. Monitoring methods can range from the collection of simple observational data to complicated plot studies using electronic sensors and data logging equipment. The purpose of the monitoring will dictate the type of monitoring used. Rainfall data, along with stream gaging (stage) data, help hydrologists and restoration specialists monitor the progress of storms and provide a basis for determining relationships between the amount, duration, and intensity of rainfall and the amount and rate of runoff expected as a result.

The National Weather Service, part of National Oceanic and Atmospheric Administration (NOAA), is the primary agency responsible for collecting rainfall data throughout the United States. There is an extensive network of both recording and non-recording precipitation gages measuring rainfall in all cities and most towns in the U.S. Other state, local and private entities may also maintain recording and non-recording rain gages in the general vicinity of a restoration site, and can be contacted for rainfall data. However, rainfall rates are usually highly localized, and data specific to an upland restoration site is best collected at the monitoring location.

Field Sampling Method

1. Select the type of precipitation monitoring that will provide the necessary data.
    a. Precipitation can be monitored as a volume or a rate (volume per unit time). The most basic installation is a simple storage gage, and these can be purchased from a variety of sources. Storage gages allow for collection of precipitation volumes, but do not allow for analysis of rainfall intensity.
    b. Non-recording rain gages require less operation and maintenance and volunteer observers can periodically read and relay their information to the appropriate project managers. The disadvantage to non-recording rain gages is that they record only an accumulated rainfall depth for the time between readings. It is, therefore, difficult to get an estimate of the intensity of rainfall. The most suitable storage rain gages allow for readings of 0.01-inch precipitation, and for storage of at least eight (8) inches of total precipitation without overflowing. Large overflow containers can be installed in areas where precipitation gages are not likely to be emptied before their normal capacity has been exceeded.
    c. Rainfall rates can be monitored through the installation of tipping bucket or weighing rain gages and data recorders. Recording rain gages are used when it is necessary to know the various rainfall intensities throughout a storm.
2. Install rain gages in close proximity to the monitoring site, and in a setting that is protected from high winds yet not sheltered from rainfall. Gages should be installed on

the same slope aspect and at a similar elevation to the restoration site being monitored. Specific installation instructions for most rain gages are included with the gage, or can be found in most standard texts on applied hydrology. In areas where snow is expected, gages must be heated or otherwise modified to function in freezing conditions.

More quantitative monitoring methods for infiltration and runoff include the use of infiltration devices (infiltrometer, tension infiltrometer, permeameter, infiltration rings) or runoff plots to document the rate of infiltration of water into a soil. Testing can be performed during the dry season or during high moisture conditions to evaluate the effectiveness of restoration treatments that have been designed to increase infiltration and reduce runoff. These can be used in controlled plot studies or in uncontrolled sampling studies of treated and untreated sites to document changes in infiltration rates over time, or to document changes in filtration rates before and after restoration treatment. The specific protocols for each type of infiltration monitoring device are described in most hydrology texts and in the literature available from the vendors of these devices.

4D. Runoff plots, basins, weirs and troughs

Runoff plots are constructed to capture runoff (water and/or sediment) from plots or contributing areas. Artificial barriers may be used to bound plots so their contributing areas are unambiguous. Runoff plots can be used to monitor treated and untreated areas, as well as restoration sites before and after treatments have been applied. Typically, runoff plots have collection devices (troughs, basins, tanks, etc) that store runoff and/or sediment generated during runoff events. These devices can be monitored for volumetric data (much like a storage rain gage) or for rate information (volume discharged per unit time). Simple runoff plots and storage collection devices are often sufficient for restoration monitoring studies.

Field Sampling Method

1. Select the area that is to be monitored for runoff. The "plot" may be an artificially bounded area (sheet metal boundaries or other impervious edges) or a naturally bounded site whose contributing area can be clearly documented and measured. Runoff from plots should only come from within the plot area, and plots should not have springs, seeps or other sources of runoff that originate from areas outside the plot. One example of a study plot would be a road segment of known drainage area that is then significantly modified by restoration work thereby reducing the contributing area or increasing the infiltration capacity of the surface.
2. Construct a collection basin, trough or container into which runoff (and sediment) from the plot is directed and stored. The collection device can be used to store water and/or sediment. Devices used to collect water should be lined and/or sealed to prevent loss (infiltration) of runoff.
3. Monitor runoff rates. The simplest methods involve physically capturing runoff over a known time period. For very small runoff volumes and rates, this can consist of timing the filling of a five (5) gallon bucket, or other container of known volume, over a known time interval. The results give a runoff rate or discharge from the plot. The disadvantage

of this technique is that someone has to be present whenever a runoff measurement needs to be taken, and this is rarely the case.

4. Monitor sediment rates by excavation of accumulated volumes. The more frequently runoff and precipitation data is collected, the better will be the resolution of the information, but this method yields only volumetric data (not rate data).

If there is interest in continuously monitoring the rate of water discharged from a plot, weirs (rectangular, V-notched, etc.) can be installed in or before the settling basin. Weirs of certain shapes and dimensions, installed according to standard engineering practice, can be used to quantitatively monitor the discharge of runoff from the runoff plot using automated stage recorders and data loggers. Some types of flumes can be purchased from scientific vendors, but most such equipment is designed and fabricated for each particular installation. Specific construction details for weirs can be found in many hydrology texts and manuals. All recording equipment is commercially available. Trained, experienced scientists or technicians should install both types of monitoring devices (weirs and data loggers). Data reduction and analysis for continuous monitoring of runoff usually requires technical experts experienced in hydrologic analysis and interpretation.

4E. Sediment delivery

Sediment delivery from runoff plots can be intermittently or continuously monitored using a variety of standard and non-standard equipment. If only bulk sediment (no runoff) is to be measured, settling basins can be installed and monitored. Continuously monitoring sediment discharge is more complex than monitoring bulk sediment volumes. Turbidity (a partial analog of suspended sediment discharge) can be monitored continuously using data loggers with special probes. Automated suspended sediment samplers (such as an ISCO sampler) can be used to collect samples of flow from runoff plots (or streams) at intervals programmed into the sampling station. For most purposes, bedload sampling is performed by hand during runoff events. A trained hydrologist should perform or oversee the collection and analysis of complex water and sediment data.

Field Sampling Method

1. Construct a settling basing to monitor bulk sediment delivered from a plot. This type of settling basin is called a bulk bedload trap and the accumulated sediment can be excavated or measured (surveyed) at desired intervals. Suspended sediment is measured or sampled by hand or using an automated pumping sampler.
    a. The size of the settling basin will depend on sediment particle size (larger basins are required for smaller sediment particles) and the volume of sediment to be stored between site visits (when it will be emptied of accumulated sediment). The basin should have sufficient storage capacity to allow most sediment to drop out while the water ponds then flows out of the structure through a spillway or overflow device. Unless the settling basin is large relative to the inflow discharge, most suspended sediment will continue to move through the system and exit at the outflow point. The optimal surface area of the settling basin, to

allow settling and storage of entrained sediment of a particular diameter, is contained in many hydraulic engineering and hydrology texts.

2. Collect bedload sediment delivered from very small plots with low discharges by episodically capturing runoff and sediment in containers (such as a five gallon bucket or 50 gallon drum).
    a. Bedload is not easily monitored continuously; so sampling schemes usually consist of using trained field personnel to collect runoff and bedload samples during runoff events.
3. Collect stream bedload using standardized samplers such as the Helley-Smith sampler. Bedload samplers, including a variety of pressure-difference samplers modeled after the Helly-Smith, typically have a relatively high variability in efficiency and accuracy. They can be purchased in a variety of sizes for different applications. Bedload sampling in stream channels requires specialized training.
4. Monitor plot runoff for turbidity or suspended sediment using hand-collected grab samples or sampling devices that run continuously or at programmed intervals.
    a. Grab samples can be analyzed for turbidity or suspended sediment, and if water runoff or streamflow has been monitored continuously, rating curves can be developed for each sampling station or plot.
    b. Turbidimeters (with data loggers) and programmable automated suspended sediment samplers can provide a continuous or near-continuous record of fine sediment movement from the plot or stream channel. Installation and use instructions are available from the manufacturers or from practicing, experienced hydrologists or technicians.

IDENTIFYING THE CORRECT PROTOCOL FOR USE WITH A PROJECT

As with any monitoring project, the study objectives (the questions to be answered) will determine the methods and protocols to be used. Some research-level monitoring projects may require the use of sophisticated field equipment, complex analytical procedures, or statistical analyses that are beyond the capabilities of many restoration project managers. In these cases, highly trained personnel are needed. In other cases, basic questions regarding aspects of upland restoration can be answered in a straightforward and simple way. Many of the techniques described above can be installed or undertaken with minimal field training and oversight for quality control. Table 1 provides guidance on the choice of protocols for monitoring erosion and sedimentation, and certain elements of hydrology and sediment transport, related to upland restoration projects.

Table-1, Protocols recommended by project/study objectives

Project/study Elements and Objectives	Recommended Protocols
Monitoring Erosion and sediment delivery	
Reduced surface erosion on connected surfaces Increased vegetative cover on connected surfaces Reduced rates of rill erosion on connected surfaces	Photo points and photos; contributing areas; vegetative cover; erosion pins; caps; bridges; traps; basins; troughs; measuring rills
Reduced delivery from gullying Reduced channel erosion	Photo points and photos; erosion pins; monument stakes; tag-line cross sections; topographic

	surveys; water and discharge measurements
Reduced delivery from mass wasting	Photo points and photos; monument stakes; stake lines; topographic surveys
Reduced hydrologic connectivity between roads and streams (restoration of natural drainage patterns) Increased dispersion of surface runoff Increased infiltration	Mapping contributing areas; photos of runoff; precipitation and infiltration studies; runoff basins; settling basins
Reduced turbidity and sediment transport in natural stream channels	Sediment transport monitoring (turbidity, suspended sediment sampling, bedload sampling)
Monitoring infiltration, flow dispersion and overland flow	
Reduced surface runoff Increased dispersion of surface runoff Increased infiltration Increased vegetative cover and interception	Photos of runoff and treated areas; precipitation and infiltration studies; runoff plots, basins and weirs; vegetation cover mapping
Reduced connectivity between roads and streams	Mapping contributing areas; runoff basins and weirs
Reduced rates of runoff (peak flows, and time to peak) to stream channels	Runoff studies (recording and non-recording discharge measurements); runoff basins and weirs
Monitoring reduced risk (e.g., road and stream crossing failure)	
Stream crossings, including culverts, are designed for the 100-year discharge Culverts have a low plugging potential Stream crossings have no diversion potential Slopes (fillslopes and excavated sideslopes) leading to streams are stable Excavated stream crossings have stable longitudinal profiles Excavated stream crossings have stable side slope profiles	Photo points and photos; documentation of restoration implementation effectiveness (not described here); documented maintenance records; topographic surveys (profiles and cross sections); tag line cross sections; stakelines, vegetation cover mapping;

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E-5: Quantitative Protocols for Effectiveness Monitoring of Roads and Upland Restoration Following Stressing Events

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INTRODUCTION

Forest roads are significant sources of sediment. Abandoned and unmaintained roads once used for timber harvest are common across the steep forested landscape of the Pacific Northwest. Road cuts and drainage structures, such as culverts, can disrupt natural drainage patterns. Stream crossings fail when culverts plug with sediment or wood, or are too small to convey storm discharge. Failed roads across steep slopes frequently result in massive landslides, road fill failures, and extensive gullying that contribute sediment directly into stream channels.

The main focus of restoration has been to reduce sediment delivery from roads. Sediment delivery is either chronic or catastrophic as a result of failure during high precipitation events. Projects that are undertaken to reduce the risk of catastrophic sediment input may include upgrading stream crossings, installing drainage structures, installing rolling dips and removing berms. Full road obliteration involves excavating culverts and associated road fill, decompacting the road surface, removing drainage structures, mulching and replanting the sites. Projects that are focused on decreasing chronic sediment inputs may include these treatments, as well as road surface upgrades, excavating unstable sidecast fill from the downslope side of road benches, filling in or draining the inboard ditch, and outsloping.

The monitoring approach proposed below is intended to evaluate the effectiveness of road restoration projects at avoiding catastrophic sediment input. The approach is largely based on the work of Madej (2000), who evaluated the impact of the 1997 storm in northern California on road decommissioning projects in the Redwood National Forest.

The appropriate time frame for monitoring of catastrophic events is by definition uncertain. This makes monitoring challenging since it may be many years or decades until a restoration project undergoes a stressing event such as a 10-year runoff event. Consequently, the decision on undertaking a study of this nature means planning in advance so that pre-implementation data may be collected.

MONITORING STRATEGY

APPENDIX E: QUANTITATIVE MONITORING PROTOCOLS

Monitoring of road projects may attempt to answer a variety of questions pertinent to restoration program performance goals. These questions may attempt to compare the effectiveness of one treatment versus another, treatments in different geologic settings, or sediment losses of treatments versus non-treated areas. Customized study designs will be needed based on specific monitoring objectives. Depending on the objective, a sample of restoration project sites will be selected prior to treatment for subsequent monitoring following a high runoff event. Pre-selection of monitoring projects is preferred for gathering pre-implementation site data, thereby strengthening the ability to detect the response to restoration.

Currently, DFG requires a roads assessment before funding road projects. These assessments can serve as the foundation of information for post-stressing event effectiveness monitoring. Site inventory forms contained in CDFG Manual Chapter 9 include requirements for collection of pre-project information. This includes site description, age of road, road fill volume, culvert condition, unstable road reaches and landings, photopoints, current and future erosion potential estimates and priorities, and prescribed treatment approach. Assessments carried out under this methodology also include longitudinal profiles, geomorphic characteristics, vegetation descriptions, etc.

Additional information that would be useful to post-event assessment includes site scale maps of topography, existence of springs or seeps, and site-specific soils information such as existence of poorly drained soils and bedrock. Observations on type and density of trees and percent ground cover of herbaceous vegetation are also recommended.

METHODS

Quantitative protocols to describe the effectiveness of projects following stressing events are described below.

- Obtain pre-project data including project inventory, assessment and photographic data available for the selected monitoring sites.

- Obtain or map current geomorphic and hydrologic features of the road and adjacent hillslopes for each site. Maps should include erosion features, drainage structures, the stream network, and the location of all roads, skid trails, seeps and springs which are plotted on enlarged aerial photographs at a scale of 1:1200. Much of the general site attribute data will be available in GIS format from resource agencies.

- Conduct post-event sediment source inventories according to the methodology prescribed DFG manual Chapter 9, to map the location and volume of erosion. [For a detailed description of methods, see Chapter 9]. This inventory will include measurement of voids and material deposited downslope to calculate how much sediment entered the water column.

Additional data will be collected based on a site-specific study plan. Data will be collected for parameters according to the erosion processes specific to individual watersheds and treatment conditions. For example, in Madej's work (2000), hillslope position (upper, mid, or lower) and date of treatment were the greatest causal factors explaining erosion. Parameters and methods of quantifying these site-specific causal factors will be developed for each monitoring study.

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APPENDIX F: EFFECTIVENESS MONITORING AT THE WATERSHED SCALE

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INTRODUCTION

Until recently, most fish habitat restoration projects have been site-specific, focusing at the habitat unit or at most, the stream reach level (Elmore and Beschta 1987). Over the past few years, efforts to restore anadromous fish habitat have taken a different perspective. Restoration emphasis has shifted to improving watershed conditions mainly through remediation and prevention of upland erosion. This shift is reflected in project types funded by the DFG restoration grant program. Most funds are now allocated to erosion control treatments on rural roads. Monitoring the effectiveness of these projects is a complex task since they may involve relatively large areas and are only indirectly related to anadromous fish streams. To detect responses to this type of restoration, monitoring must be done at the site as well as at the watershed scale.

This appendix has three purposes: 1) to provide guidelines for the development of monitoring projects for effectiveness monitoring at the watershed scale; 2) to demonstrate the application of those guidelines by means of a proposed pilot study; and 3) to provide a proposal screening procedure that can be used by DFG to evaluate proposals for watershed-scale projects. The appendix focuses on road-related instream water quality improvement projects, but the strategy may be applied to other monitoring projects at this scale. Moreover, the proposal screening procedure, with modifications, may be useful for screening other types of monitoring proposals.

The appendix is divided into two sections presenting the guidelines and the pilot study. The proposal evaluation procedure is included as an attachment. A second attachment provides some tips on quality control and assurance. The proposed pilot study is developed to the point that it will actually be implemented for the purpose of protocol testing over the next winter. In addition to indicating a format and level of detail for a monitoring plan, it illustrates some of the constraints and opportunities associated with mounting a watershed scale restoration effectiveness monitoring project in the real world. The commitment and complexity involved with undertaking such a project should not be taken lightly either by funding agencies or by project applicants.

GUIDELINES FOR DEVELOPING A MONITORING PROJECT

General Rules

There are numerous things that should be considered in developing a plan for monitoring restoration effectiveness at the watershed scale. This discussion focuses primarily on design alternatives, protocol selection, and sampling methods. It is assumed that monitoring at the watershed scale will be accompanied by coordinated monitoring at other scales as well (site, stream or road reach) within the context of an integrated effectiveness monitoring approach.

There have been several experimental studies at the watershed scale that provide valuable insights into designing a restoration effectiveness monitoring plan. Monitoring to detect the effects of restoration is not fundamentally different than "monitoring" watershed responses to land use change. There have been classic studies of this type at several locations including Hubbard Brook (Likens et al. 1977), Coweta Hydrological Laboratory (Swank and Crossley

1988) and in California, Caspar Creek (Ziemer 1998). The methods for these types of studies are well documented (Molden and Cerny 1994). In addition, there are texts and manuals that can serve as guides for developing monitoring programs at the watershed scale (Haan et al. 1994; MacDonald et al. 1991). A monitoring program, especially at this scale, is more than data collection, and more than a source of information in the adaptive management cycle. Equivalent consideration must be given to collecting, managing, and reporting information (Mulder et al. 1999).

The first general rule to be used in developing a watershed-scale monitoring proposal is to think small. Natural systems are inherently dynamic and spatially heterogeneous. As a result, the ability at the watershed scale to detect change from restoration that is above and beyond this dynamic and heterogeneous background is difficult at best. Since heterogeneity and complexity increase with watershed size, the chances for change detection are greatest at the small (<1000 acres; preferably much less) watershed scale. This is the scale at which virtually all the experimental watershed studies have been done.

The second general rule is to think intensive, in terms of the proposed restoration. That is, unless the restoration effort encompasses a large proportion of a watershed or treats things that are dominating natural processes, it is unlikely that a response will be detected. Detection of impacts to instream water yield from timber harvest for example, may not be possible unless at least 20 percent of the watershed has been harvested (Stednick 1996). There may be a threshold of impact from restoration or from other activities, below which watershed scale monitoring may not be able to detect change (McDonald 1992).

The third general rule is to think long term. Existing studies that have successfully detected changes due to intensive uses at the small watershed scale have required years, sometimes decades of monitoring to see the whole picture. In relation to upland erosion control restoration projects, which are the main topic addressed here, time is required for collecting pre-project information, for short-term adjustments to treatments and for exposure to stressing climatic events. Nature doesn't always work well under funding cycle constraints.

Although not generally true, there will be cases in which local watershed groups or coalitions of landowners may wish to develop and implement restoration effectiveness monitoring plans. This was the situation, for example in the Feather River basin where the local Coordinated Resource Management group attempted to mount a monitoring program (Harris et al. 2000). Successful monitoring programs involving complex social relationships are the exception rather than the rule. If programs of this type, perhaps involving citizen monitoring, are to be funded by public agencies, there should be ample evidence that stakeholder commitment is adequate.

So, any serious proposal for monitoring restoration effectiveness at the watershed scale should be initially justified according to watershed size, intensity of treatments and long-term commitment. Passing these tests, additional considerations then come into play.

Monitoring Plan Contents

Generally the scope, complexity, and magnitude of the proposed monitoring will determine the level of effort required, which will vary on a case-by-case basis. A proposal submitted to DFG for funding should include, at a minimum, the information listed below. Though there is no "cookbook" for effectiveness monitoring, these requirements are applicable and necessary in most cases. They form the basis for the proposal evaluation procedure provided in Attachment A. That procedure requires responding to a series of questions and completing a summary checklist. At the present time, there are no definitive criteria in the DFG request for proposals by which either a project proposer or reviewer can prepare or evaluate proposals for restoration effectiveness monitoring at the watershed scale. Using this procedure will insure that proposals contain at least the minimum amount of information to warrant advancement to the next review stage. Due to the difficulty and complexity inherent in setting up a monitoring program, it is probable that few should be funded.

Minimum information requirements are:

- Clear feasible monitoring objectives (hypotheses) linked to restoration project objectives
- Description of watershed characteristics and condition
- Location maps for restoration treatments and proposed monitoring sites
- Description of available data
- Landowner or stakeholder commitment
- Site selection justification
- Coordination with other research and monitoring projects
- Restoration project(s) description
- Monitoring study design, including pre-project data collection, sampling strategy, protocol selection and description, and duration of program
- Field data collection including data collection methods, sampling locations and timeframe, and field data forms
- Data management and analysis
- Qualified staff available
- Quality control approach
- Cost estimate
- Description of equipment and instrumentation required
- Accessibility for the duration of the program
- Reporting

The proposed pilot study in the next section of this appendix indicates what we consider to be an appropriate level of detail for this information in a proposal.

Pilot Studies

In some cases, DFG will be asked to fund the pilot testing of a small watershed monitoring approach. Any serious long term monitoring project should probably have a pilot study before full implementation. Pilot projects can serve as a proving ground for new ideas or methods. They also offer opportunities to test whether the appropriate approaches are being taken, with less stress on budgets. They are used to refine and improve selected monitoring methods, indicators, sampling designs, or data evaluation techniques (Mulder et al. 1999). In the case of road and upland restoration projects, pilot watershed monitoring efforts can indicate the level of restoration that may be detectable in such monitoring programs. In addition, they provide examples of potential products from monitoring, such as databases and reports that will help cultivate the support (funding) and understanding required to make long-term monitoring successful. Ideally, pilot studies funded by DFG can evolve into long-term projects with funding from other sources.

Alternative Monitoring Designs

It is assumed that any proposal for monitoring at the watershed scale will include an integrated system of monitoring at the site, stream or road reach and watershed levels. Methods for monitoring at the site and stream reach scales are described in the body of this manual and in other appendices. Integrated monitoring is described in the pilot study, below. Focusing at the watershed scale, the concentration is on instream water quality sampling and analysis for effectiveness monitoring of restoration projects such as streambank stabilization and road improvement. There are numerous designs available for this type of monitoring. Sampling locations and study design alternatives include above and below project, before (pre-) and after (post-) project, and no project (control) and project (treatment) paired sampling schemes (Spooner et al. 1985). Each of these designs has its benefits and drawbacks. In the ideal monitoring program, these individual designs would be combined in the format of the experimental watershed approach (Moldan and Cerny 1994).

Above and Below

One option is to conduct water quality sampling and analysis above and below restoration projects. The assumption is that water quality at these two sampling sites should be similar. Any differences noted at the downstream site would be attributed to the restoration activities. Since the drainage area of the downstream location may be larger than the upstream location, discharge must be measured when each water quality sample is collected.

Before and After

A second monitoring design is sampling and analysis before and after project implementation. The assumption is that water quality before and after project implementation should be similar except for project effects. In many cases this assumption holds true but such a monitoring program can be confounded by stochastic events such as large infrequent storms, landslides, or fires that occur during one period of the monitoring program but not during the other.

Control and Treatment

In this design, watersheds are paired with one containing the treatment or project and one representing the control. The assumption in this design is that water quality conditions are similar in each watershed with the exception of the project. Matched pairs must have similar climate, soils, geology, vegetation, drainage area, and historical land use. If this match is not successful, monitoring results could falsely indicate the restoration project's impact on water quality.

Experimental Watershed

The most effective monitoring design would combine the above and below, before and after, and control/treatment designs in a comprehensive program. This design may be more appropriately considered a research design, thus the name experimental watershed approach. The underlying concept is that an experiment to determine land use effects on water quality is being conducted by collecting data before and after project implementation from within a treated and untreated watershed. This design accounts for differences that can occur before and after project implementation, as well as between the paired watersheds. The more comprehensive and complex the monitoring design, the more costly it is likely to be. Such is the case in this design, where the amount of staff salary, travel, and sampling and analysis expenses are increased. In all cases, the complexity and cost of a study design should be balanced with overall project objectives.

Parameter Selection and Methods

Our emphasis is on the reduction of impacts to aquatic habitats from sediment loading in streams and rivers. Sediment is transported to these water bodies by surface runoff and elevated stream flows when watersheds are primed or saturated. Commonly, the vehicles for sediment transport are roads, and the delivery mechanisms are culverts, inboard ditches, and gullies that ultimately connect road runoff to streams.

Transported sediment load has two components: suspended and bed load (Maidment 1994). For this discussion of parameter selection we focus on suspended load and parameters that can be feasibly measured through the monitoring designs discussed above. Bedload is difficult to measure, and is not applicable to upland erosion control on roads since most sediment originating from road-related surface erosion contributes to the suspended component. In some cases, bedload measurement may be warranted, but probably not within the context of a study of restoration effectiveness.

Measuring suspended load is done directly through analysis for Total Suspended Solids. This analytical method measures the sample concentration of suspended solids, which are a combination of inorganic (sediment) and organic solids. Because analysis for suspended solids is time consuming and requires laboratory facilities, indicator analytical methods for suspended solids have been developed that rely on the influence that these solids have on light penetration in water. These methods assess turbidity and visual water clarity. In addition to these options it is important to measure or estimate stream discharge to account for its influence on sediment transport.

Total Suspended Solids

Total suspended solids (TSS) is a parameter used to measure water quality as a concentration (weight of solids/volume of water; mg/L) of mineral and organic sediment. In general, it is assumed that most suspended solids are inorganic and therefore results from this analysis represent the concentration of suspended sediment. In some watersheds, this assumption may not be accurate and would require verification in a pilot program. TSS is determined by measuring the weight of dry solid material remaining after vacuum filtration of a known sample volume (50 to 100 mL). Samples are filtered through a 0.45-micron filter in accordance with standard protocols (Clesceri et al. 1998). Analytical laboratories provide this service for a fee. Instruments that collect these data automatically are also available.

Turbidity

Turbidity is the measurement of the amount of light that is scattered and absorbed as it passes through a water sample. It is measured with nephelometry methodology and recorded in nephelometric turbidity units (ntu) (MacDonald et al., 1991). The amount of light scattered or absorbed changes as a function of the size, shape, surface characteristics, and quantity of particles within the sample (Clifford et al. 1995; Gippel 1995). Samples are analyzed according to American Public Health Association protocols (Clesceri et al. 1998). Analytical laboratories provide this service for a fee or an easy to use turbidity meter can be purchased for several hundred dollars. Automatic turbidity recorders are available as well but are costly.

Water Clarity

Water clarity is typically measured in the stream column using a black and white disc known as a Secchi disc. The disc is lowered into the stream and the depth at which it disappears is recorded. In general, the greater the depth at which the disc is visible, the lower the concentration of total suspended solids is in the water. Transparency tubes are a recent adaptation of the Secchi disc (Sovell et al. 2000) in which a disc is attached to the bottom of a closed clear tube. The sampler pours water into a tube and the length of tube at which the disc is no longer visible is recorded. Several distributors of clarity tubes can provide the tubes for less than one hundred dollars each.

Streamflow

In addition to sampling and analysis of water quality parameters, it is necessary to measure streamflow at the time each water quality sample is collected. With streamflow data, water quality results can be normalized for flow thus allowing results from locations with different discharge amounts to be compared. Measuring streamflow or discharge is based on the principle that discharge (Q), or rate of flow, is the product of a cross-sectional area (A) of flowing water and its velocity (V), which is calculated Q=AV. It is usually expressed in terms of volume per unit time (e.g., cubic meters per second). Measuring stream discharge requires training but in general there are two approaches that can be used; area-velocity; and stage-discharge (Tate and Nader 1996).

The area-velocity approach represents discharge as the product of the area of water within a stream cross-section and the velocity at which that water is moving past that cross-section. It is important to account for the fact that water velocity varies across a stream channel with faster speeds at the surface and middle of the channel and slower speeds at the bottom and sides. Because of this variability stream channels are often divided into sections wherein respective cross-sectional area and velocity measurements are made and then summed to calculate the total streamflow. In cases where a streamflow meter is available, velocity can be measured not only at the surface but also throughout the water column.

The stage-discharge approach is based upon the relationship between stream stage and discharge at a fixed cross-section or permanent flume. This involves measuring stream water depth or stage and relating that depth to a predetermined rating curve of discharge as a function of stage. Rating curves are developed by attaching a staff gage at the determined location and making a series of stage height and discharge measurements at different flows to establish a relationship.

Sample Collection Techniques

Results from water quality sampling can be influenced by sampling techniques and their representation of stream conditions. The question here is how well does the collected sample represent water quality parameters throughout the water column? The assumption and hope when collecting water samples is that the water column is well mixed. This may or may not be true because of the variability in discharge across the stream cross-section. Two approaches to account for this variability in discharge and resulting water quality parameter values are depth integrated sampling and one-third rule.

Depth integrated sampling (Maidment 1993) involves a very systematic collection of a composite water quality sample. This composite sample consists of equal volumes of stream water collected at equal depths and distances across the stream channel. This method is time consuming but returns a sample representative of the variability in water quality parameters within the channel.

The one-third rule directs the sampler to collect the water quality sample in the center of the stream below the stream surface approximately one-third the maximum stream depth at the time of sampling. The assumption is that water at this point in the stream is the best mixed and provides an integrated representation of water quality.

Sample Timing and Frequency

In addition to design and parameter selection, the implementation of instream water quality monitoring for restoration effectiveness will need to have appropriate timing and sufficient frequency to account for the spatial and temporal variability of water quality parameters.

> Concentrations of sediment and other nonpoint source constituents in surface waters are variable at the storm event, seasonal (within year), and interannual (between year) time scales (Tate et al. 1999). For example, during a storm total suspended solid concentrations will increase and decrease in direct response to the rise and fall of stream flow. Over the duration of one season, total suspended solid concentrations will generally decrease. Differences in total suspended solid concentrations from one year to the next result from annual differences in rainfall. Higher rainfall years will have greater total suspended solid values in comparison to lower rainfall years.

This variability has important implications for successfully monitoring water quality. Incorrect conclusions will be made about total suspended solids, turbidity, and water clarity if the designed monitoring program does take this variability into account. Monitoring programs can achieve this by sampling before, during, and after storms, throughout the duration of the season, and across several years.

Grab Sampling versus Automated Instrumentation

Collection of water quality samples and measurement of stream discharge can be done by grab sampling or through automated instrumentation. In the former, monitoring staff make scheduled field visits to hand collect water samples and measure discharge. The primary cost for this approach is staff time and travel. The drawback to this approach is that samples are collected and measurements made only when staff can make field visits. This presents a problem when desired sampling conditions, such as during storms, are not capitalized upon. It can also introduce bias into the data from collection and measurements made by different staff. By comparison, data can be collected more frequently and consistently through the use of automated samplers and stage recorders. This instrumentation requires an initial outlay of funds to purchase the instruments and install the required flume or weir. In addition, staff time and travel costs are required to routinely visit the sampling stations, download data, and change sample bottles.

Duration of Monitoring

The duration of monitoring depends on a number of factors. Generally, watershed scale projects require several years of data collection to provide useful information on long-term trends. Some projects can be monitored at the same time from year to year; others can apply a pulsed monitoring approach (Bryant 1995). Those that require a stressing event will need a longer timeframe, since storm frequency cannot be reliably predicted. For example, measuring the effects of road improvement projects on instream water quality requires the occurrence of storm events, and therefore, a longer monitoring duration may be required for these project types. These issues should be considered in selecting a realistic timeframe in the study design phase.

CONCLUSIONS

Any proposed watershed monitoring program should meet the general rules of watershed size, intensity of restoration and time commitment previously described. The proposal should also contain the descriptive information listed above and explained further in Attachment A. Beyond that, a watershed scale monitoring program that is able to detect changes in water quality must account for the temporal and spatial variability of the monitored parameters. It must also take into account the other sources and factors influencing instream water quality within the watershed (Tate et al. 1999). Within these background conditions, the level of beneficial impact from any single restoration site may be below the monitoring program's level of detection. This does not mean the project failed in its intent, but that instream water quality monitoring at the watershed scale is not the most appropriate method to detect change and assess success or failure. This is why monitoring instream water quality at the watershed scale should be one component of an overall effectiveness monitoring program.

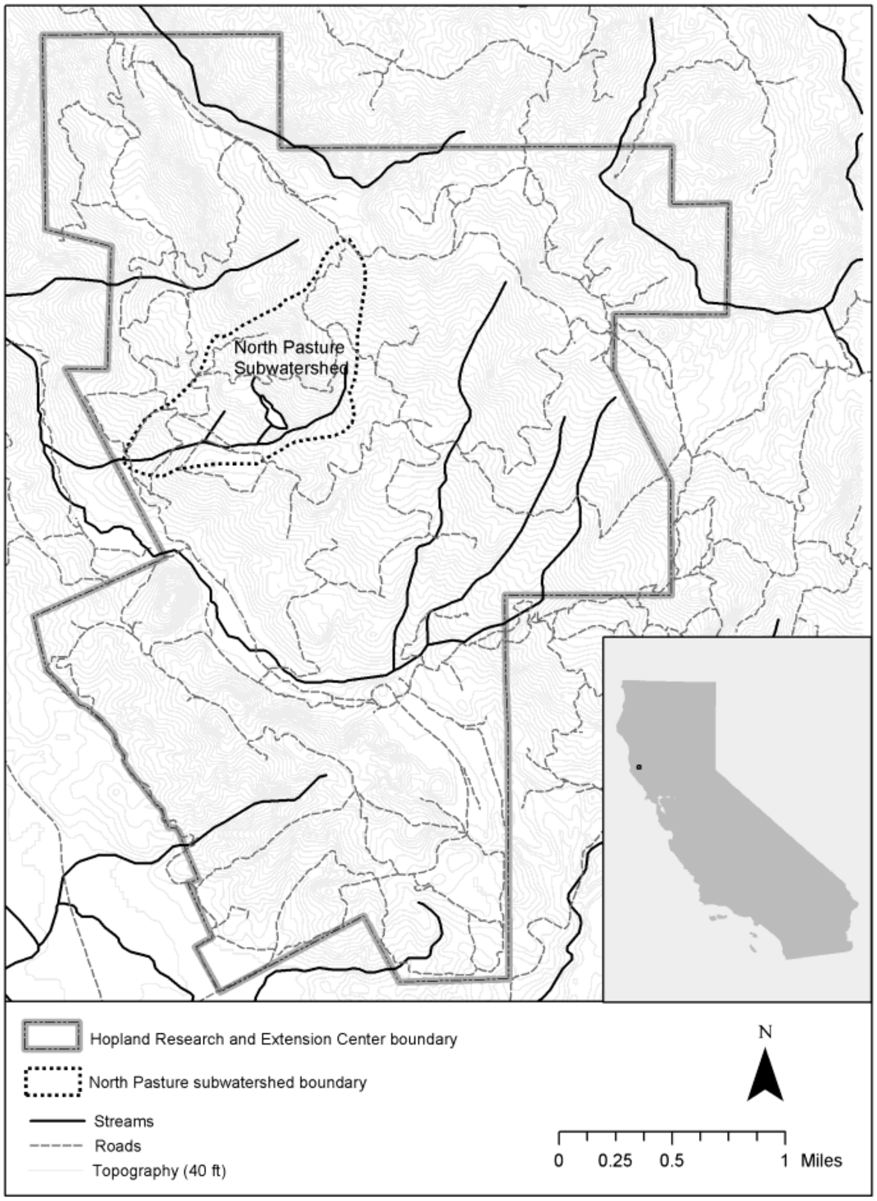
PROPOSED PILOT STUDY

Purpose

Parson's Creek watershed, which contains the University of California's Hopland Research and Extension Center (HREC), was selected for developing a restoration effectiveness monitoring program at the small watershed scale (Figure 1). The pilot study described here is intended to illustrate the informational requirements and level of detail associated with planning such a program. After field testing, it is hoped that the pilot study will evolve into a long term monitoring study.

Figure 1: Parsons Creek Subwatershed

Hopland Research and Extension Center



The following study design is intended to be used to guide development of similar programs in other watersheds. Though site-specific characteristics will dictate specific study design, many of the issues presented here will need to be addressed regardless of project location.

Watershed Selection Criteria

This proposal would institute a restoration effectiveness monitoring program within sub-watersheds of Parsons Creek totally contained within HREC. There are several compelling reasons for selecting HREC as a site for restoration effectiveness monitoring:

- There are a number of sub-watersheds available for study. These include some that are slated for intensive restoration as well as some that can serve as controls. Watershed sizes are commensurate with effectiveness monitoring objectives.

- HREC is under sole management by UC and is committed to research and extension purposes. Long-term access is ensured and highly qualified personnel are potentially available.

- Extensive historical and current watershed studies carried out in the basin will provide good baseline data for the monitoring program that is not available for other locations

HREC was awarded a grant from the DFG restoration program in 2001, and substantial road improvement is anticipated over the next few years. Watershed assessment and restoration plans have already been produced to prioritize restoration efforts, and the HREC can draw upon the significant resources of the University of California system to maintain a long-term program. The accessibility of the watershed provides a unique real world opportunity for agency staff and private landowners to observe the effects of road restoration on water quality and flow. These factors make the watershed an attractive candidate for long-term monitoring.

Watershed Description and Condition

Parsons Creek watershed (PCW) is a fourth or fifth order tributary to the Russian River located approximately five miles east of Hopland, California in Mendocino County. Watershed vegetation cover consists primarily of montane hardwood (41 percent) and grass/oak savanna (43 percent), with smaller proportions of chaparral (9 percent), and developed areas (1 percent) (PWA 2001). Stream flow varies seasonally: winter flows have been estimated at several hundred cubic feet per second, while summer flow may be intermittent from reach to reach. The lower reaches of Parsons Creek historically supported a winter run of steelhead trout, which has been dramatically reduced in the last several decades, according to local residents.

HREC manages 3,437 acres of the PCW or approximately 63 percent of the watershed. The Center's educational mission spans animal science, rangeland management, wildlife, plant science, entomology, and public health. The University obtained the property in 1951, and in the past, it has been operated as an agricultural field station focused predominantly on sheep ranching. Historically, several management activities have negatively affected Parsons Creek, including riparian grazing, ranch-road systems, gravel extraction, channelization, and water draw down for irrigation. Most of the PCW was originally operated as private ranches and was managed for livestock production prior to acquisition by HREC. Current land uses include livestock grazing (both cattle and sheep), a limited amount of agriculture, and surface and ground water removal for domestic and agricultural uses.

Instream Conditions

Much of Parsons Creek is currently in a degraded condition, providing poor habitat for fish. Erosion and sediment transport rates are high, streambanks are unstable in many locations, riparian cover is minimal or lacking along much of the creek, and as mentioned above, the steelhead run has been dramatically reduced. HREC's primary goals for restoration include reduction of sediment in the water column, reduced rates of bank erosion, and the restoration of healthy riparian vegetation and fish habitat. Since it is believed that roads are a major cause of erosion in the watershed, monitoring will focus on evaluating changes in road surface erosion and stream discharge following implementation of road treatments, as discussed below.

Road and Upland Conditions

Since the early 1900's, much of the chaparral and forested areas of the watershed have been converted to pasture, to increase forage production for grazing. A limited road system existed prior to 1942, mainly on the lower portions of the watershed. By 1952, ranch roads had been extended to the upper reaches of the watershed, circling it entirely.

HREC manages approximately 36 miles of road within the PCW, including some along the main stem and several tributaries. All roads and stream crossings have been mapped and inventoried for potential sediment delivery to the channel. Road surface drainage problems were also identified where long stretches of road or ditch deliver fine sediments to stream channels. Based on the findings, 56 sites are proposed for treatment with DFG funds. These sites include 37 stream crossings, 2 potential landslides, and 17 "other" sites, that include gullies, culverts, and swales or springs. These sites were identified as having a high, high-moderate, or moderate risk of future sediment delivery to the channel. It has been estimated that 9.2 miles (25 percent) of the roads managed by the HREC currently deliver sediment and runoff directly to streams (PWA 2001).

Concentrated road surface runoff can generate fine sediment, which can negatively impact general stream health and fish habitat (PWA 2001). Significant erosion can occur due to undersized culverts and poor culvert installation. Undersized culverts can be plugged with debris causing flow to overtop the road and erode stream-crossing fill, or flow can be diverted down the road to create hillslope gullies. Poorly installed culverts can cause major gully erosion below the outlet. Twenty-six out of the 37 culverted stream crossings have a moderate to high plugging potential (PWA 2001). Most are scheduled to receive restoration treatment.

The proposed monitoring program will enable HREC to measure the effect of intensive restoration conducted on the station's road network to reduce the delivery of sediment to fish-bearing streams from road surfaces, potential landslides, and stream crossings.

Historic Data

A series of watershed demonstration studies were undertaken at HREC from the 1950's to the present in areas ranging from 30-210 acres (Dahlgren et al., 2002). A substantial database from these studies is available for some parts of the watershed. Initial watershed studies focused on predicting the effects of vegetation conversion from oak-woodland to grassland on watershed-scale water yields, soil stability and erosion (Pitt et al. 1978). Vegetation, stream flow and sediment data were collected for over a decade following conversion. More recently, beginning in 1998, a long-term watershed-scale study was launched focussing on fire and grazing management effects on vegetation, hydrology, nutrient cycling and water quality in seven new experimental watersheds at HREC (Lewis et al. 2002). To date, four years of baseline data have been collected to calibrate selected paired watersheds with two vegetation types. Stream flow and water quality are monitored at flumes installed at the outlet of each watershed. Grazing and prescribed burning treatments will be implemented over the next three years and effects will be monitored. In addition, stream flow and water quality have been monitored since 1998 on Parsons Creek, which "nests" the small experimental watershed studies in a larger watershed context. HREC has also developed and maintains a Geographical Information System (GIS), which contains an extensive number of data layers that will be useful in the course of this project.

Field Testing Strategy

The general objectives of the proposed monitoring program at HREC are to evaluate the effectiveness of upslope restoration practices (primarily road storm-proofing through the practices of stream crossing upgrading, road drainage improvements and gully control) and to detect near-site and downstream changes in fine sediment concentrations, water quality (turbidity) and discharge in receiving waters due to implementation of these upland restoration treatments.

There are several potential constraints to meeting these monitoring objectives at Hopland. The primary constraint is the paucity of pre-treatment data, especially in regards to water quality and flow variables. Physical measurements of site-specific effectiveness and documentation of reduced risk to stream crossings, reduced connectivity of road drainage with the natural drainage network and reduced gully erosion are likely to have the greatest chance for definitive monitoring results. However, due to the timing of the restoration treatments and monitoring activities at HREC it may not be possible to causally link changes in instream water quality or discharge to the upslope restoration treatments.

In order to directly measure changes in instream conditions that are attributable to the restoration treatments there would need to be one or more road segments with documented surface erosion contributions that would be left untreated for long enough to gather pre-treatment data. All road segments with significant road surface erosion potential are slated for treatment this year.

Pre-treatment data do exist for certain parameters on the station. As mentioned previously there are four years of discharge, TSS and turbidity data for grazed and ungrazed watersheds. None of the monitored watersheds have roads in them and none are proposed for upland restoration treatment. The potential value of these data for the restoration monitoring effort will be determined during the pilot phase.

There are also pre-treatment data collected by Pacific Watershed Associates (PWA). These include a quantification of the length of road that is hydrologically connected to stream channels and the location, drainage area and approximate volumes of road related gullies. These data provide a valuable basis for post-project monitoring and many of the original measurements can likely be supplemented prior to restoration activities. It would be possible to measure the length of hydrologically connected roads after treatment and compare that to PWA's pre-treatment data. It would also be possible to monitor known gullies for changes in size after removal of their source water.

Even in the absence of pre-treatment TSS, turbidity and discharge data it will still be possible to infer some conclusions regarding both the magnitude and duration of impacts associated with road upgrading restoration practices, as well as the effectiveness of the restoration measures themselves. For example, it would be possible to measure flow rate and volumes from connected road reaches in adjacent settings and to apply these runoff and erosion rates to the treated reaches. It will be possible to measure flow and sediment discharges from treated road reaches, cross drain outfalls and gully systems, whose pre- and post-treatment drainage areas have been measured. It would also be possible to compare measured instream conditions above and below the treated road reaches to historical data on instream conditions above and below *un*treated road reaches. Finally, there may be historical studies on the HREC that contain data on the effects of roads on instream TSS or turbidity levels.

Sampling Design

Given the lack of pre-treatment data, the best available study design includes three main elements: 1) monitoring of implementation and effectiveness performance of specific restoration practices; 2) direct sampling of discharge, TSS and turbidity levels at the delivery points to the stream for all inboard ditches, ditch relief culverts, gullies and other points of connectivity between the road system and the stream channel network; and 3) instream sampling above and below treated road reaches at existing stream crossing culverts. In spite of the lack of pre-treatment water quality data for the natural stream system, the water quantity/quality data from the road reach discharge points can be compared to the total discharge, turbidity and TSS of the receiving stream to evaluate the effect that the road drainage is having on instream conditions. Finally, water quantity/quality can be sampled at two or more locations downstream of the treatment area to determine the effect that natural erosion sources have on instream conditions. The following null hypotheses will be tested using this design:

Ho1 – The absolute turbidity levels and relative (to discharge) TSS levels from road drainage are not significantly higher than the levels measured in the receiving stream.

Ho2 – Turbidity and TSS levels are not significantly different between instream samples taken above and below discharge points for road generated runoff.

Ho3 - The absolute turbidity levels and relative (to discharge) TSS levels observed at the downstream location are not significantly higher than levels observed at the 'below' stations.

The design would facilitate analysis of upland restoration techniques and their effect on road related runoff exclusive of and relative to instream conditions. Even if instream samples above and below treated reaches do not show any significant differences, it would still be possible to quantify the effects of the road related runoff in terms of discharge and water quality. The tradeoff is that it will require more work to sample a variety of road discharge points in addition to the instream samples.

A potentially confounding factor is the presence of non-management related erosion in the stream channel, which may be occurring along with the road related erosion. A survey of the stream channel within the influence zone of the road will be conducted to document and quantify all non-management related sediment sources. The data on non-management related sediment sources would be useful for interpreting results and evaluating the utility of the study design. A stream survey would document the presence of non-management related active sediment sources such as surface erosion, bank erosion, slumps, earthflows, and gullies.

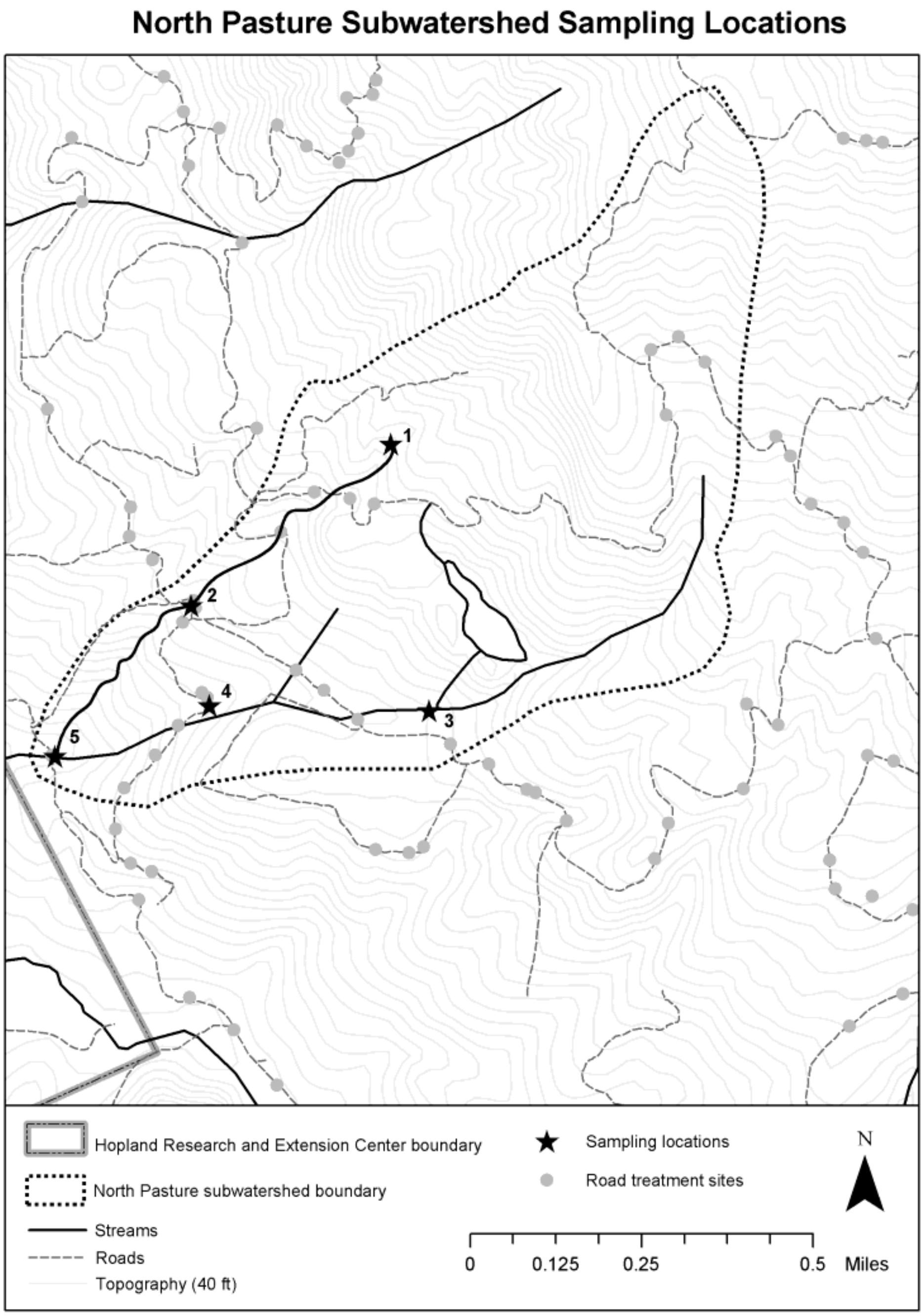
Sampling Sites

Two stream crossings and adjacent (contributing) road reaches have been proposed for restoration implementation and monitoring. The treatments consist of stream crossing upgrading (culvert upsizing, elimination of diversion potential, treatment of plugging potential) and disconnecting road runoff from the natural stream channels to the extent that is feasible. Road surface treatments may consist of installation of additional ditch relief culverts, rolling dips and road shaping to disperse road surface runoff and to disconnect and prevent the road surface, ditch and gully systems from delivering runoff and fine sediment to the stream channel system.

Each road treatment site will be monitored for the hydrologic, erosion and sediment delivery parameters listed in Table 1. To the extent possible, sediment collection basins, runoff basins/troughs, erosion monitoring devices and sediment delivery installations will be situated at locations where unambiguous conclusions can be derived from the resulting data. If restoration treatments have not been implemented at these sites prior to installation of monitoring devices (work is currently underway along numerous roads at the Hopland Field Station), as much pre-treatment data will be collected as is possible.

Five water quality sampling sites have been selected within the affected stream channel system of the North Pasture sub-watersheds; two samples each on two unnamed tributaries and one sample below the confluence of these tributaries (see Figure 2). No sampling is proposed in Parsons Creek. The upstream sites on each tributary (sites 1 and 3) are above any road restoration treatment sites and will be unaffected by restoration activities. The downstream sites (sites 2 and 4) are located at stream crossing culverts that receive inboard ditch water from the adjacent road segments. The stream reaches between the 'above' sample sites and the 'below' sample sites receive road runoff at multiple points along their length and may also be subject to natural erosion, which will need to be assessed. The lowermost site (site 5), downstream of the confluence of the tributaries, receives water from the treated road reaches and stream channel below the road reaches where natural erosion may also be occurring.

Figure 2: Monitoring Sampling Stations in North Pasture Subwatershed



Protocols

One set of protocols will be used to monitor water and sediment runoff from the road system and within the natural stream channel network. A second set of protocols will be used to document and monitor the implementation and effectiveness of the upland restoration treatments to the road system.

Protocols for monitoring the specific restoration techniques are listed in Table 1. These are the basic treatments, and their associated monitoring techniques, that are designed to reduce water and sediment delivery from the road network, and to reduce the risk of road and stream crossing failure following the completion of road upgrading. The study plan calls for pre-treatment measurements of the current hydrologic connectivity between the road system and the natural drainage network (where restoration treatments have not yet been performed). In addition, monitoring will be initiated to document future enlargement of rill systems, gullies and other erosional features that are currently within the "connected" sub-watersheds that are draining to the stream network.

Table 1: Proposed Monitoring of Upland Restoration Treatments

Project Type	Objective	Parameter	Protocol
Road and Upland Restoration (control of erosion and sediment delivery)	1. Measure changes in connectivity between road and stream network	Connectivity length and surface area of contributing road reaches	Map and characterize sub-watersheds draining to stream from disturbed road prism
	2. Document changes to road drainage pattern	Drainage density	Map connectivity paths before and after treatment; calculate drainage densities
	3. Document changes to the risk and magnitude of stream crossing failure	Culvert discharge capacity, plug potential, diversion potential; crossing fill volume	Design capacity calculations; installation evaluation
	4. Detect changes in fine sediment discharge from road	TSS, bedload	Grab samples and sample filtration; settling basins and sediment traps
	5. Detect changes in gully erosion and downcutting	Gully downcutting, headcut migration and widening	Photography; erosion pins and monument stakes in selected active gullies
	6. Detect changes in water quantity from road	Discharge and flow volume	Runoff basins and collection troughs; flow measurements
	7. Detect changes in water quality from road	Turbidity	Grab samples, metered readings

The protocols for monitoring runoff and sediment delivered from the road system to the stream, as well as runoff and sediment discharged through the stream channel network are interrelated and will use similar equipment and methods (see Table 2). The basic study plan is to take runoff measurements and to collect grab samples from discharge points along the road and from the natural stream channel both above and below the discharge points for the treated road reaches. These samples will be analyzed for TSS and turbidity at an offsite laboratory. Within the stream system, discharge would be measured at the nearest culvert each time a grab sample was collected and a nearby staff gage would be read to provide a correlative record of gage height and discharge. Grab samples would be collected before, during, and after storm events to capture the effects of within-storm hysteresis. Flow volumes and sediment discharges will be similarly monitored at points of connectivity along the road using techniques appropriate for the expected discharge of runoff and sediment. This may entail the use of small weirs, sediment collection basins, grab sampling, or other techniques. At least three storm events would be sampled in the early, mid, and late part of the rainy season to capture the effect of seasonal variability. During the pilot phase, staff from the UC Monitoring team would be responsible for sample collection and shipping of samples to a laboratory for analysis. The study should be conducted for several years after successful completion of the pilot phase, or at least until a stressing event (>10 year recurrence interval storm) is experienced.

Table 2: Proposed Monitoring at Stream Sampling Stations

Project Type	Objective	Parameter	Protocol
Road and Upland Restoration (control of erosion and sediment delivery)	1. Detect changes in fine sediment concentration	TSS	Grab samples and sample filtration
	2. Detect changes in water quality	Turbidity	Grab samples, metered readings
	3. Detect changes in flow	Stream discharge	Area-velocity or stage-discharge method

Timing

Monitoring and measurements of connectivity and installation of the hydrologic, erosion and sediment delivery monitoring stations at the restoration work sites can begin immediately. The study team will monitor weather forecasts during the winter sampling season. One day prior to when a storm is predicted to occur the team will gather field supplies and travel to the Hopland Field station. The team will collect water quality and discharge samples at each sampling station prior to the onset of the storm, during the storm and after the storm has passed to capture in as many points along the hydrograph as possible.

In subsequent years after the pilot phase, data collection will likely be done by HREC staff living on or near the station. That will facilitate rapid response to sampling opportunities.

Collection of Water Quality Samples

Water quality sampling is performed in accordance with protocols developed by the USGS (Pickering 1976). A brief summary description of equipment and methods is provided below.

Turbidity and TSS will be grab sampled at the selected sampling sites. This entails completely submersing a 500 ml/ one-quart clean, rinsed sample bottle into the flowing water. Sample bottle is filled until all air bubbles have been evacuated, then capped beneath the water.

All samples will be labeled with station name, date, time, gage height and technician name. At the end of the sample day all samples will be transported to the UC Davis water quality laboratory.

Measuring Discharge

If sediment and discharge measurements are collected at points of connectivity and cross drain outfalls along the road system (ditches, ditch relief culverts, gullies, etc) they will be measured using the most straightforward techniques (see Table 1). Most runoff along the road alignment is expected to occur during precipitation events and this is most accurately measured using buckets and other collection methods. Runoff and road-related sedimentation which occurs during periods when sampling crews are not present will be collected and measured utilizing impermeable basins and storage devices, where possible. These will be measured and emptied at regular and frequent intervals.

Stream discharge will be measured in cubic feet per second at each sample station using the stream crossing culvert as a weir. A staff gauge will be installed in each culvert and stage will be recorded each time a water quality sample is collected. Stage height values will be converted to discharge values using pre-existing engineering equations for each culvert diameter and slope. The accuracy of the equations may be checked using the area velocity method at each culvert.

The area-velocity method of measuring discharge would be used at non-culverted sampling stations.

Sample Size

Only one set of samples needs to be collected before and after each sampled storm. However during the storm, the more samples collected the better. The sampling team will sequentially collect water quality and discharge samples at each station for as many rotations as possible. The length of the storm, number of sample bottles, number of sample stations and size of the team will naturally limit the number of samples collected. The general goal is to collect a set of samples at the early, mid and late parts of the storm. If possible, more samples should be collected on the rising limb of the hydrograph rather than the falling limb, because most sediment is transported on the rising limb. For the road system, nearly all runoff and sediment delivery is expected to occur during periods of the most intense precipitation, and these events will be important to capture by on-site monitoring.

Equipment Needs

All equipment needed for sampling is either currently available or will be purchased during the pilot test phase. The sampling strategy focuses largely on manual data collection, so equipment needs are relatively limited**.** For the most part, equipment will be provided using the Principal

Investigator's state funds. When practical, sharing of HREC equipment and data will be requested to maximize efficiency. These decisions will be made with HREC field staff.

Maintenance and calibration requirements for equipment to implement this plan are minimal. Fiberglass measuring tapes are routinely checked for stretching or tearing. The hip chain (string machine) is checked against the fiberglass tape each time a spool of string is changed. Annual maintenance and calibration of turbidity and flow meters are needed and will be conducted.

Laboratory Analysis

Sediment (TSS) and turbidity grab samples will be analyzed at laboratory facilities located at UC Davis. The laboratory analyzes water quality samples from other ongoing projects at Hopland.

Staff and Training Needs

During the pilot field season commencing in winter, 2002-2003, UC will provide staff to conduct sampling under the existing contract with DFG. This will be a period for testing and refining sampling techniques. In subsequent years, additional funding will be sought to continue the project either from DFG or from other sources. The project has been approved by UC as a research project at HREC. This enables requests for HREC staff hours and facilities to conduct field sampling.

During the first field season, experienced field staff will conduct sampling. In future years there will a need to train staff in protocols. This training will be conducted by the UC team under the direction of the Principal Investigator.

Data Integration and Management

Data management during the pilot phase will be conducted by UC staff under the existing DFG contract. The data management system, including field forms, will be developed in the first few months of project implementation, concurrently with field sampling. An operational data management system will be created and delivered to HREC and DFG at the close of the pilot program.

Quality Assurance

Quality assurance (QA) procedures will be followed to ensure that data collection and analysis, and output reports are of high enough quality to meet project needs. The proposed field procedures and data collection are relatively simple, so a separate document is not required in this case. For a more complex project, preparation of a stand-alone quality control plan may be advisable recommended, as outlined in Attachment B.

Cost Estimate

At the close of the pilot phase, a cost estimate for full implementation of the monitoring program over a several year period will be developed. This may be a basis for future funding proposals.

Reporting

Project status reports will be provided to DFG and HREC on a quarterly basis. A full report of the pilot program, including recommendations, will be provided at the close of the sampling season (by June 2003).

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ATTACHMENT 1: PROPOSAL SCREENING PROCEDURE

Part 1: Preliminary Screening Questionnaire for Watershed Monitoring Proposals

This questionnaire is for use with the summary checklist provided for evaluating proposals to conduct restoration effectiveness monitoring at the watershed scale.

Clear feasible objectives:

- Does the proposal have a clear statement of objectives?
- Are these objectives feasible in relation to the proposed timeframe and funding?
- Is there a definite link between monitoring objectives and a scientific justification to expect results?
- Are the objectives directly related to selected protocols and proposed data analysis methods?
- Are the protocols and analysis methods proposed appropriate for addressing the objectives?

Watershed characteristics and condition:

- Is adequate information on the watershed available for designing and implementing the monitoring project?
- Does the proposal contain an adequate summary of that information or cite sources?
- Are the location, size, diversity and current condition of the watershed conducive to a successful monitoring project?
- Is the watershed potentially a good demonstration site?

Location maps:

- Is the information provided adequate to determine exactly where monitoring will occur?
- Are proposed or existing restoration sites adequately documented?

Historic data:

- Are historic data available that will facilitate either data collection or interpretation of results?

- In cases where restoration activities have already been implemented, are pre-project data available?

- Are there any historical events in the watershed that may necessitate overly complex data collection and analysis procedures?

Landowner or stakeholder commitment:

- Is there evidence that the landowner(s) will commit to long term monitoring?

- If applicable, were local landowners, appropriate government agencies, and technical experts involved in the development of the proposal?

Site selection justification:

- Is the study area of a size that is conducive to producing monitoring results?

- Is the area accessible for a long-term study?

- Is the intensity of proposed restoration sufficient to produce a significant change?

- What other factors make the area a good candidate for monitoring?

Coordination with other projects:

- Are there opportunities for coordinating this monitoring project with other ongoing studies in the watershed?

- Does the proposal exploit those opportunities?

- Is the proposed project redundant with other efforts?

Restoration scale and extent:

- Does the proposal provide convincing evidence that it will produce meaningful results given the type and extent of proposed restoration in the watershed?

- Is the restoration program of sufficient scale to create a monitoring response?

Detailed study design:

- Does the proposal contain adequate details on study design so that its feasibility can be assessed?

- What scientific input has there been to the study design?

Pre-project data collection:

- Does the project propose collection of pre-restoration implementation data?
- If so, how will that be accomplished?
- If not, what is the basis for the study design?

Sampling strategy:

- Is there a sampling strategy in the proposal?
- If not, who will prepare one and when?
- Is the proposed sampling strategy consistent with the study objectives?
- Is it feasible given funding and time constraints?
- Are the project sponsors capable of collecting the data or will others be doing the data collection?
- Is there evidence in the proposal that the sampling strategy is statistically sound?

Protocol selection and description:

- What sampling protocols are proposed?
- Are these consistent with adopted DFG protocols?
- If not, what is the rationale for choosing different protocols?
- Are protocols adequately described or cited?

Duration of program:

- Since the DFG grant program only provides funding for two years at the most, is there evidence that this program will continue (e.g., cost sharing, additional funding sources, etc.)?
- If a short-term program, is there reason to believe that meaningful results will be obtained?

Field data collection:

- Are field data collection procedures adequately described or cited?

- Are sampling locations and frequency documented?
- If standard DFG protocols will be used, then associated field data forms should also be used. If other protocols will be used, are field forms available or yet to be developed?

<u>Data management and analysis:</u>

- Is there an adequate description of how field data will be processed and archived?
- Is there a description of how the project sponsor will interact with DFG on data management?
- How will the monitoring data produced by this effort be made available to DFG?
- What analysis procedures are proposed?
- Will the project sponsors conduct analysis or retain others to do it?
- Are the monitoring objectives clearly related to the analysis methods?

<u>Qualified staff:</u>

- Is the proposed staff qualified to do the work?
- Is staff competent in all phases: study design, data collection, data management and analysis?
- What is the commitment of staff to the project beyond the initial grant period (<2 years)?

<u>Training requirements:</u>

- Are any staff training requirements specified?
- If so, how will training be conducted and who will do the training?
- How will skills be maintained over the life of the project in incumbent or new staff?

<u>QAQC:</u>

- Is quality control and assurance addressed in the proposal?
- If so, does it appear to be adequately covered?

- If not, will a quality control and assurance plan be prepared prior to project implementation? (DFG needs to develop standards for QAQC on monitoring projects.)

Cost estimate:

- Is the proposed budget commensurate with the proposed level of effort?

Equipment and instrumentation required:

- Does the proposal contain a list of required equipment or instruments?
- Are these presently in the possession of the project sponsor?
- If not, how will equipment or instruments be procured?

Reporting:

- Does the proposal specify a method for reporting results (in addition to reports otherwise required by the grant program)?
- How will results be disseminated?

Part 2: Summary Checklist

Preliminary Screening Checklist for Small Watershed Proposals

Checklist Criteria	**OK**	**More Detail**	**Absent**	**Notes**
Clear feasible objectives				
Watershed characteristics and condition				
Location maps				
Historic data				
Landowner or stakeholder commitment				
Site selection justification				
Coordination with other projects				
Restoration scale and extent				
Detailed study design:				
Pre-project data collection				
Sampling strategy				
Protocol selection and description				
Duration of program				
Field data collection:				
Data collection methods				
Sampling locations				
Sampling frequency and timing				
Field data forms				
Data management and analysis:				
Data storage and integration				
Analysis objectives				
Qualified staff available				
Training requirements				
Quality control plan (QAQC)				
Cost estimate				
Equipment and instrumentation required				
Reporting				
TOTAL =				

Proposals pass preliminary screening if 80 percent of the information is satisfactorily provided.

ATTACHMENT 2: GUIDELINES FOR QUALITY ASSURANCE

A Quality Assurance (QA) approach should be included in all monitoring proposals submitted for consideration. The purpose is to provide a quality management system that will guide collecting and evaluation of monitoring data. Oversight could include implementing QA project plans, QA management reviews, and QA reports (Mulder et al. 1999). A structured QA provides a process for identifying and meeting the needs and expectations of the end user. It also ensures that data collection programs provide and document high-quality data, and ensures that analyses of these data are repeatable and defensible. Data collection techniques, data management, analysis and interpretation form the cornerstone of a QA plan. These concepts are discussed more fully below.

Quality-system Specifications

A QA plan should list the specific activities contributing to project quality. This should include information on: study objectives; experimental design; procurement; measurement procedures; calibration procedures and frequency; training and certification requirements; preventative procedures; quality controls; corrective action; data collection, reduction, and verification; and data validation and reporting. Procedures for conducting accuracy (measurement-error) assessments for all monitoring data should be provided. All data analysis methods should be documented and tested.

The following format is commonly used to document quality control measures for studies funded with federal agency dollars (USDA 1996). The specific activities described above should be captured in this outline. The format serves as a template that can be used on most monitoring projects.

Quality Control Plan Outline

A. Introduction
    a. Goals and objectives
    b. Work scope overview
    c. Expected types of data
    d. Site information
B. Background and location
C. Data quality objectives
    a. Data uses
    b. Expected data quality
    c. Data quality indicators
    d. Data management checklist
    e. Assessment oversight
D. Sampling design
E. Sampling methods and procedures
    a. Field procedures
    b. Equipment
    c. Staffing
    d. Calibration and maintenance

e. Field sampling procedures

The level of effort required will be variable, depending upon the scope, complexity and magnitude of the proposed project. For small, focused projects, this information could be covered in the proposal along with the description of protocols. In a large complex project, a separate stand-alone document is probably necessary to document quality control measures. Requiring this information will greatly improve prospects that the monitoring will be implemented and that it will yield meaningful results. It also will strengthen the overall validity of a monitoring program.

Additional Considerations

Data Collection

Data collection represents the largest component of a monitoring program, usually employs the most staff, and is the most costly part. To insure that collected data meets project needs, the monitoring design is critical. A major goal of all monitoring programs should be to continually improve the quality and utility of data. This can be accomplished through periodic debriefings with field crews, review of the quality of data, reports from data analysts about the consistency and utility of the collected data, and feedback from DFG staff. Personnel responsible for collecting data over the long term should also be identified.

Data Management and Interpretation

The reporting of information has been a major problem in environmental monitoring. Two essential types of reports, data summaries and interpretive reports, should be provided to insure quality control standards are maintained. In addition, personnel required to support data summary and analysis activities should also be specified.

Data summaries are brief, comprehensive reports of essential data collected for the monitoring program. This report presents data in an organized and useful manner. Summaries should be prepared at least annually or as appropriate to the resource monitored. Preparing the summaries serves to motivate data collectors to process their data in a timely manner so that assessment and reporting needs can be met. They also provide a tangible product for which staff and DFG can be held accountable each year. Most importantly, data summaries are essential building blocks for preparing interpretive reports and for providing intermediate progress reports for assessing program objectives. Mulder et al. (1999) describe options for preparing data summary reports. Steps include quality check of the data, or data validation; data analysis, data presentation, and report preparation.

Interpretive reports present a synthesis of monitoring results and statements of their implications to management for each resource being monitored. The key task of interpretive reporting is to address the effectiveness monitoring questions by using all available data. The focus is on evaluating and interpreting the significance of trends emerging from data provided in the data summaries. This information is also critical to the adaptive management process; it will be used to change plans, direction or policies, and contribute to budgetary and other decisions that are needed. These reports are more analytical and comprehensive that data summaries. Considerable effort and planning are required to develop these reports, and they will require significant participation by knowledgeable agency scientists. Mulder et al. (1999) provide a process for preparing interpretive reports, including options for staffing, reporting frequency, and a strategy for future improvement.

Literature Cited:

USDA Environmental Protection Agency. 1996. *The Volunteer Monitor's Guide To Quality Assurance Project Plans.* Manual 68-C3-0303, 58p.

APPENDIX G: DATA MANAGEMENT

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DATA MANAGEMENT OVERVIEW

A major component of evaluating restoration project effectiveness is having easy access to project data. The data management system developed for restoration effectiveness monitoring both builds upon and enhances existing resources at the California Department of Fish and Game (CDFG), particularly the California Habitat Restoration Project Database (CHRPD), which contains data related to all CDFG restoration projects. However, very few projects have any monitoring data.

The Restoration Effectiveness Monitoring Data System (REMDS) will expand the CHRPD effort to include not only monitoring data, but also an online proposal submission form, reducing redundant data entry efforts, and an internet-based Geographic Information System that will provide a portal to restoration project information and make restoration monitoring data available in both spatial and non-spatial query formats (see Figure 1). This data management system will ultimately streamline the entire fishery restoration project process, from initial proposal submittal to data retrieval.

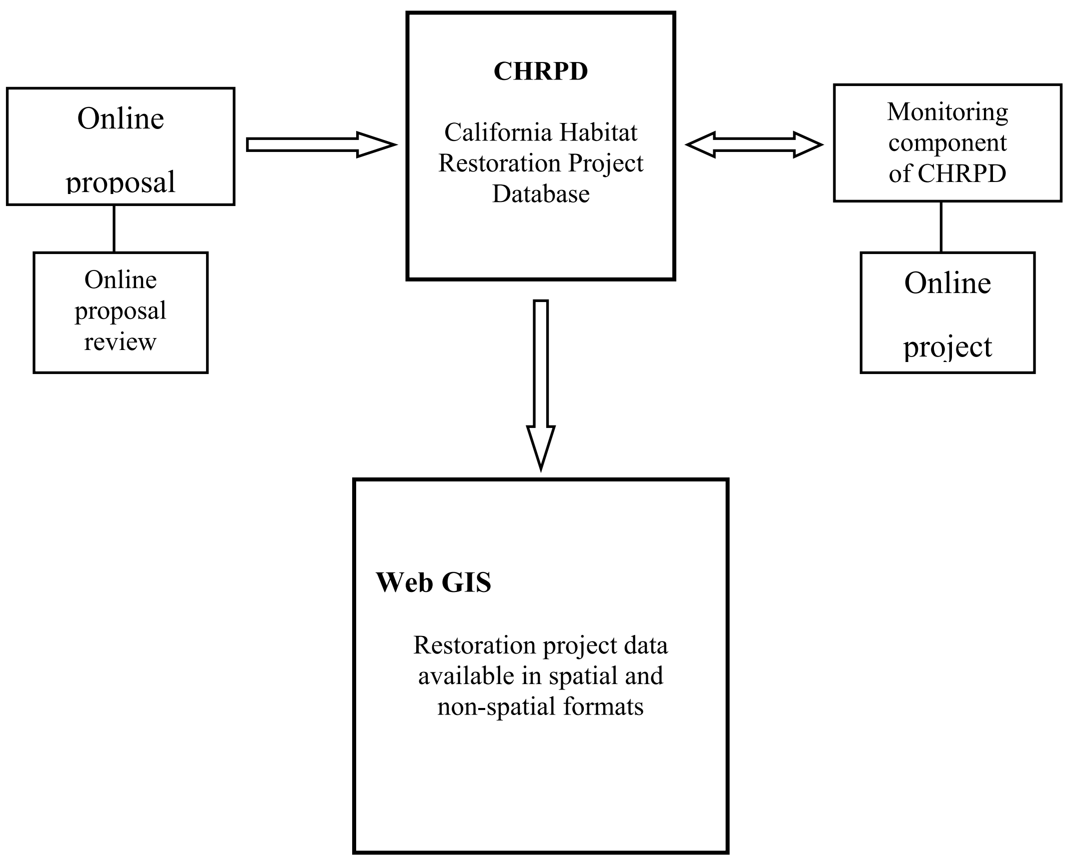

Figure 1. Conceptual diagram of the REMDS. Building upon existing resources, this data management system will improve access to CDFG restoration project data.

After a brief description of the CHRPD, this section is organized to provide an overview of the progression of information through the data management system (Figure 2), from the initial online proposal submission to data availability through the webGIS, as well as detailed descriptions of each of the system components.

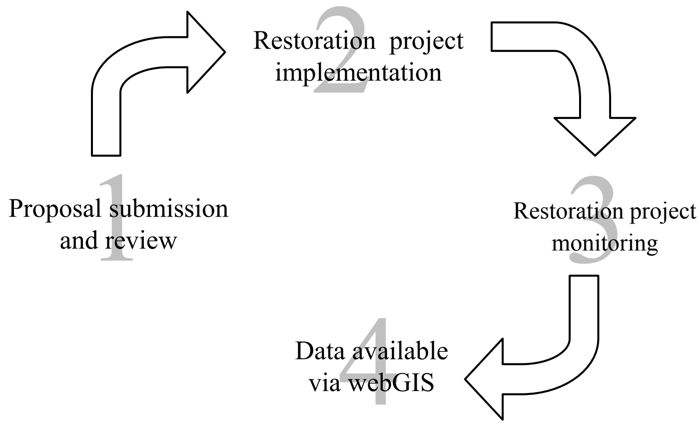

Figure 2. Schematic of the sequence through which data will progress through the REMDS.

California Habitat Restoration Project Database

The California Habitat Restoration Project Database (CHRPD) was created to manage anadromous fishery restoration project data for California, with an emphasis being placed on budgetary data. This database contains detailed information, including georeferenced project locations, for all completed and ongoing restoration projects funded by the CDFG Fisheries Restoration Grants Program. CHRPD tables include project goals, cost rates, and treatment details. Though this database does contain a monitoring table, very few projects have any monitoring data. The REMDS effort expands the current monitoring table to include several additional tables and forms for collecting and managing both physical and biological restoration monitoring data. Expanding the monitoring component of the CHRPD further adds to the value of the CHRPD, and minimizes the collection of duplicative administrative information.

Further information about the CHRPD (including database structure, data quality, and how project locations are obtained) can be obtained by contacting Robin Carlson, CHRPD Data Analyst/Programmer, CDFG ITB, 1807 13th Street #201, Sacramento, CA 95814, (916) 324-8298, rcarlson@dfg.ca.gov.

Online Proposal Submission

The online proposal submission form works directly with the tables contained in the CHRPD (Figure 3). When a restoration project proposal is submitted, project data will be added directly to the database and the project will be assigned a unique identification number. Though this Project ID number will be the main identifier for the project, another key field will be the project location, which will allow data to be accessed via a webGIS using geographic specifications, greatly enhancing the utility of the database. Proposal information can be added directly by the project proposer, or by CDFG staff. In addition to submitting proposals online, it is also possible to review proposals online using a password-protected interface that summarizes proposal information.

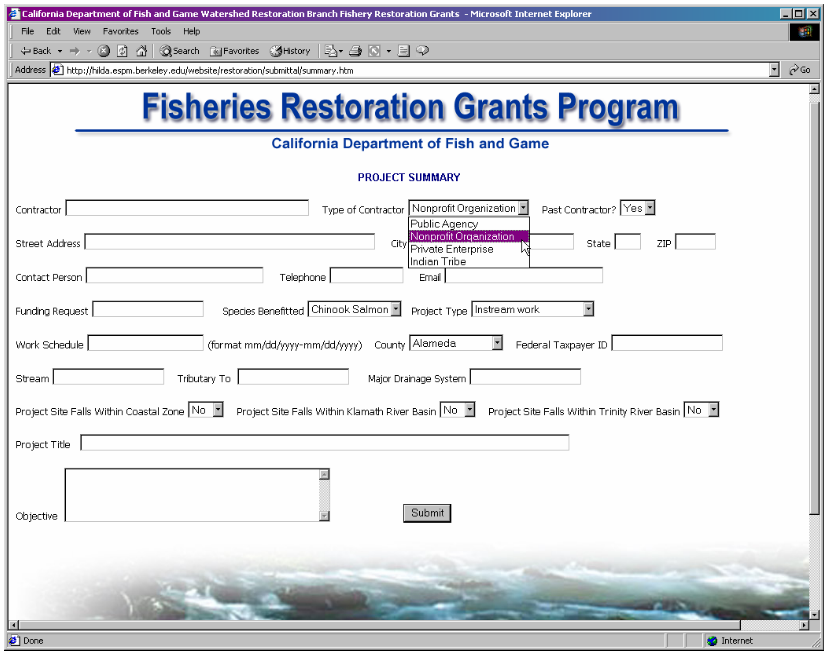

Figure 3. The first page of the online proposal submission form. The information entered here is equivalent to the "Project Summary Sheet" of the CDFG Fisheries Restoration Grants Program proposal, and will be added directly to the CHRPD, reducing redundant data entry. See Table 2 for further information on the linkages between the proposal and the online submission form.

Monitoring Data Updates

Once a project has been funded and implemented, it will be easy to access and update within the database using the unique Project ID assigned during the proposal process.

FIELD DATA COLLECTION AND ENTRY

Field data forms have been designed to directly interface with the monitoring section of the CHRPD (Figure 4). Data forms are included in each of the protocol descriptions (See Appendix B, C, D, and E). A data management system for data entry and management has been developed. The field data management system consists of a series of related Microsoft Access tables that link to the California Habitat Restoration Project Database (CHRPD). Project ID (ProjID), sometimes referred to as Contract Number, along with Work Location ID (WLID) are the primary keys to create this linkage. The combination of ProjID and WLID provide a unique reference to a specific location within a DFG project.

The fundamental design goal of Field Data Management system is to provide consistent and accurate data entry by mimicking the field forms as closely as possible, eliminating redundant data entry, presenting pick lists for specific entries, and providing real time error checking during data entry.

Field data forms and related database tables have three components; header information, field data, and codes. The header information includes components such as the Project ID and Work

Location ID, date, crew, stream name, and other identifying information. The field data itself is arranged in a single or multiple tables. Various codes are used to simplify and unify data entry.

Upon entering the Field Data Management System, the user will be requested to provide a Project ID by either typing the Project ID or searching for the correct ID using other identifying information. The user will then be able to switch to a form for data entry using a pick list matched to the field data forms. A provision for printing project specific field data forms is planned. Data entry will be controlled as much as possible through the use of pick lists and range checking.

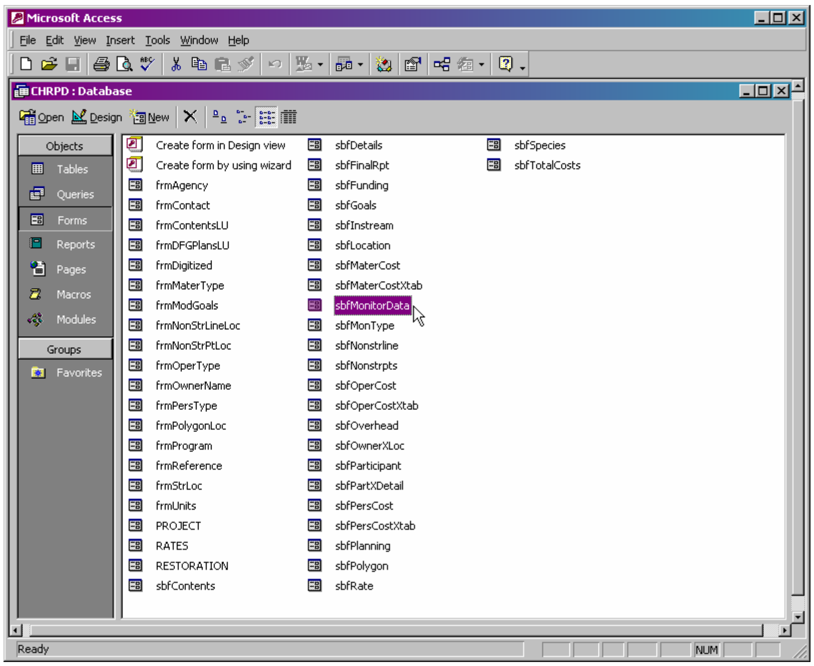

Figure 4. Monitoring data tables added to the CHRPD contain information for both biological and physical monitoring.

PROJECT DATA ACCESS

Data Availability

Restoration project monitoring data will be accessible via an interactive web-based Geographic Information System (GIS) (Figure 5). Data layers contained in this GIS include CalWater watershed boundaries, routed hydrography, and topographical information. This website will become the main portal to all information relating to monitoring restoration effectiveness, allowing users to search tabular data, and design spatially specific queries. For example, by searching tabular data, a user could determine all the projects that utilized fish ladders or how many projects took place in a particular year. Using geographically based queries, projects could be compiled by, for example, county, stream, or site. The following table provides a list of potential products and applications of this type of data:

Table 1. Compiling data into a central location will provide users with many potential products and applications.

Potential Products	Potential Applications
Statistics from user-driven queries, e.g., • Project data queries (type, date, etc.) • Location-based queries • Cost-based queries	Determine project effectiveness Restoration project prioritization Post-hoc data analysis Cost analysis
Maps	Adaptive management (adjust project design)

Restoration project locations will be taken directly from the CHRPD. Updates to the project location data will be made as projects are funded.

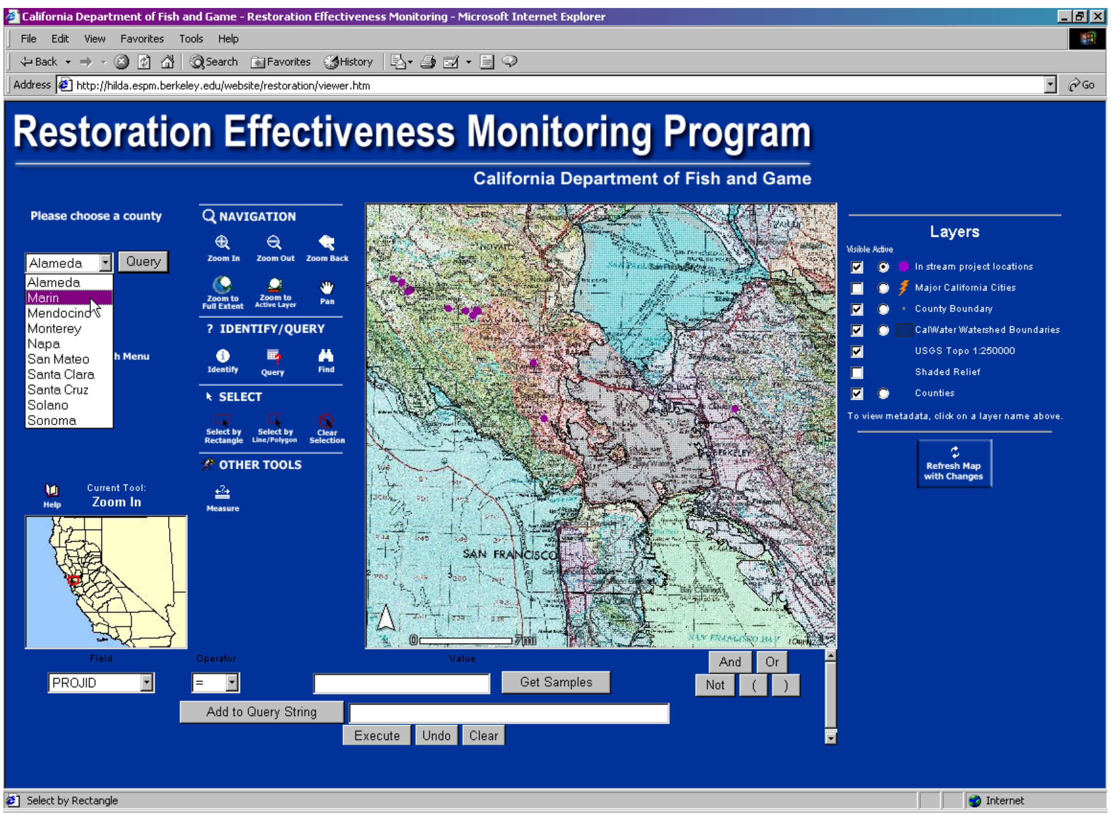

Figure 5. This webGIS interface will allow users to access both. See Table 3 for a list of data layers contained in the webGIS.

Table 2. Relationship between the DFG Fishery Restoration Grants proposal, data contained in the CHRPD, and the online proposal submission form. This is only information from the summary sheet required for proposals. This type of documentation is being created for the rest of the required proposal information and is a highly iterative process.

Proposal Summary Sheet and Visible Web Fields	CHRPD table	CHRPD and Web Field Names	Web page	Relationship to Project ID
Contractor	MitParticipant	ParticipantID	Summary	One
Type of Contractor	MitAgency	DFGCntrorType	Summary	One
Street Address	MitContact	Address1	Summary	One
City	MitContact	City	Summary	One
State	MitContact	StateID	Summary	One
Zip Code	MitContact	Zip	Summary	One
Contact Person	MitParticipant	ContactID	Summary	One
Telephone Number	MitContact	Phone	Summary	One
Email Address	MitContact	Email	Summary	One
Project Title	MitProject	ProjectName	Summary	One
Funding Request	DFGProposalReview	AmtReq	Summary	One
Objective	MitProject	Purpose	Summary	One
Species Benefitted	MitSpecies	SpeciesID	Summary	Many
Work Schedule	MitProject	TimeFrame	Summary	One
County	DFGCounties	County	Summary	Many
Stream	DFGStreams	DFGStream	Summary	Many
Tributary To	DFGTributaryTo	DFGTributaryTo	Summary	Many
Major Drainage System	DFGMajDrainSys	DFGMajDrainSys	Summary	Many
Past Contractor	MitAgency	PastCntror	Summary	One
Federal Taxpayer ID#	MitParticipant	FedTaxNum	Summary	One
Project Site Within Coastal Zone?	DFGProposalReview	CoastalZone	Summary	One
Project Site Within Klamath River Basin?	DFGProposalReview	KlamathBasin	Summary	One
Project Site Within Trinity River Basin?	DFGProposalReview	TrinityBasin	Summary	One
Project Type	DFGProposalReview	ProjTypeCode	Summary	One

Table 3. Data layers for webGIS.

ArcIMS data layers
Restoration project locations
Major cities
Major waterways
Hydrography
1:100K
1:24K
Basins
Watershed boundaries (HA)
CalVeg vegetation
Counties
DFG Regions
USGS 24K topo quad boundaries
Major roads
Federal, state, and regional parks
Shaded relief
Other
Hyperlinks to photos
Queries
Aggregated data

Part II.

Validation Monitoring of Watershed Restoration: Guidelines for California Coastal Watersheds

Report to the California Department of Fish and Game
Interagency Agreement No. P0010565

January 2003

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Executive Summary

The California Department of Fish and Game provides support for restoring watersheds in coastal regions of the state. The goal of this program is to assist in anadromous salmon and steelhead trout population recovery. Like other states in the Pacific Northwest, California expends millions of dollars annually in its efforts to restore coastal watersheds. To date, however, no validation monitoring protocols have been developed for assessing the response of salmon and steelhead trout to coastal watershed restoration.

The report on developing validation monitoring measures is the first step in developing protocols for assessing the response of salmon and steelhead trout to coastal watershed restoration. A companion report addresses effectiveness monitoring of physical processes.

Our report is organized in seven sections, along with an introduction. We begin by review existing biological monitoring programs that could serve as models to provide guidance in developing protocols. We then discuss program objectives and considerations for the design of a validation monitoring program.

The fourth section considers conceptual models of the biological responses to restoration actions. It is organized around stream and watershed features that are the subject of restoration actions. Topics include riparian condition, channel morphology, large woody debris, turbidity and sediment, and water quality, including nutrients, dissolved oxygen and water temperature. Conceptual models characterize the habitat feature, describe interactions with other habitat features, summarize biological responses, anthropogenic activities altering the habitat, restoration treatments and appropriate monitoring parameters.

This presentation of conceptual models is followed by descriptions of measures having potential value in validation monitoring. These measures are organized with consideration for appropriate spatial and temporal scales. A brief rational for using each is provided. Finally, quality assurance and control issues needed to insure data reliability are discussed.

We believe that a biological monitoring program to evaluate the effect of watershed restoration actions is both necessary and valuable to California. If properly designed and fully supported, it will provide guidance to watershed restoration as well as consistent information on the health of anadromous salmon and steelhead trout populations throughout coastal California. Proper design of the program can be achieved through rigorous scientific peer review. Support must come from various funding sources provided by the people of California.

Introduction

The goal of California's coastal watershed restoration program is to assist in the recovery of salmon and steelhead trout populations. The desire to restore salmon and steelhead trout populations in California watersheds represents a sweeping societal challenge. Achieving this goal will require a process to identify and guide restoration actions and the resources needed to carry them out. Ideally, the process of identifying and guiding restoration actions would; 1) identify the types of restoration actions needed to improve stream habitat for salmon and steelhead trout, 2) identify where restoration actions may be most effective, 3) determine how much restoration is required to bring about a population response and 4) implement procedures for evaluating the success of restoration actions in meeting objectives.

Watershed restoration may be defined as any action that starts or accelerates the recovery of a watershed toward its pre-disturbance trajectory (SER 20002). Trajectory here implies some trend in biological and physical composition, processes and functions. Although the ideal pre-disturbance trajectory may be interpreted as the historical condition, resetting watershed functions to the historical condition is often unrealistic and goals are more commonly defined in the context of existing reference conditions.

A restored watershed has been defined as one that "…contains sufficient biotic and abiotic resources to continue its development without further assistance of subsidy" (SER 2002). This definition does not mean the watershed has been returned to a pristine condition. Rather, it means the watershed has recovered enough to be resilient to periodic disturbances such as floods or fires and that it interacts with the surrounding ecosystem. Some characteristics of functioning or restored watersheds are that they, contain species assemblages similar to a reference watershed, have primarily indigenous species, contain all the functional groups needed for continued functioning and development, and have physical habitat adequate for sustaining naturally reproducing populations. Goals or end points for watershed restoration cannot be successfully established using intuition or seat-of-the-pants reasoning. Restoration goals should be developed with careful consideration of societal wishes and economic realities, and be guided by science.

In this report we describe protocols for validation monitoring to evaluate the outcome of restoration actions in meeting California coastal watershed restoration program objectives. Three monitoring activities are commonly recognized (ONRC 2000). *Implementation monitoring* is monitoring to document the fulfillment of contract obligations or compliance with regulations or laws. *Effectiveness monitoring* is monitoring to document trends in resource condition following a management action. Effectiveness monitoring is most often associated with physical or chemical processes and habitats. *Validation monitoring* is monitoring to document the response of biota to restoration actions. Validation monitoring, ideally, establishes cause-and-effect relationships between restoration actions and biota (ONRC 2000). However, lack of pre-project monitoring data or inadequate replication limits the ability of validation monitoring in establishing cause-and-effect relationships. Validation monitoring differs from implementation and effectiveness monitoring in that it is primarily concerned with the response of biota, as opposed to physical habitats or processes.

This report presents recommendations for validation monitoring protocols intended to detect responses of salmon and steelhead trout to watershed restoration actions. The question guiding our selection of protocols was:

What measurements are both practical and sensitive enough to detect a response by salmon and steelhead trout to restoration actions?

Because of this, protocols recommended in this report are not comprehensive. Rather, our protocol selection was guided by the watershed restoration program goal of restoring salmon and steelhead trout, with consideration of the varied types of restoration actions. It is focused on fish, although other the response of other biota have been considered.

VALIDATION MONITORING OBJECTIVES

The objective of the validation monitoring program we propose for adoption by the California Department of Fish and Game for coastal watershed restoration is to evaluate the success of restoration actions in meeting goals for salmon and steelhead trout recovery. We view meeting this objective to be a two-tiered process. The first tier addresses the general success of a particular restoration action (e.g. road decommissioning, riparian management, placement of large woody debris in a stream) in recovering or enhancing salmon. The second tier addresses whether the suite of restoration actions in a particular watershed are leading to salmon recovery. Using a medical analogy, tier one is comparable to asking if a particular treatment is effective in treating a health problem while tier two is comparable to asking if a particular patient recovered from the health problem, given the treatment received.

Addressing the first tier requires experimentation, and likely iterative experiments with varying factors and levels of treatment, in a design that incorporates basic principles of replication, randomization, and blocking. Common with all experimental designs, the outline of steps that should be taken include: 1) recognition of and statement of the problem; 2) choice of factors and levels; 3) selection of the response variable; 4) choice of experimental design; 5) performing the experiment; 6) data analysis, including analysis of practical as well as statistical significance; and 7) conclusions and recommendations (Montgomery 2000). It is only at this tier that cause and effect relationships between restoration and salmon response can be inferred, and that data can be obtained appropriate for adaptive management. Addressing first tier objectives will require a level of effort and expertise many individual restoration contractors do not possess. Instead, this effort should be met or at least coordinated by California Department of Fish and Game staff.

Addressing the second tier objective does not require experimentation, but merely monitoring to determine if the symptoms are alleviated. It should go without saying that the symptoms should be known beforehand, for the particular watershed receiving a restoration treatment, and that a reasonable basis exists for the selection of a treatment type. A road decommissioning project, for example, should not be undertaken just because of a general understanding that minimizing sediment inputs to a stream is a good idea, but because of evidence that: 1) the road in question is supplying a significant proportion of the sediments to a stream; 2) sediment in the stream is adversely affecting redd development, egg/larval survival, and/or juvenile growth or otherwise limiting the salmon population; and 3) other factors that might prevent salmon recovery are not operating (e.g. migration barriers, food limitation). In addition, restoration targets for salmon recovery need to be established that would allow evaluation of restoration success. These should be presumably based upon an estimate of the innate carrying capacity of the stream to support salmon, coupled with information on the size of the metapopulation available to re-populate the stream. Burnett et al. (2002) have suggested that intrinsic potential of a stream to support coho salmon, for example, can be assessed as a function of channel gradient, valley constraint, and mean annual discharge. Inasmuch as the restoration projects are being undertaken specifically to recover or enhance salmon and steelhead trout, numbers of these fish or other measures of their performance must be monitored. But because the timeframe for evaluation of restoration success in recovering salmon may be very long – in the realm of a decade or longer - owing to the long life span of anadromous salmon and large natural variability in salmon population abundance and dependant on the specific type of restoration treatment adopted, supplemental monitoring may be useful to suggest that recovery is on-track. Response variables chosen for monitoring should have a known relationship with salmon performance (e.g. characterization of prey availability), or should be attributes that describe ecosystem integrity (e.g. species assemblages of algae or invertebrates similar to a reference watershed supporting healthy salmon populations, or functional group composition).

VALIDATION MONITORING PROGRAM DESIGN CONSIDERATIONS

Any monitoring program intended to detect a response from salmon and steelhead to restoration actions, or other management actions, must incorporate elements of sound science. Scientific elements to incorporate in a monitoring program are the spatial and temporal scale of samples, replication, and power of the data to detect change.

Sample locations for the monitoring must be drawn from an area that is representative of the area of interest. If sample locations are not representative, results from the monitoring program cannot be used to make inferences to a broader area (e.g. watershed or region). One approach to monitoring is to select sites representative of broader areas, such as U.S. Geological Survey, National Water Quality Assessment (NAWQA) sites. NAWQA sampling sites are fixed and sampled at regular intervals. Another approach has been to completely randomize the process of selecting monitoring sampling sites. The U.S. Environmental Protection Agency has adopted this randomized approach in their Environmental Mapping and Assessment Program (EMAP). Alternatively, a monitoring program can incorporate both fixed and randomized sampling locations. The state of Oregon has adopted this latter approach. To incorporate both fixed and randomized sampling elements into their monitoring program, the Oregon Department of Fish and Wildlife has adopted a rotating panel design guided by the life history of coho salmon. In this rotating panel sampling design, all sampling sites are randomly selected and a proportion are fixed, or sampled each year. A proportion of other sites are sampled every 3 years, every 6 years or every 9 years. It appears that a rotating panel design could allow the flexibility to address the response of salmon and steelhead trout in specific watersheds or over entire regions.

The temporal scale of monitoring includes two elements, the frequency of sampling and the duration of sampling. In validation monitoring, the frequency of sampling is often dictated by the life history of the organism(s) being sampled. However, sampling that requires only annual or less frequent visits are more feasible than sampling requiring more frequent visits. The primary consideration in establishing a duration of sampling is the expected time required to detect a response by biota to the restoration action. This may vary from weeks or months for algae and macroinvertebrates to years or decades for salmon and steelhead trout populations.

Replicated sampling provides the underpinnings for precision and accuracy of results. Replication applies to both individual restoration actions and to samples collected at each location. For example, the ability to detect a response by salmon and steelhead trout to road removal would be greater if 5 projects were evaluated than if only 1 or 2 were evaluated. Similarly, the ability to detect biological responses increases, to a point, with number of replicate samples. In monitoring, sample replication is often provided by duration of sampling. That is, each successive year of sampling adds to the replication. Power analysis should be conducted on preliminary sampling data to determine the number of replicate sites, samples or years required to detect change at the level of precision desired.

The power of a statistical test is the probability that it will yield statistically significant result. Power is a probability value and takes on a number between 0 and 1, sometimes expressed as a percentage (0 - 100%). It is defined as 1 – ß (beta), with ß being the probability of accepting the null hypothesis as true when it is actually false, known as a Type II error. Power is the likelihood of correctly rejecting the null hypothesis. In a monitoring program, correctly accepting or rejecting a hypothesis is influenced by many factors. These factors include count variability over space and time, survey size, number of sample sites, within-year effort, chosen magnitude of trend to be detected (effect size), and statistical level of significance or alpha (α) - the probability of mistakenly rejecting the null hypothesis, known as a Type I error). Many of these factors are determined by program goals and support available.

Conceptual Models of Habitat-Biological Linkages

In this section we present conceptual models of how salmon, steelhead trout and other stream biota respond to habitat. Emphasis here is placed on habitat variables most likely to be changed by watershed restoration actions. We try to follow a consistent format for each conceptual model that includes:

1) Characterization: Determinants; Natural Variability/Scale
2) Interactions with other habitat factors
3) Biological Responses
4) Anthropogenic Activities resulting in altered level of habitat parameter
5) Restoration Treatments
6) Appropriate Monitoring Parameters

Conceptual Model 1 - Riparian Vegetation

1) Characterization:

Riparian zones, as defined by Swanson et al. (1982), are three-dimensional zones of direct interaction with aquatic ecosystems, extending outward from the channel to the limits of flooding and upward into the canopy of streamside vegetation. Geomorphic processes create and modify riparian zones and the stream channel structure. These processes provide the link between terrestrial and aquatic ecosystems.

Specific functions of the riparian zone can be seen in the forest canopy, the vegetation, and the vegetation's roots. The forest canopy controls the light regime and helps maintain water temperatures. The roots of the riparian zone stabilize stream banks, maintain undercut banks, and hold nutrients. Vegetation in the floodplain captures and holds sediment particles as well as provides allochthonous materials such as leaves, needles, grass and woody debris. In addition, riparian vegetation also produces insects that fall into the stream.

Natural Variability/Scale:

Spatial: The riparian forest varies longitudinally and laterally throughout a drainage network as a function of valley morphology, physical processes, vegetative legacies, and life history strategies (Naiman et al., 1998).

Temporal: Floodplain vegetation provides seasonal nourishment for organisms in the form of leaves, needles, and wood. The canopy provides cool stream temperature in summer and insulates the stream from heat loss in winter. Succession of riparian vegetation generally proceeds from shrubs to hardwood, then conifers. However, disturbance events such as floods, debris flows and fire may reset succession of riparian plant communities.

2) Interactions with other habitat factors

Water temperature: The forest canopy controls the light regime and helps maintain temperatures.

Dissolved oxygen: Increases in nutrients, detritus or temperature may decrease oxygen concentrations.

Flow: Riparian vegetation roots dissipate stream energy, preventing erosion and scour.

Sediment: Vegetation captures and holds sediment.

Channel Characteristics: Streamside vegetation stabilizes the bank preventing channel widening and aggrading, while maintaining undercut banks and channel structure.

Large Woody Debris: Large trees in the riparian zone, allow new debris to be available to replace decaying in-stream large woody debris. The woody debris shapes channel morphology, retains organic matter and provides cover for fish.

3) Biological Responses

Several studies have shown that streamside management zones minimize damage to the habitat, and therefore, maintain the integrity of fish populations (Hicks et al. 1991). Since the riparian zone is the link between the terrestrial and aquatic ecosystem, a study of each of the habitat factors would show many biological responses of salmonids.

One important interaction of the riparian zones to the stream not provided by the habitat factors aforementioned is the food base. Autochthonous organic matter generated by light penetration and thus photosynthesis, and allochthonous organic matter generated from terrestrial plants and animals fuel lotic systems and are the energy source for microbial communities. The supply of plants, detritus, and associated microbes to the stream determines the abundance and community structure of consumers (Gregory et al. 1987). These organisms provide food materials for salmonids.

4) Anthropogenic Activities Resulting in Altered Habitat

Effects of land uses can be multiple and varied, depending on type of land use, degree of disturbance, size of stream, physical setting, and succession after disturbance. A few of the anthropogenic activities affecting riparian areas are forest harvest, river regulation, and livestock grazing.

Forest Practices: Timber harvest can increase solar radiation, increasing stream temperature, light levels and autotrophic production. Timber harvest, however, can also decrease supply of large woody debris. In the short-term, it can add logging slash increasing dissolved oxygen demand, amount of fine particulate organic matter, and in-stream cover. Overall, timber harvest can create erosion of streambanks, decreasing cover in the stream, increasing stream width, and reducing depth, as well as(Murphy and Meehan 1991), increasing fine sediment in spawning gravels and food production areas (Hicks et al. 1991).

Opening the canopy has been a practice recently studied. Murphy and Meehan (1991) reviewed the effects of altering riparian vegetation. Canopy removal can increase primary production, and therefore, abundance of invertebrates and fish, mainly by enhancing the quality of detritus. However, as riparian vegetation recovers after removal, the canopy covers the stream, nutrient input decreases, and aquatic primary production declines. Negative effects of canopy removal, however, are that it can cause high stream temperatures that may be lethal to salmonids. Microorganisms may be negatively affected by a decreased quantity of detritus or decreased oxygen concentrations. Cumulative effects from numerous disturbances can negate any beneficial effects of increased food production. Salmonid biomass may increase in a local area of stream upon canopy removal, but cumulative effects downstream may reduce overall salmonid biomass.

Hicks et al. (1991) reviewed studies which were performed to identify the response of salmonid populations to timber harvest and streamside management zones. Studies from Carnation Creek identified distinct changes in the life history of coho salmon that were related to year-round temperature increases. Several studies of the Cascade Mountains found that greater food availability in the opened canopy compensated for any negative effects of increased sedimentation and other habitat changes in the first 10-15 years after logging. Some evidence, however, suggested that after 15 years there was a decrease in trout abundance below that of the old growth stands. Bilby and Bisson (1987) studied summer residency and production of coho salmon. They found that summer production was most strongly influenced by trophic conditions, whereas volitional residency was most strongly influenced by habitat quality. Hicks et al. (1991) concluded that most evidence indicates that careful streamside treatment is a better strategy than clear-cutting to the stream edge.

River regulation: Dams change transport of materials and alter the hydrologic regime, disrupting riparian forest species composition and distribution, sediment moisture retention and soil biogeochemistry.

Livestock Grazing: Livestock grazing in the riparian environment can harm or even eliminate vegetation, create channel widening and channel aggrading. In livestock areas, stream channels contain more fine sediment, streambanks are more unstable, banks are less undercut, and summer water temperatures are higher than in ungrazed areas (Platts 1983).

5) Restoration Treatments

Replanting and rehabilitating riparian vegetation
Livestock exclusion
Flow augmentation and channel reconstruction

6) Appropriate Monitoring Parameters

To effectively measure the success of an intact riparian zone, the interaction of the riparian zone and the aquatic ecosystem has to be taken into account. Several of the habitat parameters as listed above are directly affected by the riparian zone. These parameters could be measured, but an overall picture of the interactions has to be understood as well. The effects of the life history stages of salmonids needs to be studied in order to fully understand the potential recovery of the population.

Conceptual Model 2 - Channel Morphology

1) Characterization:

Channel morphology of streams is a reflection of the work done be the energy in moving water. The morphology of a stream is not static, rather it is continually changing. Energy in stream water is expended in; 1) overcoming internal friction and friction with the channel boundary -including substrate, woody debris and vegetation; 2) transporting sediment and 3) eroding channel boundaries. Streams considered to be “stable” are in reality, dynamic and their channel changes with time, even though changes may no be obvious. Changes in sediment load, flow regime or boundary conditions can accelerate changes in channel morphology, often resulting in negative effects on fishes.

The evolution of river morphologies is influenced by regional climatic patterns and parent geology. In longitudinal profile, streams and rivers are generally characterized as having short reaches of steep, step-pool type habitats in the headwaters. As gradient decreases and stream order increases downstream, habitats change to a run-riffle-pool sequence. These habitat changes also influence fish communities, which also change along the longitudinal profile of rivers (Vannote et al. 1980). In general, stream morphology progresses from straight channels to meandering to braided, in response to slope, discharge, and sediment load. Bar formation is more common in wider channels and channel bars may be part of pattern development from a straight reach to a meandering or braided reach (Jaeggi, 1984). Rosgen (1994) developed a classification system to describe the morphological character and function of rivers using channel gradient, width, depth, sinuosity, substrate and valley width.

Natural channels are generally irregular with patterns of shallows and deeps (i.e. riffles and pools) and the thalweg alternates from side to side (Leopold et al 1964). Pool-riffle sequencing in streams provides resistance to flow necessary for sediment deposition, with smaller particles settling into slow, deeper habitats and the coarsest substrate materials found in riffles. Pools are generally scoured during high flows.

Stream meanders dissipate energy in stream systems, eroding the outside bank and depositing finer materials on the inside curve. Meanders lengthen the stream channel and reduce its slope, which can increase available fish habitat area and quality. The wavelength of a stream meander ranges from 10 to 14 times the channel width with an average of 11 times. The radius of curve is approximately 2.3 times the channel width (Leopold, 1994). Wavelength and amplitude of meanders are correlated with discharge, sediment load and gradient. Channelizing a stream can reduce its sediment transport capabilities. Increased deposition in the reach then often leads to extensive unstable braiding.

The amount of sediment contributed to a stream is a major determinant of its shape and behavior. Net annual sediment yield is the sum of erosion from overland flow, erosion by mass movement, and erosion of channels minus instream deposition. In north coast watersheds, the bulk of sediment yield comes from relatively small highly erosive areas (Madej 2001). Channel cross sections constantly changing longitudinally in response to hydrology and upstream sediment load.

2) Interactions with other habitat factors

Large woody debris. Large wood (and other large substrate elements) deflect flow, decrease water velocity and dissipate energy. Diverting water can increase scour in localized parts of the stream, which increases channel complexity and depth.

Discharge. Precipitation patterns, land use and watershed drainage patterns influence the duration, magnitude and timing of flow events. Bankfull flows typically occur every 1.5 to 2 years, transport considerable sediment and are primary channel forming events.

Riparian Areas. The amount and type of vegetation in riparian areas influence a stream banks resistance to erosion.

Valley Form. Confined valleys limit the amount of meander in stream channels and therefore affect stream gradient.

Geology. The resistance of underlying bedrock to erosion influences stream channel character.

3) Biological Responses

Channel morphology directly influences habitat available to fish and their distribution. Fish communities change with gradient and stream order (Vannote et al 1980). In coastal streams, abrupt changes in gradient often provide barriers to migration of anadromous species. Fish species richness and abundance also increase with volume of water available during summer (Platts 1979). Areas available to spawning adult salmon and steelhead trout are influenced by volume of water during spawning in winter, as well as substrate composition.

4) Anthropogenic Activities Resulting in Altered Habitat

The morphology of rivers and streams has been drastically altered throughout North America. The construction of dams for water storage and flood control has had enormous effects on discharge, channel character, and substrate of rivers. In California, large-scale projects to use rivers in the conveyance of water to agricultural and urban centers have reduced variability in discharge and altered the morphology of rivers.

Changes in upland land use alter the magnitude, timing and frequency of flow patterns. Timber harvest alters runoff patterns, introduces sediment and reduces or eliminates large wood that is an important element in stream channel morphology. Agricultural practices often remove water from streams and contribute to erosion. Urbanization increases the area of hard surfaces within watersheds, reducing infiltration and accelerating runoff.

Mining has severely altered the morphology of many California rivers. Hydraulic mining has increased sediment inputs to rivers, leading to increased sediment storage in channels and flooding. Responses to this flooding often included levee construction and damming, further altering river morphology.

Aggregate mining California rivers continues to alter their morphology. More than one billion short tons of aggregate material was removed from California streams during a 10 year period beginning in the 1980's, or as much as 10 times the amount of bedload supplied to rivers. (Mount, J, 1995) Limited research has been conducted on effects of in-stream mining on streams. However, aggregate miners remove material at a rate exceeding natural replenishment, reducing sediment storage in channels and creating excess stream power. Excess stream power has then resulted in channel incision, bank erosion and a reduction in riparian cover (Mount, J. 1995) and may affect available spawning habitat.

5) Restoration Treatments

Efforts to restore stream and river morphology to a more natural state range from the placement of minor structures, such as logs and boulders, to reconfiguration of entire channels. Restoration projects that alter stream channels must consider the geomorphic context, range of discharge, sediment transport capabilities and upstream source of sediments. Restoration activities, particularly those intended to modify channel morphology, should address the cause of the problem before undertaking remedial action (Frissell and Nawa, 1992, Reeves et al 1997). Reviews of instream restoration activities suggest that 1) project failure is common (Frissell and Nawa, 1992) and 2) post project evaluation is often lacking (Reeves and Roelofs 1982). Project failure is often results from a failure to consider geomorphic processes (Kondolf, 1996).

6) Appropriate Monitoring Parameters

Most instream restoration activities are guided by one of two general objectives: 1) reducing erosion or 2) improving fish habitat. We address validation monitoring measures appropriate for detecting a response to sediment and turbidity on page 22. The appropriate monitoring response variable for evaluating projects intended to improve fish habitat is obviously fish. Reeves et al. (1991) suggested monitoring the population response of three life stages of salmonids: juveniles or parr, smolts and adults. Others have suggested monitoring only the population size or abundance of the smolt stage because sampling for this stage is more efficient than for other life stages and smolt sampling can be designed to address spatial scales ranging from stream reaches to entire watersheds (Roni et al. 2003).

Conceptual Model 3 - Large Woody Debris

1) Characterization

The importance of large woody debris in creating and providing fish habitat became widely accepted in the 1980's (Bisson et al 1987). Woody debris enters streams as a result of streamside tree mortality, blowdowns, debris slides, and streambank undercutting (Keller and Swanson, 1979). Windthrow and debris torrents may result in large volumes of wood recruited to localized areas. Tree mortality (due to insects or disease) and bank undercutting more often result in wood being introduced more irregularly along the stream channel (Bryant 1983). Woody debris is eventually removed from channels by invertebrate and microbial decomposition, downstream transport, leaching, and physical fragmentation (Bilby and Bisson, 1998).

Spatial variability. In general, the amount of large woody debris (LWD) decreases with increasing stream size and smaller streams have greater amount of randomly distributed LWD than rivers. Ease of transport in downstream in rivers and larger reaches typically results in less frequent, larger sized wood aggregations (Bilby and Bisson 1998).
Temporal variability. LWD is recruited to streams and rivers from the immediate riparian during storms. Debris flows also recruit to the stream LWD originating beyond the immediate riparian area. Redistribution of LWD is influenced by channel width, gradient (Keller and Swanson, 1979) and discharge patterns. Therefore, movement generally occurs during floods.

2) Interactions with other habitat factors

Discharge. Debris dams have been shown to reduce stream velocity and discharge (Heede 1981) and to delay the timing of peaks in storm flow (Gregory et al, 1987). In small streams, LWD can provide refuge during high flow events (McMahon and Hartmon 1989). In larger streams, however, turbulence immediately downstream from LWD structures during high flow events apparently reduces their value as habitat (Harvey et al. 1999).

Instream habitat. Woody debris is a major pool forming factor in Pacific Northwest streams (Swanson et al. 1976, Keller and Swanson 1979). Large wood has been shown to influence pool frequency (Lisle and Kelsey 1982), area (Bilby 1984) and depth (Lisle 1995). Large wood maintains physical stability by creating stepped longitudinal profiles that dissipate energy and retain sediments.

Channel morphology. Large wood can influence channel morphology by increasing stream depth (Fausch and Northcote, 1992) and channel complexity (Keller and Swanson, 1979, House and Boehne, 1986).

Cover. Many investigations have documented the importance of LWD as cover for fish (Bryant 1983; Harmon et al. 1986). The mechanism by which LWD provides cover is, however, not well understood and may change seasonally. The complexity provided by LWD reduced feeding efficiency by cutthroat trout during summer (Wilzbach 1985).

During fall and winter, however, cutthroat trout in pools containing LWD or other cover moved less than in pools lacking cover (Harvey et al. 1999).

Water Quality. Large wood can moderate the amount and timing of sediment transport. Debris may provide thermal pocket refugia during summer

Riparian area Composition. The amount of wood in streams has been shown to increase with tree density in riparian areas (Bilby and Wasserman, 1989) Conifers have slower decomposition rates than hardwoods, and larger conifers are less likely to be transported downstream (Harmon et al, 1986).

3) Biological Responses

Invertebrates. LWD influences the abundance and composition of aquatic invertebrate communities. It is an important source of organic material and colonization substrate for invertebrates and microorganisms.

Fish habitat use. With abundant food sources in the current and low metabolic costs in slow current, pools provide an energy efficient feeding location for juvenile salmonids. The amount of large wood in streams has been related to fish abundance (Fausch and Northcote 1992) and density (Flebbe and Dolloff 1995). Backwater eddies associated with large wood are used extensively by salmonids for rearing in all seasons (Bisson et al. 1987). Low gradient sediment deposits from upstream wood accumulations can provide suitable spawning substrates in sediment poor drainages. The relationship between wood and survival is poorly understood.

Migration. Many studies have investigated LWD as migration barriers for both adult spawners, and juvenile migrants. Although massive dams may form barriers to adults, what appears to be a complete blockage during summer low flows, may in fact be passable with elevated winter flows (Bryant, 1983). Most barriers to upstream migration are caused by debris torrents, which trap large amounts of sediment (Baker 1979). It is unlikely that debris flows prevent or delay juvenile downstream migration (Bisson et al. 1987).

4) Anthropogenic Activities Resulting in Altered Habitat

Historically, widespread reaches of rivers were cleared for log transport and navigation. Splash dams were widespread across the Pacific Northwest. The violent release of both water and logs from a splash dam scoured wood and other material from streams. Debris dams, including LWD, were historically also removed to better allow fish passage into headwater areas.

Concurrently, alteration of riparian zones from logging, agriculture or development limited the source of large woody debris inputs to streams. Many streams in the Northwest have only a fraction of the wood that was present historically (Bisson et al. 1987). In addition, riparian logging practices have resulted in smaller diameter trees, and distribution of LWD outside of the active stream channel (Ralph et al. 1994), resulting in reduced pool frequency and depth.

5) Restoration Treatments

Restoration projects intend to restore LWD loading in watersheds focus on the instream channel, bankfull and/or riparian areas. Placement of LWD into the active channel is a common technique for restoring and enhancing streams in the Pacific Northwest (Kaufman et al. 1997). LWD is often anchored in the active channel using cable, placed unanchored with rootwads into the channel or on the flood plain, or used to secure banks. The objective in adding LWD to streams is usually to increase cover and add habitat complexity. LWD added during restoration projects may differ from natural debris in size and density. Smaller pieces associated with human activities may remain unstable for longer periods than larger pieces (Bryant 1983).

The use of biological measures to evaluate large wood placement has produced variable results. Density of juvenile coho salmon increased during both summer and winter after LWD placement (House and Boehne 1986, House 1996, Cederholm et al.1997, Roni and Quinn 2001). However, density of juvenile coho salmon in spring and fall did not change after LWD placement (Cederholm et al. 1997). Juvenile steelhead trout exhibited less of a density response to the addition of LWD, with no change in three of six studies and a decline in density during spring in one study (House and Boehne 1986, House 1996, Roni 2001).

6) Appropriate Monitoring Parameters

Monitoring of biological responses to LWD additions should focus on fish. Abundance of juveniles, smolts and adults or only smolts, as discussed under channel morphology, may be appropriate. Roni and Quinn (2001) suggest monitoring more than one species and more than one life history stage. Monitoring the response of fish to LWD placement should distinguish localized density effects, brought about by redistribution, from true population change. Detecting true population change requires statistically valid random sampling throughout the stream, or in large enough reaches to detect redistribution.

Conceptual Model 4 - Turbidity and Suspended Sediment

1. Characterization

Turbidity is a measure of the degree to which light traveling through a water column is scattered by the suspended organic and inorganic particles. The scattering of light increases with a greater suspended load. Turbidity is measured in Nephelometric Turbidity Units (NTU) while suspended sediment is measured as mass in $mg \cdot l^{-1}$. Turbidity is directly correlated with suspended sediment and turbidity measurements can be used to accurately determine suspended sediment load using a technique known as turbidity threshold sampling (Lewis 2001).

Natural turbidity varies with the parent geology and soils within a watershed. Sand, silt, clay, and organic particles mobilized by rainfall and carried by overland flow may cloud surface water. Landslides resulting from either natural processes or human activities, typically contribute large volumes of sediment to streams and rivers. Additional suspended organic matter may result from natural in-stream detritus or algae. Particulate matter may be re-suspended from the bottom sediments by changes in the speed or direction of the water current, particularly during winter discharge.

Land disturbing activities are a primary source of anthropogenic turbidity in Pacific coastal streams and rivers. Elevated turbidity resulting from human activities is becoming more common in streams and rivers of this region. Road building contributes chronic turbidity from erosion and may destabilize hillslopes, leading to mass wasting events that introduce large volumes of sediment to streams (Jones et al. 2000, Madej 2001). Logging removes soil stabilizing vegetation from watersheds and exposing soils to the erosive capacity of water (Chamberlain et al. 1991). While traditional logging practices have been improved over those historically used, most logging continues to depend on road building. Mining of aggregates and other minerals may also introduce sediment to streams, resulting in turbidity (Waters 1985). Finally, riparian uses such as grazing (Platts 1991) or residential development often results in removal of vegetation, erosion and bank sloughing.

Water velocity influences the composition of the suspended load, but both gentle and fast currents carry suspended loads. In streams and rivers, the suspended load usually consists of smaller diameter particles and the silt-clay fraction may be carried at nearly the same velocity as water (Waters 1995). Turbidity and suspended sediment can have negative effects on a range of biological organisms and processes.

Temporal variability: Pacific coastal streams exhibit clear seasonal patterns in turbidity and sediment load. The onset of winter storms often mobilizes fine sediments and organic matter that has settled during the summer - fall period of low discharge, resulting in a turbidity peak. Periodic storms over watersheds susceptible to erosion contribute additional sediment and turbidity throughout the winter and spring. Elevated turbidity and suspended sediment may be ephemeral, persist for longer periods, depending on the severity of storms, their frequency and condition of the watershed. Furthermore, turbidity at sites low in the watershed persists for longer periods than at sites high in the watershed. Turbidity and suspended sediment usually declines with declining precipitation in summer and reaches the annual minima during the summer and fall.

Spatial variability: turbidity and suspended sediment load in streams may vary substantially within a watershed. Streams originating in sub-watersheds experiencing land disturbance may contribute large volumes of sediment resulting in high turbidity and suspended sediment while those originating in undisturbed areas may contribute little. Thus, within a watershed having a patchy distribution of either human caused or natural sediment input, turbidity and suspended sediment from a smaller stream may be introduced at the confluence with a larger receiving stream. Depending on the position of the turbid stream in a watershed, turbidity and suspended sediment may either increase lower in the drainage network or decrease as less turbid streams dilute sediment inputs. Where land disturbance is either uniformly distributed and/or very severe, turbidity would be expected to increase with stream size.

2. Interaction with other Habitat Factors

Primary influences of turbidity and suspended sediment are to reduce light transmission in water and to alter the particle size structure of deposited sediments. Reduced light penetration has negative effects on biological processes ranging from algal periphyton production (Van Neiuwenhuyse and La Perriere 1986) to reduced visibility by sight feeding fish (Sweka and Hartman 2001a). Suspended sediments consist of small particles in the range of fine sand to clay. When these fine sediments settle over more coarse materials, the finer sediments shift the particle size distribution toward smaller particle sizes. Depending on the severity of suspended sediment and turbidity, the settling of fine sediments can fill interstices among larger diameter gravels and cobbles or completely blanket the stream bottom. Biological ramifications of this phenomenon are discussed below under 'biological responses.'

3. Biological Responses

Periphyton. Generation times for periphytic algae are short relative to most benthic macroinvertebrates and fish. Turbidity reduces light penetration and suppresses photosynthetic activity of periphytic algae (Figure 1). Furthermore, periphytic algae use solar energy to convert nutrients into biological tissue that may be consumed by invertebrates, which are the primary foods of juvenile salmonids. Thus, a measure of primary production such as periphyton chlorophyll *a* may be effective in detecting biological affects from turbidity over short temporal scales.

Investigations of gold mining in Alaska streams document the influence of turbidity on light and periphyton. Turbidity of 170 NTU associated with gold mining in Alaska streams reduced gross primary production to roughly 50% of that measured in control streams having turbidity of < 2 NTU (Van Nieuwenhuyse and LaPerriere 1986, Lloyd et al. 1987). In these same streams, turbidity of 1,100 – 3,400 NTU reduced gross primary production to undetectable amounts.

Macroinvertebrates. Since benthic macroinvertebrates are, by definition, associated with the substrate most documented impacts to macroinvertebrates from sediment have been associated with the settling of suspended solids. These include shifts in taxonomic composition from larger taxa such as mayflies, stoneflies and caddisflies to smaller bodied taxa represented by chironomid larvae and oligochaete worms (Waters 1995), as well as reductions in the number and behavior of macroinvertebrates.

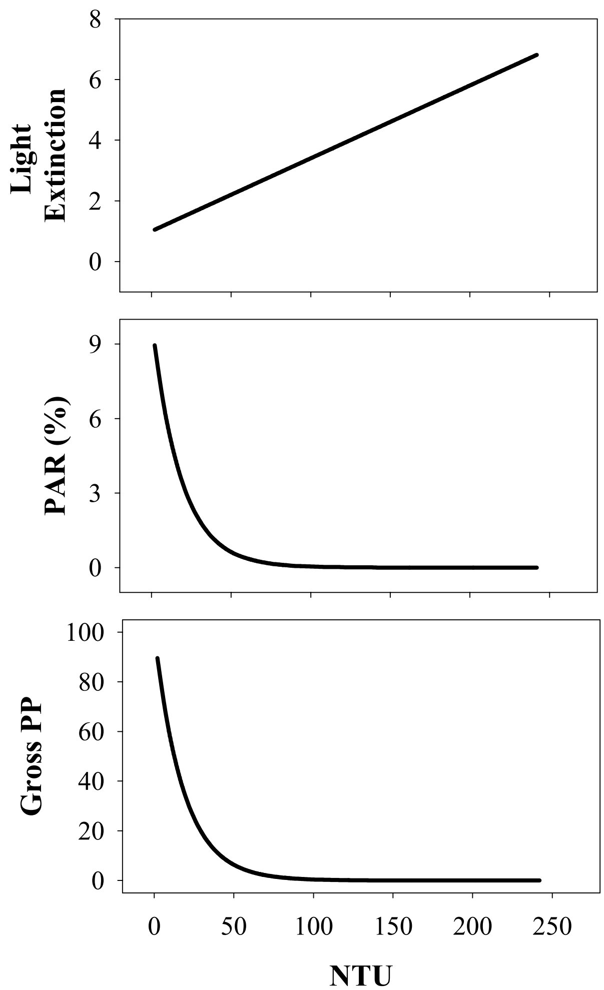

Figure 1. Relationship between turbidity and the light extinction coefficient (top), percent photosynthetically active radiation (middle) and percent gross primary production relative to clear water for Alaska streams (derived from equations in Lloyd et al. 1987).

Survival of larval *Chironomus tentans* in chronic sediment tests ranged from 68-92% (Nebeker et al. 1984). Invertebrates in experimental streams receiving 1.7 ug/l sediment delayed their nocturnal drift (Fairchild et al. 1987). Effects of turbidity on benthic macroinvertebrates have been less well studied. A measure of macroinvertebrate community integrity was correlated with and declined as winter storm related turbidity increased in 27 Oregon coastal streams (Mulvey and Hamel 1998). Turbidity tolerances for larval Chironomidae suggest few species are tolerant of concentrated turbidity (U.S. Environmental Protection Agency 1977). Similarly, larval Trichoptera are considered relatively intolerant of turbidity (U.S. Environmental Protection Agency 1978).

Studies of the differential influences of mineral and organic turbidity are currently being carried out (P. Wilzbach, USGS, Arcata, CA, unpublished). Preliminary results from this work suggest that organic turbidity, up to some threshold concentration, may be beneficial to filter feeding aquatic invertebrates.

Fish. Elevated turbidity and sediment in streams and rivers is widely recognized as having negative influences on fishes, and may be "the principal factor in the degradation of stream fisheries" (Waters 1985). Considerable research has now addressed the influence of suspended sediment on salmonid fishes, particularly the egg and juvenile life stages.

Direct or acute effects of turbidity and suspended sediment resulting in mortality of salmonids have been recorded by several investigators. Newcomb and Jensen (1991, 1996) summarized published and unpublished reports of suspended sediment effects on fish. Their summary suggests turbidity and suspended sediment can reach acute concentrations, and suggest that smaller salmonids are more sensitive to turbidity and suspended sediment than are adults. However, concentrations reported to be lethal in salmonids vary considerably and acute concentrations may vary with water temperature.

Indirect and chronic effects of turbidity and suspended sediment on fish are more difficult to document than are acute effects. In assessing chronic effects, duration of exposure becomes important (Newcomb and Jensen 1996) and continuous monitoring techniques have only recently been developed. After reviewing the available literature, Newcomb and Jensen (1996) concluded that the expression of chronic or indirect effects increased with duration of exposure. They proposed a turbidity severity index of 15 categories based on amount of turbidity and duration of exposure. In their model for juvenile salmonids, severity increases with both time and concentration and reflects acute responses documented at concentrations over 1,000 mg . l^{-1} suspended sediment (Figure 2).

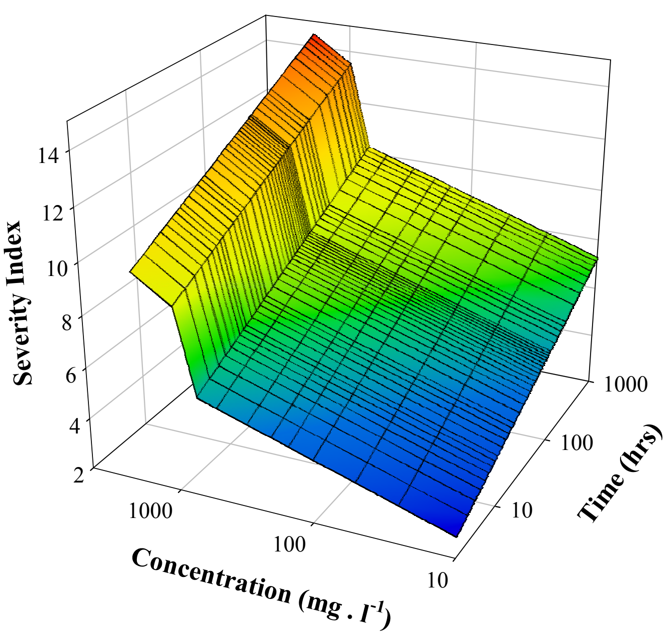

Figure 2. Relationship between severity of ill effects on juvenile salmonids from suspended sediment as a function of sediment concentration and duration of exposure (developed from data presented in Newcombe and Jensen 1986).

The reduced light penetration with increasing turbidity has long been thought to negatively affect food acquisition by sight feeding fish. Recent experiments with brook trout not only confirm this effect (Sweka and Hartman 2000), but also illustrate potential negative effects on fish growth (Sweka and Hartman 2001). Swetka and Hartman (2000) found the distance at which brook reacted to prey declined exponentially as turbidity increased (Figure 3). The surprising result of this study was not the response of brook trout, rather it was that their feeding was impaired with even low amounts turbidity. Another unexpected result of these studies was that brook trout did not feed less as turbidity increased, but moved more to compensate for reduced visibility and capture the same amount of prey. The net result of this compensation was more energy being expended on swimming and less on growth (Sweka and Hartman 2001).

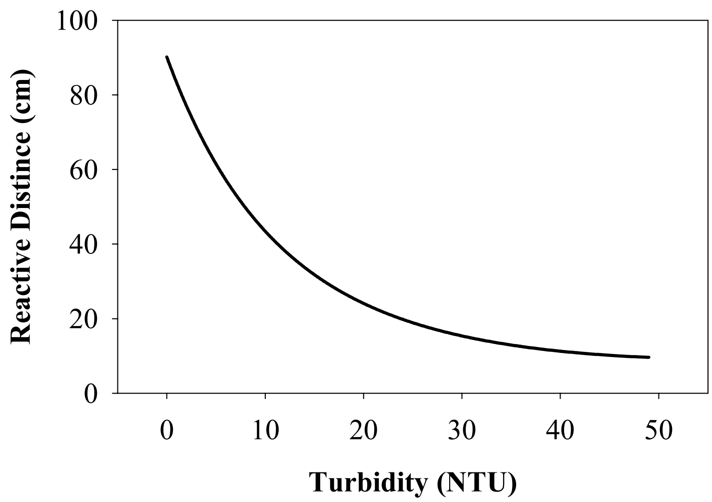

Figure 3. Distance at which brook trout reacted to prey with increasing turbidity (adapted from Swetka and Hartman 2001).

Pacific salmon spawn during fall and winter when turbidity and suspended sediment are more frequently elevated by storms. The effect of fine sediments on eggs in salmon redds is to reduce percolation and the continued introduction of oxygenated water. The deleterious effect of fine sediment in salmon redds has long been a topic of interest (see reviews by Cordone and Kelly 1961, Chapman 1988). Recent work in Prairie Creek, California, (Meyer in prep., Sparkman in prep.) has quantified the relationship between fine sediment in redds and survival of salmon embryos. Both studies evaluated the influence of multiple factors on survival of coho salmon embryos and found fine sediment explained much of the variability in survival.

4. Anthropogenic Activities Resulting in Altered Habitat

Forestry practices. Forestry practices and other land disturbing activities, such as development, are recognized as contributing sediment to streams (Waters 1995). Sediments entering streams from these practices result in elevated turbidity and/or deposited sediments.

Grazing. Grazing by livestock, when not restricted from streams, causes banks to become unstable and negatively influences riparian vegetation (Platts 19. Both actions result in sediment being introduced to streams, and elevated turbidity and/or deposited sediments.

Channel modification. Modifying channels with the goal of conducting more water, or for other purposes, alters the natural hydrology of the stream. Altered hydrologic regimes often result in the stream readjusting its channel and eroding down- or upstream banks, thus incorporating sediment into the stream.

Road. Road construction, existing roads having poor road drainage and road decommissioning all introduce sediment to streams. Sediment is delivered to streams during both the construction and decommissioning of roads. However, sediment introductions associated with these actions occur over relatively short periods (less than 2 years) and can often be mitigated. Sediment delivery from poorly draining roads presents a chronic problem that may exist for decades.

5. Restoration Treatments

The objective of many restoration treatments currently in use is to reduce erosion from uplands within watersheds or from stream banks, or to prevent the mobilization of fine sediments in stream channels. These treatments range from complete or partial road decommissioning to grazing management. All treatments seeking to reduce erosion or sediment mobilization, if successful, would reduce turbidity and suspended sediment in streams.

6. Appropriate Monitoring Parameters

Sediment and turbidity in streams may impact a wide scope of biological functions ranging from primary production to fish population persistence. To monitor the biological response to sediment and turbidity it is, therefore, appropriate to employ a suite of measures which include the range of potential impact. We recommend monitoring periphyton chlorophyll *a,* a measure of primary production, where site specific or a short temporal response is needed. Stream macroinvertebrates may also be effective in detecting sediment and turbidity impacts, on an intermediate temporal scale. Sediment and turbidity may impact all life stages of salmonid fishes, either directly or indirectly. In view of the central role of salmonid recovery in this validation monitoring program, we recommend monitoring multiple life stages of these species. These stages include; eggs (survival), juveniles (relative weight, age structure, population size) smolts (production).

Conceptual Model 5 – Water Quality

Water quality includes physical, chemical, and biological components that affect the stream and its physical conditions and chemical constituents. The inorganic characteristics include hardness, alkalinity, pH, nutrients, metals, and total dissolved solids. Some of the physical variables include temperature, total suspended solids, and solids deposited in the substratum. Some of the biological constituents include periphytic algae, bacteria, macroinvertebrates, and pathogenic bacteria (Welch et al. 1989).

Streams of the Pacific coast are naturally cool, clear, typically shaded and of high chemical quality. They have relatively low acid neutralizing capacity and are oligotrophic. They are highly sensitive to nutrient enrichment, temperature increases, introduction of suspended solids, and acidic precipitation (Welch et al. 1998).

Natural spatial variation is determined mainly by the type of rocks weathering, how wet or dry the climate is, and by the composition of rainwater (Allan 1995). Spatial variation can also be examined through elevation. High elevation streams have less acid neutralizing capacity, hardness, total ions, nutrients, and metals than lowland waters. Increases in these characteristics in low-elevation streams are attributed to changes in soil and bedrock, as well as anthropogenic disturbances (Welch et al. 1998).

Nutrients

1) Characterization:

Nutrients are inorganic materials necessary for life. The supply of nutrients is potentially limited by biological activity within stream ecosysytems. Their uptake, transformation and release are influenced by a number of abiotic and biotic processes. Important metabolic processes likely to affect and be affected by the supply of nutrients include primary production and the microbial decomposition of organic matter.

Temporal variability. Nutrient concentrations vary seasonally due to influences in hydrology, the growing season, biological uptake, and changes in anthropogenic inputs (Allan 1995). For example, in winter when algal growth is minimal, nutrient concentrations are highest.

Spatial variability. Natural distributions of nutrients are strongly influenced by biological, chemical and physical processes. The course of reactions varies mainly as a function of hydrologic regime, temperature, and biological community composition.

Nutrient spiraling is an important concept to consider when examining spatial variability. The term describes the interdependent processes of nutrient cycling and downstream transport (Webster and Patten 1979). The concept states that one nutrient cycle is complete when first a nutrient atom has been taken up by an organism from a dissolved available state, then passed through the food chain, and finally returned to a dissolved available state for reutilization (Newbold et al. 1982).

2) Interactions with other habitat factors

Temperature. As temperature increases, so does microbial activity increasing plant litter processing and redox reaction rates. These reactions increase rates of both nutrient mineralization and uptake.

Riparian. Riparian vegetation along streams modifies cation and nutrient content in watershed runoff. Forest plants and microbes are instrumental in the initial uptake of nitrogen from atmospheric sources, and phosphorus and sulfur from geologic sources and transfer these elements to river corridors. Plants also remove and temporarily store these nutrients through uptake from channel and hyporheic waters. Input vectors for plant nutrients include litter fall, lateral transport, and flooding of adjacent riparian zones (McClain et al.1998).

Channel Morphology. Complex habitat units collect and retain organic matter, increasing the overall abundance of nutrients in the system.
Flow. Nutrient fluxes increase in response to increasing stream discharge, but concentrations of nutrients may be positive or negative, depending on the season.
Large Woody Debris. Large Woody Debris creates channel form in small streams which facilitates deposition of sediment and the accumulation of fine organic matter.
Turbidity and Sediment. Sorption onto sediments is a physical-chemical process that influences the nutrient concentrations of some ions.

3) Biological Responses

Nitrogen or phosphorous, and sometimes both, usually limit autotrophic production in fresh water (Welch 1992). Nutrient uptake from channel water supports primary production by both periphyton and planktonic algae. Microbial decomposition and consumption by invertebrates contribute to nutrient availability and trophic level communities by conditioning plant litter.

Invertebrates and fish communities ingest various forms of organic matter and associated nutrients. These organisms also release nutrients in waste products and as they decompose after death.

Effects of increases in nutrients on invertebrate and salmonid populations have not been thoroughly studied. Studies of logging effects have however, indicated that nutrient increases are limited to the first decade after logging. They have found that primary production is stimulated in the presence of increased light and nutrient concentrations. Watersheds dominated by volcanic rock are more likely to show enhanced autotrophic production after logging than watersheds dominated by sedimentary or metamorphic rock. Herbivorous invertebrates will most likely benefit form increased algal growth. Finally, salmonid production may or may not be enhanced during periods of increased nutrient concentration (Gregory et al. 1987).

Periphyton assemblages are among the stream communities that are most responsive to changes in water quality. Periphyton may respond positively to nutrient enrichment causing aesthetic, water quality, and invertebrate habitat degradation (Welch et al. 1989).

4) Anthropogenic Activities resulting in altered level of habitat parameter

Sources of nutrient inputs into streams are stormwater runoff from urbanized areas, nonpoint source runoff from agricultural zones, and wastewater from combined sewer overflows or failing septic systems in unsewered areas. Numerous studies demonstrate the stimulatory effect of this inorganic nutrient enrichment on periphyton biomass (Welch et al.1998).

Concentrations of inorganic nutrients in streams may increase after logging, but usually by moderate amounts and for short periods (Fredriksen 1971; Scrivener 1982). The mobilization of nutrients is tempered by their adsorption onto soil particles and by their uptake by microorganisms that decompose stream detritus (Murphy and Meehan 1991). Nutrient additions after logging, when accompanied by increased light often results in increased algal growth (Gregory et al. 1987). The effects of nutrient increases on invertebrate and salmonid populations, however, have not been thoroughly studied.

5) Restoration Treatments

Hicks et al.(1991) reviewed studies on the effects of adding nutrients (nitrogen and phosphorus) to streams. Bisson et al. (1976) found a temporary increase in biomass of benthic invertebrates and rainbow trout, but after 2 years of continuous nutrient additions, no significant differences were found between enriched and un-enriched streams. Slaney et al. (1986) found steelhead to grow faster and smolt earlier but larger, and smolt output to increase, but did not determine whether returning adult run size had increased.

6) Appropriate Monitoring Parameters

Monitoring parameters that may detect a response to changes in nutrient concentration are those reflecting stream productivity. With the emphasis here on recovery of salmon and steelhead trout, we recommend several measures using these species and describe them in the section on selected measures beginning on page 31.

Oxygen Concentration

1) Characterization

Fish and aquatic invertebrates require dissolved oxygen for life. Dissolved oxygen is introduced to stream water as a product of photosynthesis by algae and rooted vascular plants and by diffusion from the atmosphere.

Spatial variability. Dissolved oxygen is typically present in headwater streams at concentrations that will support salmonid fish. Headwater streams often have little organic matter that can create biological oxygen demand and have frequent riffle habitats that introduce oxygen through turbulent exchange with the atmosphere. Areas of low oxygen concentration can be found in small streams where groundwater inputs make up a substantial proportion of total discharge. Estuaries and lower reaches of rivers may experience greater variability in oxygen concentration. These habitats have greater volumes of water and experience less turbulent flow than smaller streams, lessoning oxygen diffusion from the atmosphere. Algal production and organic matter are also usually greater in lower river reaches and estuaries than in headwater streams. Increased organic matter can create biological oxygen demand, while algal photosynthesis and respiration can create diel variability in dissolved oxygen concentration.

Temporal variability. The influence of seasonal changes develops from discharge regime, precipitation inputs and biological activity. Seasonal variability of dissolved oxygen depends greatly on temperature. In summer, high temperatures both accelerate respiration and lower the solubility of oxygen. In winter, ice cover may prevent diffusion of oxygen from air to water.

2) Interactions with other habitat factors

Temperature. The solubility of oxygen in water declines as temperature increases (Colt 1984).

Channel Morphology. If channels are aggraded and pools shallow, the reservoir of dissolved oxygen is small.

Flow. Generally, when apparent water velocities are low, dissolved oxygen is low; when they are high, dissolved oxygen is usually high (Coble 1961). Turbulent exchange of gases with the air decreases when flow decreases.

Turbidity and Sediment. Tagart (1976) and Reiser and White (1981) found direct relations between dissolved oxygen and permeability and inverse relations between dissolved oxygen and percentage of fine particles in stream substrates. Clogging of surface gravels by fine inorganic sediments can restrict intergravel flow enough to lower dissolved oxygen concentrations. In salmon redds, dissolved oxygen concentration can be further reduced by respiration of eggs and biological oxygen demand created by organic matter.

3) Biological Responses

Salmonids may be able to survive when dissolved oxygen concentrations are relatively low (<5mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected. Embryos may survive when dissolved oxygen concentrations are below saturation (but above the critical level), but suffer abnormal development often deviates from normal (Bjornn and Reiser 1991). Chapman (1988) concluded that any reduction in dissolved oxygen below saturation may cause salmonids to be smaller than normal at emergence. Smaller individuals are at a competitive disadvantage and likely have reduced fitness (Mason 1969).

4) Anthropogenic Activities resulting in altered level of habitat parameter

Intragravel dissolved oxygen concentrations have been reduced in some Oregon streams after adjacent areas had been logged. These reductions in dissolved oxygen were attributed to elevated stream temperatures after riparian canopy removal and to increased concentrations of fine sediment that reduced substrate permeability and flow (Hall and Lantz 1969, and Moring 1975).

Concentrations of dissolved oxygen in inter-gravel spaces may be reduced if fine organic debris is introduced into the gravel matrix or by reduced interchange of surface and intra-gravel water. The high chemical and biological oxygen demands of such debris and the bacteria on it may persist for long periods until the bottom material is removed by high flows (Chamberlin et al. 1991).

Several field studies have demonstrated reductions in oxygen concentration in redds following logging (e.g., Ringler and Hall 1975). Increased intra-gravel sediment, decreased permeability, and decreased velocity of intra-gravel water often coincide with reduction of dissolved oxygen concentrations, and therefore the reduction of oxygen levels is hard to identify as a primary cause of mortality of embryos and alevins in gravel.

In one small coastal Oregon drainage that was logged to the stream edge, dissolved oxygen concentrations of surface water decreased following timber harvest to below levels acceptable for salmonid survival and growth (Hall and Lantz 1969, Moring 1975).

5) Restoration Treatments

Restoration treatments for low dissolved oxygen concentrations involve either 1) introducing oxygen and/or 2) remove organic materials that result in oxygen demand.

6) Appropriate Monitoring Parameters

Changes in dissolved oxygen concentration in streams will impact on salmon and steelhead trout. These impacts will be dramatic if dissolved oxygen concentration declines below threshold amounts, and appropriate monitoring measures may be mortality or redistribution. Where dissolved oxygen concentration declines are more subtle, impacts on salmon and steelhead trout may be subtle and expressed in reduced health, growth or condition, or production.

Water Temperature

1) Characterization:

Stream water temperature is the net result of heat exchange several processes. First, warming of water is the result of net radiation from direct beam solar radiation, modified by cloud cover, day length, sun angle, vegetation or topographic shading exhibits daily and seasonal variation and influences water temperature. Radiation can warm the stream substrate, with the heat energy conducted from the substrate into the water. The heat energy from upstream water can also influence local water temperature through advection.

Evaporation and convection operate to cool water. Evaporation and convection are influenced by air temperature, vapor pressure and wind speed. Thus, the influence of evaporation and convection is greater in streams that flow through open riparian areas such as meadows than in streams flowing through forested areas. Both heating and cooling processes are modified by discharge and stream surface area relative to volume. Within seasons, stream water temperature is inversely proportional to discharge and directly proportional to surface area.

Natural Variability:

Temporal variability. Water temperature exhibits seasonal patterns, with maximum temperatures in summer and minimums in winter. The period of the summer maximum may extend 1-2 months after the period of maximum solar radiation. Year to year variation in monthly average water temperatures is low, generally < 2 C.

Diel fluctuations are greatly affected by canopy cover. Diel fluctuations in forested watersheds are generally small and greatest during summer when discharge is low. In more open watersheds, such as those in grasslands, diel fluctuations can be 5-10 ^{o}C (Engle and Duffy 2000). Over the diel cycle, water temperature reaches a maximum in late afternoon and declines to a minimum before dawn.

Spatial variability. Stream width, discharge, and number of tributaries all increase with stream order. In small forested streams, temperature of water resembles that of the watershed's subsoil environment. As stream width increases, surface area exposed to solar radiation increases as riparian vegetation shades less of stream surface. Discharge also increases as one moves downstream. A balance of solar radiation, water volume and discharge determines the rate of temperature change downstream, especially in summer. In California, frequent coastal fog during summer reduces solar radiation and diel fluctuations in water temperature. Diel fluctuations in summer water temperature in California coastal streams are often low near the coast and increase beyond the influence of fog.

2) Interactions with other Habitat Factors

Shading: Riparian vegetation 'filters' solar radiation and acts to decrease peak summer stream temperatures and elevate minimum nighttime water temperatures (in colder, non-coastal locations). The extent to which minimum nighttime water temperature is buffer by riparian vegetation is poorly known.

3) Biological Responses

Trophic effects: Water temperature has important implications for all trophic levels. Both algal production and rates of microbial decomposition are temperature-dependant. Algae and bacteria are consumed by invertebrates, whose feeding efficiencies are temperature dependent. Finally, invertebrates are consumed by fish whose feeding efficiency and metabolism are temperature dependent.

Fish Metabolism: Q_{10} relationship affects all metabolic processes, at all life stages, including developmental rates of embryos and alevins.

Energy mass balance equation: Consumption = metabolism + wastes + growth,

With temperature (and fish size) as controlling variables affecting metabolism, growth, digestion, and consumption rates. Physiological parameters for consumption, respiration, and waste losses for coho and Chinook salmon and steelhead are available in the literature (e.g. Stewart and Ibarra 1991, Stewart et al. 1983, Rand et al. 1993).

Fish Habitat Use: Because of temperature – dissolved oxygen interactions, fish may have to occupy non-preferred habitat to avoid low dissolved oxygen. For example; brown trout occupy stream riffles rather than preferred pools when dissolved oxygen concentration declines in association with high temps.

Disease: Elevated water temperature presents conditions favorable to the spread of some diseases. Disease outbreaks occasionally occur during migration, when salmon encounter warm water and are crowded (California Department of Fish and Game, 2003).

Acute effects: As metabolic costs exceed consumption, fish lose mass, become stressed and more vulnerable to other mortality agents (disease, competitive and predator-prey interactions). Fish die as upper lethal temperatures are reached, because of enzyme inactivation and protein denaturation. Actual lethal temperatures are affected by acclimation temperature and duration of exposure. Little information is available on long-term exposure to sub-lethal temperatures. In natural stream settings, occurrences of salmonids have been reported at temperatures above lethal limits (Table 1), suggesting that existence of thermal refuges and/or behavioral mechanisms may allow fish persistence above lab-determined thermal tolerances.

Over a longer temporal scale, temperature effects on metabolism affect the timing of life history events, including adult migrations, fry emergence, and smoltification.

Table 1. Summary of temperature requirements[1] for anadromous salmonids occupying coastal California streams.

Species	Upstream migration	Spawning	Incubation	Preferred rearing	Upper lethal
Coho	7.2-15.6	4.4-9.4	4.4-13.3	12.0-14.0	26.0
Fall Chinook	10.6-19.4	5.6-13.9	5.0-14.4	12.0-14.0	26.2
Spring Chinook	3.3-13.3	5.6-13.9	5.0-14.4	12.0-14.0	26.2
Summer Chinook	13.9-20.0	5.6-13.9	5.0-14.4	12.0-14.0	26.2
Steelhead	--	3.9-9.4	--	10.0-13.0	23.9
Cutthroat	--	6.1-17.2	--	--	22.8

[1](data from Bjornn and Reiser 1991).

4) Anthropogenic Activities that Alter Natural Temperature Regime

In the Pacific Northwest, removal of forest canopy cover from logging may increase mean monthly maximum stream water temperature as much as 8 ^{o}C and the mean annual temperature as much as 15 ^{o}C (Champerlin et al. 1991). Incident solar radiation is major contributor to energy balance and localized water temperature in streams. Removing the riparian canopy results in increased solar radiation reaching the stream surface, thereby increasing water temperature. Other anthropogenic activities contributing to elevated water temperature include water removal or storage (dams); discharge of heated water from power plants, industrial uses; and diking or channelization that interrupts groundwater supply.

5) Restoration Treatments that Address Temperature Impairment

Planting riparian vegetation. Because of the high specific heat of water, alternation of shaded and unshaded reaches is not an effective strategy for reducing temperatures. There appears to be an assumption that the overhead shading provided by riparian vegetation is always desirable for temperature control. Because of potential gains in productivity that may accrue from increased solar radiation, riparian plantings solely for temperature control should be recommended only in situations where temperatures are known to be adversely affecting salmonids.

6) Appropriate Monitoring Parameters

Because biological response to temperature is well-studied, it is probably sufficient to monitor temperature (effectiveness monitoring) without a need for monitoring biological response. Temperature is easily monitored with continuously recording thermometers. If restorations succeed in lowering temperature regimes to optimal ranges and salmonids do not respond, one need to then ascertain that other habitat factors don't impose overriding limitations.

Selected Measures for Validation Monitoring

Measures for monitoring the response of salmon and steelhead trout to watershed restoration actions would, ideally, satisfy three criteria. They would; 1) be sensitive to the response of salmon and steelhead to restoration actions, 2) provide results quickly and 3) be applicable over a range of spatial scales. Unfortunately, no single measure captures these criteria. Therefore, we recommend evaluating a suite of measures that are applicable at multiple scales (Table 2) and use information from all life history stages of salmonid fishes (Table 3).

We envision the choice of measures to be guided by monitoring objectives. Although none of these measures meet all three of the desired criteria, each may be used to address specific objectives or in combination with other measures to meet other or multiple objectives. For example: measurements of periphyton chlorophyll *a* may be useful in assessing the effect of turbidity on stream function in a localized area, but would provide little information on how fish responded to turbidity. In combination with other measures, such as juvenile salmonid relative weight and age structure, it could be used to identify sources of turbidity and the influence of turbidity on fish over broader spatial scales. We provide rational for selecting each criterion below.

Rationale

1. Periphyton chlorophyll *a.*

Periphyton consists primarily of attached algae. Attached algae employ photosynthesis to convert solar energy and nutrients into biomass. Chlorophyll *a* is a measure of biomass in periphyton, and change biomass over time is a measure of growth. Since turbidity and suspended sediment reduce the penetration of photosynthetically active radiation in water, growth of periphyton should be reduced under turbid conditions. Periphyton chlorophyll *a* should respond quickly, relative to other biological measures, to reduced light. Because periphyton consists of attached algae, it is a measure that should also be applicable to detecting change at specific sites or stream reaches.

2. Macroinvertebrates

Stream macroinvertebrates transfer energy produced by periphyton and other primary producers into biomass that may be consumed by fish. A considerable body of literature also describes how macroinvertebrate communities respond to perturbation. This literature is the basis for macroinvertebrate community measures developed for monitoring stream water quality and biological integrity. Many of these measures, however, have been developed to detect organic or chemical pollution, rather than turbidity and suspended sediment. Recent investigations into the distribution of macroinvertebrate species in the Pacific northwest relative to sediment impacts have yielded positive results (Relyea et al. 2000).

Table 2. Potential measures for watershed restoration validation monitoring. Arranged by applicable spatial scale and time required to acquire data for measure.

	Time		
Measure	Weeks	Months	Years
Site			
Periphyton chlorophyll a	√		
Macroinvertebrates		√	
Juvenile salmonid presence-absence	√		
Redd presence/abundance		√	
Macroinvertebrates		√	
Stream Reach			
Macroinvertebrates		√	
Juvenile salmonid abundance	√		
Juvenile salmonid diseases/parasites	√		
Juvenile salmonid relative weight		√	
Juvenile salmonid age structure		√	
Stream			
Juvenile salmonid population size		√	
Juvenile salmonid biomass		√	
Juvenile salmonid relative weight		√	
Salmonid spawner/recruit ratio		√	
Smolt size		√	
Smolt production		√	
Proportion individuals as alien fish species		√	
Watershed			
Adult salmonid Escapement		√	
Salmonid population trajectory			√
Salmonid genetic structure		√	

Table 3. Potential measures for watershed restoration validation monitoring. Arranged by level of biological organization.

Measure
Primary Producer
1. Periphyton chlorophyll a
Primary Consumer
2. Macroinvertebrates
Secondary Consumer
3. Salmonid egg-fry survival
4. Presence or absence of salmonids
5. Juvenile salmonid age structure
6. Juvenile salmonid abundance or population size
7. Juvenile salmonid biomass
8. Juvenile salmonid relative weight
9. Presence of diseases/parasites
10. Salmonid spawner/recruit ratio
11. Salmonid smolt size
12. Salmonid smolt production
13. Adult salmonid escapement
14. Salmonid population trajectory
15. Salmonid population genetic structure
16. Proportion of individuals as alien fish species.

3. Salmonid egg survival

Survival of salmon and steelhead trout during the egg stage is directly influenced by fine sediment introduced to streams (Waters 1995). We hope to develop methods for indexing egg survival using eggs from disease free hatchery eggs, if this activity is allowed.

4. Presence/absence of salmonids

The presence of various life history stages of salmon or steelhead trout where these species were formerly absent may be a useful measure in evaluating specific restoration actions. For example: the presence of either redds, adults or juveniles above barriers to migration that have been removed or modified to allow fish passage.

5. Juvenile salmonid age structure

Anadromous salmonids must attain a critical size to successfully smolt and enter the ocean. Time to attain this critical size is thought to be influenced by a variety of environmental factors, among them turbidity. Turbidity has been hypothesized to result in reduced feeding success and delayed time to smolting (Personal Comm., B. Trush, McBain and Trush, Arcata, CA). If correct, juvenile steelhead trout populations negatively influenced by turbidity would require more time to grow to smolting size and would exhibit a broader range in age distribution.

6. Juvenile salmonid abundance or population size

Population density is widely thought to reflect habitat quality. Thus, density of salmon and steelhead trout may be a useful site or reach specific measure for restoration actions such as instream restoration. Population size may be estimated when samples for density estimates are randomly allocated among available habitats. Under some circumstances, population size may be a more desirable measure of conditions within a stream or watershed because is is not influenced by variability in distribution of fish among years.

7. Juvenile salmonid biomass

Number of juvenile salmonids in streams often varies considerably among years. Also, growth of juvenile salmonids is inversely density dependent or at least influenced by density. Standing stock biomass combines information on the number and size of individuals per unit area at one point in time. It is considered a measure of stream productivity and thought to vary less than number of individuals or mean size.

8. Juvenile salmonid relative weight

Weight of fish varies as a power function of length as: $w = a\,l^{b}$ or, $\log w = \log a + b(\log l)$, a and b are constants. In fish having an unchanging body form and specific density with growth, the slope of the regression (b) would equal 3 and growth would be characterized as isometric (Ricker 1975). In fish exhibiting variation in body form or density with growth, the slope of the regression (b) would be greater or less than 3 and growth is characterized as allometric.

Condition factors have been developed from these relationships to compare relative weight and length of fish. The most common condition factors employed have been Fulton's condition factor, w/l^3 (Ricker 1975) and the allometric condition factor, w/l^b, where the constant "b" is determined for a species under standard or reference conditions. Both are, however, influenced by fish size and not useful in comparisons among populations.

Relative weight (Wr) is the single condition factor not correlated with fish size (Blackwell et al. 2000). Relative weight was developed for the purpose of comparing condition or health of populations. A relative weight equation is developed from length weight relationships from 50 or more individual populations representative of an entire region. Individual population data are used to estimate weight at predetermined length intervals, and the estimated weights at length used to construct a regional Wr equation.

9. Salmonid diseases/parasites

The frequency of diseased individuals or individuals having parasites has been applied as an index of health or stress. Recording the presence of diseases and/or parasites on individual juvenile salmonids may help identify watersheds where health is an impediment to recovery.

10. Salmonid recruit/spawner ratio

The number of juveniles produced per adult (recruit/spawner ratio) provides an index that incorporates information on fecundity and survival. Theoretically, an atypically low spawner/recruit ratio could provide evidence that survival from egg deposition to juvenile sampling may be a problem in recovering populations.

11. Smolt size

Smolt size varies less within species than many other measures. However, when combined with limited aging data it can be used to infer age of smolts. Delayed smolting could provide evidence of watershed problems affecting growth.

12. Salmonid smolt production

Salmon and steelhead smolt production determined by smolt trapping has been recommended as a measure for the response of salmon and steelhead trout to habitat modifications (Reeves et al. 1991). Smolt production offers a compromise between adult escapement that is viewed as the best ultimate response and juvenile abundance, which offers the greatest amount of uncertainty.

13. Adult salmonid escapement

Escapement of adult salmon and steelhead trout is a measure of the number of individuals within a population that survived to reproduce. This measure provides the basis for assessing population viability and, in most cases, is the ultimate measure of restoration success or failure.

14. Salmonid population trajectory

Salmon and steelhead trout population trajectory, whether population size is increasing, declining or unchanged, is constructed from multiple years of adult escapement data. It is not a field measure, rather an analysis tool.

15. Adult salmonid genetic structure

Information on the genetic structure of salmon and steelhead trout populations in California is limited, but increasing. Genetic information will be needed to evaluate the efficacy of certain restoration practices, particularly hatchery augmentation and other rearing projects.

16. Proportion of individuals as alien fish species

The presence of alien species may pose problems for the restoration of salmon and streelhead trout populations in some watersheds. For example: the introduction of northern pikeminnow to some rivers has resulted in their competing with and preying on juvenile salmonids. This measure has been used elsewhere in the Pacific Northwest as a measure of general river health.

Quality Assurance and Quality Control Protocols

QUALITY ASSURANCE

Quality assurance refers to the process of insuring that data collected are dependable and credible. A quality assurance plan describes issues of experimental design, field methods, laboratory procedures, data analysis and reporting of data.

The watershed restoration monitoring program is designed to produce reliable data on the status of fish populations and watersheds for managers and policy decision makers. A quality assurance (QA) program that can be implemented consistently by all participants throughout the life of the program is needed to achieve this goal. The QA plan contains more detailed information regarding activities and procedures associated with sample collection, measurement data collection, and data reporting activities. Elements of a QA plan include:

TRAINING. Training requirements should be documented and past training received by personnel involved with the monitoring program should be kept on file. A training program should be implemented that includes practice sampling visits to insure consistency in methods, laboratory procedures, and the use of a qualified museum facility or laboratory to confirm any field identifications of biological specimens.

Field Sampling Procedures. Standard operating procedures for field collections should be included in the QA plan. At a minimum, the field collection SOP should include:

Collecting Permits
Field data forms
Methods used in collecting data
Field Processing
Handling and Care
Specimen Preparation and Preservation
Labeling

Chain of Custody. Chain of Custody is necessary part of collecting samples that will be removed from the field for later analysis. A chain of custody form is used to track samples from the field to the laboratory and then to their archival location. The chain of custody form contributes to organizational integrity and will assist in locating lost or misplaced samples.

Laboratory Analysis Procedures. Standard operating procedures for laboratory analysis of samples should be included in the QA plan. Elements of a laboratory SOP include:

Accurate Taxonomic Identification
Taxonomic Specialists
Voucher Specimens
Independent Taxonomic Verification
Taxonomic References

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QUALITY CONTROL

Quality control (QC) refers to the specific procedures used to insure dependability and credibility of data collected, processed and reported. Quality control activities associated with field operations are integrated into the field procedures. Elements of QC procedures include:

Instruments. Instruments should be maintained, including regular inspection, calibration and testing. A log, in which maintenance actions are recorded, should be kept for each instrument.

Data Management. How data are to be managed, including the electronic format to be used, where they will be stored and processed, should be described. Also, describe procedures implemented to insure accuracy of data and procedures to validate the accuracy.

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Appendix A. Association between restoration activities, habitat elements and landscape factors.

Restoration Activity	Critical Habitat Element	Contributing Landscape or Habitat Factors
Instream habitat restoration (HI)	Cover	Water depth Discharge LWD Riparian condition Substrate particle size
	Water temperature	Upstream inflow Solar radiation Air temperature Fog Shade Groundwater inflow Water depth/pool volume Discharge
	Pool frequency	Gradient LWD Hard points
	Pool depth	Discharge LWD Hard points Substrate Stream size
	Sediment particle size	Discharge Water depth Soil type Bank/upslope condition Roads (km/km^2) Hillslope failures % logged % urban % agricultural
Instream bank stabilization (HS)	Turbidity	Water depth Discharge Soil type Riparian fencing
	Cover Pool frequency Pool depth Sediment particle size	(see HI above)

Restoration Activity	Critical Habitat Element	Contributing Landscape or Habitat Factors
Instream barrier modification (HB)	Access to habitat	Gradient LWD Hard points (e.g. rocks, boulders) Discharge Stream size
Fish ladder (FL)	Access to habitat	Human placed barrier
Fish screening of diversions (SC)	Limiting access by fish	Water withdrawn from stream
Upslope watershed restoration (HU)	Turbidity	Forest harvest % and frequency Fire frequency Basin slope Roads - density and condition Hillslope failures Soil type % forested % urban % agricultural
	Sediment particle size	(see HI above)
	Organic inputs	Basin vegetation type % urban % agricultural and agricultural practices
	Nutrient cycling	Discharge Groundwater inputs Basin land use Soil type
	LWD recruitment	Basin vegetation type Forest harvest % and frequency Fire frequency Basin slope
Riparian restoration (HR)	Cover Water temperature Pool frequency Pool depth Turbidity Sediment particle size Organic inputs	(see HI and HU above)

	Nutrient cycling LWD recruitment	
Restoration Activity	Critical Habitat Element	Contributing Landscape or Habitat Factors
Cooperative fish rearing (RE)	Emergency population augmentation	
Acquisition of water rights	Water volume Water temperature Pool frequency Pool depth	Discharge Groundwater inputs Climate Soil type Basin land use Basin vegetation type % urban % agricultural and agricultural practices

APPENDIX B. FINE SEDIMENT TOLERANCE CATEGORIES AND INDEX SCORES FOR AQUATIC INSECTS.

Taxa intolerant to fine sediment (0% to 30% fine sediment)

Taxon	Streams present in (n = 562)	FSBI Score
Ephemeroptera		
Caudatella spp.	53	8
Epeorus grandis	54	8
Plecoptera		
Megarcys spp.	73	8
Trichoptera		
Arctopsyche grandis	117	8
Arctopsyche spp.	122	8
Ecclisomyia spp.	52	8
Oligophlebodes spp.	74	8

Taxa moderately intolerant to fine sediment (31% to 50% fine sediment)

Taxon	Streams present in (n = 562)	FSBI Score
Diptera		
Antocha spp.	196	6
Atherix spp.	72	6
EPHEMEROPTERA		
Acentrella spp.	105	6
Attenella spp.	70	7
Cinygmula spp.	256	6
Drunella coloradensis /flavilinea	92	7
Drunella doddsi	219	7
Drunella grandis	63	7
Drunella grandis/spinifera	188	7
Drunella spinifera	52	7
Drunella spp.	502	7
Epeorus albertae	77	6
Epeorus longimanus	80	6
Epeorus spp.	291	6
Rhithrogena spp.	279	6
PLECOPTERA		
Cultus spp.	56	7
Doroneuria spp	67	7
Hesperoperla pacifica	154	7
Pteronarcys spp.	55	6
Zapada oregonensis	99	6
TRICHOPTERA		
Apatania spp.	89	7
Brachycentrus americanus	117	7
Brachycentrus occidentalis	67	6
Brachycentrus spp.	204	6
Dicosmoecus spp.	66	6
Glossosoma spp.	239	6
Neophylax spp.	86	6
Rhyacophila Betteni grp.	131	6
Rhyacophila Hyalinata grp.	58	7

Taxa moderately tolerant to fine sediment (51 – 70% fine sediment)

Taxon	Streams present in (n = 562)	FSBI Score
Coleoptera		
Heterlimnius corpulentus	104	5
Heterlimnius spp.	249	5
Narpus concolor	52	5
Narpus spp.	104	5
Zaitzevia spp.	215	5
Diptera		
Clinocera spp.	84	5
Glutops spp.	79	5
Hemerodromia spp.	57	5
Pericoma spp.	140	5
Ephemeroptera		
Ameletus spp.	209	4
Baetis bicaudatus	110	5
Baetis bicaudatus/tricaudatus	547	5
Baetis spp.	562	4
Baetis tricaudatus	399	5
Diphetor hageni	165	4
Ephemerella inermis/infrequens	230	4
Ephemerella spp.	251	4
Paraleptophlebia bicornuta	59	5
Serratella spp.	168	5
Serratella tibialis	141	5
Tricorythodes minutus	71	4
Tricorythodes spp.	99	4
Plecoptera		
Calineuria californica	116	5
Skwala spp.	189	5
Sweltsa spp.	317	4
Visoka cataractae	53	5
Yoraperla spp.	64	5
Zapada spp.	499	4
Trichoptera		
Hydropsyche spp.	242	5
Hydroptila spp.	95	5
Lepidostoma - sand case larvae	86	5
Micrasema spp.	217	4
Parapsyche elsis	88	4
Parapsyche spp.	110	4
Rhyacophila Brunnea grp.	228	5
Rhyacophila Coloradensis grp.	69	4
Rhyacophila spp.	916	5

Taxa tolerant to fine sediment (71% to 100% fine sediment)

Taxon	Streams present in (n = 562)	FSBI Score
Coleoptera		
Cleptelmis ornata	58	2
Cleptelmis spp.	150	2
Lara avara	78	2
Optioservus spp.	348	3
Diptera		
Chelifera spp.	205	2
Dicranota spp.	232	2
Dixa spp.	98	1
Hexatoma spp.	253	3
Limnophila spp.	59	2
Simulium spp.	268	3
Tipula spp.	98	3
Ephemeroptera		
Cinygma spp.	64	2
Heptagenia/Nixe spp.	78	2
Paraleptophlebia spp.	426	2
Megaloptera		
Sialis spp.	109	1
Plecoptera		
Isoperla spp.	219	2
Malenka spp.	68	2
Zapada cinctipes	308	3
Zapada columbiana	66	3
Trichoptera		
Cheumatopsyche spp.	100	2
Lepidostoma - panel case larvae	51	2
Lepidostoma spp.	312	2
Psychoglypha spp.	52	3
Rhyacophila Sibirica grp.	178	3
Wormaldia spp.	86	2

APPENDIX C: EXISTING VALIDATION MONITORING PROGRAMS

EXISTING VALIDATION MONITORING PROGRAMS

A number of agencies and citizens groups have implemented stream biological monitoring programs. Most of these programs are intended to provide data on the current status or trends in the health of streams and rivers. As of this writing, we could not find any validation monitoring programs that are assessing the biological responses to watershed restoration. Nor could be locate validation monitoring programs intended to provide data on the responses of fish to management actions, although several programs to incorporate fish into stream assessments. The state of Washington is currently developing a validation monitoring program, but it appears to be in a stage of development similar to the program being developed in California. Below we summarize stream monitoring programs that include biological sampling.

1. California Aquatic Bioassessment Workgroup

The California Aquatic Bioassessment Workgroup (CABW) is a program sponsored by the California Department of Fish and Game, California Water Resources Control Board and U.S. Environmental Protection Agency. Members of the CABW consist of biologists from university, consulting firms and industry and representatives of state and federal agencies responsible for assessing, monitoring and protecting the biological integrity of surface waters. The mission of the California Aquatic Bioassessment Workgroup is to promote the use of biological information in the evaluation of the integrity of aquatic systems.

CABW uses primarily Rapid Bioassessment Protocols (RBPs) developed by the U.S. Environmental Protection Agency to evaluate the biological integrity of California streams and rivers. Specific objectives of the CABW include:

a) Applying consistent, sound methodological approaches to aquatic bioassessment.
b) Providing a mentor and support network concerning technical and professional issues for workgroup participants.
c) Facilitate communication about bioassessment in California.

2. San Francisco Bay/Delta Ecological Workgroup

The San Francisco Bay/Delta Ecological Workgroup is supported by multiple agencies working in the Bay/Delta. Monitoring by this group includes both biological and physical parameters. The purpose of the work team is to:

a) Develop, evaluate, implement and maintain a comprehensive estuarine and lower river monitoring program that will allow the determination of trends in abundance of aquatic organisms
b) Ensure that compliance with established water quality standards are determined, all monitoring mandates are achieved and meaningful changes in water quality and population trends are identified
c) Coordinate monitoring activities with other monitoring programs in the Estuary.

The workgroup's Objectives are to:

a) Monitor the relative abundance and timing of juvenile Chinook salmon rearing and migrating through the Lower Sacramento River and Delta.
b) Evaluate the significance of Delta fry rearing to overall production of the four races of chinook salmon.
c) Determine the impacts of water development within the delta on the abundance, distribution and survival of juvenile salmon.
d) Identify management measures that could lessen the impacts of water project operations on salmon migrating through and rearing in the

3. Oregon Salmon Life Cycle Monitoring Project

The Oregon Coastal Salmonid Inventory Project is part of the Oregon Plan for Salmon. The project conducts monitoring and research to assess the status of wild stocks of coastal anadromous salmonid populations. Monitoring includes coordinating and conducting coastal adult salmon spawning ground surveys and juvenile abundance surveys, as well as implementing special studies to improve inventory methods. As part of the program, habitat monitoring is also conducted.

The inventory project uses a statistically based rotating panel design to sample about 50 sites within each of four regions of coastal Oregon annually. Sampling provides data that can be used to make inferences about the status of salmon within each region and evaluate trends in abundance. Data used in analyses include adult escapement, juvenile abundance, juvenile/adult ratios, smolt production and habitat condition.

4. Oregon Regional Environmental Monitoring and Assessment Program (REMAP)

The Oregon REMAP is a program of the Oregon Department of Environmental Quality. It uses a statistical sampling design patterned after The U.S. Environmental Protection Agency's EMAP program and employs aquatic macroinvertebrate indicator concepts, although vertebrates are included in assessments.

5. ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP)

The Environmental Monitoring and Assessment Program (EMAP) is a U.S. Environmental Protection Agency research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition and forecasts of future risks to our natural resources.

EMAP aims to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate multi-agency monitoring through large regional projects. EMAP develops indicators to monitor the condition of ecological resources. EMAP also investigates designs that address the acquisition, aggregation, and analysis of multiscale and multitier data.

6. National Water Quality Assessment Program (NAWQA)

The National Water Quality Assessment Program (NAWQA) is a U.S. Geological Survey program intended to provide data on water quality trends throughout the United States. The NAWQA program collects and analyzes data and information in more than 50 major river basins and aquifers across the Nation. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions. The NAWQA program is designed to answer these questions:

a) What is the condition of our Nation's streams and ground water?
b) How are these conditions changing over time?
c) How do natural features and human activities affect these conditions?

7. Rapid Bioassessment Protocols (RBP)

The U.S. Environmental Protection Agency initiated the Rapid Bioassessment Protocol (RBP) program in the 1980's. The purpose of this program was to assist in restructuring existing monitoring programs to better address the U.S. EPA's priorities, e.g., toxics, non-point source impacts, and documentation of "environmental results." The study also provides specific recommendations on effecting the necessary changes. Principal among these are:

a) To issue guidance on cost-effective approaches to problem identification and trend assessment.
b) To accelerate the development and application of promising biological monitoring techniques.

RBPs provide basic aquatic life data for water quality management purposes such as problem screening, site ranking, and trend monitoring (Plafkin et al.1989). The RBP protocols were designed to supply pertinent, cost-effective information when applied in the appropriate context. Technical guidance for biocriteria have been developed by EPA and used to support states in their monitoring programs.

8. Washington DEQ Stream Biological Monitoring

The Washington Department of Environmental Quality monitoring uses aquatic invertebrates as health indicators for Washington streams. They survey about 20 wadeable stream sites annually. Monitoring is intended to reveal changes in streams that may occur from forest and agricultural practices, urbanization, or other controllable sources of impact. In addition to sampling for aquatic invertebrates, sites are surveyed for other conditions including canopy cover, stream bed substrate, flow, turbidity, water temperature, acidity (pH), and dissolved oxygen. Objectives of the program are:

a) Define and document baseline conditions of instream biology
b) Measure spatial and temporal variability of population and community attributes
c) Relate biological integrity of streams with the Department of Ecology's Water Quality Management Areas (WQMA's) using stream invertebrates

9. National Park Service Inventory and Monitoring Program

The purpose of the NPS Inventory and Monitoring Program is to comply with legal requirements, fully implement NPS policy, and guide management activities. The Inventory and Monitoring Program includes aquatic and terrestrial biological sampling, as well as geological and other resources. The program focuses on attaining the following major long-term goals:

a) Establish natural resource inventory and monitoring as a standard practice throughout the National Park system that transcends traditional program, activity, and funding boundaries.
b) Inventory the natural resources and park ecosystems under National Park Service stewardship to determine their nature and status.
c) Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments.
d) Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.
e) Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

10. National Aquatic Monitoring Center

The National Aquatic Monitoring Center (The Bug Lab) is a cooperative venture among the U.S. Bureau of Land Management, the U.S. Forest Service, and Utah State University. This program focuses on the use of aquatic macroinvertebrates in assessing stream health. The purpose of the program is to encourage and foster scientifically sound watershed monitoring programs on public lands with the goal of increasing the consistency and quality of aquatic resource assessments and providing clear, accurate, and timely information to resource managers and the public.

Part III.

Validation Monitoring of Watershed Restoration in California

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Draft Final Report to the Department of Fish and Game
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Introduction

Basic Life History of Salmon and Steelhead in California

Coho Salmon. Juvenile coho salmon, (at least the large majority of those life history types that still exist), spend their entire freshwater residence in or near their small natal streams. If trapping sites are located on large enough streams such that juvenile rearing occurs primarily above the trap sites, adult and juvenile migrant trapping will provide information on the freshwater and marine survival of coho salmon. Marine survival, as we use it here, encompasses the survival of fish from the time the smolts migrate out of the study stream until the adults return to the stream. Thus, this survival includes migration through mainstems and estuaries as both smolts and adults.

Chinook Salmon. Most fall chinook juveniles migrate out of their natal stream by the early summer, and continue rearing in the mainstem rivers and estuaries before migrating to the ocean in late summer and fall. Because of this life history pattern, the trapping program will not be able to estimate marine survival rates for chinook salmon. Trapping will provide estimates of the number presmolt chinook leaving the streams each year. In addition, information on size of migrants and the timing of the migration will be collected.

Steelhead. Steelhead juveniles may move and rear considerable distances from their natal streams before they make their seaward migration. Therefore, unless trapping operations are located near the ocean, no estimate of the total number of ocean migrating juvenile steelhead produced from a known number of adult spawners can be obtained. Consequently, in most cases trapping will not provide information on the marine and freshwater survival of steelhead. Those sites located in the lower portions of river basins will provide information on smolt abundance each year. The sampling will also provide information on the migration timing, and the size and age of the migrants.

Coastal Cutthroat Trout. The freshwater life history of coastal cutthroat trout, which is similar to that of steelhead, presents similar obstacles to using trapping information to estimate their freshwater and marine survival. In addition, the small size of returning searun cutthroat trout adults makes them difficult to trap. Most returning searun cutthroat are small enough to swim through the upper picket fence in the adult trap. In most cases the spacing of the bars in the picket fence cannot be reduced to insure the capture of all searun cutthroat because it would result in the adult trap clogging with debris during high stream flows. Therefore, in most cases, trapping will only enable monitoring of trends in the number of downstream juvenile migrant cutthroat trout. Experiments are currently being conducted with an infrared fish counter that may enable us to count returning adult searun cutthroat trout without actually capturing them in a trap.

Validation Monitoring Protocols

1. Juvenile Salmon and Steelhead Abundance and Population Size

Abundance and population size are terms used, in fisheries biology, to express two similar but different measures. Abundance refers to the number of fish sampled in an area. Abundance is often expressed as the catch given some standardized unit of effort (CPUE), for example the catch per hour of electrofishing. It is sometimes expressed as the number per unit area, in which case it may be referred to as density.

Population size refers to the absolute number of fish in a defined area consisting of multiple habitat units. The area is most often an entire stream or reach of stream having similar habitat conditions. Estimates of population size could be obtained from sampling the entire area of interest, but is usually obtained by sampling a statistically selected sub-sample from those habitats available, then extrapolating to the total area of habitat.

I. Rational

The number of juvenile salmon or steelhead present in a stream or stream reach often requires less effort than estimating abundance of other life history stages, such as adults, smolts or eggs. Measurements of the number of juvenile salmon or steelhead present in a stream also provides several types of information useful to monitoring. First, when measured over multiple years these measures provide information on the response of salmon and steelhead to environmental and other conditions. Second, when combined with measures of the number of adults spawning, they provide information of survival from during the egg to juvenile period. Third, when combined with data on the number of smolts migrating from a stream, they provide information on survival during the entire juvenile period.

Methods described here are intended to provide information on juvenile salmon or steelhead abundance and population estimates. Abundance estimates require less rigorous sampling and are usually better suited to monitoring population trends or the response of a watershed to management actions. For example, measuring change in the abundance of juvenile salmonids over time. However, more rigorous sampling for population estimates is required when comparisons of survival at distinct life stages is desirable.

II. Limitations

Methods described here are intended for small – medium size streams in which most pools (>75%) are <1.1m in deep ant the stream has a wetted perimeter of ≤ 10 m. Water in streams must also allow divers to see fish clearly at 3-5 m if visual counts of juvenile salmonids are to be considered reliable.
These conditions are necessary for two divers to effectively sample a stream. Streams that are too large to be sampled with snorkeling should be sampled with electrofishing equipment. Similarly, streams too small to dive or in which the visibility is limited should be sampled with electrofishing equipment.

Sampling during August – October will insure that meeting these requirements is most probable. During this period, water clarity in California streams is greatest and juvenile coho salmon and steelhead are large enough to be visually located and distinguished.

III. Sampling Methods

A. Estimating Abundance

Estimating the abundance of fish in an area requires information on the habitat and fish. This information is gathered in two steps, first, the habitat available is classified and second, the fish using those habitats are counted.

1. Measuring habitats

Two people are needed to classify and measure habitat units. Habitat measurements should be completed soon enough before fish sampling that habitat depths and areas do not change during the interval. In measuring habitats, one person carries a hip-chain to measure linear distance from the starting point and a stadia rod to measure width of the habitat units and their depth, if desired. A second person records data. All habitat units within the stream or stream reach in which abundance estimates are to be made must be classified and measured.

Individual habitat units are classified as either runs, riffles, pools, deep pools or other habitats. Each habitat unit must be longer than its average width. It should be separated from neighboring habitat units by a distinct hydraulic break so that movement of fish between units during the dive survey is limited. Habitat units that appear to be comprised of two habitat types should be classified to reflect the majority of the unit. General definitions of habitat types for fish sampling adopted from Flosie et al. (2000) are:

1. Pool (P) - a scoured habitat unit with slow currents, little surface turbulence, and maximum depth < 1.1 m.
2. Run (N) – quickly flowing water having little surface agitation and few occurrences of substrate breaking the surface. In defining habitat for fish sampling, we recommend combining glide and run habitats as defined by Flosie et al. (2000). Run habitats have a minimum of 60% of their area in water > 40 cm deep.
3. Riffle (R) – habitats with fast-flowing water and substrate breaking the surface, causing surface turbulence. Riffle habitats are too shallow to dive.
4. Deep Pool (DP) – a scoured habitat unit with slow currents, little surface turbulence and a maximum depth > 1.1 m.
5. Other (O) – other habitats are those that present features that make either snorkel observations or electro-fishing difficult. For example; side channel habitats may be small and shallow relative to the main channel, or habitats having complex structures that present obstacles to visual recording or netting of fish.

Habitat unit length, width, depth and surface area are recorded on the data sheet (Appendix table 1) in numerical sequential order (NSO) from the downstream starting point. Each NSO number can then be associated with a specific habitat unit.

Time and effort of measuring habitats can be reduced by visually estimating surface area of the habitat. If visual estimation is used, accurate measurements should be recorded on subset of the total of each habitat type. This can be accomplished by systematic random sampling (see Box 5.1).

Box 1.1. Instructions for systematic random sample selection.

Steps in systematic sampling if 20% of the total habitat units are selected for accurate measurement.

1. For each habitat type, first draw a random starting number between 1 and 5. If, for example, the starting random number for pool habitats was 3, then accurate measurements should be recorded on NSO 3, 8, 13, 18, 23, etc. until the survey is completed. A separate random starting number must be drawn for each habitat type.
2. Visually estimate and record the area of the habitat unit.
3. Physically measure and record the area and habitat characteristics of that unit.
4. Physically measure and record habitat characteristics on units at the same interval between units.
5. Calculate a calibration ratio (Q) using at least 10 habitat units:

   $Q = \Sigma m_j / \Sigma x_j$, where m_j = the accurate measurement of habitat area and x_j = the visual estimate of habitat area.
6. The total area of each habitat type (M) may then be estimated from:

   $M = T_x * Q$, where $T_x = \Sigma x_j$ = sum of 1 to N visual estimates of area for a habitat type and N = the total number of units of a particular habitat type.
7. The variance (V, a measure of uncertainty) of the estimated total habitat type can then be calculated from:

   $V(M) \simeq [N^2 * (N-n) / N*n] * [\Sigma(m_j - Qx_j)^2 / n - 1]$, where n = sample size or number of accurately measured habitats.

Accurate measurement of habitat units should follow standardized procedures. We recommend measuring width in 2 m intervals on simple habitats. Measurement interval may require adjustment on irregularly shaped habitat units. Use width measurements to calculate average width, and multiply average width by habitat length to obtain surface area.

2. Conducting the Fish Census

The primary sampling method recommended for counting fish is visual observation using snorkel gear. This method is less costly and intrusive than other methods. However, visual observation techniques are not possible in all types of habitats, nor are they applicable in some streams. Electro-fishing is recommended in situations where visual observation is either not possible or would provide inaccurate results. Methods for electro-fishing are described later in this section.

Visual observation may be used to sample run, pool, and deep pool habitats. A systematic random sample of each habitat type should be drawn from the total of habitat units measured (Hankin and Reeves 1988). Selection of fish sampling units may be carried out using the methods described in box 5.1. The proportion of units selected for sampling can differ among habitat types. For example, sampling could include 30% of pool and run habitats, but only 10% of riffle habitats. If the proportion of habitat units to be sampled is determined before habitats are classified, the upper and lower boundaries of habitat units selected for later fish sampling should be marked with flagging during habitat surveys. Having habitat surveyors delineate those habitats to be sampled for fish minimizes uncertainty in later locating specific habitat units and delineating their boundaries.

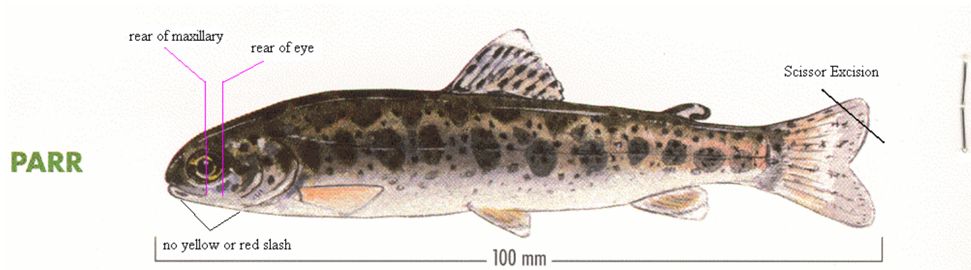
Two pool or run habitat units outside the area to be sampled should be identified for practice. Snorkel divers should survey these habitats before starting the fish survey. These practice habitats allow the divers' to familiarize themselves with the species and size classes of salmonids they will likely encounter in subsequent habitats. Ages and size classes of salmonids can very among streams during any season because of differences in time of emergence and growth.

Identification of all species can be problematic within the range of coastal cutthroat trout. Juvenile steelhead and cutthroat trout cannot be consistently distinguished until the reach a length of around 80 mm fork length (Figure 5.1). Thus, from the Eel River northward, small trout should be counted as age 0+ trout species. Steelhead and cutthroat trout > 80 mm FL can usually be assigned to age 1+ of their species. However, these species should be recorded as age 1+ trout if divers are not confident in their ability to separate these species.

The fish census is conducted primarily by visual observation using snorkeling, with limited electro-fishing. Visual observations of pre-selected pool, deep pool and run habitats are conducted, progressing from downstream to upstream. Divers should enter the downstream end the habitat unit to be surveyed. They should move upstream, parallel to one another, through the habitat unit using deliberate movements so as to minimize disturbance to fish. Fish are counted as divers move upstream and recorded using either a hand counter or underwater record slate. Using a recording device is especially important where fish are abundant and where multiple species occur. After completing the census for a specific habitat unit, data are recorded in small "Write-in-the-Rain" or plastic paper notebooks than can be carried in a dive pouch.

Visual observation methods are not possible in riffle habitats and may not be effective for entire reaches of some shallow streams. Furthermore, cobble and other obstructions in riffle and other shallow habitats also make seine netting inefficient. These habitats must be sampled using electro-fishing techniques.

A



B

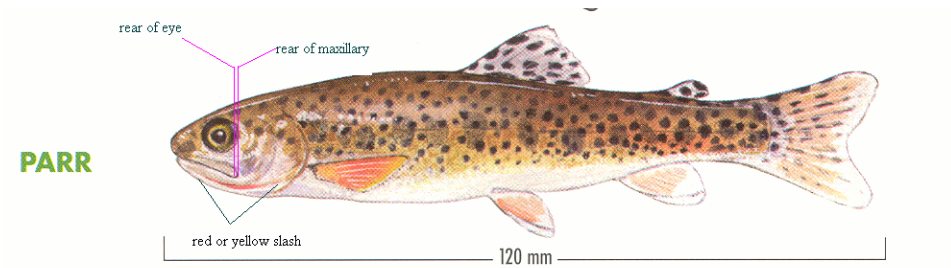


Figure 1.1. A) Steelhead parr illustrating the location of the eye relative to the length of the maxillary and lack of a red or yellow jaw slash and B) cutthroat trout parr illustrating the location of the eye relative to the length of the maxillary and presence of a red or yellow slash.

Sampling with electro-fishing techniques requires two or three people. One person carries the backpack electrofishing unit, while others net fish that are stunned by the electrical current. Specific conductance and temperature of the water should be measured and recorded before sampling (see Box 5.2 for guidelines on water temperature and specific conductance). Specific conductance provides information on how well water will conduct an electrical current and should be used in selecting electrofisher settings. Before sampling, a fine mesh net should be stretched across the downstream end of the habitat unit. This net serves to block stunned fish that may float downstream so that they may be captured and properly revived before release.

As with visual observations, the electrofishing crew enters a riffle or other habitat unit at the downstream end and proceeds upstream. The area of the habitat unit should be electrofished thoroughly, but excessive time should not be spent in small areas due to potential harm of exposing fish to the electrical field for extended periods (NOAA 2000). Fish that are stunned should be removed from the electrical field as quickly as possible and placed in a bucket containing fresh stream water. After the habitat unit has been completely sampled, fish collected are enumerated, allowed to recover and released.

Box 1.2. Stream electrofishing guidelines (from NOA, 2000).

Initial Site Surveys and Equipment Settings

1. In order to avoid contact with spawning adults or active redds, researchers must conduct a careful visual survey of the area to be sampled before beginning electrofishing.
2. Prior to the start of sampling at a new location, water temperature and conductivity measurements should be taken to evaluate electroshocker settings and adjustments.
3. No electrofishing should occur when water temperatures are above 18°C or are expected to rise above this temperature prior to concluding the electrofishing survey. In addition, studies by NMFS scientists indicate that no electrofishing should occur in California coastal basins when conductivity is above 350 µS/cm.
4. Whenever possible, a block net should be placed below the area being sampled to capture stunned fish that may drift downstream.
5. Equipment must be in good working condition and operators should go through the manufacturer's preseason checks, adhere to all provisions, and record major maintenance work in a logbook.
6. Each electrofishing session must start with all settings (voltage, pulse width, and pulse rate) set to the minimums needed to capture fish. These settings should be gradually increased only to the point where fish are immobilized and captured, and generally not allowed to exceed conductivity-based maxima (Table 5.1). Only direct current (DC) or pulsed direct current (PDC) should be used.

Table 1.1. Guidelines for initial and maximum settings for backpack electrofishing.

	Initial settings	Maximum	settings
Voltage	100 V	Conductivity (uS/cm)	Max. Voltage[2]
		<100	1100
		100–300	800
		>300	400
Pulse width	500 us		5 ms
Pulse rate[1]	30 Hz		70 Hz

[1] In general, pulse rates > 40 Hz will injure more fish than rates < 40 Hz.
[2] In California coastal streams, settings should never exceed 400 volts and electrofishing should not occur if conductivity is greater than 350 µS/cm.

Electrofishing Technique

1. Sampling should begin using straight DC. Remember that the power needs to remain on until the fish is netted when using straight DC. If fish capture is unsuccessful with initial low voltage, gradually increase voltage settings with straight DC.
2. If fish capture is not successful with the use of straight DC, then set the electrofisher to lower voltages with PDC. If fish capture is unsuccessful with low voltages, increase pulse width, voltage, and pulse frequency (duration, amplitude, and frequency).

Box 1.2 (continued).

3. Electrofishing should be performed in a manner that minimizes harm to the fish. Stream segments should be sampled systematically, moving the anode continuously in a herringbone pattern (where feasible) through the water. Voltage gradients may be high when electrodes are in shallow water where boundary layers (water surface and substrate) tend to intensify the electrical field.
4. Do not electrofish in one location for an extended period (e.g., undercut banks) and regularly check block nets for immobilized fish.
5. Fish should not make contact with the anode. Remember that the zone of potential injury for fish is 0.5 m from the anode.
6. Electrofishing crews should be generally observant of the condition of the fish and change or terminate sampling when experiencing problems with fish recovery time, banding, injury, mortality, or other indications of fish stress.
7. Netters should net fish quickly and not allow the fish to remain in the electrical field any longer than necessary.

Sample Processing and Recordkeeping

8. Fish should be processed as soon as possible after capture to minimize stress. This may require a larger crew size.
9. All sampling procedures must have a protocol for protecting held fish. Samplers must be aware of the conditions in the containers holding fish; air pumps, water transfers, etc., should be used as necessary to maintain safe conditions. Also, large fish should be kept separate from smaller prey-sized fish to avoid predation during containment.
10. Use of an approved anesthetic can reduce fish stress and is recommended, particularly if additional handling of fish is required (e.g., length and weight measurements, scale samples, fin clips, tagging).
11. Fish should be handled properly (e.g., wetting measuring boards, not overcrowding fish in buckets, etc.).
12. Fish should be observed for general condition and injuries (e.g., increased recovery time, dark bands, apparent spinal injuries) and be completely revived before releasing at the location of capture. Every attempt should be made to process and release ESA-listed specimens first.
13. Pertinent water quality (e.g., conductivity and temperature) and sampling notes (e.g., shocker settings, fish condition/injuries/mortalities) should be recorded in a logbook to improve technique and help train new operators.

Numbers of juvenile salmonids observed during visual surveys and captured during one-pass electrofishing can be used to provide and index of abundance. When divided by the area of habitat sampled, this index of abundance can be expressed as a density estimate (number/m2). However, neither is equivalent with a population estimate.

B. Estimating Population Size

Estimating the size of a juvenile salmonid population requires additional sampling and analysis. The additional sampling is essentially devoted to validating assumptions about the efficiency of visual observations (Hankin and Reeves 1988). Added analyses are needed to extrapolate estimates from a sub-sample of habitats to the entire area represented by that type of habitat.

Steps in estimating population size from systematic random samples.

1. Complete a survey of habitats available within the stream or reach of interest, as described in Box 5.1.
2. Complete snorkel surveys as described on pages 3 –6.
3. Draw a systematic random sample of habitats in which visual observations were made. This sample should include at least 10 units from each habitat type.
4. Conduct 3 – 5 pass depletion electrofishing in each of these habitat units and calculate the number of juvenile salmonids of interest (Y_T) as:

   $Y_T = M_0 * \Sigma Y_i / \Sigma M_i$, where M_0 = the total size of all habitat units, M_i = the size of the primary habitat unit, and Y_i = total number of the fish species being sampled in unit M_i. An estimate of precision for this estimate of abundance is presented in Hankin (1984).
5. A ratio for calibrating the diver visual observations with the more accurate electrofishing samples results is calculated as:

   $R = \Sigma Y_T / \Sigma D_T$, where the sum applies to T = 1 – n', n' = the number of habitat units in which both diver counts and electrofishing estimates are made, and D_T = the mean count by two divers in habitat unit T.
6. For habitat units in which only diver counts were recorded, use the calibration ratio to correct for visual uncertainty:

   $Y_T = R * D_T$
7. Last, the total number of fish in all units of a specific habitat type is estimated from:

   $Y_{hat} = N * \Sigma Y_T / n$, where N = the total number of units of the specific habitat type and n = the total number of units in which diver counts have been made.

While the above calculations seem tedious, they are needed to produce a statistically valid population estimate and satisfy the assumptions of sampling theory.

IV. Considerations Before Sampling

Natural variability

Number of juvenile salmonids present varies among reaches, seasons and years within a single stream and among different streams. We sampled juvenile steelhead in Bull Creek, Humboldt County, during August 2002 to test how variable results of abundance and population estimates would influence ability to detect change.

The area sampled included the lower 2.5 km of Bull Creek, beginning at the streams confluence with the South Fork Eel River. We stratified this section into three stream reaches, based on visual observation of habitats and stream gradient. Habitat was classified for 96 units covering the entire 2.5 km and measurements of area recorded for each habitat unit (Table 5.2).

Table 1.2. Summary of habitat area in three reaches of Bull Creek, Humboldt County, during August 2002.

	Lower	Middle	Upper
Number Run Units	7	6	15
Mean Area (m^2)	196	140	147
S.D. of Mean	82	98	88
Σ Area (m^2)	1,373	839	2,202
% Area	21.8	17.6	49.9
Number Pool Units	8	17	10
Mean Area (m^2)	448	127	125
S.D. of Mean	308	81	72
Σ Area (m^2)	3,587	2,152	1,246
% Area	56.9	45.0	28.2
Number Riffle Units	8	14	11
Mean Area (m^2)	168	128	88
S.D. of Mean	141	99	55
Σ Area (m^2)	1,342	1,788	965
% Area	21.3	37.4	21.9

For fish sampling, we selected a random sample consisting of 25% of the total habitat units. These habitat units were sampled entirely by 3-pass depletion electrofishing to insure accurate estimates of density were made, density and population size calculated as described above. Density estimates increased from the lower reach to the upper reach, while population size was greatest in the middle reach (Table 5.3).

Table 1.3. Mean density (+ S.D.) and population size (+ S.D.) of juvenile steelhead in three reaches of Bull Creek, Humboldt Count, during August 2002.

	Lower	Middle	Upper	All
Mean Density (m^2)	0.10	1.86	2.01	1.34
S.D. of Mean	0.09	0.68	0.77	1.04
Population Estimate	401	9296	8098	
S.D. of Population Estimate	77	1017	875	

We used power analysis to evaluate the ability of both density estimates and population size to detect change over years of sampling (Gibbs 2003). In analyzing density estimates, we evaluated three amounts of sampling effort. First, we evaluated the power of the total of 25 samples from Bull Creek change over time, we then randomly eliminated one-third of the samples and repeated this analysis, and last, we randomly eliminated another one-third of the samples and repeated the analysis.

Conditions we assumed were that samples for monitoring would be collected once each year and that the coefficient of variation among years was 50% (a CV we calculated for coho salmon abundance in Prairie Creek was 51% over four years). We set α at 0.10, and ran 500 iterations of a 2-tailed t-test to estimate how many years of sampling would be required to detect change at a desired power level of 0.80. Results from this analysis suggest that change, under these conditions, can be detected after three years of sampling with 17 samples, and that increasing sample size adds little to the ability to detect change (Figure 5.1). With only nine samples, the ability to detect change under these conditions is delayed to five years.

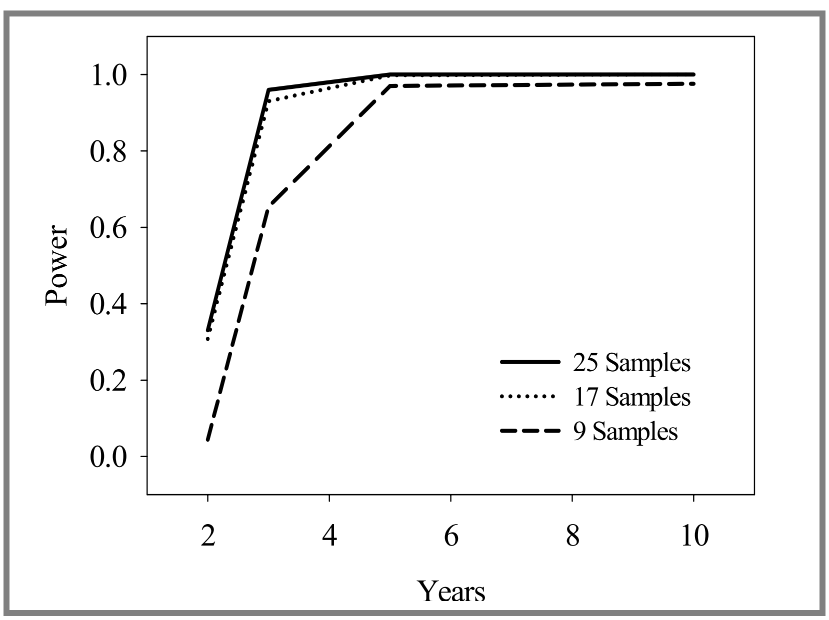


Figure 1.1. Power to detect a 10% increase in density of juvenile steelhead within a 2.5 km portion of Bull Creek, Humboldt County, California, with a sampling effort of 9, 17 and 25 randomly selected habitats per year.

In evaluating population estimates, we used the same assumptions and employed the same statistical technique as for density estimates. Results suggest that a 10% increase in population size in the lower reach could be detect in five years, but detecting the same change in the middle and upper reaches would require about eight years (Figure 5.2).

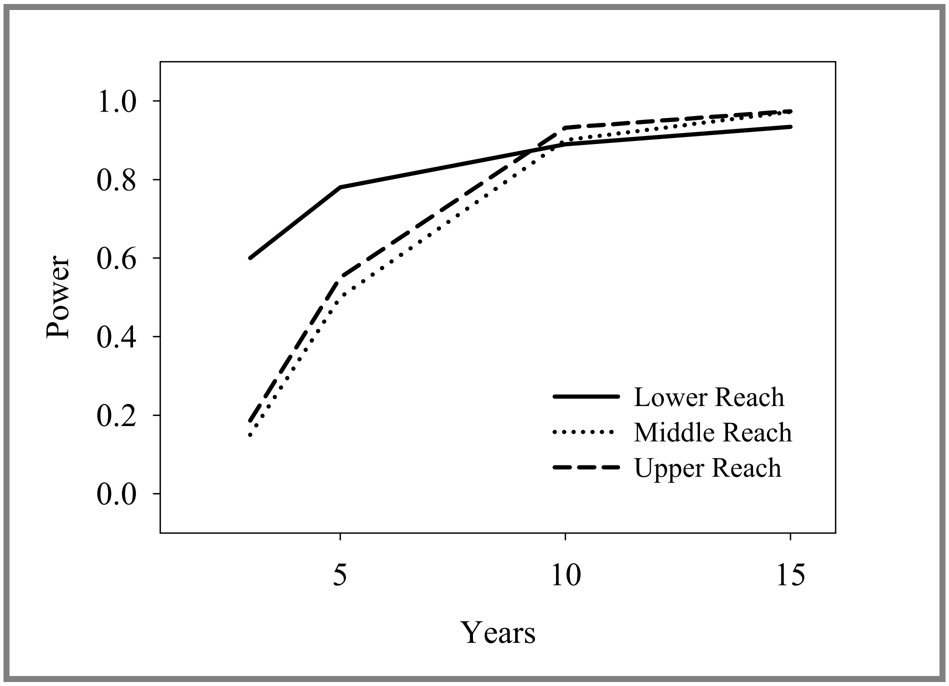


Figure 1.2. Power to detect a 10% increase in the population size of juvenile steelhead within the lower, middle and upper third of a 2.5 km portion of Bull Creek, Humboldt County, California.

V. Quality Control and Quality Assurance

Quality assurance and quality control procedures should be established before juvenile salmon and steelhead sampling. These procedures should include elements of the following:

Training that addresses,

1) safety practices in both stream snorkeling and electrofishing,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) recognition of fish when diving.

The quality assurance plan for data entry and management should include,

1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency. This might include;

1) independent divers sampling a percentage of habitats previously sampled and
2) independent observers participating in electrofishing (we hesitate to recommend added electrofishing due to the potential for added stress on fish).

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

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2. Salmon and Steelhead Presence

I. Rational

The presence of salmon or steelhead in a stream, or reach of stream, can be used to validate some restoration actions. It is obviously a measure that could be employed to validate whether or not removing barriers to migration was successful. Presence surveys may also have application in severely degraded streams that no longer support salmon or steelhead.

II. Limitations

Determining whether or not a species is present in a stream or watershed is not always an easy task. Indeed, one of the sources of uncertainty in monitoring programs is the ability to detect the animal of interest (MacKenzie et al. 2002). Our ability to detect the presence of salmon and steelhead varies with life stage, sampling method and location. For example, while adult salmon and steelhead are much larger than juveniles, their presence in streams is most often restricted to periods when visibility in streams is limited. In contrast, although juvenile salmon and steelhead are relatively small they are more numerous than adults and most are present in streams during periods when water is low and clear.

The Department of Fish and Game is currently investigating the statistical distribution of juvenile salmon and steelhead that will provide guidance on presence or absence surveys. In the interim, we propose a presence method similar to one currently employed by the Department of Fish and Game. The method we describe can be easily modified when statistical information on the probability of detecting different species has been developed.

III. Sampling Methods

The primary sampling method recommended is visual observation using snorkel gear. This method is less costly and intrusive than other methods. However, visual observation techniques are not possible in all types of habitats, nor are they applicable all streams. Electro-fishing is recommended in situations where visual observation is either not possible or would provide inaccurate results. Methods for electro-fishing are described in the section on abundance.

Systematic random sampling should be used in surveys for the presence of juvenile salmon or steelhead (Hankin and Reeves 1988). Sampling effort may vary with the area of stream to be sampled. All pool and run habitats should be sampled if the stream reach is less than 200 or 300 m long. In sampling large reaches or entire streams, samples should be randomly distributed within the area of interest. The randomization process should also be repeated for each type of habitat type and proportion of units selected for sampling can differ among habitat types. For example, a systematic random sample for 20% of the pool habitats can be achieved by drawing a random starting number between 1 and 5. If the starting random number for pool habitats in this example was 2, then the 2nd, 7th, 12th and 17th, etc. pool habitat should be sampled until the survey area has been covered. This process should be repeated for run habitats and any other habitats that might be defined, but we do not recommend visual observation methods in riffle habitats.

Divers should practice in two pool or run habitat in a stream having the juvenile salmonid species presence surveys are intended to detect. This practice allows divers' to familiarize themselves with the species and size classes of salmonids they may likely encounter in the stream to be surveyed. Ages and size classes of salmonids can very among streams during any season because of differences in time of emergence and growth.
Identification of all species can be problematic within the range of coastal cutthroat trout. Juvenile steelhead and cutthroat trout cannot be consistently distinguished until the reach a length of around 80 mm fork length (Figure 5.1). Thus, from the Eel River northward, small trout should be counted as age 0+ trout species. Steelhead and cutthroat trout > 80 mm FL can usually be assigned to age 1+ of their species. However, these species should be recorded as age 1+ trout if divers are not confident in their ability to separate these species.

Visual observations of pre-selected pool, deep pool and run habitats are conducted, progressing from downstream to upstream. Divers should enter the downstream end the habitat unit to be surveyed. They should move upstream, parallel to one another, through the habitat unit using deliberate movements so as to minimize disturbance to fish. Fish are counted as divers move upstream and recorded using either a hand counter or underwater record slate. Using a recording device is especially important where fish are abundant and where multiple species occur. After completing the census for a specific habitat unit, data are recorded in small "Write-in-the-Rain" or plastic paper notebooks than can be carried in a dive pouch.

Visual observation methods are not possible in riffle habitats and may not be effective for entire reaches of some shallow streams. Furthermore, cobble and other obstructions in riffle and other shallow habitats also make seine netting inefficient. These habitats must be sampled using electro-fishing techniques described in the section on abundance and population estimates.

It may be necessary to sample an individual habitat unit a second time if both divers are not confident in their results or the habitat unit is disturbed. At least 20 minutes should elapse between the completion of one dive and the beginning of a second. This time allows frightened fish a period to settle down and reoccupy microhabitats.

IV. Considerations Before Sampling

Natural variability

Habitats and reaches of streams occupied by juvenile salmon and steelhead may vary from year to year as water conditions vary. However, we are not aware of any published information on the probability of detecting juvenile salmonids relative to abundance. The Department of Fish and Game is presently supporting efforts to develop this kind of information and further guidance may be provided in the future.

V. Quality Control and Quality Assurance

Quality assurance and quality control procedures should be established before juvenile salmon and steelhead sampling. These procedures should include elements of the following:

Training that addresses,

1) safety practices in both stream snorkeling and electrofishing,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) recognition of fish when diving.

The quality assurance plan for data entry and management should include,

1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency. This should include re-sampling 5% of all habitat units by a second snorkel survey team. The second dive team should;

1) not have access to the survey results of the first team data to avoid bias,
2) should use methods identical to the first dive team, and
3) conduct the second dive within one week of the first dive.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Hankin, D.G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Canadian Journal of Fisheries and Aquatic Sciences 41: 1575-1591.

MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle and C.A. Langtimmm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

3. JUVENILE SALMON AND STEELHEAD CONDITION

I. Rational

Length and weight of fish is commonly used as a management tool in inland fisheries. Relationships between length and weight in fish have been mathematically expressed as various ways as condition factors (Blackwell et al. 2000). Condition factors express the predicted weight or plumpness of a fish at a given length. Until recently, however, limitations imposed by the statistical properties of length and weight relationships prevented their use in comparisons of populations. The development of a "relative weight" index (Murphy et al. 1990) appears to have overcome these statistical limitations and presents potential for comparing condition among different populations. Condition has been used as a surrogate for fish body composition, as a measure of fish health and to assess productivity or prey available (Blackwell et al. 2000).

Weight of juvenile Pacific salmon and steelhead has not been routinely recorded in the past. Recording weight of small live fish in the field was difficult with earlier technology, and many saw limited use in these data. Consequently, condition indices for these Pacific salmon and steelhead have not been calculated. However, improvements in portable electronic balances now offer the opportunity to collect precise measurements to the 1/100th of a gram in the field.

We propose to develop relative weight indices for juvenile coho salmon and steelhead. Both species use freshwater habitats for a year or more and condition of these species should reflect productivity of habitat. Assuming productivity is correlated with habitat quality, condition indices may provide a tool for measuring the response of juvenile salmonids to habitat.

II. Limitations

The primary limitation of this method is that it has not been applied to juvenile Pacific salmonids. Therefore, the relative weight index must be developed, tested and peer reviewed before being an acceptable measure.

Development of a relative weight index or equation requires gathering data from broad areas that reflect all conditions the species might encounter. Based on previous experience, Murphy and his colleagues (1990) recommend gathering length and weight information from 50 or more populations across the range of a species. We now have data for 44 populations of juvenile coho salmon ranging from California to Alaska. Below we present preliminary results in developing a relative weight equation for this species. At present, we have fewer data for juvenile steelhead.

III. Sampling Methods

Gathering data essential to calculating relative weight is easy and can be combined with other methods that produce a sample of juvenile salmonids. Electrofishing, minnow trapping and seining all should produce reliable data. The objective in sampling should be to obtain measurements that reflect the current range in size of the species being sampled.

After capture, fish should be anesthetized using tricane methanesulfonate (MS222), clove oil or Alka Seltzer in cool oxygenated water. Human health concerns have been raised over chronic exposure to MS222, therefore any personnel using this agent should be familiar with cautions explained on the material safety data sheet accompanying the product and should take appropriate precautionary measures. Effectiveness of anesthetic agents varies with concentration of the agent, water temperature, and fish density. Those using anesthetics should be familiar with dosage recommendations. Oxygenated, cool water should be provided to fish being held before anesthesia and those recovering from anesthesia.

Measurements of length should be recorded to the nearest 1.0 mm and measurements of weight should be recorded to the nearest 0.01 g, wet weight.

IV. Considerations Before Sampling

The relative weight index for juvenile coho salmon has not been fully developed. Therefore guidance on variability and the number of samples needed is not possible. However, most populations sampled to date exhibit similar length weight relationships (Figure 1.1, Table 1.1).

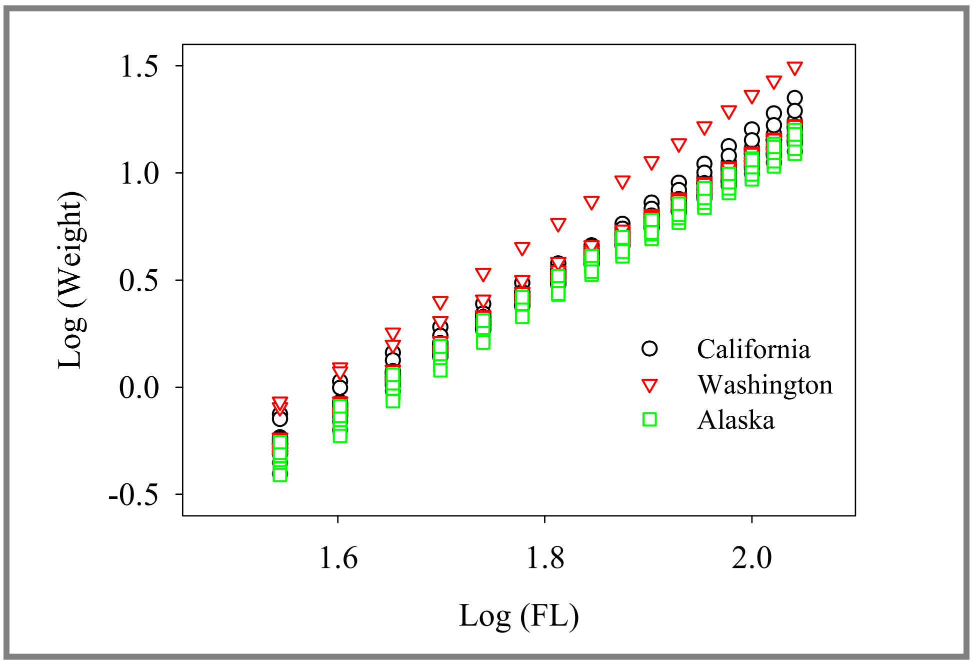

Figure 1.1. Predicted log of weight at 5 mm log length intervals for 44 populations of juvenile coho salmon from California, Washington and Alaska.

Table 1.1. Populations of juvenile coho salmon, their location and log length log weight parameters.

Location	Water Body	Year	n	a	b	R^2
CA	Lindsay Creek	1998	35	-4.1605	2.6134	0.979
CA	Lindsay Creek	1999	50	-5.1213	3.1127	0.972
CA	W.F. Sproul Creek	1998	30	-4.9495	3.0329	0.983
CA	W.F. Sproul Creek	1999	152	-5.0045	3.0466	0.934
CA	Hollow Tree Creek	1998	30	-4.0231	2.5092	0.950
CA	Casper Creek	1998	40	-4.8349	2.9617	0.944
CA	Casper Creek	1999	144	-4.6044	2.8302	0.893
CA	Freshwater Creek	1998	68	-4.7947	2.9433	0.976
CA	Freshwater Creek	1999	199	-4.7808	2.9034	0.905
CA	Sharber Creek	1999	113	-5.8512	3.5269	0.902
CA	S.F. Broken Kettle Creek	1999	88	-5.4501	3.3014	0.900
CA	Redwood Creek	2001	34	-4.8456	2.9373	0.954
CA	Prairie Creek	1999	118	-4.6938	2.8710	0.963
CA	Prairie Creek	2000	204	-4.5408	2.7853	0.928
CA	Prairie Creek	2001	157	-4.9330	3.0110	0.976
CA	Streelow Creek	2001	100	-4.7511	2.9170	0.962
CA	Boyes Creek	2001	74	-4.6261	2.8221	0.984
WA	Forks Creek	1995	310	-5.0939	3.0868	0.931
WA	Forks Creek	1996	288	-4.7211	2.9045	0.947
WA	Forks Creek	2001	189	-5.0667	3.0827	0.967
WA	Forks Creek	2002	169	-5.3012	3.1967	0.980
WA	Herrington Creek	1997	49	-4.7332	2.9111	0.975
WA	Herrington Creek	1998	37	-3.8069	2.4218	0.806
WA	Herrington Creek	1999	66	-4.7759	2.8981	0.994
WA	Herrington Creek	2000	141	-5.0962	3.0951	0.973
WA	Huckelberry Creek	2001	110	-4.7496	2.8907	0.975
WA	Huckelberry Creek	2002	91	-4.8550	2.9525	0.974
AK	Ken’s Pond	1995	879	-5.0989	3.0700	0.959
AK	Lost Pond	1995	239	-4.9822	3.0129	0.966
AK	25 Mile Pass Creek	1995	482	-4.7851	2.8819	0.946
AK	E.F. Slippery Lake Creek	1988	254	-5.2272	3.1393	0.982
AK	E.F. Slippery Lake Creek	1989	360	-4.9217	2.9676	0.903
AK	E.F. Slippery Lake Creek	1990	95	-4.8252	2.9426	0.952
AK	E.F. Slippery Lake Creek	1991	38	-4.4809	2.7339	0.946
AK	Saginaw Creek	1989	182	-4.7548	2.8930	0.981
AK	Saginaw Creek	1994	116	-4.9326	2.9904	0.977
AK	Saginaw Creek	1995	170	-5.3431	3.2050	0.988
AK	Maybeso Creek	1999	481	-4.7709	2.9154	0.915
AK	Maybeso Creek	2000	46	-4.7739	2.8716	0.958
AK	Kake Bake Creek	1983	174	-4.8790	2.9511	0.974
AK	Kake Bake Creek	1984	81	-4.7649	2.8789	0.984
AK	Staney Creek	1996	220	-4.8772	2.9610	0.979
AK	Tonalite Creek	1989	38	-5.2746	3.1514	0.970
AK	Tonalite Creek Pond	1999	166	-4.7180	2.8888	0.973

V. Quality Control and Quality Assurance

Quality assurance and quality control procedures should be established for each salmon and steelhead smolt trapping program. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1) safety practices for handling anesthetic agents,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) data entry and management.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Blackwell, B.G., M.L. Brown and D.W. Willis. 2000. Relative weight (Wr) status and current use in fisheries assessment and management. Reviews in Fisheries Science 8:1-44.

Murphy, B.R., M.L. Brown and T.A. Springer. 1990. Evaluation of the relative weight (Wr) index, with new application to walleye. North American Journal of Fisheries Management 10:85-97.

4. JUVENILE STEELHEAD AGE

I. Rational

Age of juvenile steelhead may be a useful measure for detecting a response to watershed restoration for several reasons. First, juvenile steelhead are widely distributed in coastal watersheds of California. Second, juvenile steelhead spend multiple years in fresh water before smolting and migrating to the ocean. Third, smolt transformation in salmonids is regulated, in part, by size and will not occur if a fish has not reached some critical size (Groot et al. 1995). Finally, use of juvenile steelhead age as a watershed response measure assumes that growth is related to habitat condition.

The rational for using age of juvenile steelhead as a measure for detecting a response to watershed restoration is that growth will be slower under poor habitat conditions. With slower growth, more time will be required to reach the critical size for smolting, resulting in fish being older at the time of smolting. Extending this assumption, growth would hasten as restoration actions improve habitat conditions until age at smolting is eventually reduced.

II. Limitations

While intuitively appealing, the assumption that growth is related to habitat quality has not yet been rigorously tested. Multiple environmental factors such as water temperature, food available and density of juvenile salmonids influence growth and may present insurmountable obstacles in establishing a relationship between habitat and growth. We propose to test this assumption as part of the process of validating protocols for assessing watershed restoration.

III. Sampling Method

Juvenile steelhead for aging can be acquired from the distribution and abundance, presence sampling methods described, or by any method that produces fish-in-hand. After a collection of fish has been obtained, two basic methods are available for age determination. First, one may use hard structures such as otoliths or scales to assign ages to individual fish (Frie 1982). Second, one may analyze the size distribution of populations for indications of age groupings (Nielsen and Johnson 1983). We propose a combination of these two methods be used (Box 4.1).

Text Box 4.1. Assigning ages to juvenile steelhead.

Determining age structure of juvenile steelhead population.

1) Obtain a sample of fork lengths, in mm, from 100 or more juvenile steelhead.
2) Collect a scale sample from 20% or more of the individual fish distributed across 10 mm length categories.
3) Count the number of fish in each 10 mm length category and plot this length frequency distribution.
4) Identify modes in the distribution and assign ages to each mode.
5) Determine the age of individual fish from scale samples and use these data to verify age modes as well as the uncertainty between ages.
    a. Scales should be collected from mid-way between the back of the dorsal fin and the lateral line.
    b. Collect 3-6 scales from each fish since some may present difficulties in aging due to false annuli, and other anomalies.
    c. Mount the scales between two microscope slides and view them through a microscope or micro-fish reader.

Age distributions can sometimes be easily distinguished from plotted data (Figure ..1). However, modes in distribution that are well separated are often the result of too few samples being collected. With adequate sample sizes, all size ranges are typically represented and there is some overlap in size at age between modes (Figure x.2). This overlap presents difficulty is assigning ages, but we are less concerned with the total number of fish in each age category than we are with the age at smolting. If with the total number of fish in each age category is considered important, statistical methods may be employed to assign ages to individuals of size at age overlaps (Nielsen and Johnson 1983).

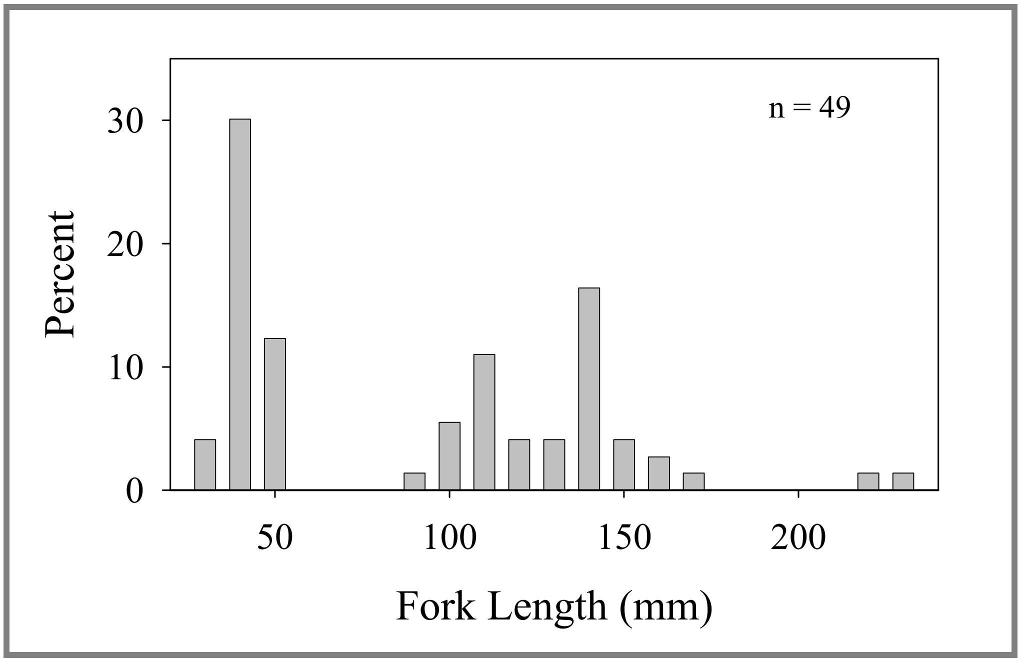

Figure 4.1. Length frequency distribution of juvenile steelhead from South Fork Roach Creek, Humboldt County, California during July 2002.

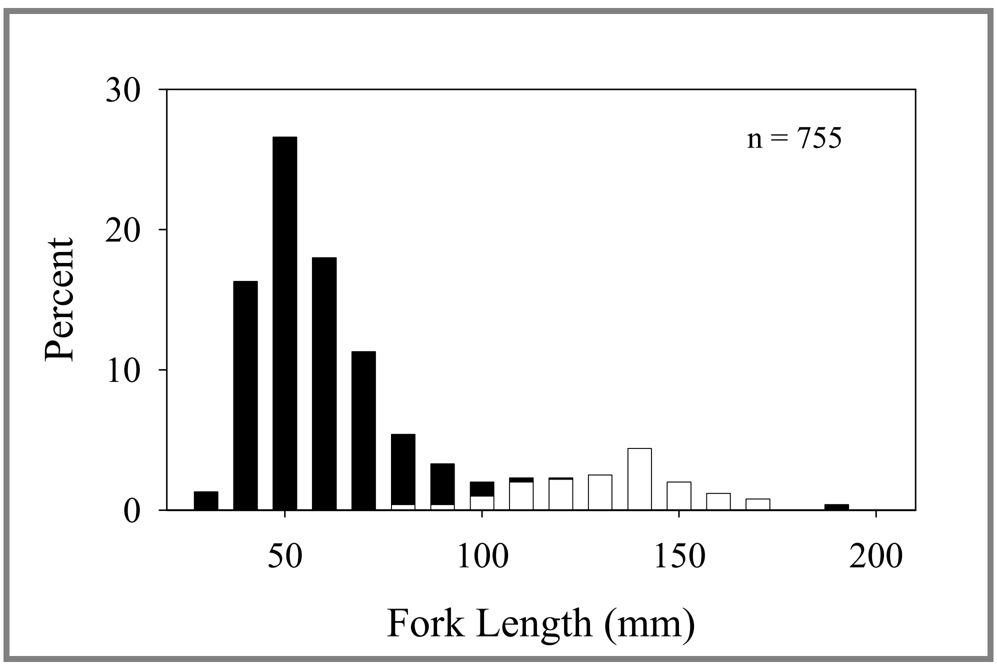

Figure 4.2. Length frequency distribution of juvenile steelhead from Bull Creek, Humboldt County, California during August 2002.

IV. Considerations Before Sampling

We are presently evaluating this method. When analyses are complete, we will evaluate the statistical properties of age data and provide guidance on their variability and ability to detect change.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for aging juvenile steelhead. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1. identification of fish species likely to be encountered,
2. proper handling of fish,
3. scale sampling and
4. assigning ages to scales. .

QA/QC procedures in assigning ages to scales should include the verification of 5 – 10% of the original ages. That is, a second person or persons without knowledge of ages assigned, reads scales previously aged and determines ages independently.

VI. References

Frie, R.V. 1982. Measurement of fish scales and backcalculation of body lengths using a digitizing pad and microcomputer. Fisheries 7:5-8.

Nielsen, L.A., and D.L. Johnson (Eds.). 1983. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

5. Salmon and Steelhead Smolt Production

I. Rational

Smolt production is defined as the number of salmon or steelhead smolts migrating from a stream toward the ocean. Smolt production is typically measured by capturing migrants using traps. This measure is most often applied to coastal populations of coho salmon or steelhead because each species resides in freshwater habitats one or more years before undertaking ocean migration. Juvenile Chinook salmon from interior populations, such as those spawning in the upper Klamath River, may also remain in fresh water for up to a year before beginning their migration to the ocean. Data on production of salmon or steelhead smolts leaving a stream can provide information on freshwater survival and, by inference, habitat quality. When combined with estimates of the numbers of adults returning to spawn, it can also be used to calculate ocean survival.

II. Limitations

Several problems limit the use of smolt production data in assessing watershed response to restoration. The first of these is that it cannot be applied to all species of salmonids. Trapping juvenile chinook salmon leaving coastal streams does not provide information on smolt production. Populations of coastal Chinook salmon migrate from their natal streams as fry, then rear and undergo smoltification in lower rivers or estuaries before entering the Pacific Ocean during summer or fall. Smolt production is also not applicable to coastal cutthroat trout since this species exhibits a variable period of freshwater residence before ocean migration, or may not use the ocean environment.

A second limitation arises from criteria necessary for operating a trap to capture migrating smolts. Sites selected for migrant smolt trap placement should be located near the lower end of the basin so as to provide an estimate of the number of smolts leaving, the gradient should be relatively low and the stream should not be very large nor very small. While rotary screw traps can be deployed in large rivers, errors associated with efficiency estimates usually prevent estimates of smolt production. When considering watersheds, these criteria reduce or eliminate the element of randomness that is desirable in sampling. However, streams could be randomly selected for smolt trapping within regions that encompass multiple watersheds.

III. Considerations Before Sampling

Natural variability and number of samples

Number of migrating salmonid smolts captured within a stream varies with season, discharge, and probably day length. In 2002, we estimated that 5,245 coho salmon smolts were produced in upper Prairie Creek in Humboldt County. Smolts were captured from late February through May, but 58% of the total catch occurred during a two week period in April. At a site 6 km downstream, this peak in smolt timing was about one month later and smolts were present until June when trapping was discontinued.

We applied power analysis to data from this site to estimate the number of years needed to detect a change in production. Our analysis assumed that trend in abundance had a coefficient of variation of 50%, less than the 66% variation observed at this site over 4 years. Our analysis suggests a minimum of 10 years of monitoring at this site would be required to detect a 10% change in production with power of 0.80 and α = 0.10 (a 10% probability of being wrong), even with our conservative assumption (Figure 5.1).

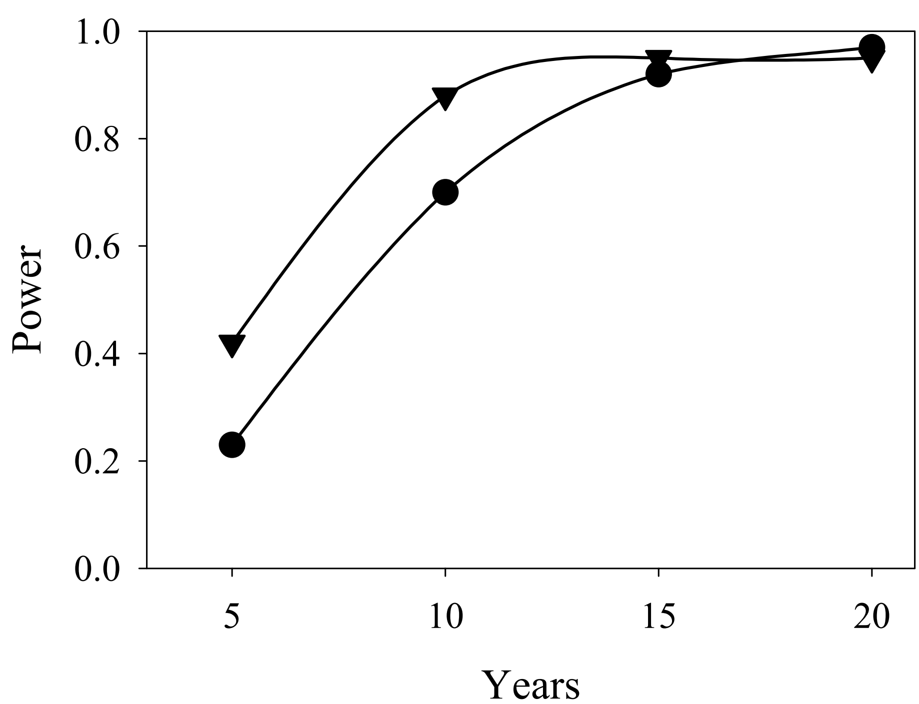

Figure 5.1. Power to detect a 10% increase (circles) or 10% (triangles) decrease in number of coho salmon smolts from an immigration trap. Data are calculated from one trap having average catch 13 smolts per day (S.D. ± 10.3) and assuming a trend coefficient of variation of 50%.

Variability in smolt production estimates typically is greater among streams than within. Coefficients of variation in coho salmon smolt production among streams are typically 50% – 120% of the average (Keeley and Walters 1994). In 2002, the coefficient of variation among three streams from Redwood National Park, California was 114% of the mean and varied from 17 – 41% of the mean within streams. Again, we applied power analysis to these data to determine the number of samples needed to detect a difference in production from a watershed. Again, our analysis suggested that to detect a 10% change with power of 0.80 and α = 0.10 would require 10 traps operating for 10 years (Figure 5.2).

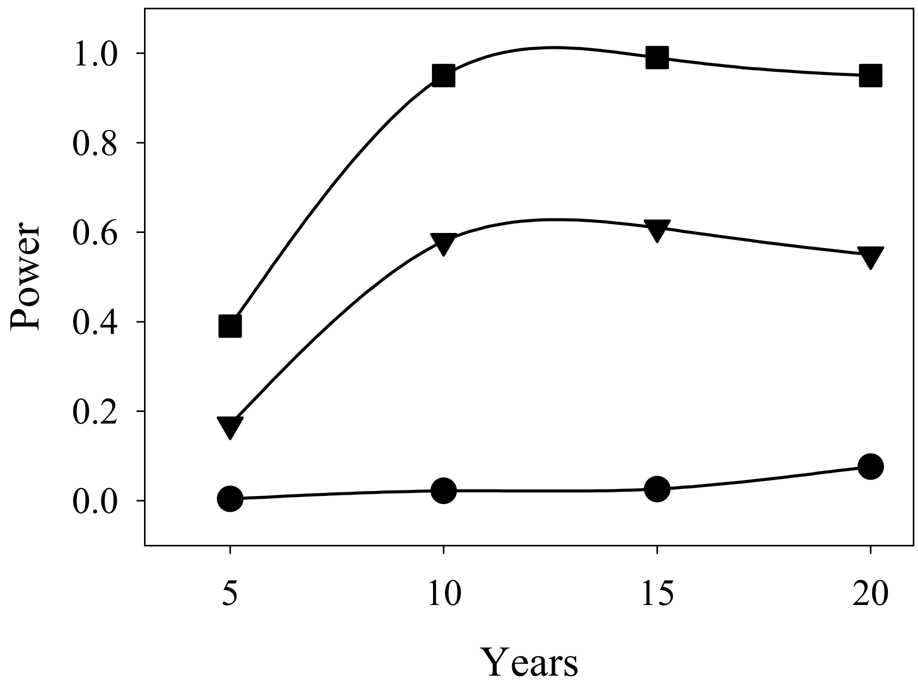

Figure 5.2. Power to detect a +10% difference in the number of coho salmon smolt from a theoretical watershed having three (cicles), five (triangles) and ten (squares) immigration traps. Data are calculated from multiple traps operated in Redwood National Park, California during 1999 - 2002 and assuming a trend coefficient of variation of 50%.

IV. Sampling Methods

Personnel and training

The labor needed to operate a smolt trap varies with the type of data being collected. Installing a trap or later removing a trap requires four people for four – six hours. After installation, one person can process the sample if only the number of smolts captured is being recorded. However, for safety reasons we recommend that two people be assigned to smolt trap sampling. A two person crew can also record size of smolts and collect scale samples for later aging, if desired. Personnel conducting the sampling should be posses a minimum set of biological skills:

1) All personnel should be competent in identifying juvenile salmonids.

2) All personnel should be trained in procedures to anesthetize juvenile salmonids.

All personnel should be trained to handle juvenile salmonids and, other fish, in a manner that does not induce undue stress. Proper handling is necessary for identification when multiple species are present and for marking individual fish to be used in trap efficiency testing.

Gear needed

Salmon and steelhead smolts migrating downstream may be captured using traps of various design. The most common are traps fyke net, inclined plane or rotary screw traps.

Fyke net traps consist of a fyke net having a live box attached to the cod end. In smaller streams, the fyke net can be fitted with wings and effectively cover all or most of the stream. Smolts are carried into the net and live box by the current.

Inclined plane traps are constructed from rigid material and have a large rectangular opening that leads to a smaller opening at the live box (Figure 6.3). Inclined plane traps may be fished with the trap mouth resting on the stream bottom, or they can be fitted with pontoons and fish off bottom in larger streams (Todd 1994). Again, smolts are carried into the net and live box by the current.

Rotary screw traps consist of a cone covered with screen and having an archemedes screw built into the cone. The trap is suspended on pontoons with the larger end of the cone facing upstream and adjusted so that the lower half of the cone is in the water. Water pressure forces the cone to turn on a central shaft and migrating smolts that enter the cone are trapped by the rotating screw and forced into a live box at the end of the trap. Rotary screw traps are better suited to larger streams and rivers having adequate flow to turn the cone and enough depth to float the trap.

None of these trap designs is appropriate for all streams or flow conditions. The type and size of trap used is both a function of the size and flow characteristics of the stream being sampled, and the size and species of the fish that are targeted for trapping. In general, the screw trap is more effective in larger streams, while the fyke net and inclined-plane traps are better suited to small or medium sized streams.

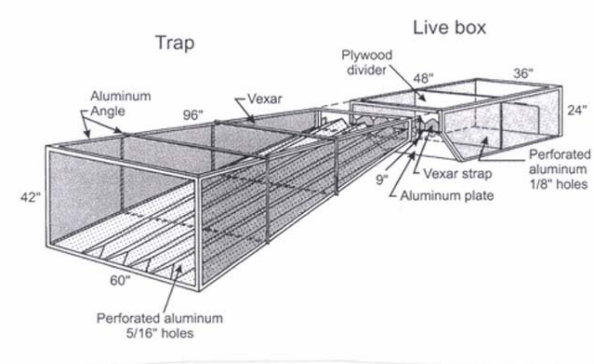

Figure 5.3. Image of inclined-plane trap without pontoons attached (From Todd 1994).

Selection of Sampling Locations

Sample locations should be selected on the basis of answering the question being asked. A reasonable question might be; have restoration projects within a sub-watershed resulted in greater numbers of smolts migrating from the sub-watershed? Locating a smolt trap as near the sub-watershed outlet as possible would provide the best data to address this question. General considerations in locating smolt traps are listed below.

- The stream being sampled should have spawning populations of steelhead, coho salmon or Chinook salmon.
- The stream should not be either so large or small that efficiency of the trap cannot be evaluated. Trapping sites should be located in streams as large as the gear will effectively sample since larger streams will usually yield more smolts. Size of streams in which various smolt trapping gear can effectively sample are generally second to fifth order and have an active channel width of no more than 30 m.
- Stream gradient should not be too great, a gradient of 1 – 2% is best. High gradient sites can result in high water velocity that may injure fry and smolts during trapping. Conversly, velocity in wide unconstrained channels may not be adequate to operate some types of traps.
- Depth of water is an important consideration in selecting sampling sites. Fyke net traps are limited to depths of 1 m or less. Rotary screw traps and inclined plane traps must be located at depths of 0.75 m or greater.
- Water velocity or flow (m/s) must be sufficient to carry fish into fyke net or inclined-plane traps. For rotary screw traps, a flow of 0.8-2.0 m/s has been observed to be sufficient to rotate the screw. At some sites, panels can be installed to direct water into traps. Stream flow should enter the trap on a straight line. Placing traps in bend pools or near obstructions that create eddys may cause fry to be impinged on trap surfaces.
- The stream substrate at the site should be relatively uniform. Presence of boulders and cobble will create turbulence that may limit trap efficiency or contribute to injury of fish.
- Access is an important consideration, both physical and legal access. Trapping sites should be near roads, particularly if operating a rotary screw or inclined plane trap. The site should also be located where a land owner is willing to allow access for long periods, 10 or more years.
- Finally, the site should be located where large trees or other suitable anchor sites are available on the stream side.

Operation of rotary screw or inclined-plane traps during high stream flow can result in mortality from debris jamming the net and live box. Fyke net traps cannot be fished during high stream flow, but can also become choked with debris during spates. In either case, a live box or trap choked with debris can result in mortality to both salmon smolts and fry. Therefore, smolt traps must be carefully monitored during times when flow is high or when excessive debris might be carried in the stream.

In operating smolt traps, care must be taken to minimize mortality. Predation by larger fish on smaller fish in the trap live box is common. Fern fronds or fir boughs are often placed in the trap live box to provide hiding cover for smaller fish. A v-shaped water current deflector is also often placed in trap live boxes constructed of plywood or metal. These v-shaped deflectors are intended to create a pocket of calm water for small fish. Our research suggests that neither of these techniques is particularly effective in reducing mortality of fry. Instead, we recommend a 2 m long, 1 m wide and 1 m high live box constructed of ¼ inch square knotless nylon netting. This trap live box is divided into forward and rear compartments by ¾ inch square knotless nylon netting and attached to the fyke net cod end using a 2 m length of 6 inch PVC pipe. The principle of this live box design is that the PVC pipe connector provides enough water velocity to carry small fish into the trap and through the dividing panel. Water velocity then quickly dissipates. Larger fish may be impinged on this panel briefly, but are strong enough to overcome the water velocity. Experimentation with this trap live box design has resulted in marked declines in mortality from predation (Reisburger in prep.)

Sampling duration and frequency

In California, migration of coho salmon and steelhead smolts may occurring from fall through summer, but peak migration for both species during most years is in April and May (California Cooperative Fish Research Unit 2002, Shapovalov and Taft 1954). Sampling for migrating smolts should begin in late February or early March and continue until the catch decreases, usually in early June. Traps are usually operated 24 hours per day seven days per week and must be monitored daily.

Estimating trap efficiency

No migrant smolt trap will sample 100 percent of the water column, therefore the number of smolts captured represents an unkown portion of the total number migrating downstream. Trap efficiency, the proportion of the total migrant population captured by the trap, is influenced by stream flow, fish species, size and behavior. And, most of these variables change during the period of sampling. Trap efficiency tests must be conducted regularly to accurately estimate the number of downstream migrating smolts.

Trap efficiency tests are essentially mark-recapture experiments. Each week, 50 – 100 smolts of each species are marked, then released upstream from the trap. The number of marked smolts recaptured is then recorded on subsequent dates. Smolts for marking and releasing should be selected from those captured in the trap the previous night. Frequently not enough smolts are captured during a single night to allow for an accurate trap efficiency estimate. Therefore, efficiency estimates may be calculated on a daily basis using the formula:

$$N_i = n_i / (m_i \text{ recapture} / m_i \text{ release})$$

Where N_i = total number of migranting smolts passing trapping location in week 1,
n_i = number of unmarked fish caught in trap in week 1,
m_i recapture = number of marked fish recaptured in trap on week 1,
m_i release = number of marked fish released above the trap in week 1,

The total number of fish migrating past the trap site for the season is then estimate by:

$$N_{total} = \sum N_i$$

Improved trap efficiency estimates can be achieved by releasing marked smolts at dusk. This is because most downstream migrating salmon smolts migrate at or soon after dusk and repeatedly releasing marked fish at the same spot every day can lead to increased predation by resident cutthroat trout. Releasing smolts at dusk reduces predation by reducing the time of marked fish are exposed to predators.

Salmon and steelhead smolts that are marked for efficiency estimates must be allowed time to recover from handling prior to release. This can be accomplished by using a timer-activated, self-releasing live box. Traps are checked in the morning and marked smolts are placed in the self-releasing live box to recover before being released at dusk. The self-releasing live box consists of three dark-colored five-gallon buckets that are suspended between two small floating pontoons. A spring wound timer is connected to a 12-volt automobile door lock actuator. At the appropriate time, the timer energizes the door lock actuator, which pulls a pin releasing the buckets. The buckets pivot on a pipe inserted through holes in their base, turn upside down, and release the fish. Each bucket has wire mesh panels along their sides to allow transport of oxygenated water into them. Periodically the fish are examined just prior to release to make sure that there is no mortality and that the buckets dump at the appropriate time.

The release location for marked fish for trap efficiency estimates is located far enough upstream so the fish can evenly mix with unmarked fish moving downstream, yet not be so far upstream as to cause an extracted period of migration of marked fish over multiple days. Marked fish are typically released at least two pool/riffle units, but no more than 300 meters, above the trap.

In some streams, the number of migrating smolts caught in the trap insufficient to obtain a weekly trap efficiency estimate. Low catches may result from a low number of migrants, low trap efficiency, or a combination of both. If weekly trap efficiency estimates are not possible, an efficiency estimate for the entire season is calculated based on the total number of marks released and recaptured while the trap was in operation. This seasonal trap efficiency estimate is used to expand the number of fish caught in the trap during the season to obtain an estimate of total migrants. The use of seasonal trap efficiency in calculating total smolts migrating is usually results in less accurate estimate than estimates expanded from weekly trap efficiency. Loss of accuracy is the result of expanding estimates of smolts migrating from low numbers where a difference of one or two fish can change estimates substantially.

Fish Handling

Any smolts, or other fish, that are handled for marking or size measurements should be anesthetized. Recognized fish anesthetic agents include tricaine methanesulfonate (MS222), Alkaseltzer ™, and clove oil. Human health concerns have been raised over chronic exposure to MS222, therefore any personnel using this agent should be familiar with cautions explained on the material safety data sheet accompanying the product and should take appropriate precautionary measures. Effectiveness of anesthetic agents varies with concentration of the agent, water temperature, and fish density. Those using anesthetics should be familiar with dosage recommendations. Oxygenated, cool water should be provided to smolts being held before anesthesia and those recovering from anesthesia.

Marking smolts for trap efficiency tests may be accomplished in several non-destructive ways. Often the upper or lower tip of the caudal fin is clipped using small scissors or a razor blade. Different colors of acrylic paint can also be injected under the skin using either a Panjet needleless injector or small hypodermic needle.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for each salmon and steelhead smolt trapping program. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1) safety practices,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) data entry and management.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Keeley, E.R., and C.J. Walters. 1994. The British Columbia watershed restoration program: summary of the experimental design, monitoring and restoration techniques workshop. Ministry of the Environment, Lands and Parks and Ministry of Forests, Watershed Restoraton management Report No. 1. 34 pp.

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Todd, G.L. 1994. A lightweight, inclined-plane trap for sampling salmon smolts in rivers. Alaska Fishery Research Bulletin 12:168-175.

Migrant smolt trapping data sheet.

Date:	Page ___ of ___
Time:	Site: (Lat/Long or UTM)
Stream name:	Personnel:
County:	Stream condition:

Fry	**Total number**	**Smolts**	**Total number**
OC		**OC**	
OK		**OK**	
OM		**OM**	
OT		**OT**	
TR		**TR**	

Species	**Length (mm)**	**Weight (g)**	**Mark applied**	**Recapture mark**	**Mortality**	**Comment**

Meta data for migrant smolt trapping.

Item	Description
Date	Calendar date (MM/DD/YY)
Time	Military time (HHMM)
Stream name	Stream name on USGS 1:24,000 Quad. Map
County	California county name
Location	Coordinates of trap site in either latitude and longitude or UTM
Stream condition	Includes discharge or stage height if available, amount of debris visible, turbidity.
Page	Number pages consecutively
Personnel	Name of field personnel recording data
Species code	
OC	Cutthroat trout
OK	Coho salmon
OM	Steelhead
OT	Chinook salmon
TR	Trout too small (< 80 mm) to accurately identify
Total number	Total number of each species collected on that date
Length	Fork length in mm
Weight	Wet weight in g
Mark applied	Type and location of any mark applied to fish
Recapture mark	Type and location of mark on any recaptured fish
Mortality	Record if fish died during collection
Comment	Note any unusual conditions or circumstances.

6. ADULT SALMON AND STEELHEAD ESCAPEMENT

I. Rational

Estimates of the number of adult salmon or steelhead returning to spawn provide essential information on the size of populations. The number of adults escaping to spawn is influenced by mortality at all younger life history stages. Since habitat conditions in freshwater and the ocean influence survival, estimates of escapement are the often considered the ultimate measure of population response.

II. Limitations

Estimating numbers of salmon or steelhead escaping will not be possible in all streams. Present methods rely on visual observation of adults. In streams that remain turbid for periods during the spawning period, visual observations are often not possible. Visual observation techniques also require that observers regularly census portions of streams where spawning may occur, and this requires considerable labor.

III. Sampling Methods

Personnel and training

One or two people are needed to gather data for estimating escapement. For safety reasons, we recommend two people be devoted to collecting these data. Personnel should be trained to identify adult salmon and steelhead, whether alive or dead.

Gear needed

No specialized gear is needed to carry out escapement estimates. A list of basic equipment sufficient to gather these data includes:

1) Chest waders
2) Rain gear
3) Hip chain
4) Flagging
5) Write-in-the-Rain notebook or data sheets.
6) Polarized glasses, amber or brown are preferred.

Survey methods

Sampling should begin when the first adult salmon or steelhead enter the stream of interest and continue until no adults are observed. Most species of salmon complete spawning over a period of two months or less. A hip chain is used to measure distances when conducting the initial observations. During this initial sampling, plastic flagging can also be affixed to riparian vegetation at 50 – 100 m intervals and a distance written on the flagging with a waterproof marker. If this is done, distances at which fish are observed during subsequent sampling dates may be estimated.

Sampling frequency should be guided by the period of residence for individual adult fish. We have estimated the average residence time of adult coho salmon to be eight days in Prairie Creek, Humboldt County, California. Ideally, one would repeat sampling for coho salmon in this stream every eight days. However, entry of adult fish into streams is not regular and through analysis of past we determined that a sampling frequency of 10 days is sufficient to provide escapement estimates.

Sampling during each of these periods involves two personnel walking every stream reach of interest. Observations of both numbers and location (m upstream) of live fish and salmon carcasses are recorded. Record both species and sex of individual adults or carcasses. Recording the number of jacks can provide initial data. A disc type tag having a number is affixed to salmon carcasses with plastic electrical ties when they are first observed. The condition of salmon carcasses (Sykes and Botsford 1986) is recorded each time they are observed (see Appendix Table) as are numbers from carcasses previously tagged.

Efficiency
The ability of each observer to see fish should be measured to provide an estimate of efficiency. This may be accomplished by having the crew separate during short portions of a survey, each record data separately, and submit their results "blind." The alternative is to have a second trained crew visit sites sampled earlier. Time elapsed between the survey and efficiency check should not exceed three or four hours since adult fish may move.

Data analysis
Analysis of escapement data involves developing an estimate of total population size using data from observations made at intervals during the period of spawning. Either carcasses or live fish may be used to estimate escapement. Estimating escapement from periodic counts of live fish has been accomplished using area-under-the-curve techniques (English et al. 1992). These methods are best suited to streams having a weir or other obstruction at which fish entering the stream may be counted. However, they can be employed on streams lacking a weir.

Capture-recapture methods are usually employed to estimate escapement from carcass data. These methods range from simple Lincoln type index to more rigorous statistical methods (Sykes and Botsford 1986, Schwarz et al. 1993). However, when working with low numbers of fish, assumptions of some of the more rigorous methods often cannot be met. We present the steps for calculating an estimate of escapement using the Lincoln type index in Box 6.1 and refer readers to the specialized literature on more rigorous methods.

Box 6.1. Calculating salmon escapement from carcass data using a simple Lincoln index.

1. *During sampling period 1 record*:

1) 1) n_1 - the total number of carcasses observed and
1) 2) a_1 - the total number of carcasses marked.

2. *During sampling period 2 record*:

1) 1) n_2 - the total number of carcasses observed,
1) 2) r_2 - the total number of marked carcasses observed and
1) 3) a_2 - the total number of new carcasses marked.

3. Calculate the estimated number of adults (N) in the area during the period as:

$$N = a_1^2 * (n_2 + 1) / (r_2 + 1)$$

4. The variance of this estimate is calculated as:

$$V = a_1^2 * (n_2 + 1) * (n_2 - r_2) / (r_2 + 1)^2 * (r_2 + 2)$$

5. During sampling period 3 record the same data recorded during period 2 and calculate N for the interval 2-3, continue this process until the period of sampling is covered.

IV. Considerations Before Sampling

Natural Variability

Numbers of adult salmon returning to spawn varies among years. In streams with low total population size, variation in escapement may limit the ability of this measure to detect a signal from watershed restoration.

> **We used power analysis to evaluate the ability of escapement estimates to detect a 10% increase in population size over years (Gibbs 2003). The data used were for coho salmon from Prairie Creek, Humboldt County, California, during 1999-2002. Escapement estimates ranged from 49 – 353 adults during this period.**

Conditions we assumed were that one estimate would be available for monitoring each year and that the coefficient of variation among years was 50%. We set α at 0.10, and ran 500 iterations of a 2-tailed t-test to estimate how many years of sampling would be required to detect change at a desired power level of 0.80. Results from this analysis suggest that, in Prairie Creek, it would require 15 years to detect a 10% increase in population size (Figure 6.1).

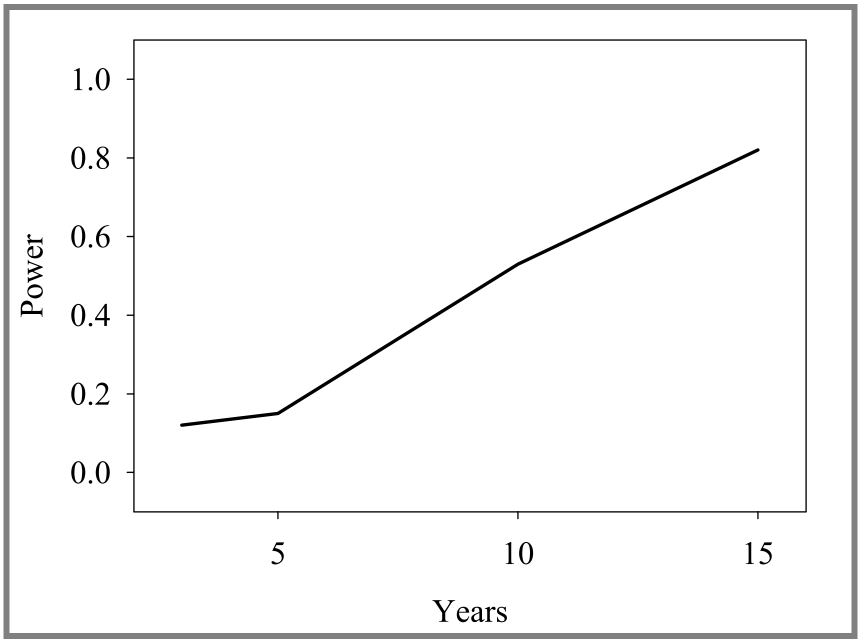

Figure 6.1. Power to detect a 10% increase in adult coho salmon escapement to Prairie Creek, California.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for all programs estimating salmon and steelhead escapement. These procedures should include:

Training that addresses,

1) safety practices in the field and hypothermia,
2) identification of adult salmonid species likely to be encountered,

The quality assurance plan for data entry and management should include,

1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency as discussed above.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check of 5 – 10% of the original entries.

VI. Literature Cited

English, K.K., R.C. Bocking and J.R. Irvine. 1992. A robust procedure or estimating salmon escapement based on the area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Sciences 49:1982-1989.

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Schwarz, C.J., R.E. Bailey, J.R. Irvine and F.C. Dalziel. 1993. Estimating salmoon spawning escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50:1181-1197.

Sykes SD, and LW Botsford. 1986. Chinook salmon, Oncorhynchus tshawytscha, spawning escapement based on multiple mark-recapture of carcasses. Fishery Bulletin: Vol. 84, No. 2: 261-270.

Salmon and Steelhead escapement data sheet.

Date:	Page ___ of ___
Time:	Site boundaries: (Lat/Long or UTM)
Stream name:	Personnel:
County:	Stream condition:

Distance	**Species**	**# Live**	**# Carcass**	**Carcass condition**	**Mark number**	**Recapture number**

Meta data for salmon and steelhead escapement data sheet.

Item	**Description**
Date	Calendar date (MM/DD/YY)
Time	Military time (HHMM)
Stream name	Stream name on USGS 1:24,000 Quad. Map
County	California county name
Location	Coordinates of trap site in either latitude and longitude or UTM
Stream condition	Includes discharge or stage height if available, amount of debris visible, turbidity.
Page	Number pages consecutively
Personnel	Name of field personnel recording data
Distance	Distance in meters upstream from starting point.
Species code	
OK	Coho salmon
OM	Steelhead
OT	Chinook salmon
# Live	Total number of that species observed at that distance location.
# Carcass	Total number of that species carcasses observed at that distance location.
Carcass condition	
1	Recently died, eyes clear and flesh firm
2	Eyes are cloudy, but flesh still firm
3	Eyes are cloudy and flesh is soft
4	Eyes are cloudy and flesh is very soft, beginning to slough off
5	Only the head and part of the skeleton remain
Mark number	Number of mark applied to that carcass.
Recapture number	Number of mark existing on that re-sighted carcass.

APPENDIX A:

Table 1. Watershed restoration action categories, objectives of these actions and validation monitoring criteria.

Restoration Action	Validation Monitoring Criteria
Fish Passage Objective: To improve fish passage and access.	Presence of adult or juvenile life stages of salmon or steelhead.
Fish Sceens Objective: To prevent fish from accessing waterbody.	Absence of juvenile salmon or steelhead.
Instream Habitat Restoration Objective: Increase cover, habitat or complexity or increase interaction of stream and floodplain.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Streambank Stabilization Objective: Increase bank stability and reduce erosion.	Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Riparian Land Use Control Objective: Eliminate livestock use of stream to increase bank stability, reduce erosion and promote riparian vegation.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Control vegetation Objective: Increase native vegetation, reduce exotic vegetation and increase fish habitat.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Riparian Vegetation Management Objective: Increase shade, bank stability, LWD recruitment and nutrients.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Restore Water Flow Objective: Improve stream flow to benefit fish and riparian plants.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.

Restoration Action	Validation Monitoring Criteria
Slope Stability or Erosion Control Objective: Reduce erosion and sediment delivery to stream.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Gully Repair Objective: Reduce erosion and sediment delivery to stream.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Road Upgrading or Decommissioning Objective: Reduce erosion and sediment delivery to streams.	Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead. Salmon and steelhead spawner/recruit ratio.
Combined Restoration Actions Objective: To improve fish populations within a sub-watershed or watershed.	Size of juvenile of salmon or steelhead population. Condition of juvenile salmon or steelhead. Age structure of juvenile steelhead. Salmon or steelhead escapement. Salmon and steelhead spawner/recruit ratio. Salmon and steelhead smolt production.