PART X

UPSLOPE EROSION INVENTORY AND SEDIMENT CONTROL GUIDANCE

This manual describes methods and techniques used with varying degrees of success by watershed restoration specialists. The methods and techniques described here represent only a starting point for project design and implementation. They are not a surrogate for, nor should they be used in lieu of, a project design that has been developed and implemented according to the unique physical and biological characteristics of the site-specific landscape.

The techniques and methods described in this manual are not a surrogate for acquiring the services of appropriate professionals, including but not limited to licensed professional engineers or licensed professional geologists, where such expertise is called for by the Business and Professions Code section 6700 et seq. (Professional Engineers Act) and/or section 7800 et seq. (Geologists and Geophysicists Act).

TABLE OF CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

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INTRODUCTION

Watersheds and streams have a natural background rate of erosion. Delivery of eroded sediment to stream systems occurs through various transport processes that operate in all watersheds. Natural erosion and sediment delivery varies from relatively low amounts in stable watersheds underlain by resistant rock types, to comparatively high amounts in watersheds that have soft rock types that erode more easily. During large storm events, mass wasting or landsliding, large-scale gully erosion, and stream bank erosion are more likely to occur. Between large disturbance events, erosion rates are generally lower and overall sediment delivery is low, although sediment may still enter the stream from various erosion processes. This can increase due to human influences. Native anadromous salmonids have evolved and successfully adapted through eons to stream habitat conditions produced by these natural processes within this dynamic environment. Excessive sediment delivery to streams can have a deleterious effect on anadromous salmonids by filling in pool habitat and burying spawning substrate.

Purpose

Part X, Upslope Erosion Inventory and Sediment Control Guidance, describes the California Department of Fish and Game (DFG) methodology for the identification of upslope and stream bank erosion, and techniques for the implementation of cost-effective erosion control treatments in salmonid watersheds. These treatments focus on erosion prevention and control on managed lands. The goal is to reduce the human influences and restore erosion to a level more consistent with the natural background rate. *Part X* discusses several components of watershed restoration:

- Sediment production and delivery;
- Upslope erosion assessment;
- Analysis and reporting of assessment data;
- Implementing sediment control work;
- Quality control, documentation of projects, and project monitoring.

The erosion assessment protocols included in *Part X* are for the identification and quantification of existing and potential sediment sources in upslope and stream bank locations. The inventory data forms include problem identification, quantification of existing and potential sediment sources, and the selection of proper treatment options. To conduct a successful assessment, the survey team must understand basic upslope erosion processes and be familiar with basic erosion control and erosion prevention techniques applicable to a particular setting. They must also be familiar with the heavy equipment used, its application for the various restoration techniques, and have the ability to estimate production rates. The general erosion control techniques presented must be adapted to site-specific conditions. Additional topic-specific publications and manuals for erosion prevention and control are included in the list of references.

Scope and Limitations

Part X has been prepared to provide the reader with an overview of basic information on watershed erosion processes (especially road-related erosion). This includes: how to identify and conduct a basic or simplified inventory of the erosion features associated with these processes; and some of the most common, less technical methods by which these processes and their impacts can be prevented or controlled. Only the most straightforward and most common of erosion control and erosion prevention treatments have been described. Because this is not a comprehensive technical guidance manual, and because of the highly varied site specific conditions that are likely to be encountered in the field, not all the information needed to identify, evaluate and treat complex erosion processes or mass wasting features has been included.

Steps for identifying potential and existing landslides are outlined. After following these steps, the restoration practitioner should be able to recognize whether a landslide problem exists within a specified area, and then to seek the expertise of a geotechnical specialist for further analysis of the problem, assessment of risk, and recommendations for control and correction. Consultation with licensed and experienced professionals may also be required in situations that require a more detailed evaluation of field conditions, prescription options and treatment methods to address complex geomorphic processes or in situations that require highly technical analyses or employ complex treatment methods. This is especially true for situations involving all but the smallest mass wasting features (e.g., cutbank failures, minor embankment failures) and treatment areas located in steep and potentially unstable hillslope areas. Identification and prescriptive treatment of all but the most simple of earth failures is outside the scope of this document.

Audience

This guide has been written in non-scientific terms and is intended for persons conducting field inventories to identify areas that may be contributing excessive sediment to streams. Among others, this may include contractors, equipment operators, watershed planners, field technicians, and landowners. This guide is not intended to supplant, nor is it capable of supplanting, trained, experienced, and skilled watershed scientists and workers. It is intended as supplemental guidance on inventory and erosion control methods for the specialist. It is also intended to provide a basic knowledge of erosion control and prevention, and road and culvert removal planning and implementation techniques for persons without specialized training but an interest or need to participate in watershed protection activities.

LEGAL REQUIREMENTS

Upland erosion control and erosion prevention work typically involves earth moving and other work in around stream channels and on lands that often have other environmental limitations and restrictions. Permits for such activities are a normal component of restoration work. When working on Fisheries Restoration Grant Program (FRGP) projects, the Department of Fish and Game generally takes the lead role in securing the necessary California Environmental Quality Act (CEQA) permits.

For all projects that modify the bed or banks of a stream channel or divert the flow of a watercourse, no matter how small, a Streambed Alteration Agreement will be required from DFG. The Agreement spells out the permitted activities, the allowed timing of project work and the on-the-ground mitigations and protections that must be applied. Typical activities covered by the Streambed Alteration Agreement process include installation of stream crossing culverts, armored fill and bridge installations, installations of rock armor on a stream bank, and excavations of stream crossing fill.

Other CEQA clearances typically handled by DFG may include field surveys by trained experts in several disciplines and include archaeological surveys, listed plant surveys and surveys for threatened or endangered animal species. These surveys may identify listed species or areas of particular sensitivity that result in operating restrictions or exclusions of operations in certain portions of the project area. All of the biological surveys must be conducted at key times of the year (e.g., plant surveys are conducted during blooming periods), so pre-project planning is critical.

On the field level, federal and state water quality and pollution regulations are administered and enforced by Regional Water Quality Control Boards. Depending on the type of project being considered, consultation with a Regional Board may be required. The DFG Streambed Alteration Agreement contains requirements for controlling sediment and other pollution from a project site, but the Regional Boards enforce water quality violations through Stop-Work Orders, Clean Up and Abatement Orders, and Waste Discharge Requirements. Regional Board staff can provide technical information on how to control project-related pollution.

If trees will be cut during restoration activities and the logs and wood sold as byproducts of the restoration work, the project will also be subject to the California Forest Practices Act. A licensed forester can assist with preparation of the required permits needed for commercial forestry operations. If, on the other hand, the wood will not be sold but used in the project (e.g., to place in the stream channel or to use as bank protection), a timber harvest plan may not be necessary. In either case, consultation with a local office of the Department of Forestry and Fire Protection is recommended.

Finally, if the preliminary survey of an erosion area suggests that a failure area of unknown type and depth may be present, characterization of the problem and any treatment prescriptions must be developed in consultation with a licensed geotechnical specialist. All but the smallest landslides can be very complex features and the development of effective treatment options more often than not will require consultation with a licensed geotechnical specialist. The Board for Geologists and Geophysicists (BGG) examines and licenses Professional Geologists, Certified Engineering Geologists and Certified Hydrogeologists in California. The Board and licensed professionals in the field can provide information on circumstances that require professional advice.

SEDIMENT PRODUCTION AND DELIVERY

Land use activity can accelerate the natural background rate of erosion. It may also result in chronic delivery of sediment to stream channels. Three geomorphic processes are responsible for most sediment delivery from upland areas (Figure X-1). These are:

- Chronic surface erosion from bare soil areas;
- Fluvial erosion, including gully and stream channel erosion;
- Mass wasting or landsliding.

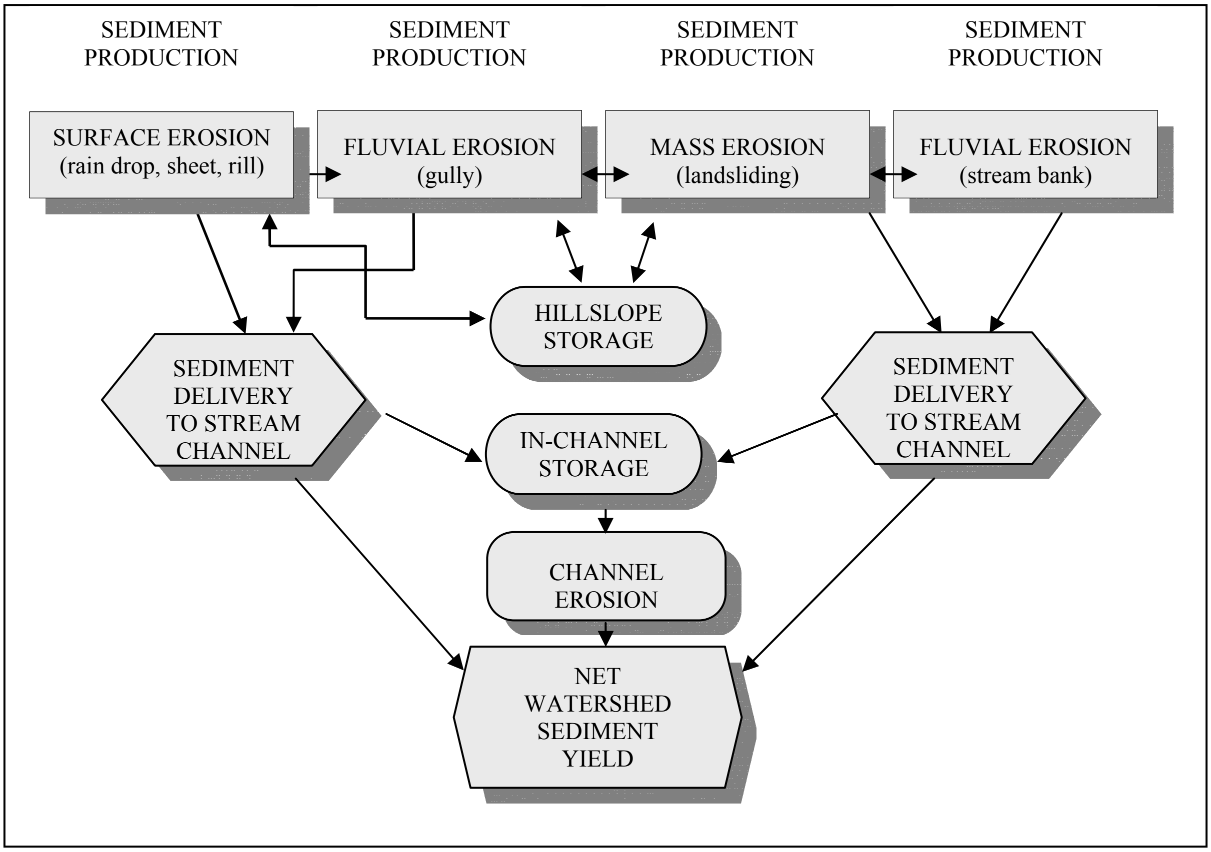


Figure X-1. Flow chart of erosion and sediment delivery to stream channels.

Understanding these processes is necessary for conducting successful upslope assessment and restoration (Table X-1). Most of these processes, once initiated, result in erosion of sediment, which transports to hillslopes or stream channels. Whether the sediment remains in storage, either on the hillslope or within the channel, depends on the sediment types; and the timing, magnitude and frequency of storm events within a watershed. Once sediment suspends in water, or is mobile within the streambed, it becomes part of the net watershed sediment yield.

Watershed erosion processes are neither simple nor easily controlled by human intervention. Some conditions are not restorable, reversible, or correctable. Successful treatments for erosion prevention and erosion control should be designed to address the erosion process (surface erosion, fluvial erosion, or mass wasting), not the land use. Thus, gully control practices are generally the same whether they are applied on agricultural areas, grazed land or for road-related erosion sites.

Finally, it is generally not possible, nor necessarily desirable, to stop all erosion. The preferred approach is one that reduces the risk of erosion or reduces the volume of eroded sediment delivered to a stream by the most effective and cost-effective method.

Process	Typical upslope sediment source locations	Sediment source characteristics and restoration opportunity					
		Nature of erosion processes	Aggregate sediment delivery	Sediment type	Preventable erosion?	Controllable erosion?	Preventable sediment delivery?
Surface erosion	Surface erosion from bare soil areas (road surfaces, construction sites, burned areas, etc.)	Chronic	Moderate	Fine Grained	Sometimes	Rarely	Usually
Mass wasting	Road fillslope failures	Mostly episodic, triggered by large storm events	Low to Moderate	Fine to Medium Grained	Usually	Rarely	Usually
	Landing failures		Low to Moderate	Fine to Medium Grained	Usually	Rarely	Usually
	Road cutbank failures		Low	Fine to Medium Grained	Rarely	Sometimes	Usually
	Stream bank landslides		Low to Moderate	All Grain Sizes	Sometimes	Rarely	Rarely
	Non-road (hillslope) debris landslides		Low to High	All Grain Sizes	Sometimes	Rarely	Rarely
	Earthflows and large, slow moving landslides		Low to Moderate	All Grain Sizes	Rarely	Rarely	Rarely
Fluvial erosion	Stream crossing washouts (gullies)		Low to Moderate	Fine to Medium Grained	Usually	Usually	Rarely
	Stream diversions (gullies)		Low to Moderate	Fine to Medium Grained	Usually	Usually	Rarely
	Other road-related gullying		Low	Fine to Medium Grained	Usually	Usually	Usually
	Non-road gullying		Low	Fine to Medium Grained	Sometimes	Sometimes	Rarely
	Stream bank erosion		Low to Moderate	All Grain Sizes	Sometimes	Sometimes	Rarely

Table X-1. Sources, magnitude and restoration potential of sediment production and delivery mechanisms in upland watersheds.

To accurately identify upslope sediment sites and recommend effective and cost-effective treatments, restoration practitioners must have a clear understanding of the following:

- How erosion processes operate and lead to sediment delivery to streams;
- How land use affects erosion processes in predictable ways;
- Which erosion processes are preventable and controllable, and which are not;
- How the recommended erosion treatment will result in reduced sediment delivery to a stream.

Surface Erosion

Surface erosion results from raindrop impact and un-channeled water flowing over bare soil during and after rainstorms. Exposed soil is a direct consequence of almost all land use activities. Anywhere there is bare soil there will be potential for surface erosion. Runoff and surface erosion from bare soil areas depends on rainfall intensity and duration, the frequency of disturbance, the length of time exposed, soil type and grain size. Often, surface erosion from bare soil areas diminishes after the first rain event, except on unsurfaced roads and other bare soil areas where disturbance and resultant surface erosion can become a chronic problem.

Rates of surface erosion vary from watershed to watershed. In some watersheds where mass wasting is relatively uncommon, but soil easily erodes, surface erosion can be the predominant sediment delivery process. Surface erosion turns into sediment delivery when the runoff discharges into a stream channel, often through rills or small gullies. The development of rills, defined as channels smaller than 1' x 1' in cross section, is included with surface erosion processes.

Characteristics of Surface Erosion

- Surface erosion is greatest in fine granular soils such as silt and sand. Areas of decomposed granitic bedrock are particularly susceptible. It is typically lowest in rocky or clay-rich soils.
- Surface erosion is greatest in the first year after exposure and usually diminishes greatly thereafter unless the area is chronically disturbed as on unsurfaced roads.
- Surface erosion moves and delivers mostly fine sediment such as clay, silt or fine sand.
- Eroded sediment does not move long distances unless transported by rills, gullies or other concentrated flow channels such as road ditches or ruts.
- Sediment delivery to a stream requires direct connection of bare soil areas with stream flow channels such as rills, gullies, and ditches.
- Site-by-site, surface erosion volumes are often comparatively small, but cumulatively, over time, or over large watershed areas, volumes can be very large.

Restoration and Protection Principles for Surface Erosion

- Keep bare soil to an absolute minimum when conducting land use activities. This is the single most effective method for preventing land use related surface erosion.

- Mulch or revegetate bare soil adjacent to stream channels, or other flow transport paths, to the break-in-slope near those areas. Mulching is the single most effective and cost-effective method for controlling surface erosion.
- Keep runoff from bare soil areas well dispersed. Dispersing runoff keeps sediment on-site and prevents sediment delivery to streams.
- Direct any concentrated runoff from bare soil areas into natural buffers of vegetation or to gentler sloping areas where sediment can settle out.
- Prevent rills by breaking large or long bare areas up into smaller patches that can be effectively drained before rills can develop.
- Disconnect and disperse flow paths, including roadside ditches, which might otherwise deliver fine sediment to stream channels. This prevents most sediment delivery.

Fluvial Erosion

Fluvial erosion includes gully erosion and stream bank erosion. It occurs when concentrated flowing water scours and erodes soil along its path, whether it is within a natural stream channel, or on a previously un-channeled slope. The amount of erosion that occurs is a combined function of the energy of the flowing water and resistance of the flow path to scour. Thus, the greater the flow volume or flow velocity, the greater is the erosive power. Similarly, the more erodible the soil type, the more soil loss will occur. Fine grain granular soils like silt and sand are most likely to erode; and rocky soils and bedrock are the least likely to erode.

Fluvial erosion can also be a chronic source of sediment, where gullies gradually increase in size or stream banks continue to erode, with routine runoff events. However, most erosion and sediment delivery from fluvial processes occurs during episodic storm events. The largest storm events usually trigger greatly increased fluvial erosion, as new gullies form and existing gullies enlarge. Periods between episodic storm events are usually times of lower fluvial erosion rates.

Fluvial erosion is usually a very efficient sediment delivery mechanism. The larger a gully system, the more likely the eroded sediment will be delivered directly to a stream channel. Fluvial erosion rates can vary greatly between watersheds, depending on soil types, land use and land management practices.

Fluvial erosion may be accelerated by land use activities that result in increased runoff, or allow runoff to concentrate and discharge onto hillslopes prone to erosion. Fluvial erosion commonly occurs at gullies developed on hillslopes at culvert outlets, diverted streams, washed-out stream crossings, inboard ditches, and stream channels exposed to increased runoff.

Stream crossings are common sites of gully erosion along road systems. They commonly fail in the following ways:

- Overtopping, which may occur when a culvert plugs, or its capacity is exceeded and water flows over the road;
- Stream diverts when a culvert plugs or its capacity is exceeded, and the stream flow is diverted down the road, instead of over-topping the stream crossing fill;

- The crossing collapses when the stream flow tunnels through the fill, as occurs with Humboldt log crossings, and rusted out culverts;
- Stream crossing fills without culverts on abandoned roads gradually erode and wash out.

Characteristics of Fluvial Erosion

Although minor scour may occur and banks may locally collapse and erode between storms, a gully formed by a large runoff or flow event may not grow significantly, until an equal or larger event occurs. The following are characteristics of fluvial erosion:

- Sediment delivery from fluvial erosion can be both chronic and episodic. Fluvial erosion produces, transports, and delivers both fine and coarse sediment to stream channels.
- Stable gullies can serve as conduits for fine sediment delivered from other sources, such as roads. Any sediment delivered to a gully system from another sediment source such as road surface runoff, is likely to deliver to a stream channel somewhere down slope.
- Gullies are channels that have a cross sectional area over one square foot (1' x 1'). Gullies are like conveyor belts; they are very efficient sediment delivery mechanisms that can transport eroded sediment long distances over varied terrains and slopes.
- Gullies in rocky soils tend to eventually armor themselves and become increasingly resistant to continued down cutting and enlargement.
- Individual fluvial erosion sites may be small (less than 10 yd^3) but huge gullies (greater than 1,000 yd^3) can also develop on unstable hillslopes. Concentrated runoff and diverted streams can create large gullies, and may trigger the formation of landslides on otherwise stable hillslopes.

Restoration and Protection Principles for Fluvial Erosion

- Prevent gullies by dispersing runoff from roads, ditches and construction sites, by correctly designing, installing and maintaining drainage structures (e.g., road shape, rolling dips and culverts) and by keeping streams in their natural channels. No single point of discharge from a road or other disturbed area should carry sufficient flow to create gullies. If gullies continue to develop, further disperse the runoff.
- Direct any concentrated runoff from bare soil areas, such as road surfaces, into natural buffers of vegetation, or to areas where sediment can settle out of the runoff.
- Dewater active gullies to prevent their enlargement and to reduce their capacity for sediment transport.
- When dewatering is not possible, options include channel armoring and grade control structures. These specialized erosion control techniques are more costly and less effective than prevention and dewatering, and do not stop sediment transport. They typically require an engineered design, proper installation, and a commitment to maintenance (*Part VII*).

Mass Wasting

In many watersheds in north coastal California, mass wasting is the most common geologic process of sediment production. Common types of landslides in the natural environment range from large rotational and translational landslides and earthflows, to large and small debris slides, to small slumps. Landslides typical in steep forested terrain of coastal California have been described (CGS 1999) and mapped (CGS 1982-95) in many coastal watersheds of northern California. CGS Note 50, *Factors Affecting Landslides in Forested Terrain*, provides descriptions and illustrations of the various types of landslides that have been identified on the north coast. The California Geological Survey (CGS) landslide inventory maps (CGS Note 40) can be used to locate basic landslide features that have been identified and mapped in many salmonid watersheds of Del Norte, Humboldt, and Mendocino counties, as well as selected other watersheds of the State (CGS 1982-95). These maps can help restorationists identify unstable and potential unstable terrain within watersheds that are targeted for erosion inventories and development of erosion control plans.

Landsliding is a gravitational process. Soil slides down slope when the gravitational forces exceed the forces that hold it in place (friction). Factors affecting landslide sediment delivery include proximity to a stream, slope steepness, slope shape, moisture content, and soil composition. Landsliding occurs in the natural environment, but land management activities that cause increased driving forces or decreased slope resistance can accelerate it. Road construction and its associated spoil disposal is an example of a land management activity that may trigger landsliding. Land management activities that cause or increase landsliding include:

- Slopes undercut and destabilized during road or other construction activities;
- Un-compacted and unstable spoil materials disposed of onto steep slopes;
- The diversion and collection of water on otherwise stable slopes.

There are a number of indicators of unstable or potentially unstable slopes. In the field, potentially unstable ground often, but not always, displays direct evidence of instability such as cracks, scarps, and leaning or pistol-butted trees. Previous failures in similar locations in nearby areas may also suggest the potential for addition slope instability. Slopes may also exhibit indirect evidence or a suite of contributing factors that can lead to slope instability. These factors include but are not limited to steep or oversteepened slopes, convergent topography, colluvial soils on impermeable shallow bedrock, emergent groundwater, hydrophillic (water loving) vegetation and mottled soils indicative of elevated ground water, known unstable soils and geologic formations, and proximity to faults and shear zones.

Water in and on hillslopes is usually a key contributing factor to the occurrence of landslides. Landslides often occur in close geographic proximity to springs, seeps and other forms of emergent groundwater. Roads intercept subsurface flow paths, with water either emerging from the cutbank (contributing to cutbank failures) or being blocked by overburden and uncompacted earthen materials disposed of downslope of the road (sidecast materials). Subsurface damming of groundwater contributes to fillslope failures and to larger debris slides where topographic swales and colluvial hollows fail by the build up of water pressures in the subsurface.

In general, the smaller the landslide, the more easily it can be prevented or controlled. In contrast, larger management-related landslides may be preventable, but they are rarely controllable once they begin sliding (TRB 1978; GSA 1987). Landsliding rates can vary greatly between watersheds, depending on natural slope stability, land use and management practices. Landsliding becomes sediment delivery when material slides or flows into a stream channel. Some types of landslides are efficient at delivering sediment to streams while others rarely result in sediment delivery. Both timing and location in the watershed determine this. For example, streamside debris slides are infrequent but may result in substantial direct delivery of sediment, whereas cutbank landslides along roads are notoriously frequent, but typically lack major amounts of sediment delivery. Very few landslides deliver all their material to a stream; some sediment is generally stored on the hillslope.

Characteristics of Mass Wasting

- Sediment delivery to stream channels from landsliding occurs primarily as episodic inputs as the result of direct landsliding. Some slide surfaces, such as those on large landslides along roads or stream channels may remain largely un-vegetated for years, but surface erosion and gulling of the slide surface usually produces far less sediment delivery than the landslide event itself.
- Landsliding is predominantly an episodic process that occurs during or in response to rainfall and runoff events. Large storm events typically cause more and bigger landslides.
- Steep hillslopes, weak rock types and certain soils are more prone to landsliding than other soil types. In general, steeper hillslopes have a higher potential for landslides. Diverted runoff or slopes undercut by migrating streams can cause landslides to form on previously stable hillslopes.
- Sediment delivery is largely controlled by slope steepness, slope shape (i.e., concave, convex or planar), landslide volume, water content (fluidity), and proximity to the stream. Not all landslides deliver sediment to a stream channel. This depends on the failure mechanism, the distance between the failure area and the stream channel, and the overall mass of the slide.
- Some landslides that start out as small volumes can quickly increase in volume as they move down slope. Other landslides may quickly lose material as they move down slope. Water content, hillslope steepness and shape, landslide mass and the type, size and amount of vegetation in the landslide's path largely control the distance sediment moves.
- Landslides that do result in direct delivery, deliver any trees and other organic material present in the area of failure along with all sediment grain sizes that are present on the hillslope and in the underlying soil and bedrock material.

Restoration and Protection Principles for Mass Wasting

- Prevent accelerated landsliding by identifying, avoiding and protecting potentially unstable slopes through appropriate land management.
- Only treat landslides that have the potential to deliver sediment to a stream channel.
- Divert surface and subsurface drainage to stable areas away from steep, unstable slopes.
- Revegetation is a valid long-term restoration technique for unstable and potentially unstable slopes, but revegetation is sometimes very difficult and the benefits will take decades to develop.
- Small landslides, especially those that occur in sidecast materials, are often most effectively prevented or controlled by direct excavation of all or most of the potentially unstable material. This is often the most effective and cost-effective technique for preventing road-related landsliding.

- In some instances, sediment delivery from some medium and large size landslides can be controlled by excavating and removing material at the head of the slide. Removal of mass from the top of a slide may unload the slide sufficiently to stabilize the remaining mass. Projects to stabilize landslides must consider the size and volume of the slide, the volume of sediment to excavate, and the predicted volume of sediment prevented from delivery to a stream. The amount of unloading required is a technical assessment that requires professional analysis. The California Business and Professions Code requires that such a determination be made by a registered Professional Geologist, a Certified Engineering Geologist, or geotechnical Professional Engineer working within their area of expertise.
- The most cost-effective restoration treatment for large, uncontrollable landslides is often direct excavation and removal of slide material poised for delivery to a stream. This technique reduces sediment delivery but does not attempt to prevent or control landslide movement. Corrective actions and control measures for medium and large landslides are outside the scope of this document and require the assistance of appropriately trained and experienced Professional Geologists, Engineering Geologists and Geotechnical Engineers.
- Large landslide scars can be slow to revegetate, and although highly visible for many years after the initial failure, the scars may be an artifact of past landsliding and not an indication of future landslide potential. In many cases, most future sediment delivery from bare landslide scars will come from surface erosion and gullying. These processes are often not cost-effective to control due to the difficulty of access, extremely steep slopes, and harsh site conditions.
- Vertical head scarps and tension cracks around the top of old landslides are usually signs of stress relief that developed during or immediately after the original landslide failure. They are usually not sites of future sediment delivery because the potential sediment volumes are comparatively small and any material that does fail is usually redeposited immediately down slope on the original slide mass. Head scarp areas of old landslide scars should only be considered for treatment if there is the potential for future sediment delivery, and then only in consultation with licensed and experienced geotechnical professionals.

UPSLOPE EROSION ASSESSMENT

Determining which watersheds have the greatest potential for salmonid restoration is critical in identifying candidate watersheds for erosion assessment. Impacted watersheds with restorable salmonid populations are obvious targets for erosion assessment. Recovery of ecosystem function will be most successful where there is both restoration and prevention efforts. There is no easy, quick, or cheap way to restore most watersheds.

Healthy watersheds with strong salmon and steelhead populations are also in need of erosion assessment, for they will be the seat of future stock recovery for nearby degraded watersheds (Bradbury et al 1995). Although healthy watersheds may serve as refugia for salmonid populations, consider the potential for future sediment-related degradation. This dictates the inventory of healthy watersheds, and inclusion of sediment reduction measures in future land use activities.

Assessment Scales and Priority Criteria

Watershed problems and restoration treatments vary across the landscape. It is important to set priorities for both upslope assessment and for resultant protection and restoration actions. In the context of this manual, salmonid conservation biology drives the need for upslope assessment and restoration. For this reason, it is important to develop a biologically based strategy for setting watershed assessment, protection and restoration priorities (Bradbury et al 1995).

Watershed Categorization

Divide watersheds into logical assessment and restoration units. Prioritize both upslope assessment and actual restoration treatments on these land units (Figure X-2). From large to small, these assessment land units include:

- River basins - large land units with an integrated drainage system often exceeding 300 square miles in area and containing many named subbasins and watersheds and many miles of fish bearing (or Class I) stream channels (e.g., Mattole River, 396 mi^2);
- Subbasins - intermediate to large size land units, consisting of integrated drainage systems with an area generally ranging from 50 to 300 square miles or more and generally including many named watersheds and Class I stream channels and tributaries (e.g. Western Mattole Planning Subbasin, 89 mi^2);
- Watersheds - intermediate sized land units, consisting of integrated drainage systems with an area generally ranging from 10 to 50 square miles with a number of named tributaries and few to many sub-watersheds and Class I stream channels (e.g., Honeydew Creek, 17.2 mi^2);
- Sub-watersheds - smaller watershed units generally ranging from 1 to 10 square miles with few or no Class I stream channels (e.g., Bear Trap Creek, 1.7 mi^2);
- Hillslope units - logical topographic or management units within a watershed or sub-watershed that may be defined by natural boundaries (such as ridges and streams) or by management features (such as roads);
- Sites - individual treatment sites of on-going or future sediment delivery ranging in size from 100 ft^2 (or less) to 100 acres. This includes individual stream crossings, gullies, stream banks, road reaches, landslides and other erosion sources.

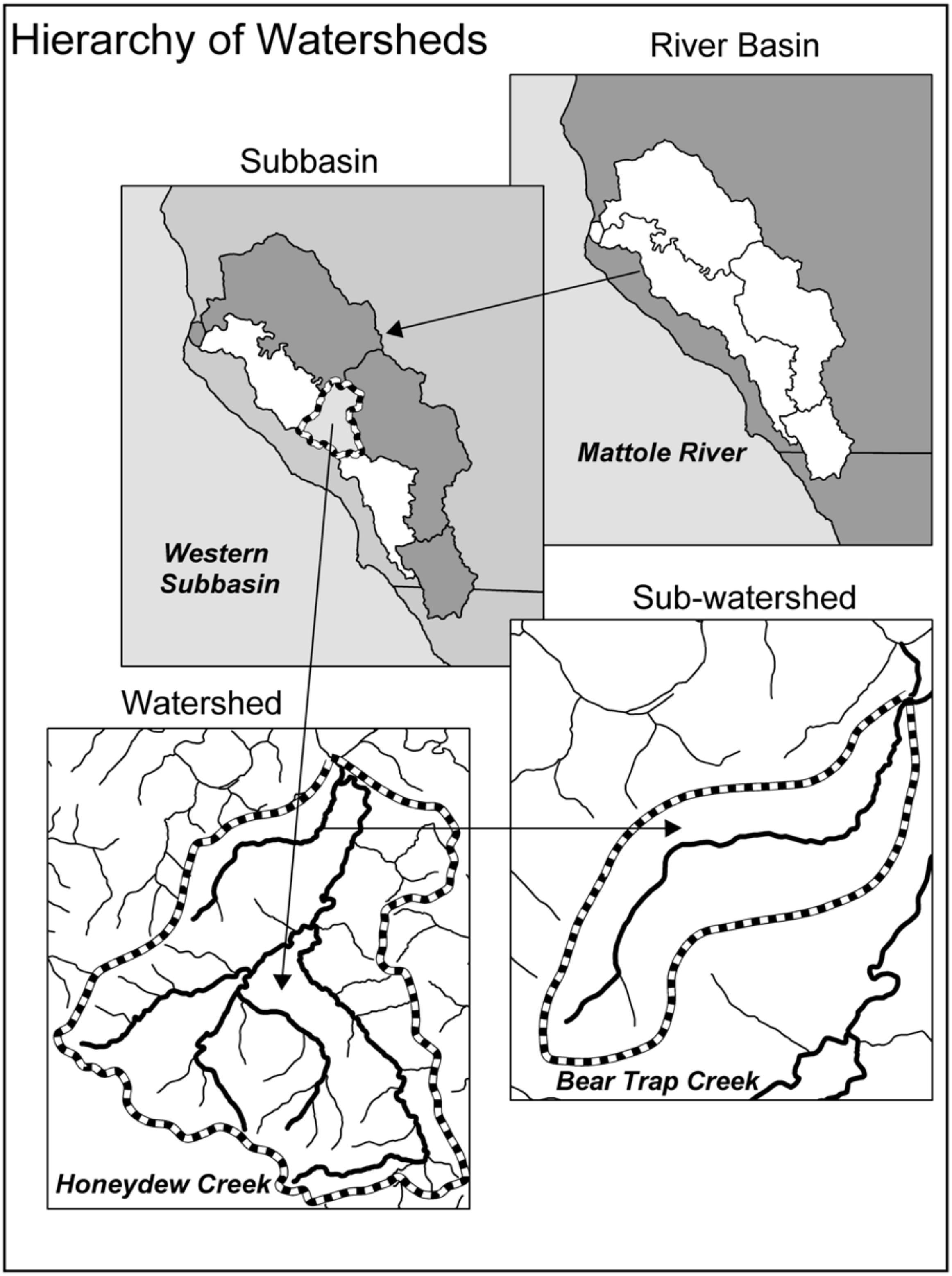


Figure X-2. Watershed hierarchy.

Priority Criteria

Prior to conducting an upslope assessment, research the relative health of the salmonid populations and habitat conditions in the assessment area of interest. Base the assessment on known or suspected limiting factors for salmonids, as well as on potential resources at risk where the aquatic system is not severely impaired but where watershed threats may be imminent. This dual focus will direct assessments to watersheds where the best benefit to the resources are achievable. Information that would support this conclusion, and the decision to proceed with an upslope assessment, is often available from DFG or other professionals who are most familiar with watershed conditions, historic and present use by salmonids, limiting factors, threats and the overall health of the aquatic system. A restoration and protection strategy can then be employed which makes logical and biological sense.

1st Priority - Habitat Protection

Aim initial efforts at protecting the best remaining refuge watersheds; that is, those areas with the best habitat, and healthiest and most diverse populations of fish and other forms of aquatic life. This may also include areas where special at-risk populations are present. The success of the protection effort is dependent on the effective use of protective land use practices and preventative land management.

2nd Priority - Habitat Restoration

This includes impacted watersheds that still have the potential for recovery. In these watersheds, use restoration as a tool to enhance or recover fish populations and aquatic ecosystem function over the intermediate term. These watersheds include streams that have had historic fish runs but do not currently support viable fish populations. Because of relatively few limiting factors, restoration activities should focus on the causes, not symptoms, to improve watershed and habitat conditions and processes. These sites, when improved, will become logical areas for fish to re-colonize most rapidly. Even though protective land use practices are undertaken, full recovery of these watersheds could take decades.

3rd Priority - Water Quality Restoration

This includes those sub-watersheds and headwater areas where access for anadromous fish is naturally limited due to increased stream gradient or natural barriers. These areas nonetheless perform vital ecological function for the entire aquatic ecosystem, by providing cool, clean water, large woody debris, and food (nutrient) products for aquatic species. Example treatments include upslope and riparian restoration to reduce sediment inputs and to lower summer water temperatures to larger connecting streams utilized by anadromous fish.

4th Priority – Mainstem River Restoration

Estuary enhancement, adult and juvenile salmonid migration improvements and riparian restoration are projects done directly to improve the main channel of most large river basins to improve fish and aquatic habitat. These areas are critical for anadromous fish.

5th Priority or Last Priority Watersheds

It may be best to consider watersheds with multiple limiting factors non-restorable. These watersheds could absorb most of the money that is available for watershed restoration, with little or no chance for noticeable recovery within the time span of several human generations (Frissell

1993). Identify non-restorable watersheds early in the planning process. Consider work in these areas after protection and completion of erosion prevention in the more productive watersheds is accomplished.

Site Specific Assessment Strategies

When not all of a watershed or sub-watershed can be completely inventoried with the available funding and resources, there are other strategies that can be employed to help direct assessment efforts. Certain sub-watershed areas and management conditions are more likely to contain problems than others; these are usually the best places to focus on when inventory resources are limited. Two recommended areas to focus on are:

- Sensitive landscape areas**:** Lower hillslope areas; steep hillslopes; riparian zones; fish bearing stream channels; areas with a high density of stream channels; and areas of highly erodible or unstable soil. These areas are sensitive because of their susceptibility to erosion and/or mass wasting, or because they are so close to stream channels that any significant erosion would deliver sediment to streams and adversely affect fish habitat.
- Common sediment producing areas in managed landscapes: This considers roads of all types, including railroad grades, jeep trails, and logging skid trails; quarries and rock pits; cultivated agricultural areas on hillslopes; all terrain vehicle (ATV) and livestock trails; development and construction sites; and recently burned or cleared areas.

Assessment Scales

When possible, assess a watershed in its entirety. If social and economic factors necessitate a partial assessment, then assess the most biologically important sub-watersheds first, with completed inventories developed into prioritized restoration plans for the inventoried sub-watersheds as the assessment progresses. Alternately, if funds are limited, assessment of low risk areas (e.g., ridge tops) in these same sub-watersheds can be deferred while those portions of the landscape that are most likely to contain significant, treatable sediment sources (e.g., lower and middle hillslope areas with high road densities and/or abandoned roads and numerous stream crossings) can be inventoried first. Sometimes, landowner access will partially dictate which watershed areas can be inventoried.

The following list outlines some examples of high and low priority assessment areas or features used to stratify a watershed or sub-watershed for partial assessment.

Higher priority assessment areas in watersheds typically include such features as:

- Roads in sensitive hillslope locations (steep, unstable slopes);
- Roads built in highly erodible terrain (decomposed granite and erodible grassland soils);
- Roads with numerous and/or volumetrically large stream crossings;
- Old roads and abandoned roads with stream crossings;
- High use, unsurfaced or rock surfaced roads;
- Hillslopes exhibiting diverted streams and skid trails;
- Class I stream channels;
- Recent construction areas, rock pits and borrow sites.

Lower priority assessment areas typically include such features as:

- Ridge tops and ridge top roads;
- Upper hillslope roads with gentle or moderate slope gradients (<35%);
- Hillslopes with roads but few or no streams;
- Roads built on moderate or gentle hillslope areas anywhere in a watershed;
- Harvested hillslopes that have been cable yarded or helicopter logged;
- Hillslope areas with little or no recent land management.

If portions of a watershed or sub-watershed are selected for assessment, as opposed to the entire area, have the plan reviewed by an experienced restoration specialist or DFG biologist before proceeding. Partial assessments run the risk of improperly ignoring or excluding portions of a watershed that may be affecting or threatening salmonid spawning and rearing habitat.

Landowners have found sediment source inventories to be very useful for conserving both natural resources, and time and money. For example, the landowner can query the resultant database to determine how many sites exist and how much future erosion could occur along each particular road. If erosion at a number of sites is uncontrollable, then the landowner may choose to decommission the road and access that portion of the property through a new, more stable route. Through this analysis, the landowner may decide some roads may be worth upgrading while targeting others for permanent or temporary decommissioning.

Upslope Sediment Source Assessment Elements

Watersheds where salmonid resources are impaired or threatened by sediment derived from land use impacts are important candidates for upslope assessment and treatment. Conduct upslope assessments only after securing written permission from landowners or land managers. Two important watershed conditions to identify and consider include:

- Watersheds where degraded instream or riparian habitat limits salmonid populations and the problems have been caused by excessive sediment from the watershed to the streams;
- Watersheds where the instream habitat and riparian zone is not presently impaired, but stream resources are at potential risk because impacts may be imminent due to upslope instability and/or disturbance.

This dual focus will direct upslope assessment to watersheds where assessments will most likely lead to treatments that benefit salmonids and the overall health of the aquatic system. This methodology for upslope assessment promotes proactive watershed restoration for salmonids. It identifies significant sources of ongoing or future erosion that will lead to sediment delivery to streams in the watershed and that are amenable to treatment. This is termed a “forward looking assessment of sediment delivery”. Not all potential sediment sites may be treated, but their identification is an important first step to developing a cost-effective restoration plan.

Base a forward-looking upslope assessment upon field assessments that use logical, standardized, science-based observations, measurements, and deductive reasoning. The goal of this uniform data collection and resultant inventory is to deliver a watershed restoration plan that:

- Identifies the nature and magnitude of the erosion problems in the watershed;

- Provides quantified risk assessment data;
- Estimates the volume of sediment potentially prevented from delivery to streams;
- Develops a prioritized list of site-specific treatment prescriptions and associated cost estimates.

Assessment of past erosion and sediment delivery can provide an estimate of the relative magnitude and causes of various past sources of sediment delivery. This will provide some understanding of the importance of human-caused sediment sources over which there could be some control. Such an analysis may also provide insight about which land use practices contribute to increased sediment delivery, and might still be a factor in accelerated erosion.

Transportation Planning

The process of identifying a long-term strategy for road and erosion management is termed a transportation plan. Such a plan is developed by working closely with the landowner, and includes and integrates an estimate of the capital expenditures needed to upgrade and/or decommission elements of the present road network as well as the expected reduced long-term maintenance costs once all erosion prevention work has been undertaken.

In developing and implementing a transportation plan, consider all existing roads for either decommissioning or upgrading, depending upon their utility to the landowner and their risk to the aquatic ecosystem. Not all roads are high-risk roads and those that pose a low risk of affecting aquatic habitat may not need immediate attention. It is therefore important to rank and prioritize roads in each sub-watershed based on their potential to impact downstream resources, as well as their importance to the overall transportation system and management needs of the landowner.

Quality Assurance and Quality Control in Upslope Assessment

Quality assurance is an important component of both the assessment and the implementation phase of watershed restoration. Sediment source assessments, and the subsequent erosion prevention activities, are expensive. In the assessment process, the use of quality assurance measures minimizes the likelihood that incorrect interpretations will lead to unnecessary or overly expensive implementation. Quality assurance during a sediment source assessment ensures that the assessment is as thorough and accurate as possible. To achieve quality assurance it is required that:

- Inventory personnel are properly trained;
- Crew size is a minimum of two persons for efficiency and safety;
- Data are collected in a systematic and standardized format;
- Established protocols are followed;
- Significant sediment sources are not overlooked or ignored;
- Sediment savings volume estimates are accurate;
- Treatment cost-estimates are accurate and reasonable.

Quality control during implementation treatments represents another critically important component of effective and cost-effective upslope restoration and sediment control. Quality control measures utilized during the on-the-ground erosion prevention and control work helps ensure that the most effective and efficient techniques are applied, and that the completed project meets the design standards established during the inventory process.

Technical Oversight of Inventory Crews
The work of inventory crews should receive regular technical review by qualified erosion control or watershed assessment specialists to verify the thoroughness, accuracy and consistency of problem identification, field interpretations, volume calculations, delivery estimates and treatment prescriptions.

Review of Field Assessments and Treatment Prescriptions
Once the field component of the inventory is completed, conduct a review of the preliminary assessment data. Include in the review the crew supervisor, affected landowners, and the erosion control or watershed assessment specialist(s). The review should consist of field site inspections and review of the products of the assessment including:

- Adherence to established assessment protocols;
- Accuracy in problem site identification;
- Accuracy in problem site quantifications (e.g., volume measurements and delivery estimates);
- Correctness in proposed restoration treatment prescriptions;
- Precision of heavy equipment and labor prescriptions, and associated cost estimates.

On large watershed assessments, or in cases where there are significant revisions identified during the review, more than one field visit may be warranted. The crew supervisor should write a brief report describing the revisions and attached it to the *Upslope Inventory Data Form*.

Review of Prioritized Restoration Plan and Cost Analyses
Review the draft restoration plan before it is finalized, to assure the cost analysis is accurate and correct, and that the prioritized restoration plan for the watershed is supported by the inventory results. Reviews conducted by qualified and experienced agency personnel or qualified specialists should include a brief narrative or checklist confirming the content, accuracy, and thoroughness of the inventory and the restoration plan, as well as the appropriateness, effectiveness and cost-effectiveness of the proposed restoration treatments.

Assessment Preparation

Prior to conducting field inventory work, several preliminary tasks will make the subsequent fieldwork easier and more meaningful.

Review Available Information

Contact DFG fisheries staff to see if there is a watershed assessment report or stream inventory report for the assessment area. Contact other public resource agencies, private landowners, watershed groups and any other potential data sources to gather all relevant information on land use, erosion, stream conditions and aquatic resources for the area. Review existing maps, data and reports that might be useful in conducting the assessment and preparing the plan.

Obtain Supplies and Equipment

Prior to beginning the sediment source assessment, assemble the necessary office and field supplies and equipment (Table X-2).

Complete Contractor and Field Crew Trainings

Project personnel should complete DFG-approved basic field training in sediment source assessment. The trainers are qualified and experienced erosion control and watershed assessment specialists. The training includes erosion site identification, site description methods and classification, problem quantification, prescription development, cost-effectiveness analysis, air photo analysis, map making, field sketching, monitoring techniques and database analysis procedures. The training also includes discussion about and typical examples of complex erosion problems and mass wasting features likely to require consultation with a licensed, experienced geologist, engineering geologist, geotechnical engineer, hydrologist or qualified erosion control specialist.

Conduct Analysis of Stereo Aerial Photos

Prior to going into the field, conduct an air photo analysis of the assessment area to help identify the location of sensitive roads and other high priority areas for field mapping, analysis and potential treatment. Potential sources for air photos include:

- California Department of Forestry (CDF);
- Department of Conservation/California Geological Survey (CGS);
- Department of Fish and Game (DFG);
- Regional Water Quality Control Boards (RWQCB);
- County Assessor or Planning departments;
- United States Geological Survey (USGS);
- National Resource Conservation Service (NRCS);
- Bureau of Land Management (BLM);
- Environmental Protection Agency (EPA);
- US Forest Service (USFS);
- Private industrial landowners;
- Commercial air photo vendors.

Public resource agencies are likely to know the best sources of available photography for a particular watershed. Select historic aerial photographic coverage from a number of years (perhaps one flight per decade) to bracket major storms. Photos are available beginning in the 1940's or 1950's for most watersheds.

Air photo analysis is useful to develop a general basin background and land use history, including a road construction history. It is important to identify maintained and abandoned roads, and landings that are potential or on-going sediment sources. Air photos can also be used to develop an optional landslide history for the watershed, as well as an historical assessment of stream channel conditions, although in most streams only major areas of bank erosion or channel aggradation will be visible.

Necessary or desirable items:

- Aerial photos (1:12,000 or larger scale; laminated if using in the field)
- Mylar (3 mil, frosted on one side cut to 9" x 9"; for mapping sites on photos)
- Data form, on waterproof paper
- Computer with database software (e.g., MS Access)
- Clipboards
- Mechanical pencils (several per person)
- Scientific calculators, with trigonometric functions (solar powered preferable)
- Permanent markers, fine point (for marking information on flagging at sites)
- 150 foot tape with marks in 10ths of feet (one per crew)
- Pocket rulers (with 10ths and 50ths scale; one per person)
- Clinometers (marked in degrees and percent; one per person)
- Flagging - color(s) to be identified by crew (several boxes)
- Vests (one per person)
- Good field boots (treated waterproof)
- Drafting tape
- First aid kits, first aid supplies and survival supplies (e.g., matches, knife)
- Day packs
- Pocket stereoscopes (one per crew is probably sufficient)
- Map wheel (for measuring distances on maps and photos)
- Planimeter or dot grid (for measuring areas on maps and photos)

Optional items:

- 4x4 field vehicle(s)
- Distance measuring computer(s) for vehicles
- Geographic Positioning System (GPS) unit (portable, for mapping site locations)
- Electronic range finder (laser hand-held distance measuring device)
- Small chain saw, axe, brush hook or equivalent
- Rope (for going down steep slopes)
- Tow rope, cable or chain (for moving downed trees)
- Increment borer (for dating trees on landslides)
- Laptop computer (for field data entry, database and data analysis)
- Software for calculating stream crossing volumes
- Geographic Information System (GIS) mapping software
- Pocket rods marked in 10ths of feet (one per person)
- Compass
- Colored pencil set
- Rain gear and rubber boots
- Table stereoscope
- Monopod
- Digital camera and batteries, or 35mm camera and film, with 28mm zoom lens (wide angle required)
- Radio (CB, mobile phone or other for emergencies and communication)

Table X-2. Field equipment and material needed for upslope watershed assessments.

Results of the air photo analysis should be represented on a large format hard copy map (scale 1" = 1000', or larger), or in electronic GIS format so that future field inventoried sediment sites can be accurately plotted. The map will show roads by type, time of construction and past use, and status. Once fieldwork is completed, this base map will show all inventoried sites and it will form an important component of the watershed restoration plan.

Collect Field Data

Use the *Upslope Inventory Data Form* and the *Stream Bank Inventory Data Form* to record information in the field. Collect data on paper data forms or electronically in hand held or laptop computers. Paper data forms provide the security of a hard copy of the original data and the flexibility of allowing for developing field sketches and collecting other non-database information. Collecting data on waterproof paper forms is generally the preferred method.

Data Format

Collect field data in both qualitative and quantitative formats, depending on the question. Enter the data in a relational database with all data fields in unique, pre-established formats. Exceptions are where a descriptive response is necessary, or where other types of information are recorded that cannot be entered in the database, such as a sketch map of the site (Figure X-3). Collect data measurements in predefined units (feet, inches, meters, cubic yards, etc.).

Site Definition Criteria

Most watersheds have many locations of existing and potential erosion. It would not make sense to inventory them all, because some are very small and some will not deliver sediment to a stream channel.

- Inventory only sites of future sediment delivery. When working for DFG, do not inventory an erosion site if it is unlikely to deliver sediment to a stream in the event of future erosion or hillslope failure.
- Prior to the start of a sediment source inventory, establish a minimum sediment delivery volume to qualify a site as a measurable site. Typically, the minimum volume will be between 10 and 50 yds^3 of sediment delivery. Smaller sites should be located on a map or photo, but not described on a site data form. Use the *Upslope Inventory Data Form* to record sites that meet or surpass the established minimum volume criteria.
- For chronic road-related sediment sources, there is no minimum site volume. Inventory all sites of chronic sediment delivery.

Some sites of past erosion remain as eyesores. Often, large bare soil areas are mistaken to be more important than they really are. Define sites not by appearance, but by an analytical evaluation of the potential for future sediment delivery by erosion processes.

Upslope inventories often focus on road-related erosion because of its comparative importance, accessibility, and the relatively high cost-effectiveness of erosion prevention and erosion control treatments at road sites. In road-related inventories, include all stream crossing sites. Stream crossing sites normally have extremely high potential for direct sediment delivery to streams in the event of a culvert failure or stream diversion.

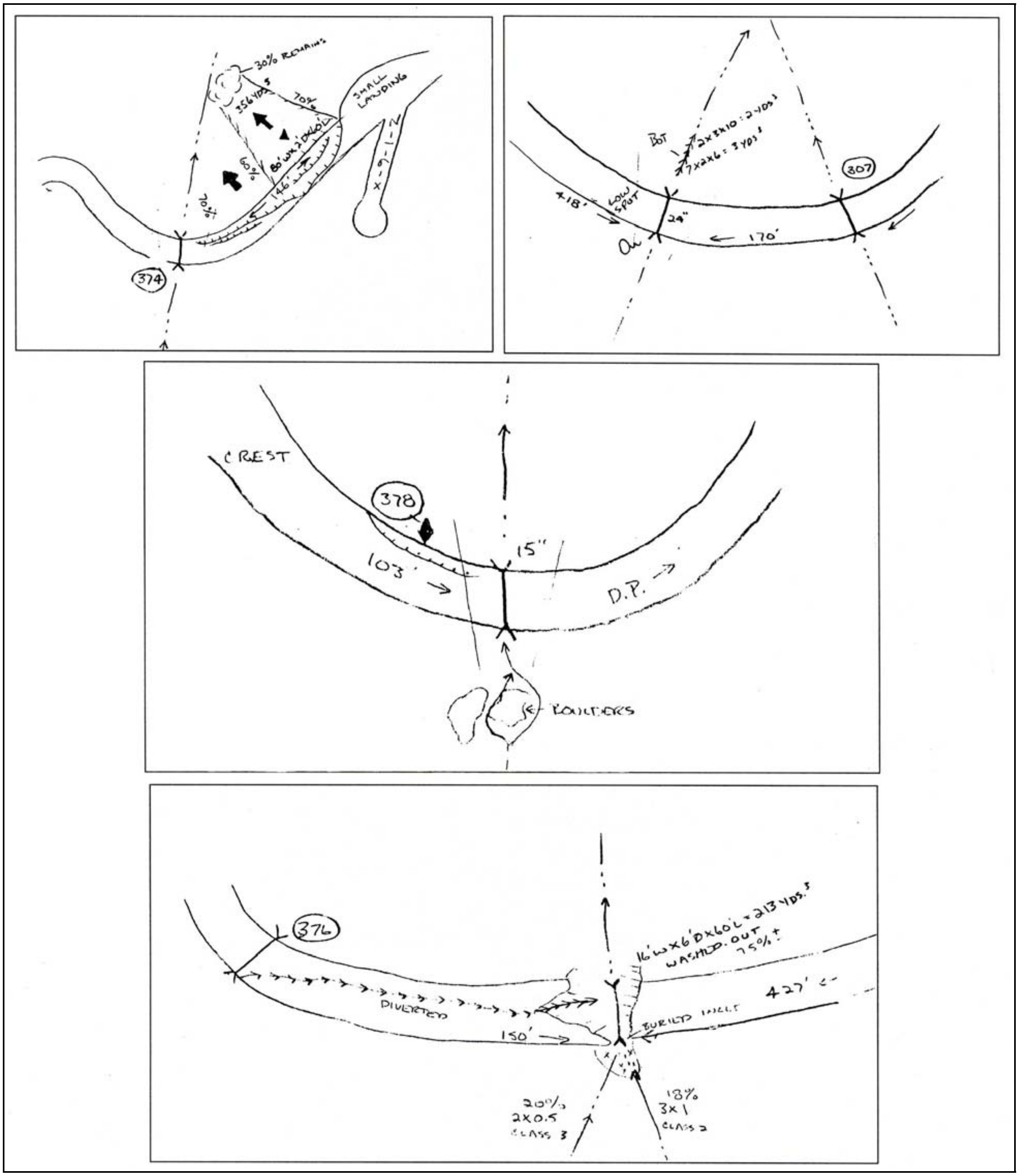


Figure X-3. Sample sketch maps of potential restoration sites, as portrayed on the *Upslope Inventory Data Form*.

Map Data

As field inventory proceeds, the potential sites identified can be numerous. Map the location of each site on a Mylar overlay, on the most recent aerial photo or map of the assessment area. Laminated copies of air photos work well for this purpose (Figure X-4). Enlarged aerial photos work well to map sites accurately. If aerial photos are not available, map site locations on the best available large-scale topographic or road map. For site identification, include GIS map coordinates or GPS satellite coordinates, where possible.

Use a standardized set of mapping symbols for recording site locations on air photo overlays or maps (Table X-3). Include these same symbols on field site marker flagging ribbons to identify the site and designate its type. Sketch in as accurately as possible abandoned roads not shown on the map.

Geology maps are available for the entire state and CGS Watershed Maps are available for many of the coastal areas. The maps are intended for the public for uses aimed ultimately at the reduction of erosion and landsliding, and the enhancement of water quality. The maps and explanations will enable users to: 1) recognize and "flag" areas of potentially unstable ground, and 2) foresee and minimize potential problems in these areas. The maps should be most useful for identifying unstable and erosion-prone areas on a regional scale, and in the preparation of large scale, long-range management plans that use geologic information to minimize environmental impacts. The maps are not a substitute for on-the-ground site-specific studies, but rather for identification of possible problem areas that may require consultation with a professional geotechnical specialist.

The watershed maps provide essentially the same information for each of the watersheds studied. Physical characteristics that can be correlated to landslide potential, soil erosion potential, and stream bank erosion potential are mapped at a scale of 1:24,000. The maps may be purchased from the California Geologic Survey, and are available for downloading in PDF format at http://www.consrv.ca.gov/cgs/thp/watersheds.htm.

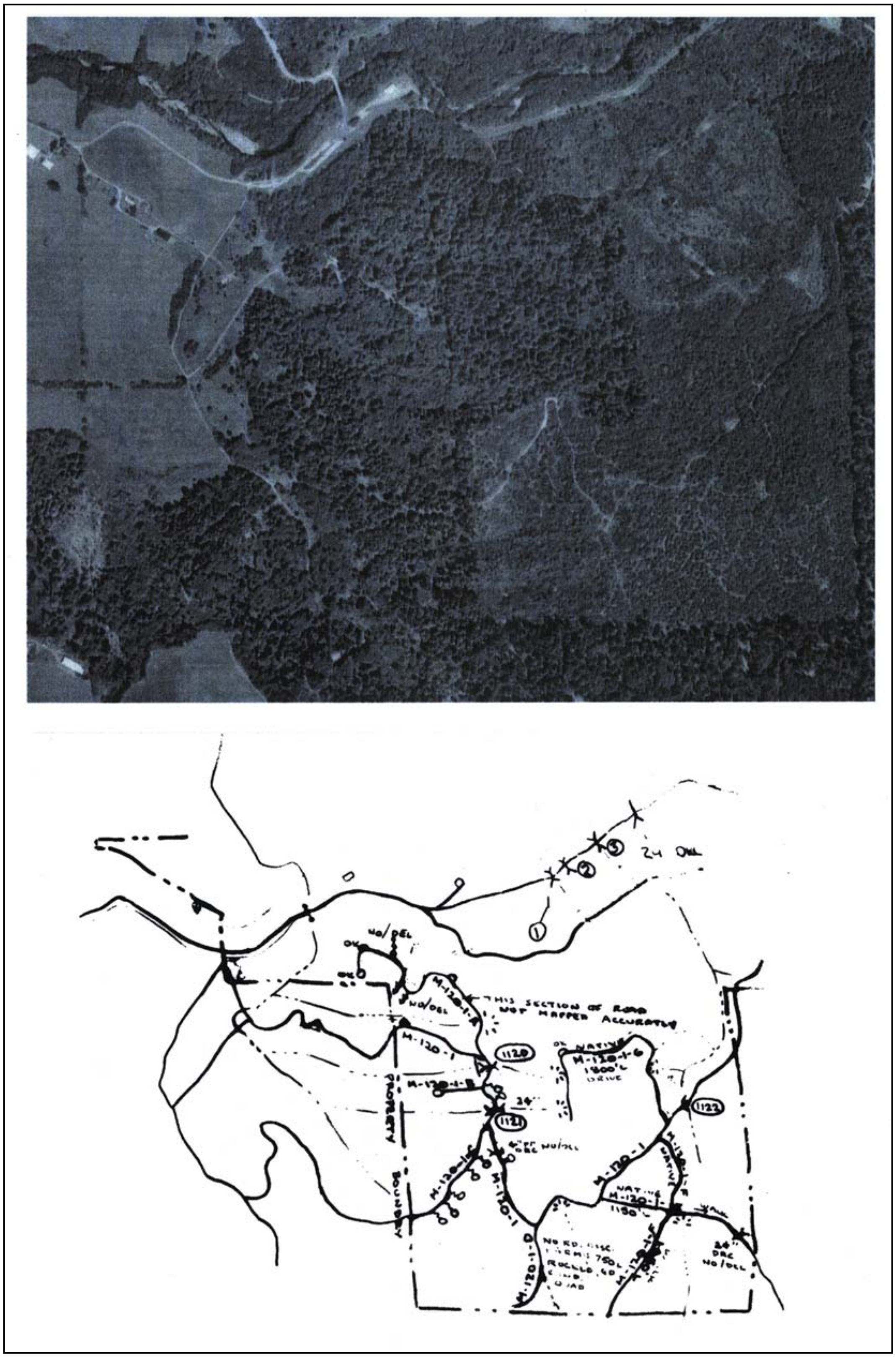


Figure X-4. Aerial photo and matching copy of Mylar overlay map showing roads and sites.

Standardized mapping symbols for use on site sketches, air photo overlays, report maps and flagging in the field.

Symbol		Site map symbols
(5)		Site Number
	Stream crossing	Culverted stream crossing
	Stream crossing	Humboldt log crossing
	Stream crossing	Ford or armored fill
	Stream crossing	Unculverted stream crossing (unculverted fill)
	Stream crossing	Bridge
	Landslide	Potential landslide with delivery potential
	Landslide	Potential landslide with low or no delivery potential
	Landslide	Past landslide with delivery
	Landslide	Past landside with no delivery
3/2	Other	Gully (with width/depth dimensions in feet)

General map symbols

	Ditch relief culvert		Spring or seep
	Plugged culvert (stream crossing/ditch relief culvert)		Swale or headwall swale
	Road (maintained or open)		Waterbar
	Abandoned road		Cross road drain
	Gate		Rolling dip
	Class 1 stream		Earth berm
	Class 2 stream	6''	Scarps (with visible offset)
	Class 3 stream		Cracks (little or no visible offset)

Table X-3. Standardized mapping symbols.

The Inventory Process

The field inventory process is straightforward, once the assessment preparation is completed. Visit each site once. Collect all data needed to describe, quantify and recommend potential treatments for each site on the first visit.

Inventorying Hillslope Areas and Roads

Fieldwork for sediment source assessments concentrates on inspecting hillslope areas most likely to contain sites of preventable or controllable management-related sediment delivery. This may include a variety of managed areas. Usually, most of the treatable sites are located on road systems where problems are abundant and access for treatment is good. Therefore, the assessment requires a walking inventory of all active and abandoned roads in the assessment area. All existing and potential sediment delivery sites that fit the minimum sediment delivery criteria are then identified and quantified in the *Upslope Inventory Data Form*. If it meets the minimum definition of a site then it should be mapped, inventoried and added to the database. At this point, make no assumptions about which sites will or will not be treated.

Inventorying Stream Channels

A second component of the erosion assessment involves stream channels. Usually, bank erosion sites are the primary stream channel locations of future erosion and resultant sediment delivery to streams. Regardless, it is generally not practical to survey all the stream channels in a sub-watershed due to poor or difficult access. However, DFG can often provide stream inventories as described in *Part III* of this manual for fish bearing streams.

High priority areas for conducting stream bank inventories are: stream channels where reasonably good equipment access exists from nearby roads, open areas proximate to the stream, and reaches along larger Class 1 streams. In areas where access is a problem, conducting a sample inventory may determine if stream channels are likely candidates for future cost-effective restoration projects, and worthy of further inventory and analysis.

Completing the Upslope Inventory Data Form

Use the *Upslope Inventory Data Form* to record the location, nature and magnitude of sites of future or potential sediment delivery, and include the description of recommended treatments to prevent erosion and/or sediment delivery. Develop the erosion prevention and erosion control prescriptions concurrent with the identification and inventorying of sites of current and future sediment delivery in the watershed.

There is no substitute for practical experience in the selection and construction of effective erosion control treatments. Previous work supervising or operating heavy earth moving equipment and labor crews provides grounding for what is possible to accomplish. With more experience, the better this judgment becomes. With a job fully described by a completed upslope assessment, many heavy equipment operators can provide feedback on project feasibility, safety, appropriate equipment types, and reasonable production rates (times) and costs. Refer to restoration implementation methods and cost-estimating techniques, later in *Part X*, to complete the analysis.

The *Upslope Inventory Data Form* is on page X-29. For detailed instructions to complete the form, see Appendix X-A.

Data collected includes information in the following categories:

- **General site data**: Collect and record general site information, including site number, site location, road name, maintenance status, name(s) of inventory crew, date of inventory, and other relevant data site location and site description information.
- **Site characterization**: Characterize problem areas by their type (e.g., stream crossing, gully, landslide, etc.) and by variables that describe their main characteristics. Completely fill out the data form for the relevant problem type. That is, for stream crossings, complete the 23 data fields listed under stream. Do not fill out questions under the landslide category. For landslides, complete only those questions listed under landslide. The data form requires the user to collect qualitative and quantitative data for:
    - Landslide sites – 4 data fields;
    - Stream crossings – 23 data fields;
    - Fish passage– 3 data fields.
- **Erosion quantification**: Evaluate the erosion potential (likelihood of erosion). Measure the site for potential future erosion, and estimate sediment delivery volumes.
- **Comment(s) on problem**: Fully explain site conditions, apparent processes, relationships or quantities to more completely describe individual answers provided in the data form. Concisely describe the nature of the problem, as a quick abstract of the site and its problems.
- **Treatment**: Estimate of the urgency or priority for treating the erosion site. Identify possible treatment options. Describe and quantify the erosion prevention and erosion control treatments identified as the most likely to correct the problem(s). The treatment section of the data form contains the most common types of erosion prevention and erosion control treatments encountered, as well as measures that quantify the number or magnitude of the proposed treatments (e.g., cubic yards of rock armor or length of outsloping). Note: if you have identified a failure area of unknown type and depth (see footnote on data form), treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.
- **Heavy equipment excavation data**: Provide a quantitative calculation of excavation volumes. Identify the volume of the spoil material to be used or stored locally, or if it must be endhauled by dump trucks. Excavation volumes and the excavation production rate are important elements of this section, as they will determine the estimated equipment times that will be required to complete the site work (pages X-39 and X-40).
- **Equipment and labor hours**: Based on the tasks performed, the volumes excavated and moved, and the equipment and labor production rates outlined above. List the number of hours required for each piece of heavy equipment and for labor.
- **Comment(s) on treatment**: Note any details in the proposed treatments that a contractor or equipment operator needs to know to complete the treatment. Include any specific information or insights that describe how to perform the job. Provide this comment section to the operator or contractor to guide them in completing the details of the project work for each site. It might include such information as the number of needed dump trucks, the endhaul distances and spoil locations, the specific labor tasks to be completed and other notes on completing the work at that particular site.

- **Survey data***:* On the back of the data form, fill in the spatial measurements for all stream crossings inventoried in the project area. For stream crossings only, enter the survey data. Use these measurements to calculate potential erosion volumes and excavation volumes required to perform the decommissioning or upgrading treatments. The equations for calculating these volumes are in Measuring and Estimating Future Erosion Volumes.
- **Site sketch***:* Make a sketch of the site, including any obvious landmarks and features that will identify the relationships between features described in the data form. Include such elements as roads, streams, springs, slope gradients, drainage structures (e.g., culverts) and erosion features. Examples of site maps are included in Figure X-3. Use standardized mapping symbols (Table X-3).

UPSLOPE INVENTORY DATA FORM

ASAP (Y, N)______

GENERAL	Site no:	Treat (Y/N):	Watershed:	Quad:	
	GPS:		CALWAA:	Photo:	
	T/R/S:		Road name/#:	Drivable (Y/N):	
	Mileage:		Inspector(s):	Date:	Year built:
	Surface: □ rock □ native □ paved		Status: □ maintained □ abandoned □ decommissioned		
	Proposed: □ upgrade □ decommission			Sketch (Y/N):	
PROBLEM	Stream crossing (Y/N):		Landslide: □ fill □ hill □ cut	Roadbed: □ bed, □ ditch, □ cut	
	□ ditch relief culvert		□ gully	□ bank erosion	Road related (Y/N):
	Other non-road related site: □ home □ agricultural □construction □ mining □ other site				
LANDSLIDE	□ road or landing fill		□ hillslope debris slide[1]	□ other hillslope landslide (depth unknown)[1]	
	□ cutbank slide		□ potential failure	□ past failure	Slope (%):
	Distance to stream (ft):				
STREAM	□ culvert	□ bridge	□ Humboldt	□ fill	□ ford	□ armored fill
	□ excavated crossing		% excavated:		
	Ditch road length (ft): Left:		Right:	Culvert diameter (in):	
	Pipe condition (O, C, R, P): Inlet:		Bottom:	Outlet:	□ separated
	Headwall (in):		Culvert slope (%):	Stream class (1,2,3):	
	Culvert rust-line (in): Inlet:		Outlet:	Culvert undersized (Y, M, N):	
	Washed out (%):		Diversion potential (Y/N):	□ currently diverted	
	Road grade (%):		Plug potential (H, M, L):	Plugged (%):	
	Channel gradient (%):		Channel width (ft):	Channel depth (ft):	
	Sediment transport (H, M, L):		Drainage area (acres):		
FISH PASSAGE	Culvert outlet drop (in):		Bankfull drop (in):		
	Pool size bankfull width (ft):			Pool size bankfull depth (ft):	
EROSION	Erosion potential (H, M, L):		□ potential for extreme erosion		
	Volume extreme erosion (<500, 500-1,000, 1-2K, 2-5K, >5K):			Past erosion (yd^3) (optional):	
	Past delivery (%) (optional):		Total past delivery (yd^3):		
FUTURE EROSION	Future erosion (ft): Width:		Depth:	Length:	Future erosion(yd^3):
	Future delivery (%):		Total future delivery (yd^3):		

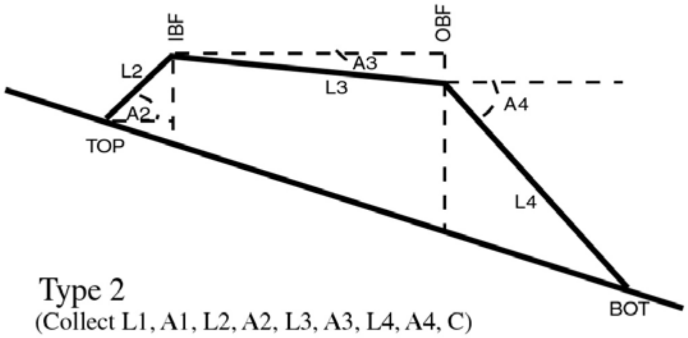
COMMENT(S) ON PROBLEM:

TREATMENT	Immediacy (H, M, L):		Complexity (H, M, L):		
	check culvert size (Y/N):		□ bridge	□ no treatment	Mulch (ft^2):
TREATMENT OPTIONS	□ excavate soil	□ critical dip	□ ford	□ armored fill	Sill height (ft):
	Sill width (ft):	□ trash rack	□ Add downspout: Length (ft):		Diameter (in):
	□ repair culvert	□ clean culvert	□ install/replace culvert		
	Culvert: Diameter (in):		Length (ft):	□ flared inlet: Diameter(in):	
	□ reconstr. fill	□ armor fill face (U, D, B):		Armor area (ft^2): U: D:	
	□ clean or cut ditch, (ft):		□ remove ditch, (ft):		
	□ outslope road, (ft):		□ outslope & remove ditch, (ft):		
	□ outslope & retain ditch, (ft):			□ inslope road, (ft):	
	□ rolling dip, (#):		□ remove berm, (ft):		
	□ ditch relief culvert, (#):		Length (ft):	□ rock road surface, (ft^2):	
	□ cross road drain, (#):		□ other:		
HEAVY EQUIPMENT EXCAVATION DATA	Total vol. excavated (yds^3):		Volume put back in (yds^3):		
	Volume removed (yds^3):		Volume stockpiled (yds^3):		
	Volume endhauled (yds^3):		Distance endhauled (yds^3):		
	Excavation production rate: (yds^3/hr):				
EQUIPMENT HOURS	Excavator:	Dozer:	Backhoe:	Grader:	Loader:
	Dump truck:		Labor:	Other:	

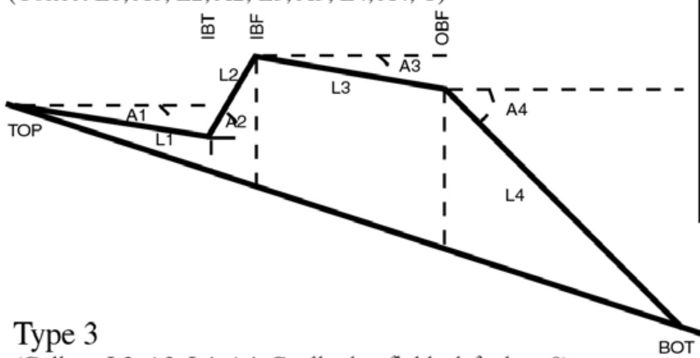
COMMENT(S) ON TREATMENT:

[1] *Consultation with a licensed geotechnical specialist is required to estimate slide volumes and to evaluate or develop treatment options. The location of these features should be noted on the field form and on maps, but the inventory crew should not estimate the sediment volumes for calculation of cost-effectiveness.*

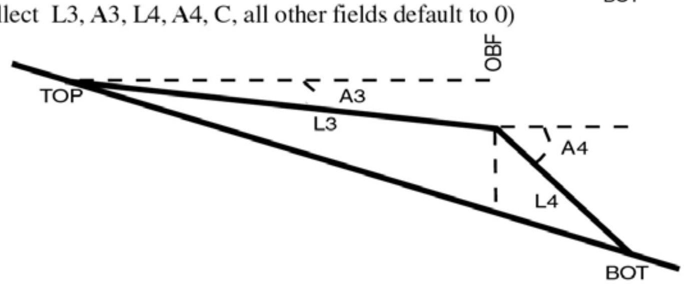
Type 1
(Collect L2, A2, L3, A3, L4, A4, C, all other fields default to 0)



Type 2
(Collect L1, A1, L2, A2, L3, A3, L4, A4, C)



Type 3
(Collect L3, A3, L4, A4, C, all other fields default to 0)



Field data

Length of sediment fan (L1): _____ ft

Angle of sediment fan (A1): _____ degrees

Length of inboard fillslope (L2): _____ ft

Angle of inboard fillslope (A2): _____ degrees

Length of road bed (L3): _____ ft

Angle of road bed (A3): _____ degrees

Length of outboard fillslope (L4): _____ ft

Angle of outboard fillslope (A4): _____ degrees

Channel width (C): _____ ft

Sketch

Completing the Stream Bank Inventory Data Form

Use the *Stream Bank Inventory Data Form* to assess past, ongoing and potential stream bank erosion, including anything that can be said about the nature, cause, and magnitude of the problem, and potential treatment options. In addition, use the inventory form to identify and classify erosion problems along stream channels, prioritize potential work sites, and prescribe specific treatments aimed at protecting stream channels and fish habitat. *Part III* describes methodologies for stream channel classification and inventory protocols for assessment of stream habitat, large woody debris, and riparian inventories.

The *Stream Bank Inventory Data Form* provides the standardized DFG protocol for evaluating stream-related erosion and identifying erosion control options. Use it to evaluate all types of riparian sediment sources. Where roads are in close proximity to a stream channel, there may be individual sites described by both an *Upslope Inventory Data Form* and a *Stream Bank Inventory Data Form*. If the proposed treatments are sufficiently different, retain both forms to describe the same location. However, do not duplicate recommended treatments and treatment times. Using the *Stream Bank Inventory Data Form*, field personnel can measure, describe and make initial interpretations about landforms and erosion problems in a consistent and uniform manner. Enter the data into an electronic database. Prepare a prioritized erosion control plan.

The data collected should provide information that both quantifies sites of future erosion and leads to a cost-effective treatment of stream bank sites. The form is on page X-33. The detailed instructions for completing each field are in Appendix X-B.

The data collected includes information in the following categories:

- **General site data***:* Record the general site information, including site number, site location (station number and bank side), stream name, names of inventory crew, date of inventory, other relevant data site location, and site description information.
- **Problem type***:* Characterize the apparent nature of the problem (e.g., debris slide, hillslope failure of unknown depth, bank erosion, log jam, etc.) and by variables that describe their main characteristics, such as activity level, age, gradient of eroding hillslope, land use and the degree of stream undercutting.
- **Erosion quantification***:* Classify the erosion potential (likelihood of future erosion). Record measurements of expected future erosion and sediment delivery volumes, as well as measurements of length, width and depth of past erosion scars.
- **Comment(s) on problem***:* Explain any site conditions, processes, relationships or quantities needing more detail than the individual answers provided in the data form. In addition, use this space to describe the nature of the problem, as a quick abstract of the site and its problems.
- **Treatment***:* Evaluate and record the urgency or priority of the proposed treatment (Treatment Immediacy), the expected complexity of the project work, heavy equipment and labor needs, access difficulty, and material needs.
- **Treatment options***:* Describe and quantify the specific erosion prevention and erosion control treatments thought most likely to correct the problem identified. List the recommended treatment(s) for the site, including excavation volumes (except as noted for debris slides and deeper hillslope failures), structures, fencing, and likely vegetation

measures. The treatment section of the data form contains many common types of erosion prevention and erosion control treatments for stream banks. If necessary, design specific solutions for sites that require unique erosion control treatments. Describe these treatments in the Comment(s) on Treatment section. Provide a full accounting of material needs for the project. Note: if you have identified a failure area of unknown type and depth (see footnote on data form), treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.

- **Equipment and labor hours:** Based on the required tasks, the excavation volumes, and the equipment and labor production rates, list the number of hours required for each piece of heavy equipment and for the labor to construct structures and/or plant the site.
- **Comment(s) on treatment***:* Note any details in the proposed treatments that a contractor or equipment operator needs to know to perform the treatment. Include any specific information or insights that describe how to complete the job. Provide this information to the operator or contractor to guide them in completing the details of the project work for each site. Include such information as the number of dump trucks needed, the endhaul distances and spoil locations, the specific labor tasks to be completed and other notes on completing the work at that particular site.
- **Site sketch***:* Make a sketch of the site, including any obvious landmarks and features that will identify the relationships between features described in the data form. Include such elements as roads, streams, springs, slope gradients, log debris accumulations, bedrock exposures, and erosion features. Use standardized mapping symbols (Table X-3).

STREAM BANK INVENTORY DATA FORM

GENERAL	Site no:	Distance (ft):	Date:	Inspector(s):
	Watershed:		Stream:	
	Air photo:	Location (LB, RB, B):	☐ road related	Treat (Y/N):
PROBLEM	Type:	☐ debris slide ☐ debris torrent[1]	☐ hillslope failure of unknown depth and activity[2]	
		☐ torrent / debris flow channel[1]	☐ bank erosion ☐ LDA [3]	☐ other
	Delivery:	☐ past ☐ future	☐ both	Apparent activity (A, IA, W):
	Age (decade):	Stream bank slope (%):		
	☐ land use	☐ undercut by stream		
PAST EROSION	Width (ft):	Depth (ft):	Length (ft):	Volume (yd^3):
FUTURE EROSION	Future erosion potential (H, M, L):	Width (ft):		Depth (ft):
	Length (ft):		Volume (yd^3):	

COMMENT(S) ON PROBLEM:

TREATMENT	Immediacy (H, M, L):	Complexity (H, M, L):	Equipment or labor (E, L, B):
	Equipment access (E, M, D):	☐ local materials	☐ import materials
TREATMENT OPTIONS	☐ excavate soil Width (ft):	Depth (ft): Length (ft):	Volume (yds^3):
	☐ rock armor/buttress	rock armor size (ft or ton):	rock armor area (ft^2):
	☐ log protection	Log size: Length (ft):	Diameter (ft):
		Bank length protected (ft):	Bank area to cover (ft^2):
	☐ remove logs/debris		☐ boulder deflectors
	Deflectors (#):	Deflector (yd^3):	☐ bio-engineering
	☐ plant erosion control	☐ riparian restoration	Area planted (ft^2):
	☐ exclusionary fencing	Length of fence (ft):	☐ other

EQUIPMENT HOURS	Excavator:	Dozer:	Dump truck:	Backhoe:	Labor:	Other:

COMMENT(S) ON TREATMENT:

[1] A debris torrent is a mudflow that originates as a debris slide and then fluidizes (through the addition of water) and flows down a stream channel. It typically ends as a deposit or dam of poorly sorted sediment and woody debris in a lower gradient section of channel. The process is the mudflow; the evidence of that process is the scoured channel through which the flow passed, and the sediment and debris that is deposited at the end of the flow path. The activity level is typically that of the potential debris slide that would form the source of the mudflow. Note: if you have identified a potential hillslope debris slide, treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.

[2] If a failure of unknown type and depth is identified, treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.

[3] LDA is a log jam or accumulation of logs and woody debris in the channel; that is causing bank erosion or other erosion and sediment delivery problems.

Sketch on back.

Measuring and Estimating Future Erosion Volumes

A critical step in conducting a sediment source inventory is the quantification of erosion and sediment delivery volumes. Sediment delivery volumes and excavation volumes are the key variables needed for the computation of treatment cost-effectiveness and creating a watershed restoration plan. Excavation volumes are important for the derivation of heavy equipment times and costs for restoration work.

Surface Erosion Volumes

It is difficult to estimate sediment delivery volumes from surface erosion processes, because different soils have markedly differing propensities for erosion, and because surface erosion is a chronic process that may occur every storm. Use the following surface lowering rates (erosion rates in feet/year) to provide a gross estimate of erosion from bare soil areas:

- Cutbanks and continually bare soil areas   Low-0.01; Moderate-0.03; High-0.05
- Native surfaced (unimproved, dirt) roads   0.03
- Rock surfaced roads   0.02

Any unusual circumstances, such as high amounts of runoff or the presence of highly erodible soils, such as sand, may increase the surface-lowering rate. Use local site conditions and field evidence when assigning these rates. Calculate chronic surface erosion volumes from persistently bare areas on an annual basis, assuming overall conditions and use patterns remain unchanged. Estimate sediment delivery volumes from surface erosion processes as follows:

- $Q_s = [(A \times E)/27] \times T \times D$, where
- Q_s = sediment delivery (yds^3) from surface erosion;
- A = exposed area (ft^2);
- E = erosion or lowering rate (feet/year);
- T = time (years);
- D = delivery ratio (percent of erosion that is delivered to the stream).

For example, estimate 10 years of sediment delivery from a 500-foot section of actively used, rock-surfaced, 18 feet wide insloped road; that is 10 feet high; with a 50% bare, moderately erodible cutbank; that drains to the inlet of a stream crossing with a culvert, as follows:

- Road surface: A = 500' x 18' = 9,000 ft^2
  E = 0.02 ft/yr
  T = 10 years
- Cutbank: A = (500' x 10') ft^2 x 0.50 (only 50% of the cutbank is bare and eroding)
  E = 0.03 ft/yr
  T = 10 years
- Q_s = [((500 x 18) x 0.02)/27 + ((500 x 10x0.50) x 0.03)/27] x 10 years x 100%
  = (6.7 + 2.8) yds^3 x 10 years x 100%
  = 95 yds^3 (assumes 100% delivery from the contributing areas)

This generalized methodology of estimating sediment delivery from road surfaces allows for an order-of-magnitude estimate of sediment delivery that is suitable for use in evaluating the cost-effectiveness of proposed restoration work. Modify assumptions and rates according to local conditions. Sediment delivery rates for surface erosion can be variable. If the area encompassed by the analysis is limited to that which drains directly into a stream channel, delivery rates of 100% are reasonable.

Fluvial Erosion Volumes

Estimate future fluvial erosion volumes for the following:

- The expansion of existing gullies (including culvert outfall erosion);
- The creation of new gullies (usually from predicted stream diversions);
- Stream crossing washouts;
- Stream bank erosion.

Existing Gullies

Existing, active gullies can continue to enlarge by lengthening, widening and deepening until they become stable. These final dimensions, and hence future erosion, involve estimating future increases in gully width and depth. If flow conditions are unchanged, then the potential for future gully expansion can be inferred based on observed dimensions and behavior. If the gully is no longer down cutting, most erosion will be limited to gradual bank retreat and collapse. In this case, future erosion consists of vertical gully walls (side slopes) laying themselves back to a stable slope angle of about 1:1. If the gully still exhibits potential for future down cutting, then estimate how much deeper the gully will get over the length of gully. The gully will still be assumed to eventually develop 1:1 side slopes, and the amount of additional down cutting can be quantified as a rectangle (i.e., length x width x depth).

New or Future Gullies

In cases where it is predicted that a new gully will form, such as from a predicted stream diversion, then gully dimensions and lengths must be estimated from analogous sites nearby, or from thoughtful and well documented assumptions. Estimating future gully erosion is very difficult because the future path of the gully is hard to predict, gully erosion rates are generally unknown and variations in soil depth and erodibility, which control gully volumes, vary greatly. Estimates of gully erosion must be reasonable compared to similar documented sites nearby or in comparable areas. Delivery rates are typically high (75% - 100%) for gullies formed by stream diversions, but the figure should be supported by site observations and conditions.

Stream Crossings

Measure stream crossing fills to determine washout volumes, excavation volumes, and equipment times needed to perform various upgrading or decommissioning tasks. Crossing geometries are complex; therefore, estimating the volume of fill material contained in stream crossings requires a systematic approach and technique. There are three acceptable methods:

- Using field measurements, determine average dimensions and multiply width, depth and length to estimate volume (divide ft^3 by 27 to get yds^3);
- Taking systematic field measurements, use equations of plain geometry and end-area computations to calculate crossing volumes;

- Utilizing simple field surveys and a specialized computer program perform volume calculations and design treatments.

The more rigorous and systematic the computational method, the better will be the outcome of the calculations and volume estimates. Use the diagrams, measurements and equations shown in Figure X-5 and Figure X-6 to develop a quantitative estimate of stream crossing volume. Figure X-7 and Figure X-8 give examples of Type 1 and 2 volume calculations. The *Upslope Inventory Data Form* contains the data fields needed to perform volume calculations for each of three types of stream crossing geometries (Type 1, Type 2 and Type 3).

Stream Crossing Washouts

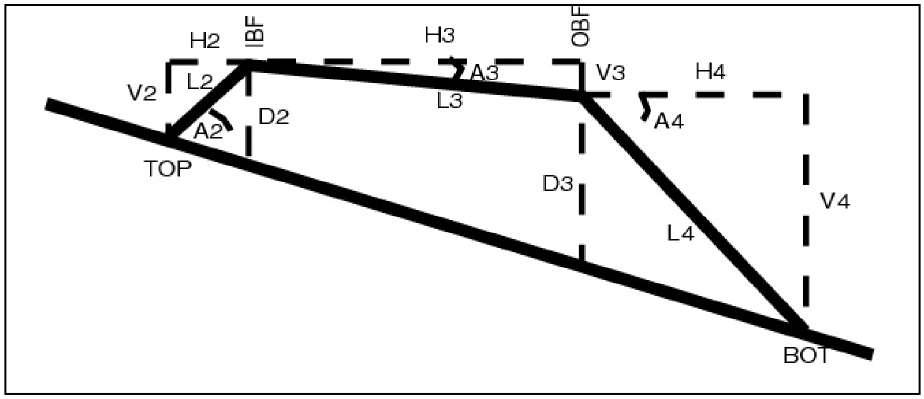
Base the predicted volume of a stream crossing washout on field measurements and geometric calculations that determine the volume of fill in the crossing (Figure X-5 and Figure X-6). Unless there are local indications to the contrary, assume that the gully, which forms from a full stream crossing washout, will eventually scour down to and assume the original pre-road channel profile. In addition, assume that it will have the same width dimensions as the natural high flow channel upstream from the crossing, and that the left and right side slopes to the washed out crossing will form a 1:1 slope (45E or 100%). From these assumptions, use geometry to calculate the predicted washout volume. Because the majority of potential sediment delivery sites in a watershed may occur at stream crossings, the accuracy and reproducibility of the volume estimate is critical. Perform simple tape and clinometer surveys, combined with geometric calculations, to ensure accuracy and reproducibility. Assume 100% delivery of sediment to the stream for washed out stream crossings.

Material used to fill-in a stream channel when a road is constructed is often irregular in shape. Generally, most of the fill would eventually be lost if the culvert plugged and the crossing fill washed out. Use simple geometry to develop an estimate of the stream crossing volume for the three basic types of stream crossings (Figure X-5 and Figure X-6). The volume of fill material contained in a Humboldt crossing is sometimes significantly more difficult to estimate because of uncertainties in the depth and volume of the logs and slash buried when the crossing was built. The volume of material in landings constructed in stream channel valleys prior to implementation of the Forest Practices Act (1973) is also difficult to estimate using simplified field measurement techniques. This is primarily because the original stream valley configuration has been obliterated by earthmoving.

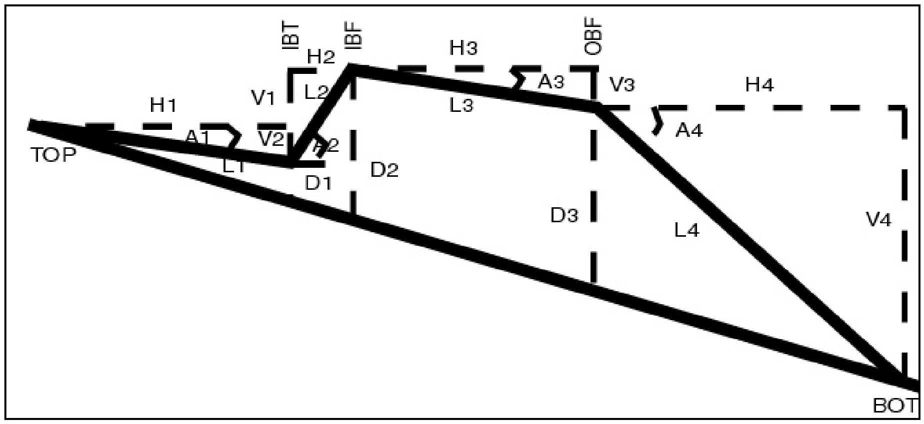
Stream Bank Erosion

Base the predicted erosion volume at each stream bank site on documented site conditions and measurements that support logical assumptions and observed bank retreat rates or erosion dimensions from comparable sites nearby. Assume all stream bank erosion will result in 100% sediment delivery (since the erosion is occurring within a stream channel). Calculate stream bank erosion by assuming a bank retreat rate (i.e. depth of erosion landward from the creek) and multiplying this by the length and height of the eroding bank.

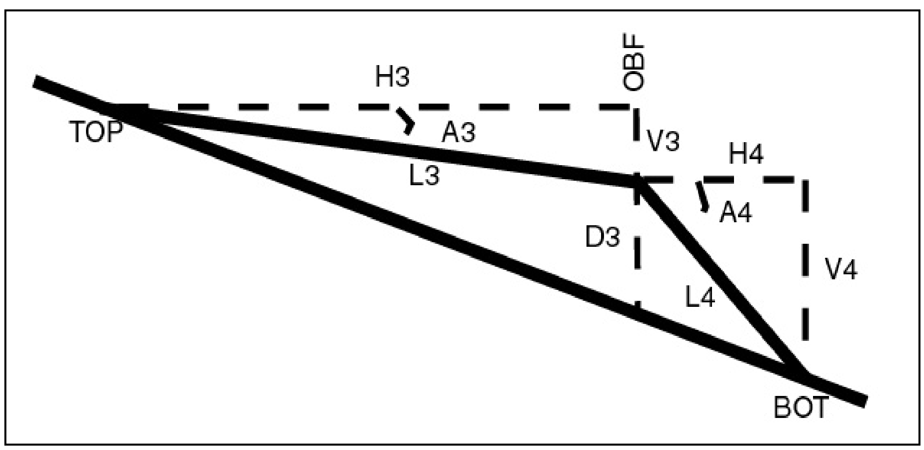
Type 1
(Collect L2, A2, L3, A3, L4, A4, C, all other fields default to 0)



Type 2
(Collect L1, A1, L2, A2, L3, A3, L4, A4, C)



Type 3
(Collect L3, A3, L4, A4, C, all other fields default to 0)



Field data		
	Length of sediment fan (L1):______ft	Angle of sediment fan (A1):______degrees
	Length of inboard fillslope (L2):______ft	Angle of inboard fillslope (A2):______degrees
	Length of road bed (L3):______ft	Angle of road bed (A3):______degrees
	Length of outboard fillslope: (L4):______ft	Angle of outboard fillslope (A4):______degrees
	Channel width (C):______ft	

Figure X-5. Geometric designs for determining typical stream crossing volumes and excavation volumes for upgrading and decommissioning the three main types of crossings.

Calculations	
Horizontal components	H1 = L1(cosA1) = ______'*(cos(______)) = ______ft H2 = L2(cosA2) = ______'*(cos(______)) = ______ft H3 = L3(cosA3) = ______'*(cos(______)) = ______ft H4 = L4(cosA4) = ______'*(cos(______)) = ______ft
Vertical components	V1 = L1(sinA1) = ______'*(sin(______)) = ______ft V2 = L2(sinA2) = ______'*(sin(______)) = ______ft V3 = L3(sinA3) = ______'*(sin(______)) = ______ft V4 = L4(sinA4) = ______'*(sin(______)) = ______ft
Fall rate	F = (V1+V2+V3+V4)/(H1+H2+H3+H4) = (______+______+______+______)/(______+______+______+______) =____ft
Depth calculations	D1 = V1-(F*H1) = ______-(______*______) = ______ft D2 = (V1+V2)-(F*(H1+H2)) = ______-(______*(______+______)) = ______ft D3 = (V1+V2+V3)-(F*(H1+H2+H3)) = ((______+______+______)-(______*(______+______+______)) = ______ft
Cross section area calculations	XSA1 = C*D1+$(D1)^2$ = (______*______)+$(\_\_\_\_\_\_)^2$ = ______ft^2 XSA2 = C*D2+$(D2)^2$ = (______*______)+$(\_\_\_\_\_\_)^2$ = ______ft^2 XSA3 = C*D3+$(D3)^2$ = (______*____)+$(\_\_\_\_\_\_)^2$ = ______ft^2
Volume Calculations	
Type 1 Crossing	Vol TOP to IBF (T2) = 1/3*(XSA2*H2) = 1/3*(______*______) = ____ft^3 Vol IBF to OBF (T3) = 1/2*(XSA2+XSA3)*H3 = 1/2*(______+______)*______) = ______ft^3 Vol OBF to BOT (T4) = 1/3*(XSA3)*H4 = 1/3*(______*______) = ____ft^3
Type 2 Crossing	Vol TOP to IBT (T1) = 1/3*(XSA1*H1) = 1/3*(______*______) = ____ft^3 Vol IBT to IBF (T2) = 1/2((XSA1+XSA2)*H2) = 1/2*(______+______)*______ = ______ft^3 Vol IBF to OBF (T3) = 1/2*(XSA2+XSA3)*H3 = 1/2*(______+______)*______ = ______ft^3 Vol OBF to BOT (T4) = 1/3*XSA3*H4 = 1/3*______*______ = ______ft^3
Type 3 Crossing	Vol TOP to OBF (T3) = 1/3*(XSA3)*H3 = 1/3*(______*______) = ____ft^3 Vol OBF to BOT (T4) = 1/3*(XSA3)*H4 = 1/3*(______*______) = ____ft^3
Total Volume Calculation	T(t) = (T1+T2+T3+T4)/27 = (______+______+______+______)/27 =____ yds^3

Figure X-6. Calculations for determining typical stream crossing volumes and excavation volumes for upgrading and decommissioning the three main types of crossings.

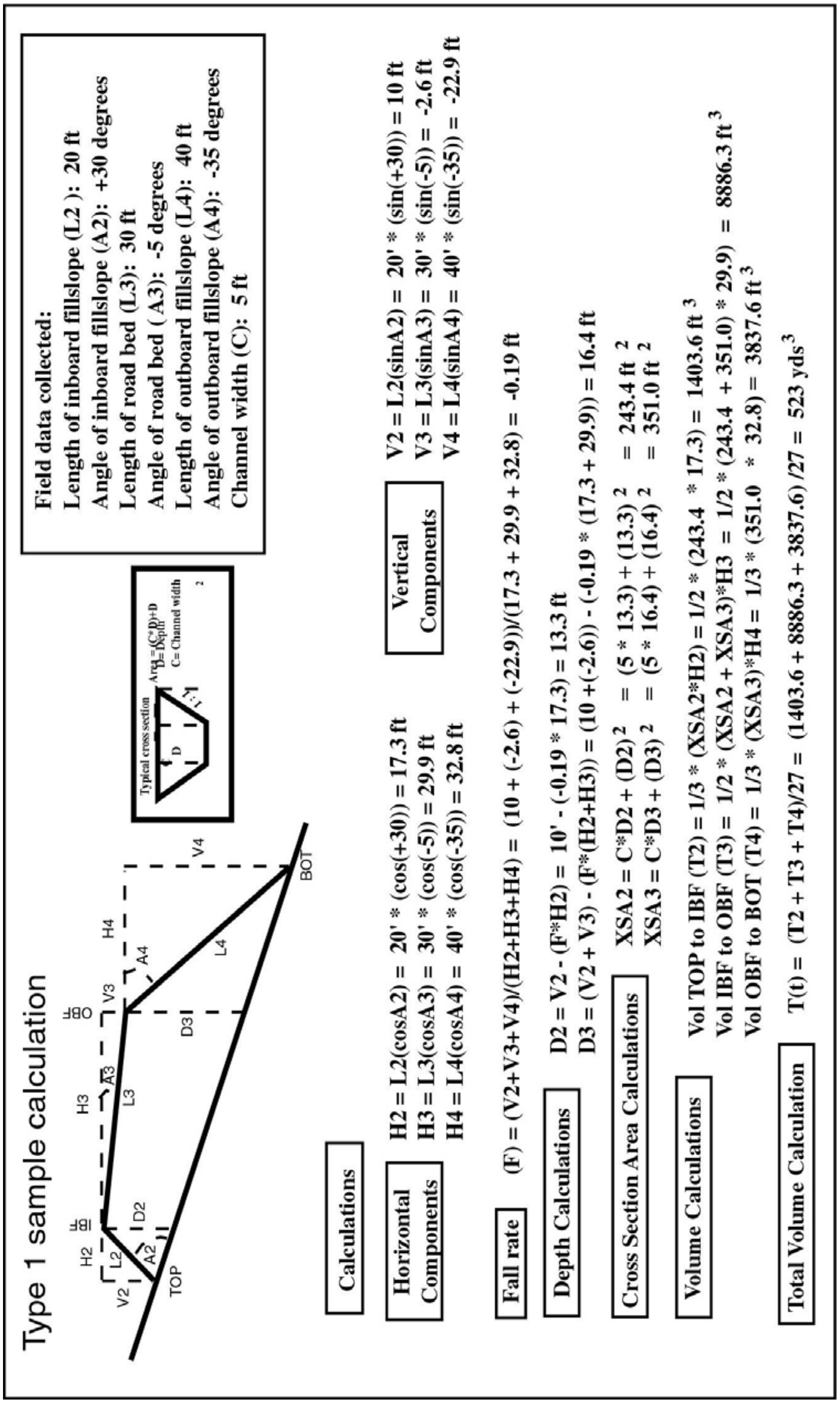
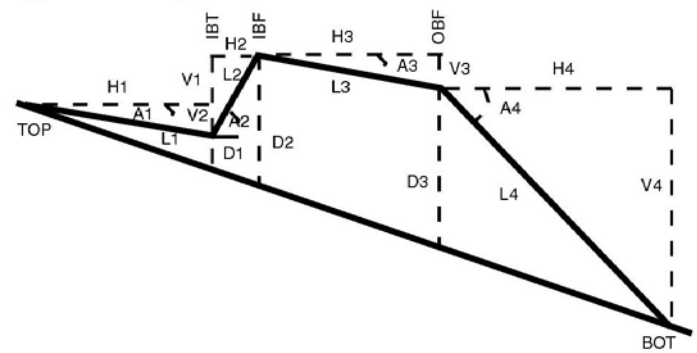


Figure X-7. Sample calculations showing derivation Type 1 stream crossing volumes.

Type 2 sample calculation



Field data collected:
Length of sediment fan (L1): 50 ft
Angle of sediment fan (A1): -3 degrees
Length of inboard fillslope (L2): 20 ft
Angle of inboard fillslope (A2): +30 degrees
Length of road bed (L3): 30 ft
Angle of road bed (A3): -5 degrees
Length of outboard fillslope (L4): 40 ft
Angle of outboard fillslope (A4): -35 degrees
Channel width (C): 5 ft

Calculations

Horizontal Components

H1 = L1(cosA1) = 50' * (cos(-3)) = 49.9 ft
H2 = L2(cosA2) = 20' * (cos(+30)) = 17.3 ft
H3 = L3(cosA3) = 30' * (cos(-5)) = 29.9 ft
H4 = L4(cosA4) = 40' * (cos(-35)) = 32.8 ft

Vertical Components

V1 = L1(sinA1) = 50' * (sin(-3)) = -2.6 ft
V2 = L2(sinA2) = 20' * (sin(+30)) = 10 ft
V3 = L3(sinA3) = 30' * (sin(-5)) = -2.6 ft
V4 = L4(sinA4) = 40' * (sin(-35)) = -22.9 ft

Fall rate

(F) = (V1 +V2 +V3 +V4)/(H1 + H2 + H3 + H4) = ((-2.6) + 10 + (-2.6) + (-22.9))/(49.9 + 17.3 + 29.9 + 32.8) = -0.14 ft

Depth Calculations

D1 = V1 - (F*H1) = -2.6 - (-0.14 * 49.9) = 4.4 ft
D2 = (V1 + V2) - (F*(H1 + H2) = 7.4 - (-0.14 * (49.9 + 17.3)) = 16.8 ft
D3 = (V1 + V2 + V3) - (F*(H1 + H2 + H3)) = ((-2.6) + 10 +(-2.6)) - (-0.14 * (49.9 + 17.3 + 29.9)) = 18.4 ft

Cross Section Area Calculations

XSA1= C*D1 + (D1)^2 = (5 * 4.4) + (4.4)^2 = 41.4 ft^2
XSA2 = C*D2 + (D2)^2 = (5 * 16.8) + (16.8)^2 = 366.2 ft^2
XSA3 = C*D3 + (D3)^2 = (5 * 18.4) + (18.4)^2 = 430.6 ft^2

Volume Calculations

Vol TOP to IBT (T1) = 1/3 * (XSA1*H1) = 1/3 * (41.4 * 49.9) = 688.6 ft^3
Vol IBT to IBF (T2) = 1/2 * ((XSA1 + XSA2) * H2) = 1/2 * ((41.4 + 366.2) * 17.3) = 3525.7 ft^3
Vol IBF to OBF (T3) = 1/2 * (XSA2 + XSA3)*H3 = 1/2 * (366.2 + 430.6) * 29.9) = 11912.2 ft^3
Vol OBF to BOT (T4) = 1/3 * (XSA3)*H4 = 1/3 * (430.6 * 32.8) = 4707.9 ft^3

Total Volume Calculation

T(t) = (T1 + T2 + T3 + T4)/27 = (688.6 + 3525.7 + 11912.2 + 4707.9) /27 = 772 yds^3

Figure X-8. Sample calculations showing derivation Type 2 stream crossing volumes.

Landslide Erosion Volumes

Landslide stabilization is generally outside the scope of this document. CGS Notes 50 (CGS 1999) and 40 (CGS 1983-1995) provide descriptive information on larger landslide types in steep forested terrain, and where these have been mapped as a part of the Watershed Mapping Project, respectively. These can be used for general planning purposes, and to identify watershed areas that have been mapped as unstable. They are generally not suitable for the measurement of landslide volumes, as the slides that have been identified and mapped are large and outside the scope of straightforward erosion and sediment control practices. However, the volumes of some of the simplest and smallest types of landslides can be measured from voids or "holes" left in the ground after the failure occurs or from field evidence of the boundaries of such landslides before they completely fail and move off site (e.g., small slides that occur on road fillslopes).

Except for debris flows and hillslope failure areas of unknown depth (as previously noted), compute future landslide volumes from estimated length, width and depth measurements taken in the field. The estimated sediment delivery to a stream is difficult to estimate and can range from 5% to 95%. Factors such as the distance the sediment must travel to the stream, hill shape and slope, soil moisture, vegetation and other factors influence the expected range of sediment delivery. A useful technique is to ask if the slide would deliver more or less than fifty percent of the potential slide mass to the stream. Often, the answer is obvious and it will provide a focus for making finer estimates by continuing to divide the remaining volumes in a like manner until the answer becomes uncertain. At that point of uncertainty, stop the division process and use the last confident answer for the estimate of delivery volume. This simple line of questioning will generally produce an acceptable estimate for determining sediment delivery volumes at each potential landslide fill failure. All but the smallest landslides can be very complex features and the development of effective treatment options more often than not will require consultation with a licensed geotechnical specialist.

Over-steepened Road and Landing Fills

Over-steepened fills typically consist of un-compacted sidecast materials, bulldozed onto steep, potentially unstable fillslopes. Unstable sidecast usually involves limited volumes of sediment when they fail by debris sliding, and these quantities can be estimated easily using simple geometric measurements of length (down slope), width (distance along the road) and average depth. The most common type of preventable or controllable landslide is the failure that develops from road or landing sidecasting on steep slopes. It is also the most common and most treatable source of road-related sediment delivered to streams in many watersheds.

The volume of a potential road-related sidecast failure is not difficult to estimate because the minimum average depth of the potential slide is typically the average depth of the sidecast material placed on the hillslope. The length of the potential slide is the length of the fillslope's sidecast material from the crown scarp to the base of the fill. Estimate the potential landslide width based on the boundaries of the over-steepened and visibly unstable sidecast material, or based on visible cracks and scarps that bound the potentially unstable material.

Headwater Swales (Potential Landslides)

Unlike simple sidecast failures, debris slides from steep headwater swales are more difficult to predict. They usually incorporate original ground beneath the road fill and often grow much larger as they move down the steep swales and channels, scouring debris from the channel bed. This makes their final volumes frequently much larger than that estimated at the initiation site itself. Often, the occurrence and volume of such slides is highly uncertain and requires professional geologic analysis. Because it is difficult to accurately identify and quantify such sites of extreme erosion, note their potential location on the field form and on maps, but do not estimate their volumes for calculating treatment cost-effectiveness. Later in the process, query the database for the sites that exhibit a potential for extreme erosion and include them in the development of the final implementation plan only after review by a licensed geotechnical specialist.

Large Earthflows and Landslides of Unknown Depth and Activity

The future volumetric yield of deep-seated landslides can be equally difficult to estimate largely because they move episodically, at unpredictable rates and they occasionally self-stabilize over time. These types of landslides are often natural features and may not be affected or caused by a road or other land use (the road may be simply going along for the ride). Evaluating and developing treatment options will require consultation with a licensed geotechnical specialist. Typically, there are few cost-effective treatments that will slow or prevent these slides from moving or delivering sediment to the stream.

ANALYSIS AND REPORTING OF ASSESSMENT DATA

Use data analysis to convert field inventory information into conclusions. Use the conclusions to assemble a prioritized summary report (Appendix X-C). Set up the database, enter and clean the data, then complete the analysis. Analysis steps include generating erosion volume calculations, treatment volume calculations, costing out projects, cost-effectiveness analyses and sorting for prioritization prior to initiating restoration work.

Database Management

Data analysis can be complicated, but it is a critically important part of an assessment project that leads to restoration. To efficiently sort, analyze and prioritize a large number of work sites in an assessment area it is important to utilize an electronic database. To prepare a database for data analysis;

- **Set up database structure**: Set up the database structure on paper, based on the field forms presented on pages X-29 and X-33 and then program the electronic database. Perform this step as a part of the initial preparations for the watershed assessment.
- **Complete any blank data fields:** Fill any blank database fields left unanswered from the field inventory prior to data entry and analysis. This could include data that was not available during the field inspection, such as drainage area measurements or volume calculations that were available only after the field inventory, as well as inadvertent omissions (which might require a second field visit).
- **Enter data in database:** Enter the data for analysis. Analysis of partial data sets may be useful to break down the assessment area into smaller management units, such as an individual landowner, a logical hillslope unit or high priority sub-watershed as stand-alone elements of the larger assessment area. This is most useful when conducting very large watershed assessments. In this manner, individual restoration plans can be developed for the smaller management area as the larger assessment effort is still underway, and

prioritized treatments can begin in areas where early assessment work has already been completed.

- **Clean data:** Once entered, perform preliminary data searches to identify any blank data fields and any mistakes in data entry. Data cleaning is the last step prior to analysis. Perform data cleaning to make sure the necessary data is both present and internally consistent. Electronic data searches (reports) involving a number of related data fields (such as all questions related to stream crossings, or all questions related to treatments) should be viewed on the screen or in printed format as data tables so that any data inconsistencies or blank data fields will be visibly obvious. It may take several data searches, involving a variety of interrelated fields and combinations of fields to determine if all the data is there, and that it is present in the correct format.
- **Revisit selected sites and complete database:** Enter data that is missing or inconsistent and needs correction. Errors in data entry are easy to correct. Inadvertent omissions during field inventory work can sometimes be clearly determined from the other information that is on the paper form. If important data is missing from the form or it is clearly inaccurate a re-inspection of the site is necessary. For efficiency, it is generally best to schedule site re-inspections after all data cleaning has occurred.

Analyzing the Inventory Data

Data analysis can only occur when all the inventory information has been collected, properly entered in the database, and cleaned. The use of a database allows for rapid data analysis. Perform searches to isolate the nature, frequency and magnitude of a host of problems and treatments. Specific searches might include analyses that look at the frequency and cause of potential sediment delivery associated with each sediment source (landsliding, fluvial erosion and surface erosion). Searches might include an analysis of all stream crossings, looking for the frequency of undersized culverts, stream crossings with a diversion potential, or active culvert outlet erosion, among others.

Data tables developed for the summary report contain information regarding the number of sites recommended for treatment, erosion potential, treatment immediacy (priority), sediment savings, recommended treatments, excavation volumes, estimated heavy equipment and labor hours and costs. Proposed restoration plans may be grouped a variety of ways, for example geographically, according to the number of high priority sites they contain, the expected volume of future sediment delivery, or the number of undersized culverts on stream crossings with a high diversion potential. Appendix X-C contains examples of a number of assessment data tables that are useful for displaying the results of the sediment source inventory.

Estimating Costs

Use the sediment source assessment to develop cost estimates by employing the following steps:

- Problem identification - determine the population of potential treatment sites;
- Problem quantification - accuracy in calculating excavation volumes is critical in predicting heavy equipment times and project costs (Figure X-5 and Figure X-6);
- Determine equipment needs - select heavy equipment based on desired capabilities and types. Picking the wrong equipment can severely inflate costs above predicted levels;

- Estimate production rates and equipment times – selection of appropriate equipment production rates is critical in determining heavy equipment times for each site;
- Estimate equipment costs - use locally appropriate rates for heavy equipment rental (cost/hour), and a logistic multiplier of 20% to 30% for prescribed site treatments (number of hours x 0.2 or 0.3). This should cover equipment travel times, consultations with the operator and most unforeseen complications. Finally, develop cost estimates that cover all needed road drainage work between sites;
- Estimate road opening costs (hours x cost rate) for either upgrading or decommissioning abandoned roads or for treating off-road sites. Access costs will be dependent on maintenance status and degree of revegetation on the abandoned road;
- Estimate equipment mobilization costs - mobilization costs include lowboy transportation for moving heavy equipment to the project area and are dependent on equipment availability and lowboy rental rates;
- Calculate materials costs including culverts, road rock, riprap sized rock, filter fabric, seed, mulch, tools, etc.;
- Calculate labor costs and apply to the labor hours itemized on the data forms for each site. Use a locally reasonable labor rate (cost/hour);
- Calculate indirect costs including coordination, ordering, field layout, technical oversight (such as by restoration specialists, or professional engineers and geologists) reporting, monitoring, administrative and contracting costs. This requires an assessment of the hours for each task and the labor rate applied to the work. The required amount of on-the-ground supervision time with the heavy equipment or with labor crews will depend on the experience of the work crews. Inexperienced operators and laborers need more oversight.

Predicting Cost-effectiveness

Define the cost-effectiveness of treating a restoration work site as the average amount of money spent to prevent the delivery of one cubic yard of sediment from entering the stream system (Weaver and Sonnevil 1984). Cost-effectiveness is determined by dividing the cost of accessing and treating one site, or group of sites, by the volume of sediment delivery prevented to a stream channel. For example, if it would cost $3,500 to access and treat an eroding stream crossing that would have delivered 250 yds^3 (had it been left to erode), the predicted cost-effectiveness would be $14/$yd^3$ ($3500/250 yds^3). The key elements in determining cost-effectiveness are a fair and accurate estimate of future sediment delivery (in the absence of treatment) and a reasonable estimate of treatment costs.

Controls on Cost-effectiveness

A variety of factors control the ultimate cost-effectiveness of the restoration work that is being proposed (Weaver et al 1981). Some of these are predictable and controllable, and others are not. Ultimately, factors that affect either the cost of the work, the potential volume of sediment delivery or the effectiveness of sediment control treatments will control cost-effectiveness. The more that is done to reduce costs, decrease sediment delivery and increase treatment effectiveness, the greater will be the cost-effectiveness of the restoration project.

Costs

Of all the factors controlling cost-effectiveness, cost factors are the most amenable to manipulation. Controls on restoration costs include many obvious factors and some more subtle elements. These include:

- Goals and objectives of the restoration: goals and objectives establish the level of effort that will be undertaken, and ultimately control cost-effectiveness;
- Hourly equipment rental or contract rates: all else equal, the higher the rental rate, the lower will be the cost-effectiveness of the resultant restoration work;
- Choice of heavy equipment types and sizes;
- Skill and experience of the equipment operator;
- The magnitude of indirect costs, such as administration, contracting, overhead, profit, supplies and other indirect expenses that diminish cost-effectiveness;
- A large influence on treatment cost-effectiveness can result from incorrect identification of the problem, incorrectly estimating potential sediment delivery volumes, and/or recommending inappropriate or ineffective treatments;
- The design standards of the treatment: culvert sizing and excavation geometry (side slope steepness for decommissioned crossings have a substantial influence on restoration costs - the higher the standard, the higher the cost);
- The method of contracting including fixed price, hourly rental, or cost-plus. There is often a significant difference between total restoration project costs under fixed price (minimum bid) contracting and hourly equipment rental; the former frequently being more costly;
- Road reopening and other mobilization costs: these include the costs of clearing and opening access on abandoned roads and for hauling equipment to or within the project area. The higher these indirect expenses are, the greater their negative effect on cost-effectiveness;
- Choice of specific treatments used to prevent or control erosion: even if a number of methods are equally effective at preventing or controlling sediment delivery, the more costly approaches will be less cost-effective;
- Secondary treatments: if secondary erosion control treatments (e.g., check dams, rock armor or other hand labor treatments) are recommended, primary project cost-effectiveness will diminish because these treatments are typically expensive compared to the amount of sediment prevented from delivery to a stream channel (Weaver and Sonnevil 1984).

Sediment Delivery Estimates

Variables that affect estimated sediment delivery and project cost-effectiveness include the interpretation of a potential site, the inventory methods, assumptions, and measurement accuracy reported and used. Inflated sediment delivery volumes exaggerate the sediment savings and cost-effectiveness. Similarly, if the volume of future delivery is understated, then the project will not look as cost-effective as it might actually be. Achieve controls on sediment delivery estimates using appropriate:

- Volume calculation methods (assumptions and methods for calculating or estimating potential failure volumes for landslides, and potential erosion volumes for stream crossings, gullying and surface erosion). Volume calculations should be repeatable and sufficiently accurate;
- Sediment delivery estimates (methods and assumptions for determining the delivery ratio for potential landslides, fluvial erosion and surface erosion processes);
- Sediment loss assumptions (assumptions made about how much erosion and sediment delivery would actually occur at a site before the problem was corrected);
- Erosion rate and amortization assumptions (assumptions made about the rate of erosion and the duration over which erosion and sediment delivery is calculated, especially for large landslides, gullying, stream crossing washouts, bank erosion and surface erosion).

Treatment Effectiveness

The effectiveness of erosion prevention and erosion control measures has a significant influence on sediment delivery to stream channels from inventoried sites. Certain techniques are nearly 100% effective at preventing sediment delivery (such as completely excavating a potentially unstable fillslope). Others are partially effective (e.g., disconnecting road surface runoff from stream channels to cut off road drainage and prevent fine sediment delivery). Measure treatment effectiveness by the volume of sediment prevented from delivery to a stream, not on the amount of dirt moved by heavy equipment or by the volume of soil erosion that is controlled or prevented. Treatment effectiveness varies according to the process and the erosion prevention technique that is applied.

Surface Erosion

Surface erosion processes are sometimes controllable and preventable (through the application of mulching and seeding). More importantly, controlling sediment delivery from surface erosion sites is usually highly effective (through diversion and dispersion of runoff).

Fluvial Erosion

A number of cost-effective treatments can effectively prevent most gullies. For example, dewatering existing gullies can be nearly 100% effective in preventing continued erosion and sediment delivery. Gully control is less effective and more costly than gully prevention, and preventing sediment delivery from an eroding gully is very difficult.

Landslides

Landslide size and accessibility influence treatment cost-effectiveness. Streamside landslides, non-road landslides (i.e., poor access) and large landslides have low treatment cost-effectiveness and are very difficult to treat. Treating small potential landslides or excavating a large proportion of the material on larger landslides can result in a high level of effectiveness.

Evaluating Treatment Priorities

Evaluate treatment priorities by considering factors and conditions associated with each potential sediment delivery site:

- Delivery volume - the expected volume of sediment to be delivered to streams;

- Erosion potential - the potential for future erosion (high, moderate, low);
- Access and access costs - the ease and cost of accessing the site for treatments;
- Treatment costs - recommended treatments, logistics and costs;
- Treatment immediacy - the urgency of treating the site;
- Treatment cost-effectiveness - money spent per cubic yards saved.

Proposed work should meet pre-established cost-effectiveness criteria, and this often forms the basis for restoration prioritization. However, other local factors may also be considered. For example, factors such as the protection of potable water supplies, sensitive resources at risk, or other beneficial uses may assume a significant role when developing final restoration priorities. The prioritization criteria will be a function of the goals of the restoration project.

Prioritizing Restoration by Cost-effectiveness

Cost-effectiveness calculations directly and indirectly integrate a number of the most commonly employed factors used for prioritizing restoration work. By using the cost-effectiveness formula, a comparison of proposed projects is possible using the same criteria: reducing accelerated erosion and keeping the greatest volume of eroded sediment out of the watershed's streams for the least amount of money. The sites selected for eventual treatment are the ones expected to generate the most cost-effective reduction in sediment delivery to the drainage network and the mainstem stream channel. The larger the potential future contribution of sediment to streams, the more important it becomes to evaluate the project for cost-effectiveness.

After prescribing treatments and evaluating all costs, employ cost-effectiveness calculations and other criteria to prioritize all the sites for actual treatment. Use cost-effectiveness as a tool to prioritize potential treatment sites throughout the assessment area. Sites, or groups of sites, that have a predicted marginal cost-effectiveness value for the particular region, or have a lower erosion potential or treatment immediacy, or low sediment delivery rates, are less likely to receive funding from agencies that administer cost share grant programs. Address these sites when conducting future management activities, or if heavy equipment is performing routine maintenance or restoration work on nearby, higher priority sites.

Criteria for Cost-effective Treatments

For consideration of priority treatment, a site should typically exhibit:

- Potential for significant sediment delivery to a stream channel that directly or ultimately results in delivery to a fish-bearing stream. Significance of delivery is guided by the minimum inventory volume established for the watershed assessment;
- A high or moderate treatment immediacy;
- Favorable cost-effectiveness. Project cost-effectiveness is different for similar projects in different areas of California. This rate varies regionally, and changes over time due to inflation and changes in related costs. For example, the cost of similar projects is generally lower in the northern-most counties such as Humboldt or Del Norte as compared to the Bay Area from Sonoma to Monterey County. Furthermore, in the case of high value refuge streams and/or watersheds with listed species, domestic water supplies or

other high value downstream resources, exceptions to cost-effectiveness criteria can be justified. Consultation with DFG fisheries staff can help with this determination.

Site Groupings
In most cases, apply cost-effectiveness to a group or groups of sites so that the most cost-effective groups of projects are undertaken first. For example, during road decommissioning, groups of sites are usually considered together because there will be only one opportunity to treat potential sediment sources along the road. Even if an individual site is highly threatening to the protected resources, recommending treatment priorities based on the cost-effectiveness of one site is generally discouraged. This would lead to a costly shotgun approach to restoration.

Treatment of Abandoned Roads
Another factor influencing a site's treatment priority is the difficulty (cost and environmental impact) of reaching the site with the necessary equipment to treat the potential erosion. Many sites found on abandoned or un-maintained roads require brushing and tree removal to provide access to the site(s). Other roads require minor or major rebuilding of washed out stream crossings and/or existing landslides in order to reach potential work sites farther out the alignment. Road reconstruction adds to the overall cost of erosion control work and reduces project cost-effectiveness. Potential work sites with lower cost-effectiveness, in turn, may be a lower priority. However, just because a road or potential work site is abandoned and/or overgrown with vegetation is not sufficient reasoning to discount its assessment and potential treatment. Treatments on heavily overgrown, abandoned roads are often both beneficial and cost-effective.

Prioritizing Restoration Projects

Once treatment priorities and cost-effectiveness standards are established, it is important to review the restoration plan and prioritize projects for implementation. Not all sub-basins within a large watershed will merit the same type or intensity of protection or restoration measures. Through field inventories, identify areas where there is a potential for cost-effective watershed protection and restoration for fisheries recovery.

Design protection and restoration options for sites in watersheds with the most potential of restoring productive conditions and protecting against future catastrophic damage or persistent degradation. For most sediment assessments, a large number of potential treatment sites are identified and classified into individual treatment priorities. Strategies for prioritizing groups of sites for treatment include:

Prioritize Sub-watersheds
Prioritize and treat sub-watersheds according to their biological importance, not necessarily according to the magnitude of the potential threat that exists in the basin. High quality sub-watersheds may only need a small amount of upslope restoration work or erosion prevention but it is critically important to perform this work and secure the drainage before moving to other sub-watersheds.

Prioritize Hillslope Units

There are many ways to group sites in a watershed or sub-watershed for treatment. Each watershed may warrant a different approach to grouping sites for treatment. This will depend on the sensitivity of the resource, the nature and magnitude of the upslope erosion threat and access to the sites. All groupings should be practical; that is, they should consist of groups or clusters of sites in relatively close proximity and be treatable in a timely, coordinated and cost-effective manner. For example:

- Treatment immediacy – Group based on the identified clustering of high priority units in the watershed. Treat these cluster units according to the magnitude and immediacy of the threat they pose (high priority clusters contain concentrations of high priority sites, but may also include other lower priority sites). Examples might include roads or groups of roads that contain many high priority sites, or many sites immediately adjacent Class 1 stream channels. This strategy will focus on the most immediate threats to the aquatic system, but the unit groups might not be the most cost-effective ones that could be addressed.
- Threat of future sediment delivery-Group based on their volumetric threat to the stream system, as determined by the inventory results.
- Logical treatment units - Sites can be grouped on the basis of logistic considerations, similar work effort requirements, natural topographic boundaries, equipment access points, restoration type (e.g., road decommissioning or road upgrading), or other factors. This is the most basic grouping, and in fact all groupings should fit the definition of logical treatment unit.
- Cost-effectiveness - Group sites based on the average cost-effectiveness of restoration treatments that have been calculated from the inventory and prescription data. This strategy assures the most bang for the buck with restoration funds, but it does not assure treating the highest biological priority units first.

Prioritize Critical Sites

Identify, target and treat individual, extremely high priority sites that if not immediately treated are likely to fail and deliver significant volumes of sediment to the stream system. These sites are likely widely dispersed across the watershed. They may be termed “ASAP” sites. In watersheds with high value aquatic resources, it may be worth going after individual, isolated sites even though there may be a decrease in the relative cost-effectiveness of this restoration strategy due to the higher logistic costs (e.g., multiple staging and increased equipment hauling).

Preparing the Summary Report

Reports for upslope inventory and assessment projects should contain the following information: (Appendix X-C).

- Project identification #
- Project location (descriptive location)
- Map of watershed (location map, showing relationship of project area to the region)
- Map of project area with inventoried sites and roads, which shows:

  - Base information, (streams, roads, sections, contours (optional), scale, north arrow, labels for stream names, road names and cultural features)
  - All roads within the inventory area with current maintenance status:
    - Maintained roads, and
    - Abandoned (un-maintained) roads
  - All stream crossings by type (Humboldt, culvert, unculverted fill, armored fill, ford or bridge)
  - Potential and active landslides with sediment delivery potential if left untreated
  - Ditch relief culverts and other ditch drains
  - Gullies and other fluvial erosion features
- Map of all sites recommended for treatment (with site numbers)
- Map of all sites according to treatment priority (high, moderate, low)
- Project report which contains the following:
  - Introduction (setting, problem, purpose of assessment project)
  - Methods (office, field inventory and data analysis - discuss map data and database)
  - Results and discussion of sediment source assessment
  - Results of transportation planning (discussions with landowner)
  - Future erosion and sediment delivery data (if sites were left untreated)
  - Restoration plan
  - Description of overall treatment plan (upgrading and decommissioning)
  - Road upgrading (show and describe roads planned for upgrading)
  - Road decommissioning (show/describe roads for decommissioning)
  - Describe treatments and sites recommended for treatment, by road
  - Stream crossings, landslides, surface erosion treatments
  - Cost analysis, including:
    - Estimated equipment rates (for all heavy equipment)
    - Estimated labor rates (cost/hr)
    - Total estimated site costs (all site costs added together)
    - Equipment move-in and move-out costs (lowboy) for project
    - Other project costs not listed above (specify)
    - Total estimated costs for entire project (equipment + labor + materials + other)
    - Cost-effectiveness analysis
    - Total estimated sediment savings (delivery prevented in yds^3)
    - Total project cost-effectiveness (cost/yd^3 of sediment delivery prevented).
- Project report appendices including database and data sheets from field surveys, containing the following information for each site recommended for treatment:
  - Site # (as flagged or marked in the field)

- Problem type (stream crossing, landslide, roadbed, ditch relief culvert, gully, other)
- Problem description (narrative or data describing the apparent nature of the problem)
- Erosion activity (active and/or potential)
- Erosion potential (likelihood of erosion, if not treated - high, moderate, low)
- Future erosion (yds^3 of erosion likely to occur if problem is not treated)
- Future delivery (yds^3 of eroded sediment that would be delivered to a stream left untreated)
- Recommended treatment (quantitative description of proposed treatments, e.g., yds^3 of soil to be excavated, or classification of treatment type from a list of possible standard treatments)
- Treatment immediacy or priority (high, moderate, low)
- Equipment times (hours for each category of equipment used at each site)
- Labor times (for each site)
- Materials per site (e.g., culvert, downspout, rock, etc.).

IMPLEMENTING RESTORATION WORK

Restoration Strategies

Upland watershed restoration can take several basic forms: prevention (through avoidance or altered management practices), control, mitigation and/or cleanup. The goal of upslope restoration is to prevent or substantially reduce sediment delivery to streams from accelerated erosion sources. Accomplish this through the implementation of protection measures, restoration measures, and improved land use practices designed to result in more natural sediment yield rates. As with other forms of watershed conservation practices, erosion prevention is usually far more effective and cost-effective than trying to control erosion once it has begun.

Prevention

Accomplish prevention by altering and improving land use practices that would otherwise result in sediment delivery to streams; avoiding sediment producing activities or locations; and treating existing potential sediment sites. The latter includes traditional upland watershed restoration, erosion prevention and erosion control, as described throughout *Part X*.

Reduce the risk of failure or erosion by treating existing sediment sites. This type of preventive restoration, to reduce or eliminate erosion, includes decommissioning of abandoned or unnecessary roads, excavation of potentially unstable fillslopes and small landslides, upgrading road stream crossings, installing critical dips to prevent stream diversions, and dispersing surface runoff.

Erosion Control

Employ erosion control to reduce accelerated sediment delivery to a stream. However, traditional erosion control techniques are naturally limited in their ability to be widely effective and cost-effective. Erosion control is only applicable to erosion processes that are actively occurring, and not to sediment sources that have not yet developed. It is difficult to conduct erosion control for processes that are episodic and for processes that generally cannot be cost-effectively controlled (e.g., large landslides). Some processes are just too large or complex to control once they have begun. Reserve control treatment for erosion processes that are amenable to cost-effective treatment.

Mitigation and Clean-up

These strategies are limited in their utility. Mitigation to counter balance the expected impacts of sediment producing land use activity is difficult. Clean up may be impossible to apply in many circumstances (sediment is difficult to remove once it is in the stream channel) and is typically of limited effectiveness.

Modification of Land Use Practices

The most cost-effective tools for minimizing future erosion and sediment delivery to streams are preventive land use practices and protection measures that limit watershed disturbances. Certain combinations of land use practices and site variables (soils, slope gradient, bedrock geology, slope position, etc.) have been documented to contribute to, or influence, the magnitude or location of watershed erosion. As the result of the watershed assessment and collection of inventory data, recommended modifications to land use practices may provide passive protection to downstream aquatic resources, especially from impacts that occur during infrequent floods.

Practical protection measures related to road networks should address issues such as improved road location and design standards; limiting operations on steep inner gorge slopes, other suspect geomorphic locations and riparian corridors; improved road construction and drainage practices; proper stream crossing installation; frequent road maintenance; and road decommissioning. Seasonal road use restriction is a passive measure to lessen the potential for sediment-related impacts to stream channels. Protection measures for grazed lands include; grazing allocations, riparian planting and fencing, localized enclosures, and other seasonal restrictions.

Road Related Restoration Techniques

Roads are typically a common and disproportionately significant source of accelerated sediment delivery in managed watersheds. Most significant and common erosion problems occurring along roads are predictable and cost-effective to prevent or treat.

There are two basic techniques for road risk reduction and restoration:

- Decommissioning (closure);
- Upgrading.

Following are generic treatment descriptions for a variety of preventive treatments for both decommissioning and upgrading roads. These treatments are collectively referred to as “storm-proofing” (Figure X-9) (Weaver and Hagans 1999). The treatments described for roads or hillslopes have been tested, documented and evaluated in similar erosion control and erosion prevention projects. They have been shown to be generally effective in reducing sediment delivery from managed forest and ranch lands when used in a properly planned and constructed project (California State Parks 2001; Harr and Nichols 1993; Sonnevil and Weaver 1981; USDA

Forest Service 1996; USDI Park Service 1992; Weaver and Hagans 1996; Weaver and others 1981; Weaver and others 1987a,b; Weaver and Sonnevil 1984). In every case, the road upgrading and decommissioning treatments listed in *Part X* must be informed by, and customized by, an evaluation of the characteristics of each potential treatment site.

Road Decommissioning

Decommissioning is the same as road closure. It can be permanent or temporary, but the treatments for both are similar. Decommissioning is defined as removing those elements of a road that reroute hillslope drainage and present slope stability hazards. Another term for this is "hydrologic obliteration" (USDA 1993). It involves such tasks as decompacting road surfaces and installing road surface drainage (e.g., cross road drains or road out sloping) (Figure X-10 and Figure X-11), excavating unstable sidecast and road fill (Figure X-11), and fully excavating stream crossing fills (Figure X-12) (not just culvert removal). Decommissioning essentially involves reverse road construction, except that full topographic obliteration of the roadbed is rarely required to accomplish sediment prevention goals. In order to protect the aquatic ecosystem, hydrologically decommission the road by dispersing runoff, reestablish drainage patterns and remove or stabilize any potential sources of sediment delivery along the alignment. Estimating the sediment savings and treatment cost-effectiveness of such projects will help identify which roads in the watershed are truly the best targets for decommissioning (Table X-4).

<u>Roads with High Priority for Decommissioning</u>
Relative to potential threats to the aquatic ecosystem, certain roads frequently qualify as a high priority for decommissioning. These include poorly built roads in riparian areas, on steep inner gorge slopes, across unstable or highly erodible soils, in tributary canyons where stream crossings and steep slopes are common, roads with high short-term or long-term maintenance costs and requirements, and abandoned roads containing large or numerous sediment delivery sites.

<u>Roads with Low Priority for Decommissioning</u>
Roads that are of low relative priority for decommissioning includes those that follow low gradient ridges, traverse large benches or low gradient upland slopes, and have few or no stream crossings. Roads no longer needed for land or resource management may or may not be a high priority for removal depending on where they are located in the watershed. These would include dead-end spur roads with no stream crossings located high on the hillslope.

Road Decommissioning Treatments

The following tabulated and diagrammed treatments do not represent rigorous specifications, but rather descriptions of basic techniques that must be informed by site-specific evaluations.

Decommissioning consists of three basic tasks.

- Complete excavation of stream crossing fills, including 100 year flood channel bottom widths and 2:1 or otherwise stable side slopes;
- Excavation of unstable or potential unstable sidecast materials that could otherwise fail and deliver sediment to a stream;
- Road surface treatments (ripping, outsloping and/or cross draining) to disperse and reduce surface runoff.

Road Decommissioning Effectiveness

The effectiveness of road decommissioning tasks is usually expressed over two time periods: 1) the volume of sediment that has been prevented from being delivered to stream channels (long term effectiveness) and 2) the volume of sediment that is eroded from the decommissioned sites and delivered to local stream channels in the first several years after decommissioning activities (short term effectiveness). The goal of a decommissioning project is to maximize long-term effectiveness (sediment savings) and to minimize short-term sediment release from the site.

Treatment of road surface runoff (hydrologic connectivity) and excavation of potentially unstable fillslopes have been shown to be highly effective sediment control techniques (PWA 2005). Excavating stream crossings using protocols outlined in *Part X* also proved highly effective (PWA 2005). Most short-term sediment loss from decommissioned sites originated at excavated stream crossings. The primary sources of this sediment delivery, accounting for 91% of the soil loss, were channel incision, surface erosion, and slumps on the sideslopes of excavated stream crossings. Operator error (mostly consisting of leaving unexcavated fill in the stream crossing) accounted for 40% of the potentially avoidable erosion. The remaining 60% of sediment loss was judged to be unavoidable. The single most effective erosion prevention practice, measured by the reduction of post-decommissioning erosion and sediment delivery, was the correct application of recommended treatment prescriptions as outlined in *Part X*.

Role of Emergent Groundwater

Emergent groundwater along roads scheduled for decommissioning plays an important role in the eventual effectiveness of the road closure treatment. Perform road erosion inventories during the wet season, when springs on the roadbed and cutbank are most likely to be active and identifiable. If inventories are conducted during dry summer conditions, hydrophyllic (water loving) vegetation or mottled and discolored soils can be used to indicate the presence of seeps and springs.

Design treatments of wet areas to allow free drainage of springs and other emergent water and connection of these flow sources with downslope channels and swales. Do not place spoil material against cutbanks or cover springs that occur on the roadbed; spoil endhauling may be required. Some springs may not be visible during the assessment phase of the project, even if conducted during wet winter conditions. For example, some natural springs are buried during road construction and are only revealed when the road is decommissioned (typically during dry summer months). Excavated stream crossing sideslopes occasionally expose pre-existing springs, and these sources of emergent water can cause soil saturation and gullying or slope instability. In cases where embankment materials are saturated, as evidenced by winter surveys, excavation may be indicated even where no other signs of potential failure are identified. At the same time, excavation methods must be designed for wet and potentially hazardous conditions where equipment or laborers are working near wet cuts and fills[1]. Saturated materials need to be properly stored where they will not enter a watercourse.

[1]Applicable worker health and safety regulations include but are not limited to sections: 29, the Code of Federal Regulations (CFR) 1926.650, 601 (b)(6) of and Title 8, Sections: 1540, 1541, 1541.1 of the California Code of Regulations.

Characteristics of Storm-proofed Roads

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year flow (with debris).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers & graded drainage).
- Protect stream crossing outlets from erosion (extended, transported or dissipated).
- Culvert inlet, outlet and bottom are open and in sound condition.
- Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert.
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Fills are stable (unstable fills are removed or stabilized).
- Road surfaces and ditches are "disconnected" from streams and stream crossing culverts.
- Class I stream crossings meet DFG and NMFS fish passage criteria (Part IX).

Storm-proofed fills

- Unstable and potentially unstable road and landing fills are excavated or structurally stabilized.
- Excavated spoil is placed in locations where it will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Road surface drainage

- Road surfaces and ditches are "disconnected" from streams and stream crossing culverts.
- Ditches are drained frequently by functional rolling dips or ditch relief culverts.
- Outflow from ditch relief culverts does not discharge to streams.
- Gullies (including those below ditch relief culverts) are dewatered to the extent possible.
- Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides.
- Decommissioned roads have permanent drainage and do not rely on ditches
- Fine sediment contributions from roads, cutbanks and ditches are minimized by utilizing seasonal closures and installing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping or crowning), rolling dips, ditch relief culverts, water bars and other measures to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

Figure X-9. Common characteristics of storm-proofed roads.

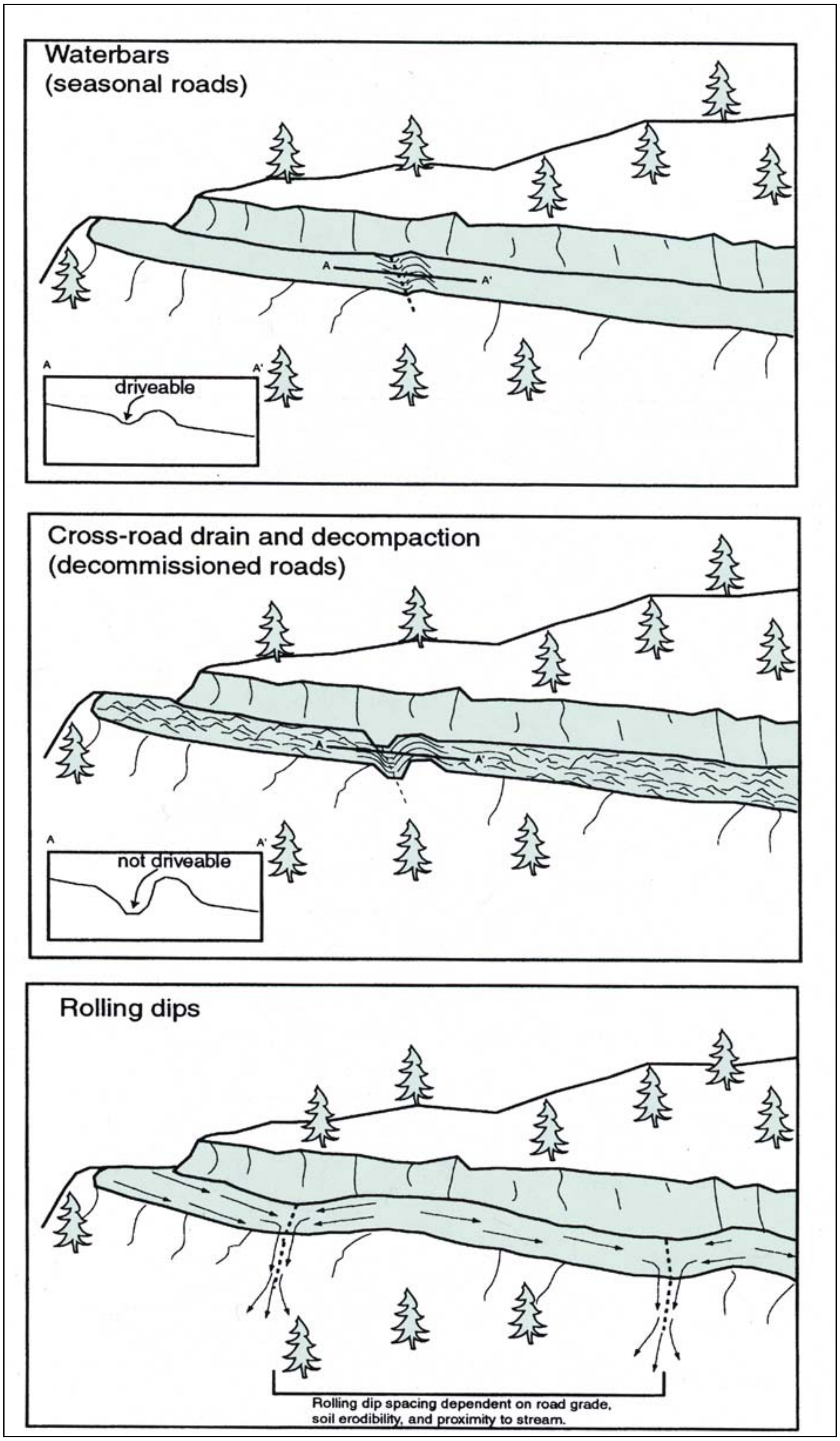


Figure X-10. Techniques for dispersing road runoff.

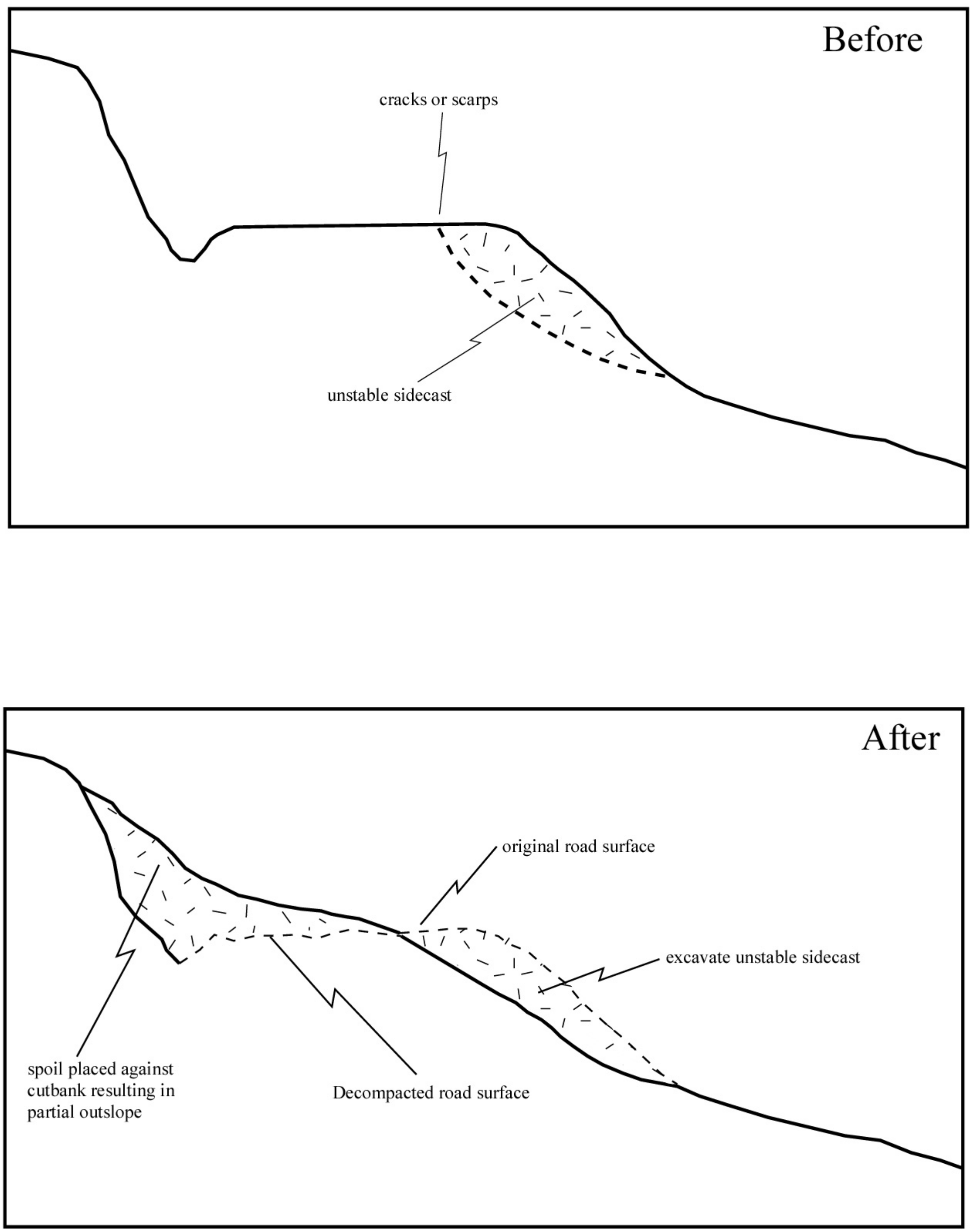


Figure X-11. Partial outsloping for road decommissioning.

Condition

- Diversion potential
- Road surface and ditch flows drain to stream
- Undersized culvert high in fill with outlet erosion and elevated plugging potential

Treatment

- Road surface decompacted
- Cross road drains on old road
- Stream crossing fill completely excavated
- Excavated spoil used to outslope adjacent road

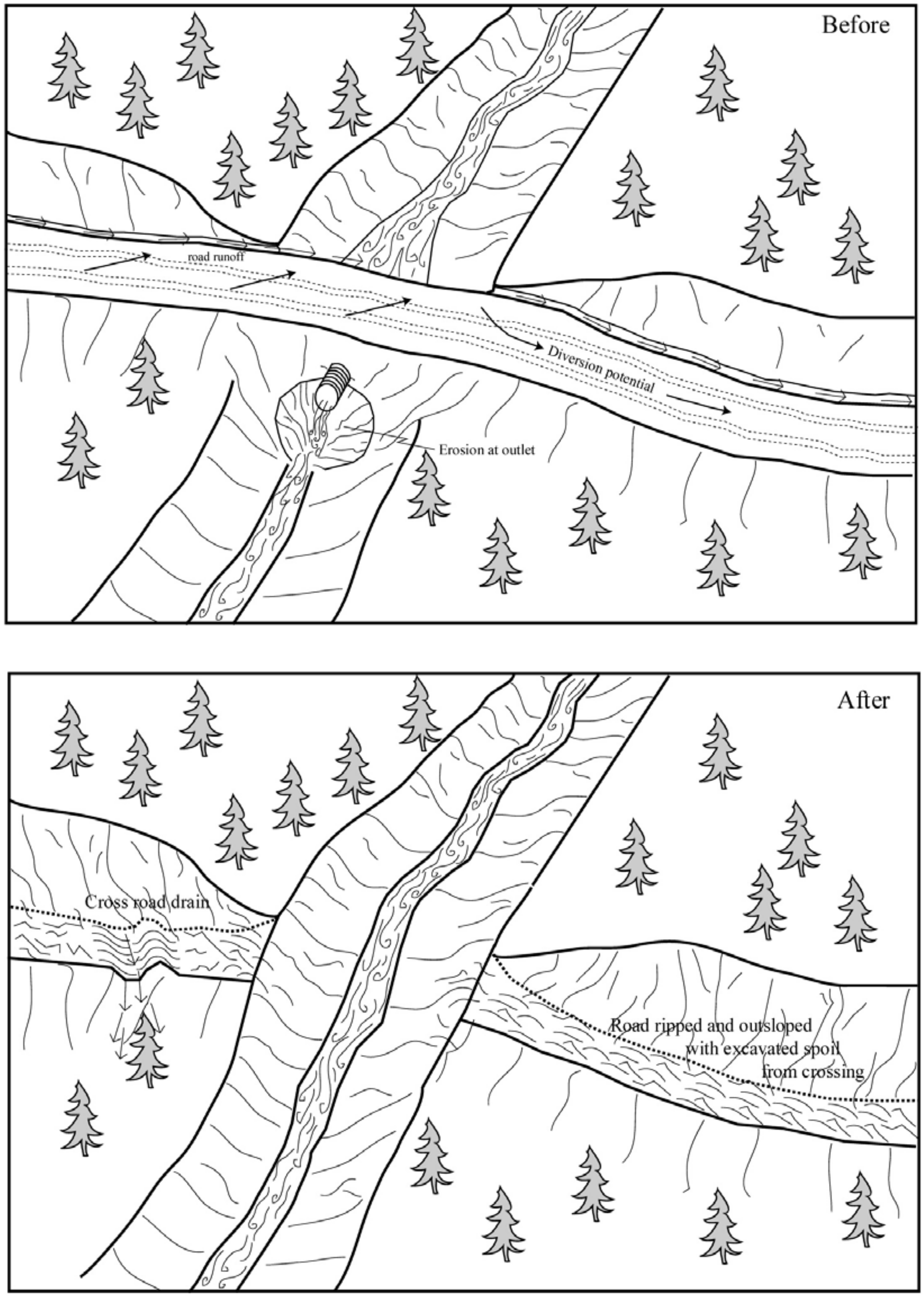


Figure X-12. Typical stream crossing excavation on a decommissioned road.

Treatment	Typical Application	Typical Actions	Typical Costs[1]
Ripping or Decompaction	Improve infiltration; decrease runoff; assist revegetation	Rip roads, landings and compacted areas with multiple passes to average depth of 18".	\$1,000 - \$2,000/mile
Construction of cross-road drains	Drain springs; drain insloped roads; drain landings	Drains deeper and wider than waterbars, extending from cutbank to outside edge of road (captures ditch flow).	\$1/ft (\$25-\$50 ea)
Partial outsloping (local spoil site; fill against the cutbank)	Remove minor unstable fills; disperse cutbank seeps and runoff	Road should be ripped before adding spoil for outsloping. Springs should not be covered. Ditches can be filled.	\$2,500 - 12,500+ /mile
Complete outsloping (local spoil site; fill against the cutbank)	Used for removing unstable fill material where nearby cutbank does not include seeps or springs	Road should be ripped before adding spoil for outsloping. Springs should not be covered. Ditches can be filled.	\$10,000 - 75,000+/mile
Exported outsloping (fill pushed or hauled away and stored down-road)	Used for removing unstable road fills where cutbanks have springs and cannot be buried	Spoil site should be located in stable area where sediment will not be delivered to stream.	\$2 - \$5/yd^3, depending on haul distance
Landing and fillslope excavations (with local spoil storage)	Used to remove unstable material around landing perimeter	Landing should be ripped and spoil placed on inside half of landing. Springs should not be covered.	\$2 - \$5/yd^3, high organics can increase costs
Stream crossing excavations (with local spoil storage)	Complete removal of stream crossing fills (not just culvert removal)	Excavate all fill from crossing, down to original channel bed with straight or concave profile; original or 2:1 side slope gradient; natural channel width	Averages \$3 - \$10/yd^3 but can vary considerably
Truck endhauling (dump truck)	Hauling excavated spoil to an offsite spoil disposal site	Haul to a stable site not near stream channels. Place spoil where it is stable and will not deliver to a stream.	\$2 to \$5/yd^3 on top of basic excavation work

[1] These are estimated treatment costs for equipment working at a site. Heavy equipment treatments performed using D-7 tractors and hydraulic excavators with average 2 yd^3 bucket size. They do not include transportation, moving from site-to-site, overhead, project supervision by or consultation with restoration or professional geotechnical specialists, layout, or any other costs. Costs can vary considerably from these typical figures, depending on operator skill and experience, equipment types, local site conditions, and regional location. Example costs are from 2004 data for north coastal California and are not based on prevailing wage rates. Production rate data from from PWA (unpublished) and NPS (1992).

Table X-4. Typical techniques and costs for decommissioning forest and ranch roads.

Road Upgrading

Managed watersheds need roads to provide for long-term resource management and access to private properties or recreational areas. Good land stewardship requires road systems be protective of fish habitat and the aquatic ecosystems in the watershed. Transportation planning requires that landowners or land managers consider the erosion consequences of retaining the road and the expressed needs for management activities. Retained roads should be located on stable terrain, where the risk and impacts of fluvial erosion, stream crossing failure, storm damage and mass soil movement is low. Roads should be largely self-maintaining or require low levels of maintenance. To facilitate this, many existing roads will likely need to be upgraded.

For fisheries protection and restoration, the goal of road upgrading is to minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk and impacts of episodic erosion and sediment delivery when storms and floods occur.

Road upgrading or storm-proofing involves a variety of treatments designed to make a road more resilient to runoff from large storms and flood flows (Figure X-9 and Table X-5)(Weaver and Hagans 1999). The most important of these include upgrading stream crossings for the 100-year flood flow, elimination of stream diversion potential, removal of unstable sidecast and fill materials from steep slopes, and the application of drainage techniques to improve dispersion of road surface runoff. Newly constructed roads may not need as much corrective treatment as older roads. For example, timberland owners and foresters are now required by the Forest Practice rules, as amended by the California State Board of Forestry and Fire Protection in 2000, to design all new and reconstructed permanent watercourse crossings to accommodate an estimated 100-year flood flow, including wood and sediment loads. They are also required to design stream crossings such that there is no chance of future stream diversion.

Road Upgrading Treatments

In general, road upgrading consists of stream crossing upgrades, excavation of selected unstable or potential unstable fillslopes, and dispersion of road runoff (Figure X-9).

The following guidance, typical diagrams and tables summarize common road upgrading techniques, including road surface shaping (insloping and outsloping), berm removal, rolling dips, ditch relief culverts, and non-fish bearing culvert installation. For more detail, see *Handbook for Forest and Ranch Roads* (PWA 1994) or the corresponding video *Forest and Ranch Roads* (MCRCD 2003).

Treatment	Ideal Equipment	Sample Cost Rate[1]	Sample Application Rate and Assumptions	Sample Cost[2]
Outslope road and fill ditch	Grader with rippers	$85/hr	500ft/hr for 20' wide road	$170/1000 ft
Rolling dip	Dozer with rippers	$85/hr	1 hr each (30-40' long on flat roads) 2 hrs each (50-100' long on steep roads)	$85 - $170 each
Remove berm or clean ditch	Grader	$85/hr	1000'/hr (no trees on berm or in ditch)	$85/1000 ft
Rock road (1.5" minus crushed)	Dump truck spread	$17 – $40/ yd^3 - delivered	4" deep x 20' wide = 250 yds3/1000 ft road	$4,250 - $10,000/1000 ft
Install ditch relief culvert (assumes 40' of 18" culvert	Back hoe or Excavator[2] and Laborer	$65/hr $125/hr $30/hr	3 hours each + $8.50/ft + $18 coupler + $90 labor	$645 to $825 each
Stream crossing installation (36" x 40' culvert with 200 yd^3 fill)	Excavator Tractor Water truck and Laborer	$125/hr $85/hr $85/hr $30/hr	$1,520 culvert (w/coupler) + $875 excavator + $595 dozer + $170 water truck + $90 labor + $100 tamper	$3,270 each
Culvert downspout installation	Hand labor and Equipment (>24")	$30/hr $125/hr	20' x 24": 2 hrs labor 40' x 36": 3 hrs labor + 1 hr excavator	$60 + materials $375 + materials
Straw mulch bare soils areas	Labor	$30/hr $5/bale straw	1 bale/600 ft^2 - 700 ft^2 + spreading @ 4 bales/hr	$19-$22/1000 ft^2
Complete road upgrading	Excavator, Tractor and Dump trucks	$125/hr $85/hr $65/hr	Average mid-slope road requiring stream crossing upgrades	$15,000 - $40,000/mile

[1] Costs can vary considerably from these typical figures, depending on operator skill and experience, equipment types, local site conditions and regional location. Example costs are from 2004 data for north coastal California and are not based on prevailing wage rates. Production rate data from PWA (unpublished).

[2] Costs are variable depending on materials costs, equipment types and rental rates, and operator experience. Culvert cost assumptions (<= 24" - 16 gauge galvanized culvert, >=30" – 12 gauge galvanized culvert): 18" - $8.50/ft; 24" - $11.50/ft; 36" - $29/ft; 48" - $38/ft; 60" - $48/ft. Some treatments (e.g., outsloping road and filling the ditch) may be performed for different rates using tractor instead of grader. Dozer and dump trucks are often needed on culverted stream crossing installations larger than 200 cubic yards.

Table X-5. Example logistics and costs for a variety of upgrading task for forest and ranch roads.

Stream Crossing Upgrading

- Eliminate stream diversion potential by dipping the entire stream crossing fill or by installing a critical dip (Figure X-13). A critical dip is a rolling dip that is constructed on or close to the down-road hinge line of a stream crossing that displays a diversion potential.
- Upgrade stream crossings by installing culverts sized for the 100-year flood flow, including sufficient capacity for expected wood and sediment (Figure X-13 and Figure X-14). These requirements are determined by both field observation and calculations using a procedure such as the Rational Formula (PWA 1994; Dunne and Leopold 1978) for small watersheds (<100 acres), or regional regression equations developed for ungaged watersheds up to several hundred acres in size (Waananen and Crippen 1977; Cafferata et al. 2004).[2] Where necessary, install inlet protection (trash barriers) to prevent culvert plugging on non-fish bearing streams.
- Place culverts in line and on grade with the natural stream channel above and below the crossing site (Figure X-14). This minimizes the probability of culvert plugging. In streams with resident or anadromous fish, or where there is a requirement to provide for passage of non-fish aquatic species, culverts must be embedded in the natural stream channel according to specific guidelines (DFG Manual, Part IX). If non-fish stream crossing fills are exceptionally deep (beyond backhoe reach from the road surface) then a full round downspout can be installed to take the stream flow to the base of the fill and discharge it into the natural stream channel. At the point of return flow from the pipe to the natural stream channel, some form of energy dissipation and erosion protection may be required to control scour at the culvert outfall (Figure X-14).
- Replace large high-risk culverts with bridges. Consider replacing any culvert greater than 72 inches in diameter with a bridge, especially in Class 1 streams.
- Replace culverted fills with hardened fords or armored fills (Figure X-15 and Figure X-16) on non-fish bearing streams where regular winter inspections and culvert maintenance is not feasible, or on steep gradient stream crossings where the culvert plug potential will always be high.

<u>Stream Crossing Culvert Installation for Non-fish Bearing Streams</u>

- Align culverts with the natural stream channel orientation to ensure proper function, prevent bank erosion and minimize debris plugging problems.
- Place culverts at the base of the fill and at the grade of the original streambed or install a downspout past the base of the fill (Figure X-13 and Figure X-14). Down-drain (or downspout) assemblies should only be installed if there are no other options.

[2] Technical references for rainfall and runoff data include the California Data Exchange Center http://cdec.water.ca.gov, the Department of Water Resources http://wdl.water.ca.gov (under construction), the Department of Forestry http://cdf.ca.gov/projects/esu/esulooup.asp and the Western Regional Climate Center http://www.wrcc.dri.edu/summary/climsmnca. Software for performing peak flow calculations is also available (e.g., USGS Peak Frequency Software, http://water.usgs.gov/software/peakfq.html and USGS National Flood frequency Software, http://water.usgs.gov/software/nff.html

- Culverts should be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
- Culvert beds should be composed of rock-free soil or gravel, evenly distributed under the length of the pipe.
- Compact the base and sidewall material before placing the pipe in its bed.
- Lay the pipe on a well-compacted base. Poor basal compaction will cause settling or deflection in the pipe and can result in separation at a coupling or rupture in the pipe wall. If compaction is problematic, then the potential sagging after burial can be accounted for by maintaining an upward camber between 1.5 to 3 inches per 10 feet culvert pipe length.
- Backfill material should be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around the pipe.
- Cover one end of the culvert pipe, then the other end. Once the ends are secure, cover the center.
- Tamp and compact backfill material throughout the entire process, using water as necessary for compaction.
- Backfill compacting will be done in 0.5 – 1.0 foot lifts until 1/3 of the diameter of the culvert has been covered (Figure X-14). A gas powered tamper or sheep's foot roller should be used for this work.
- Armor inlets and outlets with rock, or mulch and seed with grass as needed (not all stream crossings need to be armored).
- Install a trash rack (only on non-fish bearing streams) upstream from the culvert inlet where there is a high hazard of floating debris plugging the culvert.
- Push layers of fill over the crossing to achieve the final design road grade, at a minimum of one-third to one-half the culvert diameter.

Trash Racks

All trash racks require on-going maintenance. Two efficient trash rack designs include:

- On streams with culverts 48 inches diameter or greater, build a grate or sieve across the entire channel to collect the large material that would otherwise plug the culvert inlet. Locate the trash rack anywhere from five to 25 feet upstream from the culvert inlet.
- On streams with culverts under 48 inches diameter, set a single post vertically in the steam bed, centered directly upstream from the culvert inlet, and located one culvert diameter distance upstream from the inlet. Size the post and set the post deep into the streambed to withstand the size of woody debris transported by the stream during extreme runoff events.

<u>Ten steps to building an effective armored fill stream crossing</u>

Install armored crossings (Figures X-15 and X-16) in areas where debris torrents are common, can be expected or where small steep gradient streams cross the road. Armored fill crossings are for sites where it will be very difficult to prevent frequent culvert plugging due to high amounts of transported sediment and debris. The treatment requires excavating a portion of the fill in the stream crossing and leaving a very broad dip in the axis of the natural channel, with long and gently sloping ramps into and out of the stream crossing. This treatment may be most appropriate along roads built on a floodplain and terrace, or where roads cross steep gradient stream channels with relatively small depths of fill at the outboard edge of the road.

Before prescribing or building an armored fill, make sure the site is appropriate for the structure. Evaluate the suitability of the site for an armored fill, making sure the stream is not too big and the fill is not too deep. The stream should be a relatively small Class 2 or Class 3 stream (a fish-bearing Class 1 in not appropriate) and the fill depth at the outside edge of the road should not exceed about six (6) feet in depth. Once the site is determined to be potentially suitable, there are ten basic steps to converting the stream crossing to a stable armored fill.

1) Evaluate design and construction requirements - The four most important concepts to understand when constructing an armored fill are: a) constructing a broad and deep rolling dip through the road where the stream is to cross, b) excavating a keyway in the outer half of the roadbed, down the fillslope and across the toe of the fillslope to hold the rock armor, c) selecting rock armor that is suitably sized to resist transport by the stream during design flood flows, and d) placing the rock armor. Proper shaping of the excavated road fill, proper armor sizing, and good armor placement will reduce the likelihood of crossing failure.

The rock must be placed in a broad “U” shaped excavation across the channel and the roadbed so that the streamflow will always stay confined within the armored area; even during the 100-year design flood flow. If the flow gets around (outside) the rock armoring on the road surface or on the armored fillslope, it will quickly gully around and through the remaining road fill.

A range of interlocking rock armor sizes should be selected and sized so that peak flows will not pluck or transport the armor off the roadbed or the sloping fill face of the armored fill (e.g., see Racin et al., 2000). There are two key places where rock size and rock placement is critical: 1) at the base of the armored fill where the road fill meets the natural channel and 2) at the break-in-slope between the outer roadbed and the upper fill face. The largest rocks must be used at the toe to support or buttress the armor placed on the fillslope above it. This will provide toe support for the rest of the armor and reduce the likelihood of it washing downslope. Armor placed at the slope break at the top of the fillslope is also critical in that it will provide the stable “base level” for the creek as it crosses the road surface and accelerates down the fill face.

2) Remove drainage structures - Remove any existing drainage facilities in the fill, including culverts and Humboldt logs or large organic debris in the stream crossing fill (Figure X-16; cross sections A-B).

3) Dip the roadbed - Construct a broad rolling dip across the roadbed, centered at the crossing, which is large enough to contain the expected 100-yr flood discharge while preventing flood flow from diverting down the road or around the rock armor (Figure X-16; cross sections C-D; E-F). For many crossings, the broad dip typically averages two to three feet deep along the “thalweg” or axis of the dip.

4) Excavate the keyway and armored area - Excavate a two to three foot deep “bed” into the dipped road surface and adjacent fillslope (to place the rock in) that extends from approximately the middle of the road, across the outer half of the road, and down the outboard road fill to where the base of the fill meets the natural channel. Peak flow calculations for the 100-year discharge (e.g., using the rational formula) should be performed to determine the proper width of the armored area through the roadbed and on the fillslope. Typically, for small Class 2 and Class 3 channels, the required armored width at the outside edge of the road has been found to be at least five times the estimated peak flow width of the natural channel upstream of the crossing. At the base of the fill, excavate a three (3) foot deep keyway trench extending across the channel bed (Figure X-16; cross sections G-H; I-J).

5) Install fabric lining - Install geo-fabric within the trenched keyway at the toe and extending up the excavated fillslope and across the excavated part of the roadbed; anywhere rock armor is to be placed (Figure X-16; cross sections G-H). Bury the top of the fabric in a trench across the roadbed to key in the fabric. The fabric will support the rock armor in wet areas and prevent winnowing of the fine sediments and road fill beneath the rock armor when the stream flows over the armored fill.

6) Armor the basal keyway - Put aside the largest rock armoring to create two buttresses. Use the largest rock armor to fill the basal trench and create a buttress at the base of the fill. This should have a “U” shape to it and it will define the outlet where flow leaves the armored fill and enters the natural channel (Figure X-16; cross sections K-L).

7) Armor the fill - Backfill the fill face with the remaining rock armor making sure the final armor is unsorted and well placed, the armor is two coarse-rock layers in thickness, and the armored area on the fill face also has a “U” shape that will accommodate the largest expected flow (Figure X-16; cross sections K-L).

8) Armor the top of the fill - Install a second trenched buttress for large rock at the break-in-slope between the outboard road edge and the top of the fill face. The level of the armor rock placed in this “buttress” at the top of the fill face will define the base level of the stream as it crosses the roadbed (Figure X-16; cross sections M-N).

9) Armor the roadbed - Backfill the rest of the roadbed keyway with the unsorted rock armor making sure the final armored area on the roadbed has a “U” shape (Figure X-16; cross sections O-P) that will accommodate the 100-year design flood flow.

10) Inspect and maintain the crossing - Monitor the armored fill for the first several winters and make maintenance repairs to any armor that may have moved during peak flow periods. Maintain the flood flow capacity of the armored fill on the roadbed (Figure X-16; cross sections O-P) by grading alluvial deposits and debris off the road as needed.

Erosion Control Measures for Culvert Installation

Use a combination of mechanical and vegetative measures to minimize accelerated erosion from stream crossing and ditch relief culvert installation. Erosion control measures may include:

- Minimizing soil exposure by limiting excavation areas and heavy equipment disturbance.

- Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to down slope areas and stream channels.
- Insloping the road prism at newly constructed or upgraded stream crossings to minimize fillslope erosion caused by road runoff.
- Protecting bare slopes created by construction operations until vegetation can stabilize the surface. Minimize surface erosion on exposed cuts and fills by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first fall rains.
- Storing extra or unusable soil in long-term spoils disposal locations that are not subject to excessive moisture, steep slopes, archaeological sites, listed species, or proximate to a watercourse.
- If there is running or standing water, pumping or diverting water past the crossing and into the downstream channel during the construction process.
- Installing straw bales and/or silt fencing where necessary to control runoff and sediment movement within the construction zone.

Excavation of Unstable Fillslope

Remove unstable sidecast and fill materials from steep slopes (Figure X-17), steep headwater swales, and along road approaches to deeply incised stream channels, where there is potential for sediment delivery. Worker safety in potentially hazardous areas, where slopes are steep, wet and potentially unstable, must be in conformance with applicable worker safety regulations (e.g., see Caltrans 1990).[3]

- Excavate small volumes of unstable fill along the outside edge of the road, turnout or landing if it has the potential to fail and be delivered to a stream channel.
- Unstable fill that has little or no potential to fail or be delivered to a stream need not be excavated if fish habitat protection is the only goal.
- Excavate fill material in an arc-shaped downslope profile, so as to remove as much of the unstable mass as is possible.
- Store excavated spoil materials in a location where eroded sediment will not enter a watercourse.

[3] Wherever workers have to enter an area where the banks or cuts are greater than five feet in height (functionally a trench), the banks of such areas will need to be properly sloped, benched, or shored (trenching needs to be in compliance with all applicable worker health and safety regulations including but not limited to sections: 29, the Code of Federal Regulations (CFR) 1926.650, 601 (b)(6) of and Title 8, Sections: 1540, 1541, 1541.1 of the California Code of Regulations.

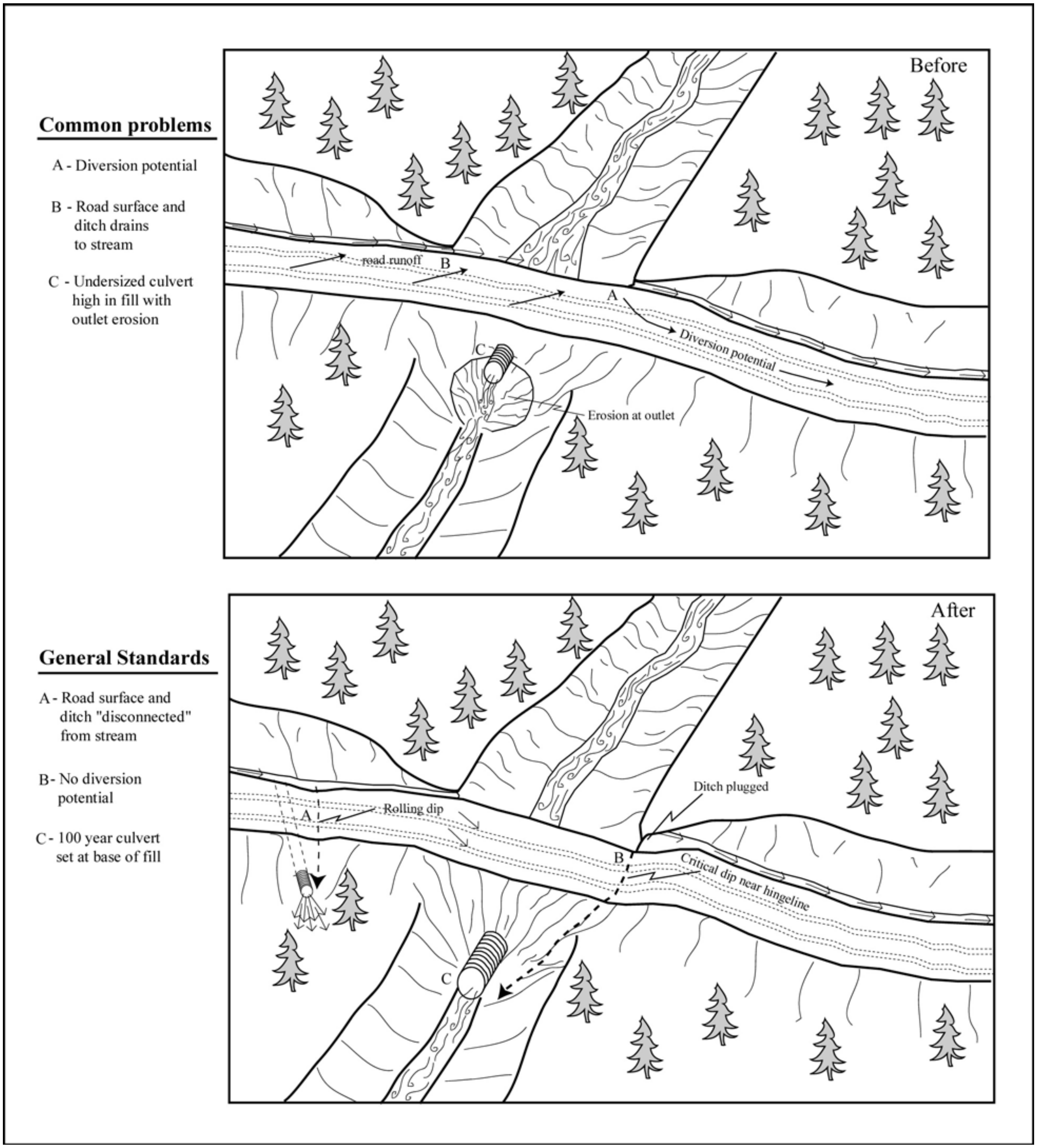


Figure X-13. Typical upgraded stream crossing.

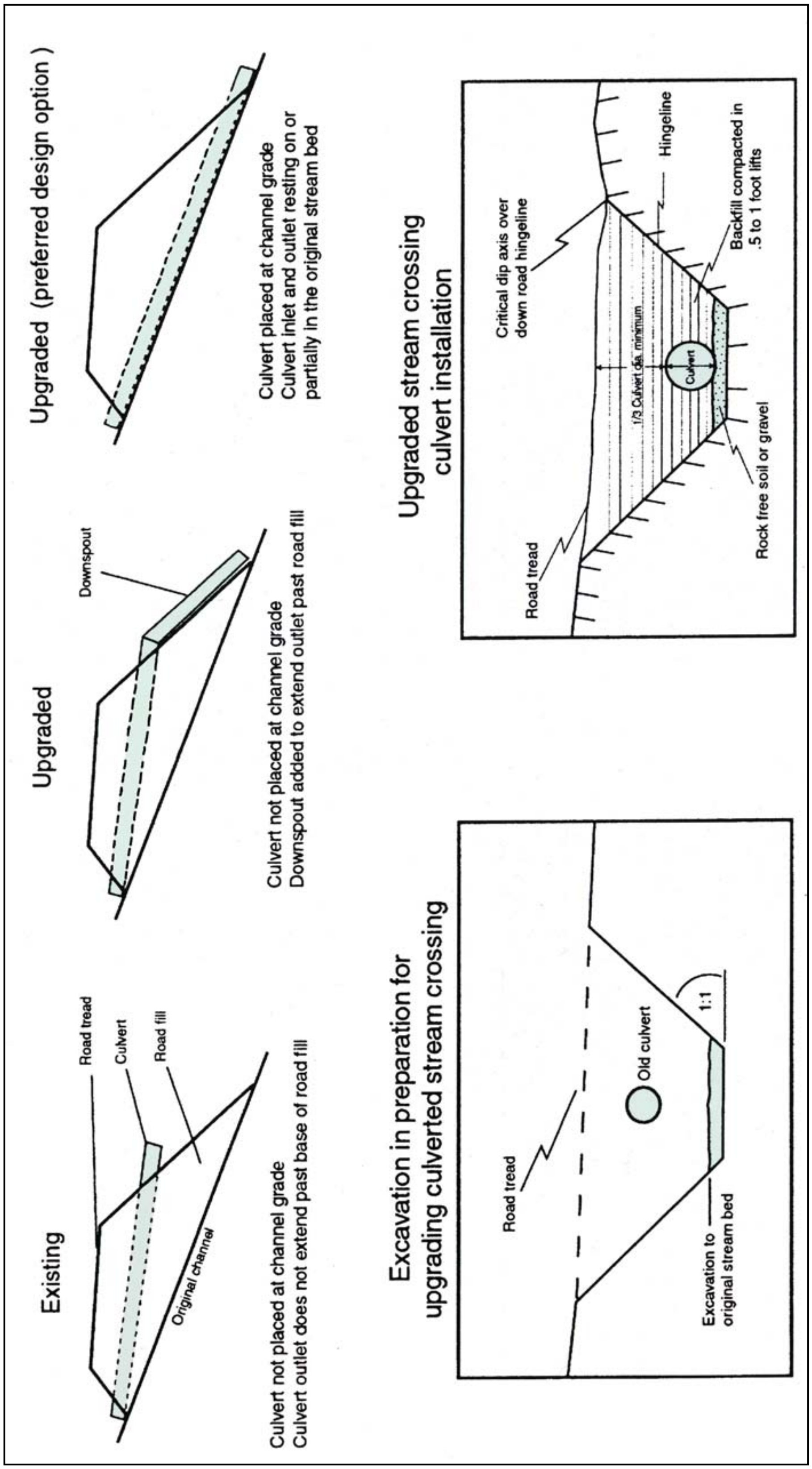


Figure X-14. Typical culvert installation on non fish-bearing streams.

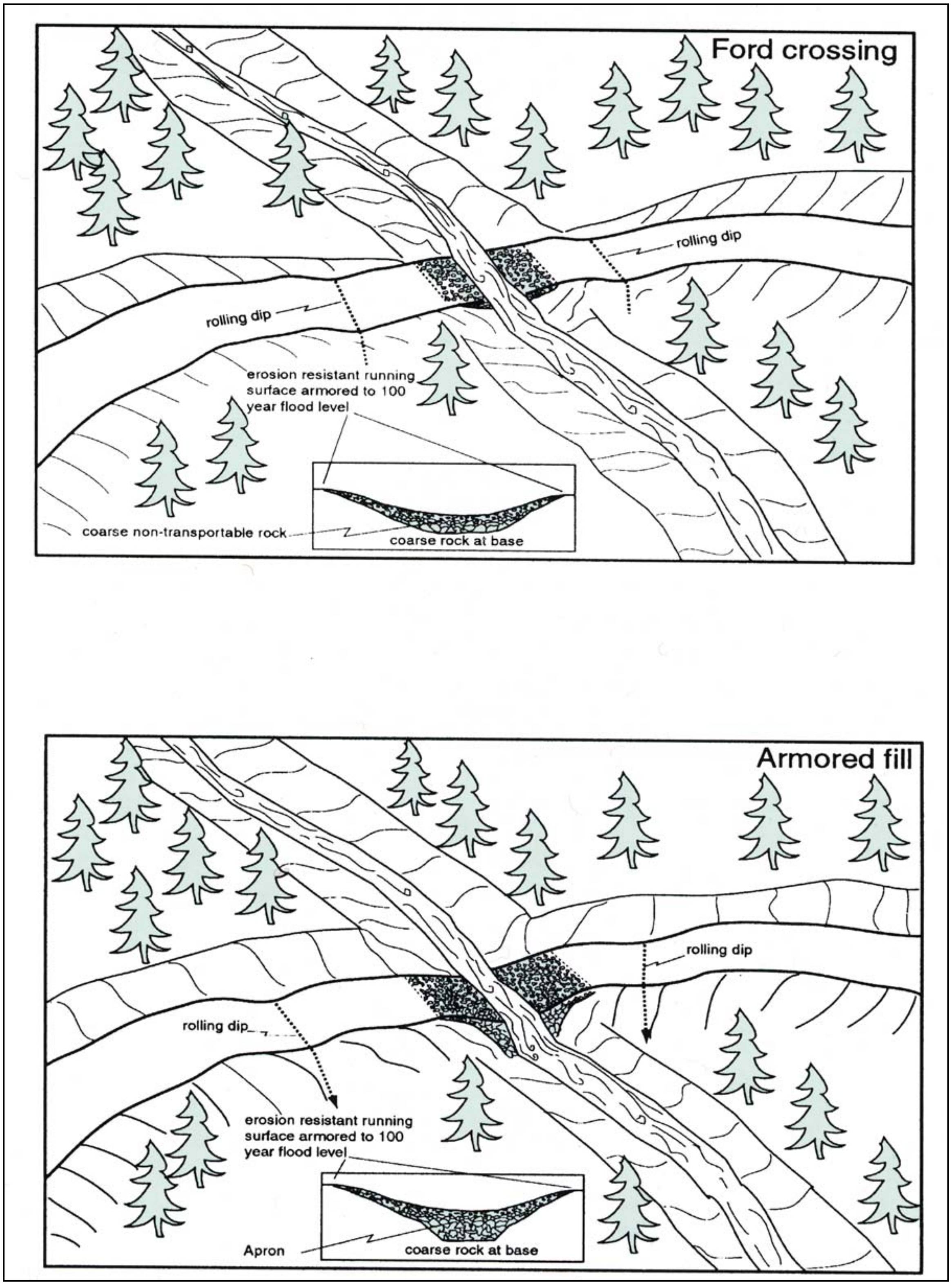


Figure X-15. Typical ford and armored fill stream crossings.

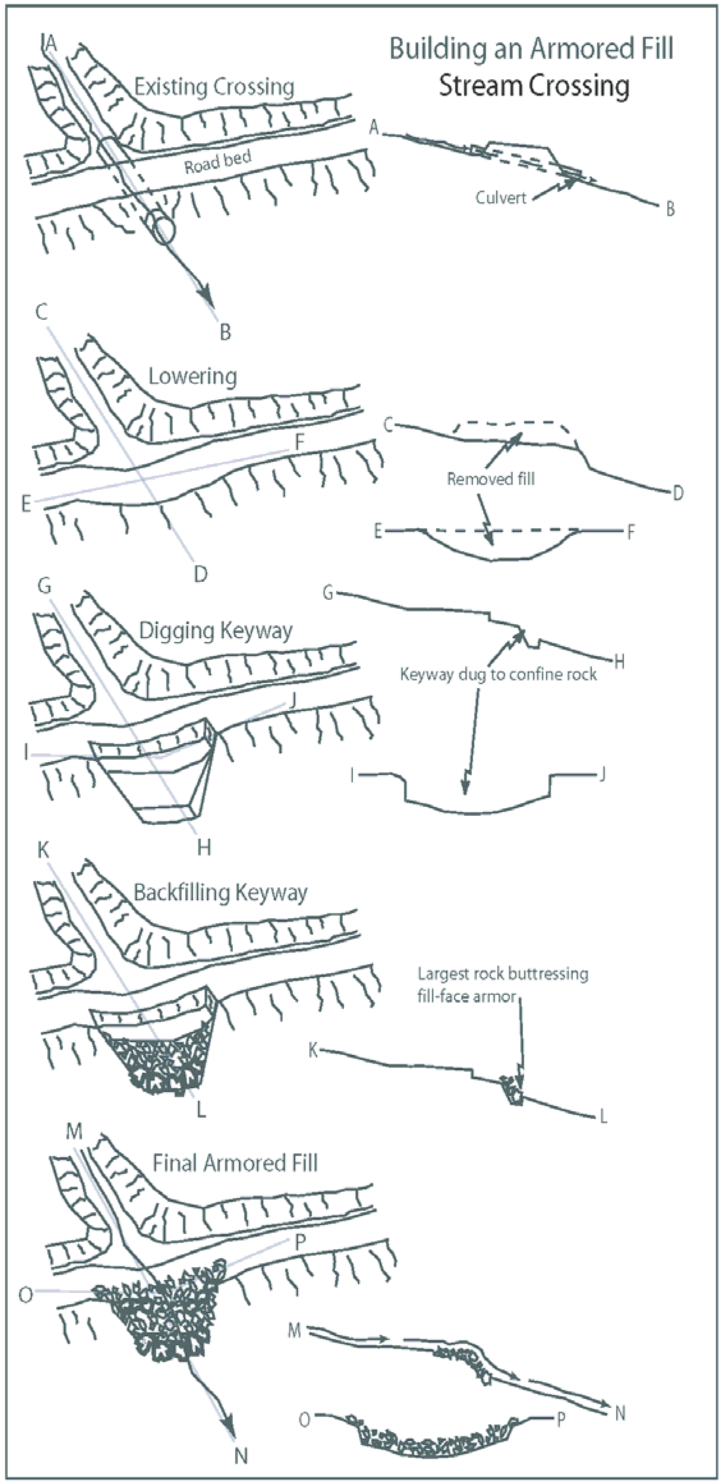


Figure X-16. Design elements of a typical armored fill crossing. Note: where geotextile fabric may interfere with passage of amphibians in any Class 2 or 3 crossing, bury geotextile fabric with at least 6 inches of rock. Do not expose geotextile fabric in the bed of fish-bearing stream channels.

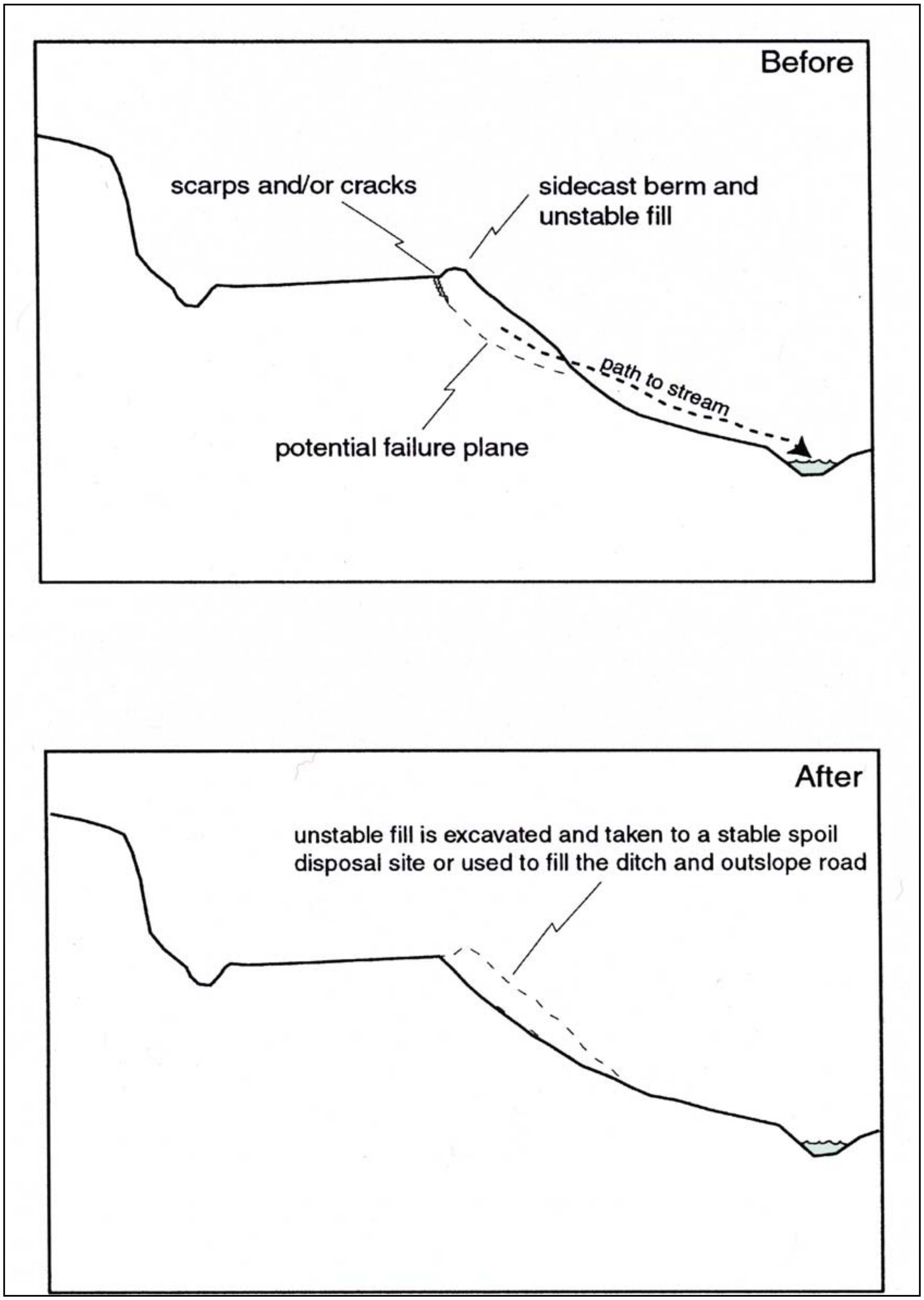


Figure X-17. Removal of unstable sidecast materials.

Dispersion of Road Runoff

Disperse and disconnect road surface runoff from streams. Road cutbanks and road ditches are known to deliver substantial volumes of fine sediment to streams in some watersheds (e.g., Reid 1981; Reid and Dunne 1984) and they have been found to significantly affect watershed hydrology (Wemple 1994). Relatively simple treatments can be performed to upgrade road drainage systems to significantly reduce or largely eliminate this source of fine sediment delivery to streams. Sediment may be minimized by utilizing seasonal closures or traffic restrictions, and dispersing road runoff. Choose from a variety or combination of surface drainage techniques including berm removal (Figure X-19), water bars (Figure X-10), road surface shaping (outsloping, insloping or crowning (Table X-6), ditch relief culverts (Figure X-19), rolling dips (Figure X-19), and other measures that effectively disperse road surface runoff and reduce or eliminate sediment delivery to the stream. To be effective, they must effectively disperse most road runoff and ditch flow before it reaches the stream. It is critical that all road surface drainage techniques effectively drain the road surface and be drivable for the expected traffic.

Spring and seeps along the road may occur in the roadbed or on the inside cutbank. Drain these sources of emergent groundwater to minimize damage to the road bed and to control sediment delivery to local stream channels. Drain roads with common or high volume springs with frequent ditch relief culverts. Culvert spacing must be close enough to prevent downslope gully erosion or hydrologic connectivity to nearby streams. Drain emergent water from the roadbed using such techniques as French drains and drainage blankets.

Road Shaping (outsloping, crowning and insloping)

- Where suitable and appropriate, road outsloping is the preferred method of road shaping for protecting water quality and minimizing fine sediment delivery to streams.
- Outsloped roads drain their surface runoff to the outside edge of the roadbed and onto the fillslope (provided there is no berm) (Figure X-19). The degree of outslope is typically at least 2% for low gradient roads (<4%) but increases as road grade increases (Table X-6), with consideration for driver safety.
- Outsloped roads may or may not have an inside ditch. If the cutbank is wet or has springs during part of the year, a ditch will be necessary to drain emergent water to a ditch relief culvert or rolling dip.
- Insloped roads can be converted to outsloped roads in several ways. If there is no spring flow in the ditch and the ditch can be filled, the insloped road can be ripped and regraded with the spoil material generated on the outside half of the road being used to fill the ditch and provide the outslope shape to the roadbed. Alternatively, fill can be imported to fill the ditch and outslope the roadbed. If an inside ditch needs to be maintained, because emergent groundwater and seeps are present along the cutbank, either of these construction techniques can be used to outslope the roadbed without filling the ditch.
- Crowned roads drain both to the outside of the road onto the fillslope, as well as to the inside of the road into a ditch (Figure X-19).
- The crown or high spot in the road cross section is often the center of the road, but it can be shifted towards the inside third of the road decrease the amount of road runoff that is delivered to the ditch.
- Steep roads (greater than about 14%) are difficult to drain, so crowned road shapes are sometimes employed to improve road drainage and to increase vehicle safety. However, it

is imperative that an appropriate number of ditch relief culverts and/or rolling dips be used to drain the ditch on steep roads.

- Insloped roads are used where water cannot be discharged over the outside fillslope because of soil erodibility, fillslope instability or potential water quality problems, or where cutbanks are very unstable (Figure X-19).
- Insloped road surfaces typically slope at 3% to 4% towards the ditch, but the degree of inslope will increase as the grade of the road increases in order to drain road runoff into the ditch (Table X-6).
- Insloped roads need a ditch to carry road runoff and spring flow from the cutbank and from upslope areas to the nearest ditch relief culvert or rolling dip where it can be discharged to the hillslope.
- Insloped roads with ditches are one of the most common ways in which roads are hydrologically connected to streams in a watershed. Thus, to the maximum extent possible, insloped roads should be frequently drained onto the hillslope, using ditch relief culverts or rolling dips, where runoff will not enter a stream channel.

Outsloping pitch for roads up to 12% grade		
Road Grade	**Outslope Pitch for Unsurfaced roads**	**Outslope Pitch for Surfaced Roads**
4% or less	3/8” per foot	1/2” per foot
5%	1/2” per foot	5/8” per foot
6%	5/8” per foot	3/4” per foot
7%	3/4” per foot	7/8” per foot
12% or more	1” per foot	1/4” per foot

Table X-6. Outsloping pitch for roads up to 12% grade.

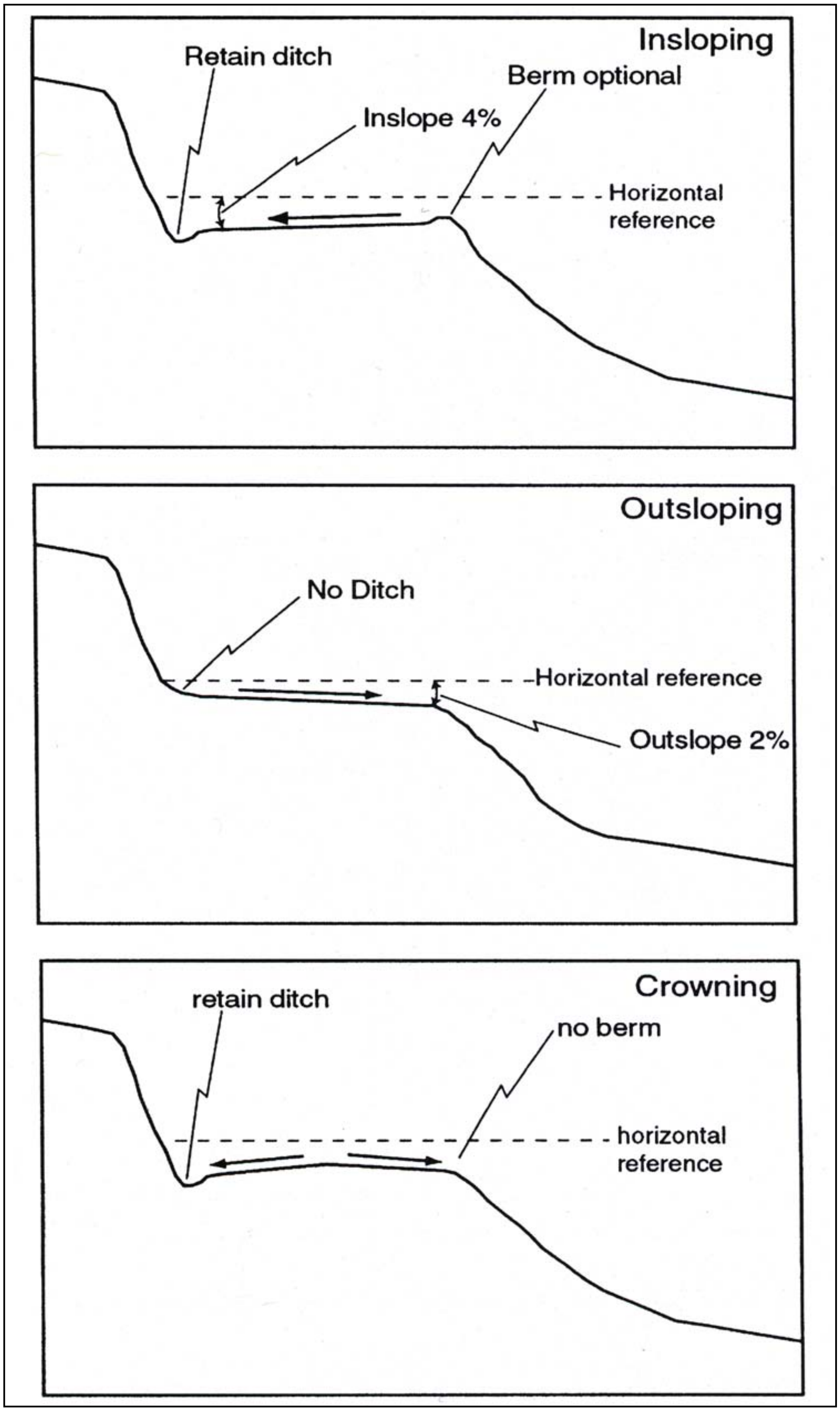


Figure X-18. Utilizing road shape to reduce surface runoff rates.

Berm Removal

- Road berms on insloped roads do not affect road drainage and can usually be left in place with little negative effect.
- Berms located along the outside edge of a crowned or outsloped road prevents road runoff from leaving the roadbed. This often results in roadbed erosion or gully erosion where the concentrated runoff is discharged off the road.
- On steep gradient roads, berms are sometimes used as a real or perceived safety measure to keep vehicles from sliding off the road. In other places, berms are sometimes intentionally used to keep road runoff from discharging onto an erodible, unstable or potentially unstable fillslope. Some berms are simply the end-product of years of grading that have left a continuous or discontinuous berm of road grader spoil material along the outside edge of the roadbed, so that the grader operator can use it to pull back onto the roadbed during future maintenance work.
- Berm breaks are locations where the berm is not intact and road runoff is allowed to discharge onto the slopes below the road. The runoff from berm breaks can be discharged directly onto the fillslope or directed into a culverted or sheet metal berm drain that is used to carry the runoff some distance downslope or to the base of the fillslope (Figure X-19).
- If they are not needed, or if they are causing road drainage and erosion problems, road berms on crowned and outsloped roads can be either partially or completely removed. On low gradient roads, berms can often be completely removed. On steeper roads, where safety is an issue, the berm can be frequently breached with short gaps spaced 30 to 100 feet apart. A semi-continuous berm is thereby left for safety reasons and the road is frequently drained (Figure X-19).
- Depending on the slope steepness and proximity of the road to a stream, berms can be removed by excavation or sidecasting. Sidecasting should not be used if there is a possibility that spoil or eroded sediment could enter a watercourse.

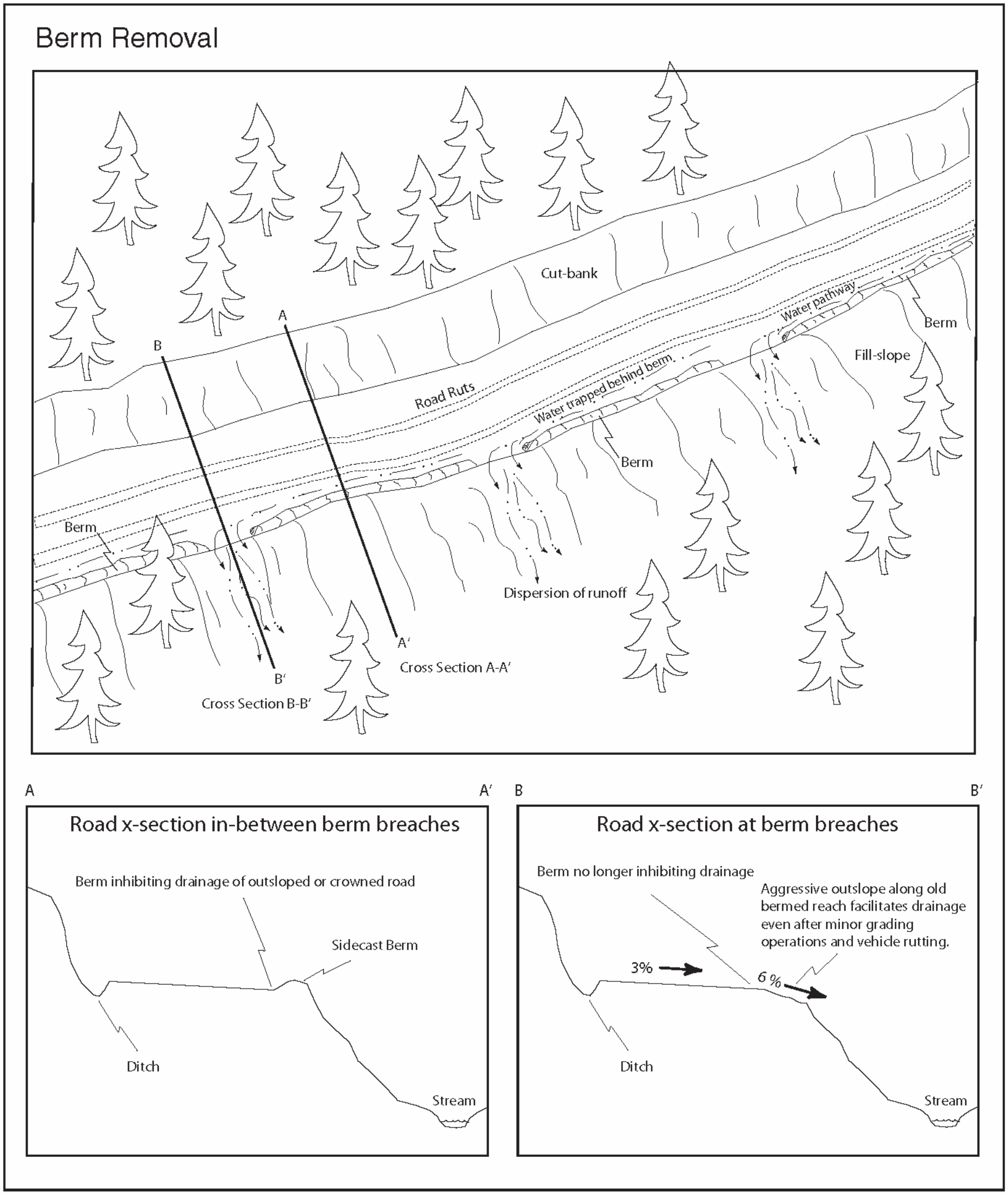


Figure X-19. Berm removal for improved drainage on outsloped and crowned roads.

Ditch Relief Culverts

- Install ditch relief culverts at an oblique (typically 30 degree) angle to the road so that ditch flow does not have to make a sharp angle turn to enter the pipe (Figure X-20). On low gradient roads (<5%), where ditch flow is slow, ditch relief culverts can be installed at right angles to the road.
- Install ditch relief culverts (DRC) to outlet at, and drain to, the base of the fill (preferred option) (Figure X-20).
- If it cannot be installed at the base of the fill, install the DRC with a grade steeper than the inboard ditch draining to the culvert inlet, and then install a downspout on the outlet to carry the culverted flow to the base of the fillslope (Figure X-20).
- Downspouts longer than 20 feet should be secured to the hillslope for stability. Full round downspouts are preferred over half-round downspouts.
- Ditch relief culverts should not carry excessive flow such that gullying occurs below the culvert outlet. Use field evidence and culvert spacing tables (e.g., PWA 1994) to provide guidance on proper culvert spacing along upgraded roads.
- Do not discharge flow from ditch relief culverts onto unstable or highly erodible hillslopes.
- If the ditch is on an insloped or crowned road that is very close to a stream, consider using outsloping to drain the road surface. The ditch and the ditch relief culvert would then convey only spring flow from the cutbank, and not turbid runoff from the road surface.

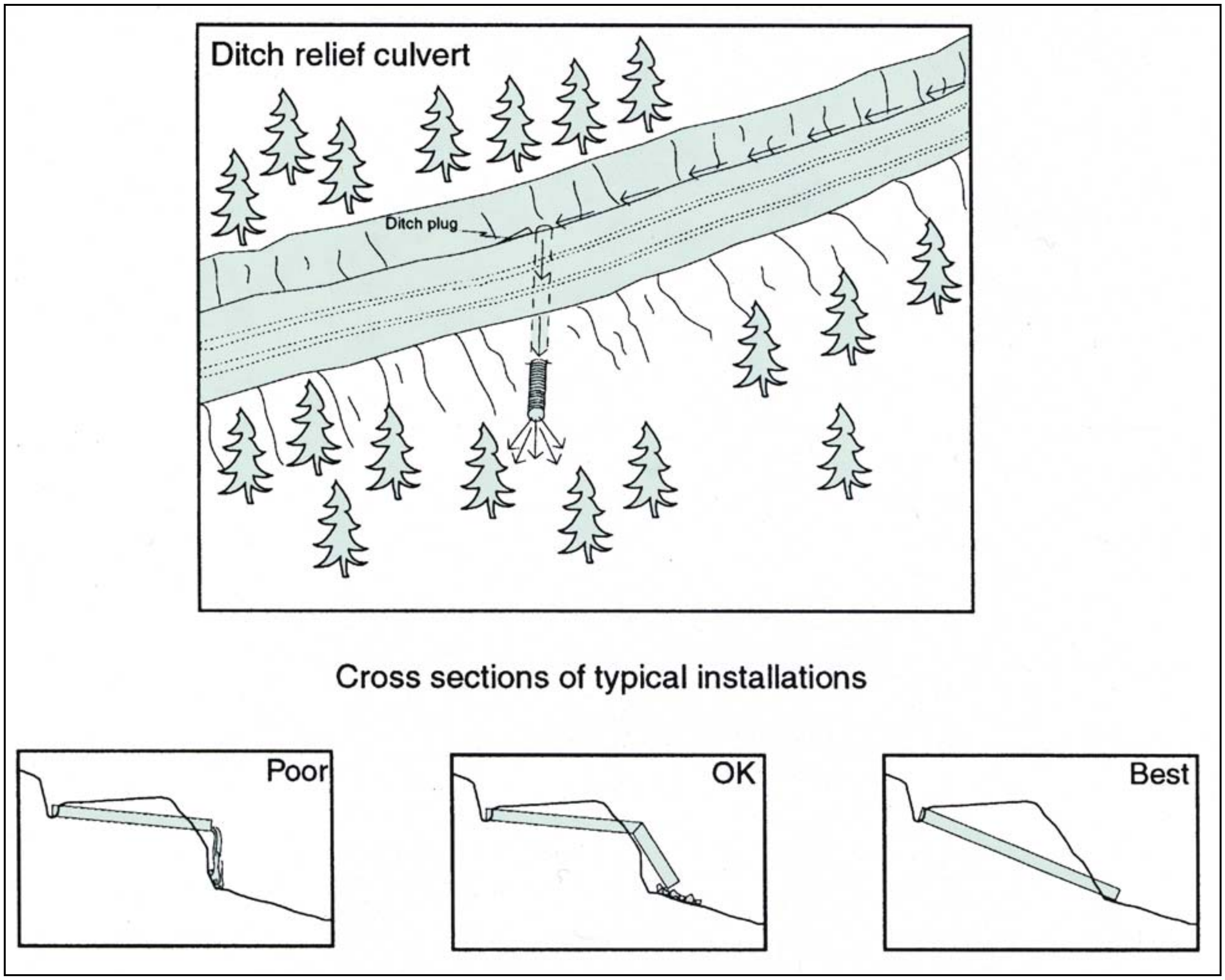


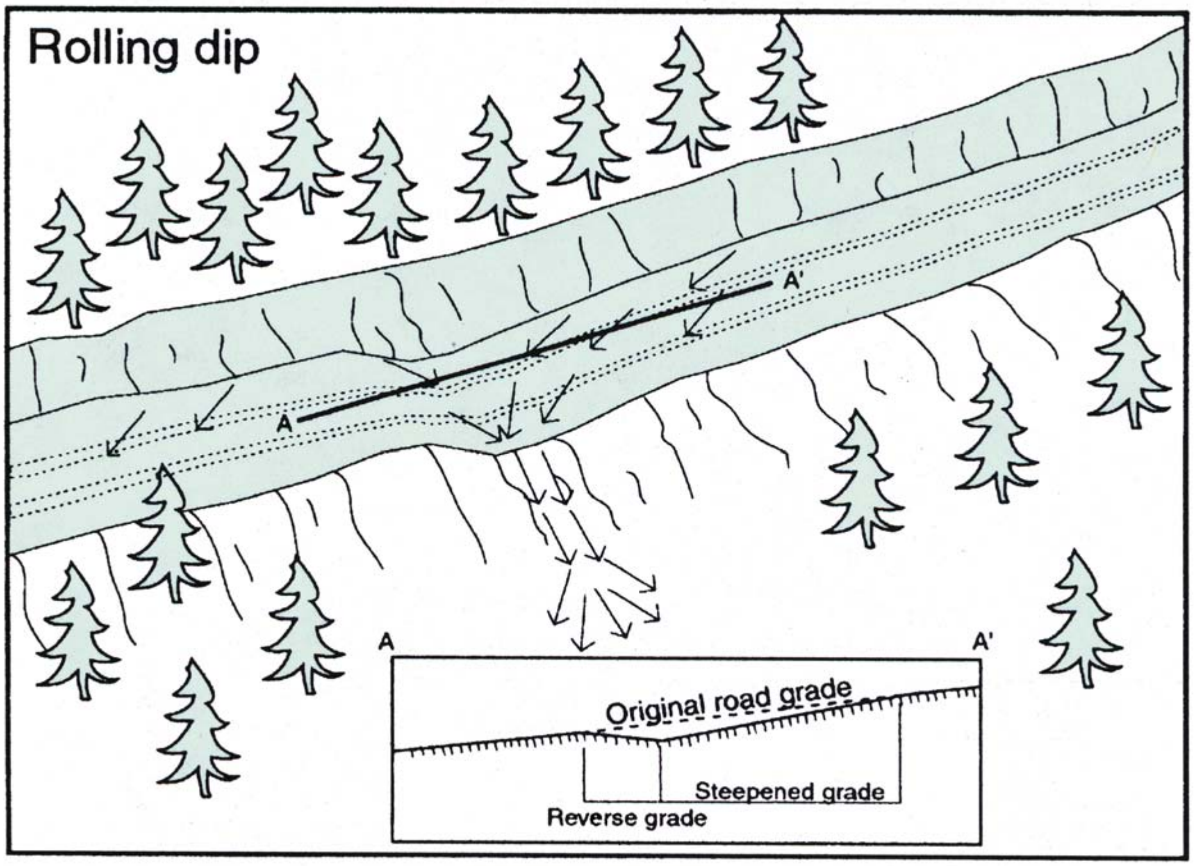
Figure X-20. Typical ditch relief culvert installation.

Rolling Dip Installation

- Install rolling dips in the roadbed as needed to drain the road surface. Rolling dips can be sloped either into the ditch (use sparingly) or to the outside of the road edge (preferred design) as required to properly drain the road and disperse surface runoff.
- Rolling dips should be located frequently enough to prevent erosion on the hillslope below the road and placed where they will not cause instability or gullying. To the extent that they can be, outboard sloping rolling dips should be coincident with natural drainage swales that are well-vegetated. They will likely need to be constructed at many other locations as well.
- Do not discharge rolling dips or ditch relief culverts into swales that show signs of instability or active landsliding.
- If the rolling dip is designed to divert both road surface and ditch runoff, block the down-road ditch with compacted fill. Ditches that carry a large volume of spring flow should probably be drained using ditch-relief culverts rather than rolling dips.
- Rolling dips are usually built directly across the road alignment with a cross grade at least one percent greater than the grade of the road (so that it will drain).
- Excavate the rolling dip with a medium size bulldozer (D-7 size) with rippers or with a grader.
- Begin excavation of the dip approximately 50 to 100 feet up-road from the proposed axis of the dip (Figure X-19). Progressively excavate material from the roadbed, with the grade becoming steeper, until reaching the axis (Figure X-21).
- Determine the depth of the dip, by the grade of the road (Figure X-19). In all cases, rolling dip dimensions must be consistent with the type of vehicles that will be using the road (Figure X-21).
- On the down-road side of the rolling dip axis, install a grade change to prevent runoff from continuing down the road. Carry the rise in grade for about 15 to 25 feet, or more, and then fall back to the original slope (Figure X-21). The axis of the dip must be a broad “u” shape to facilitate good driveability.
- In all cases, the rolling dip must be driveable and not significantly inhibit traffic and road use. It must also effectively drain the road surface.

Road grade %	Upslope approach (distance from up-road start of rolling dip to trough) (ft)	Reverse grade (distance from trough to crest) (ft)	Depth below average road grade at discharge end of trough (ft)	Depth below average road grade at upslope end of trough (ft)
<6	55	15-20	0.9	0.3
8	65	15-20	1.0	0.2
10	75	15-20	1.1	.01
12	85	20-25	1.2	.01
>12	100	20-25	1.3	.01

Table X-7. Table of rolling dip dimensions.



Note: Rolling dips must drain the road surface and be driveable for the expected traffic.

Figure X-21. Use of rolling dips to reduce ditch erosion and surface runoff.

Upslope Restoration Treatment Production Rates

Upslope restoration treatments consist of both heavy equipment and manual labor tasks. Heavy earth moving tasks, such as landslide excavations and road upgrading or decommissioning, often entail 80% to 95% of the total project costs. Upslope restoration project manual labor consists of such tasks as: culvert installation, installation of trash racks and culvert downspouts, flared inlet assembly and installation, gully control, stream bank protection, planting, seeding and mulching. On individual sites, there is generally a mix of heavy equipment and manual labor work.

Heavy Equipment Guidelines

Restoration involving heavy earth moving equipment can involve a wide range of equipment types. The key is to match the size of the equipment with the size of the job. If the job requires extensive excavation, large equipment can move greater amounts of material faster than smaller equipment for an overall cost saving, even though hourly cost rates are higher. If space or excavation volumes are limited, smaller equipment will be most cost-effective. The three most commonly used equipment types for road restoration are:

- Hydraulic excavator, with 1.5 to 3 yd^3 bucket and thumb;
- Crawler tractor (D5, D6, or D7 size, with hydraulic rippers and a U-blade, 3-way blade or 6-way blade);
- Dump truck (10 yd^3).

Other equipment frequently used on upslope restoration projects include backhoes, road graders, front-end loaders, compactors, water trucks, tractors with a winch, D-8 sized tractors and 20-30 yd^3 off-highway dump trucks.

Safety

A complete discussion of worker safety requirements, including those for laborers and equipment operators, is beyond the scope of this document. However, common sense practices and basic accident prevention techniques are required of all contractors, workers and supervisory personnel on a restoration project site. Safety should be the prime consideration on all jobs. Equipment operators know their personal limitations and strengths, and supervisory personnel should not request operators to perform tasks that are beyond their ability or comfort level. Department of Fish and Game grants contain specific provisions regarding required safety measures that must be followed during the conduct of State grants. Among others, these include:

- Pre-work safety sessions and grant requirements
- Development of a workers safety plan in case of accidents including appropriate first aid kits, ear plugs for work around heavy equipment, hard hats, high visibility clothing or safety vests, and appropriate field clothing and protective gear
- Fire safety plan; charged and appropriately sized fire extinguishers, emergency fire fighting hand tools (like a Pulaski fire axe), and spark arrestors on heavy equipment (or require turbo charged machinery)
- Equipment oil and fuel spill prevention plan and spill response kits
- Communication tools, including CB radios for travel on back roads to and from the work site and development of pre-determined hand signals during equipment operation

It is also recommended that erosion control practitioners have basic training and certifications in first aid and cardiopulmonary resuscitation (CPR). Specialized training in swift water rescue (for work on larger streams), wildland firefighting, emergency medical technician and confined space awareness (for trenches and culverts) can also be useful for some projects and personnel.

Equipment Production Rates

Most upslope restoration involves some type of excavation work. Excavation is involved in some types of landslide treatments, culvert installations and culvert replacements, and stream crossing installations for road upgrading, as well as decommissioning tasks such as stream crossing excavations, road outsloping, and excavations associated with road fill failures. Listed below are example production rates used to estimate job times and costs. Production rates include all work associated with excavations, not just digging dirt. Adjust time according to actual excavator production rates.

<u>Stream Crossing Excavations</u>
Excavator with 1.5 yd^3 bucket and thumb:

- Direct excavating of soil, 50 – 75 yd^3 per hour;
- Excavating extensive organics (such as Humboldt stream crossings) or excavating complicated long, deep and/or steep crossing fillslopes, 35 – 50 yd^3 per hour.

<u>Sidecast Fill Excavations</u>
Excavator with 1.5 yd^3 bucket and thumb:

- For clean sidecast dirt, 100 -120 yd^3 per hour;
- For sidecast with extensive organic debris or if many trees exist to work around, 50 - 100 yd^3 per hour.

Compaction

Proper compaction is very important in a variety of restoration project activities including: culvert installation, armored fills, rolling dips, and development of spoil disposal sites. Compaction during the dry summer months, when most restoration work is accomplished, will likely require the use of water trucks and artificial wetting of dry soil materials.

Pumping and Flow Diversion

Project work in live streams requires that the work site be dewatered and flow diverted around the site when equipment is working. Dewatering is performed to keep soils and excavated materials as dry as possible during work activities, and to reduce the potential for causing excessive erosion and downstream water quality impacts. If streams in the project area are live (flowing) delay instream work until the last possible moment, so that flows have dried up or are at a low point for the season. It is always best to work in dry streambeds.

Dewatering can be accomplished on small streams by diverting flow around the project site. Flows can be diverted with pumps or passive (gravity) systems such as side channels, constructed canals, or flexible pipe. Flow diversions require careful consideration of the backwater effects on diversions, pump capacities, diversion-channel capacities, and the need for temporary erosion protection to prevent scour at the point where the water is returned to the natural channel downstream of the project site.

On larger streams, coffer dams can be used. Cofferdams are temporary watertight dams that may be used to impound the flowing water so that it can then be diverted around the project site. Coffer dams can be constructed by excavating into the alluvial stream bed (to capture both surface flow and intergravel flow) or by building a small dam to block flow in the channel. The diverted flow is then returned to the natural stream channel downstream of the work site.

Regardless of the technique employed, dewatering systems should be able to divert the one-year flows anticipated during the period of construction (i.e., the greatest flow with a 100-percent chance of occurring during the construction period). The possibility that the system will be overwhelmed by storm flows should also be planned for in the dewatering design.

In Class 1 streams, install screens upstream and downstream of the affected reach, then have a qualified fisheries biologist remove all fish and amphibians, prior to initiating flow diversions and dewatering. Similarly, a plan must be in place to recover any fish that might be left behind when the water is gone. Contact the Department of Fish and Game prior to initiating flow diversions in Class 1 streams. Dewater streams by gravitational diversion of stream flow in flexible pipes, or by using gas-powered pumps that can lift water out of and around the work site. Unless the stream reaches have been isolated and cleared of fish, pumps used in fish-bearing streams will require screens designed to DFG and NMFS specifications to prevent loss of fish. Whenever pumps are used, backup pumps and hoses should be available on-site in case of equipment breakdown. Pumps require on-site management; if pumps will be used only during the standard work week, then a plan for gravity diversions during nights and weekends will need to be in place until the site work is completed.

Specifically designate personnel to monitor and maintain each site diversion so as to minimize the potential for construction-related sediment releases. Limit diversions to the dry season operating period (before October 15) and only install diversions when weekly weather forecasts do not call for rain. Install silt fences, straw bales or other flow-filtering measures in the channel to reduce turbidity and suspended sediment when flow is reestablished through the work site. Strictly follow all requirements listed in the DFG 1600 Streambed Alteration Agreement for each site.

Mulching, Seeding, Planting

Cost-effective labor techniques include mulching, seeding and planting. Completely cover bare soil areas where surface erosion may deliver sediment to a stream with mulch, such as weed free straw. Rates of about 4,000 pounds per acre, or approximately 50 bales/acre of straw meet this standard. Use mulch to cover seed to improve microclimatic conditions for germination and seedling survival. Seeding and mulching rates are highly variable, depending on the seed mix used. Consult your local extension office, Natural Resource Conservation Service (NRCS), Resource Conservation District (RCD), or seed supplier for recommended rates of application and local site conditions. Mulching, seeding and planting are often good cost share jobs for landowners and volunteers.

Typical Road Upgrading and Road Decommissioning Costs

Costs for road upgrading and road decommissioning are highly variable and depend on a host of factors (Weaver and Hagans in press). General cost-estimating rules are not available, and extrapolating documented costs from an actual project to another is risky without close evaluation. See Tables X-3 and X-4 for generalized, estimated costs for a number of road upgrading and road decommissioning tasks. Table X-8 gives estimated cost ranges for road reaches developed from watershed inventories and actual forest and ranch road projects completed in northern coastal California between 1995 and 2000.

Road restoration activity	Typical unit costs[1]
Road upgrading (watershed-wide average, 100-year design)	$15,000 - $40,000/mile
Road upgrading (high priority road - moderate to high difficulty)	$45,000 - $75,000/mile
Road decommissioning (range of roads from ridge spurs to moderate complexity mid-slope roads)	$2,000 - $35,000/mile
Road decommissioning (moderately difficult roads)	$25,000 - $50,000/mile
Road decommissioning (difficult roads and/or full recontouring)	$50,000 - $100,000+/mile

[1] Example unit costs for road upgrading and road decommissioning are from 2000 to 2005 project data for a number of roads and road segments treated in north coastal California (PWA, unpublished).

Table X-8. Estimated road restoration cost ranges.

In general, overall road restoration costs closely correlate with the frequency of sites along the road and the volume of soil moved to perform the necessary erosion prevention and erosion control treatments. The higher the site frequency and the larger the sites, the more expensive it becomes. Widely spaced projects can significantly increase move-in/move-out costs. In addition, projects and sites requiring endhauling of excess spoil material are typically more expensive than similar projects where spoil is stored locally.

Implementation Methods

There are several ways to accomplish restoration work. These include direct contracting, equipment rental and in-house for landowners with equipment. Each method has advantages and disadvantages.

Contracting

Contracting is a common way to accomplish restoration projects. This starts by developing a written description of the job and the desired finished product, then soliciting bids to perform the work. Consider the following before deciding to contract out a project.

- Contracted restoration work requires extensive up-front planning, the development of enforceable specifications and project layout. Lay out the job as accurately (typically using surveys and grade staking) and as precisely as possible so that the contractor knows exactly what they are bidding on and what they will be responsible for in the end.

- Contractors usually bid vague projects high because they are not sure what will be required or what they may encounter.
- Any encountered changes (increases) in the job require a change-order in which the contractor may be charging a premium price.
- Preparing detailed project specifications, volume surveys and/or grade staking is a complicated and time-consuming job that represents a substantial investment in up-front time and money. This planning effort may not be possible due to personnel limitations or restricted timeframes.
- Awarding a contract to the lowest bidder is not always best. Depending on the contracting evaluation rules, this can encourage low-ball bids and may require acceptance or use of less qualified or less experienced contractors.

Equipment Rental

Under this method, hire contractors on an hourly basis (equipment with operators) and technically supervise the contractors to complete the restoration work on an hourly basis. This is termed a time-and-materials contract.

- Seek to hire equipment operators skilled and experienced in erosion prevention and control techniques.
- If equipment operators are less experienced, the on-site supervisor must be able to provide technical guidance. As described elsewhere, some types of projects will require supervision by professional geotechnical specialists. On-site supervision or oversight is important for all projects, but becomes even more critical when using inexperienced or unfamiliar operators. For reasons of safety and project cost-effectiveness, inexperienced contractors and operators should not be hired for restoration projects.
- This allows modification of work, without the need for change orders, when encountering unexpected conditions in the field. This added flexibility is often important.
- The equipment rental rate is set for all restoration work, regardless of the nature and magnitude of the project.
- Contractors are likely to provide favorable rates because they know they will be paid for all work they complete (there is little or no risk on their part).
- It is possible to replace contractors if their performance is not up to required standards.

In-house

Some landowners have in-house capability to conduct upslope restoration, especially road upgrading and decommissioning, using their own equipment. To be successful, equipment operators and supervisors must have experience with the types of restoration treatments being implemented. Because they are typically in business for other purposes (e.g., logging or ranching) restoration experience of available in-house operators may be lacking.

- Hourly rates for the use of in-house heavy equipment are frequently lower (more favorable) than for contracting or equipment rental.
- In-house capability is typically the indirect result of having heavy equipment purchased for other purposes such as logging. As such, available equipment may not be perfectly suited for the restoration work. If a special piece of equipment is required to complete the

work (e.g., a larger excavator, or a dozer with a 6-way blade and rippers, etc.), do not compromise the cost-effectiveness of the entire project by not requiring the landowner to lease or rent the proper equipment. This is often a disadvantage.

- Many landowners have old equipment that is subject to frequent breakdowns.
- In-house equipment operators and laborers who are hourly employees are more likely to work restricted hours (to avoid overtime) as compared to a contractor or owner/operator who will work full days. With a limited summer work schedule, long work hours are often a necessary component of successful restoration projects.
- Equipment shortages are likely to occur if the landowner or land manager prematurely moves the equipment off-site to conduct logging or other activities.

QUALITY CONTROL, DOCUMENTATION AND MONITORING

Quality Control Measures

Quality control measures implemented in the field before and during the on-the-ground work help ensure the most effective, efficient techniques are applied, and that projects meet the established design standards. There are a number of ways that incorrect implementation can result in ineffective projects, excessive costs and/or environmental damage. A quality control/assurance program can help prevent these occurrences. Various procedures can be instituted that will increase the probability that the proposed restoration work is effectively and cost-effectively implemented by heavy equipment contractors and labor crews.

Selecting Contractors and Operators

Trained and experienced contractors, equipment operators and technical specialists are one of the most important keys to completing effective and cost-effective upslope restoration work. High quality work is much more likely to occur by screening operators for experience, skill and the proper heavy equipment prior to selection.

Check certifications, past job experience and professional references to ensure that contractors, equipment operators, engineers and geologists that are to be selected for the job are appropriately licensed and skilled. Request and check references and job performance for similar projects. Specifications of heavy equipment required for the job should be stated and checked against those listed by the contractor or operator.

Adaptive Project Design

Prior to heavy equipment or laborers arriving to conduct restoration work, check final prescriptions and clearly flag each work site. Marking should be sufficiently explicit to provide complete guidance as to the boundaries and general prescriptions for the treatments. Review the entire project area in the field. If conditions have changed since the original prescriptions were developed, prepare revisions to the original site plans. The discovery of new sites due to changed conditions, or sites originally overlooked, require site plans and prescriptions be prepared for additional restoration treatments. Finally, identify and flag treatments for surface drainage improvements along the roadbed. These treatments include the exact location of rolling dips, crossroad drains, ditch relief culverts and other work items originally prescribed but not precisely located. If skilled operators are used, they can often perform the road drainage tasks on their own.

Pre-treatment Orientation Tour

Take the lead contractor, lead equipment operator and on-site labor supervisor on a pre-work field tour of the restoration project area to review all proposed treatments. The project supervisor who has intimate knowledge of the proposed treatment plan should lead the field inspection. Give the operator a complete treatment-log that describes the proposed treatments to be completed along the road (by milepost) or at other work areas.

Treatment Summaries

During the orientation tour, provide equipment operators and labor leaders a clearly written site-by-site summary of the treatments that are in the project work plan.

Measurable Standards

Provide contractors, equipment operators and the labor crew leader a list of typical standards, specifications, and/or technical drawings to be met for each general restoration treatment included in the project (e.g., the typical standards for a decommissioned stream crossing excavation; mulching, rolling dips and ditch relief culvert installation, etc.). These standards should be included in the site-specific treatment summaries provided to the operators.

Technical Supervision and Oversight

An important quality control practice is to have technically trained and experienced project supervisors on-site regularly during operations. Their job is to interpret and answer questions about the treatment prescriptions, to provide general guidance to the operator or labor crew leader on specific design requirements for each site, and to verify and approve completed work. Inexperienced operators should have careful and ongoing supervision until their skills, judgment and performance consistently meet expectations. Road decommissioning requires frequent inspections because access is cut-off as work proceeds. Mistakes made during road decommissioning are difficult to correct or repair. Rarely can labor crew treatments prevent or correct erosion problems caused by poor or inadequate heavy equipment work.

Documentation

Documentation and Monitoring

Documentation of work performance and monitoring of restoration effectiveness are two techniques that allow for adaptive management at a relatively short and useful time scale. For example, use documented equipment operations and productivity to institute more efficient treatment procedures. Use qualitative and quantitative monitoring of project performance in the first few years following restoration work to alter procedures and prescriptions for current and future projects. Thus, effectiveness monitoring for adaptive restoration can consist of simply reviewing the erosion response of a variety of past restoration projects and identifying techniques that have worked well and others in need of modification.

Documenting Work Activities

Document work procedures and production rates for various restoration tasks to improve the efficiency and the cost-effectiveness of on-the-ground restoration projects. Document work effort by direct observation of operations, by measuring a sample of production rates (e.g., counting dump truck loads or excavator buckets) or by requiring contractors (operators or laborers) to keep accurate records of work production on a site-by-site basis.

At a minimum, have equipment operators keep a daily record of work accomplishments (hours spent, loads hauled, etc.) on a site-by-site basis. Table X-9 provides a sample form for operators and laborers to complete on a daily basis. Compare actual work with the treatment prescriptions of the restoration plan.

Project Site Implementation Reporting

The project leader should take before and after photos from selected photo-point locations (Hall 2002), assemble and analyze production records from the operators, and check production data by surveying selected sites to determine actual volumes or by counting/timing equipment activities (Table X-9) The project leader also must review each project to confirm the quality and quantity of work performed.

The implementation report should contain many similar elements to the summary report. Report the quantities as known rather than estimates (Appendix X-D). This information forms the basis of implementation monitoring and is very important for post-project effectiveness monitoring used in evaluating the success of the upslope restoration efforts.

The completed implementation report should contain the following information:

- Project identification #
- Project location (descriptive location)
- Map of watershed (location map, showing relationship of project area to region)
- Map of project area and roads treated, which shows:
    - Base information (streams, roads, sections, contours (optional), scale, north arrow, stream labels, road names, cultural features)
    - All roads within the treatment area (whether treated or not), including symbols for current maintenance status (maintained roads, and abandoned (unmaintained) roads) and treatment status (treated and untreated)
    - All treated and untreated sites, including:
        - All stream crossings, showing which ones were actually treated
        - Potential and active landslides which were treated
        - Ditch relief culverts and other ditch drains
        - Gullies and other fluvial erosion features
- Other pertinent maps of the project area, including but not limited to geologic maps, landslide hazard maps, and fault location maps.
- Project report should contain the following information:
    - Introduction (setting, problem, purpose of restoration project)

- Site characterization, areas of concern, landslide and fault location information or other hazards and/or limitations on activities.
- Methods, including:
  - What was done (planning, gear-up, implementation, documentation, monitoring)
  - Describe documentation data that was collected (production rates, volumes, etc.)
  - Describe monitoring efforts initiated (photo points, surveys, etc.)
- Results of implementation work, including work accomplished and costs, including:
  - Description of deviations from original plan or proposal
  - Layout work completed (flagging, prescription marking, etc.)
  - Move-in and move-out, and site preparation work (e.g. road opening)
  - Description of actual treatments (keyed to the site map), including:
    - Road upgrading (show and describe upgraded roads)
    - Road decommissioning (show and describe roads decommissioned)
  - Describe treatments and sites recommended for treatment (including stream crossings, fillslopes, and surface erosion treatments)
- Cost analysis, including:
  - Actual equipment rates (cost/hr) and hours for each site
  - Actual manual labor rates (cost/hr) and hours for each site
  - Total site costs (all site costs added together)
  - Equipment move-in and move-out costs (lowboy)
  - All other project costs not listed above (specify)
  - Total costs for entire project (equipment + labor + materials + other)
- Cost-effectiveness analysis, including:
  - Total measured or estimated sediment savings (yds^3)
  - Total project cost-effectiveness (cost/yd^3 of sediment delivery prevented)
  - Explain any differences between projected and actual costs and sediment savings
- Sources of funds used in project.

DAILY AND WEEKLY HEAVY EQUIPMENT LOG														
Name of restoration project:					Date:				Road name:			Inspectors:		
					Dump truck									
					#1		#2							
Date	Site #	Site type (St = stream LS =landslide RR = road reach DR=ditch relief OT = other)	Excavator (hrs)	Dozer (hrs)	hrs	loads	hrs	loads	Grader (hrs)	Water truck (hrs)	Labor (hrs)	Backhoe (hrs)	Oth er (hrs)	Comment/ activities

Table X-9. Daily heavy equipment log (for operators).

PHOTO POINT MONITORING LOG								
Project #:			Road:		Date:		By:	Weather: Sun____ / Shade____
Site #	PP #	Time	Roll & frame # or digital #	Lens (mm)	Framing (horizontal or vertical)	Compass direction	PP location (site description)	PP description (scene description)

Table X-10. Photo point monitoring log.

Monitoring

Effectiveness Monitoring

Qualitative and quantitative site and project monitoring techniques can be undertaken with the specific objective of documenting the performance of various watershed restoration treatments or for documenting post-restoration erosion rates on treated areas. Detailed monitoring protocols for upslope erosion prevention and erosion control work is beyond the scope of this chapter.

Site Monitoring

It is not always practical to monitor all sites of a large restoration project. Prior to implementation, select a representative range of sites of varying complexity and type (e.g., stream crossings, fillslopes, road surface treatments, etc.) to monitor. Two types of monitoring can be useful:

- "Topographic" surveys - These surveys document the volume of spoil excavated, as well as erosion changes or slope movements that occur in the post-restoration period. Conduct simple surveys, using a tape and clinometer, or auto-level, before restoration activities begin. After the work is completed repeat the survey, and at irregular intervals thereafter. A tag line cross section survey (stretch a taught line across an excavated stream channel between monumented endpoints, and take measurements of the ground surface beneath the line) is an especially simple and useful way to document channel changes (erosion) following stream crossing decommissioning. Void measurement of erosional features is another way to monitor and document changes to a treated site.
- Photo points - Install monumented photo points (Hall 2002) at selected work sites to document before and after scenes of restoration work sites (Table X-10). This type of monitoring is especially useful to portray the nature of the restoration work that is undertaken. Carefully planned and executed photo documentation will graphically portray project effectiveness through time. Monitor revegetation of work sites though sample plot inventories, or more generically through photo point monitoring. Consistent photographs include site documentation, photo point number, date, time, lens, weather (sun/shade), compass direction, orientation (vertical or horizontal), landmarks and other identifying data. Re-take photo points using the original photo to duplicate the exact framing of the scene.

Process Monitoring

Although more difficult than site monitoring, geomorphic processes operating at restoration sites can also be monitored through time. Use site monitoring, such as tag line channel cross-section surveys, to monitor channel change through time. In addition, perform sediment sampling above and below work sites to document sediment delivery to stream channels from the restoration sites both before and after implementation work (Klein 2003). Process monitoring requires a relatively long term, continuing commitment of personnel and money beyond what is typically required for most intermittent site monitoring activities. In general, the closer the monitoring station is to the work site, the more likely you will be able to attribute monitoring trends to restoration actions.

Upland restoration is recognized as partly science-based and partly art. This makes the process of experimentation and extrapolation of monitoring findings difficult. In a sense, most projects contain elements that can be considered experimental. The challenge for effectiveness monitoring projects is to be able to uniquely identify restoration projects or project components that have measurable parameters that will allow comparisons to a class of projects (Switalski et al. 2003). In this way hypotheses can be successfully tested, differences identified and results extrapolated. Results will provide a better basis for design and implementation and should eventually lead to better projects.

As with any monitoring project, the study objectives (the questions to be answered) will determine the methods that are used. A complete and thorough study design will be the foundation of any successful monitoring project. Both feature and process measurements may be included in a monitoring study (Kahklen 2001, Wemple and Jones 2003). Depending on the need for associating specific stressing events with resultant geomorphic responses, process measurements may best be performed using automated data collection devices rather than manual sampling.

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GLOSSARY

Note: The following terms and words are defined in the context of upslope restoration. Additional terms, concepts and words not included here are in Appendices X-A and X-B.

Abandoned road - A road no longer maintained. An abandoned road may be still driveable although overgrown with vegetation (see *road abandonment*).

Abutment (bridge) - A solid foundation on each stream bank, which to secure the ends of a bridge. Naturally occurring rock outcrops may serve as abutments. Engineered abutments are generally constructed of concrete, logs or concrete or steel piers.

Accelerated erosion - Erosion directly or indirectly influenced by human activities or land use. Accelerated erosion is erosion which is not natural or in excess of that occurring naturally.

Active road - A road that is part of an overall road network that needs to be inspected and maintained.

Anadromous fish - Fish that are born in freshwater, migrate to the ocean to grow, then return to freshwater to breed. This includes salmon and steelhead trout, as well as several other species of fish.

Angle of repose - The steepest slope or angle, sediment will freely stay without failing or sliding down slope. The angle of repose of material without cohesion, like loose sand, is about 33 degrees. For material with some cohesion, the comparable term is the angle of internal friction. Slopes steeper than the angle of repose or angle of internal friction are likely to be unstable.

Axis - The central line of a rolling dip, critical dip, or stream channel.

Berm - A curb or dike constructed to control water and prevent roadway runoff water from discharging onto roadside slopes. Many road berms are the unintentional result of years of grading.

Borrow site - Excavation locations for sand, gravel and/or rock that is used in road construction activities. Borrow pits and rock quarries in California may be subject to the new Surface Mining and Reclamation Act (SMARA). This act requires landowners to develop site reclamation plans for many such sites (see *rock pit*).

CEQA - The California Environmental Quality Act, requires public disclosure of the environmental impacts and alternatives associated with any project, including restoration projects.

Check dam - A grade control structure used to prevent gully down cutting or to contain eroded soil from leaving a construction site. It is common to use straw bale check dams in swales, ditches, and small channels and gullies to collect and store sediment eroded from a work site. Straw bale check dams quickly decompose. They usually provide sediment storage or protection for only a single season. Permanent check dams are difficult structures to correctly build and require maintenance to function properly. Check dams treat the symptom rather than the problem.

Class I watercourse - For forestry purposes, those watercourses serving as domestic water supplies and/or those watercourses where fish are present or restorable.

Class II watercourse - For forestry purposes, watercourses where non-fish aquatic species are present.

Class III watercourse - For forestry purposes, watercourses that have no aquatic life present, but under normal high water flow conditions are capable of sediment transport downstream.

Class IV watercourse - For forestry purposes, watercourses that are human made and supply water for domestic, agricultural, hydroelectric or other beneficial uses.

Clinometer - A pocket field instrument which measures slope steepness in degrees and percent.

CMP - An abbreviation for corrugated metal pipe, often used synonymously with culvert. Typically, metal culverts are galvanized steel or aluminum. Many new culverts, especially in the 18" to 36" diameter classes, are plastic.

Cofferdam - A barrier constructed across a waterway to control the flow or raise the level of water.

Compaction - Soil where an increase in bulk density (weight per unit volume) and a decrease in soil porosity results from applied loads, vibration or pressure. Compaction is often achieved by using gas powered vibrators, rollers, or heavy equipment.

Cost-effectiveness - In upslope restoration, the amount of money spent to prevent the delivery of a cubic yard of sediment to a stream. Measure cost-effectiveness by the volume of sediment delivery prevented from entering a stream not the amount of material excavated by heavy equipment.

Crossroad drain - A deeply cut ditch, excavated across a road surface, which drains the roadbed and inboard ditch. Crossroad drains are more substantial and deeper than conventional water bars used to drain forest and ranch roads, and are steeper and more abrupt than rolling dips. Properly constructed crossroad drains will often be deep enough to prevent vehicular traffic, therefore use them to close roads. Crossroad drains are constructed (excavated) using a tractor, a hydraulic excavator, or a backhoe.

Crowned - A crowned road surface is one which slopes gently away from the centerline (or near centerline) of the road and drains to both sides of the crown. Crowning a road surface is one method of providing for surface drainage on roads built on flat terrain. The inside half of the road drains inward to the cutbank and ditch, while the outside half drains out across the fillslope.

Crown scarp - A crown scarp is a visible fracture across the top of a landslide. Lateral scarps run down the hillslope from the crown scarp. For fill failures along the outside edge of a road, crown scarps, or cracks, mark the boundary between stable materials on the inside of the road and unstable fill on the outside edge of the road.

Culvert - A transverse drain, usually a metal or plastic pipe, set beneath the road surface to drain water from the inside of the road to the outside of the road. Use culverts to drain ditches, springs and streams beneath the road alignment.

Cutbank - The artificial face or slope cut into soils or rock along the inside of a road.

Debris flow – When a rapidly moving mass of rock fragments, soil and mud, saturated with water, flows down a hillside, with more than half of the particles being larger than sand size.

Debris slide – The slow to rapid slide, of relatively dry and predominantly unconsolidated materials, moving down a hillside, involving down slope translation, with more than half of the particles being larger than sand size.

Debris torrent – The rapid movement of a large quantity of materials (wood and sediment) down a stream channel during storms or floods. This generally occurs in smaller, steep stream channels and results in scouring of the streambed.

Decommission - To remove those elements of a road that unnaturally reroute hillslope drainage or present slope stability hazards. The process of proactively abandoning a road by eliminating all significant risks of delivery until the road is needed in future years. Decommissioning may be permanent or temporary (the road will be used again), but the treatments do not markedly differ. Decommissioning involves completely removing stream crossing fills and associated drainage structures and eliminating the risk of sediment delivery from unstable road and landing fills, and providing for permanent surface drainage (see *road abandonment*, *road closure,* and *put-to-bed)*.

Decompaction - See *ripping*.

Ditch - A human-made channel constructed to drain water from one location to another. Ditches are often located on the inside of the road (at the base of the cutbank - see *inboard ditch*), but they may also be located on the outside of a road, along a berm, on both sides of a crowned road or elsewhere on a slope.

Ditch relief culvert - A culvert installed to drain water from an inside road ditch to an outside area, beyond the outer edge of the road fill. Ditch relief culverts take the flow through or beneath the road surface. Rolling dips or cross road drains can perform the same function taking water across the road in a trough.

Diversion potential - A stream crossing has diversion potential if, when the culvert plugs, the stream would back up and flow down the road or ditch rather than directly over the fill crossing and back into the natural drainage channel. If flow would divert beyond the hinge line of the stream crossing fill, the site has a diversion potential.

Downspout - A flume or trough attached (bolted) to a culvert outlet and used to convey water from the culvert outlet down over and beyond the road fill to prevent erosion. Culverts placed at the base of the road fill discharge directly into the natural channel or hillslope and usually do not require a downspout. Downspouts may be half round or full round. Use full round downspouts (rather than half round) for a downspout on a stream crossing culvert.

Drainage basin - See *watershed*.

Drainage structure - A structure installed to control, divert or to cross over water, including but not limited to culverts, bridges, ditch drains, fords, water bars, road shape (e.g., outsloping or crowning) and rolling dips.

Earthflow - A mass-movement landform and slow-to-rapid mass movement process characterized by down slope translation of soil and weathered rock over a discrete shear zone at the base, with most of the particles being smaller than sand. Referred to as a soil glacier because of similarities in movement patterns.

Endhauling - The loading and transportation of excavated material from a site, and the storage of the hauled material in a stable location where it cannot enter stream channels. Dump trucks are most commonly used. Mobile scrapers are used on large jobs.

Ephemeral stream - A stream or portion of a stream that flows briefly in direct response to precipitation in the immediate vicinity and whose channel is at all times above the water table.

Erodible soils - Soils that are prone to erosion by raindrop impact and surface runoff. Granular, non-cohesive soils (such as soils derived from sand dunes or decomposed granite) are especially erodible.

Erosion - The dislodgement of soil particles caused by wind, raindrop impact or by water flowing across the land surface. Erosion usually refers to processes of surface erosion (raindrop erosion, rilling, gulling and raveling) and not to mass soil movement (landsliding). Erosion is not synonymous with sediment delivery if eroded sediment re-deposits before reaching a watercourse.

Erosion control - Treatments designed to control on-going erosion caused by raindrop impact, rilling, gulling, raveling and other surface processes.

Erosion prevention - Preventing erosion before it has occurred. Erosion prevention is typically less expensive and more effective than erosion control.

Erosion-proof - See *storm-proof.*

Fill - Consists of loose soil material that is placed or pushed (often by bulldozer) into low areas or onto a natural slope, and which is then compacted and built up to form a roadbed or landing surface.

Fillslope - That part of a road fill between the outside edge of the road and the base of the fill, where it meets the natural ground surface. On a half-bench road built by sidecast construction, the fill typically extends from near the centerline of the road to the outside edge of the road and down slope to where the sidecast meets the natural hillslope.

Filter fabric (geotextile) - A synthetic fabric manufactured and designed for use in subsurface and surface drainage applications. Filter fabric is especially useful in maintaining a separation between coarse aggregate and finer native soil particles. It comes in a number of different types, with different specifications and uses. It is common to use filter fabric in a number of different road building settings. Consult manufacturer's specifications before using a fabric for drainage or other engineering applications.

Fish bearing - A stream known to support fish during some part of the year.

Flared inlet - A flared or widened culvert inlet to increase its capacity and reduce the chance of inlet plugging and damage. Attach flared inlets to the normal culvert inlet using a band or bolts. Mitered inlets, made by cutting a normal culvert at an angle, improve culvert efficiency and increase capacity.

Fluvial - Pertaining to the processes of, or related to streams or flowing water.

Ford (dry) - A rock, concrete or other hardened structure built on the bed of a swale, gully or usually dry stream, allowing vehicle passage during periods of low or no flow.

Ford (wet) - A rock, concrete or other hardened structure built on the bed of a live stream, allowing vehicle passage during low flow periods. A ford can also be a naturally stable section of stream that vehicles use in low flow periods.

Geomorphic - Pertaining to the form or shape of the earth's surface, and to those processes that affect and shape the land's surface. Geomorphic processes include all forms of soil erosion and mass soil movement, as well as other surface processes.

Grading - Involves the excavation and movement of soil along a road alignment to an established grade-line during road construction or reconstruction. Grading is one of the tasks of road construction, and is preceded by ripping and followed by surfacing. Grading also refers to the mechanical smoothing of the roadbed to maintain a free-draining, smooth traveling surface.

Gully (gullied) - An erosion channel formed by concentrated surface runoff, larger than one square foot in cross sectional area (1' deep by 1' wide). Gullies often form from road surface or ditch runoff directed onto unprotected slopes. Gullies are a symptom of a problem: too much water collected and discharged onto a hillslope.

Headwater swale - A swale or dip in the natural topography that is upslope from a stream, at its headwaters. There may or may not be any evidence of overland or surface flow of water in the headwater swale.

Humboldt log crossing - See *log crossing*.

Inboard ditch - A ditch located on the inside of the road, usually at the foot of the cutbank (see *ditch*).

Inner gorge - A geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream channel, having a side slope of generally over 65%, and being situated below the first break in slope above the stream channel.

Insloped road - A road surface sloped in toward the cutbank. Insloped roads usually have an inboard ditch that collects runoff from the road surface and cutbank.

Intermittent stream - A stream that flows only at certain times of the year, as when it receives water from springs or from a surface source; a stream that does not flow continuously, as when water losses from evaporation or seepage exceed the available stream flow.

Landing - Any place on or adjacent to a logging site (usually on a road) where logs are collected and assembled for further transport.

Landslide - The down slope movement of a mass of earth caused by gravity is termed a landslide. This includes, but is not limited to debris slides, torrents, rock falls, debris avalanches, and soil creep. It does not include; dry ravel, raindrop erosion or surface erosion caused by running water. Landslides may be the result of a natural erosion processes, such as earthquakes or fire events; or human disturbances such as, mining or road construction.

Log crossing (Humboldt log crossing) - A drainage structure made out of logs or woody debris, sometimes laid in parallel to a stream channel, covered with soil. Before the mid-1980's, log crossings were frequently used as permanent stream crossings instead of culverts or bridges. Log crossings are highly susceptible to plugging and washout during storm flows. Log crossings are used today only for temporary stream crossings that are to be removed prior to the winter period.

Lowboy transportation - Long, low trailers used to haul heavy equipment (tractors and excavators) to a work site.

Maintained road - A road whose cutslopes, road surface, drainage structures, and fillslopes are regularly inspected and repaired to prevent erosion and deterioration.

Mass soil movement - Down slope movement of a soil mass under the force of gravity. Often used synonymously with "landslide" common types of mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents (see *landslide*).

Mulch - Material placed or spread on the surface of the ground to protect it from raindrop, rill and gully erosion. Mulching is an erosion prevention treatment. Mulches include wood chips, rock, straw, wood fiber and a variety of other natural and synthetic materials.

Outsloped road - A road surface sloped away from the cutbank toward the road's fillslope. Outsloped roads may or may not have an inboard ditch.

Outsloping - To improve road drainage, by converting an insloped road to an outsloped road. Outsloped roads may or may not have an inside ditch to drain spring flow. Outsloping can also refer to the act of excavating the fill along the outside of the road and placing and grading it against the cutbank, thereby creating an outsloped road surface.

Peak flow (flood flow) - The highest amount of stream or river flow occurring in a year or from a single storm event. Design stream crossing culverts to pass the 100-year peak flood flow.

Permanent road - A road planned and constructed to be part of a permanent all-season transportation system. These roads have a surface suitable for travel and, where applicable, for hauling of forest and ranch products throughout the entire winter period. Permanent roads have drainage structures, at watercourse crossings designed to accommodate the 100-year flood flow. Permanent roads receive regular and storm-period inspection and maintenance.

Put-to-bed - See *decommission.*

Range finder - A hand-held field instrument used to measures distances less than 1,000 feet.

Rill - An erosion channel varying in size from a rivulet, to one-foot square in cross section, that typically forms where rainfall and surface runoff is concentrated on bare fillslopes, cutbanks and ditches. If the channel is larger than one square foot in size, it is a gully.

Riparian - The banks and other adjacent terrestrial environs of lakes, watercourses, estuaries and wet areas where transported surface and subsurface freshwater provides soil moisture to support mesic vegetation.

Ripping (of a road) - The process of breaking up or loosening compacted soil (e.g., skid trails, spur roads or landings) to better assure penetration of roots of young tree seedlings and to increase infiltration. Use a tractor with rear-mounted, hydraulically operated ripping chisels to rip roads. Also used are excavators, graders or other earth moving equipment. Three or four passes is usually sufficient to decompact a normal road surface.

Riprap - The rock placed on the ground, stream bank or gully to prevent or reduce erosion.

Road abandonment - Road abandonment involves a series of proactive activities which erosion-proof a road so that further maintenance will not be needed and significant erosion will not occur. In the past, road abandonment was synonymous with blocking the road and letting it grow over with vegetation, which led to significant erosion (see *road closure and decommission*).

Road closure (proactive road abandonment) - A method of closing a road so that regular maintenance is no longer needed and future erosion is largely prevented. The goal of road closure is to leave the road so that little or no maintenance is required for stability while the road is unused. Road closure usually involves storm-proofing techniques including removing stream crossing fills, removing unstable road and landing fills, installing cross road drains for permanent road surface drainage and other erosion prevention and erosion control measurers as needed. Proper road closure is not accomplished by blocking a road and walking away from it to let nature reclaim the road (decommission, road abandonment).

Road failure - Damage to the roadbed, usually caused by a roadbed slump, fill failure, stream crossing washout or major gully, which prevents vehicular passage; not minor cutbank or fill sloughing incidental to road settling.

Road grade - The slope of a road along its alignment is the road grade. Road grades typically run up to a maximum of 20%, but may exceed this slope for short pitches.

Road maintenance - Upkeep of a roads cutbanks, road surface, fillslopes, and all drainage structures, intending to prevent erosion and deterioration. Road maintenance activities include; grading, ditch cleaning, brushing and culvert cleaning.

Road runoff - Surface runoff drained from the road surface, usually as a direct response to rainfall.

Rock armor - Course rock placed to protect a soil surface, usually from erosion caused by flowing or falling water. Rock armor is one type of material used for energy dissipation at culvert outfalls.

Rock pit - A large outcrop of bedrock developed for aggregate uses, such as road surfacing material and/or larger rock armor. A borrow pit is an excavation from which material is removed for use in another location (see *borrow site*).

Rolling dip - Shallow, rounded dip in the road that reverses road grade for a short distance, and directs road surface runoff in the dip or trough to the outside or inside of the road. Construct rolling dips to allow vehicles to travel at normal or slightly reduced speeds.

Rotational slide - A failure plain landslide that is arcuate and concave-up. Its movement is predominantly rotational verses translational.

Runoff - Water from rainfall or snowmelt that drains from hillslopes, or bare areas along roads and trails becomes runoff.

Seasonal road - A road planned and constructed as part of a permanent transportation system whose use is restricted to periods when the surface is dry. Most seasonal roads are not surfaced for winter use, but have a surface adequate for hauling of forest and ranch products in the non-winter periods, and in the extended dry periods or hard frozen conditions occurring during the winter period. Seasonal roads have drainage structures at watercourse crossings designed to accommodate the 100-year flood flow.

Sediment delivery - The eroded material that is delivered to a stream channel. Sediment delivery refers to the percent of material eroded from a site and delivered to a stream channel, as opposed to that which is eroded but then stabilized on the hillslope and does not enter a stream. Sediment delivery is not the same as erosion.

Sediment yield - The quantity of soil, rock particles, organic matter, or other dissolved or suspended debris transported through a cross-section of stream in a given period. Technically, sediment yield consists of dissolved load, suspended load, and bed load.

Sidecast - Excess earthen material pushed or dumped over the side of roads or landings.

Skid trail or **tractor trail** - A tractor-constructed trail usually built while logging or in response to fire control or prevention activities.

Slope angle - The gradient of a slope, usually expressed as percent or degrees, but sometimes as a unit-less ratio (100% = 45E = 1:1; 50% = 26E = 2:1).

Slope stability - The resistance to failure, of a natural or artificial slope, or other inclined surface by landsliding (see *mass movement*).

Slump - An episodic, fast to very slow, mass movement process involving rotation of a block of hillslope or road along a broadly concave slip surface (see *rotational slide*).

Soil texture - The relative proportion of sand, silt and clay in a soil; grouped into standard classes and subclasses in the Soil Survey Manual of the U.S. Department of Agriculture.

Spoil (spoil materials) - Material (soil and organic debris) that is not used or needed as a functional part of the road or a landing. Spoil material is generated during road construction and maintenance activities and during restoration work when stream crossings are upgraded or removed and unstable material is excavated. Spoil may be stored locally (pushed) or it may be endhauled with dump trucks.

Spoil disposal site - The location to place spoil material (woody debris and excavated soils) without the threat of accelerated erosion and sediment delivery, or initiating slope instability. Stable spoil disposal sites may include the cut portion of closed roads, the inside portion of landings and turnouts, and flat or low gradient natural benches. Evaluate each spoil disposal site for its suitability before material is stored at the site.

Spur road - A side road off a main trunk road or a secondary road. Most spur roads are dead-end.

Storm-proof - Erosion control and erosion prevention activities which will protect a road, including its drainage structures and fills, from serious erosion and sediment delivery during a large storm and flood, as well as from chronic surface erosion and sediment delivery during normal runoff events.

Stream class (1, 2, 3): California stream classification methods are based on biological parameters, and not on flow conditions or the magnitude or frequency of stream flow. Class 1 streams are fish bearing, or provide a domestic water supply. Class 2 streams provide habitat to macroinvertebrates and/or amphibians at some time of the year, but are not fish bearing. Class 3 streams move sediment but do not provide habitat to macroinvertebrates or amphibians. Biological classification allows restorationists to prioritize problems and proposed treatments based on their potential to affect aquatic resources. Similarly, many in-channel treatments (e.g., the type of allowable culvert installation) are closely tied to the biological classifications. California stream classes do not correspond to generally accepted USGS classifications of perennial, intermittent and ephemeral streams. Thus, the biological classification has little relevance to the frequency of flow or the size of the stream channel. These factors are often necessary in designing effective in-channel and bank stabilization treatments.

Stream crossing - The location where a road crosses a stream channel is a stream crossing. Drainage structures used in stream crossings include bridges, fords, culverts and a variety of temporary crossings. If a stream diverts down a road to a ditch, it is a stream crossing.

Stream crossing excavation - The excavation of the fill material used to build (fill) a stream channel crossing during road construction. Specifically, this includes the removal of fill from culverted crossings, log crossings and fill (unculverted) crossings. A stable stream crossing excavation must be dug down to the level of the original stream bed, with side slopes graded (excavated) back to a stable angle (usually 50% or less, depending on soil and site characteristics).

Surface erosion - Soil particles detached and transported by wind, water or gravity. Surface erosion can occur as the loss of soil in a uniform layer (sheet erosion), in many rills, gullies, or by dry ravel. Surface erosion may deliver sediment to a stream channel.

Surfacing (surface course) - The top layer of the road surface, also called the wear course. Rock aggregate and paving are two types of surfacing used to weatherproof a road for year-round use.

Swale - A channel-like linear depression or low spot on a hillslope that rarely carries runoff except during extreme rainfall events. Some swales may no longer carry surface runoff under the present climatic conditions.

Tag line cross section survey - A surveying technique for monitoring channel and gully erosion, taking vertical measurements from a taught level line stretched between fixed endpoints on either side of the channel to the ground surface. Use tag line cross sections to monitor erosion of excavated stream crossings.

Temporary road - A road used temporarily. These roads have a surface adequate for seasonal hauling use and have drainage structures, adequate to carry the anticipated flow of water during the period of use. Remove all drainage structures prior to the beginning of the winter period (see *temporary stream crossing*).

Tension cracks - Cracks in the ground (usually in a road fill) that may indicate slope instability. Cracks that form as un-compacted fill material naturally settles, and may indicate the beginning of a potential fillslope failure.

Through-cut - A road cut through a hillslope or, more commonly, down a ridge, in which there is a cutbank on both sides of the road. Through-cuts more than two feet deep are very difficult to drain and prone to forming gullies.

Trash rack (debris barrier) - A barrier built just upstream from a culvert inlet to trap floating organic debris before it can plug the culvert. Design trash racks or barriers to filter organic debris from flood flows. All trash racks require periodic cleaning.

Treatment prescription - A suggested treatment for erosion prevention or erosion control is a treatment prescription.

Trough - A long depression between two ridges.

Upgrade - Road upgrading consists of storm-proofing treatments designed to reduce the risk of road failure and the volume of sediment delivery from roads. Treatments generally consist of upgrading stream crossings (to increase flow capacity and to prevent stream diversion), excavating unstable fillslopes (which would otherwise fail and deliver sediment to a stream channel), and disconnect road surface drainage from the natural stream network (thereby dispersing road surface runoff and preventing delivery of fine sediment to streams).

Unstable areas - Areas characterized by mass movement features or unstable soils. An example of an unstable area is hummocky topography consisting of rolling bumpy ground, with frequent benches, and depressions. Short irregular surface drainages which begin and end on the slope, visible tension cracks, and head wall scarps and irregular slopes which may be slightly concave in upper half and convex in lower half as a result of previous slope failure also indicate unstable areas. Evidence of impaired ground water movement resulting in local zones of saturation including sag ponds with standing water, springs, or patches of wet ground; hydrophilic (wet site) vegetation; leaning, jack-strawed or split trees; and pistol-butted trees with excessive sweep in areas of hummocky topography are generally unstable.

Unstable soils - Characteristics of unstable soils include unconsolidated, non-cohesive soils (coarser textured than loam) and colluvial debris including sands and gravels, rock fragments, or weathered granitics. Such soils are usually associated with a risk of shallow-seated landslides on slopes of 65% or more, having non-cohesive soils less than 5 feet deep in an area where precipitation exceeds 4 inches in 24 hours in a 5-year recurrence interval. Soils that increase and decrease in volume as moisture content changes are unstable. During dry weather, these materials become hard and rock-like exhibiting a network of polygonal shrinkage cracks and a blocky structure resulting from desiccation. Some cracks may be greater than 5 feet in depth. When wet, these materials are very sticky, dingy, shiny, and easily molded.

Washed-out stream crossing - A partially or completely eroded stream crossing fill washed downstream. When a culvert plugs and stream flow backs up and flows over the roadbed during flood events washouts occur. They are most common on abandoned roads, but may also occur on maintained roads in response to severe storm events.

Water bar (water break) - Shallow ditch excavated at an angle across a road or trail to drain surface runoff. Water bars are typically built on seasonal or temporary roads receiving little or no traffic during the winter period.

Watercourse - Any well defined channel with distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand or gravel. Watercourse also includes human-made watercourses (see *Class I, II, III and IV watercourse*).

Water quality - The chemical and biological characteristics of a stream and lake water defines water quality.

Watershed - The area or drainage basin contributing water, organic matter, dissolved nutrients and sediments to a stream or lake. An area bounded mostly by ridges and drained, at its outlet, by a single trunk stream.

APPENDIX X-A. INSTRUCTIONS FOR COMPLETING UPSLOPE INVENTORY DATA FORM

ASAP (Y, N): Enter “Y” if a site urgently needs treatment to prevent imminent damage to a stream, otherwise enter “N”.

GENERAL INFORMATION

Site No: A unique systematic identification number assigned to a specific site. Also, record the site number on the aerial photo Mylar overlay. Use only numbers, not letters, for effective database searches.

Treat (Y, N): Enter “Y” if the final assessment recommendation is for site treatment; and "N" if not recommended for treatment.

Watershed: Write in the name of the watershed from the USGS 7.5 minute topographic map, (i.e. Bull Creek).

Quad: Write in the name of the USGS 7.5 minute quad.

GPS: Record the GPS coordinates for the specific site.

CALWAA: The California Watershed Analysis Area number assigned to the inventoried sub-watershed or land unit.

Photo: The flight line and frame number of the air photo used for mapping the location of this particular site. Original field mapping information is contained on acetate or Mylar overlay for each of the aerial photos covering the assessment area.

T/R/S: From the USGS quadrangle, enter the township, range, and section for the site.

Road Name/#: Enter the road name or number where the site is located. Many roads have posted names, such as the 500 Road. For unnamed road systems, adopt a logical road numbering system for the survey and include the names on the final site map.

Drivable (Y/N): If the road is drivable, even if abandoned, enter “Y”; if there are obstructions, washouts or vegetation that make it impassible, enter “N”.

Mileage: For each drivable site, log a distance from start on the data sheet and a photo overlay map. Typically, start recording mileage at the beginning of the road to the site. Use an odometer or vehicle mileage computer to record mileage to the nearest 0.01 mile. If the road is not drivable, enter the word "WALK" instead of a mileage. The length of roads walked is determined later from digitizing maps or aerial photographs.

Inspector(s): Record the names or initials of the inventory crew. List the data recorder first.

Date: Record the date of the survey.

Year Built: Record the first year the road is visible on aerial photographs. This is likely not the year it was constructed, but provides a frame of reference for its construction.

Surface: Check one. Check "rock" for surfaced roads with pit-run or river-run rock, crushed or not crushed. Unsurfaced roads are "native" roads or dirt roads, even though they may contain some natural rock. Use "paved" for all roads surfaced with asphalt, concrete, or chip-seal.

Status: Check "maintained" for a maintained road or if there is evidence of maintenance activities having been performed recently. Check "abandoned" for an abandoned, blocked, or not maintained road. The road may still be drivable, but classify it as abandoned if there is no obvious maintenance at culvert sites, the ditches need cleaning, and vegetation has overgrown the roadbed. Spur roads are also considered abandoned if their access is completely and permanently blocked. A road is either "abandoned" or "maintained". Check "decommissioned" for a decommissioned road. Check "decommissioned" if the stream crossings have been excavated and permanent surface drainage has been installed. A gated road, an overgrown road or a road with a tank trap at the beginning does not qualify as decommissioned.

Proposed: Check "upgrade" if recommending upgrading the road. Check "decommission" if recommending decommissioning the road. The site must be identified as either upgrade or decommission, but not both.

Sketch: Enter "Y" if a site sketch is included on the back of the data form (Figure X-3). Enter "N" if a site sketch is not included.

PROBLEM

Occasionally, more than one problem may occur at a single site.

Stream Crossing: Enter "Y" if the site is a stream crossing. Enter "N" if the site is not a stream crossing.

Landslide: Check "fill" if the site is a fillslope landslide involving the failure of sidecast materials along the outside edges of a road, especially those built on steep slopes, and around the outside edges of landings. Fillslope landslides usually cut into the roadbed and the slide material is deposited down slope from the road. Check "hill" if the site is a hillslope landslide above, across, and/or below the road, and involves more than just sidecast or cutbank material.
Check "cut" if the site is a cutbank landslide occurring on the inside, or cut side, of the road. Cutbank slides deposit material on the roadbed.

Roadbed: Check "bed" if the site involves erosion, rilling, or runoff from the roadbed. Check "ditch" if the site involves erosion from or runoff in the inboard ditch. Check "cut" if the site involves erosion from a cutbank.

<u>Ditch Relief Culvert:</u> Check if a ditch relief culvert (DRC) is delivering sediment to a stream channel. Erosion at the outlet of a ditch relief culvert does not warrant classification unless the eroded sediment reaches, or could reach, a stream. However, even a small gully or channel that extends from the outlet of a DRC down to a stream effectively connects the road and ditch to the stream, and merits classifying such a culvert as a site.

<u>Gully:</u> Check for a newly formed or actively eroding gully.

<u>Bank Erosion:</u> Check if the site involves eroding banks of a natural stream channel.

<u>Road Related:</u> Enter "Y" if the potential or existing erosion problem is directly related to the road. Enter "N" if the potential or existing erosion problem in not directly related to the road.

<u>Other Non-road Related Site:</u> If it is not road-related, check the location and land use associated with the on-going or potential erosion problem:

- ☐ home
- ☐ agricultural
- ☐ construction
- ☐ mining
- ☐ other site.

If "other site" included description.

LANDSLIDE

<u>Road or Landing Fill:</u> Check if the site involves failure of fill material on the outside edge of a road, landing, or pullout from loose material pushed over the road's edge during construction or maintenance.

<u>Hillslope Debris Slide:</u> Debris slides move fast and are typically relatively shallow compared to deep-seated, slow moving landslides. Debris slides may or may not turn into debris flows, depending on confinement, slope gradient and water content.

<u>Cutbank Slide:</u> Check for landslides confined to the cutbank on the inside of the road. Unless connected to an inboard ditch, these landslides just dump material on the roadbed and little or none of it gets into a stream channel. Some of the bigger cutbank slides cross over the road and continue down slope into a channel. Cutbank slides are usually just maintenance problems and do not often become sediment delivery problems.

<u>Hillslope Landslide of Unknown Type and Depth:</u> Check if the site is large with areas of multiple scarp systems running through natural slopes and/or across roads and skid trails. Large hillslope landslides often have the following characteristics: emerging groundwater; leaning trees; active and inactive scarp systems; and episodic, seasonal movement from several feet to several hundred feet annually. Some may not move annually. Most deep-seated hillslope landslides involve far more than just a road and are difficult and expensive to control.

Potential Failure: Check if the site has the potential to fail. The site may be currently inactive and show no signs of movement in the last several years, but the scarps and other indicators suggest that during an especially large storm the instability could become active and fail or move down slope. Potential failures may also be earth block remainders from a slide that previously failed. If an unstable mass is on-site, even if it shows developed scarps and has moved or dropped several feet, classify the site as a potential failure.

Past Failure: Check if the landslide has already failed and appears to be inactive and partially or largely revegetated. Gullies will often have armor lag deposits in the channel bed. Landslides may be inactive even though vegetation is still sparse and it still looks bad.

Slope (%): Enter the percent slope of the hillside below the site. This is the slope of the natural ground below the base of the fillslope, not the slope of the road fill looking from the outside edge of the road. Take the measurement from the foot of the fillslope with a clinometer. This is the steepness of the slope the slide mass would first have to travel over to reach a stream channel.

Distance to Stream (ft): Enter the distance in feet from a landslide site to the nearest stream. Measure the distance from the foot or base of the potential slide down to the channel. It is the minimum distance soil would have to travel to deliver sediment to a stream.

STREAM

Check the most appropriate type of stream crossing. It is possible to have more than one crossing type at a single location (e.g., Humboldt and culvert).

- culvert
- bridge
- Humboldt
- fill
- ford
- armored fill.

Excavated Crossing: Check for an excavated stream crossing on an abandoned or decommissioned road.

% Excavated: Estimate the percent of the fill excavated.

Ditch Road Length(ft): Left: and **Right:** Record in feet, the longest distance of the road and/or ditch which drains water to the stream crossing from each side. This is the length of ditch and/or road contributing surface runoff and fine road sediment to the stream crossing. Measure the distance along the ditch/road on both the left and right approaches. Right and left are determined when looking in the downstream direction.

Culvert Diameter (in): Enter the diameter of the culvert. Typical choices include 12, 18, 24, 30, 36, 42, 48, 52, 60, or 72 inches. Measure each culvert with a measuring tape or pocket-rod because it is easy to estimate incorrectly.

Pipe Condition (O, C, R , P) Inlet:, Bottom:, and **Outlet:** Record the condition of the three components of a culvert pipe crossing: the inlet, the bottom, and the outlet. Use the following codes: "O" for OK; "C" for Crushed (if any dents block 20% or more of the culvert, consider it crushed); "R" for Rusted (severe, to the point of having holes in the bottom); "P" for Plugged (any blockage of the culvert exceeding 20%, consider it plugged).

Separated: Check separated if a culvert joint has separated. Use a flashlight to determine if a separation exists. In a separated culvert, flow may enter the culvert but not come out the other end. Look for water flowing out from beneath the culvert outlet.

Headwall (in): Enter the headwall height on stream crossings with culverts. Measure the vertical height from the bottom of the culvert inlet to the lowest point in the stream crossing fill where the water would begin to flow out of the crossing and down an inboard ditch, or over the road and down its outboard fillslope. As long as water is ponding and backing up and not flowing down the road or over the crossing, the headwall height is not reached. Note: Make some headwall height measurements to the inboard edge of the road and make others to the ditch. The low point is merely the point where water would flow from the crossing inlet area if the culvert were to plug.

Culvert Slope (%): Enter the average slope of a culvert. Take this measurement by looking up the culvert from the outlet, or down the culvert from the inlet. Use a clinometer. If the culvert is straight, place the clipboard in the culvert inlet, put the clinometer on the clipboard and read out the slope gradient. If the crossing is on a fish bearing stream, see *Part IX*.

Stream Class (1, 2, 3): Enter the stream classification number. Class 1 streams are fish bearing, or provide a domestic water supply. Class 2 streams provide habitat to macroinvertebrates and/or amphibians at some time of the year, but are not fish bearing. Class 3 streams move sediment but do not provide habitat to macroinvertebrates or amphibians. California stream classification methods are based on biological parameters, and not on flow conditions or the magnitude or frequency of stream flow. Biological classification allows restorationists to prioritize problems and proposed treatments based on their potential affect aquatic resources. California stream classes do not correspond to generally accepted USGS classifications of perennial, intermittent and ephemeral streams.

Culvert Rust-line (in): Inlet: and **Outlet:** Enter the height of the rust-line at the inlet and outlet of the culvert. This is the vertical distance between the bottom of the culvert and the top of the rusted area in the pipe. The inlet rust-line is generally the best indicator of pipe capacity for accommodating the stream's flow and will have a higher rust-line than the outlet. Plastic, aluminum, and concrete pipes will not have rust-lines, but may show scour or moss lines.

Culvert Undersized (Y, M, N): Enter "Y" for yes if there is field evidence a culvert is undersized. Enter "N" for no if the field evidence indicates it will pass the design flow. Enter "M" for maybe if uncertain. Describe the evidence in the comment section.

Washed Out (%): Enter the percentage of the fill material at the crossing that has eroded and is already gone. If the entire fill washed out, enter 100. Culverted stream crossings can wash out by having stream flow over the fill, by having extreme culvert outlet erosion, or by having a Humboldt log crossing develop sinkholes and subsurface gully erosion.

Diversion Potential (Y/N): Enter "Y" for yes if diversion potential exists. If the culvert plugged and the water would flow down the road or inboard ditch there is diversion potential. A stream has a diversion potential if the flow would leave the fill crossing and divert down the road past the fill's hinge line, even if it would re-enter the natural stream channel at some distance down slope. Enter "N" for no if there is no diversion potential. If the culvert plugs and floodwaters would flow straight across the road and spill back into their stream channel downstream of the road, there is no diversion potential. If the crossing has no diversion potential, overflow might cause a washout of the road fill, but the stream flow would not divert out of its natural channel. All stream crossings have either diversion potential or no diversion potential. There are no other choices.

Currently Diverted: Check for a stream currently diverted down the road or ditch, or if there is evidence that even part of the peak stream flow currently diverts down the road or ditch.

Road Grade (%): Enter the road grade in percent. Measure the downhill slope of the road leading away from the crossing or the direction a diversion would flow.

Plug Potential (H, M, L): Estimate the potential for the crossing to plug with sediment or woody debris (High, Moderate or Low). The plugging potential is an estimate of how likely the culvert is to plug in the next big storm. Plugging potential typically is higher for streams that transport significant organic debris and sediment. Write "H" if the evidence for high plugging potential includes:

- Culvert is currently plugged or partially plugged
- Culvert is too small for the drainage
- Culvert has plugged in the past (note terraces, ponding evidence, etc.)
- Culvert has been cleaned once or more in the past as evidenced by scattered debris
- Culvert inlet is damaged
- Cutbank or slope failure threatens the inlet.

If the culvert is undersized, it still might not have a high plugging potential. An effective trash barrier may reduce plugging potential. Make note of a trash rack in the comments.

Plugged (%): Enter the percent of the culvert inlet or outlet that is currently plugged with sediment or organic debris.

Channel Gradient (%): Enter the slope of the natural channel upstream from the stream crossing. Do not measure channel gradient in the flat reach influenced by the stream crossing and culvert inlet.

Channel Width (ft): The estimated width of the 100-year flood event channel. Record the width of the expected flow dimensions in feet. Measure channel dimensions in the undisturbed, natural channel above the influence of the road crossing.

Channel Depth (ft): The estimated depth of the 100-year flood event channel. Record the depth of the expected flow dimensions in feet. Measure channel dimensions in the undisturbed, natural channel above the influence of the road crossing.

Sediment Transport (H, M, L): Estimate the relative capability of the stream to transport sediment and thereby move sediment and debris down to the culvert inlet. Enter "H" for high, ""M" for moderate, or "L" for low. This is a subjective evaluation of stream competence and capacity that is used to provide qualitative information on culvert plugging potential. If a lot of sediment is moving during annual high flow events, then sediment transport is high. If the streambed has moss-covered cobbles that are stable, then transport might be considered low. In performing an inventory, it is important to be consistent in classifying sediment transport so that sites can be ranked or compared against each other at the end of the assessment.

Drainage Area (acres): Enter drainage area of the sub-watershed draining to the stream crossing. The drainage area is calculated later from a scaled topographic map or GIS map using a planimeter or dot grid, or employing a digitizer and GIS software. Drainage area is necessary for calculating peak stream flow estimates and culvert sizes.

FISH PASSAGE

Fish passage data provides information to determine possible barriers to adult and juvenile fish migration on Class 1 streams (*Part IX*).

Culvert Outlet Drop (in): Measure the vertical height in inches from the bottom of the culvert to the water surface at the time of the survey.

Bankfull Drop (in): Estimate, based on channel bank scour lines, the bankfull outlet drop.

Pool Size Bankfull Width (ft): Measure the maximum width of the pool, in feet, below the culvert outfall, from the bank scour lines, at bankfull stage.

Pool Size Bankfull Depth (ft): Measure the maximum depth of the pool, in feet, below the culvert outfall, from the bank scour lines, at bankfull stage.

EROSION

Collect information about past erosion, future erosion, and erosion potential for each site. Give estimates of how much past erosion occurred at the site, how much was delivered to a stream channel, how much future erosion is to be expected, how much will be delivered to a stream channel and the likelihood of future erosion.

Erosion Potential (H, M, L): Estimate the potential for future erosion, based on observation. This is a qualitative evaluation of the likelihood of erosion, not a quantitative volume estimate. Enter "H" for High if erosion is very likely to occur. This does not quantify volume, or if the erosion will reach a stream channel. For potential landslides, base erosion potential on the likelihood that the slide will move or continue to move in response to a large magnitude rainfall and runoff event. For fluvial erosion, it is an evaluation of the likelihood of continued or future gullying in the event of a large magnitude rainfall and runoff event.

Potential for Extreme Erosion: Check if potential for extreme erosion and sediment delivery exists or if there is a potential for erosion of more than just the obvious road fill or stream crossing fill material. This usually implies erosion or landsliding of original ground and may be associated with deep fill failures, torrenting of road fills in steep swales and the diversion of large streams onto steep, erodible or unstable hillslopes.

Volume of Extreme Erosion (<500, 500-1,000, 1-2K, 2-5K, >5K): Estimate the expected volume of erosion or slope failure from an extreme erosion event. Enter one of the volume ranges of the potential extreme erosion.

Past Erosion (yd^3) (optional): Enter the volume of past erosion for the site, derived from field measurements. Enter width, depth and length measurements. If the feature is complex, take several different measurements to account for the entire feature. Show these measurements on the sketch. Often small gullies form below outlets to ditch relief culverts where there is diverted road and ditch runoff to a slope that previously did not carry such concentrated flow. These gully volumes are easily estimated using width, depth and length measurements. The largest road-related gullies form when a stream diverts out of its natural channel and then discharges into another channel or onto a hillslope area. These diversions can cause large gullies or even landslides and such erosion features are often down slope, out-of-sight of the road where the diversion originated.

Past Delivery (%) (optional): Estimate the percent of the past eroded material that was actually delivered to the stream channel system. The rest should still be in storage on the hillside.

Total Past Delivery (yds^3): Past erosion (yd^3) times past delivery (%). This is the estimated volume of erosion that has been delivered to a stream channel.

FUTURE EROSION

Future Erosion (ft):, **Width:**, **Depth:**, and **Length:** Measure the potential erosion feature, recorded as average width, depth, and length in feet. If the feature is complex, take several different measurements to account for the entire feature. These measurements describe the planimetric assumption used by field personnel to determine future erosion volumes and should be shown on the sketch map of the site. For existing gullies, potential and existing landslides and potential stream crossing washouts, it is possible to estimate the volume of future erosion that is likely to occur. Detailed descriptions on measuring and estimating future erosion volumes begin on page X-34.

Future Erosion (yd^3): Calculate the volume of future erosion from the Future erosion measurements by using the formula width x depth x length, or by geometric calculations (Figure X-5, Figure X-6, Figure X-7, and Figure X-8.

Future Delivery (%): Estimate the future eroded sediment that will enter a stream channel. If all the eroded sediment will be stored on the slope and never move into the stream system then there will be no delivery. Estimate how much sediment, as a percent of the volume of expected erosion, is likely to be delivered to the stream channel. For erosion at stream crossings, assume 100% delivery to the stream. Delivery from landslides is usually less, and often considerably less, than 100%, depending on distance to the stream, steepness of the slope and other factors. Delivery can be to any size stream. Once it is in the stream system it will eventually work its way downstream.

Total Future Delivery (yds^3): Future erosion (yd^3) times future delivery (%). This is the estimated volume of erosion delivered to a stream channel if the site is untreated and the erosion event triggers.

COMMENT(S) ON PROBLEM

The summary comments for each site generally describe the nature of the erosion problem as well as important site characteristics. It should also contain enough information to clearly depict this site and differentiate it from other nearby sites. It should describe the features contained in the sketch map on the back of the data form. Someone who has never been to the site should gain an immediate understanding of the nature and scope of the problem from reading the comment.

TREATMENT

Identify those sites that will require consultation with a licensed geotechnical specialist to develop treatment options, and prescribe treatments for all other inventoried sites of future erosion and sediment delivery for which there is an identifiable erosion control or prevention treatment that would reduce or prevent sediment delivery. In prescribing treatments, assume access for equipment to the site unless it is completely and obviously impossible to do so. In general, if there was ever a road or equipment trail to the site, there is a good chance access can be developed. After developing treatments, and evaluating costs for access and treatment, employ cost-effectiveness and other considerations to prioritize all the treatment sites.

There is a very real difference between the cause and the symptom of many erosion problems. For example, the gully below a ditch relief culvert is a symptom of the true cause; too much water flowing along the road and ditch to the culvert (i.e., too large a drainage area for the culvert). The treatment is not to stabilize the developing gully with grade control structures, or to release the water at another single location; rather, it is to disperse the water in the ditch (e.g., by using multiple ditch relief culverts) so gullying cannot continue here or elsewhere. Wherever feasible, it is important to treat the cause of the problem rather than the symptom.

Immediacy (H, M, L): Decide if the work needs to get done immediately. If the evidence suggests the feature is likely to change dramatically in the next storm event or winter season and the erosion at this site seriously threatens important downstream resources like salmonid spawning or rearing areas, enter "H" for High. Base this answer on the severity of the potential erosion, its volume, its predicted activity level and the sensitivity of the resources at risk. If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy is high. Treatment immediacy is a summary assessment of a site's need for immediate treatment. Generally, rate sites likely to erode or fail in a normal winter that may deliver significant quantities of sediment to a stream channel, as having high treatment immediacy. The answers can also include combinations, such as "HM" or "ML" to cover sites where the answer is not clear-cut.

Complexity (H, M, L): Estimate the difficulty of performing the recommended treatment. For example, classify a 1,000 yd^3 excavation of a Humboldt log crossing that will require construction of a lower access road and dump truck endhauling as "H" for High complexity. Classify a simple stream crossing excavation or the excavation of a small unstable fill along the outboard edge of the road as "L" for Low complexity. Use the Comment(s) on Treatment for explanation.

Check Culvert Size (Y/N): Enter "Y" if the culvert may be undersized. This is not a treatment as such, but it requires a future action to determine proper culvert size for the drainage. It will alert staff to conduct further analysis to check for the correct culvert size. Make sure the site is accurately located on the photo (or map) so drainage areas can be correctly measured. Enter "N" if the culvert size does not need to be checked.

Bridge: Install a bridge. Check this recommendation for crossings of Class 1 streams, especially if culvert flow analysis calls for 72" or larger pipe.

No Treatment: Check if no treatment is required.

Mulch: Estimate the exposed area in ft^2 needing mulching, after heavy equipment operations, to prevent delivery of fine sediment to a stream. This is the area needing mulching and seeding to control erosion after operations are complete. Sites located away from stream channels may not need mulching if there is no sediment delivery potential to a stream.

TREATMENT OPTIONS

Excavate Soil: Check for permanent excavations of soil from the site. Replacing or installing a culvert is not marked excavate soil if all the dirt is returned to the site after the culvert is installed. However, check if removing any portion of the soil from the work site.

Critical Dip: Check for installation of a critical dip. A critical dip is a rolling dip constructed on or close to the down-road hinge-line of a stream crossing, displaying a diversion potential. Build a critical dip at all stream crossings in order to prevent stream diversions when a culvert plugs and water flows out onto the road (Figure X-13).

Ford: Check for installation of a ford. Install fords at sites prone to frequent culvert plugging due to high amounts of sediment and debris in transport. The treatment requires excavating the entire volume of fill placed in the stream crossing and leaving a very broad dip in the axis of the natural channel, with long and gently sloping ramps into and out of the stream crossing. Build fords along roads built on floodplains and terraces and where the natural streambed is not prone to downcutting. Also, install fords where roads cross steep gradient stream channels with relatively small depths of fill at the outboard edge of the road (Figure X-14).

Armored Fill: Check for installation of an armored fill. Install armored fills at small stream crossings where culverts are prone to plugging or where maintenance during the winter is unlikely. Use armored fills on crossings with fill depths of six feet or less, instead of a ford. Protect the outer fillslope from erosion with rock armor, with a rock sill set in a key way, and with rock surfacing on the fill face. Shape the rock in a broad swale across the road to contain flood flows and direct flow over the armored fillslope (Figure X-15).

> ***Armor Size:*** The rock used for armor protection must be larger than that which can be transported by the stream during the design flood flow. This is determined by calculating minimum stable rock or stone size (Racin, et al. 2000) for the site. A seven step process is used to quantitatively determine the most appropriate minimum rock size for channel armor (Racin, et al. 2000). This includes an analysis of the local site conditions and calculations that determine the minimum rock weight (W) that will resist the flowing water. The outside layer of rock must interlock and be stable in design flows. In a typical armored fill, the rock armor covers the outer half of the road, with rock sizes increasing in the downstream and downslope direction. The largest boulders are keyed into the base of the armored fill structure, at the base of the fillslope and where flow will re-enter the natural stream channel.

Sill Height (ft): If all the fill cannot be removed from the stream crossing while still providing for easy vehicular passage, then a sill wall and energy dissipation apron will need to be constructed down the outside edge of the road to prevent erosion of the underlying erodible fill in the crossing (Figure X-15). The sill is the armored outside slope of the stream crossing fill that must be protected with armor. Enter the sill height in feet at the centerline of the stream channel, adding two feet for embedding the lowest boulders below the level of the natural stream channel at the base of the structure (e.g., if three vertical feet of fill remain at the outboard edge of the road, enter 5 feet for the sill height). This will allow for a standard two-foot deep keyway into the natural streambed for the sill wall. The armored fill treatment is typically designed for small steam crossing fills, with outboard fill depths no more than about six vertical feet. Do not recommend using this treatment if a sill wall is greater than 6 feet high, excluding the keyway or footing.

Sill Width (ft): Enter the sill width, needed to span the 100-year return interval storm. Construct sills of concrete poured into plywood forms or, more commonly, they may be made of coarse riprap or quarry rock.

Trash Rack: Check to add a trash rack just upstream from the culvert inlet to catch organic debris and to prevent culvert plugging.

Add Downspout: Length (ft): and **Diameter (in):** Check if a downspout is needed, and enter length and width of downspout required. Add a downspout to the culvert outlet to carry stream flow beyond the fill and to prevent discharge of flow onto erodible road fill or sidecast. Record the length (in feet) and diameter (in inches) of the downspout. Downspouts longer than 20 feet require anchor posts. Downspouts on stream crossings should be full, round culverts. In some instances, rock armor can provide energy dissipation, and substitute for a short downspout.

Repair Culvert: Check for repairing a culvert damaged or significantly dented by a backhoe, grader or other equipment.

Clean Culvert: Check for cleaning a plugged or partially plugged culvert inlet, and for cutting vegetation, including trees, away from the inlet or outlet.

Install/Replace Culvert: Check to install or replace a culvert.

Culvert: Diameter (in): and **Length (ft):** Specify the recommended culvert diameter, in inches, and length, in feet. Base culvert diameter on 100-year storm discharge and determine diameter from one or more empirical equations or formulas. Guessing is not a very good way to determine the appropriate culvert size. Estimate culvert length by measurements taken in the field.

Install Flared Inlet: Check if prescribing a flared inlet to prevent culvert plugging. Specify the diameter of the flared inlet, in inches.

Reconstruct Fill: Check for a completely or partially failed road due to a landslide. This will probably involve a newly engineered fill that will likely require design by a qualified engineer. Do not use this space for reconstructing or filling in a washed-out stream crossing.

Armor Fill Face (U, D, B): Check for armoring fill face(s) of a stream crossing fill with coarse boulders that will protect the fill from stream erosion caused by stream flow and scouring at the culvert inlet or unavoidable culvert plugging or overtopping at the culvert outlet. Enter “U” for armoring the upstream crossing fill, “D” for downstream, or “B” for both.

Armor Area (ft^2): Specify the surface area of rock needed to armor the upstream (U) and/or downstream fill faces.

Clean or Cut Ditch (ft): Check if a plugged ditch needs cleaning or a new ditch built. Specify the length in feet.

Remove Ditch (ft): Check to remove (fill) a section of inboard ditch. Specify the length in feet.

Outslope Road (ft): Check for the conversion of a flat, crowned or insloped road to an outsloped road. Generally, this treatment is for road upgrading or decommissioning where road surface drainage needs to be improved. “Outslope Road” is the correct prescription to use to change the surface drainage pattern on the roadbed. Specify the length of outsloping required, in feet. Use “Excavate Soil” (instead of “Outslope Road”) when decommissioning a road and there is need to excavate substantial material from the outside edge of the road in order to prevent fillslope landslides.

Outslope and Remove Ditch (ft): Check if the road is to be outsloped and the inboard ditch removed. Specify the length of road to be outsloped with the ditch removed.

Outslope and Retain Ditch (ft): Check for road reaches to be outsloped but the inboard ditch retained. Specify the length of road to be outsloped with the ditch retained.

Inslope Road (ft): Check for the conversion of a flat, crowned or outsloped road to an insloped road. Generally, this treatment is for areas where it is important to keep water off the outside fillslope. “Inslope road” is the correct prescription to use to change the surface drainage pattern on the roadbed. Typically, but not always, an inboard ditch is needed when the road is insloped. For a retained ditch, prescribe clean or cut ditch as well (see above). Specify the length of insloping required, in feet.

Rolling Dips (#): Check for installing rolling dips on the road surface. Typically, install rolling dips in road upgrade projects. Usually, but not always, the rolling dip connects to an inboard ditch if present. Also, use rolling dips on outsloped roads to drain the road surface (Figure X-21). Specify the number of rolling dips needed along the road reach. This is not the correct prescription to use for critical dips at stream crossings to prevent stream diversions.

Remove Berm (ft): Check to remove or grade a berm along the outside edge of the road. Specify the length of berm in feet.

Ditch Relief Culvert: Check for the installation of ditch relief culverts to drain the inside ditch. Specify the number and total length of the culvert needed. Unless otherwise specified, a ditch relief culvert will be 18 inches diameter (Figure X-20)

Rock Road Surface (ft^2): Check to rock the surface of a section of road. Use this treatment only for prescribing new rocking. Specify the total area needing rock in ft^2. To re-rock a site after installing a rolling dip or replacing a culvert on a rocked road, do not check this treatment.

Cross Road Drain (#): Check for installing cross road drains, or exaggerated waterbars, on decommissioned roads. Specify the number of cross road drains.

Other: Check if recommending another treatment. Fully describe in the Comment(s) on Treatment section.

HEAVY EQUIPMENT EXCAVATION DATA

Track and manage spoil according to the following equations:

- Total Volume Excavated = Volume Returned + Volume Removed
- Volume Removed = Volume Stockpiled + Volume Endhauled

Total Volume Excavated (yd^3): The total volume of material excavated from the unstable fillslope or stream crossing. Use this volume to help predict costs and equipment times needed to perform the excavation work. In addition, it is used to help determine whether endhauling will be necessary to dispose of spoil from the site.

Volume Put Back in (yd^3): This is the volume of material that is to be put back into the excavation hole, as in a culvert replacement.

Volume Removed (yd^3): This is the volume of excavated material removed from the excavation hole. For example in the excavation of unstable sidecast material, zero would be returned and all of it would be removed.

Volume Stockpiled (yd^3): Excavated spoil that can be locally stored without using dump trucks.

Volume Endhauled (yd^3): From measurements in the field, the available storage volume is calculated and compared to the total excavated volume to determine the need for endhauling equipment. If local storage is insufficient, identify additional storage sites in nearby areas along the road.

Distance Endhauled (ft): Record the distance materials will need to be endhauled for storage.

Excavation Production Rate (yd^3/hr): Estimate the excavation production rate for the site to determine the required equipment hours. Use the Comment(s) on Treatment section to itemize the hours needed for each piece of equipment, for every assigned task and sub-task. See Table X-5 for guidelines in estimating equipment production rates for various tasks. For equipment and labor time estimates do not include time for traveling or other miscellaneous tasks.

EQUIPMENT HOURS DATA

If a piece of equipment is to perform several different tasks or sub-tasks, then list the individual times that go together to add up to total equipment time for each piece of equipment.

Excavator: Estimate the hours of excavator time needed at the site.

Dozer (Crawler Tractor): Estimate the hours of tractor time needed for excavation and spoil management at the site.

Backhoe: Estimate the hours of backhoe time needed at the site.

Grader: Estimate the hours of grader time needed at the site.

Loader: Estimate the hours of loader time needed at the site.

Dump Truck: Estimate the hours of dump truck time needed for endhauling excess spoil to stable storage locations.

Labor: Estimate the hours of laborers needed to perform such tasks as culvert installation, culvert cleaning, etc.

Other: Any other tasks or equipment not listed above.

COMMENT(S) ON TREATMENT

Add details for equipment or labor treatments and logistics or any information useful for the project. Fill this comment section with descriptive information that will be useful for the equipment operators, and will make it clear what work has been prescribed for the site.

UPSLOPE INVENTORY DATA FORM

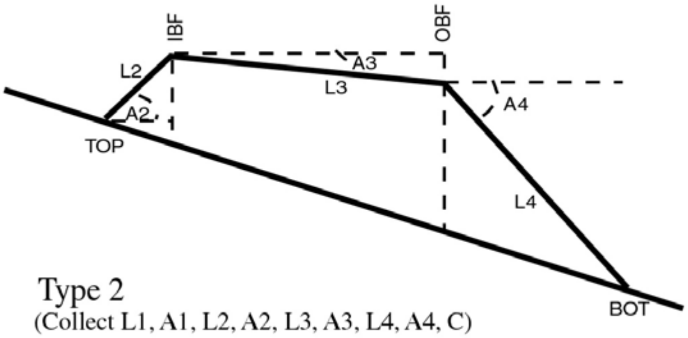
ASAP (Y, N)______

GENERAL	Site no:	Treat (Y/N):	Watershed:	Quad:	
	GPS:		CALWAA:	Photo:	
	T/R/S:		Road name/#:	Drivable (Y/N):	
	Mileage:		Inspector(s):	Date:	Year built:
	Surface: □ rock □ native □ paved		Status: □ maintained □ abandoned	□ decommissioned	
	Proposed: □ upgrade □ decommission			Sketch (Y/N):	
PROBLEM	Stream crossing (Y/N):		Landslide: □ fill □ hill □ cut	Roadbed: □ bed, □ ditch, □ cut	
	□ ditch relief culvert		□ gully	□ bank erosion	Road related (Y/N):
	Other non-road related site: □ home □ agricultural □construction □ mining □ other site				
LANDSLIDE	□ road or landing fill		□ hillslope debris slide[1]	□ other hillslope landslide (depth unknown)[1]	
	□ cutbank slide		□ potential failure	□ past failure	Slope (%):
	Distance to stream (ft):				
STREAM	□ culvert	□ bridge	□ Humboldt	□ fill	□ ford	□ armored fill
	□ excavated crossing		% excavated:		
	Ditch road length (ft): Left:		Right:	Culvert diameter (in):	
	Pipe condition (O, C, R, P): Inlet:		Bottom:	Outlet:	□ separated
	Headwall (in):		Culvert slope (%):	Stream class (1,2,3):	
	Culvert rust-line (in): Inlet:		Outlet:	Culvert undersized (Y, M, N):	
	Washed out (%):		Diversion potential (Y/N):	□ currently diverted	
	Road grade (%):		Plug potential (H, M, L):	Plugged (%):	
	Channel gradient (%):		Channel width (ft):	Channel depth (ft):	
	Sediment transport (H, M, L):		Drainage area (acres):		
FISH PASSAGE	Culvert outlet drop (in):		Bankfull drop (in):		
	Pool size bankfull width (ft):			Pool size bankfull depth (ft):	
EROSION	Erosion potential (H, M, L):		□ potential for extreme erosion		
	Volume extreme erosion (<500, 500-1,000, 1-2K, 2-5K, >5K):			Past erosion (yd^3) (optional):	
	Past delivery (%) (optional):		Total past delivery (yd^3):		
FUTURE EROSION	Future erosion (ft): Width:		Depth:	Length:	Future erosion(yd^3):
	Future delivery (%):		Total future delivery (yd^3):		
COMMENT(S) ON PROBLEM:					
TREATMENT	Immediacy (H, M, L):		Complexity (H, M, L):		
	check culvert size (Y/N):		□ bridge	□ no treatment	Mulch (ft^2):
TREATMENT OPTIONS	□ excavate soil	□ critical dip	□ ford	□ armored fill	Sill height (ft):
	Sill width (ft):	□ trash rack	□ Add downspout: Length (ft):		Diameter (in):
	□ repair culvert	□ clean culvert	□ install/replace culvert		
	Culvert: Diameter (in):		Length (ft):	□ flared inlet: Diameter(in):	
	□ reconstr. fill	□ armor fill face (U, D, B):		Armor area (ft^2): U: D:	
	□ clean or cut ditch, (ft):		□ remove ditch, (ft):		
	□ outslope road, (ft):		□ outslope & remove ditch, (ft):		
	□ outslope & retain ditch, (ft):			□ inslope road, (ft):	
	□ rolling dip, (#):		□ remove berm, (ft):		
	□ ditch relief culvert, (#):		Length (ft):	□ rock road surface, (ft^2):	
	□ cross road drain, (#):		□ other:		
HEAVY EQUIPMENT EXCAVATION DATA	Total vol. excavated (yds^3):		Volume put back in (yds^3):		
	Volume removed (yds^3):		Volume stockpiled (yds^3):		
	Volume endhauled (yds^3):		Distance endhauled (yds^3):		
	Excavation production rate: (yds^3/hr):				
EQUIPMENT HOURS	Excavator:	Dozer:	Backhoe:	Grader:	Loader:
	Dump truck:		Labor:	Other:	
COMMENT(S) ON TREATMENT:					

[1] *Consultation with a licensed geotechnical specialist is required to estimate slide volumes and to evaluate or develop treatment options. The location of these features should be noted on the field form and on maps, but the inventory crew should not estimate the sediment volumes for calculation of cost-effectiveness.*

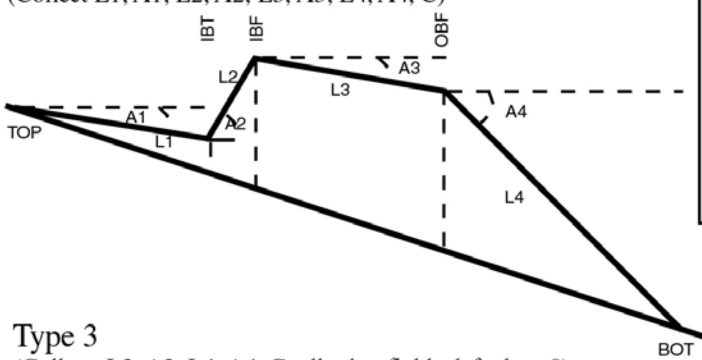
Type 1

(Collect L2, A2, L3, A3, L4, A4, C, all other fields default to 0)



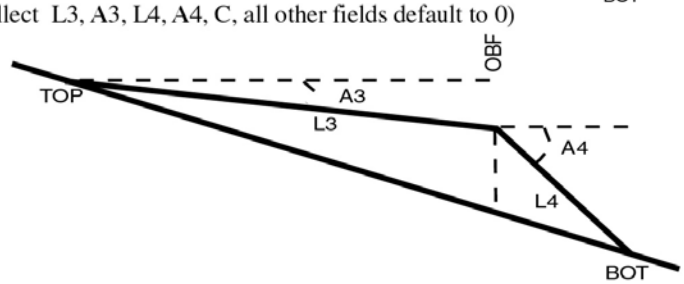
Type 2

(Collect L1, A1, L2, A2, L3, A3, L4, A4, C)



Type 3

(Collect L3, A3, L4, A4, C, all other fields default to 0)



Field data

Length of sediment fan (L1): _____ ft

Angle of sediment fan (A1): _____ degrees

Length of inboard fillslope (L2): _____ ft

Angle of inboard fillslope (A2): _____ degrees

Length of road bed (L3): _____ ft

Angle of road bed (A3): _____ degrees

Length of outboard fillslope (L4): _____ ft

Angle of outboard fillslope (A4): _____ degrees

Channel width (C): _____ ft

Sketch

APPENDIX X-B. INSTRUCTIONS FOR STREAM BANK INVENTORY DATA FORM

Use the *Stream Bank Inventory Data Form* in the assessment of past and potential erosion problems along stream channels, including determining their nature, cause, magnitude and treatment. Also, use it to identify and classify erosion problems along stream channels, to prioritize potential work sites, and to prescribe specific treatments aimed at protecting stream channels and fish habitat. *Part III* describes methodologies for stream channel classification, stream habitat inventories, and large woody debris and riparian inventories.

The *Stream Bank Inventory Data Form* provides a standardized protocol for evaluating stream-related erosion and identifying erosion control options. Also, use it to evaluate all types of riparian sediment sources. Where roads are in close proximity to a stream channel, there may be individual sites described by both the *Upslope Inventory Data Form* and the *Stream Bank Inventory Data Form*. If the proposed treatments are sufficiently different, retain both forms to describe the same location. However, do not duplicate recommended treatments and treatment times. Using the *Stream Bank Inventory Data Form*, field personnel can measure, describe and interpret landforms and erosion problems in a consistent and uniform manner. Enter the data collected into a database for analysis, leading to the preparation of a work plan for implementation.

General Information

Site Number: The identification number assigned to each site. This is a unique ID number for future reference. Also, write the Site Number on an aerial photo Mylar overlay. This number identifies each site in database searches. Use only numbers, not letters, for effective database searches.

Distance (ft.): Enter the stream channel distance, in feet, to the beginning of the site, from a known beginning point, usually a confluence, road, bridge, etc.

Date: Date of the survey.

Inspector(s): Record the names or initials of the inventory crew. List the data recorder first.

Watershed: Major drainage as described on the USGS 7.5 minute topographic map, for example Bull Creek.

Stream: As described on the USGS 7.5 minute topographic map.

Air Photo: List the flight line and frame number of the air photo used for mapping. Original field mapping information is contained on acetate or Mylar overlay for each of the aerial photos covering the assessment area.

Location (LB, RB, B): Enter the location of the site along the stream channel (“LB” = left bank, “RB” = right bank or “B” = both banks). Location is always determined when facing downstream.

Road Related: Check for erosion related to a road. If it is road-related, identify the corresponding road site number, if one exists, in the Comment(s) on Problem section.

Treat: Enter "Y" if recommended for treatment and "N" if not recommended for treatment.

Problem

Type: Check the appropriate type of problem at each locality. More than one problem may occur at a single site.

- debris slide: These slides may involve a substantial percentage of original bedrock and soil materials, or they may be composed of un-compacted spoil or road sidecast material. Debris slides move relatively fast and are typically shallow compared to larger deep-seated hillslope landslides. Stream side debris slides can range from small slope failures less than 10 yd^3 in volume, that are not visible on aerial photos and are only identifiable from a field inventory, to large landslides that can be easily identified from small scale aerial photos.
- debris torrent: Debris slides may or may not turn into fluid debris flows or torrents. Confinement, slope gradient and water content determine if a debris slide becomes a debris torrent. Torrents typically originate somewhere upslope or upstream and carry soil materials and organic debris to a hillslope or lower gradient stream channel where it is deposited.
- hillslope landslides of unknown depth: Usually cover relatively large areas with multiple scarp systems running through natural slopes and/or across roads and skid trails. Slow, deep-seated landslides characterized by emerging groundwater; leaning trees; active and inactive scarp systems; and episodic, seasonal movement from several feet to several hundred feet annually. Along a stream channel, a slow, deep-seated landslide may express itself as continuous length of raw, eroding stream bank, or as one or more shallow debris slides that are forming along the leading edge of the deeper slide mass. Some slides may not move annually. Most deep-seated landslides are difficult and expensive to control, if at all.
- torrent channel: The channel left after a debris torrent or mudflow has passed.
- bank erosion: The most common channel erosion problem encountered during a stream bank inventory. Bank erosion occurs wherever stream flow impinges against a soft stream bank. The erosion may occur in previously deposited alluvial materials (e.g., a terrace or flood plain surface) or along the base of the confining hillslope. Bank erosion may result in the development of debris slides where the hillslope erodes and undercuts. Bank erosion often occurs along the outside bend of a stream or river where stream flow diverts or deflects against a stream bank from woody debris (logs), boulders, a sediment deposit or other channel obstructions.
- LDA: Stream bank erosion related to a log debris accumulation.
- other: A problem other than those listed above. Describe in the Comment(s) on Problem Section.

Delivery: Check "past" for stream bank erosion that is unlikely to deliver additional sediment to the stream. Check "future" for a site currently delivering sediment to a stream channel. Check "both" for a site that contributed sediment in the past, and is likely to deliver sediment in the future.

Activity (A, IA, W): Enter "A" for an active feature such as a stream bank that is bare and erodes during each high flow period. Enter "IA" for a feature that appears inactive such as an older failure area that looks like it may no longer have the potential for further movement. Enter "W" for waiting if the feature is not currently active but shows substantial potential for future activity. An example of a waiting feature might include an unstable slope exhibiting scarps and leaning trees, but no indication of recent slope movement.

Age (Decade): Enter the estimated age, by decade, of the site. Age is typically determined using historical accounts, photos or other information to date the feature. Oftentimes use vegetation (leaning trees, recent sprouts, or vegetation size) to date features to within 10 years. A typical answer might be "1980's". For a continuously active feature, answer "1980 – 2000".

Stream Bank Slope (%): The slope of the bank at the site. This is the slope of the natural ground. Stand at the base of the erosion feature and take a clinometer reading looking upslope.

Land Use: Check if there is direct evidence for some type of land use contributing to the occurrence or activity of the erosion site. Describe the land use associated with the erosion site in the Comment(s) on Problem section.

Undercut by Stream: Check for a bank undercut by the stream. It is important to identify an existing or potential debris slide that is threatening to develop because of stream bank erosion.

Past Erosion

Estimates of past erosion and sediment delivery volumes provide an indication of erosion activity along the stream channel. Calculate the volume of past bank erosion and debris slides, the two most common erosion features, by multiplying average linear dimensions of width, depth and length.

Width (ft): Estimate the average width of past erosion in feet. Width is the average thickness of bank cutting.

Depth (ft): Estimate the average depth of past erosion in feet. Depth is the bank height.

Length (ft): Estimate the length of past erosion in feet. For stream banks, measure length along the stream channel.

Volume (yd^3): Estimate the volume of past erosion (yd^3) at the site. Sketch the site on the back of the form, including the measurements, recorded on the data form. Volume (yd^3) = (width x depth x length)/27. Assume that stream bank erosion is 100% delivered to the stream.

Future Erosion

Estimate future erosion by applying reasonable rates or by calculating debris slide volume and delivery (page X-41).

Future Erosion Potential (H, M, L): Estimate the potential for future significant erosion at this site, based on observations. This is a probability estimate, not an estimate of how much erosion is likely to occur. Enter "H" or high, "M" for moderate or "L" for low. High means that erosion is very likely to occur at this site.

Width (ft): Estimate the width of future erosion in feet. Width is the average thickness of bank cutting.

Depth (ft): Estimate the depth of future erosion in feet. Depth is the bank height.

Length (ft): Estimate the length of future erosion in feet. For stream banks, measure length along the stream channel.

Volume (yd^3): Estimate the volume of future erosion. Volume (yd^3) = (width x depth x length)/27. For stream bank erosion, delivery is 100%.

Comment(s) on Problem

The comments for each site generally describe the nature of the erosion problem as well as important site characteristics. Include enough information to clearly depict the site and differentiate it from other nearby sites. Describe the features contained in the sketch map on the data form.

Treatment

Immediacy (H, M, L): Enter "H" for high if the work needs to get done immediately. Base this prioritization on the severity of the potential erosion, its volume, its predicted activity level and the sensitivity of the resources at risk.

Complexity (H, M, L): Estimate the difficulty of performing the recommended treatment. For example, simply moving a small boulder to prevent flow deflection enter "L" for low, whereas performing heavy equipment treatments in remote locations requiring road construction, endhauling or riprap enter "H" for high. Explain in the Comment(s) on Treatment section.

Equipment or Labor (E, L, B): Enter one of these treatment types. Treat the site using heavy equipment (E), manual labor (L) or both (B).

Equipment Access (E, M, D): Estimate the degree of difficulty of getting appropriate heavy equipment to the work site. Use "E" for easy, "M" for moderate, or "D" for difficult.

Local Materials: Check if material is available and sufficient for treating the site.

Import Materials: Check if material (e.g., boulder riprap) needs to be imported to treat the site. If needing local and imported materials, check both answers.

Treatment Options

Check each of the recommended treatments prescribed for a work site (*Part VII*). The treatments include:

Excavate Soil: Check if the treatment option is to excavate soil and remove it from the site. Landslide excavations would fall under this category of treatment. Enter width, depth and length of excavated material, in feet. Calculate excavated volume, in cubic yards.

Rock Armor / Buttress: Check for sites where armoring the stream bank with boulders will eliminate or reduce erosion of a stream bank or toe of a landslide. Specify both the size (diameter or ton) and surface area of rock armor (ft^2) needed.

Log Protection: Check for use of logs and other organic debris to protect stream banks from erosion. Identify the size (length and diameter) of the woody debris, the length of the bank protected, and the bank area to be covered (ft^2). In the Comment(s) on Treatment section identify the anchoring method (if any), the source of the woody materials (local or imported) and describe the placement method.

Remove Logs / Debris: Check if logs, boulders or other debris in the channel are deflecting flow and aggravating bank erosion and sediment delivery, identify this as a possible treatment. Include treatment details in the Comments on Treatment section.

Boulder Deflectors: Check for use of boulder deflectors to protect stream banks from erosion. Identify the number of boulder deflectors. Identify the yds^3 of boulder to necessary for each deflector.

Bio-engineering: Check for bio-engineering. Describe the bio-engineering methods to be used in the Comment(s) on Treatment section.

Plant Erosion Control: Check if recommending planting for erosion control. Revegetation with grasses is a short-term (1 to 2 years) treatment to control surface erosion. Plant woody species, such as willow and coyote brush, for intermediate term revegetation. Planting conifer or hardwood trees will provide for long-term erosion control and stability. Planting conifers reestablishes a large woody debris source. Describe the planting recommendations in the Comment(s) on Treatment section.

Riparian Restoration: Check if recommending manipulation of the riparian zone. An example of vegetation manipulation is thinning red alders and planting of conifers for long-term restoration of streamside vegetation (*Part XI*).

Area Planted: Measure or estimate the size of the area to plant or treat, in square feet. Identify the spacing, species composition, and number of trees to be planted in the Comment(s) on Treatment section.

Exclusionary Fencing: Check if the erosion control treatment is to exclude grazing animals from the stream or riparian zone. Identify the length of fencing needed, in feet.

<u>Other:</u> Check if recommending some other treatment. Fully describe in the Comment(s) on Treatment section.

Equipment Hours

If heavy equipment is needed to perform one or more different tasks, then list the individual times that go together to add up to total equipment time for each piece of equipment. In the Comment(s) on Treatment section, itemize equipment times by task for all equipment, which includes:

<u>Excavator:</u> Estimate the hours of excavator time needed for direct excavation, log and rock placement, and for other tasks at the work site. Include time needed for developing access for all equipment.

<u>Dozer:</u> Estimate the hours of tractor time needed for direct excavation work, winching or other work tasks.

<u>Dump Truck:</u> Estimate the hours of dump truck time needed for endhauling excess spoil to stable storage locations, or for importing rock armor other materials to the project.

<u>Backhoe:</u> Estimate the hours of backhoe time needed for direct excavation at the work site. Estimate time for travel or other miscellaneous tasks.

<u>Labor:</u> Estimate the hours of laborers needed to perform such tasks as rock placement, planting, seeding, mulching, winching, cabling, and providing assistance to heavy equipment.

<u>Other:</u> Describe other tasks or equipment not listed above, such as a front-end loader or lowboy.

Comment(s) on Treatment

Include details for equipment or manual labor treatments and logistics. Be as specific as is possible, and relate the comments to the sketch map.

STREAM BANK INVENTORY DATA FORM

GENERAL	Site no:	Distance (ft):		Date:	Inspector(s):	
	Watershed:			Stream:		
	Air photo:		Location (LB, RB, B):		☐ road related	Treat (Y/N):
PROBLEM	Type:	☐ debris slide	☐ debris torrent	☐ hillslope failure of unknown depth and activity[2]		
		☐ torrent / debris flow channel[1]		☐ bank erosion	☐ LDA[3]	☐ other
	Delivery:	☐ past	☐ future	☐ both	Apparent activity (A, IA, W):	
	Age (decade):		Stream bank slope (%):			
	☐ land use	☐ undercut by stream				
PAST EROSION	Width (ft):	Depth (ft):	Length (ft):		Volume (yd^3):	
FUTURE EROSION	Future erosion potential (H, M, L):		Width (ft):		Depth (ft):	
	Length (ft):			Volume (yd^3):		
COMMENT(S) ON PROBLEM:						
TREATMENT	Immediacy (H, M, L):		Complexity (H, M, L):		Equipment or labor (E, L, B):	
	Equipment access (E, M, D):		☐ local materials		☐ import materials	
TREATMENT OPTIONS	☐ excavate soil	Width (ft):	Depth (ft):	Length (ft):	Volume (yds^3):	
	☐ rock armor/buttress		rock armor size (ft or ton):		rock armor area (ft^2):	
	☐ log protection		Log size: Length (ft): Bank length protected (ft):		Diameter (ft): Bank area to cover (ft^2):	
	☐ remove logs/debris				☐ boulder deflectors	
	Deflectors (#):		Deflector (yd^3):		☐ bio-engineering	
	☐ plant erosion control		☐ riparian restoration		Area planted (ft^2):	
	☐ exclusionary fencing		Length of fence (ft):		☐ other	
EQUIPMENT HOURS	Excavator:	Dozer:	Dump truck:	Backhoe:	Labor:	Other:
COMMENT(S) ON TREATMENT:						

[1] A debris torrent is a mudflow that originates as a debris slide and then fluidizes (through the addition of water) and flows down a stream channel. It typically ends as a deposit or dam of poorly sorted sediment and woody debris in a lower gradient section of channel. The process is the mudflow; the evidence of that process is the scoured channel through which the flow passed, and the sediment and debris that is deposited at the end of the flow path. The activity level is typically that of the potential debris slide that would form the source of the mudflow. Note: if you have identified a potential hillslope debris slide, treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.

[2] If a failure of unknown type and depth is identified, treatment prescriptions must be developed in consultation with a licensed geotechnical specialist.

[3] LDA is a log jam or accumulation of logs and woody debris in the channel that is causing bank erosion or other erosion and sediment delivery problems.

SKETCH

APPENDIX X-C. CASE STUDY #1

1999 S.B. 271 WATERSHED ASSESSMENT FOR PARSONS CREEK, MENDOCINO COUNTY, CALIFORNIA

prepared by
Pacific Watershed Associates

for
The U.C. Hopland Research and Extension Center and the California Department of Fish and Game

Background

Parsons Creek is a fourth or fifth order, steelhead producing tributary to the Russian River located approximately five miles east of Hopland, California. The majority of the watershed is located within the boundaries of the U.C. Hopland Research and Extension Center (HREC). The watershed is approximately 6 mi^2 in area upstream from the western HREC boundary on the mainstem of Parsons Creek (Figure X-C-1). Parsons Creek watershed is primarily composed of oak woodlands, chaparral, and converted and natural grasslands, which are managed for sheep and cattle grazing and various academic research projects.

Parsons Creek has recently been recognized as a viable steelhead producing tributary to the Russian River region of Northern California. Since the early 1900's, much of the forested and chaparral portions of the watershed have been converted to pasture.

By 1952 roads had been pioneered to the upper reaches of the watershed and more intensive livestock management practices had been implemented. These initial roads essentially circled the entire watershed and provided access to the upper reaches of the watershed.

By 1963 the road network had expanded to access most of the mid-slope portions of the watershed and many of the roads built prior to 1952 had been partially rerouted or abandoned due to their deteriorating condition. This time frame exhibits the most extensive, post 1952 new road construction, in the Parsons Creek watershed and provided access to the more remote areas of the watershed.

Over the next 33 years the road network of the Parsons Creek watershed expanded by only a fraction of the existing network. Most of these new roads were built as connecters to the main roads which already provided access to the majority of the watershed.

Currently there are over 40 miles of dirt road managed by six separate landowners on the Parsons Creek watershed with the majority of the roads (36 miles) managed by HREC. Of the 36 miles of road most are currently maintained with only a small portion abandoned or permanently gated to restrict vehicle use. These roads are currently used predominantly for ranching and research and receive light traffic and minimal heavy vehicle use.

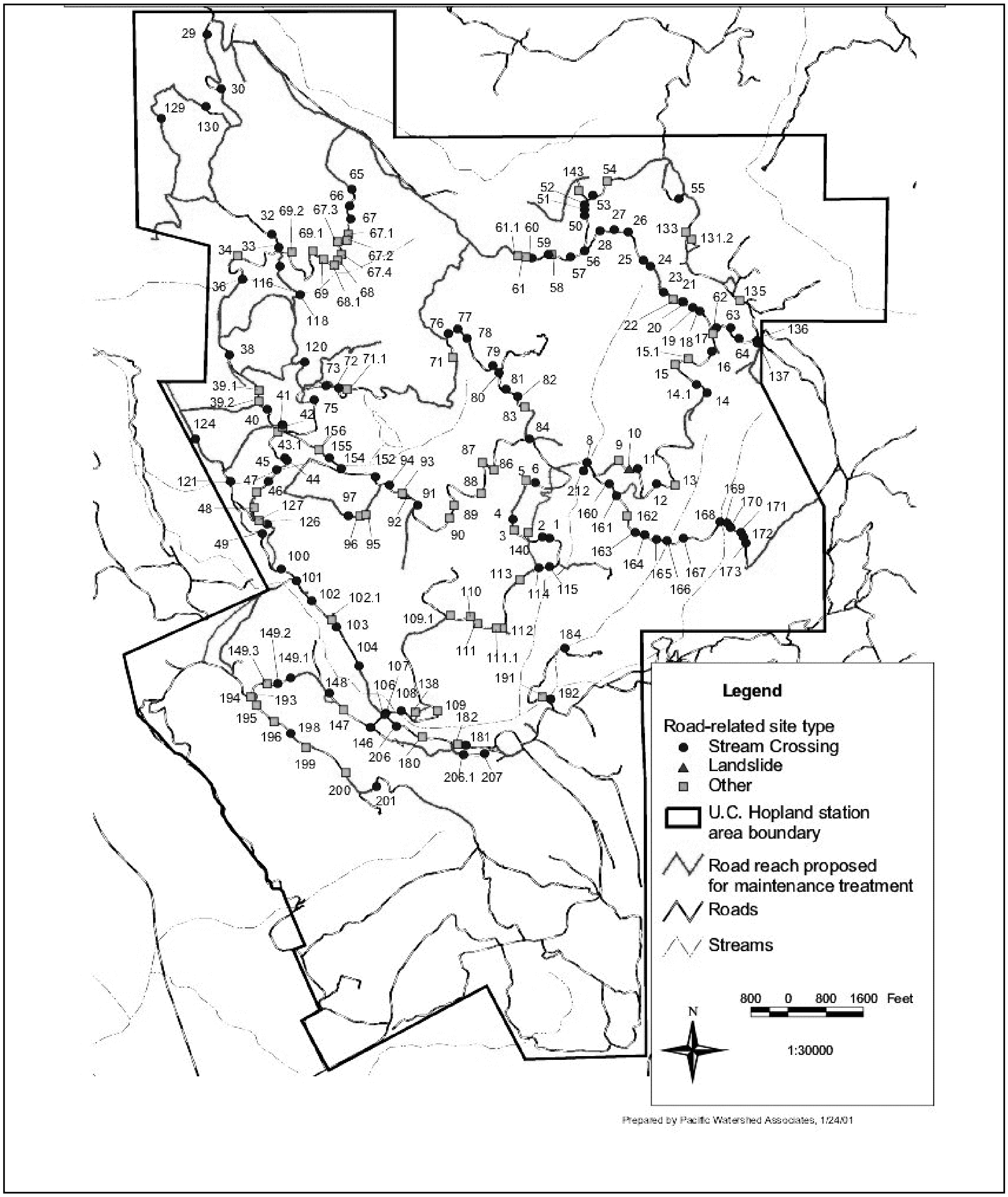


Figure X-C-1. Road-related sites with future sediment delivery, UC Hopland Experimental Station, Parsons Creek, Mendocino County, California.

Geologic setting of the Parsons Creek watershed
Sediments and rocks within the Parsons Creek watershed consist almost entirely of undifferentiated sedimentary and metamorphic rocks of the Franciscan formation. Most of the rocks found within the watershed have undergone severe post depositional deformation. This deformation ranges from pervasive fracturing to intense recrystallization. The most common rocks found in the watershed are Mesozoic marine sandstones, cherts and mudstones. These rocks tend to outcrop at higher elevations in the study area and where major tributary channels have cut through the overlying thick mantle of colluvium in the lower portions of the watershed. These rocks are extensively sheared and tend to erode into small fragments in all but the largest outcrops. Other rocks present in lesser amounts in the watershed include highly metamorphosed fragments of the oceanic lithosphere. These rocks vary in their degree of metamorphism and include greenschist and blueschist facies rocks. Metamorphic rocks rarely outcrop in the study area but tend to litter the tributary channels because of their resistence to erosion. The geology in the lower watershed is dominated by Quaternary alluvium and thick colluvial deposits, on the hillslopes. These deposits are interstratified where the hillsides are adjacent to the active and historic fluvial terraces.

The southern 60% of the Parsons Creek watershed is mantled by multiple, coalescing, mountain scale landslides. These landslides tend to dominate the topography resulting in large amphitheater shaped cavities in the upper headwall areas of the watershed and thick unconsolidated deposits in the lower sections. The slides are presently inactive, probably thousands of years old and are clearly unrelated to present land use activities and historic climatic fluctuations. Although the slides are inactive and old they do significantly influence the watershed drainage patterns and sediment sources for Parsons Creek. The toes of these large landslides appear to have merged and formed the southern margin of the lower Parsons Creek drainage, possibly dividing a historically more extensive drainage basin. Further up the hillside the deposits of the landslides mantle a high percentage of the southwest portion of the watershed. They vary in thickness but are typically less than 80 feet thick. These deposits consist of broken rock fragments, of various sizes and lithologies, jumbled within a matrix of heterogeneous sand and mud. This type of deposit is highly erodible and significantly affects the distribution of erosion within the watershed.

Parsons Creek watershed assessment and implementation
Perhaps the most important element needed for long term restoration of steelhead habitat, and the eventual recovery of salmonid populations in Parsons Creek, is the reduction of accelerated erosion and sediment delivery to the channel system. This summary report describes the watershed assessment and inventory process that was employed in the Parsons Creek Assessment.

It also serves as a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments for the Parsons Creek watershed. When implemented and employed in combination with protective land use practices, the proposed projects are expected to significantly contribute to the long term protection and improvement of salmonid habitat in the basin. The implementation of erosion control and erosion prevention work is an important step towards protecting and restoring watersheds and their anadromous fisheries (especially where sediment input is a limiting or potentially limiting factor to fisheries production, as is thought to be the case for Parsons Creek).

Project Description

The watershed assessment process consisted of two distinct project elements. These included: 1) a completed inventory of all future road-related sediment sources in the watershed, and 2) an inventory of sediment sources along the mainstem of Parsons Creek, totaling approximately 3.3 miles of stream channel in both the upper and lower watershed.

In the first phase of the Parsons Creek inventory project all roads within the study area were identified and age dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. A composite map of the road systems in both lower and upper Parsons Creek was developed from GIS base maps produced by HREC. The base maps, updated through analysis of aerial photos, depict the primary road network in the watershed and show the location of sites with future erosion and sediment delivery to the stream system.

The second phase of the project involved a complete inventory of the road systems, selected hillslope areas and major stream channels. Technically, this assessment is neither an erosion inventory nor a road maintenance inventory. Rather, it is an inventory of sites where there is a potential for future sediment delivery to the stream system that could impact fish bearing streams in the watershed. All roads, including both maintained and abandoned routes, were walked and inspected by trained personnel and all existing and potential erosion sites were identified. Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to a stream channel. Sites of past erosion were not inventoried unless there was a potential for additional future sediment delivery. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were identified but, were not included in the assessment.

In the final phase of the watershed assessment project, the mainstem of Parsons Creek was inventoried for bank erosion sites and stream side landslides. Data was collected on the location and volume of sediment sources along approximately 3.3 miles of the mainstem and the largest major tributary of Parsons Creek. Data collected included the type of erosional process, the current activity level, the volume of sediment delivery, and applicable treatment prescriptions at sites where work has been recommended. In addition, erosion sites were mapped on mylar overlays to the 1:14,000 scale aerial photos. Derivative site maps of the channel system were then produced (see channel maps in back of report).

Inventory Results

Approximately 36 miles of roads were inventoried for future sediment sources within the Parsons Creek watershed. Inventoried road-related erosion sites on HREC lands fell into one of two treatment categories: 1) upgrade sites – defined as sites on maintained open roads that are to be retained for access and management and 2) decommission sites – defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure. Virtually all future road-related erosion and sediment delivery in the Parsons Creek watershed is expected to come from three sources: 1) the failure of road fills (landsliding), 2) erosion at or associated with stream crossings (from several possible causes), and 3) road surface and ditch erosion.

A total of 214 sites were identified with the potential to deliver sediment to streams. Of these, 180 sites were recommended for erosion control and erosion prevention treatment. Approximately 62% (n=131) of the sites are classified as stream crossings and 2% (n=6) as potential landslides (Figure X-C-1, Table X-C-1). The remaining 36% (n=77) of the inventoried sites consist of other sites which include ditch relief culverts and gullies.

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future delivery (yds^3)	Stream crossings w/a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Landslides	6	2	61	NA	NA	NA
Stream crossings	131	111	8,853	75	6	41
Other	77	67	1,356	NA	NA	NA
Total (all sites)	214	180	10,270	75	5	41
Persistent surface erosion[1]	14.94	14.94	14,608	NA	NA	NA
Totals	214	180	24,878	75	6	41

[1] Assumes 25' wide road prism and outbank contributing area, and 0.2' of road/cutbank surface lowering per decade.

Table X-C-1. Site classification and sediment delivery from all inventoried sites with future sediment delivery in the Hopland field station assessment area, Mendocino County, California.

<u>Landslides</u> Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. Potential landslides account for approximately 2% of the inventoried sites in the Parsons Creek assessment area (Figure X-C-1, Table X-C-1). Most of the potential landslide sites were found along roads where material had been sidecast during earlier construction and now show signs of instability. Potential landslides are expected to deliver nearly 61 yds^3 of sediment to Parsons Creek and its tributaries in the future. Correcting or preventing potential landslides associated with the road is relatively straightforward, and involves the physical excavation of potentially unstable road fill and sidecast materials.

There are a number of potential landslide sites located in the Parsons Creek assessment area that did not, or will not deliver sediment to streams. These sites were not inventoried using data sheets due to the lack of expected sediment delivery to a stream channel. They are generally shallow and of small volume, or located far enough away from an active stream such that sediment delivery is unlikely. For reference, all landslide sites were mapped on the mylar overlays of the aerial photographs, but only those with the potential for future sediment delivery were inventoried using a data sheet (Figure X-C-2).

ASAP____	**R O A D I N V E N T O R Y D A T A F O R M**						Check_____
GENERAL	**Site No:** ________	GPS:	Watershed:		CALWAA:		
Treat (Y,N):	Photo: ______	T/R/S:	Road #:		Mileage: ___________		
	Inspectors:_______	Date: ________	Year built:______	Sketch (Y):			
	Maintained	Abandoned	Driveable	Upgrade	Decommission	Maintenance	
PROBLEM	Stream xing	Landslide (fill, cut, hill)	Roadbed (bed, ditch, cut)	DR-CMP	Gully	Other	
	Location of problem (U, M, L, S)	Road related? (Y)	Harvest history: (1=<15 yrs old; 2=>15 yrs old) TC1, TC2, CC1, CC2, PT1, PT2, ASG, No		Geomorphic association: Streamside, I.G., Stream Channel, Swale, Headwall, B.I.S.		
LANDSLIDE	Road fill	Landing fill	Hillslope failure; depth unk	Cutbank	Already failed	Pot. Failure	
	Slope shape: (convergent, divergent, planar, hummocky)			Slope (%) ______	Distance to stream (ft) __________		
STREAM	CMP	Bridge	Humboldt	Fill	Ford	Armored fill	
	Pulled xing: (Y)	% pulled ______	Left ditch length (ft) ___________		Right ditch length (ft) ___________		
	cmp dia (in) ______	inlet (O, C, P, R)	outlet (O, C, P, R)	bottom (O, C,P, R)	Separated?		
	Headwall (in) ____	CMP slope (%) _____	Stream class (1, 2, 3)	Rustline (in)			
	% washed out ____	D.P.? (Y)	Currently dvted? (Y)	Past dvted? (Y)	Rd grade (%) ________		
	Plug pot: (H, M, L)	Ch grade (%) _____	Ch width (ft) _____	Ch depth (ft) ____			
	Sed trans (H, M, L)	Drainage area (mi^2) _________					
EROSION	E.P. (H, M, L)	Potential for extreme erosion? (Y, N)		Volume of extreme erosion (yds^3): 100-500, 500-1000, 1K-2K, >2K			
Past erosion…	Rd&ditch vol (yds^3) (yds^3)___________	Gully fillslope/hillslope (yds^3)__________	Fill failure volume (yds^3) _________	Cutbank erosion (yds^3)__________	Hillslope slide vol. (yds^3)	Stream bank erosion (yds^3)	xing failure vol (yds^3)
	Total past erosion (yds) __________	Past delivery (%) __________	Total past delivery (yds) _________	Age of past erosion (decade)_______	________________	__________	_________
Future erosion…	Total future erosion (yds) __________	Future delivery (%) __________	Total future delivery (yds) _________	Future width (ft) _________	Future depth (ft) ________	Future length (ft) _______	
TREATMENT	Immed (H,M,L)	Complex (H,M,L)	Mulch (ft^2)				
	Excavate soil	Critical dip	Wet crossing (ford or armored fill) (circle)		sill hgt (ft) ___	sill width (ft) _______	
	Trash Rack	Downspout	D.S. length (ft) ________	Repair CMP	Clean CMP		
	Install culvert	Replace culvert	CMP diameter (in) _____	CMP length (ft) _______			
	Reconstruct fill	Armor fill face (up, dn)	Armor area (ft^2) _______	*Clean or cut ditch*	*Ditch length (ft) _________*		
	Outslope road (Y)	*OS and Retain ditch (Y)*	*O.S. (ft) ____________*	*Inslope road*	*I.S. (ft) _____*	*Rolling dip*	*R.D. (#) __*
	Remove berm	*Remove berm (ft) _____*	*Remove ditch*	*Remove ditch (ft) __________*		*Rock road - ft^2 ________*	
	Install DR-CMP	*DR-CMP (#) ________*	Check CMP size? (Y)	Other tmt? (Y)	No tmt. (Y)		
COMMENT ON PROBLEM:							
EXCAVATION VOLUME Total excavated (yds^3) _______ Vol put back in (yds^3) _______ Volume removed (yds^3) ________ Vol stockpiled (yds^3) _______ Vol endhauled (yds^3) _______ Dist endhauled (ft) ______ Excav prod rate (yds^3/hr) _______ **EQUIPMENT HOURS** Excavator (hrs) ________ Dozer (hrs) ________ Dump truck (hrs) ______ Grader (hrs) ________ Loader (hrs) _________ Backhoe (hrs) ________ Labor (hrs) _______ Other (hrs) ________ COMMENT(S) ON TREATMENT: Note: no excavation volume should be estimated for failure areas of unknown type and depth. Treatments must be prescribed in consultation with a licensed geotechnical specialist.							
	Vol stockpiled (yds^3)	Vol endhauled (yds^3) __	Dist endhauled (ft) ____	Excav prod rate (yds^3/hr) _________			
EQUIPMENT HOURS	Excavator (hrs) ________________	Dozer (hrs) ________	Dump truck (hrs) ______	Grader (hrs) _____ ________			
	Loader (hrs) _____	Backhoe (hrs) ______	Labor (hrs) _______	Other (hrs) ______			
COMMENT(S) ON TREATMENT:							

Figure X-C-2.Road Inventory Data Form.

Stream crossings One hundred thirty one (131) stream crossings were inventoried in the Parsons Creek assessment area including 96 culverted crossings, 9 unculverted fill crossings, 1 bridge, 1 armored fill, 2 washed out crossings, and 22 fords crossings. An unculverted fill crossing refers to a stream crossing with no formal drainage structure to carry the flow through the road prism. Flow is either carried beneath or through the fill, or it flows over the road surface, or it is diverted down the road to the inboard ditch. Most unculverted fill crossings are located at small Class III streams that exhibit flow only in the larger runoff events. If the crossing has been made temporary or decommissioned by removing the majority of the crossing fill, then these crossings are commonly known as “pulled” crossings.

Approximately 8,853 yds^3 of future road-related sediment delivery in the Parsons Creek assessment area could originate from erosion at stream crossings (Table X-C-1). This amounts to nearly 36% of the total expected future sediment delivery from the road system. The most common problems which lead to erosion at stream crossings include: 1) crossings with undersized culverts, 2) crossings with culverts that are likely to plug, 3) stream crossings with a diversion potential and 4) crossings with gully erosion at the culvert outlet. The sediment delivery from stream crossing sites is always classified as 100% because any sediment eroded at the crossing site is then delivered to the channel. Even sediment which is delivered to small ephemeral streams will eventually be delivered to downstream fish-bearing stream channels.

At stream crossings, the largest volumes of future erosion can occur when culverts plug or when potential storm flow exceeds the culvert capacity (i.e., the culvert is undersized or prone to plugging) and flood runoff spills onto or across the road. When stream flow goes over the fill, part or all of the stream crossing fill may be eroded. Alternately, when flow is diverted down the road, either on the road bed or in the ditch (instead of spilling over the fill and back into the same stream channel), the crossing is said to have a “diversion potential” and the road bed, hillslope and/or stream channel that receives the diverted flow can become deeply gullied or destabilized. These hillslope gullies can be quite large and can deliver significant quantities of sediment to stream channels. Alternately, diverted stream flow which is discharged onto steep, potentially unstable slopes can also trigger large hillslope landslides. Of the 131 stream crossings inventoried in the Parsons Creek watershed, 75 have the potential to divert in the future and 6 streams are currently diverted at stream crossing sites (Table X-C-1).

Three road design conditions indicate a high potential for future erosion at stream crossings. These include 1) undersized culverts (the culvert is too small for the 100 year design storm flow), 2) culverts that are prone to plugging with sediment or organic debris and 3) stream crossings with a diversion potential. The worst scenario is for the culvert to plug and the stream crossing to wash out or the stream to divert down the road in a major storm. These road and stream crossing conditions are easily recognizable in the field and have been inventoried in the Parsons Creek watershed.

Approximately 85% (n=111) of the stream crossings inventoried in the Parsons Creek assessment area will need to be upgraded for the roads to be considered “storm-proofed”. For example, 31% (n=41) of the existing culverts have a “moderate” to “high” plugging potential and nearly 57% of the stream crossings exhibit a diversion potential (Table X-C-1). Because most of the roads were constructed many years ago, culverted stream crossings are typically under-designed for the100 year storm flow. At stream crossings with undersized culverts or where there is a diversion potential, corrective prescriptions have been outlined on the data sheets and in the following tables. Preventative treatments include such measures as constructing critical dips (rolling dips) at stream crossings to prevent stream diversions, installing larger culverts wherever current pipes are under-designed for the 100 year storm flow (or where they are prone to plugging), installing culverts at the natural channel gradient to maximize the sediment transport efficiency of the pipe and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill, installing debris barriers and/or downspouts to prevent culvert plugging and outlet erosion, respectively, and armoring the downstream fill face of the crossing to minimize or prevent future erosion.

"Other"sites – A total of 77 other sites were also identified in the Parsons Creek assessment area. The main cause of existing or future erosion at these sites is surface runoff and uncontrolled flow from long sections of undrained road surface and/or inboard ditch. Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause gully erosion on the hillslopes below the outlet to ditch relief culverts. Road runoff is also a major source of fine sediment input to nearby stream channels. In the Parsons Creek assessment area, we measured approximately 14.94 miles of road surface and/or road ditch (representing 42% of the total inventoried road mileage) which currently drains directly to stream channels and delivers ditch and road runoff and sediment to stream channels. These roads are said to be hydrologically connected to the stream channel network. When these roads are being maintained and used for ranch access, they may represent a potentially important source of chronic fine sediment delivery to the stream system.

We estimate 1,356 yds^3 of sediment will be delivered to streams from the 77 other specific sites inventoried (Table X-C-1). From the 14.94 miles of connected road segments, we calculated over 14,608 yds^3 of sediment will be delivered to stream channels in the Parsons Creek watershed over the next 10 years if no efforts are made to change road drainage patterns. This will occur through a combination of 1) cutbank erosion delivering sediment to the ditch triggered by dry ravel, rainfall, freeze-thaw processes, cutbank landslides and brushing/grading practices, 2) inboard ditch erosion and sediment transport, 3) mechanical pulverizing and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods.

Treatment Priority

An inventory of future or potential erosion and sediment delivery sites is intended to provide information which can guide long range transportation planning, as well as identify and prioritize erosion prevention, erosion control and road decommissioning activities in the watershed. Not all of the sites that have been recommended for treatment have the same priority, and some can be treated more cost-effectively than others. Treatment priorities are evaluated on the basis of several factors and conditions associated with each potential erosion site:

- the expected volume of sediment to be delivered to streams (yds^3),
- the potential or likelihood for future erosion (high, moderate, low),
- the urgency of treating the site (treatment immediacy – high, moderate, low),
- the ease and cost of accessing the site for treatments, and
- recommended treatments, logistics and costs.

Treatments

Basic treatment priorities and prescriptions were formulated concurrent with the identification, description and mapping of both potential sources of road-related sediment delivery and road maintenance sites with no potential sediment delivery. Table X-C-2 and Figure X-C-3 outline the treatment priorities for all 173 inventoried sites with future sediment delivery that have been recommended for treatment in the Parsons Creek watershed assessment area. Of the 173 sites with future sediment delivery, 26 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 4,520 yds^3. Eighty two (82) sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 4,206 yds^3 of future sediment delivery. Finally, 65 sites were listed as having a low treatment immediacy with approximately 1,544 yds^3 of future sediment delivery.

Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**7** (site #: 41, 86, 104, 118, 148, 166, 172)	**0**	6 stream crossings, 1 other	747
High Moderate	**19** (site #: 4, 13, 14, 24, 25, 36, 40, 43, 44, 47, 64, 72, 75, 91, 94, 102, 110, 113, 163)	**0**	14 stream crossings, 5 other	3,773
Moderate	**29** (site #: 8, 10, 15, 19, 20, 22, 33, 34, 43.1, 48, 65, 68, 69, 80, 82, 88, 92, 97, 111, 116, 124, 131.2, 149.1, 160, 168, 170, 171, 181, 199)	**1** (site #: 127)	17 stream crossings, 2 landslides, 11 other	2,055
Moderate Low	**53** (site #: 1, 2, 5, 6, 9, 11, 12, 17, 21, 23, 26, 28, 29, 30, 38, 42, 45, 46, 49, 52, 54, 56, 57, 59, 62, 63, 68.1, 71.1, 76, 77, 79, 81, 83, 84, 93, 101, 106, 109, 109.1, 114, 121, 129, 149.2, 149.3, 152, 154, 155, 161, 164, 165, 167, 195, 206)	**4** (site #: 126, 133, 138, 212)	42 stream crossings, 15 other	2,151
Low	**65** (site #: 3, 14.1, 15.1, 16, 18, 27, 32, 39.1, 39.2, 42.1, 50, 51, 53, 55, 58, 60, 61, 61.1, 66, 67, 67.1, 67.2, 67.3, 67.4, 69.1, 69.2, 71, 73, 78, 87, 89, 90, 95, 96, 100, 102.1, 103, 107, 108, 111.1, 112, 115, 120, 130, 135, 136, 137, 143, 146, 147, 156, 162, 169, 173, 180, 182, 184, 191, 192, 193, 194, 196, 198, 200, 201,)	**2** (site #: 140, 207)	32 stream crossings, 35 other	1,544
Total	**173**	**7**	**180**	**10,270**

Table X-C-2. Treatment priorities for all inventoried sediment sources in the Hopland field station assessment area, Mendocino County, California.

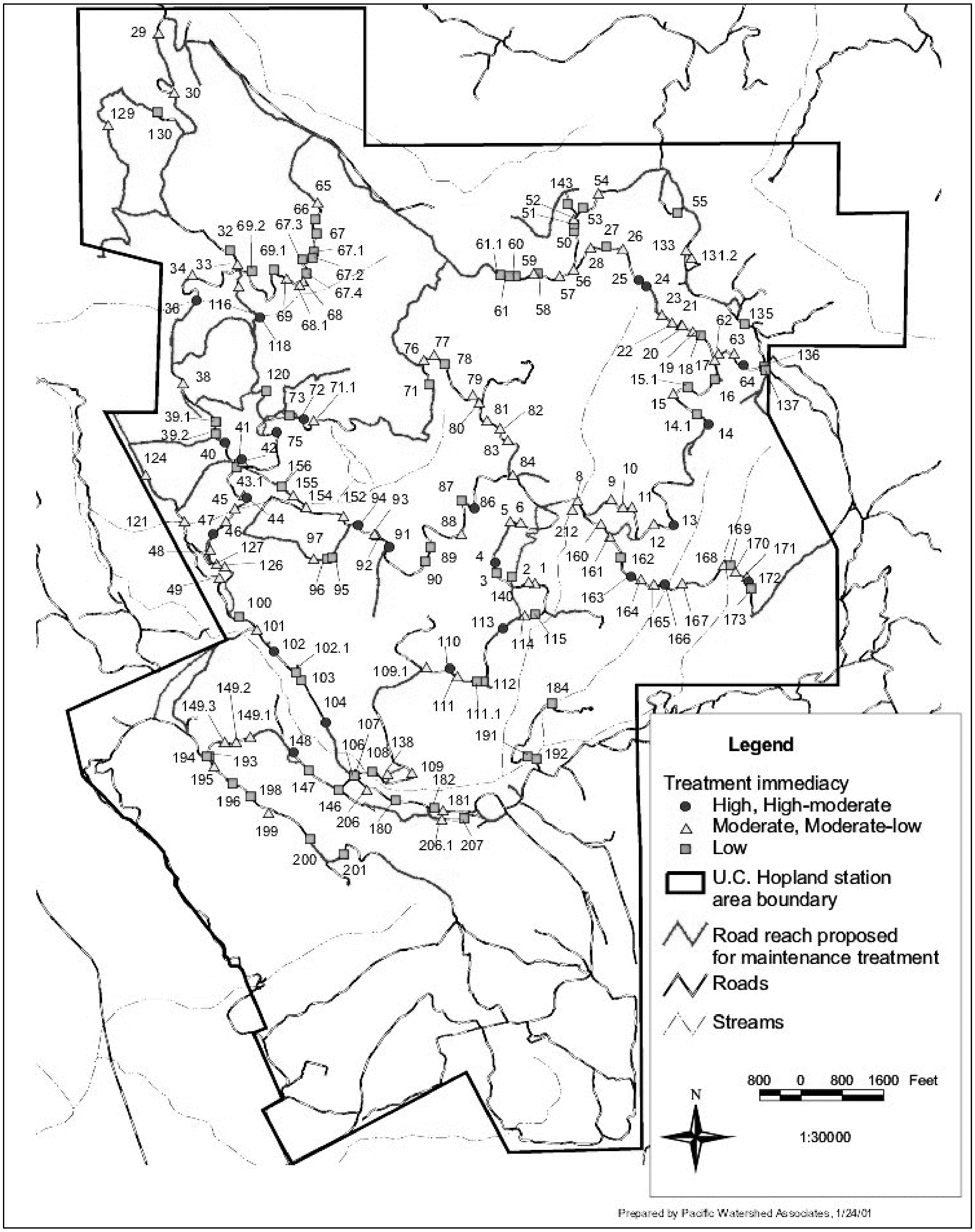


Figure X-C-3. Treatment Immediacy (priority) for inventoried road-related sites, UC Hopland Experimental Station, Parsons Creek, Mendocino County, California.

Table X-C-3 summarizes the proposed treatments for sites inventoried on all roads in the Parsons Creek assessment area, including both the upper and lower watershed areas. These prescriptions include all upgrading measures. The database, as well as the field inventory sheets, provide details of the treatment prescriptions for each site. Most treatments require the use of heavy equipment, including an excavator, tractor, dump truck, grader and/or backhoe. Some hand labor is required at sites needing new culverts, downspouts, flared inlets or culvert repairs, trash racks or for applying seed, plants and mulch following ground disturbance activities. A total of 71 critical rolling dips have been recommended to prevent future stream diversions at road crossings (Table X-C-3). A total of 89 culverts are recommended for installation at stream crossings. Eighty-five will replace existing undersized or rotten stream crossing culverts with culverts sized for the 100 year storm, and 4 culverts are recommended for installation at currently unculverted small streams.

It is estimated that erosion prevention work will require the excavation and disposal of approximately 6,171 yds^3 at 22 sites. Approximately 98% of the volume excavated is associated with upgrading or properly excavating stream crossings and nearly 2% of the volume is proposed for excavating potentially unstable road fills (landslides). Most of the stream crossing volume is associated with removal of channel stored sediment above the current culvert inlet. A total of 45 yds^3 of 0.5 to 1.5 foot diameter, mixed and clean rip-rap sized rock will be needed to construct eight proposed armored wet crossings (Table X-C-3). We have recommended 232 rolling dips be constructed at selected locations along the road, at spacings dictated by the steepness of the road. A minimum of twenty five (25) new ditch relief culverts are recommended to be installed along the road routes inventoried. Some proposed rolling dips can be replaced with additional ditch relief culverts, but the total cost for additional ditch relief culverts are not included here.

Equipment Needs and Costs

Treatments for the 180 sites identified with future sediment delivery in the Parsons Creek assessment area will require approximately 312 hours of excavator time and 454 hours of tractor time to complete all prescribed upgrading, road closure, erosion control and erosion prevention work (Table X-C-4). Excavator and tractor work is not needed at all the sites that have been recommended for treatment and, likewise, not all the sites will require both a tractor and an excavator. Approximately 8 hours of dump truck time has been listed for work in the basin for endhauling excavated spoil from stream crossings and at unstable road and landing fills where local disposal sites are not available. Approximately 358 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts.

<u>Estimated costs for erosion prevention treatments</u> – Prescribed treatments are divided into two components: a) site specific erosion prevention work identified during the watershed inventories, and b) control of persistent sources of road surface, ditch and cutbank erosion and associated sediment delivery to streams. The total costs for road-related erosion control at sites with future sediment delivery is estimated at approximately $331,345 for an average cost-effectiveness value of approximately $13.31 per cubic yard of sediment prevented from entering Parsons Creek and its tributaries (Table X-C-5).

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	71	To prevent stream diversions	Outslope road and remove ditch	97	Outslope and remove ditch for 37,342 feet of road to improve road surface drainage
Install CMP	4	Install a CMP at an unculverted fill	Outslope road and retain ditch	8	Outslope and retain ditch for 1,840 feet of road to improve road surface drainage
Replace CMP	85	Upgrade an undersized CMP	Install rolling dips	232	Install rolling dips to improve road drainage
Excavate soil	23	Typically fillslope & crossing excavations; excavate a total of 7,019 yds^3	Cross road drain	2	Install cross road drains to improve road drainage
Down spouts	5	Installed to protect the outlet fillslope from erosion	Remove berm	13	Remove 2,815 feet of berm to improve road surface drainage
Wet crossing	8	Install rocked ford and armored fill crossing using 45 yds^3 rip-rap	Install ditch relief CMP	25	Install ditch relief culverts to improve road surface drainage
Install flared inlet	2	Install flared inlet to increase intake capacity	Clean/cut ditch	4	Clean/cut 618 feet of ditch
Clean CMP	1	Remove debris and/or sediment from CMP inlet	Rock road surface	323	Rock road surface using 3,654 yds^3 road rock (includes road rock for 14 site specific locations, and post installation for 214 rolling dips, 75 stream crossings and 20 ditch relief culverts
Inslope road	1	Inslope 210 feet of road to improve road drainage	Other	10	Miscellaneous treatments
Remove ditch	1	Remove 130 feet ditch to improve road drainage	No treatment recommended	34	

Table X-C-3. Recommended treatments along all inventoried roads in the Hopland field station assessment area, Mendocino County, California.

Overall site specific erosion prevention work: Equipment needs for site specific erosion prevention work at sites with future sediment delivery are expressed in the database, and summarized in Table X-C-4 and Table X-C-5, as direct excavation times, in hours, to treat all sites. These hourly estimates include only the time needed to treat each of the sites, and do not include travel time between work sites, times for basic road surface treatments that are not associated with a specific site, or the time needed for work conferences at each site. These additional times are accumulated as logistics and must be added to the work times shown in Table X-C-4 to determine total equipment costs as shown in Table X-C-5.

Treatment Immediacy	No. of Sites	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	26	4,920	151	173	0	23	81
Moderate, Moderate.Low	87	946	124	201	8	154	194
Low	67	305	37	80	0	69	83
Total	**180**	**6,171**	**312**	**454**	**8**	**246**	**358**

Table X-C-4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment delivery, Hopland field station assessment area, Mendocino County, California.

The costs in Table X-C-5 are based on a number of assumptions and estimates, and many of these are included as footnotes to the table. The costs provided are assumed reasonable if work is performed by outside contractors, with no added overhead for contract administration and pre- and post-project surveying. Movement of equipment to and from the site will require the use of low-boy trucks. The majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road upgrading and road decommissioning operations on forest lands. The use of inexperienced operators would require additional technical oversight and supervision in the field. All recommended treatments conform to guidelines described in *The Handbook for Forest and Ranch Roads* (PWA 1994) for the California Department of Forestry, Natural Resources Conservation Service and the Mendocino County Resource Conservation District.

Table X-C-5 lists a total of 225 hours for supervision time for detailed pre-work layout, project planning (coordinating and securing equipment and obtaining plant and mulch materials), on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project cost-effectiveness analysis and reporting. It is expected that the project coordinator will be on-site full time at the beginning of the project and intermittently after equipment operations have begun.

Stream channel surveys
Approximately 3.3 miles of stream channel, extending from the private property boundary in the lower basin to the upper reaches in grasslands and oak forests of the upper watershed, was inventoried to identify past and current sediment sources (Figure X-C-1). The goals of the channel assessment were three fold: 1) to evaluate the general condition of stream banks throughout the reach, 2) to document the dominant processes and extent of sediment production along stream side slopes, 3) to determine locations where effective stream bank protection or re-vegetation efforts could be employed to reduce erosion and promote long term recruitment of large organic debris to the main channel of Parsons Creek.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Lowboy expenses)	Excavator	95	4	—	4	380
	D-5 tractor	70	4	—	4	280
Heavy Equipment requirements for site specific treatments	Excavator	115	312	94	406	46,690
	D-5 tractor	85	454	136	590	50,150
	Dump Truck	60	8	2	10	600
	Backhoe	65	246	74	320	20,800
Heavy Equipment requirements for road drainage treatments	Excavator	115	60	18	78	8,970
	D-5 tractor	85	101	30	131	11,135
	Backhoe	65	50	15	65	4,225
	Grader	85	65	20	85	7,225
Laborers[7]		20	487	146	633	12,660
Rock Costs: (includes trucking for 3,654 yds[3] of road rock and 45 yds[3] of rip-rap sized rock)						62,883
Culvert materials costs (750’ of 18’, 2,110’ of 24”, 820’ of 30”, 400’ of 36”, 280’ of 42”, 200’ of 48”, 130’ of 54”, 60’ of 60”, 190’ of 72”. Costs included for couplers and flared inlets)						91,735
Mulch, seed and planting materials for 4.3 acres of disturbed ground[8]						2,358
Layout, Coordination, Supervision, and Reporting[9]						11,254
Total Estimated Costs						**$ 331,345**
Overall project cost-effectiveness: $ 13.31 spent per cubic yard saved						

[1]Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface at sites where upgraded roads are outsloped are not included.
[2] Costs listed for heavy equipment include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.
[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.
[4] Logistic times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from site-to-site, and conference times with equipment operators at each site to convey treatment prescriptions and strategies. Logistic times for laborers (30%) includes estimated daily travel time to project area.
[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.
[6] Lowboy hauling for tractor and excavator, 4 hours round trip for the following areas within Parsons Creek. Costs assume 2 hauls for two pieces of equipment (one to move in and one to move out).
[7] Additional labor hours are included for the following: 1) 54 hours for seeding and mulching activities and 2) 75 hours for ditch relief culvert installation.
[8] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching.
[9] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 30% of the total excavator time plus 1 week prior and 1 week post project implementation.

Table X-C-5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery in the Hopland field station, Parsons Creek, Mendocino County, California.

Aerial photos (1:14,000) were used as a base map to record stream channel observations. The channel survey started at the downstream boundary of the HREC ownership and extended upstream through HREC properties (Figure X-C-1). The details of the channel mapping data is shown in three separate maps covering the lower to upper basin and three additional maps covering the same area but with the erosional sites sorted by treatment priority. The individual channel maps depict the location of debris landslides, deep-seated landslides, and sites of bank erosion. Bank erosion sites exceeding 10 yds^3 and debris landslides exceeding 50 yds^3 were quantified and described using the stream channel inventory data forms (Figure X-C-4). The location of bank erosion sites less than 10 yds^3 and debris landslides less than 50 yds^3 are shown on the strip maps, but have not been further described.

STREAM CHANNEL INVENTORY DATA FORM						
General	Site #:	Date:	Mappers:	Air Photo:	Watershed:	Stream:
	Bank (L/R):	Treat?(Y)				
Problem	Debris Slide	Hillslope failure of unknown depth and activity	Torrent channel	Bank erosion	Log jam:	Other:
	Past, future, both	Activity (A, W, IA):	Age (decade):	Hillslope (%)	Land use:	Undercut (Y)
Erosion	Past width:	Past depth:	Past length:	Past vol:	Past del (%)	Past yld (yds):
E.P.:	Future Width	Future depth:	Future length:	Future vol:	Fut del (%)	Fut yld (yds):
Treatment	Immed: (H, M, L)	Complexity: (H, M, L)	Eqpt or labor (E, L, B):		Access: (Easy, Moderate, Hard)	
	Excavate soil	Rock armor/buttress	Log protection	Remove logs/debris	Plant	Other
Hours:	Excavator:	Dozer:	Dump truck:	Backhoe:	Labor:	Other:
Problem:						
Treatment:						

Figure X-C-4. Stream Channel Inventory Data Form.

Besides documenting locations of past and current erosion and landsliding along the channel, efforts were made to document other important channel features. These included:

- the location of fish habitat structures and concentrations of large woody debris;
- the location of log jams;
- stream gradients, and
- the location of tributary stream junctions

All information collected in the field was compiled into a catalog of channel features by station number to assist in future channel surveys. The six channel strip maps summarize the data that was collected for the 3.3 miles of inventoried stream channel.

Channel survey results

A total of 117 sites of significant erosion were identified during the stream channel surveys. A total of 60 sites of past and active bank erosion were mapped along the lower reaches and main tributary to Parsons Creek (Table X-C-6). Bank erosion sites averaged 342 yds^3 in volume.

Stream side debris slides have generated over twice as much sediment delivery to the channel system than did bank erosion in the Parsons Creek watershed. Fifty seven debris slides in the >50 yds^3 class averaged nearly 1218 yds^3 in volume and accounted for 39,631 yds^3 of sediment delivery (Table X-C-6). Some of these debris slides were associated with roads near the inner gorge of Parsons Creek.

Reach	**Reach Length (feet)**	**Bank Erosion site >10 yds^3**			**Debris slides >50 yds^3**		**%**
		No.	Length (ft)	Delivery (yds^3)	No.	Delivery (yds^3)	BE/DS
Mainstem[1]	7,628	26	5,236	4,278	4	2,749	87/13
Largest Tributary of Parsons Creek	9,708	34	3,267	12,164	53	37,382	39/61
Total	17,336	60	8,503	16,442	57	40,131	----

[1] Sites 182.1 and 183 were quantified on the road erosion inventory but contributed an additional 19,925 yds^3 to the stream channel which could be added to the total Mainstem past erosion volume.

Table X-C-6. Bank erosion and small stream side debris slides along inventoried stream reaches, Parsons Creek, Mendocino County, California.

When evaluating erosion sites on Parsons Creek it is clear that the dominant erosion processes change from the mainstem to the main tributary. On the mainstem, where stream gradients are low, the channel is unconfined and meandering, and fluvial terraces are the dominant sediment source, bank erosion is the most common type of erosional process. On the main tributary where gradients are high, the channel is confined, and thick heterogeneous, low strength colluvial sediments are the dominant sideslope material, debris landsliding is the most common erosional process (Table X-C-6). Thirty seven sites have been identified as treatable along the mainstem and main tributary to Parsons Creek. These sites have been sorted by treatment priority and are summarized in (Table X-C-7).

Of the treatable sites, 2 are high priority, 4 are high moderate priority, 14 are moderate priority, 6 are moderate low priority, and 11 are low priority. Treating erosional sites along Parsons Creek is not as straight forward as treating erosion related to roads. Most of the sites of future erosion along Parsons Creek are in remote locations with little to no access by road. In most cases pioneering a road to allow heavy equipment access may generate more sediment and long term maintenance costs than is justifiable by either a sediment savings cost analysis or sediment production standpoint. The two high treatment priority sites are along the mainstem of Parsons Creek and have been deemed high priority due to their proximity to, and possible effect on, main access roads managed by HREC. These two sites do not have high future sediment delivery and are therefore not very cost-effective to treat but they are easily accessible and should be monitored for increased activity.

Treatment Priority	Upgrade sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**2** (site #: 312, 314)	2 bank erosion	94
High Moderate	**4** (site #: 305, 316, 320, 416)	3 bank erosion, 1 other	1,715
Moderate	**14** (site #:300, 302, 306, 308, 309, 313, 326, 327, 333, 344, 360, 361, 364, 381)	12 bank erosion, 2 debris landslides	2,076
Moderate Low	**6** (site #: 301, 304, 307, 311, 315, 362)	5 bank erosion, 1 debris landslide	77
Low	**11** (site #: 310, 321, 323, 339, 343, 348, 351, 351.1, 354, 369, 386)	4 bank erosion, 7 debris landslides	114
Total	**37**	**26 bank erosion** **10 debris landslides** **1 other**	**5,786**

Table X-C-7. Treatment priorities for treatable sediment sources along inventoried stream reaches in the Hopland field station assessment area, Mendocino County, California.

Sediment source summary

We extrapolated the data collected in the stream channel inventory to the other main tributaries of Parsons Creek to try to come up with an estimate of total past streamside erosion within the HREC management boundary. This was done by determining the ratio of air photo identified sites to sites actually documented during the stream inventory along the main tributary. Using this data and the known ratio of bank erosion sites to debris slides on the main tributary an estimate of the number of unidentified erosional sites for the other 4 tributaries was determined. These estimated erosional sites were then multiplied by the average erosion volume of non-air photo identified bank erosion (221 yds^3) and debris landslides (421 yds^3) respectively on the surveyed main tributary. The total estimated erosional volume of unidentified slides for the four un-inventoried tributaries was then quantified (Table X-C-8). Based on our field observations, this probably represents a maximum erosion volume. Reconnaissance of the un-surveyed tributaries suggests that the density of sites is lower for the four un-surveyed tributaries than the main tributary. Furthermore the thickness of the colluvial deposits, which are the main source of sediment along the main tributary, is thinner to the north especially in the upper portions of tributaries three and four. Other factors including stream size, road influence, conversion from chaparral to pasture, grazing practices, and other management activities most likely influence the number and size of erosion sites along the four un-surveyed tributaries.

Reach	Reach length	Air photo sites	Estimated volume of air photo identified sites (yds^3)	Estimated volume of non-visible sites (yds^3)	Total estimated erosional volume (yds^3)
Mainstem	7,628	2	460	6,567[1]	7,027
Largest Tributary of Parsons Creek	9,708	29	37,981	11,565	49,546
Tributary 1	9,700	7	4,181	5,565	9,746
Tributary 2	6,934	6	7,144	4,452	11,596
Tributary 3	8,321	5	2,679	3,760	6,439
Tributary 4	8,321	6	6,027	4,452	10,479
Total	**50,612**	**57**	**58,472**	**36,361**	**94,833**

[1]Mainstem Parsons Creek is alluvial and has abundant bank erosion sites that are not identifiable on air photos

Table X-C-8. Estimated past sediment delivery from air photo interpretation and data extrapolation for the mainstem and five largest tributaries of Parsons Creek, Mendocino County, California.

Table X-C-9 summarizes the estimated past sediment delivery to the Parsons Creek Watershed from road and streamside erosion for the last 30 years. Of a total of 201,771 yds^3 of estimated past erosion 43% is road related and 57% is streamside sediment delivery. The fact that most of the streamside sediment delivery occurred along reaches of stream bounded by thick, highly erodible, colluvial deposits suggests that the erosion is natural, although some channel incision from road related runoff and channel bed aggradation is possible. Surface erosion from converting chaparral to pasture is evident from our field observations but is difficult to quantify and has not been considered in this study.

Conclusion

The expected benefit of completing the erosion control and prevention planning work lies in the reduction of long term sediment delivery to Parsons Creek, an important steelhead stream. A critical first-step in the overall risk-reduction process is the development of a watershed transportation analysis and plan. In developing this plan, all roads in an ownership or sub-watershed are considered for either decommissioning or upgrading, depending upon the risk of erosion and sediment delivery to streams, and the future use levels. Not all roads are high risk roads and those that pose a low risk of degrading aquatic habitat in the watershed may not need immediate attention. It is therefore important to rank and prioritize roads in each sub-watershed, and within each ownership, based on their potential to impact downstream resources, as well as their importance to the overall transportation system and to management needs.

Good land stewardship requires that roads either be upgraded and maintained, or intentionally closed (put-to-bed). The old practice of abandoning roads, by either installing barriers to traffic (logs, tank traps or gates) or simply letting them naturally revegetate, is no longer considered acceptable. These roads typically continue to fail and erode for decades following abandonment.

Site Type	Number of sites or road miles	Past erosion (yds^3)	% Total
Total road inventory sites (all sites)[1]	214	43,189	21
Estimated Persistent past surface erosion[2]	14.94	43,824	22
Quantified stream past erosion sites[3]	117	76,498	38
Estimated stream past erosion sites	59	38,260	19
Totals	**390**	**201,771**	**100**

[1] The road inventory documented 63,114 yds^3 of past erosion. At sites 182.1 and 183 the past erosion volume totaled 19,925 yds^3 but both features are non-road related debris slides (i.e. the road had little to no influence on the slides). Subtracting the 19,925 yds^3 of past erosion equals 43,189 yds^3 of past road related sediment delivery.
[2] Assumes 25' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade for all existing roads for 3 decades. This is the current road connectivity, we have no way of estimating past connectivity.
[3] The channel surveys documented 56,573 yds^3 of past sediment delivery (Table X-C-6). We have added the volume of sediment delivery from sites 182.1 and 183 of the road survey (19,925) to the channel survey to total 75,498 yds^3

Table X-C-9. Estimated total past sediment delivery for Parsons Creek Watershed over the last 30 years, Hopland field station assessment area, Mendocino County, California.

Currently unused, unmaintained and/or abandoned roads in Parsons Creek were evaluated for either upgrading or permanent or temporary decommissioning. Road upgrading consists of a variety of techniques employed to erosion-proof and to storm-proof a road and prevent unnecessary future erosion and sedimentation. Erosion-proofing and storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road is capable of withstanding both annual winter rainfall and runoff, as well as a large storm event without failing or delivering excessive sediment to the stream system. All roads in Parsons Creek have been prescribed for upgrading. The goal of road upgrading is to strictly minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment delivery when large magnitude, infrequent storms and floods occur.

A plan was submitted in May to the California Department of Fish and Game to implement suggested sediment reduction upgrades for the high, high moderate, and moderate treatment priority sites within the HREC property boundary. As of February 1, 2001 it is our understanding that the proposal has been funded and implementation work will be begin as soon as the funding becomes available and CEQA is completed.

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APPENDIX X-D. CASE STUDY #2

2002 – 2003 REDWOOD CREEK SB 271

ROAD DECOMMISSIONING PROJECT FOR 1300 ROADS
Contract # P0110305

for

The Redwood Creek Watershed,
Humboldt County, California

prepared for

PCFWWRA,
California Department of Fish and Game,
and Simpson Resource Company

by

Pacific Watershed Associates
Arcata, California
(707) 839-5130
January 2004

PROJECT OVERVIEW
SB 271 Road Decommissioning Project
Redwood Creek, Humboldt County, California

INTRODUCTION

Redwood Creek, with its mouth located near Orick, California, has long been recognized as one of the more important salmon and steelhead producing watersheds in the region. Approximately 59 miles of the mainstem and 50 miles of tributary streams are utilized by anadromous salmonids in this 285 square mile watershed. The purpose of this watershed implementation project was to assist in protecting and restoring a quality habitat for fisheries, by reducing the amount of anthropogenic sediment that contributes to the stream system. This project was made possible by funding from the California Department of Fish and Game (through SB 271 funding). Simpson Resource Company provided partial matching funds. More than 4.4 miles of inner gorge and stream-side road, including fifty-six sites that threatened to deliver sediment into the Redwood Creek system, were decommissioned. This report documents the erosion prevention project that was completed in 2003.

BACKGROUND

In 1999 field work began on a SB 271 funded watershed assessment project that included 33,000 acres of the Redwood Creek watershed immediately upstream from Redwood National Park boundaries (Figure X-D-1). This area was identified in the federal legislation expanding Redwood National Park as the Park Protection Zone (PPZ). Approximately 225 miles of road were inventoried for sediment sources within this assessment area.

The PPZ assessment area is typical of the region, where land is privately managed for timber harvest and agricultural production, with the exception of several areas. The BLM manages over 920 acres in the upper Lacks Creek area and several rural residential land holdings also exist within the assessment area. Three major landowners (Simpson Resource Company, Barnum Timber Company, and Stover Ranch) control in excess of 95% of the watershed area in the PPZ.

Roads constructed to support timber harvesting activities were built as areas were entered for first and second cycle logging activities. Some major routes (Old K & K Road, K & K Road, and Dolly Varden Road) were constructed for off-highway log hauling prior to 1958. These routes were aligned across steep inner gorge slopes using Humboldt stream crossings and sidecast construction techniques.

Road systems are now widely recognized throughout the region as one of the most significant, and perhaps the most easily controlled, sources of sediment production and delivery to stream channels. Redwood Creek is underlain by erodible and potentially unstable geologic substrate, and both field observations and aerial photo analysis suggests that roads have been a significant source of accelerated sediment production in the watershed (E.P.A. 1998). In Redwood Creek, as elsewhere, excess sediment input to stream channels triggered by large rainfall events is one of the most significant factors affecting or threatening salmonid populations.

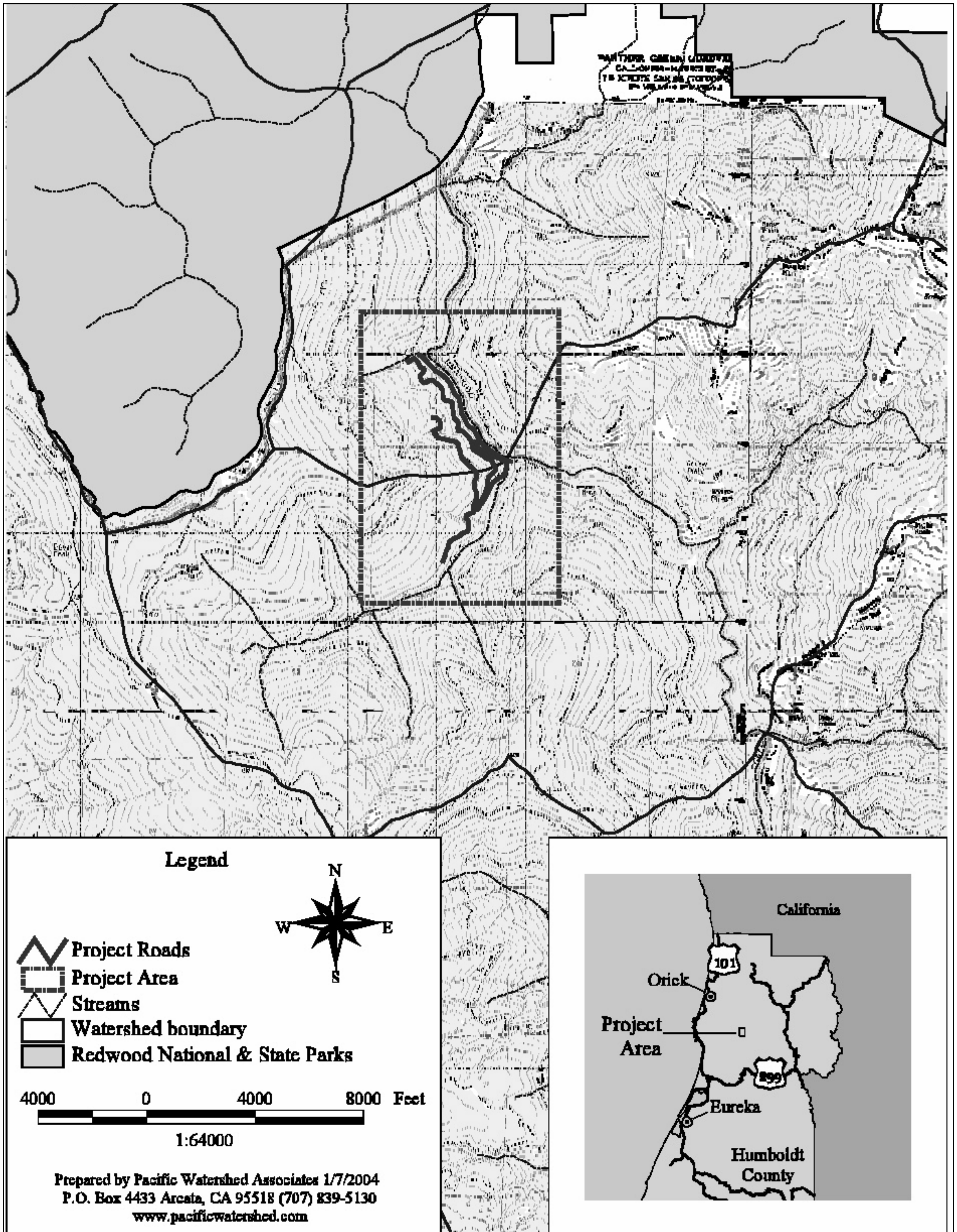

Figure X-D-1. Project Location Map Redwood Creek Road Decommissioning and Erosion Prevention Project Panther Creek USGS Quadrangle, Humboldt County, California.

Field inventories and data base analyses for the Redwood Creek watershed identified several high priority, high yield abandoned roads and road segments that threaten to deliver large quantities of sediment to the stream system if they are left untreated. Seven of these high priority road segments, totaling 4.4 miles, were decommissioned as a part of this project (Figure X-D-2). These included abandoned logging roads that had been constructed along the steep inner gorges of Redwood Creek and Panther Creek (tributary to Redwood Creek).

PROJECT OBJECTIVES

This road decommissioning project was designed to protect and improve salmonid habitat through controlling and preventing road-related erosion on several inner gorge slopes in the Redwood Creek watershed. The primary objective of the project was to implement cost-effective erosion control and erosion prevention work on high priority roads that were identified as a part of the comprehensive watershed assessment and inventory project for the basin.

The implementation of erosion control and erosion prevention work is perhaps the most important step to protecting and restoring watersheds and their anadromous fisheries, especially where sediment input is a limiting or potentially limiting factor to fisheries production, as is thought to be the case for the Redwood Creek watershed. Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" has an immediate benefit to the streams and aquatic habitat of the basin. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas. Roads treated for this implementation project have been identified as high priority for immediate implementation so that fill failures, stream crossing washouts and stream diversions do not degrade the stream system. The decommissioning work completed on this project is a significant step toward realization of long term salmon habitat protection and improvement in the Redwood Creek watershed.

LOCATION

This erosion control and erosion prevention project was focused on the area of Redwood Creek watershed downstream from the mouth of Panther Creek. It includes seven road segments (4.4 miles) in the lower watershed on Simpson Resource Company lands (Figure X-D-2). The attached maps (Figure X-D-2 and Figure X-D-3) depict the locations of the implementation projects as well as the specific sites that were treated for erosion prevention along each of the road segments.

PROJECT DESCRIPTION

The primary emphasis of the Redwood Creek watershed erosion prevention project was to treat existing and potential sediment sources identified along abandoned stream-side and inner gorge roads (Figure X-D-2 and Figure X-D-3). All roads that were treated were high priority road reaches that threatened to deliver substantial volumes of sediment to Redwood Creek or to Panther Creek if they were left untreated. A number of sites had already failed and many others showed signs of pending and potential failure and sediment delivery.

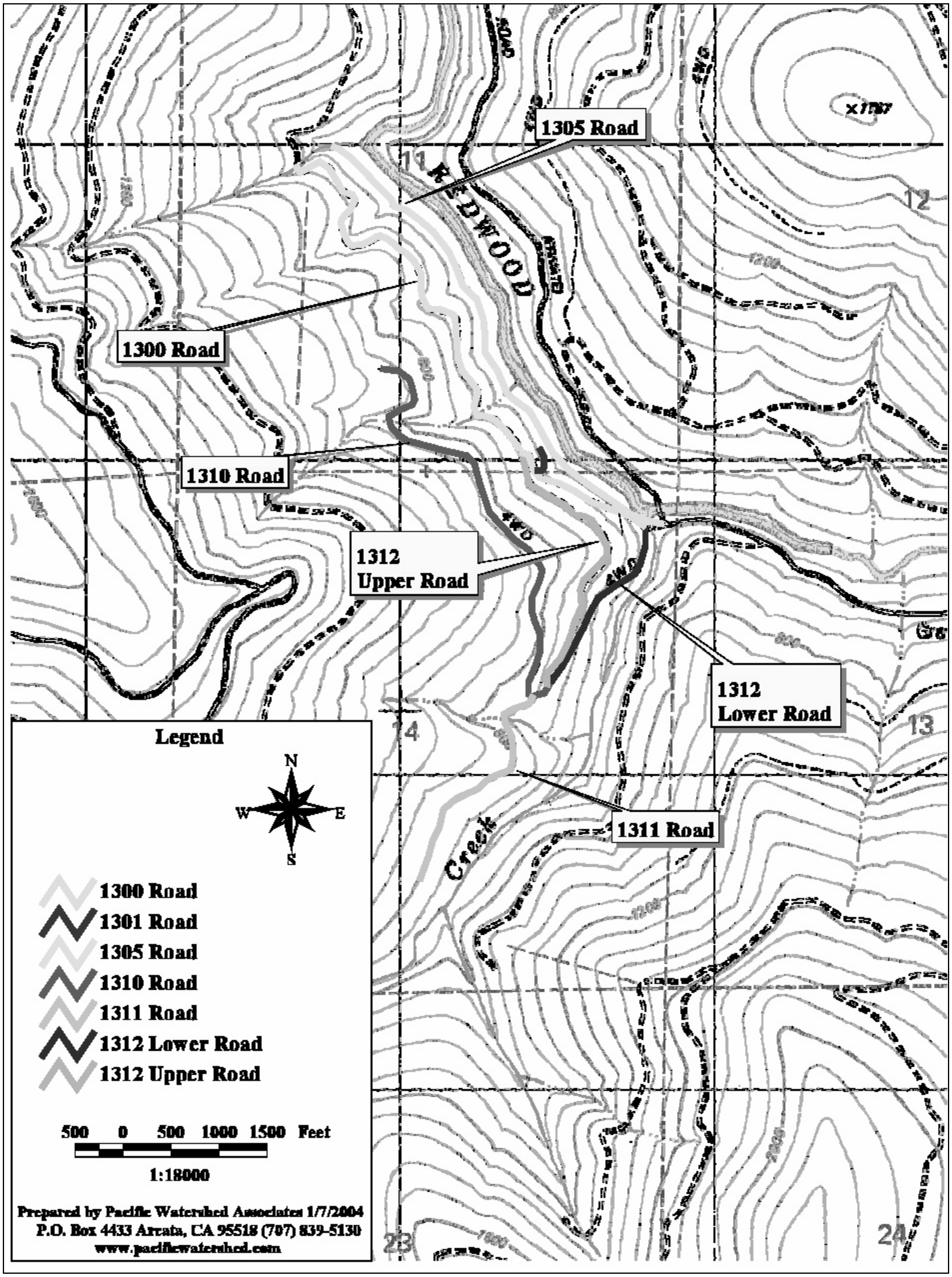

Figure X-D-2. Road location map Redwood Creek Road Decommissioning and Erosion Prevention Project Humboldt County, California.

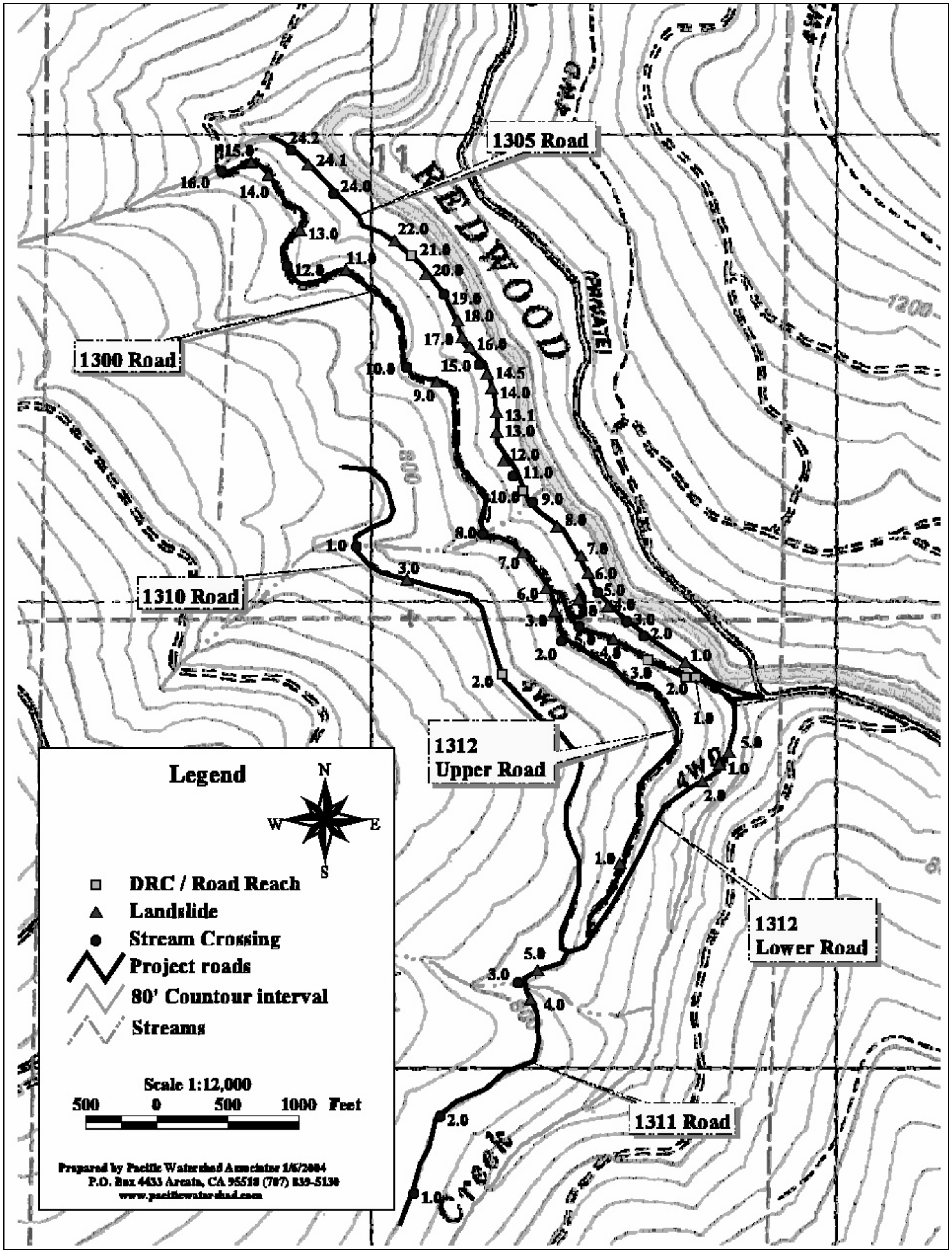

Figure X-D-3. Site location map, Redwood Creek Road Decommissioning and Erosion Prevention Project, Humboldt County, California.

This road decommissioning (closure) plan was aimed at old, abandoned high risk roads located within stream-side and inner gorge areas. Overall recommendations for the road reaches, as well as site-specific treatment prescriptions, were prepared for each road proposed for decommissioning. Only sites which would likely deliver sediment to a stream channel if left untreated were targeted for implementation.

General heavy equipment treatments for *road decommissioning* have been tested, described and evaluated elsewhere (Harr and Nichols 1993; Weaver and others 1987; Weaver and Sonnevil 1984; Weaver and Hagans 1994). Decommissioning essentially involves reverse road construction, except that full topographic obliteration of the road bed is not normally required to accomplish cost-effective sediment prevention goals. In order to protect the aquatic ecosystem, our goal was to hydrologically decommission the roads; that is, to minimize the adverse effect of the road on natural hillslope stability and watershed hydrology. From least intensive to most intensive, decommissioning included many of the following tasks[4]:

1. Road ripping or decompaction, in which the surface of the road or landing is "decompacted" or disaggregated using mechanical rippers. This action reduces surface runoff and often dramatically improves revegetation.

2. Cross-road drains, (deep waterbars) are installed at 50, 75, 100 or 200-foot intervals, or as necessary at springs and seeps, to disperse road surface runoff, especially on roads that are to be permanently or temporarily decommissioned. Cross-road drains are large ditches or trenches excavated across a road or landing surface to provide drainage and to prevent the collection of concentrated runoff on the former road bed. In some locations, such as stream-side zones, mild outsloping may be used instead of cross road drain construction.

3. In-place stream crossing excavation (IPRX) is a decommissioning treatment that is employed at locations where roads or landings were built across stream channels. The fill (including the culvert or Humboldt log crossing) is completely excavated and the original stream bed and side slopes are exhumed. Excavated spoil is stored at nearby stable locations where it will not erode, sometimes being pushed several hundred feet from the crossing by bulldozer tractor(s). A stream crossing excavation typically involves more than simply removing the culvert, as the underlying and adjacent fill material must also be removed and stabilized. Side slopes are excavated to about a 2:1 slope so that they can be mulched and seeded with minimal post-project erosion.

4. Exported stream crossing excavation (ERX) is a decommissioning treatment where stream crossing fill material is excavated and spoil is hauled off-site for storage. Spoil is moved farther up- or down-road from the crossing, due to the limited amount of stable storage locations at the excavation site. This treatment frequently requires dump trucks to endhaul spoil material to the off-site location.

5. In-place outsloping (IPOS) ("pulling the sidecast") calls for excavation of unstable or potentially unstable sidecast material along the outside edge of a road prism or landing, and

[4] Many of these and other erosion prevention and erosion control techniques are describe in the ⊳Handbook for Forest and Ranch Roads (PWA, 1994)

placement of the spoil on the roadbed against the corresponding, adjacent cutbank, or within several hundred feet of the site. Placement of the spoil material against the cutbank usually blocks access to the road and is used in road decommissioning. In road upgrading, the excavated material can be used to build up the road bed and convert an insloped, ditched road to an outsloped road.

6. Exported outsloping (EOS) is comparable to in-place outsloping, except spoil material is moved off-site to a permanent, stable storage location. Where the road prism is very narrow, where there are springs along the road cutbank or where continued use of the road is anticipated, spoil material is typically not placed against the cutbank and material is endhauled to a spoil disposal site. This treatment frequently requires dump trucks to endhaul spoil material. This is typically a decommissioning treatment as part or all of the roadbed is removed.

Only in relatively few instances does hydrologic decommissioning have to include full recontouring of the original road bed. Typically, potential problem areas along a road are isolated to a few locations (perhaps 10% to 20% of the full road network to be decommissioned) where stream crossings need to be excavated, unstable landing and road sidecast needs to be removed before it fails, or roads cross potentially unstable terrain and the entire prism needs to be removed. Most of the remaining road surface simply needs permanently improved surface drainage, using decompaction, road drains and/or partial outsloping.

Certain road segments included in this proposal contained a high density of treatment sites and subsequent decommissioning work involved relatively large portions of the road bed. Successfully decommissioning most roads typically costs a fraction of complete or total topographic road obliteration. Costs are highly dependent on the frequency and nature of the potential erosion problems along the alignment. Specific hours and costs for the Redwood Creek decommissioning project are included on the attached data tables.

We have included profiles and cross sectional diagrams of selected sites. For the sake of simplicity, specific details and drawings for each sediment treatment site are not included with this report, but are available for review and evaluation. For each treatment site, there is a detailed field data form describing site conditions, risk of future erosion, and details of the proposed treatment. For all stream crossing sites, we have prepared sketch maps, as well as cross sections and profile surveys, and design drawings for the proposed excavation.

The specific erosion prevention plan for these routes includes (for each site recommended for treatment) the recommended treatment prescription, treatment specifications, needed materials and equipment (including heavy equipment), estimated equipment times (hours), needed labor, and estimated costs to complete the project. This implementation information was included in the data forms and actual heavy equipment hours have been detailed in the attached treatment tables. All treatments for specific sites, whether roads, road segments, or other specific sites, were discussed with the landowner and land manager to ensure they were in conformance with existing or future management plans for the watershed areas.

SCHEDULE OF WORK
This road decommissioning project was administered by the Pacific Coast Fish, Wildlife and Wetlands Restoration Association. Actual project design, layout, implementation and reporting was conducted under the supervision of Pacific Watershed Associates of McKinleyville, California. On-the-ground implementation (road decommissioning) work was performed in the summer of 2002 and 2003 (Table X-D-1). All heavy equipment work was completed during summer low flow periods when impacts to water quality could be minimized or avoided.

In July, August, September, October and November 2002, the 1300, 1301, 1305, 1310, 1312 Upper and the 1312 Lower Roads were treated for permanent closure. In June and July 2003, the 1311 Road was treated for permanent closure. These roads were located along, or crossed, the steep inner gorge slopes of Class 1 and Class 2 stream channels. Each road that was treated showed evidence of substantial past erosion, as well as considerable future potential for erosion and sediment delivery.

Road Number	Length (ft.)	Number of Sites Treated	Dates of Operation	Heavy Equipment Hours[1]		
				Excavator	Dozer	Dump Truck
1300 Road	6,178	16	July 24 – October 13 ,2002	298.5	308.5	349.5
1301 Road	475	1	October 8,2002	6.5	6.5	0
1305 Road	4,716	25	August 9 – September 18,2002	162	174.5	163
1310 Road	4,488	3	July 28 – July 30,2002	24	24	38
1311 Road	2,270	5	June 25 – July 21,2003	192	109.25	115.25
1312 Upper Road	3,010	3	October 10 – November 5,2002	122	121.5	163.75
1312 Lower Road	1,742	3	September 18 – October 15,2002	31.5	33	2
Total	**22,879**	**56**	**July 23 – November 5,2002and June 25 – July 21,2003**	**836.5**	**777.25**	**831.5**

[1] Equipment hours do not include road opening and development of off-site spoil disposal areas.

Table X-D-1. Equipment work schedule and hours, Redwood Creek Decommissioning 2002-2003.

IMPLEMENTATION
Mike McDonald Construction of Trinity Center, CA was the primary equipment operator for the project area and McCullough Construction of Salyer, CA was the secondary equipment operator for the project area. Mike McDonald Construction carried out treatments using a CAT 325C hydraulic excavator, CAT D-6 high track bulldozer, 10 yd^3 dump trucks, and a CAT 22 yd^3 off-highway dump truck. McCullough Construction carried out treatments using a Komatsu hydraulic excavator, Komatsu (D-7 equivalent) bulldozer and several 10 yd^3 dump trucks (Table X-D-1). The excavators were used to: 1) open access to each site (brushing and filling of gullies), 2) excavate soil and organic debris (logs and chunks) from the stream crossings, 3) place small

volumes of excavated spoil on stable slopes near the decommissioned stream crossings, 4) decompact (rip) the road roadbed between stream crossing locations (especially if fill was to be stored on the old road surface), 5) outslope the old road bed between sites, 6) “mulch” the treated road with logs, limbs and brush and 7) construct cross-road drains on the decommissioned roads.

The bulldozer was used to help reconstruct the roads and stream crossings for access by the dump trucks, to push excavated material to nearby disposal sites, to work off-site spoil disposal sites where excavated material was dumped and to rip (decompact) old road surfaces. Up to three 10 yd^3 dump trucks were used to haul excavated spoil from the inner gorge stream crossing sites to stable storage areas.

Two separate equipment crews treated sections of seven roads in Redwood Creek (Figure X-D-2 and Figure X-D-3). Because the roads had not been used for some time, it was estimated that 91 hours of excavator and dozer time would be required to open the seven road reaches treated in this project. A total of fifty-six (56) sites were treated along 4.4 miles of road surface (Table X-D-1).

The original inventory identified 20 stream crossings, 31 landslides and 8 other sites that were all in need of treatment. By the time the project was undertaken in 2002, three sites were removed (one road fill landslide and two washed out stream crossings on the 1305 Road) from the proposed work area. The three sites (24.1, 24.2 and 25) occurred along the last 300’ of the 1305 Road. It was determined that the risk of sediment production caused by road opening and backfilling the washed out stream crossings would be greater than maintaining abandonment of the road segment. The predicted heavy equipment hours, actual heavy equipment hours and predicted excavation volumes for each treatment site are detailed at the end of this report.

It was estimated that 44,287 yds^3 of sediment would have to be excavated from the original 59 work sites identified in the initial road inventory, and that treatment of these sites would prevent the delivery of 26,425 yds^3 of sediment to Redwood Creek. Actual excavation volumes differ due to the removal of work sites by the time implementation was conducted in 2002 and due to an enlarged excavation on one stream crossing (see deviations from the original work plan). Because much of the excavated sediment was stored locally, it was not possible to determine the exact volume of material that was moved during the project.

Table X-D-2 describes the types and number of sites that were originally proposed for treatment on each road segment, as well as a general description of each decommissioned road. Landslide sites included road fill failures and instabilities, cutbank slides, hillslope slumping and large rotational slides. Stream crossings included culverted and unculverted crossings as well as Humboldt log crossings.

The 1300 Road contours along the left bank/inner gorge hillslope of Redwood Creek (Figure X-D-2). This abandoned road varies from approximately 150’ – 750’ above mainstem Redwood Creek and crosses five class 2 and class 3 streams that drain directly to Redwood Creek. The initial inventory identified five stream crossings, eight potential road fill landslides and three other sites. The five stream crossings that were decommissioned empty directly into Redwood

Creek. All sites on this road were straight forward, were treated as originally prescribed and equipment hours were relatively close to the original estimates.

A total of 6,178 feet of road length with 16 sites were treated on the 1300 Road. This took the equipment crew 32 working days and approximately 299 hours for the excavator, 309 hours for the dozer and 350 hours for dump trucks, not including all time necessary for road opening and clearing of spoil sites. All decommissioned stream crossings were seeded and straw mulched to help inhibit surface erosion.

The 1301 Road is located just off the 1300 Road near site # 5 (Figure X-D-2). This abandoned road is a 475 feet spur with a terminal landing. Only one potential road fill landslide site was identified during the initial road inventory. This site exhibited active scarps with up to 3 feet of vertical displacement and up to12 feet back from the outboard fill, perched on 70% slopes 20 feet above a Class 2 stream channel. The site was treated as originally prescribed and equipment hours were relatively close to the original estimates.

The 1305 Road contours directly above the left stream bank of Redwood Creek (Figure X-D-2). This abandoned road varies from approximately 30 to 75 feet above mainstem Redwood Creek and crosses ten Class 2 and Class 3 streams that drain directly to Redwood Creek. The initial inventory identified ten stream crossings, fourteen potential road fill landslides and four other sites. This road exhibited nearly continuous fillslope instabilities along most of the road length with the exception of the northern-most 500 feet. Most sites on this road were straight forward, were treated as originally prescribed and equipment hours were relatively close to the original estimates. One noted exception to the initial treatment plan was the elimination of three sites from the proposed work. As previously mentioned, it was determined that the risk of sediment production caused by road opening and backfilling of the washed out stream crossings would be greater than simply leaving the sites untreated.

A total of 4,716 feet of road length with 25 sites were treated on the 1305 Road. This took the equipment crew 28 working days and approximately 162 hours for the excavator, 175 hours for the dozer and 163 hours for dump trucks. All decommissioned stream crossings were seeded and straw mulched to help inhibit surface erosion.

Road Number (site list)	Location	Road Description	Number of sites of future sediment delivery (#)		
			Stream Crossing	Landslides	Other
1300 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16)	Redwood Creek	Abandoned road contours along left side of Redwood Creek and parallels above 1305 Road. Multiple medium size culverted and Humboldt stream crossings actively eroding and delivering sediment to Redwood Creek. Road exhibited multiple fillslope instabilities with potential sediment delivery.	5	8	
1301 (1)	Redwood Creek	Short 475 foot spur road with terminal landing. One Potential road fill failure perched directly above left approach of site # 5 on 1300 Road.	0	1	0
1305 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 13.1, 14, 14.5, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 24.1, 24.2)	Redwood Creek	Abandoned stream-side road contours directly above the left bank of Redwood Creek. Road averages 30' – 75' above Redwood Creek at bankfull level. Multiple small, poorly culverted, actively eroding Humboldt crossings and nearly continuous road fill failure problems.	10	14	4
1310 (1, 2, 3)	Redwood Creek	Abandoned road contours along left hillslope of Redwood Creek and parallels above 1312 and 1300 Roads. Relatively low gradient (30-45%) hillslope setting. One washed out stream crossing, one potential road fill failure in a headwater swale setting and one road reach / DRC delivery location on this road.	1	1	1
1311 (1, 2, 3, 4, 5)	Panther Creek	Abandoned inner gorge road contours along left hillslope 600' – 800' above Panther Creek. Several medium sized culverted stream crossings, one enormous eroding Humboldt stream crossing and several potential road fill failures perched above site # 3 on this road.	3	2	0
1312 Upper (1, 2, 3)	Panther and Redwood Creeks	Short abandoned tie road contours along left hillslope of Redwood and Panther Creeks. Road parallels above 1312 Lower and 1300 Roads. One very large potential road fill failure, one medium sized eroding stream crossing and one smaller potential road fill failure on this road.	1	2	0
1312 Lower (1, 2, 5)	Panther Creek	Abandoned inner gorge road contours uphill along left hillslope 200' – 500' above Panther Creek. Road exhibited nearly continuous fillslope instabilities and one very large past debris slide taking out 250' road prism width.	0	3	0
Total			**20**	**31**	**8**

Table X-D-2. 2002-2003 Decommissioned sites for Redwood Creek – 1300 roads.

The 1310 Road is located along the left hillslope of Redwood Creek (Figure X-D-2). This abandoned road parallels above the 1300 Road and is located along a gentler hillslope setting.

The initial inventory identified one washed-out stream crossing, one potential road fill failure and one road reach / DRC delivery location. This road segment was less critical and exhibited lower potential for future sediment delivery. The sites on this road were straight forward, were treated as originally prescribed and equipment hours were relatively close to the original estimates.

A total of 4,488 feet of road length with 3 sites were treated on the 1310 Road. This took the equipment crew 3 working days and approximately 24 hours for the excavator, 24 hours for the dozer and 38 hours for dump trucks.

The 1311 Road contours along the left bank / inner gorge hillslope of Panther Creek (Figure X-D-2). This abandoned road varies from approximately 500 to 700 feet above mainstem Panther Creek and crosses three Class 2 and Class 3 streams that drain directly to Panther Creek. The initial inventory identified three stream crossings and two potential road fill landslide sites. Four out of five sites on this road were straight forward, were treated as originally prescribed and equipment hours were relatively close to the original estimates.

Site # 3 on the 1311 Road turned out to be the noted exceptional site in the project area. This site was a large Class 2 Humboldt stream crossing with active collapsing fill and decomposing logs backed up by large sediment deposits and flanked on the left and right approaches by future road fill failures (sites 4 & 5). This site was a chronic sediment producer and had a very large future potential yield. The initial inventory estimated this site to have a future delivery of 1,868 yds^3 and an excavation volume of 3,481 yds^3. Upon further field review and volumetric analysis it was determined that the actual volumes were much larger. The estimated excavation volume for this site was 9,413 yds^3 and the revised potential future delivery prior to excavation was 4,750 yds^3. These volumes are reflected in Table X-D-3.

A total of 2,270 feet of road length with 5 sites were treated on the 1311 Road. This took the equipment crew 23 working days and approximately 192 hours for the excavator, 109 hours for the dozer and 115 hours for the 22 yd^3 dump truck. All decommissioned stream crossings were seeded and straw mulched to help inhibit surface erosion.

The 1312 Upper & Lower Roads are located along the left bank / inner gorge hillslope of Panther and Redwood Creeks (Figure X-D-2). The initial inventory identified one stream crossing and five potential road fill landslide sites. The 1312 Lower Road exhibited nearly continuous fillslope instabilities as well as one large past debris slide that removed the entire road prism for 250 feet. The 1312 Upper Road had one medium sized stream crossing, one minor potential road fill failure and one very large potential road fill failure. The sites on these roads were straight forward, were treated as originally prescribed and equipment hours were relatively close to the original estimates.

Treatment Category	Sites to Treat[1] (#)	Cross Road Drains (#)	Total Volume Excavated[2] (yds^3)	Volume Sediment Saved[3] (yds^3)	Cost Effectiveness[4] ($\$/yds^3$ saved)	Total Project Costs[5] ($)
Proposed	59	26	44,287	26,425	11.91	314,809
As Built	56	67	49,488	28,954	11.90	344,520

[1] Three sites were eliminated from the project. Reasons specified in the report.
[2] Total volume excavated increased from the proposed estimate. Site # 3, 1311 Road, stream crossing excavation volume was significantly larger than the original estimate. Excavation volumes from sites 24, 24.1 and 24.2 on the 1305 Road were removed from the "As Built" figure.
[3] Total volume of sediment saved increased from the proposed estimate due to a post inventory volume revision of site # 3, 1311 Road. Future erosion volumes from sites 24, 24.1 and 24.2 on the 1305 Road were removed from the "As Built" figure.
[4] Cost effectiveness increased slightly from the proposed estimate due to the volume of sediment saved and total project costs changing.
[5] Total project costs includes all equipment and labor time, materials, subcontractor costs, project management and overhead (all costs included). Simpson Resource Company provided a $129,836 cost share. National Park Service provided a $20,000 cost share. CDF&G grant monies provided $184,809 + $9,875.

Table X-D-3. Deviations from the original proposed treatment plan, Redwood Creek Road Decommissioning Project – 1300 roads.

A total of 4,752 feet of road length with 6 sites were treated on the 1312 Upper & Lower Roads. This took the equipment crew 25 working days and approximately 154 hours for the excavator, 155 hours for the dozer and 166 hours for dump trucks. The decommissioned stream crossing was seeded and straw mulched to help inhibit surface erosion.

COSTS

Total costs were broken down for the entire project area, based on cost categories listed (Table X-D-4). Rates for equipment were as follows: excavator $125/hr and $110/hr, dozer $95/hr and $90/hr, 10 yd^3 dump trucks $65/hr and $60/hr, 22 yd^3 dump truck $130/hr and labor $21/hr. Costs in Table X-D-4 include all road opening and equipment mobilization time. It also reflect costs for straw, seed, administrative overhead and technical oversight, which includes general layout, heavy equipment oversight and monitoring, plot documentation, resurveying and reporting. Total inclusive costs for decommissioning these seven roads in the Redwood Creek watershed was approximately $344,520.

DEVIATIONS FROM THE ORIGINAL WORK PLAN

Table X-D-3 shows specific deviations from the original proposed treatment plan. These deviations were caused by a variety of factors but generally because it was determined that the project would benefit if these changes were made (i.e.; reduced future erosion at stream crossing sites where excavation volumes enlarged and decreased surface runoff on road reaches due to construction of additional cross road drains). It should be expected that as work is being implemented some variation from the original work plan is necessary to accommodate unforeseen complications. The variations that were made to the original work plan were motivated by improving the overall effectiveness of the project and to reduce the likelihood of future erosion and sediment delivery.

Cost Category	Total Hours	Cost Rate[1] (average $/hr)	Total Costs ($)
Personnel Costs			
Project Manager	250	30	7,500.00
Heavy Equipment Costs			
Excavator	1,134.25	119	134,581.25
Dozer	1,078.75	93	100,068.75
10 yd^3 Dump Truck	916	61	55,688.00
22 yd^3 Dump Truck	115.5	130	15,047.50
Water Truck	28.5	55	1,567.50
Low-Boy Transport	17	82	1,401.50
Truck and Trailer	8	30	240.00
Subcontractor Costs			
Sub Labor	182	21	3,831.00
Sub Technical Oversight, Layout and Reporting	355	50	17,750.00
Mulch, Seed and Erosion Control Materials			3,356.79
Administrative Overhead @ 1.023%			3,487.71
Total Project Costs			**344,520**
Estimated Sediment Savings: 28,954 yds^3			
Overall Project Cost-Effectiveness: $ 11.90 / yd^3 saved			

[1] Cost rates listed are averages. Within several equipment categories different rates were billed for different pieces of equipment.

Table X-D-4. Total costs for road-related erosion control and erosion prevention work on all sites in the Redwood Creek Road Decommissioning Project – 1300 roads.

MONITORING

Before the project commenced, photo point stations were established for many of the project work sites. These photo points were used to document the work sites before, during and following the excavation. Examples of before and after photo point shots have been included in the report to depict excavated stream crossings, landslides and outsloped roads in the Redwood Creek Road Decommissioning Project.

Each decommissioned stream crossing was surveyed prior to treatment and re-evaluated after equipment had completed excavation work. A select number of representative decommissioned stream crossings were re-surveyed following equipment operations. depicts surveyed profiles and cross sections of three stream crossings. Also, a typical pre- and post-excavation road profile of a landslide excavation was surveyed at site # 7 on the 1300 Road. The plotted surveys show the original ground profile, the design profile and the as built profile that was surveyed following heavy equipment excavation work at the three sites. Each of the stream crossings have been excavated to a stable longitudinal and cross sectional profile.

CONCLUSION

The expected benefit of completing the erosion control and prevention work lies in the reduction of long term sediment delivery to Redwood Creek and Panther Creek, important salmonid streams. The purpose of this project was to permanently reduce the amount of sediment that could have eroded and been delivered to Redwood Creek and its tributaries. It is estimated that over 49,000 cubic yards of material was excavated in this project. This volume includes the volume that was endhauled to spoil disposal sites as well as excavated material that was stored locally on-site. In the initial inventory, it was estimated that approximately 26,425 yds^3 of sediment had a high potential to deliver to Redwood Creek and Panther Creek.

With the extensive restoration of these 56 specific sites a significant amount of sediment that once threatened these salmon bearing streams no longer poses a threat. Although it is difficult to assess the immediate benefits of the decommissioning project to fish habitat, the lasting benefit of removing over 49,000 cubic yards of material, and preventing the delivery of over 28,954 yds^3 to the Redwood Creek system should help promote habitat recovery over the next several decades.

PROJECT LOCATION DIRECTIONS AND LANDOWNER ADDRESS
The project area can be reached by the following directions. From Arcata, California travel east on highway 299 for 5 miles and take the "Blue Lake" exit. Continue east for 3 miles to "Korbel" lumber mill. Take a left at the first guard station and continue through the lumber mill to the K & K Road. On the K & K Road travel northwesterly for 14 miles to the mouth of Panther Creek. Park here and cross the foot bridge over Panther Creek. At this location is the intersection of the 1312 Lower Road and 1300 Road in the project area.

Landowner address:
Simpson Resource Company
PO Box 68
Korbel, CA 95550

REFERENCES

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Erosion Prevention Implementation Results, 2002-2003 Road Decommissioning Project, Redwood Creek Watershed

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	DRC	4	4	4	4	0	0	431	0
2	DRC	4	7	4	7.5	0	0	100	0
3	DRC	6	13	6	12.5	0	0	150	0
4	Landslide	3	8	3	8	6	0	256	0
5	Crossing	8	51	8	55	8	2	390	
6	Landslide	23	29.5	23	29.5	46	59	2599	182
7	Landslide	4	29.5	4	29.5	8	49	311	152
8	Crossing	6	14	6	14	12	28	279	84
9	Landslide	8	14	8	14	8	17	833	54
10	Crossing	75	44.5	75	44.5	75	85.5	2538	262
11	Landslide	12	10	12	10	12	20	1426	30
12	Crossing	14	17	14	17	28	32	698	
13	Landslide	3	6	3	6	0	12	291	
14	Landslide	16	20.5	16	20.5	32	41	1574	
15	Landslide	10	10.5	10	10.5	20	0	925	0
16	Crossing	61	20	61	26	122	4	2438	
Subtotal – 1300 Rd		257	298.5	257	308.5	377	349.5	15239	764

[1] Hours included only for site specific treatment and not for road reaches between sites, road opening or clearing and grubbing.
[2] Predicted equipment hours listed do not include "logistics" hours.
[3] Fields left blank indicate no operator record was kept for the number of dump truck loads removed. On the 1311 Road a 20 yd^3 off-highway dump truck was used instead of standard 10 yd^3 dump trucks.

Table X-D-5. Decommissioning data for the 1300 Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Landslide	5	6.5	5	6.5	0	0	324	0
Subtotal – 1301 Rd.		5	6.5	5	6.5	0	0	324	0

Table X-D-6. Decommissioning data for the 1301 Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Landslide	11	4	11	4	0	0	1460	0
2	Crossing	5	20.5	5	34.5	0	0	366	0
3	Crossing	4	2.5	4	1	0	0	207	0
4	Landslide	8	8.5	8	8.5	16	0	900	0
5	Crossing	2	3.5	2	3.5	0	0	54	0
6	Landslide	3	4	3	4	0	0	277	0
7	Landslide	4	3	4	3	0	0	388	0
8	Landslide	6	11.5	6	11.5	12	0	574	0
9	Crossing	7	11	7	11	14	11	359	25
10	Road Reach	5	5	5	5	10	5	527	20
11	Crossing	6	18	6	18	0	16	379	65
12	Landslide	2	5	2	5	0	8	111	28
13	Landslide	6	4	6	4	0	8	711	32
13.1	Landslide	2	4	2	4	0	8	138	16
14	Landslide	4	6	4	6	0	9	438	40
14.5	Landslide	4	4	4	4	8	8	402	16
15	Crossing	4	10	4	10	8	20	157	40
16	Landslide	3	7	3	7	6	14	277	30
17	Landslide	4	4	4	4	8	8	324	19
18	Landslide	8	3	8	3	16	6	850	21
19	Crossing	2	7	2	7	4	14	74	43
20	Landslide	9	6	9	6	0	12	1283	30
21	DRC	4	2.5	4	2.5	0	0	381	0
22	Landslide	3	4.5	3	4.5	0	9	267	20
23	Road Reach	2	3.5	2	3.5	0	7	100	30
24	Crossing	8	0	8	0	0	0	429	0
24.1	Landslide	2	0	2	0	0	0	111	0
24.2	Crossing	3	0	3	0	0	0	191	0
Subtotal – 1305 Rd.		131	162	131	174.5	102	163	11,735	475

Table X-D-7. Decommissioning data for the 1305 Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Crossing	13	10	13	10	26	20	648	
2	DRC	8	8	8	8	0	6	200	
3	Landslide	5	6	5	6	10	12	407	
Subtotal – 1310 Rd		26	24	26	24	36	38	1255	

Table X-D-8. Decommissioning data for the 1310 Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Crossing	10	24.5	10	0	0	3	962	18
2	Crossing	4	5.5	4	0	0	0	248	0
3	Crossing	78	148	78	103.25	0	102.25	4981	529
4	Landslide	4	8	4	0	8	4	941	20
5	Landslide	3	6	3	6	0	6	419	37
Subtotal – 1311 Rd		99	192	99	109.25	8	115.25	7551	604

Table X-D-9. Decommissioning data for the 1311 Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Landslide	51	113.5	51	113.5	102	163.75	3824	410
2	Crossing	6	5.5	6	5	6	0	271	0
3	Landslide	3	3	3	3	3	0	292	0
Subtotal – 1312U Rd		60	122	60	121.5	111	163.75	4387	410

Table X-D-10. Decommissioning data for the 1312 Upper Road Redwood Creek Watershed, Humboldt County, California.

Site #	Site type[1]	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
1	Landslide	5	2.5	5	2.5	15	0	620	0
2	Landslide	9	14.5	9	16	9	2	1083	8
5	Landslide	14	14.5	14	14.5	28	0	2093	0
Subtotal – 1312L Rd		28	31.5	28	33	52	2	3796	8

Table X-D-11. Decommissioning data for the 1312 Lower Road Redwood Creek Watershed, Humboldt County, California.

Heavy Equipment Work	Predicted Excavator Hrs[2]	Actual Excavator Hrs	Predicted Dozer Hrs[2]	Actual Dozer Hrs	Predicted Dump truck Hrs[2]	Actual Dump Truck Hrs	Predicted Excavated Volume (yds^3)	Dump truck loads removed[3]
Totals	606	836.5	606	777.25	686	831.5	44,287	2,261

Table X-D-12. Decommissioning data for the Redwood Creek Watershed, Humboldt County, California.

Selected Photo-point Photos of the 2002-2003 Redwood Creek Road Decommissioning Project

Figure X-D-4. Site #8, 1300 Road, before excavation.
This picture was taken just above the top of the stream crossing, looking downstream. This Humboldt crossing has been brushed out and is ready to be excavated

Figure X-D-5. Site #8, 1300 Road, after excavation. This picture was taken from the same viewpoint as above. The stream crossing has been excavated, mulched and seeded. See same view below after heavy rainfall (Figure X-D-6).

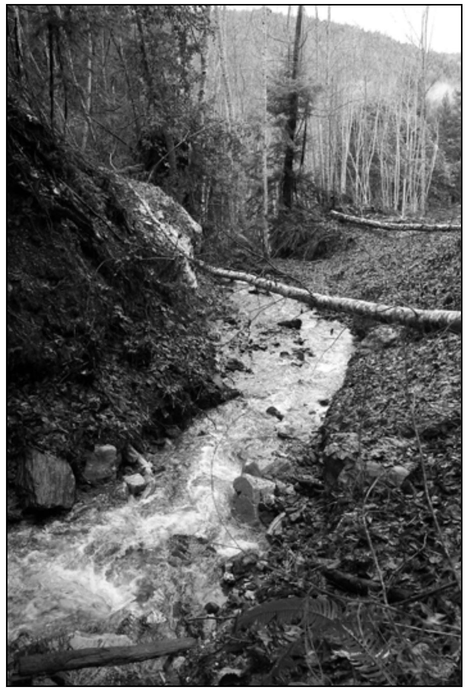


Figure X-D-6. Site # 8, 1300 Road, after excavation. Same viewpoint as Figure X-D-4 during heavy rainfall event.

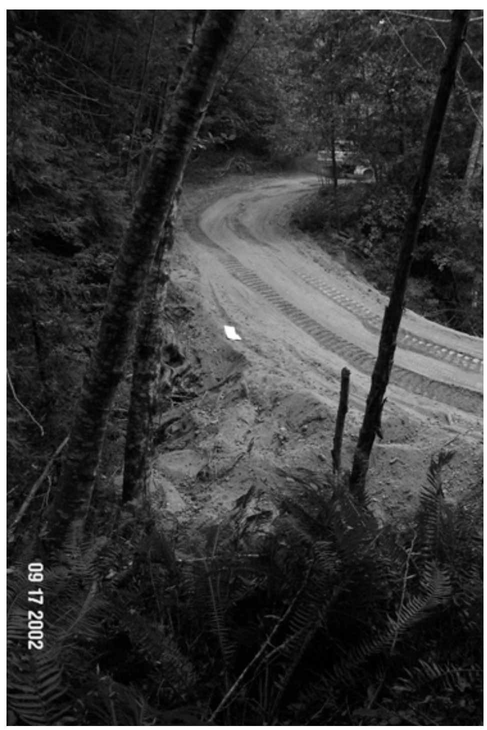


Figure X-D-7. Site #8, 1300 Road, before excavation. Picture taken 30 feet up the right bank, near the right hinge line of this stream crossing. The stream crossing has been excavated, mulched, and seeded. Note location of the two trees for reference.

Figure X-D-8. Site # 8, 1300 Road, after excavation. This picture (and Figure X-D-7) was taken 30 feet up the right bank, near the right hinge line of this stream crossing. The stream crossing has been excavated, mulched and seeded. Note location of the two trees for reference.

Figure X-D-9. Site # 12, 1300 Road, before excavation. This picture was taken 20 feet above the top of the stream crossing and along the left bank, looking downstream. The stream crossing has been brushed out and is ready to be excavated.

Figure X-D-10. Site #12, 1300 Road, after excavation. This picture was taken from the same viewpoint as Figure X-D-9. The stream crossing has been excavated, mulched and seeded. Upon excavation it was determined that the original watercourse meandered to the right prior to entering the Bot. Armor was placed along the left bank to prevent stream bank erosion (see arrow).

Figure X-D-11. Site #10, 1305 Road, during excavation. A potential road fill landslide was excavated at this site. Unstable outboard road fill was excavated and endhauled to a stable storage location, creating an outsloped road surface (see Figure X-D-12).

Figure X-D-12. Site #10, 1305 Road, after excavation. This picture was taken from the same viewpoint as Figure X-D-11. The unstable road fill has been completely excavated, mulched and seeded, leaving an outsloped road surface. Because this road exhibited nearly continuous road fill instabilities, a similar nature of treatments were applied to the remaining road, along with stream crossing excavations.

Figure X-D-13. Site # 11, 1305 Road, before excavation. This picture was taken 30 feet above the top of the stream crossing and along the left bank, looking downstream. The stream crossing has been brushed out and is ready to be excavated. A large “Humboldt” log is visible just left of the mossy alder tree in the right-center portion of the picture (see arrow).

Figure X-D-14. Site #11, 1305 Road, after excavation. This picture was taken from the same viewpoint asX-D-13. The stream crossing has been excavated, mulched and seeded. See same view below after heavy rainfall (Figure X-D-15).

Figure X-D-15. Site # 11, 1305 Road, after excavation. This picture was taken from the same viewpoint as above (Figure X-D-13 and Figure X-D-14) during a heavy rainfall event. Note the stream channel bed has developed a self armoring "lag" deposit during the first season's rainfall. Redwood Creek is in the background.

Figure X-D-16. Site # 13, 1305 Road, before excavation. A potential road fill landslide was excavated at this site. Unstable outboard fill was excavated and endhauled to a stable storage location, creating an outsloped road surface (see Figure X-D-17).

Figure X-D-17. Site #13, 1305 Road, after excavation. This picture was taken from the same viewpoint as Figure X-D-16. The unstable road fill has been completely excavated, mulched and seeded, leaving an outsloped road surface. In the background is one of the main spoil sites for this road. The sloped surface can be seen extending up above the old road bench (see arrows).

Figure X-D-18. Site #3, 1311 Road, before excavation. This is a 3 shot panoramic compilation photo taken from the cutbank on the right approach to this Humboldt stream crossing. The site has been brushed out and a temporary flex pipe has been installed along the right hinge line to divert active flow around the work area.

Figure X-D-19. Site # 3, 1311 Road, after excavation. This is a 2 shot panoramic compilation photo taken from near the same location as the previous picture. The site has been completely excavated, large woody debris removed from the fill during the excavation has been redistributed along the stream crossing slopes and seed & mulch has been applied to the bare slope areas.

Figure X-D-20. Site # 3, 1311 Road, during excavation. This picture was taken near the Bot of the stream crossing. The picture view is looking upstream with the outboard edge of the road in the upper center portion of the photo. Some fill has been excavated from the outboard edge of the road downslope towards the Bot and a swath of brush as been cleared to the Bot, in preparation for continued excavation.

Figure X-D-21. Site # 3, 1311 Road, after excavation. This picture was taken near the same location as the previous photo. The stream crossing has been excavated and an abundance of woody debris has been redistributed along the banks and the channel.

Figure X-D-22. Site #3, 1311 Road, after excavation. This picture was taken from near the Top looking downstream.

Figure X-D-23. Site #3, 1311 Road, after excavation. This picture was taken from near the right bank looking upstream.

Figure X-D-24. Site # 2, 1312 Lower Road, before excavation. A potential road fill landslide was excavated at this site. Unstable outboard road fill was excavated and stockpiled locally along the cutbank behind the site, creating an outsloped road surface (see below).

Figure X-D-25. Site # 2, 1312 Lower Road, after excavation. This picture was taken from the same viewpoint as above. The unstable road fill has been completely excavated, mulched and seeded, leaving an outsloped road surface. Note trees and brush removed during excavation have been used a ground surface mulch. Panther Creek (not visible in photo) is located to the right.

Figure X-D-26. Site # 5, 1312 Lower Road, before excavation. A potential road fill landslide was excavated at this site. Unstable outboard road fill was excavated and stockpiled locally along the cutbank behind the site, creating an outsloped road surface (see below).

Figure X-D-27. Site # 2, 1312 Lower Road, after excavation. This picture was taken from the same viewpoint as above. The unstable road fill has been completely excavated. Straw mulch and seed had not yet been spread in this picture (note straw bales near former cutbank).

Selected Pre- & Post-excavation Profiles and Cross Sections of the 2002-2003 Redwood Creek Road Decommissioning Project

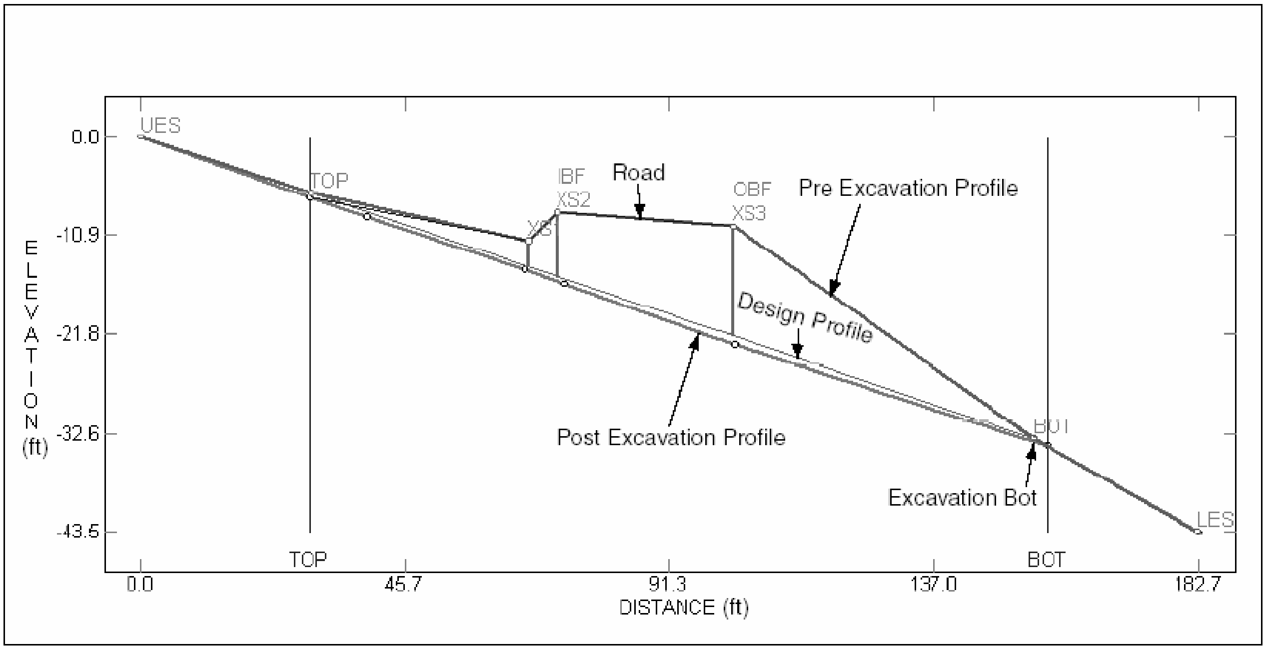


Figure X-D-28. Redwood Creek 1300 Road Site #12 – Stream Crossing Pre & Post Excavation Profiles.

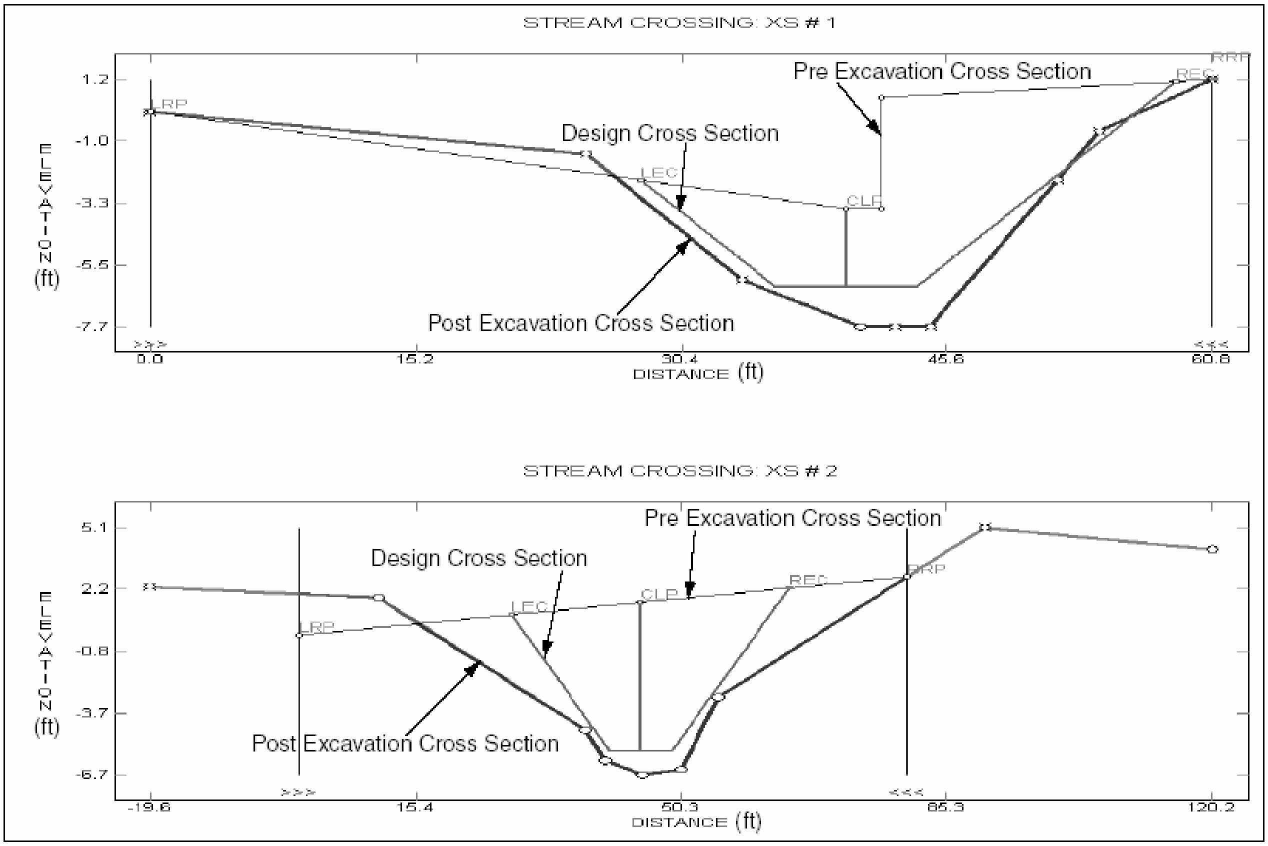


Figure X-D-29. Redwood Creek 1300 Road Site #12 – Stream Crossing Pre & Post Excavation Cross Sections.

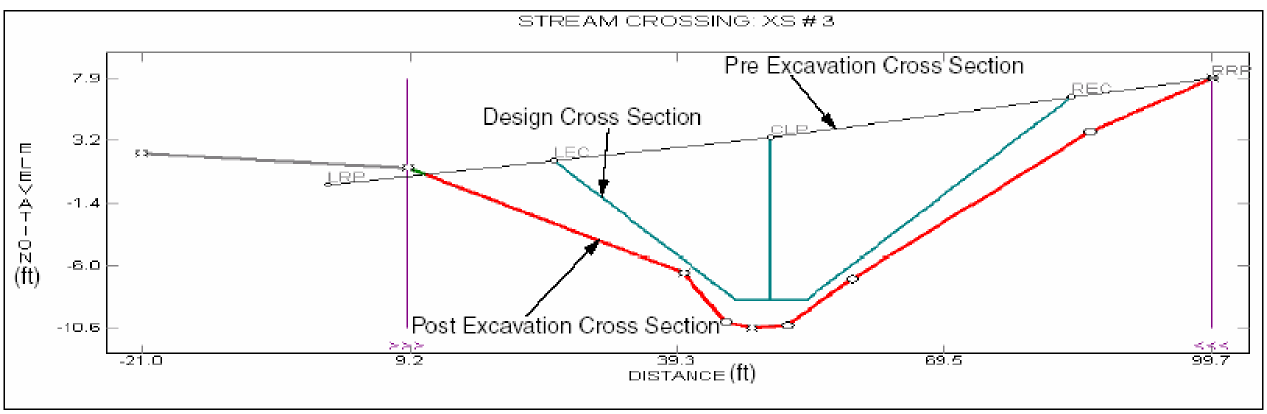


Figure X-D-30. Redwood Creek 1300 Road Site #12 – Stream Crossing Pre & Post Excavation Cross Sections.

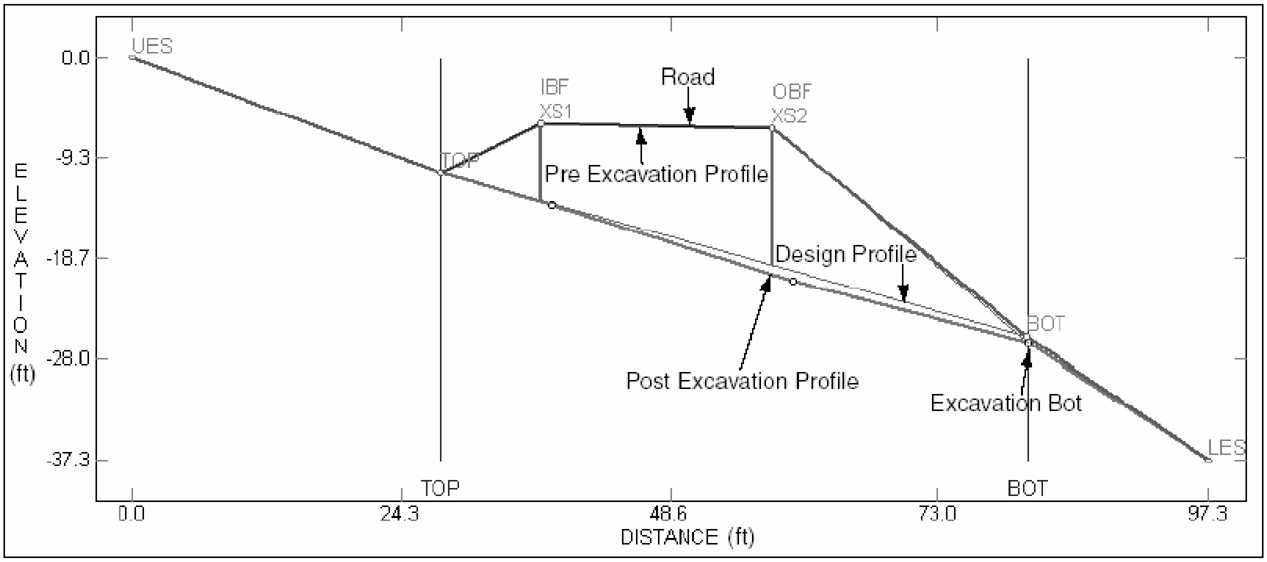


Figure X-D-31. Redwood Creek 1305 Road Site #11 – Stream Crossing Pre & Post Excavation Profiles.

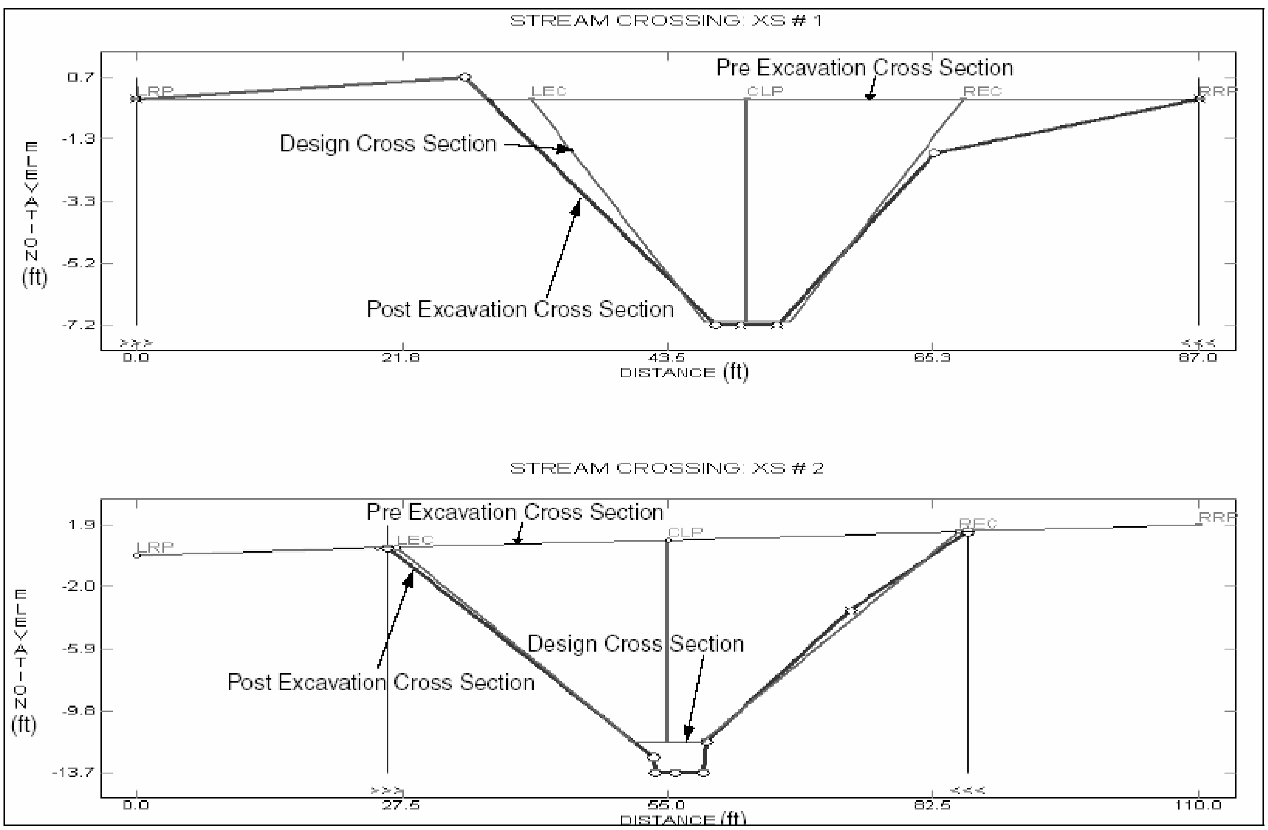


Figure X-D-32. Redwood Creek 1305 Road Site #11 – Stream Crossing Pre & Post Excavation Cross Sections.

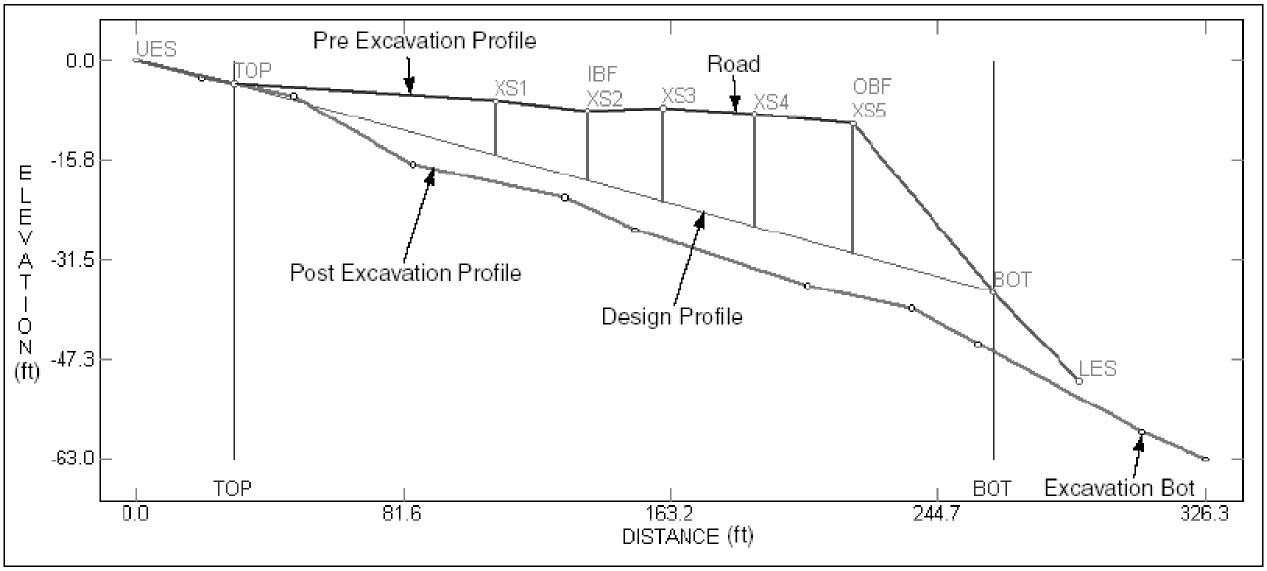


Figure X-D-33. Redwood Creek 1311 Road Site #3 – Stream Crossing Pre & Post Excavation Profiles.

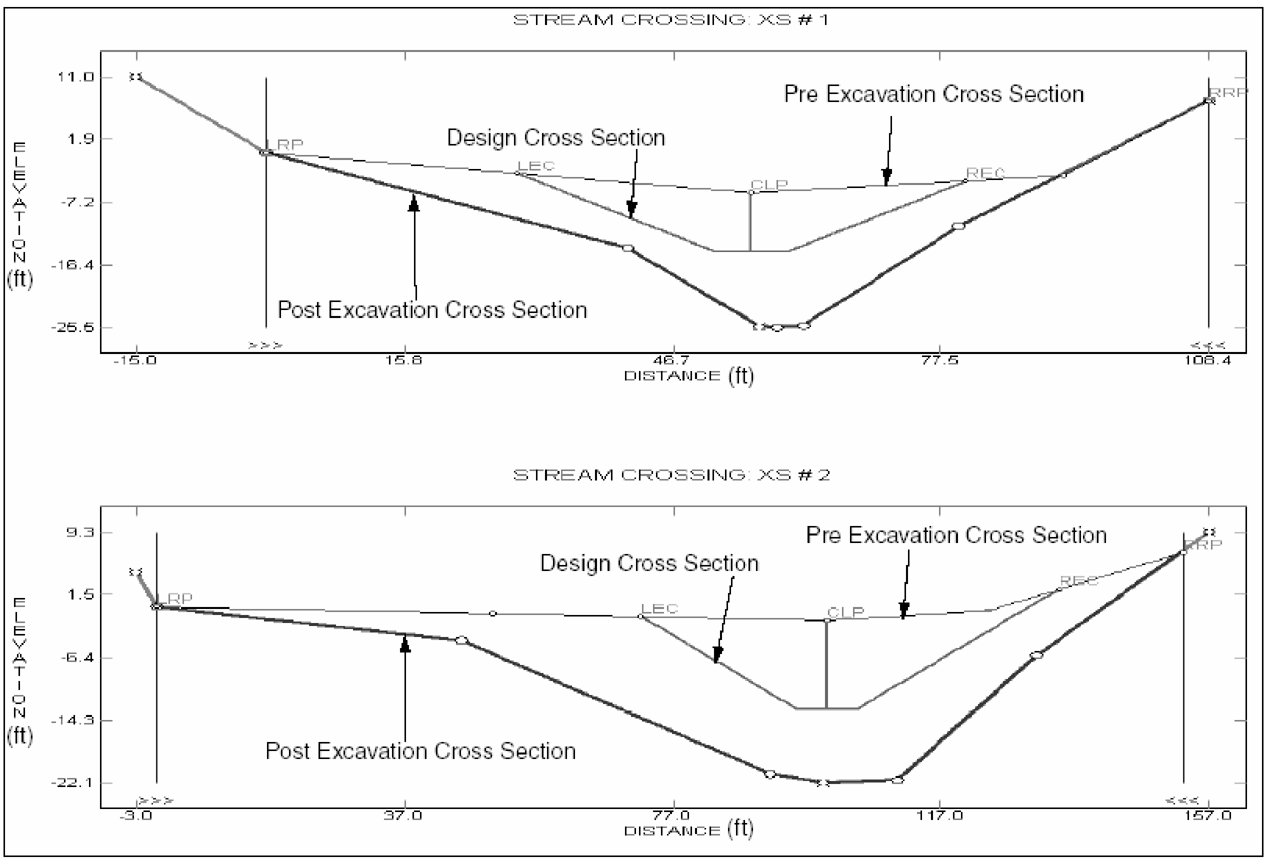


Figure X-D-34. Redwood Creek 1311 Road Site #3 – Stream Crossing Pre & Post Excavation Cross Sections.

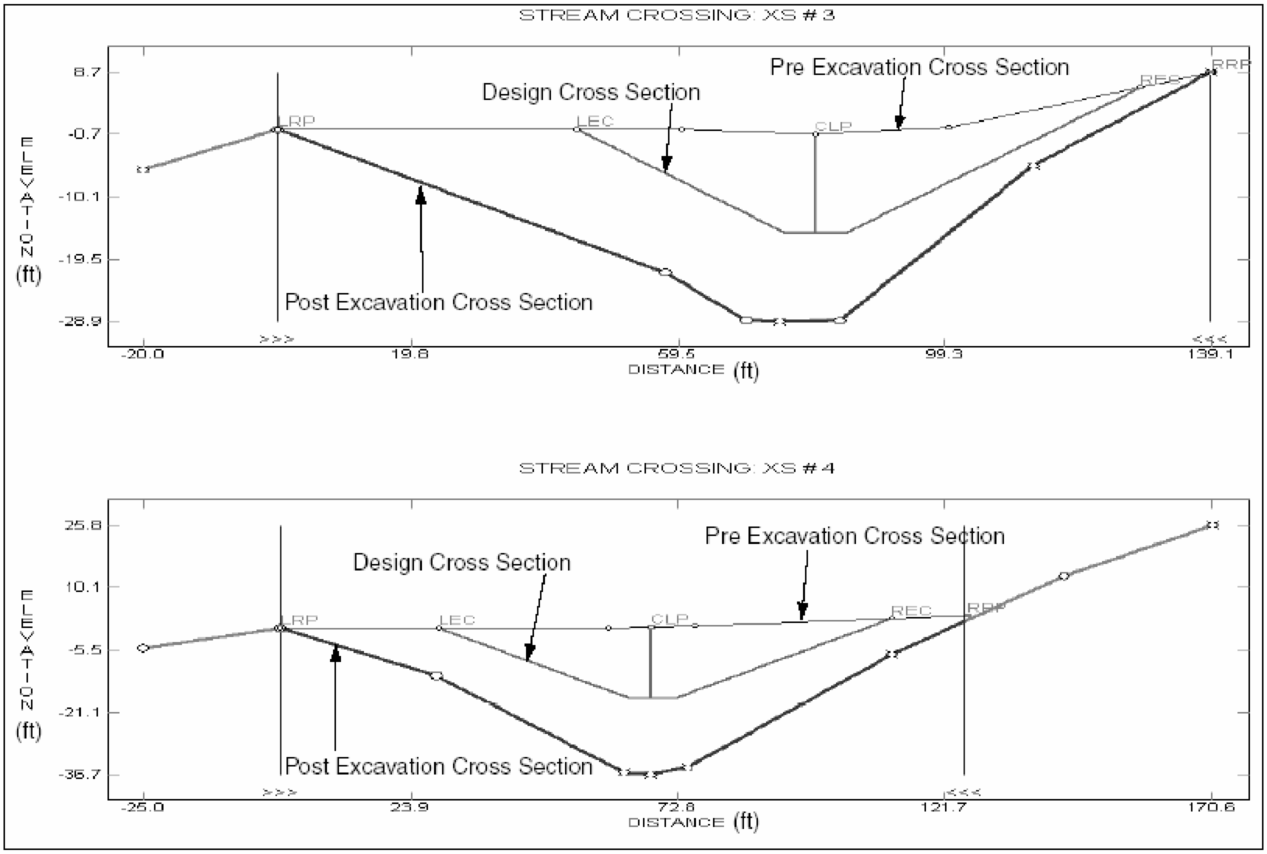


Figure X-D-35. Redwood Creek 1311 Road Site #3 – Stream Crossing Pre & Post Excavation Cross Sections.

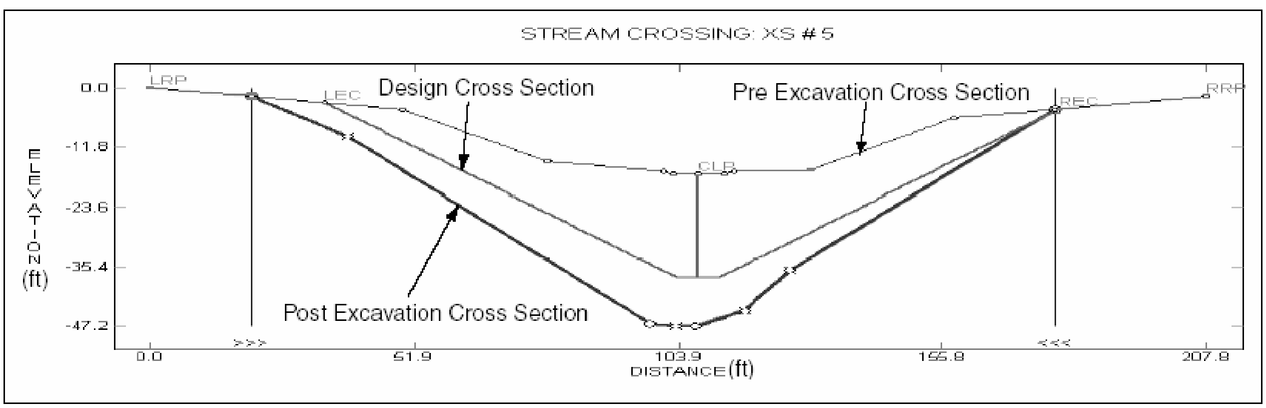


Figure X-D-36. Redwood Creek 1311 Road Site #3 – Stream Crossing Pre & Post Excavation Cross Sections.

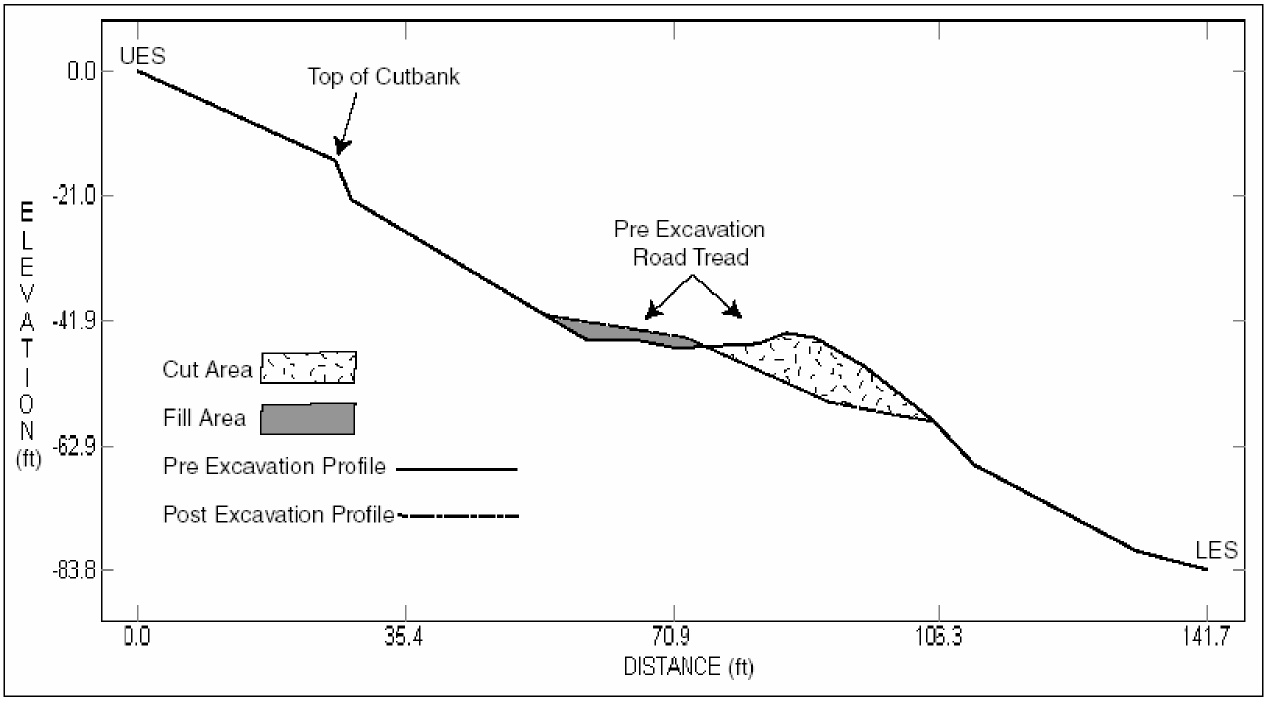


Figure X-D-37. Redwood Creek 1300 Road Site #7 – Road Fill Failure Site Pre- & Post-Excavation Profiles.

Coordinates for Site Locations 2002-2003 Redwood Creek Road Decommissioning Project

Road Name	Site #	X coordinate	Y coordinate
1300	1	423,695.41	4548,833.07
1300	2	423,674.04	4548,834.17
1300	3	423,591.82	4548,870.07
1300	4	423,519.74	4548,914.47
1300	5	423,447.11	4548,942.15
1300	6	423,375.04	4549,023.55
1300	7	423,325.16	4549,100.56
1300	8	423,239.10	4549,141.12
1300	9	423,139.62	4549,466.70
1300	10	423,076.31	4549,498.49
1300	11	422,945.03	4549,706.51
1300	12	422,818.42	4549,715.55
1300	13	422,845.82	4549,792.01
1300	14	422,777.86	4549,909.31
1300	15	422,741.68	4549,936.72
1300	16	422,678.37	4549,918.90
1301	1	423,444.92	4548,999.98
1305	1	423,674.04	4548,864.59
1305	2	423,585.24	4548,922.14
1305	3	423,548.79	4548,953.39
1305	4	423,507.41	4548,984.36
1305	5	423,486.30	4549,015.60
1305	6	423,465.75	4549,057.26
1305	7	423,450.13	4549,093.43
1305	8	423,398.06	4549,155.92
1305	9	423,345.71	4549,207.99
1305	10	423,325.43	4549,234.57
1305	11	423,304.33	4549,266.27
1305	12	423,283.77	4549,296.24
1305	13	423,268.15	4549,358.72
1305	13.1	423,268.43	4549,400.38
1305	14	423,257.74	4549,452.45
1305	14.5	423,247.05	4549,483.70
1305	15	423,231.43	4549,504.80
1305	16	423,211.15	4549,540.70
1305	17	423,195.53	4549,561.80
1305	18	423,185.11	4549,597.70
1305	19	423,156.34	4549,654.44
1305	20	423,116.87	4549,697.19
1305	21	423,085.63	4549,737.75
1305	22	423,049.18	4549,769.27
1305	23	422,977.37	4549,805.44
1305	24	422,919.27	4549,871.22
1305	24.1	422,863.91	4549,932.06
1305	24.2	422,827.19	4549,963.85
1310	1	422,966.96	4549,113.44
1310	2	423,279.66	4548,838.28
1310	3	423,076.58	4549,041.09
1311	1	423,090.83	4547,726.14
1311	2	423,147.84	4547,892.50
1311	3	423,314.74	4548,178.62
1311	4	423,341.05	4548,142.17
1311	5	423,356.40	4548,204.10
1312 Upper	1	423,533.72	4548,432.95
1312 Upper	2	423,408.47	4548,911.73
1312 Upper	3	423,393.12	4548,974.76
1312 Lower	1	423,746.94	4548,645.89
1312 Lower	2	423,710.49	4548,609.99
1312 Lower	5	423,767.49	4548,672.47

Table X-D-13. Universal Transverse Mercator (UTM) coordinates for site locations Redwood Creek Road Decommissioning Project – 1300 Roads Humboldt County, California.

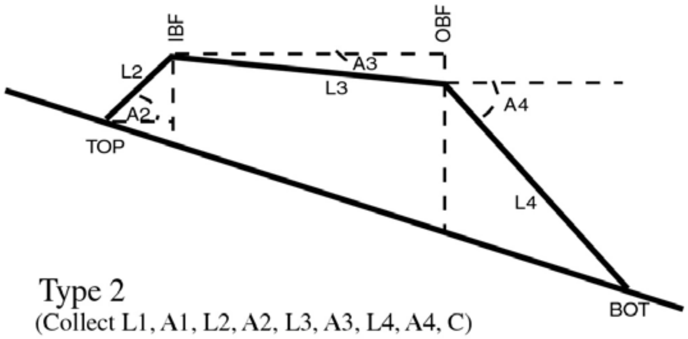
UPSLOPE INVENTORY DATA FORM

ASAP (Y, N)______

GENERAL	Site no:	Treat (Y/N):	Watershed:	Quad:	
	GPS:		CALWAA:	Photo:	
	T/R/S:		Road name/#:	Drivable (Y/N):	
	Mileage:		Inspector(s):	Date:	Year built:
	Surface: □ rock □ native □ paved		Status: □ maintained □ abandoned	□ decommissioned	
	Proposed: □ upgrade □ decommission			Sketch (Y/N):	
PROBLEM	Stream crossing (Y/N):		Landslide: □ fill □ hill □ cut	Roadbed: □ bed, □ ditch, □ cut	
	□ ditch relief culvert		□ gully	□ bank erosion	Road related (Y/N):
	Other non-road related site: □ home □ agricultural □construction □ mining □ other site				
LANDSLIDE	□ road or landing fill		□ hillslope debris slide (>50% original ground)	□ cutbank slide	
	□ deep-seated landslide		□ potential failure	□ past failure	Slope (%):
	Distance to stream (ft):				
STREAM	□ culvert	□ bridge	□ Humboldt	□ fill	□ ford	□ armored fill
	□ excavated crossing		% excavated:			
	Ditch road length (ft): Left:		Right:	Culvert diameter (in):		
	Pipe condition (O, C, R, P): Inlet:		Bottom:	Outlet:	□ separated	
	Headwall (in):		Culvert slope (%):		Stream class (1,2,3):	
	Culvert rust-line (in): Inlet:		Outlet:	Culvert undersized (Y, M, N):		
	Washed out (%):		Diversion potential (Y/N):		□ currently diverted	
	Road grade (%):		Plug potential (H, M, L):		Plugged (%):	
	Channel gradient (%):		Channel width (ft):		Channel depth (ft):	
	Sediment transport (H, M, L):		Drainage area (acres):			
FISH PASSAGE	Culvert outlet drop (in):		Bankfull drop (in):			
	Pool size bankfull width (ft):			Pool size bankfull depth (ft):		
EROSION	Erosion potential (H, M, L):		□ potential for extreme erosion			
	Volume extreme erosion (<500, 500-1,000, 1-2K, 2-5K, >5K):				Past erosion (yd^3) (optional):	
	Past delivery (%) (optional):		Total past delivery (yd^3):			
FUTURE EROSION	Future erosion (ft): Width:		Depth:	Length:	Future erosion(yd^3):	
	Future delivery (%):		Total future delivery (yd^3):			
COMMENT(S) ON PROBLEM:						
TREATMENT	Immediacy (H, M, L):		Complexity (H, M, L):			
	check culvert size (Y/N):		□ bridge	□ no treatment	Mulch (ft^2):	
TREATMENT OPTIONS	□ excavate soil	□ critical dip	□ ford	□ armored fill	Sill height (ft):	
	Sill width (ft):	□ trash rack	□ Add downspout: Length (ft):		Diameter (in):	
	□ repair culvert	□ clean culvert	□ install/replace culvert			
	Culvert: Diameter (in):		Length (ft):	□ flared inlet: Diameter(in):		
	□ reconstr. fill	□ armor fill face (U, D, B):		Armor area (ft^2): U: D:		
	□ clean or cut ditch, (ft):		□ remove ditch, (ft):			
	□ outslope road, (ft):		□ outslope & remove ditch, (ft):			
	□ outslope & retain ditch, (ft):			□ inslope road, (ft):		
	□ rolling dip, (#):		□ remove berm, (ft):			
	□ ditch relief culvert, (#):		Length (ft):	□ rock road surface, (ft^2):		
	□ cross road drain, (#):		□ other:			
HEAVY EQUIPMENT EXCAVATION DATA	Total vol. excavated (yds^3):		Volume put back in (yds^3):			
	Volume removed (yds^3):		Volume stockpiled (yds^3):			
	Volume endhauled (yds^3):		Distance endhauled (yds^3):			
	Excavation production rate: (yds^3/hr):					
EQUIPMENT HOURS	Excavator:	Dozer:	Backhoe:	Grader:	Loader:	
	Dump truck:		Labor:	Other:		
COMMENT(S) ON TREATMENT:						

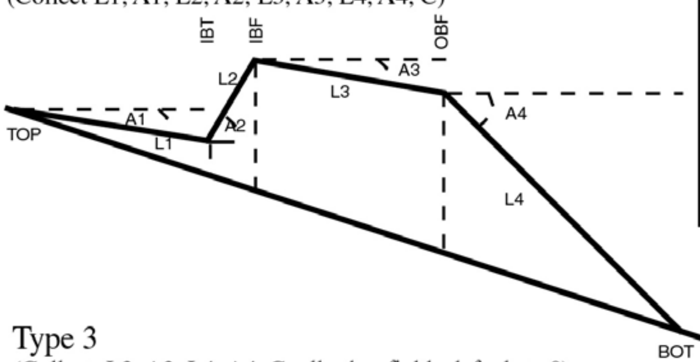
Type 1

(Collect L2, A2, L3, A3, L4, A4, C, all other fields default to 0)



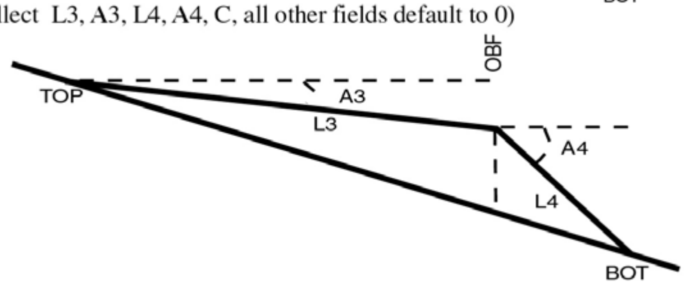
Type 2

(Collect L1, A1, L2, A2, L3, A3, L4, A4, C)



Type 3

(Collect L3, A3, L4, A4, C, all other fields default to 0)



Field data

Length of sediment fan (L1): _____ ft

Angle of sediment fan (A1): _____ degrees

Length of inboard fillslope (L2): _____ ft

Angle of inboard fillslope (A2): _____ degrees

Length of road bed (L3): _____ ft

Angle of road bed (A3): _____ degrees

Length of outboard fillslope (L4): _____ ft

Angle of outboard fillslope (A4): _____ degrees

Channel width (C): _____ ft

Sketch

STREAM BANK INVENTORY DATA FORM

GENERAL	Site no:	Distance (ft):		Date:	Inspector(s):	
	Watershed:			Stream:		
	Air photo:		Location (LB, RB, B):		☐ road related	Treat (Y/N):
PROBLEM	Type:	☐ debris slide	☐ debris torrent		☐ slow, deep-seated landslide	
		☐ torrent channel		☐ bank erosion	☐ LDA	☐ other
	Delivery: ☐ past		☐ future	☐ both	Activity (A, IA, W):	
	Age (decade):		Stream bank slope (%):			
	☐ land use	☐ undercut by stream				
PAST EROSION	Width (ft):	Depth (ft):	Length (ft):		Volume (yd^3):	
FUTURE EROSION	Future erosion potential (H, M, L):		Width (ft):		Depth (ft):	
	Length (ft):			Volume (yd^3):		
COMMENT(S) ON PROBLEM:						
TREATMENT	Immediacy (H, M, L):		Complexity (H, M, L):		Equipment or labor (E, L, B):	
	Equipment access (E, M, D):		☐ local materials		☐ import materials	
TREATMENT OPTIONS	☐ excavate soil	Width (ft):	Depth (ft):	Length (ft):	Volume (yds^3):	
	☐ rock armor/buttress		rock armor size (ft or ton):		rock armor area (ft^2):	
	☐ log protection		Log size: Length (ft):		Diameter (ft):	
			Bank length protected (ft):		Bank area to cover (ft^2):	
	☐ remove logs/debris				☐ boulder deflectors	
	Deflectors (#):		Deflector (yd^3):		☐ bio-engineering	
	☐ plant erosion control		☐ riparian restoration		Area planted (ft^2):	
	☐ exclusionary fencing		Length of fence (ft):		☐ other	
EQUIPMENT HOURS	Excavator:	Dozer:	Dump truck:	Backhoe:	Labor:	Other:
COMMENT(S) ON TREATMENT:						

SKETCH