Watershed Restoration

Manual

Redwood National Park
1992

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REDWOOD NATIONAL PARK

WATERSHED RESTORATION MANUAL

Redwood National Park
Watershed Restoration Program
P. O. Box 7
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ABSTRACT

This booklet will provide the reader with information on establishing a restoration program that addresses erosional problems related to roads in steep, forested terrain. The booklet goes through the thought processes and actions necessary to set program goals, identify and evaluate erosional problems, prioritize areas for treatment, investigate the causes of the problems through geomorphic mapping, design treatments, and finally, implement your treatments using heavy equipment, the most cost effective tool for road removal.

The information contained in this booklet is the result of 15 years of erosion control and watershed restoration experience at Redwood National Park. The approach described here is what we have found works best for us, given our goals. Watershed restoration work is a long term commitment to improving ecosystem conditions. It should be well thought out, so that funds are used effectively. It should also be well documented so that others may learn from your experiences. The problems and goals may be different in your area, but we hope that many of the principles described herein will be useful to you.

Note that this manuscript addresses only the first phase of ecosystem restoration at Redwood National Park: restoring the physical environment through erosion control and watershed restoration. Numerous specialists are working on other aspects of restoring and managing the park's ecosystems, and have a wealth of information of their own to share with interested restorationists and land managers.

NOTE TO READERS:

This is a preliminary edition of what will eventually become a manual on erosion control and watershed restoration. We are actively working on improving and adding to this booklet. We encourage your input as to how it could be made more useful or readable, what other topics should be covered, etc. Send us general comments and photo-copy pages with specific editorial comments. We are counting on you to help make this a clear, useful document!

Send your comments to us at Redwood National Park, P.O. Box 7, Orick, CA 95555. If you wish to be on the mailing list for the finished manual and future watershed restoration seminars, contact us at this address.

Feel free to contact us if we can be of assistance in your watershed restoration efforts. Our phone number is 707-488-2911.

Thank you,

Terry Spreiter, and the Watershed Restoration Staff

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WATERSHED RESTORATION

IN REDWOOD NATIONAL PARK

An Introduction by James H. Popenoe and Terry Spreiter

Goals

Goals should be formally identified prior to beginning a watershed restoration program. They may vary between different agencies and landowners. The goal at Redwood National Park is to minimize erosion caused by past land management activities and to encourage the return of the natural ecosystems to their pre-disturbance conditions as closely as possible. In so doing, erosion caused by the timber harvesting and road building that preceded park formation is minimized, sediment entering the Redwood Creek stream system is reduced and the recovery of healthy, naturally functioning ecosystems for the enjoyment of present and future generations is accelerated. Ecosystems recover on their own, up to the limit of available resources. Physical treatments restore hydrologic systems, recover soil and remove road scars; these treatments would take centuries for natural processes alone to accomplish. They set the stage for recovery of the biological ecosystems through natural succession. Thus, the bulk of efforts and costs focus on physical restoration of natural landscape components which ecosystems require to function.

Background and History of the Program

Redwood National Park is situated along the northwestern coast of California. The natural vegetation is a mosaic of forests, oak woodlands and prairies, with redwood forest being the most extensive type. The terrain is steep and mountainous. Annual precipitation averages 70 to 100 inches, coming mostly as rain during the winter months. The steep terrain, rainy climate and deep, medium textured soils make the area very susceptible to erosion. Timber is the largest industry in the region. Concern over effects of logging and related activities on park resources prompted legislation expanding the park up to watershed divides in the lower Redwood Creek basin. As part of this legislation (PL 95-250), Congress authorized a program of watershed rehabilitation for lands added to the park. Seventy-five percent of the additional land was logged and there were over 300 miles of logging haul roads.

Early work was experimental. Efforts concentrated on protection of bare soil surfaces and projects were labor-intensive. It became apparent that some traditional revegetation treatments intended for surface erosion control inhibit long-term natural succession. In addition, the sediment saved by revegetation and by labor-intensive physical treatments was insignificant in comparison to the overall sediment budget of the basin or even the park. Revegetation efforts shifted to encouragement of natural succession. Physical treatments shifted to prevention and treatment of large scale, road-related problems using bulldozers, excavators and dump trucks similar in size to those which installed roads in the first place. Through experimentation and cost analyses, techniques for watershed restoration using heavy equipment have been developed which provide permanent, cost effective erosion control and set the stage for ecosystem restoration.

Erosion Control Treatments

In Redwood National Park, the most cost effective treatment is prevention and correction of diversions of water from streams by roads. Stream diversions can cause major hillslope gullies and landslides. A small excavation is often sufficient to prevent diversion. Next in priority is removal of potentially unstable road fills. Wet, unstable fills perched on steep slopes along the outboard side of roads may trigger debris flows. Debris flows can damage resources for many hundreds or thousands of feet downslope. Unstable fills are removed to a safe site and excavations are blended with original slope contours. Third in priority is the removal of stream crossings on abandoned roads. Nearly all culverts eventually plug or fail and the fill, consisting of soil placed around the culvert, washes out. Crossings that are already washed out may be stable and simply eyesores. Erosion potential must be carefully evaluated. In removing a crossing, all fill is excavated to keep it out of the stream and to keep the stream from diverting out of its natural channel. Excavation re-exposes the natural streambed, usually a mixture of rock and woody debris. Excavated stream banks are blended with hillslopes above and below the road. Excavation of fill from stream crossings returns streams to naturally functioning hydrologic systems, which sets the stage for recovery of biota. Aquatic ecosystems can recover and function normally once abnormal inputs of sediment are controlled. Stream work is performed with a large excavator and bulldozer. For efficiency in restoration, equipment should be similar in size to that which created the problems. Generally the cheapest costs per cubic yard are achieved by using the largest piece of equipment that will fit on a given work site. Redwood National Park commonly uses D-8 size bulldozers, and excavators with a 2 to 3 cubic yard bucket.

Landscape restoration

In Redwood National Park, the preferred treatment for roads that are no longer needed is called outsloping. Outsloping means recontouring a road surface to approximate surrounding topography. This is generally done by a large excavator and bulldozer working together, retrieving sidecast road fill, placing it against the road's cutbank, then smoothing and blending the fill to match the natural relief. This provides a permanent erosion control treatment, and restores pre-existing hillslope runoff patterns. An outsloped surface does not allow runoff to divert or concentrate as do ditches, waterbars or culverts, and it requires no maintenance. A second benefit of outsloping is that it speeds re-establishment of native vegetation.

Concentrations of gravel and rock on the road surface are dispersed, depth of soil above bedrock is restored, and much original topsoil is retrieved. Topsoil is the first material to be sidecast during road construction and is generally uncovered near the end of the outsloping process. A final benefit (and one that is difficult to measure) is the restoration of the aesthetic value of natural landscapes achieved by complete road removal. Refinements in equipment application and resulting decreased treatment costs have allowed outsloping and topsoil retrieval to be widely applied in Redwood National Park.

Revegetation

Specific methods of revegetation for disturbed areas depend on strategies developed after a careful evaluation of site conditions and constraints. Both physical and biological factors may be important. Site preparation is important if prior land use degrades the soils.

In the expanded Redwood National Park, site conditions were affected by logging and road building on steep slopes. Topsoil was displaced and abandoned road surfaces consisted of compacted subsoil, often hardened using crushed rock. Physical restoration treatments, such as decompaction and salvaging side-cast topsoil, enhance conditions for planting and encourage natural colonization by native plants. Straw mulch helps control surface erosion and favors natural revegetation by protecting the seed bed. Early revegetation efforts were labor intensive and involved use of many species.

The current emphasis in revegetation is on site preparation and supplementation with nursery grown seedlings of key native species, such as redwood, which do not establish readily on their own. In Redwood National Park, as in much of the Pacific Northwest, there is abundant, vigorous regrowth of vegetation on disturbed areas. Seed of coyote brush, red alder and conifers is dispersed by wind from surrounding trees and shrubs. Even without planting, most areas are covered with a dense growth of these pioneering species. Ultimately, the physical restoration of soil depth and topsoil may be the most effective revegetation treatments. Over time, natural biological processes take over and complete the restoration process, given the limits of the physical setting provided.

Cost Summary

The park expansion legislation (PL 95-250) authorized the expenditure of thirty-three million dollars to implement watershed rehabilitation work on the lands added to the park. Between 1977 and 1990, approximately ten million dollars were spent on site specific watershed rehabilitation, and 175 miles of road were treated. The costs include all personnel, heavy equipment, and materials needed to perform the work.

SETTING GOALS AND PLANNING A RESTORATION PROGRAM

The ideal situation for planning erosion control and watershed restoration work along roads is to discuss the problems and goals with an interdisciplinary group of cultural and natural resource specialists and recreation planners at the beginning, to insure that all resource concerns are considered.

There will be much interaction with these specialists during the course of the work. However, it is <u>essential</u> that the people who do the erosion evaluation, geomorphic mapping, treatment planning and heavy equipment supervision have a strong background in <u>geomorphology</u>, particularly in fluvial and mass movement processes. Without this knowledge, many critical, and often subtle, indicators of instability may be overlooked, and the ability to achieve your goals may be compromised.

A. Identify the problems and clearly define the program goals.

1. State the problems that need to be addressed. Prioritize them, if possible. This is the justification for implementing a program and will help keep the program focussed. As you inventory the area, you may need to modify these ideas. Perceived problems are not always the true problems.

2. Clearly define the program goals. Make sure the goals address the problems. List your goals in priority order. Establishing clear goals at the beginning will make other decisions easier. These goals may also require modification as work progresses.

3. Individual projects areas should be prioritized according to the relative amount of resource damage that will occur if left untreated, and the costs, benefits and likelihood of success of the work, in relation to the program goals. Access, landownership, and untreatable problems outside the boundaries or scope of the program may affect these priorities!

4. Each individual project undertaken by the overall program should also have its goals defined. The project goals should support the program goals, though other factors may need to be considered on a site specific basis.

5. At Redwood National Park, the goals are to minimize erosion caused by past land management activities, and to encourage the return of the natural ecosystems to conditions similar to what existed in the area

before human disturbance. The treatment priority of large areas within the park is generally based on the amount of potential erosion that may occur, and its impacts on Redwood Creek and park resources. These priorities are discussed in the next section. When treatment time arrives for these large areas, many secondary factors affect site specific treatment planning, including landform and ecosystem restoration goals, vegetation and wildlife concerns, trail and campsite locations, future park development, viewsheds, etc.

6. The primary goal of your work may be something other than minimizing future erosion, depending on the objectives of your program or agency.

   a. Some projects have the goal of complete landform restoration because the land is designated wilderness, or is being set aside for future wilderness consideration.

   b. Other projects may have the goal of erosion control on existing heavy use roads, and complete removal of unneeded or abandoned roads. Some roads may be partially removed, with the intent of reconstructing them in the future.

7. The knowledge needed to set goals and priorities can come from research in similarly disturbed watersheds in your region if you don't have the resources to gather new information. As you learn more about your area, you should modify your goals and priorities as needed to reflect these new findings.

EROSION CONTROL PRIORITIES

at Redwood National Park

The excessive amount of sediment in Redwood Creek, and its impact on park resources, was defined as a major resource problem in the park. Studies identified roads as a major cause of the accelerated erosion. Road related problems were evaluated for the relative volumes of sediment generated by each different type of erosion. These are ranked below by their relative sediment production and impact on park resources. A major goal of the restoration program is to minimize the amount of sediment added to the stream system.

A. Correct or prevent stream diversions.
This is one of the most cost-effective and erosionally significant treatments in roaded watersheds. Stream diversions, or diversion potentials, exist at stream crossings where the flow is, or may be, diverted from its natural course if the drainage structure fails. Excavation of the road fill from these stream channels can prevent major hillslope gullies and/or landslides. If the crossing has diversion potential, but the road needs to remain drivable, a rolling dip (large drivable water bar) can be constructed to prevent diversion in case of drainage structure failure.

B. Prevent debris flow style road failures.
Removal of potentially unstable road fill on steep slopes can prevent debris flows or torrents which can impact resources for hundreds or thousands of feet downslope. These commonly occur along roads in steep headwater swales and inner gorges.

C. Prevent stream wash-outs.
Removal of drainage structures (culverts, etc.) and complete excavation of the fill will prevent erosion of the fill that occurs when the drainage structure fails to function as intended. Most drainage structures will fail, given enough time, water and debris, especially where road maintenance is infrequent. The future erosion potential of each stream crossing (intact or otherwise) must be evaluated. Stream crossings that have already washed out <u>may</u> be fairly stable and simply an eyesore; they may not need treatment.

D. Prevent road fill failures.
Removal of sidecast fill, particularly fills that exhibit signs of potential instability, in conjunction with restoring natural slope drainage, will prevent these mass movements. Sidecast fills along older roads often contain large amounts of organic debris. As this material decomposes, the fill may lose its integrity. Water ponded on road surfaces, or in the inboard ditches can

saturate the fill and cause failure. Fill failures are similar to debris flows but can occur anywhere along a road. How far they travel depends on slope steepness.

E. De-water gully systems.
Correcting flow diversions and keeping slope runoff dispersed will often minimize further gully development. To effectively treat a gully, its cause must be addressed.

F. Correct or prevent management related factors which may contribute to landslides.
Landslides are natural in this youthful, tectonically active terrain. They are costly and often difficult (if not impossible) to truly control. To cost-effectively minimize landslide potential, it is important to insure that landslide is not being aggravated by artificially concentrated or diverted runoff.

AIR PHOTO ANALYSIS

The steps that went into determining the erosion control priorities at Redwood National Park are similar to those used to priortize both work areas within the watershed, and specific work sites in a given project area. Only the size of the area considered, and the level of detail varies.

The first step in undertaking an inventory of erosion problems for a watershed restoration work is to conduct a thorough study of all available air photos. The goal is to get an overview of watershed conditions and disturbances through time, and identify all the road-stream and road-headwater intersections in the watershed of concern. This will enable you to pinpoint actual and potential problems areas that should be field checked.

A common mistake is to assume that all the hillslope watershed problems are along the main roads. Many areas that have been logged have smaller roads, skid trails and/or fire breaks above and/or below the main roads. Because they may not have been used much since logging, they may be overgrown, and difficult to walk (let alone drive!). They may not show up on the most recent air photos, and they seldom appear on topographic maps. However, as roads with cuts, fills and stream crossings, they may be disrupting the natural drainage patterns of the hillside and causing erosion problems. Just because they are overgrown (sometimes erroneously referred to as "healed"), does not mean that there are no erosion problems waiting to happen. All these more obscure road-stream and road-headwater intersections will need to be field checked before work plans are finalized, so that equipment access is not cut off to these other problems that may need treatment.

Recent as well as older stereo air photos should be looked at. Problems currently hidden by dense regrowth, but which are still causing erosion problems, are often clearly visible in the photos taken immediately after disturbance. Historic air photo analysis is an efficient way to become thoroughly familiar with the drainage network, history of road construction, timber harvest and other disturbances. Thorough air photo analysis prior to beginning field work will save hours of time crashing through the brush.

It is highly recommended to take a pocket stereoscope and the air photos (recent and historic, with their completed overlays and notes) into the field when mapping. Even though an area may now be completely overgrown, the old photos will show the original skid trail network, which, most likely, will still allow passage on foot (or hands and knees!). These old photos are your "road map" to find the crossings, gullies and landslides! However, before taking any photos into the field, be sure the negatives are available so that new prints can be made if necessary. Clear plastic air photo carriers will help protect photos from the elements.

Basic Steps

You will need a series of stereo air photos of your watershed (starting with photos taken 1-5 years after initial disturbance), topographic maps, mylar for overlays, colored pencils, a stereoscope and possibly a magnifying glass. Attach mylar overlays onto every other photo (or whatever is needed for complete coverage) and label the mylar to correspond to the photo number. Mark or outline several reference points on the mylar, so that you can quickly check that the mylar and photo remain correctly aligned as you do your work.

1. On a topographic map, draw in the entire drainage network, extending the "blue-line" streams headward to their beginnings in headwater swales. Dash or dot the "stream lines" up through the headwater swales, when the "divots" in the contour lines can no longer be followed upslope. These topos will be used later to determine drainage areas and estimate storm discharge, information needed for the field inventory work.

2. Using stereoscope and drainage network information from the topographic maps, identify the drainage on the air photos and trace them on the mylar (in blue). Be sure to extend them all the way to their headwaters as you did on the topo map.

3. Trace the major road network on the mylar (in black), if needed for ease of identification.

For the following steps, as you study the photos, label or number specific erosion features, using the same designation for that feature in each successive photo year. Key any written notes to these labels. Note the year that "new" erosion first becomes visible. Also note when various sections of road were built, washed out, failed, etc., and when each block of timber was cut and the harvest method used.

4. Circle all locations where roads or skid trails cross drainage (in red). Look closely at each crossing in each photo year and note if there is any evidence of diversion or wash-out. Also note if the crossing was repaired and when. If a road appears to run straight up a stream channel, circle the whole stretch of impacted channel.

5. Trace gullies (in orange). If possible, identify its cause and mark it on the mylar (in red).

6. Outline landslides (in purple). Look carefully for causes (diverted flow, roads built across steep headwater swales, etc.), and mark them on the mylar (in red).

7. Identify and mark (in green) wet areas, springs, tracing the flow if diverted down roads. Water ponded or running down roads may appear as either light or dark blotches or lines on the road surface. Springs and wet areas may be evident as areas of different vegetation.

EVALUATING EROSIONAL ACTIVITY

Professional training in geomorphology is essential for those involved in evaluating erosional activity. Without it, critical indicators of instability may be overlooked, yielding erroneous results and a potentially misguided watershed restoration program.

This work is done in the field at different scales and levels of detail depending on what stage you are at with your planning. For a watershed-wide inventory, you might only evaluate the main roads. For a site specific project, you also would want to evaluate all secondary roads and skid trails in a similar fashion, and map the geomorphic features of all disturbed areas (described in more detail in the next section). Prior to doing field evaluation work at any level, an air photo analysis should be completed for the area of concern (refer to the previous section).

A. Evaluate all existing and potential problems along the road, and document the amount of erosion that may potentially occur at each. This information is needed to prioritize general areas as well as the specific sites for erosion control and restoration work.

   1. Collect data systematically on standardized forms.

      a. This will make it easier to equitably compare many potential work sites.

      b. The information can be entered into a data-base, linked to a graphic information system and queried for any number of management and planning concerns.

      c. The road inventory form and definitions developed and being used at Redwood National Park are included in the appendix of this booklet. They are the result of extensive evaluation of erosional processes active within the Redwood Creek basin, since the mid 1970's. The organization, and the site characteristics evaluated with this form, were chosen because of basin conditions and to assist in meeting watershed restoration goals at Redwood National Park. Although the form asks for a lot of information, with practice, most sites can be documented in 10 to 15 minutes.

2. Some important things to consider as you look at the site are:

   a. Is it actively eroding, dormant, inactive and healing, or a problem waiting to happen?

   b. What is causing the problem? If necessary, go uphill until you find the cause, and note it on your form. Generally, the problems off the main road, including skid trail crossings, will be documented in more detail during the geomorphic mapping phase.

   c. Is it likely to be reactivated?

   d. What will happen in an average storm?

   e. What will happen in a major storm?

3. Quantify, as best you can, what will happen (the amount of sediment that is likely to be released) in a major storm, even if only crudely in orders of magnitude. Strive to be consistent in your estimates. This can be the most difficult part of filling out the form, because you will have to use your professional geomorphic judgement to make these estimates. However, your best estimate in the field is going to be far better than the guess of you or someone else sitting back in the office! Several helpful volume calculation worksheets and charts are included in the road inventory definitions in the appendix.

4. Consider the significance of this occurrence and its impact in relation to other problems in the project area and your goals.

5. Consider treatment possibilities: be sure you are addressing the cause as well as the manifestation of the problem.

6. Document your observations, train of thought, and conclusions in written notes on the form. There are several places on the form for comments.

7. Using the back of the road inventory forms, make a quick sketch of each site.

B. Compile and analyze the data.

   1. Once the information from the inventory is compiled and analyzed, it will be possible to prioritize areas and/or specific sites for treatment according to the cost and benefit of the work in each particular area in relation to the program goals.

2. The data on the Redwood National Park form can be entered and queried in a data-base computer program. This can be done in the field a notebook style computers.

C. Be sure to review your program goals and priorities at the conclusion of the inventory.

1. The inventory may yield new information that will cause modification of your goals.

2. You may need to spot check and re-evaluate watershed conditions after a major storm.

GEOMORPHIC FIELD MAPPING

A. Geomorphic field mapping is essential for the site specific erosion control and watershed restoration projects:

1. To document the obvious problems that drew you to the area and their possible linkages to other problems.

2. To search the area for similar or other problems that need correcting.

3. To search the area for less obvious potential problems that can be prevented.

4. To discover and document the causes of the problems.

5. To make sure that nothing is being overlooked.

6. To become familiar with the type of geomorphic (erosional) processes at work in the area, and what is normal vs. accelerated.

7. To organize and plan your restoration work.

B. Preparing for geomorphic field mapping

1. Do a thorough air photo study, using recent and historic air photos. Refer to the air photo analysis section.

2. Select the photos you wish to map on. Use whatever age photos give the clearest view of the full extent of the problem. Older photos, taken right after logging, may be better than the most recent ones for clarity of the skid trail network.

3. From the air photo negatives, have black and white enlargements and photomylars made. The enlargements are cut up and used on field map boards; the photomylars are used for final, reproducible maps. (We use a scale of 1" = 100'; this gives plenty of room for the level of detail necessary for mapping and laying out rehab work.)

4. Mount the black and white enlargements on convenient sized (18" x 24", or whatever fits under your arm!) pieces of 1/4" plywood. Cover each photo with a sheet of frosted mylar, taping just along one side, so you can lift it up. Masking tape works well. You can wet the photo to

improve visibility through the mylar. Black and white prints stand up to getting wet on a daily basis, as long as you allow them to air-dry overnight by lifting the mylar off the photo.

5. Before going to the field, transfer results of the air photo study, reconnaissance observations and basic geomorphic features (streams, ridges, roads, skid trails, etc.) to the mylar on each map board.

   a. Use standard mapping symbols (refer to the mapping symbols in the appendix). Add symbols for other features or problems if needed. Make a legend for each map.

   b. Circle or highlight all road-stream and road-headwater intersections.

   c. Highlight other obvious or potential problem areas to help pinpoint where mapping should be concentrated.

6. Use pencil (HB or H lead) to sketch on the mylar in the field. Trace all final mapping in the office at the end of each day, using a rapidograph type pen with permanent ink. Periodically transfer mapping to a mylar overlay of the photomylar. BEWARE: a wet rainsuit rubbing on your map board can easily erase pencil and sometimes ink, so transfer and ink daily!

C. Efficient geomorphic field mapping.

1. <u>Professional geomorphic training is essential for mappers.</u> One of the most common mistakes is to notice the erosion that has already happened, and not recognize the <u>potential failure indicators</u>. Geomorphic training helps in learning and identifying these indicators. Identification of the potential problems is extremely important because <u>prevention</u> is much more cost-effective than repairing the damage.

2. Map in the winter, or whenever the runoff is occurring!

3. Always take the following "tools" with you to the field:

   a. A copy of the topographic map with all drainages and crossings identified.

   b. Recent and historic stereo air photos with the overlays showing drainages and crossings. Make sure negatives are available in case they need to be replaced, and keep them in protective plastic envelopes.

c. Copies of road inventory forms completed in the initial watershed-wide road inventory for reference.

d. Pocket stereoscope, clinometer, flagging, waterproof felt pens, pencils, erasers, etc.

4. Be systematic: map roads first, then fill in detail on the hillslopes.

   a. Roads concentrate and divert runoff.

   b. Most erosion problems caused by land management activities initiate at roads.

   c. Inspect all road-stream, and road-headwater intersections. Document conditions at each intersection, both on the map and on road inventory forms. Take copies of the inventory forms that are already filled out with you for reference.

   d. Look for potential problems, not just those that have already occurred.

5. Sketch in natural topography above and below the road. Watch the cutbank height: it usually lowers as it cuts through a drainage or headwater swale.

6. Keep in mind that essentially all swales carry flow in a big storm; consider where that water will go when it gets to the road or skid trail.

7. Follow displaced water upslope to find where it is coming from.

8. Follow displaced water downslope to document impacts.

9. Be aware of vegetation types: some are moisture indicators and help identify seeps and springs. Flag seeps and springs so that you will be able to locate them during the dry heavy equipment season.

10. Note the soils: know their susceptibility to fluvial or mass wasting processes.

11. Remain alert for potential problems as well as existing problems!

D. Field safety tips.

1. Wear eye protection when working in dense vegetation.

2. Carry a first aid kit.

3. Carry a radio.

4. Let someone know where you are going.

5. On cold and rainy days, wear appropriate clothes and boots...with modern technology, there is no point in being miserable! Polypropylene under high quality raingear works best. Polypropylene fingerless gloves are nice, even if you plan to stay dry, and they last much longer than wool gloves.

DEVELOPING WORK PLANS FOR A RESTORATION PROJECT

A. Keep your goals clearly in mind. This will help establish priorities in your work area and justify funding.

B. Work plans will be controlled or limited by the availability of:

1. Funds.
2. Appropriate equipment.
3. Knowledgeable people.
4. Management support.

C. Work plans may be limited due to land ownership or access: you may not be allowed to treat the cause of the problem.

D. Once an area has been identified for a site specific project, all existing and potential problems in that area should be treated, because you will likely be eliminating future equipment access.

E. Don't get sidetracked by inactive eyesores if your goal is to minimize future erosion. A large, unattractive erosion scar may have already eroded nearly all that it can. Spending time and money on this site may not help meet your goal.

F. Don't waste efforts on things beyond your control, for example, natural erosional processes that are not significantly influenced by human activities. Be sure you are correcting the cause of the problem, not the result.

G. The bottom line: will this work plan bring you significantly closer to your goals?

BASIC RESTORATION TREATMENTS USING HEAVY EQUIPMENT

The majority of road-related erosion control and watershed restoration work involves the use of heavy equipment. Regardless of the size or shape of a road, the basic types of treatments possible with heavy equipment are fairly similar. The main thing that will vary between different sized roads is the size of the equipment used. Although the basic treatments have been briefly described in the introduction, this section lists benefits of each, what type of equipment is commonly used, and some tips on how to achieve the desired results. More information on the types of equipment and how each is best used, and average costs are in later sections.

A. Ripping.

1. Decompacts road and landing surfaces which aids revegetation and increases infiltration.

2. Generally we rip road surfaces and other locations where fill is to be placed. This decreases the chances of an impermeable surface under the fill, perching groundwater, which could cause saturation and potential failure of the fill.

3. Accomplished with a large bulldozer (D-8) with 2 or 3 rear mounted, hydraulically operated ripper teeth, which are normally 24-36" long. We decompact to a minimum depth of 24 inches, with spacing between ripped furrows of no more than 2 feet.

B. Cross road drains.

1. Disperses road runoff, and drains wet, ponded areas.

2. Located at frequent intervals, depending on road slope, amount of runoff. May be drivable rolling dips.

3. Can be built with either a bulldozer or an excavator. Site conditions and work sequencing may dictate which equipment is more cost-effective.

C. Outsloping: a road treatment with many benefits.

1. Prevents concentration and diversion of runoff along a road.

2. Prevents mass failure of road fill.

3. Restores hillslope contours.

4. Can completely obliterate all traces of a road bench.

5. Retrieves the sidecast topsoil, improving revegetation success.

6. Can be done with either an excavator or a bulldozer, depending on the terrain; most commonly a combination of the two is used. In areas without a stable cut bench, the fill may need to be pushed or otherwise transported (endhauled) to another location.

D. Stream crossing excavations.

1. Prevents or corrects stream diversions.

2. Prevents stream from washing away the fill.

3. Restores stream channels to a more natural condition.

4. Generally the first step is for the dozer (or 2, if the crossing is large) to remove the bulk of the fill. This material is pushed to stable locations along the road adjacent to the crossing, or endhauled to a more distant fill site, if there are no stable locations nearly. The dozer(s) should work on the excavation until it either becomes too steep or wet for them to cost-effectively continue.

5. The excavator is then used to define the channel and retrieve fill from steep slopes, or when the excavation area becomes too wet and muddy for the dozer.

6. Some crossings can be excavated by either piece of equipment alone, depending on size, shape, moisture, etc.

7. Try to divert flow around the work area during excavation, to minimize downstream turbidity and saturation of the remaining fill, and to maximize flexibility in equipment operations.

8. Aim to find the original channel bed and banks, for maximum stability of the finished work. Be careful not to over-excavate or you may remove the original channel armor, and initiate a new phase of downcutting! Watch for stumps, water-worn rocks or wood, buried decomposed vegetation (often black and smells bad!) sometimes with root mats still

in place, changes in soil color, increases in soil moisture, water seeping through old gravel beds of the buried channel, etc.

9. If you do not anticipate finding the original channel bed, you may need to consider armoring the finished excavation with rock. Rock can be expensive, especially if there is none available close by, but necessary in some cases.

10. The stream excavation will probably look terrible when you're about 2/3's of the way through ... don't give up!

E. Endhauling, or transporting material away from the immediate work site.

1. May be needed at stream crossings or outslopes in unstable terrain, where there are no local, stable fill sites.

2. Generally more cost-effective than pushing with a dozer when distances exceed 800 feet.

3. Requires a loading piece of equipment (loader, excavator) and dump trucks. Self-loading scrapers may be an option if there is enough room to maneuver and minimal large rock or organic debris to load.

4. Load the trucks directly with the excavating equipment if possible, to minimize the number of times the fill is passed from one piece of equipment to another. This may require maintaining a road to the edge of, or down into, the excavation, and having the trucks back up to the excavator.

5. Endhauling can quickly become quite expensive. The expense is generally due to handing the fill two or three times, the time spent in transit, and keeping the road in good shape for the trucks. There are many more pieces of equipment to keep coordinated, and problems to deal with: turn around and passing locations, grading and watering the haul route, etc. Endhauling can be a challenge to coordinate, but if conditions call for it, it should be done.

TYPICAL COSTS OF RESTORATION TREATMENTS

USING HEAVY EQUIPMENT

Redwood National Park, 1992

A. Typical costs per mile.

The cost per mile of road removed is extremely variable, depending on terrain, road width, drainage density and size and other site specific variables. Until the erosional complexity of the area is assessed and the actual work is laid out and surveyed, accurate cost estimates for future projects are difficult to determine. Some examples of typical road removal costs[1] per mile (heavy equipment only) in Redwood National Park are as follows:

1. Small road, gentle terrain, few stream crossings
   $10,000 - $20,000

2. Medium sized road, frequent small to medium size stream crossings
   $20,000 - $40,000

3. Major, mid-slope haul road, frequent large stream crossings
   $40,000 - $70,000

4. Major road, low on slope, frequent large stream crossings, unstable terrain
   $100,000 - $250,000

B. Specific treatment costs.

Although the cost per mile varies widely, recent production rates (cubic yards of material moved per hour) and unit costs, such as cost per cubic yard, at Redwood National Park have been fairly consistent. Production rates and unit costs have improved dramatically over the years as the equipment techniques have been refined and operators gained experience in this unique type of work. For example, initially, the price per cubic yard for stream crossings with local fill sites was between $3 and $7. Costs now average $1 to $2 per cubic yard of material moved from similar stream crossings, using the large equipment with experienced restoration operators. During this time, equipment rental prices rose by roughly 50 per cent, making the decrease in cost per yard even more significant. Specific treatment costs[1] are as follows:

1. Ripping (decompacting the upper 2 feet of a road bed).
   Averages \$800 per mile, or \$.15 per linear foot for a 30 foot wide graveled road.

2. Cross road drains (large waterbars).
   Average \$1.00 per linear foot of drain.

3. Outsloping (fill against cutbank).
   Averages \$10,000 per mile or \$1.00 per cubic yard. This is for a road averaging 30 feet wide, with a 8 foot cut along the outboard edge, a finished slope of 3:1, removing 1.7 cubic yards per linear foot of road.

4. Exported outsloping (fill moved a distance along the road, but not endhauled, to a more stable fill site).
   Averages \$1.50 per cubic yard, but varies with distance to fill site.

5. Haul road stream crossings.
   Average \$1.00 to \$2.00 per cubic yard for relatively straight forward crossings, but can vary with size, distance to fill site, amount of organic debris, stream flow, fill saturation, etc.

6. Skid trail stream crossings.
   Average \$2.00 per cubic yard (includes an additional 20% for gaining access).

7. Truck endhauling.
   If required for exported outslopes or stream crossings, costs average \$3.00 to \$5.00 per cubic yard more than for the basic excavation work, for hauling distances up to about 2 miles.

[1] NOTE REGARDING COSTS: Equipment rental costs (operated) on the north coast of California average \$100 to \$120 per hour for D-8 sized bulldozers, and \$105 to \$135 per hour for large, 2 to 3 cubic yard bucket excavators. If rental rates in your area are considerably different, you may wish to contact Redwood's Watershed Restoration staff in Orick for current production rates, which can then be applied to your equipment prices.

REVIEWING THE SITE SPECIFIC RESTORATION TREATMENTS

A field review of your proposed restoration treatments, with the interdisciplinary group of resource specialists, is the final step before detailed treatment design and survey work. Often, another field review is conducted after the design and survey work is completed. Usually on this second review, the group narrows down to the earth scientists, and the focus is on appropriateness and stability of the treatments in the erosionally complex areas.

A. Highlight proposed work locations on a base map, and develop a list of proposed treatments prior to the review.

B. Take the information that you have gathered, including air photos, maps and road inventory forms, to the field review to help justify and explain your proposals.

1. Geomorphic mapping and the cause-and-effect relationships of the erosion problems are reviewed.

2. The appropriateness of the prioritizing criteria and treatments are discussed.

3. Proposed work sites, as well as some of the no-action sites are field checked.

4. A discussion of treatment possibilities, the logistics of doing the work and the likelihood of success results in fine-tuning the treatment plans.

5. At Redwood National Park, a core field review team, made up of geologists, soil scientists, and vegetation specialists, may spend several days evaluating the proposed restoration and stabilization treatments on an erosionally complex project. Heavy equipment operators, labor crew leaders and others may also be involved. Input from those involved in implementing proposed treatments can be very important from a practical view point. Fishery and wildlife biologists, archaeologists and trail planners generally also review the plans, and may investigate their areas of concern in more detail independently, reporting back to the group.

6. Remember not to take the criticism and advice personally...its all in the best interest of the watershed!

DESIGNING COST-EFFECTIVE RESTORATION TREATMENTS

A. Attributes of the ideal treatment:

   1. Permanent.

   2. Maintenance free.

   3. Functions in equilibrium with the natural processes.

   4. Cost-effective.

B. Design the work to blend with the natural, undisturbed channel or hillslope above and below.

C. Design complete excavation of stream channels. This will prevent stream diversions and erosion of fill. Uncovering the original stream bed often eliminates the need for secondary protection such as check dams or rock armor.

D. Design complete restoration of hillslope contours. This minimizes fill failure potential, re-establishes dispersed surface runoff, and often has the benefit of recovering sidecast nutrient-rich topsoil. At Redwood National Park, it is considered a very cost-effective treatment for re-establishment of native vegetation.

   1. During road construction, the topsoil is generally the first material cut and pushed over the edge. It often becomes capped by the subsoil that is pushed over the edge as the road cut is widened and flattened. In complete re-contouring of a road, you generally encounter the subsoil first, and this goes back against the cutbank, roughly where it came from. Towards the end of the excavation, the displaced topsoil can often be found, and spread over the finished slope.

   2. Placing the sidecast soil back on the road cut will also increase the depth of soil on the cut bench. The vegetation that becomes established on this improved site will likely grow faster, and be in a more stable location...chances are almost no-one will miss the vegetation that used to be growing on the fill slope!

E. Excavated material should be put in a stable location (fill site), ideally where it came from, recreating natural topography. If no stable storage areas are close by, material may need to be moved by truck to a stable location. When finished, the fill site is shaped to blend with surrounding topography.

F. Don't be bashful about removing vegetation that has become established on your work site since road construction. Compromising prescriptions for vegetation can lead to less than stable excavations if it is growing on perched fill, and increase costs if the equipment has to carefully work around it. However, you can and should work around partially buried, standing trees that pre-date road construction.

G. Methods of achieving or performing treatments should be comparable to the methods used to create the disturbance. In road removal, you only have one chance to do it cost-effectively. So do it <u>right</u>, and do it to last <u>forever</u>!

1. The majority of the road-related problems you will deal with were initiated by use of mechanized equipment, and are most cost-effectively treated the same way. The beast that made the problem is often the best suited to clean it up. In other words, a road built with large bulldozers requires large bulldozers for its removal...shovels and wheelbarrows won't cut it!

2. Do the job right from the start. A larger initial cost outlay to completely restore an area is often cheaper in the long run than a half done job which requires continual maintenance or is always on the brink of failure. Keep in mind the attributes of the ideal treatment.

3. Once you remove the stream crossings along a road, you have eliminated the access for mechanized road maintenance equipment. Don't leave any culverts or in-board ditches behind that may someday require clearing with a backhoe or grader.

4. Don't get bogged down with how to get equipment to the problem. If equipment got there to create the problem, it can probably get there again. Minimal access roads can be quickly constructed and easily removed on the way out.

H. Evaluating cost-effectiveness: is it worth the effort?

1. How you define cost-effectiveness depends on your goals.

2. In the erosion control work at Redwood National Park, cost-effectiveness is determined by considering cost per cubic yard of sediment saved from entering the stream system.

3. We compare the volume of sediment that may potentially erode if we were to do nothing, with the estimated cost to perform the treatment. To estimate the cost, you will need to know the volume to be excavated (can be an estimate), typical production rates for that type of work (cubic yards per hour), and local equipment operating costs.

    a. Example of whether to armor a channel excavation...small volume of sediment saved for a large expense.

    b. Example of preventing a stream diversion/hillslope gully by removing the stream blockage...large volume of sediment saved for a small expense.

SURVEYING RESTORATION WORK SITES

A. Consistent and relocatable surveying is important for the following reasons:

1. To determine volume of fill to be moved.

2. To determine capacity of fill storage areas. Remember that excavated fill expands or "fluffs up".

3. To make cost estimates and schedule equipment.

4. To calculate actual volume moved for contract payment.

5. To calculate the production rate and cost per cubic yard for each work site. This information is very helpful for planning future work.

B. Simple field surveying methods are fine.

1. We generally use a tape, clinometer and compass.

2. For roads: survey profiles across the road wherever it significantly changes size, shape or prescription.

3. For streams: survey a long profile down the center of stream crossing, up and over the road prism, beginning and ending on stable natural channel. Then survey cross sections, perpendicular to the channel, noting at what point they cross the profile.

4. Survey well beyond the maximum anticipated bounds of the excavation...15-20% more than what you think you will need.

5. Be sure to identify reference points in the field so that you can relocate your survey endpoints for post excavation surveying, since many excavations vary from initial plans and must be resurveyed to determine actual volume.

6. Identify the approximate bounds of each work site or prescription in the field with flagging or stakes.

C. Volumes can be calculated manually or by using computer programs developed specifically for design of road removal work.

1. Manually, you can draft the surveyed profiles and cross sections, design your excavation cut and fill lines, and calculate volumes using basic double end area formulas. Refer to the Road Inventory Definitions in the appendix for further information.

2. Redwood National Park has developed computer programs that greatly speed up excavation design manipulations. The programs use raw field survey data, provide design drawings, allow for manipulations and produce a final output with volumes, contract specifications and project drawings. These are public domain programs and are available upon request. The staff at Redwood National Park is also available to train program users.

HEAVY EQUIPMENT WORK: PREPARATION AND IMPLEMENTATION

A. Plan wisely and maintain flexibility.
Achieving a balance between planning and flexibility is essential since rate of expenditure can be extremely high with equipment work: commonly $240 per hr, or $4 per minute, with 2 pieces of equipment. It is essential to have your work carefully laid out in advance. However, remain flexible. Because of the unpredictable nature of the work, you must ready to adapt to unexpected obstacles, equipment breakdowns, etc.

B. Schedule a final review.
You may wish to have your work reviewed again, before equipment work begins, to be sure nothing has been overlooked. Interaction with experienced restoration equipment operators may be useful at this point, especially in terms of logistics, equipment needs and scheduling.

C. Choose the most appropriate and cost-effective equipment to do the job.
Caterpillar Inc. publishes excellent equipment performance handbooks which contain valuable information for planning your equipment work, regardless of what brand of equipment you actually use.

1. Equipment must be matched in size both to the work site and to the other equipment that it will be working with.

2. For road removal and watershed restoration work, we have found that bulldozers and excavators are the essential, complementary pair. In some situations, other types of equipment may be used with them.

3. Our cheapest costs per yard are achieved by using large equipment: the largest that will fit on the majority of the work sites.

    a. Generally speaking, the price paid for a larger machine is more than compensated for in its increased production rates. For example, consider a 3 yd excavator for $150 per hour versus a 1/2 yd backhoe for $50 per hour: the excavator will produce more than 6 times the production for only 3 times the price.

    b. Make sure the desired equipment can physically get to your project area. Check load limits on roads, bridges, etc.

4. Equipment should be kept working independently, yet near each other, to minimize time spent waiting on one another. This is particularly important in small or cramped work sites.

5. Bulldozers.
Bulldozers are best for moving large quantities of fill quickly, re-contouring rock pits, and for final shaping of outsloped roads, landings and fill sites.

   a. Size: Road width is generally the main factor which will limit the size of dozer used. Bigger dozers have more power, and can move larger quantities of dirt faster than smaller ones. Other things to consider are the production rate of the excavator, and how far the dozer will have to push the fill. Caterpillar D-8 (or equivalent) is the most common size used at Redwood National Park.

   b. Blades: hydraulically controlled, U or straight. We mostly use U blades because, for a given size machine, the capacity of a U blade is greater and its sidecast is minimal.

   c. Tracks: wide tracks are better for sidehilling and invaluable when working in wet areas. On D-8's, we use 28" width whenever available. Groussers (the "cleats" on the tracks) are also important: they are similar to tread on a tire: if they are worn down, the tracks will spin or continually be losing headway.

   d. Winches: useful for moving large debris, for pulling equipment out of the mud or for turning excavators right side up! Generally, most of the dozer work is done by a dozer with a winch.

   e. Rippers: for decompacting ground. For rocked haul roads, rippers must be mounted securely (bolted on, not towed behind) on the rear of a D-7 or D-8 sized dozer. The extra weight of rear mounted, hydraulically operated rippers can affect the machine balance, making it a little less effective on steep ground, than a dozer with a winch. Because of this, we try to minimize the use of dozers with rippers for general earth moving work.

4. Excavators.
Excavators are best for lifting fill on steep slopes, final shaping of channel bottoms and working in tight locations, such as between trees.

   a. Excavators have a 360 degree swing, enabling them to put the fill directly behind them, where another piece of equipment can get to it. This is the excavator's supreme advantage over a backhoe.

b. Size: The overall size of excavator used depends on the road width and reach that is needed. The size of the machine may be limited by the narrowest sections of road where it will be working. Remember that they also need room to swing.

c. Buckets and thumbs: Generally we request the largest capacity bucket that a particular excavator is designed to handle. Hydraulically operated bucket clamps are often available, and useful, for moving awkward shaped organic debris or rocks that won't readily fit in, or balance on, the bucket.

d. Reach: In most cases, the bigger the excavator, the further it will be able to reach. If the fill extends beyond the excavator's reach when it is sitting on the road surface, the excavator may have to dig itself a bench part way down the fill slope to sit on in order to retrieve all the desired fill.

e. Hopefully, your road width won't limit the size of the excavator, and you will be able to use one that can easily reach the bottom of the fill, with a big bucket.

f. At Redwood National Park, many of the roads are 25 to 30 feet wide, with long fill slopes. We generally use machines with a 2 to 3 cubic yard bucket capacity. These large machines have a 35 to 40 foot reach which is useful for road removal on steep ground. It gives the machine a 70 to 80 foot working radius, which reduces the distance the dozer needs to push the fill.

5. Dump trucks.
Dump trucks are a costly but essential method to move fill longer distances.

a. If you have to move fill more than 800 feet, trucks are usually more cost-effective than bulldozers.

b. Size of truck used is limited by turn-around space; we usually use 10 yd trucks.

c. Locking differential (similar to 4 wheel drive), is useful for steep, uneven ground, such as climbing out of stream excavations.

d. Minimize the number of times fill is handled. Try to load directly with excavator whenever possible, as opposed to having another piece of equipment move the fill to a location where a loader can then load it.

6. Loaders.
   Loaders are generally reserved for loading trucks, though they are also useful for shuttling materials short distances.

   a. Available on wheels or tracks. Track mounted machines are better if the loading area is mucky, but they are slower and require more maneuvering room than an articulated wheel loader.

   b. Loaders can come with a bucket or log forks. "Four in one" buckets are very versatile. They can act as a bucket, a blade or a clamp.

7. Dragline Cranes.
   Under the control of a highly skilled operator, a crane can be useful for excavations requiring an extremely long reach.

8. Scrapers.
   Redwood National Park has utilized scrapers sparingly, but they can be useful if conditions are right.

9. Backhoes.
   Backhoes are seldom used, except for road maintenance work such as replacing culverts. Their limited swing and reach make them ill suited for most road removal work.

D. There are many factors which affect production rates, but the operator's skill and experience outweighs all other factors. A few of the other most common job related factors are:

   1. Distance the excavated material is to be moved.

   2. Uphill vs. downhill push for the excavated material.

   3. Ground moisture conditions.

   4. Amount of large organic debris buried in the fill.

   5. Amount of time that the geomorphologist stops the equipment to discuss the work.

   6. Many more! At this point you must go and read your heavy equipment "Bible" ... the Caterpillar Performance Handbook! These are absolutely invaluable reference books, and are generally free from Caterpillar dealers. Even if you don't use Caterpillar brand equipment, the principles are the same. If you are going to use older equipment, try to get an

older edition of the handbook (roughly the same age as the equipment), especially if you want to use their production rate charts. Newer machines generally have more power than older ones of the same size, so if you use information from a new book, beware. In practice, we have never been able to achieve their production rate estimates...possibly because we are always pushing material uphill, and in most construction work it is pushed downhill!

E. Dealing with operators, or how to survive and still get the job done.

1. Tell them what you want, <u>not</u> how to do it.

   a. Explain overall objectives.

   b. Assuming you have experienced operators who you can trust, ask their advice. So that you can learn, ask them why. Be open to new ideas.

   c. Remember: you have the earth science knowledge, they have the equipment knowledge!

2. Be there while work is in progress.

   a. Prescriptions may need modifying, depending on what you encounter.

   b. If the operator has misunderstood your garbled description you can correct the misunderstanding before it goes too far.

   c. The operator will not have to stop and wonder whether this is what you really meant, while the engines are idling.

   d. You should be constantly monitoring the excavation for signs of original ground, to make sure you do not over or under excavate: stumps, water worn rocks, buried organic matter, changes in soil color...all give clues whether you are excavating in the right place.

   e. Keep track of time spent at each work site, by each piece of equipment, and any difficulties encountered. This will be essential in determining overall cost-effectiveness and production rates.

3. Whenever possible, use equipment operators who have experience in restoration work.

   a. They are familiar with the techniques used in road removal, which are quite unique and different than those used in standard construction work. Their specialized knowledge can significantly decrease the costs of doing the work and increase the production rates, especially if the project geologist/supervisor is not experienced in overseeing equipment operations.

   b. They are skilled at working on steep slopes, which can be dangerous if the operator is not used to operating the machine under such conditions.

   c. If experienced operators are not available locally, contact other groups doing similar work for referrals.

4. Be humble, be alert and stay out of the way!!

DOCUMENTATION

Thorough documentation and monitoring of your work is an important aspect of any restoration project. It can be used to assess and improve the cost-effectiveness of your work, as well as build public support for your program. Historic records will often come in useful for research projects and comparison with work in other areas. Plan to keep your records and photographs forever...organize, label and archive things as you go. This won't be such an overwhelming task at the end of the program if you have kept up with it. It will also help immensely if there is turn-over in the staff, and someone new has to take over the project.

A. At Redwood National Park, we document pre- and post-excavation conditions photographically (from permanently marked photo points). Some work sites are repeatedly surveyed and photographed for several years after excavation to observe the changes with time. Photographs illustrate your accomplishments very dramatically, and are helpful when garnering management and community support, and when requesting funding.

  1. Remember that once you take out the road, or work on the problem area, it will (hopefully!) never look the same again...so take an abundance of "before" photos from locations that are marked (flagged, staked) in the field, and can be re-occupied after the work is done.

  2. Think ahead to how you might re-photograph the site in 10 or 20 years, when the vegetation is thick and healthy. You may want to climb up on the cutbank, or on a tall stump or rock for some of the before shots, so that you will have more time before your view is obscured by vegetation.

  3. Afterwards, you can re-shoot ones that best view the before and after scenes. Carry copies of the original before photos with you when you go back to re-shoot. This will help insure proper framing, which is important if you want to convince people that this is really the same place!

B. Time lapse photography can be used to document heavy equipment techniques. This provides an excellent educational tool to describe the work and how it is done.

  1. At Redwood, we have successfully used a super 8 movie camera set to shoot 1 frame every 5 seconds. Played back at normal speed (18 frames per second), the equipment movements are fairly smooth. A full work

day can be seen in about 5 minutes. The same can be done with video recorders.

2. Sites with shadows moving across them during the day do not photograph well. Open, south facing sites photograph the best.

3. Be sure to set the tripod and camera up well out of the way of any equipment work. The viewfinder should frame the full extent of what will become the completed work site.

C. Keep time and cost records of heavy equipment work on a daily basis. Note anything unusual that happens or is encountered during the work. Times and costs are totaled for each work site, and summarized in the project report, along with volumes of fill excavated.

1. Redwood National Park has developed a format for recording this information in our field books that is very simple and efficient (call if interested).

2. These records will provide essential information on production rates and costs, help assess the cost-effectiveness of the work, and be used for future project planning.

3. Production rates and cost-effectiveness of various types of treatments and equipment can be compared between sites, areas, and project leaders. When combined with the notes on what was encountered during the work, they can be used by the project leaders to learn and improve their prescription lay-outs and heavy equipment supervision skills.

4. At Redwood National Park, we prepare a final report for each project containing geomorphic and treatment maps, erosional inventory information, work summary and cost analysis. There are over 90 of these project reports on file at Redwood National Park, covering the last 15 years of watershed restoration work. These provide data for future cost estimates, as well as documenting what was done and why.

D. Post-excavation surveys can be set up to monitor channel adjustments through the years. These can provide useful feedback as to which techniques and equipment work best. The post-excavation monitoring at Redwood National Park provided key information in the formative years of the program that dictate the techniques used today.

E. At Redwood National Park, many aspects of watershed and ecosystem health are monitored basin-wide, in addition to the physical restoration work. For further information on monitoring, contact the Chief of the Research and Resource Management Division in Orick.

FINAL THOUGHTS

This booklet has only addressed one aspect of restoring a naturally functioning ecosystem to the disturbed watersheds of Redwood National Park. This first phase, restoring the physical environment through erosion control and watershed restoration, is critical to the successful recovery of the biological ecosystems.

Undertaking the physical aspects of watershed restoration requires a great deal of practicality and common sense, as well as solid professional training in the earth sciences, particularly geomorphology. It also requires close cooperation with specialists in the biological disciplines of ecosystem restoration. At Redwood National Park, there are a number of specialists in each of these disciplines, working on the restoration of park ecosystems. The staff at Redwood National Park regularly assists other parks and other Federal, State and local agencies in planning and implementing restoration work on lands under their jurisdictions.

For further information or assistance, contact any of the following staff at Redwood National Park, P.O. Box 7, Orick, CA 95555, or phone (707) 488-2911.

Terry Hofstra, Chief of Research and Resource Management Division

Terry Spreiter, Supervisory Geologist, Watershed Restoration Branch

Jim Popenoe, Supervisory Plant Ecologist and Soil Scientist, Vegetation Branch

Carolyn Meyer, Supervisory Biologist, Fish and Wildlife Branch

A wealth of information is available on the park's resource management and restoration program. Regarding the erosion control and watershed restoration program, much of what has been learned over the past 15 years can be applied in other areas and to land management activities with different goals. Road inventory forms, excavation design computer programs, heavy equipment contract specifications and heavy equipment rental agreements are available upon request; contact Terry Spreiter.

Ecosystem restoration involves doing what many people think is impossible. So be bold and don't give up! You don't know what will happen until you try!

APPENDIX

AIR PHOTO ANALYSIS EXAMPLES

Figure 1. Topographic map of Slide Creek with drainages and road-stream intersections identified.

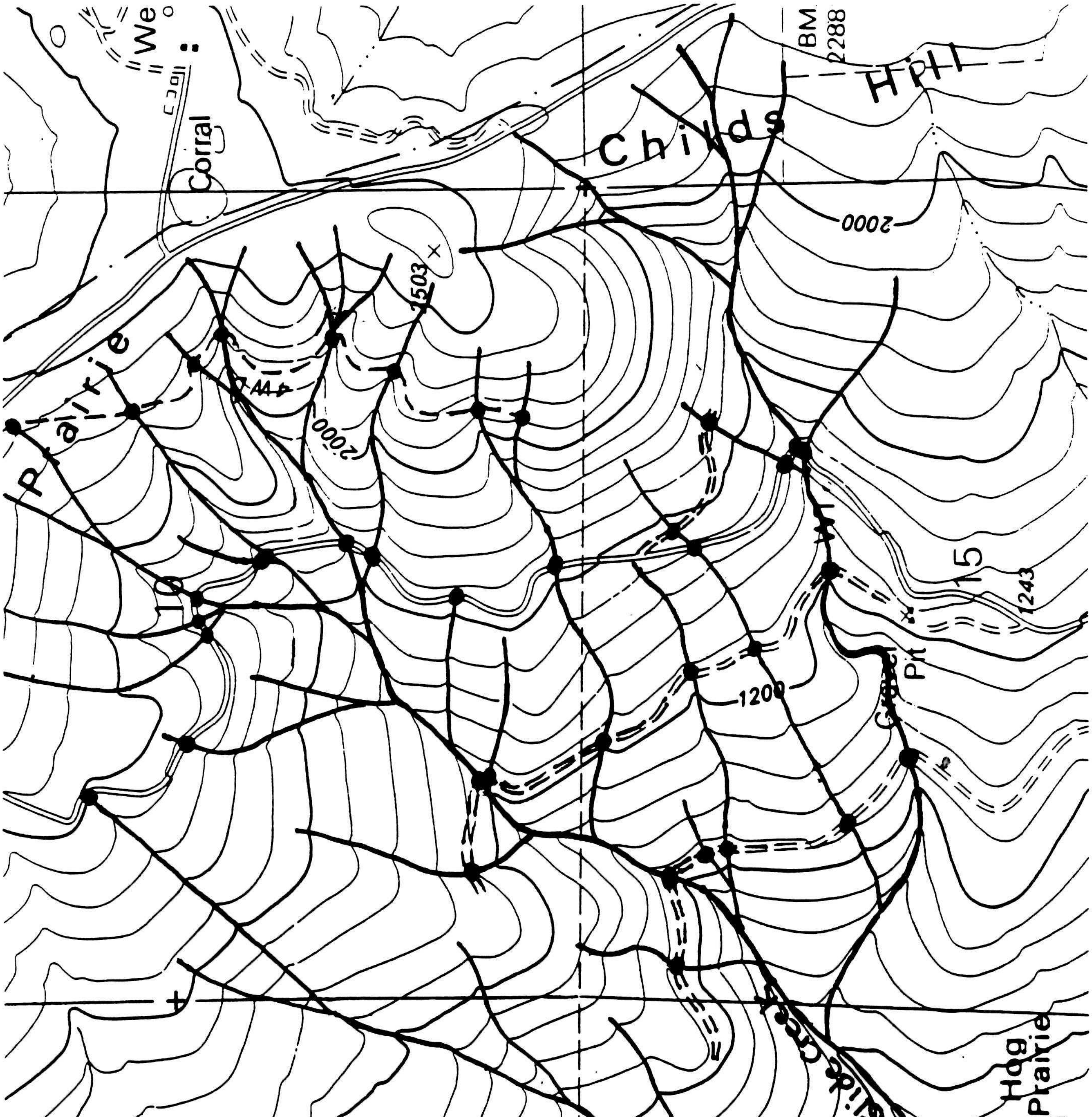


Figure 2. Air photo of Slide Creek with drainages and road-stream intersections identified.

SOURCES FOR AERIAL PHOTOGRAPHY

A wide selection of photographic negatives are held by various government agencies and private aerial survey companies in a variety of scales and photographic films. For all practical purposes, black and white prints at scales of 1:12,000 are ideal for watershed analysis. If budgets permit, 1:24,000 scale photos are an excellent compliment to 7.5 minute topographic maps, and 1:6000 scale photos allow detailed viewing of specific areas.

The following is a list of a few aerial photograph sources. Catalogs are available from the U.S. Geological Survey and the Agricultural Stabilization and Conservation Service that summarize existing, in-progress, and planned aerial photography in the United States held by several federal agencies.

Federal Government Agencies

U.S. Environmental Protection Agency
EMSL AMD/AMS
P.O. Box 93478
Las Vegas, NV 89193-3478

U.S. Army Corps of Engineers
Regulatory Functions Branch
211 Main Street
San Francisco, CA 94105
(415) 556-5966

Agriculture Stabilization & Conservation Service
U.S. Department of Agriculture
Aerial Photography Field Office
P.O. Box 30010
Salt Lake City, UT 84130
(801) 524-5856

U.S. Geological Survey
Earth Science Information Center
Box 25046
Federal Center
Mail Stop 504
Denver, Colorado 80225-0046
(303)236-5829

Forest Service
U.S. Department of Agriculture
Region 5
630 Sansome Street
San Francisco, CA 94111
(415) 705-1855

EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57148
(605) 594-6151

U.S. Geological Survey
Earth Science Information Center
345 Middlefield Road
Mail Stop 532
Menlo Park, CA 94025
(415) 323-8111

U.S. Geological Survey
Earth Science Information Center
1400 Independence Road
Mail Stop 231
Rolla, Missouri 65401
(314) 341-0851

State Government Agencies

Highway and transportation departments may have photo coverage specific to your study area. Don't forget the regulatory agencies, for example, the Regional Water Quality Control Board, and the Department of Health Services.

County Government Agencies

The county agencies are often a wealth of information. Many early photos previously used for timber tax assessment or early land surveys can be found. The county assessor, planning, and public works departments are all possible sources.

Private Company Sources

Photogrammetric companies are found across the nation. Their names and address can be found in current issues of Photogrammetric Engineering, the journal of the American Society of Photogrammetry.

REDWOOD NATIONAL PARK ROAD INVENTORY FORM DEFINITIONS
October, 1992

SITE INFORMATION AND SUMMARY

1. **Site Number:** The six digit identification number given this specific site. The first three digits of this number correspond to a specific road, and the second three digits represent sequential sites along the road.
2. **Mileage:** Field personnel may ignore. This will be computed by GIS.
3. **Date Mapped:** The date field mapping for this site was carried out.
4. **Mapped by:** The initials (first, middle, last) of those who did the field mapping for this particular site.
5. **Photos taken (Y,N):** Answer "yes" or "no" to whether or not photos were taken at this site during the inventory.
6. **Watershed:** This refers to the major tributary to Redwood Creek in which the inventory site is located.
7. **Land Ownership:** Answer Redwood National Park (RNP) if the site is located within the park boundary. If the site is outside the park boundary indicate the owner, if known.
8. **Map Sheet:** Input the USGS topographic quadrangle that contains this site (if known).
9. **Map Code:** Field personnel may ignore. This will be input by GIS personnel.
10. **Quad ID:** Field personnel may ignore. This will be input by GIS personnel.
11. **Flight line / #:** Input the flight line and frame number of the photo which contains the site, and which contains the mylar overlay used in the field inventory (ie; RNP 78 / 7-28, or; HCN-62 / 3-48, etc).
12. **Air Photo Date:** Input the date of the air photo used in the field inventory (ie; 7-15-78, or 12/86, etc).
13. **Air Photo Scale:** Input the scale of the air photo used in the field inventory. (ie; 6,000 or 12,000, etc)

ROAD INFORMATION

14. **Road Name:** Name of the road on which the site exists.
15. **Abandoned: Y N** Answer "yes" if the road is abandoned and unmaintained. The road may still be driveable, but it is classified as abandoned if there is no obvious maintenance to the culverts, the ditches are not cleaned, and vegetation is overgrowing the roadbed.
16. **Driveable: Y N** Is the road driveable at the present time?
17. **Rebuild Minor: Y N** Answer "yes" if the road requires a small scale upgrade to make it driveable to that particular site (i.e. rebuilding of small stream crossings or regrading).
18. **Major: Y N** Answer "yes" if large stream crossings or failures must be reconstructed.
19. **Built By:** If known, indicate the party responsible for road construction.

20. **Year of Construction:** Enter the year the road reach was constructed (or the air photo date in which the road first appears) where the site is located. This is based on the best available information.

SITE INFORMATION

21. **Fluvial (Section I):** Circle if the site is characterized by fluvial processes, and Section I is utilized.
22. **Mass Movement (Section II):** Circle if this is a mass movement site, and Section II is utilized.
23. **Sketch (Y,N):** Answer "yes" if a detailed sketch, outlining ground conditions, was prepared.
24. **Comments:** The summary comments for each site generally describe the nature of the erosion problem, important site characteristics, and suggestions for possible treatments. If the site is the last in a series on a specific road, then include a road summary report. This should include, but not be limited to; type of road surface, average width and slope of the road, the presence and condition of inboard ditches and outboard berms, water bars, road surface vegetation, etc. (See attached list for road summary report).

SECTION I
FLUVIAL EROSION SITE

FEATURE TYPE
CIRCLE those that apply

25. **Stream Xing**: locations where a road crosses an ephemeral, intermittent, or perennial stream. The crossing may be a culverted crossing, a "Humboldt" log crossing, a bridge or a fill crossing that has no drainage structure installed.
26. **Headwater Swale**: Where the road traverses/crosses a bowl or funnel shaped hillslope feature where hillslope runoff begins to collect, but where no distinct stream channel is present. Generally the stream channel becomes better defined further downslope from this site.
27. **Ditch/Road Relief**: A culvert or other drainage structure which allows inboard ditch or road surface runoff to cross (under) the road.

EXISTING EROSION FEATURE
CIRCLE those that apply

28. **Gully**: The site contains a large gully as one of the major erosional features. Gullies are new channels that have a cross sectional area over one square foot. Anything smaller is considered a rill and lumped with surface erosion processes. Gullies are caused by concentrated surface runoff, which often results from stream diversions.
29. **Gully-Stream/Bank Erosion**: The site is characterized by (or results in) erosion of stream channel banks or gullied stream channels.
30. **Rilling/Surface**: The site is characterized by serious past or present surface erosion problems. Rilling and surface erosion occur on bare soil areas that are not revegetating, and typically show evidence of ravelling and sheet erosion.
31. **Spring**: The crossing drains a spring or seep.

DRAINAGE STRUCTURE
CIRCLE or FILL IN all that apply

32. **Culvert** **33. Humboldt** **34. Bridge** **35. Fill**
    There may be more than one structure at the site. Occasionally a stream crossing is both culverted and also is a humboldt crossing. FILL may exist at a headwater swale, with or without a pipe or humboldt.
36. **Culvert Type**: If present, indicate the type of culvert: **CMP** (corrugated metal pipe), **Conc** (concrete), **Alum** (aluminum), **WellCase** (Well Casing), **Other.** - describe.
37. **Culvert Diam:____inches.** If present, give the culvert diameter in inches.
38. **Headwater Ht:____ inches.** Give the headwater height in inches. This is the elevation difference, as measured at the inlet, between the base of the structure and the lowest point at which water would escape if the drainage structure is blocked and water ponds behind the road prism. This may be the road surface or an adjacent inboard ditch.

39. **Culvert Capacity:_____ cfs.** Using the culvert's diameter and the headwater height, determine the discharge capability of the culvert from the attached chart. See attachment, Figure 1.

Inlet Condition: CIRCLE all that apply.

40. **OK:** Culvert is clean and not damaged.
41. **Rusted:** The presence of rust indicates deterioration.
42. **Holes:** The development of holes in the culvert may allow saturation of the fill material.
43. **Band Separation.** CMP type culverts sometimes separate where two sections are joined together with a band.
44. **Crushed:** Is the culvert crushed or bent?
45. **Plugged:** Is the culvert plugged?
46. **% Crushed:** Estimate the percent the culvert is crushed.
47. **% Plugged:** Estimate the percent the culvert is plugged.
48. **Plug Cause:** CIRCLE all that apply. If the structure is plugged or could plug, indicate the material(s) involved.
49. **Plug Potential: H M L .** CIRCLE - estimate the potential for the culvert or humboldt crossing to plug.
50. **Trash Rack.** Is there a structure or "trash rack" present to keep debris from plugging the inlet?
51. **Drop Inlet.** CIRCLE if YES. Is there a drop inlet present? These are generally composed of a pipe oriented vertically at the inlet to the culvert. Often found in terrain with high sediment production, they minimize the potential for sediment to bury, and subsequently plug, a culvert inlet.

Outlet Condition:

52. - 63. These questions are similar to #40 - #51, but they describe the culvert's condition at its outlet.

52. **OK:** Culvert is clean and not damaged.
53. **Rusted:** The presence of rust indicates deterioration.
54. **Holes:** The development of holes in the culvert may allow saturation of the fill material.
55. **Band Separation.** CMP type culverts sometimes separate where two sections are joined together with a band.
56. **Crushed:** Is the culvert crushed or bent?
57. **Plugged:** Is the culvert plugged?
58. **% Crushed:** Estimate the percent the culvert is crushed.
59. **% Plugged:** Estimate the percent the culvert is plugged.
60. **Shotgun (Y,N):** Is there a vertical drop (significant enough to lead to erosion) from the base of the culvert to the natural channel bed?
61. **Feet to grade:** Give the elevation difference, in feet, between the base of the culvert and the natural channel bed.

62. **Culvert Placement: Center Right Left.** Indicate the position of the culvert with respect to the natural thalweg, as looking downstream.
63. **___ft from center.** If placement is either to the right or left, estimate the offset in feet.

CHANNEL DESCRIPTION

64. **Grade upstr.___% :** Give the average gradient, in percent, of the channel above the crossing. When a ditch or road-relief culvert is involved use road slope for the value.
65. **Grade downstr.___ % :** Give the average gradient, in percent, of the channel below the crossing.
66. **Width: upstr.___ft.** Estimate the average channel width above and below the crossing. Consider the channel width at bankfull conditions and at a 1 foot water depth, and enter the smaller of these values.
67. **downstr.___ft.** Estimate the average channel width below the crossing for the same discharge used in no. 66.

Armor: CIRCLE the dominant types of bed material in the channel bottom.

68. **< Bldrs.** Particals less than 8 inches median diameter.
69. **Bldrs** Particals greater than 8 inches median diameter.
70. **BedRk** Bedrock.
71. **SmOD** Small Organic Debris. Less than ___ inches diameter.
72. **LrgOD** Large Organic Debris. Greater than ___ inches diameter.
73. **Soil/BR Type:** Indicate the dominant soil and/or bedrock type underlying the site, as identified in the field or on soil maps.

BASIN DESCRIPTION

74. **Area:___** Drainage area at this site. May be determined from (in descending preference) 1. GIS 2. topographic map, or 3. air photo.
75. **50 yr Q (cfs):___** Determined from accepted techniques. CDF recommends the Rational Formula. Other empirical methods may be better.
76. **DP: Y N** Is there a potential for flow to be diverted from its natural flow course as a result of existing or future conditions at this site.
77. **Exit: Y N .** If a Diversion Potential is present, will the diverted flow exit its "micro-watershed"? This questions whether the diverted flow will have impact on another culvert, or watershed, or cause offsite erosion.
78. **Rd Grade:_____%.** Give the slope (in percent) and direction (R or L, looking downslope) of the road in the direction a diversion would occur. Only a minimal gradient is necessary to create the diversion once water is on the roadbed.
79. **Now Diverted.** CIRCLE if YES. Is the stream currently diverted at the site?

X-ing History: CIRCLE all that apply

80. **Diverted**
81. **Washed out**

82. **No History.** Crossing appears to have always functioned properly.
83. **Unknown.** Site indicators and historic airphoto analysis was inconclusive, or historic photos have not been reviewed.

COND OF FILL: Describe the condition of the fill at the crossing by CIRCLING the characteristics or features that are present.

84. **Intact**
85. **Sag** = sagging. Has the edge of the road sagged, but no scarps or cracks are visible? Sagging may mean that scarps or cracks were graded away in the past.
86. **Pond H_2O** = ponded water. Are there indications of standing or ponded water at the site?
87. **Cracks.** Are there cracks in the road, suggesting initial stage of road fill failure?
88. Scarps. Are there scarps in the road with distinct displacement?
89. **Holes.** Holes indicate that fill is falling through the crossing, often suggesting the presence of decaying logs within the fill.
90. **Gully/rills.** Are gullies (greater than 1 ft X 1 ft) or rills (less than 1 ft X 1 ft) present on the road surface or on the fill slope?
91. **Fill Failure Potential: Y N .** Does this site have the potential for fill to erode.

POSSIBLE TREATMENTS Indicate the needed or suggested treatments at this site by circling the appropriate response.

92. **Replace Culvert**
93. **Larger Culvert**
94. **Add Culvert**
95. **Clean IBD**
96. **Clean Culvert**
97. **Trash Rack**
98. **Rolling Dip**
99. **Berm**
100. **Pull Fill @ Xing**
101. **Waterbar**
102. **Other**
103. **None**
104. **Immediacy: Y N**
105. **MAINTENANCE NEEDS: Y N**
106. **Comments:** Clarify or elaborate on any other important elements of this site.

SECTION II
MASS MOVEMENT SITE

FEATURE TYPE

CIRCLE those that apply

107. **Earthflow** An earthflow is a slow moving, deep seated landslide with an irregular and hummocky surface.
108. **Shallow debris slide** A debris slide moves translationally along planar or gently undulating surfaces. The head scarp is near vertical, and cracks parallel to the slope are usually present in the crown region. Blocks break up into smaller and smaller parts as the slide moves toward the toe. Movement is relatively slow as compared to a debris torrent. If forested, trees will appear jack-strawed or have curved trunks.
109. **Rotational slump** This feature involves movement of a block, or series of blocks, such that displacement is along a concave upward surface. These features are characterized by steep head scarps, and contain flanks with scarps which decrease in height from the head region to the toe. The upper surface of the blocks are either flat or tilted back into the hillslope, and may contain trees leaning upslope. Often the movement grades into a more translational nature toward the lower portion of the slump which may contain a zone of uplift, and trees leaning downslope.
110. **Torrent** A debris torrent is an extremely rapid downslope movement of material due to complete saturation. A failed surface contains a serrate or V-shaped scarp, and irregular flanks often with levees in the lower portions. Displacement occurs along a planar surface, and the surface scar is long and narrow. Debris torrents typically follow drainage routes, scouring the channel valley to bedrock and mobilizing soil to trees. They typically build up sufficient energy during failure such that the liquefied material accumulates only at drastic changes in stream valley slope.
111. **CB**. Cut Bank. Feature is a failed or slumped cut bank.
112. **FF**. Fill Failure. Feature involves perched fill from a road or landing

FEATURE DESCRIPTION

113 - 115; CIRCLE best answer.

113. **Active:** Is the site active (movement within the last several years)? "Active" means the erosion is still occurring, though not necessarily at the original rate. Gullies will have near vertical, raw banks and/or active headcuts. Landslides will show recent, mostly bare scarps, recently tilted trees and perched blocks which have just started to move.
114. **Waiting**: Features assigned this classification are thought to be currently inactive (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 downslope. This feature type also

includes sites which show subtle indicators of future mass movement, but which have not yet moved significantly.

115. **Totally Evacuated.** Has the material associated with the site been completely removed?
116. **Average scarp Height:___** What is the average scarp height (feet)?
117. **Range of scarp heights:___** What is the range of scarp heights (feet)?

118 - 125: CIRCLE all that apply.

118. **Cracks.** Are there cracks in the road or ground, suggesting slope movement?
119. **Scarps.** Are there scarps in the road or ground with distinct displacement?
120. **Sagging.** Has the edge of the road sagged, but no scarps or cracks are visible? Sagging may mean that scarps or cracks were graded away in the past.
121. **Holes.** Holes indicate that fill is falling through the crossing, often suggesting the presence of decaying logs within the fill.
122. **Partial Evacuation** Has a portion of the material at the site been eroded?
123. **Wet Veg.** Is there hydrophyllic (or wetness indicator) vegetation (such as horse tail, rush, sedge, or others) and/or shallow groundwater at the site?
124. **Ponded Water.** Are there indications of standing or ponded water at the site?
125. **Leaning Trees.** Does the unstable area have leaning or bowed conifer trees?
126. **Natural.** Is the site on a natural slope (one not affected by timber harvest or road building)? "Natural" implies that the erosion has no obvious landuse associations and/or it is occurring in undisturbed or old growth areas.
127. **Road related.** Is the site associated with a road? Road related erosion is that which appears to be caused by or directly linked with road construction, landing construction, or maintenance activities. For example, road related erosion could be a gully on a cutblock that was caused by runoff from a road culvert or stream diversion on a logging road. In this case the original cause is road related (not cutblock related).
128. **Skid Trail.** Is the site associated with a skid trail?
129. **Excess H_2O diverted onto feature.** Excess water diverted onto a site can initiate failure and/or accelerate erosion. Is upslope water diverted to this site? Is water ponded (in the inboard ditch, or poorly drained surface) on the site, causing saturation, which may lead to failure?
130. **Stream channel undercutting.** Is the site being destabilized (or has potential for being destabilized) by stream channel undercutting?
131. **Spring.** Is the mass movement feature a result of emergent ground water? Cut banks associated with road building occasionally intersect ground water flow, which if not managed properly can lead to erosion.

132. - 134. CIRCLE the responses that define the site's local position on the hillslope, not its position relative to the entire basin.

132. **Upper hillslope area.** Is this site within the upper one-third of the slope.
133. **Middle hillslope area.** Is this site within the middle one-third of the slope.
134. **Lower hillslope area.** Is this site within the lower one-third of the slope.

135. **Inner Gorge.** Is the site located within the steep side slopes of the inner gorge of a stream channel?

136.- 138. CIRCLE one. The general shape of the affected hillslope is best described as:

136. **Concave.** convergent (spoon shaped).
137. **Planar.** straight
138. **Convex.** divergent (ie. nose of ridge, watershed divide, innerfluve)
139. **BIS:** Y N. Break in slope. Is the site located at or immediately above a distinct change in hillslope gradient (BIS) which leads from either; moderate slopes above the feature to steeper slopes below, or steeper above and gentler below?
140. **Slope Above (%).** The average gradient immediately upslope of the site. This question is optional due to the time that may be involved in obtaining a measurement.
141. **Slope Below (%).** The average gradient immediately downslope of the site. This question is optional due to the time that may be involved in obtaining a measurement.
142. **Stream side.** Is this site immediately adjacent to a stream?
143. **___feet to stream** Indicate the approximate distance to the stream from the toe of the feature.
144. **Landing.** Is the site located at a landing?
145. **Swale.** Is the site located in a topographic swale?
146. **Road Reach.** Is the site located along a reach of road, that is not a landing or swale? Or, perhaps this inventory number describes more than one distinct feature along a road reach. In some areas a road reach may have a few (or more) failures all of the same nature, cause, and impact. One form can be used to account for all of the features. Document this in the comments if this is the case and indicate Road Reach here.

SOIL CHARACTERISTICS

147. **Soil/BR Type.** Indicate the general soil and/or bedrock type underlying the site, as identified in the field.
148. **Soil Depth.** If possible, give an estimate of the soil and colluvium depth to bedrock, in feet.
149. **FewRx (Y,N).** Few course rock fragments in the soil suggest concentrated runoff could result in large gullies.

150 - 152. CIRCLE those that apply.

150. **Cohesive.** Very cohesive (clayey) soils would limit the amount of expected gulleying, but might suggest a susceptibility to mass movement.
151. **Mottled.** Mottled or gleyed soils indicate high water content for much of the year and are likely sites for slope failure.

152. **Deep Colluvium.** Deep colluvial or landslide deposits also suggest a possible susceptibility to both slope failure and gulleying.

POSSIBLE TREATMENTS

153. **Pull back fill.** If the fill is perched on a steep hillslope and/or over a stream, can the fill be removed (pulled back) to lower the possibility of failure and lessen the volume which might fail?
154. **Correct Diversion.** If a stream diversion caused or is aggravating the feature, correcting the diversion may reduce the failure potential of the site.
155. **Dewater Slope.** Excessive surface and/or ground water, increasing pore pressures, may be adding to the potential for slope failure or movement. Dewatering the slope may be a viable alternative to explore; albeit costly.
156. **Buttress.** A buttress at the base of an unstable slope can provide resisting forces to balance the driving force of the feature. Costly, but perhaps an alternative in some locations.
157. **Other.** Be creative and reasonable.
158. **Immediacy: Y N**
159. **MAINTENANCE NEEDS**: Y N
160. **COMMENTS**: Clarify or elaborate on any other important elements of this site.

SECTION III
EXCAVATION AND EROSION VOLUMES
AND BASIN IMPACTS

EXCAVATION VOLUME WORK SPACES:

Use the appropriate workspace provided to compute estimated volume to be excavated. If more space is required to show the computation, then use the back side of the paper and indicate in the space that the computation is on the back (ie. "see over").

I. FLUVIAL SITE WORKSHEET: Y N .

Use this space to compute the volume of fill located at a fluvial site. If a worksheet (Fig 2.) was used to estimate volume CIRCLE Y, and attach worksheet to corresponding form. If the site geometry does not lend itself to using the worksheet for fill volume estimate at a stream crossing, then show dimensions and computations in this space or show work on back of side of paper.

II. MASS MOVEMENT (FILL FAILURE).

Use this space to compute the volume of fill located at Mass Movement sites involving perched road or landing fill (see #112).

167. Total VOLUME of fill to excavate

Enter the estimate volume as calculated in workspace.

EROSION VOLUMES

I. ROAD FILL AT CROSSING:

Fill in only if this is a Fluvial Erosion Site and Section I was used.

168 - 184 (even numbers) Past Erosion Volumes.

Estimate the volume of material (cubic yards) already eroded from the locations specified on the worksheet. Sum these estimates to compute the total volume of material eroded in the past (enter total in #189).

169 - 185 (odd numbers) Future Erosion Volumes.

Estimate the volume of material (cubic yards) that may erode during a big storm from the locations specified on the worksheet. Compute the total volume of material that may erode in the future by summing these estimates (enter total in #190).

II. MASS MOVEMENT:

187 - 188. Fill in only if this is a Mass Movement Site and Section II was used.

Volume mobilized: show dimensions for each on back

187. Estimate the volume of material (cubic yards) that has already eroded at the Mass Movement site and enter in #187.

188. Estimate the volume of material (cubic yards) that may erode during a big storm at the site and enter in #188.

VOLUMES: Total mobilized Fill in for ALL sites.

189 - 190. Estimate the total volume of material mobilized (and, to be mobilized) from the site.

% Delivery to channel

191 & 192. Estimate the percent of eroded material entered in 189 and 190 that was/is likely to be delivered to the stream system.

Total Yield to channel (% X 191 (192))

193 & 194. The calculated volume of material that was/is expected to be delivered to the stream system. Total Yield Past (193) = Total Mobilized Past (189) X % Delivery (191). Total Yield Future (194) = Total Mobilized Future (190) X % Delivery (192).

DOWNSTREAM IMPACT SUMMARY - STRICTLY A "GUESS-TIMATE"

195. Significant Offsite Impacts: Y N.
In the event of failure, would the material mobilized from this site cause significant offsite impacts. Impacts may include; stream channel aggradation, introduction of excess fine sediment, stream bank erosion, loss of riparian vegetation, or other resource concerns.

199. EP (H,M,L) Erosion Potential (High, Medium, Low). Estimate, based on information gathered in Section I or Section II, the potential for this site to erode. Consider all site conditions and past erosion processes evident within the basin in similar geomorphic, hydrologic, and soil settings in deciding the potential.

200. Extreme EP (Y,N) Does this site display the potential for an extreme erosional event, both in scale of volume eroded and in offsite impacts? An extreme erosional event is the "worst case scenario" of processes acting on the site simultaneously.

201. Extreme Eros Vol Estimate the volume of the extreme erosion in cubic yards.

202. Extreme Erosion Comments Describe the nature and likelihood of the extreme event. This is an opportunity to envision the worst.

ATTACHMENTS

Figure 1. Culvert capacity nomograph. This figure is used for calculating the discharge capacity of the culvert (see #39). The culvert diameter (in inches) and the headwater height (in culvert diameters) is needed (see #37 & #38).

Figure 2. Worksheet for fill volume estimate at a stream crossing.

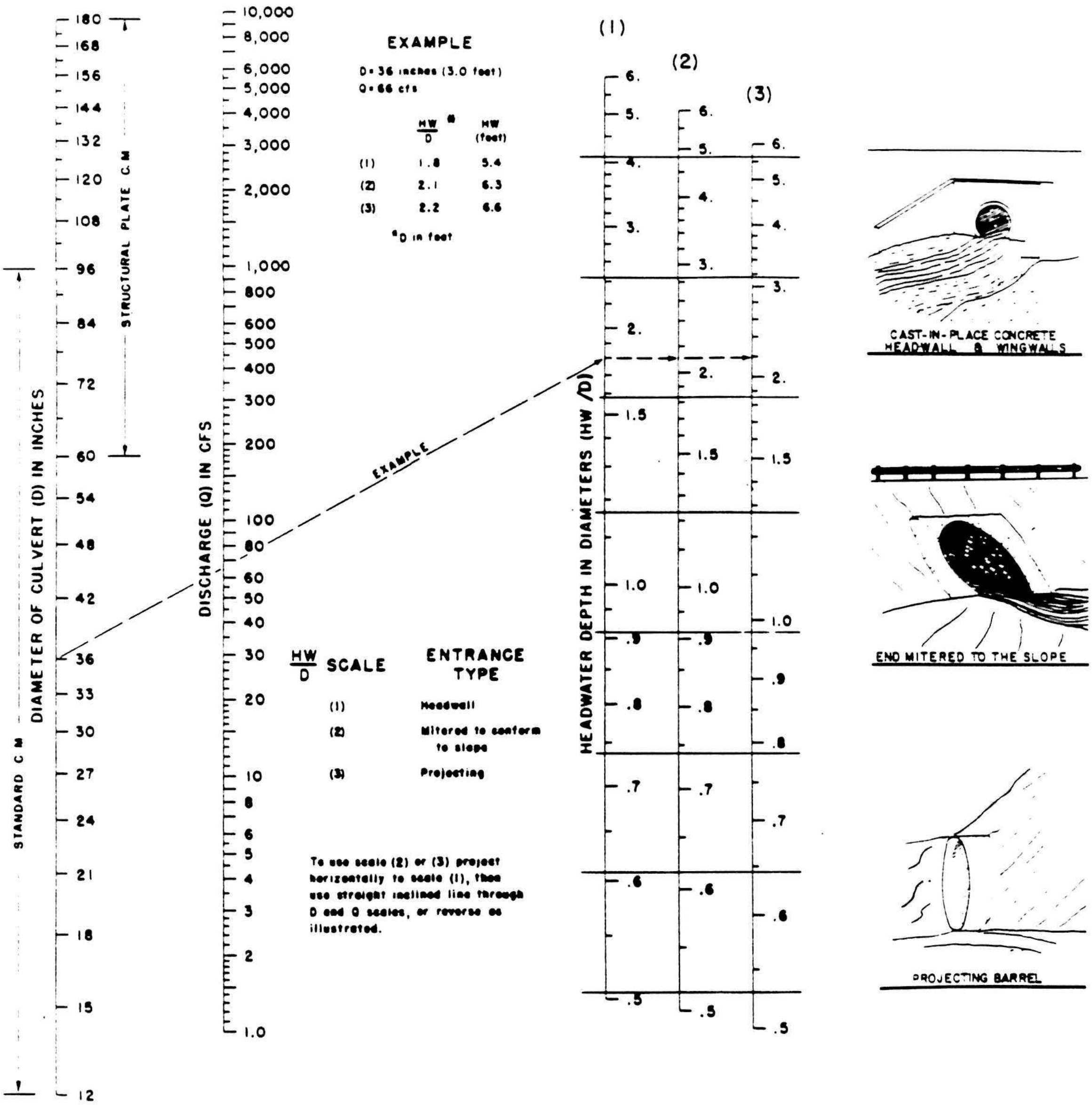
Figure 3. Table for perched fill volume estimate. This table is used for calculating fill volumes along road reaches (see #29 & #127). It gives the volume of material per linear foot of road, which can be multiplied by the road reach (in feet) to obtain the volume of perched fill.

Redwood National Park Road Inventory Form

This form, developed at Redwood National Park, is the result of extensive evaluation of erosional processes active within the Redwood Creek basin in northwestern California, since the mid 1970's. The organization, and the site characteristics evaluated with this form, were chosen because of basin conditions and to assist in meeting Watershed Restoration goals at Redwood National Park.

Redwood National Park acknowledges the input from staff geologists, both past and present, the National Forest Service, Pacific Watershed Associates (Arcata, CA), and Terra-Firma (Gold Beach, OR).

Figure 1. Culvert capacity nomograph (after, Bureau of Public Roads, Jan. 1963).

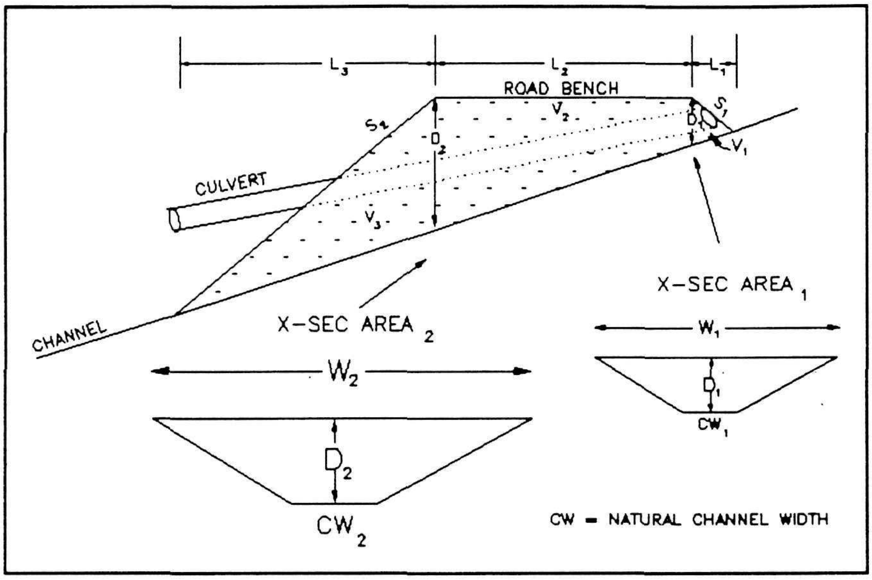


METHOD:

1. Determine "Entrance Type" from sketches above.
2. Calculate Headwater Depth in diameters (HW/D) from field measurements (see #38 for definition).
3. Place straight edge on Culvert Diameter scale (left) and on Headwater Depth in Diameters (HW/D) scale (right) pertaining to entrance type.
4. Read discharge capacity at intersection with discharge scale.

Figure 2. Worksheet for road and stream crossings: Fill Volume Estimate *

SITE __________ **DATE** __________



1. Field Measurments

L_1 ________ft. D_1 ________ft.

L_2 ________ft. D_2 ________ft.

L_3 ________ft.

S_1 ________deg S_2 ________deg

W_1 ________ft. W_2 ________ft.

CW_1 ______ft. CW_2 ________ft.

2. Cross Sectional Area Calculation

$$A_1 = \frac{D_1(W_1 + CW_1)}{2} = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^2$$

$$A_2 = \frac{D_2(W_2 + CW_2)}{2} = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^2$$

3. Volume Calculation For Each Section

$$V_1 = \frac{A_1 \times L_1}{2.5} = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^3$$

$$V_2 = \frac{(A_1 + A_2)L_2}{2} = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^3$$

$$V_3 = \frac{A_2 \times L_3}{2.5} = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^3$$

4. Total Estimated Volume

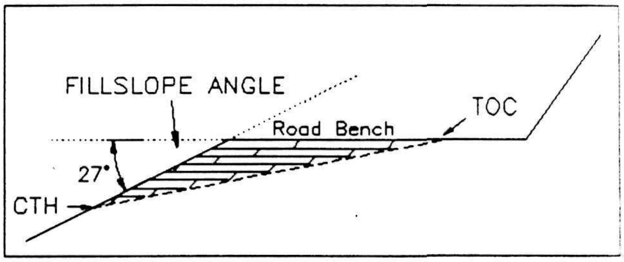
$$V_T = V_1 + V_2 + V_3 = \text{\_\_\_\_\_\_\_\_\_\_ ft.}^3$$

$$\textbf{Total Volume} = \frac{V_T}{27} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_ YDS.}^3$$

*For watershed inventory field estimates only; should not be used for prescription or contract layout. Due to simplification of standard RNP stream crossing layout and survey methods, this is a rough estimate only.

Figure 3. Table for perched fill volume estimate.

OBR-TOC (Feet)	OBR-CTH (Feet)	VOLUME PER LINEAR FOOT OF ROAD (yd3/ft) FOR EACH OF THE FILLSLOPE ANGLES BELOW:							
		5 deg	10 deg	15 deg	20 deg	25 deg	30 deg	35 deg	40 deg
5	5	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3
5	10	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6
5	15	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9
5	20	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2
5	25	0.2	0.4	0.6	0.8	1.0	1.2	1.3	1.5
5	30	0.2	0.5	0.7	1.0	1.2	1.4	1.6	1.8
5	35	0.3	0.6	0.8	1.1	1.4	1.6	1.9	2.1
5	40	0.3	0.6	1.0	1.3	1.6	1.9	2.1	2.4
10	5	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6
10	10	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2
10	15	0.2	0.5	0.7	1.0	1.2	1.4	1.6	1.8
10	20	0.3	0.6	1.0	1.3	1.6	1.9	2.1	2.4
10	25	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.0
10	30	0.5	1.0	1.4	1.9	2.3	2.8	3.2	3.6
10	35	0.6	1.1	1.7	2.2	2.7	3.2	3.7	4.2
10	40	0.6	1.3	1.9	2.5	3.1	3.7	4.2	4.8
15	5	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9
15	10	0.2	0.5	0.7	1.0	1.2	1.4	1.6	1.8
15	15	0.4	0.7	1.1	1.4	1.8	2.1	2.4	2.7
15	20	0.5	1.0	1.4	1.9	2.3	2.8	3.2	3.6
15	25	0.6	1.2	1.8	2.4	2.9	3.5	4.0	4.5
15	30	0.7	1.4	2.2	2.9	3.5	4.2	4.8	5.4
15	35	0.8	1.7	2.5	3.3	4.1	4.9	5.6	6.2
15	40	1.0	1.9	2.9	3.8	4.7	5.6	6.4	7.1
20	5	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2
20	10	0.3	0.6	1.0	1.3	1.6	1.9	2.1	2.4
20	15	0.5	1.0	1.4	1.9	2.3	2.8	3.2	3.6
20	20	0.6	1.3	1.9	2.5	3.1	3.7	4.2	4.8
20	25	0.8	1.6	2.4	3.2	3.9	4.6	5.3	6.0
20	30	1.0	1.9	2.9	3.8	4.7	5.6	6.4	7.1
20	35	1.1	2.3	3.4	4.4	5.5	6.5	7.4	8.3
20	40	1.3	2.6	3.8	5.1	6.3	7.4	8.5	9.5
25	5	0.2	0.4	0.6	0.8	1.0	1.2	1.3	1.5
25	10	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.0
25	15	0.6	1.2	1.8	2.4	2.9	3.5	4.0	4.5
25	20	0.8	1.6	2.4	3.2	3.9	4.6	5.3	6.0
25	25	1.0	2.0	3.0	4.0	4.9	5.8	6.6	7.4
25	30	1.2	2.4	3.6	4.8	5.9	6.9	8.0	8.9
25	35	1.4	2.8	4.2	5.5	6.8	8.1	9.3	10.4
25	40	1.6	3.2	4.8	6.3	7.8	9.3	10.6	11.9
30	5	0.2	0.5	0.7	1.0	1.2	1.4	1.6	1.8
30	10	0.5	1.0	1.4	1.9	2.3	2.8	3.2	3.6
30	15	0.7	1.4	2.2	2.9	3.5	4.2	4.8	5.4
30	20	1.0	1.9	2.9	3.8	4.7	5.6	6.4	7.1
30	25	1.2	2.4	3.6	4.8	5.9	6.9	8.0	8.9
30	30	1.5	2.9	4.3	5.7	7.0	8.3	9.6	10.7
30	35	1.7	3.4	5.0	6.7	8.2	9.7	11.2	12.5
30	40	1.9	3.9	5.8	7.6	9.4	11.1	12.7	14.3
35	5	0.3	0.6	0.8	1.1	1.4	1.6	1.9	2.1
35	10	0.6	1.1	1.7	2.2	2.7	3.2	3.7	4.2
35	15	0.8	1.7	2.5	3.3	4.1	4.9	5.6	6.2
35	20	1.1	2.3	3.4	4.4	5.5	6.5	7.4	8.3
35	25	1.4	2.8	4.2	5.5	6.8	8.1	9.3	10.4
35	30	1.7	3.4	5.0	6.7	8.2	9.7	11.2	12.5
35	35	2.0	3.9	5.9	7.8	9.6	11.3	13.0	14.6
35	40	2.3	4.5	6.7	8.9	11.0	13.0	14.9	16.7
40	5	0.3	0.6	1.0	1.3	1.6	1.9	2.1	2.4
40	10	0.6	1.3	1.9	2.5	3.1	3.7	4.2	4.8
40	15	1.0	1.9	2.9	3.8	4.7	5.6	6.4	7.1
40	20	1.3	2.6	3.8	5.1	6.3	7.4	8.5	9.5
40	25	1.6	3.2	4.8	6.3	7.8	9.3	10.6	11.9
40	30	1.9	3.9	5.8	7.6	9.4	11.1	12.7	14.3
40	35	2.3	4.5	6.7	8.9	11.0	13.0	14.9	16.7
40	40	2.6	5.1	7.7	10.1	12.5	14.8	17.0	19.0



OBR = The Out Board edge of the Road bench.

CTH = Cut To Here; The lowest location on a fillslope where a cut begins or ends. Measured in feet, on grade, from the **OBR**.

TOC = Top Of Cut; The location on the road surface where the finished cut slope will intersect. Measured in feet from the **OBR**.

Fillslope Angle = The angle of the current fillslope as measured from the **OBR**. Measured in degrees.

REDWOOD NATIONAL PARK ROAD INVENTORY

October, 1992

SITE INFORMATION AND SUMMARY

1. Site #__________________ 2. Mileage:______ 3. Date Mapped:________ 4. Mapped By:________
5. Photos Taken: Y N 6. Watershed:______________________________
7. Land Ownership:______________________________

8. Map Sheet:____________________ 9. Map Code:________ 10. Quad ID:______________
11. Flight Line / #__________________ 12. Date:______________ 13. Scale: 1:________

ROAD INFORMATION

14. Road Name:______________________________ 15. Abandoned: Y N 16. Driveable: Y N
17. Rebuild: Minor: Y N 18. Major: Y N
19. Built By:______________________________ 20. Year of Constr.__________

SITE INFORMATION

21. Fluvial Erosion Site (Section I) 22. Mass movement Site (Section II) 23. Sketch: Y N
24. Comments:

SECTION III: EXCAVATION AND EROSION VOLUMES

EXCAVATION VOLUME WORK SPACES:

I. FLUVIAL SITE WORKSHEET?: Y N	*II. MASS MOVEMENT (FILL FAILURE)* road length X vol/L.Ft. of road (from chart)

167. Total VOLUME of fill to excavate:__________yd³

EROSION VOLUMES	Past	Future
I. ROAD FILL AT CROSSING:	168	169
Caused by Diversion; erosion offsite of Crossing:		
Inboard Ditch	170	171
Down Road Surface	172	173
Gullied through Road	174	175
Gullied Natural Slope	176	177
Gullied Natural Channel	178	179
Fill Failure	180	181
Hillslope Failure	182	183
Other 186	184	185
II. MASS MOVEMENT:		
Volume mobilized: show dimensions for each on back	187	188
VOLUMES: Total mobilized	189	190
% Delivery to channel	191	192
Total Yield to channel (% X 191 (192))	193	194

DOWNSTREAM IMPACT SUMMARY - STRICTLY A "GUESS-TIMATE"

195. Significant Offsite Impacts: Y N
199. EP: H M L 200. Extreme EP: Y N 201. Extreme Eros Vol:______________yd³
202. Extreme Erosion Comments (nature & likelihood):

SECTION I: FLUVIAL EROSION SITE

FEATURE TYPE

25. Stream Xing 26. Headwater swale 27. Ditch/Road Relief

EXISTING EROSION FEATURE

28. Gully 29. Gully-Stream/Bank Erosion 30. Rilling/Surface 31. Spring

DRAINAGE STRUCTURE

32. Culvert 33. Humboldt 34. Bridge 35. Fill 36. Cul Type: CMP Conc Alum WellCase Other
37. Culvert Diam:______inches 38. Headwater Ht:________inches 39. Culvert Capacity:______cfs

Inlet Condition:

40. OK 41. Rusted 42. Holes 43. Band Separation 44. Crushed 45. Plugged
46. % Crushed______ 47. % Plugged:______ 48. Plug Cause: Wood Sediment Vegetation
49. Plug Potential: H M L 50. Trash Rack 51. Drop Inlet

Outlet Condition:

52. OK 53. Rusted 54. Holes 55. Band Separation 56. Crushed 57. Plugged
58. % Crushed:______ 59. % Plugged:______ 60. Shotgun 61. Feet to Grade:________
62. Culvert Placement: Center Right Left 63. __________ft from center

CHANNEL DESCRIPTION

64. Grade: upstr.______% 65. downstr.______% 66. Width: upstr.______ ft. 67. downstr.______ ft.
Armor: 68. < Bldrs 69. Bldrs 70. BedRk 71. SmOD 72. LrgOD
73. Soil/BR Type:______________________________

BASIN DESCRIPTION

74. Area:______ 75. 50 yr Q (cfs):______ 76. DP: Y N 77. Exit: Y N 78. Rd Grade:_____%
79. Now Diverted Xing History: 80. diverted 81. Washed out 82. No History 83. Unknown

COND OF FILL: 84. Intact 85. Sag 86. Pond H_2O 87. Cracks 88. Scarps 89. Holes 90. Gully /Rills
91. Fill Failure Potential: Y N

POSSIBLE TREATMENTS

92. Replace Culvert 93. Larger Culvert 94. Add Culvert 95. Clean IBD 96. Clean Culvert
97. Trash Rack 98. Rolling Dip 99. Berm 100. Pull Fill @ Xing 101. Waterbar
102. Other______________________________ 103. None
104. Immediacy: Y N 105. MAINTENANCE NEEDS: Y N
106. COMMENTS:

SECTION II: MASS MOVEMENT SITE

FEATURE TYPE

107. Earthflow 108. Shallow debris slide 109. Rotational slump 110. Torrent 111. CB 112. FF

FEATURE DESCRIPTION

113 Active 114. Waiting 115. Totally Evacuated
116. Average Scarp height:____________ 117. Range of scarp heights:__________
118. Cracks 119. Scarps 120. Sagging 121. Holes 122. Partial Evacuation
123. Wet Veg 124. Ponded Water 125. Leaning Trees
126. Natural 127. Road related 128. Skid Trail 129. Excess H_2O diverted onto feature
130. Stream channel undercutting 131. Spring
132. Upper 133. Middle 134. Lower 135. Inner Gorge 136. Concave 137. Planar 138. Convex
139. BIS 140. Slope Above________% 141. Slope Below________%
142. Stream side 143.______ ft. to stream 144. Landing 145. Swale
146. Road Reach

SOIL CHARACTERISTICS

147. Soil/Br type:______________________________ 148. Soil Depth:______ 149. Few Rx: Y N
150. Cohesive 151. Mottled 152. Deep Colluvium

POSSIBLE TREATMENTS

153. Pull back fill 154. Correct Diversion 155. Dewater Slope 156. Buttress 157. Other
158. Immediacy: Y N 159. MAINTENANCE NEEDS: Y N
160. COMMENTS:

MAPPING SYMBOLS

- rocks, and boulders or outcrops
- ridge
- pressure ridge
- break-in-slope
- seep, spring
- wet, marshy area: rushes, horse tails
- PW ponded water
- log jam
- S stump
- x' x'KP headcut, erosional x' height, knickpoint non-erosional
- alluvial fan
- skid trail, ends, continues but not mapped
- WB BWB waterbar, breached waterbar
- berm
- perched fill
- fillslope
- Humboldt crossing
- x"C trash rack/culvert (x"diameter size) half round
- x'/y' collapsed area, x'diameter in feet
- natural, perennial stream channel
- natural, intermittent stream channel
- natural, ephemeral stream channel/swale
- flow goes subsurface
- G x W/D gully, actively downcutting X% = gradient; W/D = width/depth
- x W/D gully, not actively downcutting
- R rill, (< 1ft^2) actively downcutting
- R rill, not actively downcutting

MAPPING SYSMBOLS

- x' scarp, x'vertical displacement/active
- x' scarp, x'vertical displacement/inactive
- ? ? projection of scarp
- CKS tension cracks, < .2ft vertical displacement
- large toe feature
- material upslope is over-riding material downslope
- S PP# photo point location, number
- x'/y' width/depth in feet

ABBREVIATIONS

CB	cutbank	IA	inactive
CKS	tension cracks	IBD	inboard ditch
CMP	culvert	L	leaning tree
DA	debris avalanche	LJ	log jam
DP	diversion potential	KP	knickpoint
DT	debris torrent	OD	outboard (outlet) ditch
EF	earthflow	PR	pressure ridge
EP	erosion potential	R	Rill
f	storm flow, flashy	RS	rotational slide
F	constant winter flow	ST	skid trail
	or persistent spring flow	TC	through cut
F Date	flowing at this date	TR	trash rack
G	gully	TS	translational slide
HC	headcut		

BASIC RESTROATION TREATMENT SCHEMATICS

Figure 1

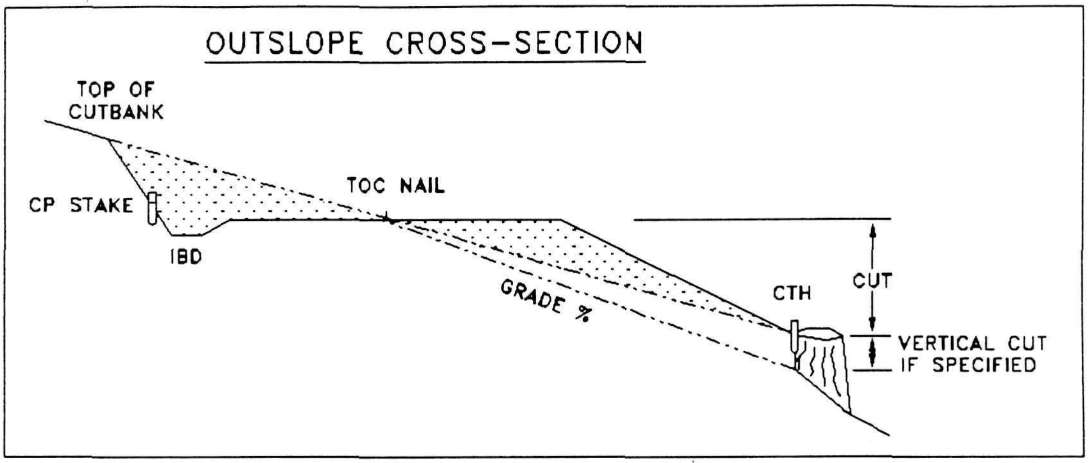


Figure 2

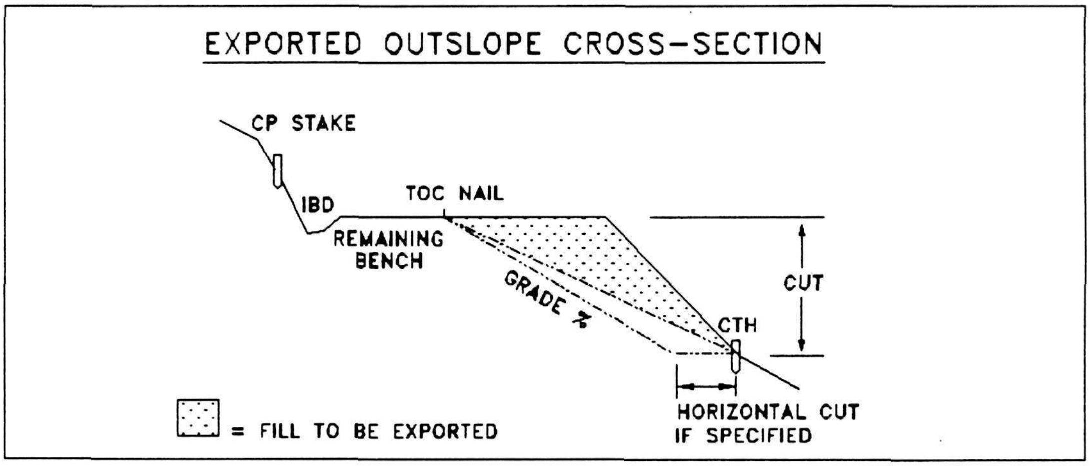
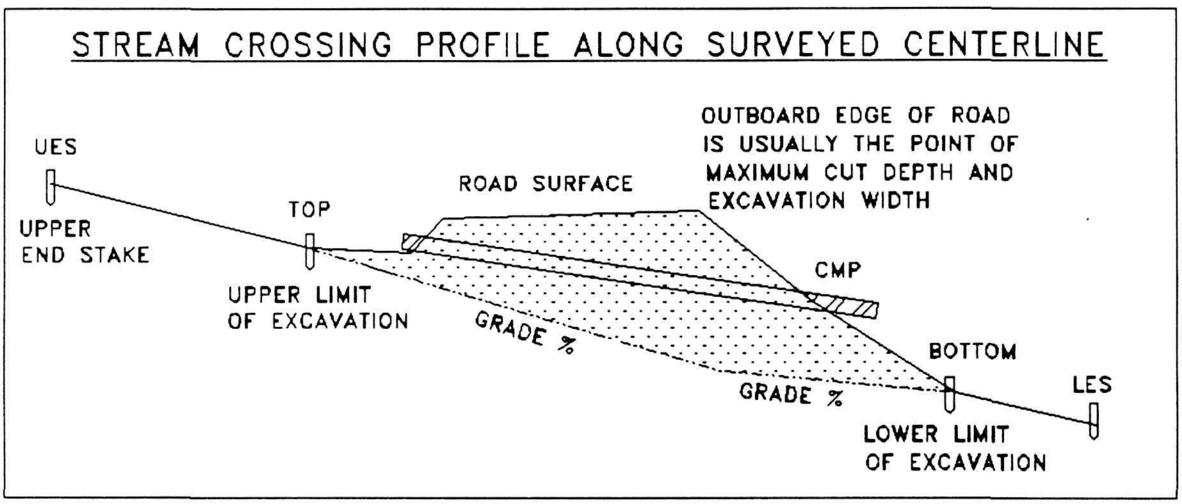


Figure 3


STREAM CROSSING PROFILE ALONG SURVEYED CENTERLINE
UES
UPPER
END STAKE
TOP
UPPER LIMIT
OF EXCAVATION
ROAD SURFACE
OUTBOARD EDGE OF ROAD
IS USUALLY THE POINT OF
MAXIMUM CUT DEPTH AND
EXCAVATION WIDTH
CMP
GRADE %
GRADE %
BOTTOM
LES
LOWER LIMIT
OF EXCAVATION