2009 Big Salmon Creek
Sediment Source Assessment Project
Mendocino County, California

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1 PROJECT SUMMARY

The Big Salmon Creek Sediment Source Assessment Project (BSCA) area is located approximately 7 mi south of the town of Mendocino, California. The project area encompasses ~51% of the Salmon Creek watershed on property now owned and managed by The Conservation Fund (TCF). It contains a large (~67 mi) road network that was constructed for timber harvest purposes starting prior to the 1960s.

The Big Salmon Creek watershed contains important habitat for anadromous salmonids, and is designated as a “salmonid refugia” for coho salmon by the California Department of Fish and Game (CDFG). In order to address problems with road related erosion and improve salmonid habitat, TCF received a grant agreement from CDFG in 2008 to conduct an inventory of road related sediment sources, and generate a restoration plan, for their entire landholdings in the Big Salmon Creek watershed. TCF contracted Pacific Watershed Associates Inc. (PWA) to complete the inventory and develop a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments for road related sediment sources in the watershed.

Using field inventories and data analysis, PWA identified a total of 187 sites along approximately 67 mi of roads with the potential to deliver sediment to streams within the project area. Of these 187 sites, we recommend 154 sites be treated for erosion control and erosion prevention. We estimate that treating these sites will prevent approximately 8,700 yd^3 of sediment from eroding into salmonid streams in the Big Salmon Creek watershed. In addition to individual, problematic erosion sites, field crews measured approximately 13.37 mi of road surfaces and/or ditches (representing nearly 20% of the total inventoried road mileage) currently draining to stream channels, either directly or via gullies. Of these 13.37 mi of hydrologically connected road segments, we recommend treating a total of 12.67 mi to diminish road surface runoff and delivery of fine sediment to stream channels: we estimate that this will prevent approximately 9,400 yd^3 of sediment from being delivered into stream channels during the next decade alone. The estimated cost for implementing all recommended erosion control and erosion prevention treatments for the BSCA area is $736,337.

The expected benefit of completing the erosion control and erosion prevention treatments recommended in this report lies in the reduction of long-term sediment delivery to the Big Salmon Creek watershed, an important area for coho salmon and steelhead production in Mendocino County, California. This assessment includes a prioritized plan of action for cost-effective erosion prevention and erosion control, which, when implemented and employed in combination with protective land-use practices, can be expected to significantly contribute to the long-term improvement of water quality and salmonid habitat in the watershed. With this prioritized plan of action, entities interested in the sustainability of the watershed and preservation of salmonid habitat can advance efforts to obtain funding and implement the road related erosion remediation plan for the BSCA area.

2 CERTIFICATION AND LIMITATIONS

This report, entitled *Big Salmon Creek Sediment Source Assessment Project*, was prepared under the direction of a licensed professional geologist at Pacific Watershed Associates Inc. (PWA), and all information herein is based on data and information collected by PWA and TCF staff. Sediment-source inventory and analysis for the project, as well as erosion control treatment prescriptions, were similarly conducted by or under the responsible charge of a California licensed professional geologist at PWA.

The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations are qualitative, or semi-quantitative, and confined to surface expressions of limited extent and artificial exposures of subsurface materials. Interpretations of problematic geologic and geomorphic features (such as unstable hillslopes) and erosion processes are based on the information available at the time of the study and on the nature and distribution of existing features.

The recommendations included in this report are professional opinions derived in accordance with current standards of professional practice, and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes or to the works of man, or changing conditions on adjacent areas. Furthermore, to ensure proper applicability to existing conditions, the information and recommendations contained in this report shall be reevaluated after a period of no more than 3 years, and it is the responsibility of the landowner to ensure that no recommendations are inappropriately applied to conditions on the property that have changed since the recommendations were developed. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

Certified by:

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3 INTRODUCTION

One of the most important watershed management elements of long-term restoration and maintenance of both water quality and fish habitat is the reduction of future impacts from upland erosion and sediment delivery. Sediment delivery to stream channels from roads and road networks has been extensively documented, and is recognized as a significant impediment to the health of salmonid habitat (Furniss et al., 1991; Higgins et al., 1992; Harr and Nichols, 1993; Flosi et al., 1998; NMFS, 2000, 2001). Unlike many watershed improvement and restoration activities, erosion prevention through "storm-proofing" rural, ranch, and forest roads provides immediate benefits to the streams and aquatic habitat of a watershed (Weaver and Hagans, 1994, 1999; Weaver et al., 2006). It measurably diminishes the impact of road related erosion on the biological productivity of the watershed's streams, and allows future storm runoff to cleanse the streams of accumulated coarse and fine sediment, rather than allowing continued sediment delivery from managed areas.

Salmon Creek is an anadromous salmonid-bearing stream, tributary to the Pacific Ocean, containing habitat for steelhead trout and coho salmon (CDFG, 2004, Chapter 6.34). It is one of the southernmost coho-bearing streams in Mendocino County. Salmonid populations in Big Salmon Creek have been surveyed annually since 1993 (NMFS, 2001), and the Big Salmon Creek watershed is designated as a “salmonid refugia” for coho due to consistent coho presence (CDFG, 2004; NMFS, 2001). As with other Northern California coastal watersheds, road related erosion and delivery of coarse and fine sediment to streams is a continuing threat to water quality and salmonid habitat in the Salmon Creek watershed.

The Conservation Fund (TCF) purchased the Big Salmon Creek properties in 2006 from the previous landlowners, The Hawthorne Timber Company and The Campbell Group. To address road related sediment delivery problems in the Salmon Creek watershed, TCF contracted Pacific Watershed Associates Inc. (PWA) to assess all roads within their 4,435 acre ownership in the Big Salmon Creek subwatershed of Salmon Creek (Map 1). PWA geologists completed an assessment of 67.1mi of maintained, seasonal, and abandoned roads on the property between January and November 2009. Specifically, the purpose of the project was to: (1) identify and quantify all current and potential sites of road related erosion and sediment delivery in the watershed; and (2) develop a prioritized plan for long-term erosion control and erosion prevention, including treatment specifications, material needs, and estimated costs for heavy equipment and labor.

In this report, we provide results of the field assessment and data analysis, and a detailed plan of action for implementing erosion control and erosion prevention treatments to reduce road related erosion in the project area. All treatment prescriptions follow guidelines described in the *Handbook for Forest and Ranch Roads* (Weaver and Hagans, 1994), as well as *Parts IX* and *X* of the California Department of Fish and Game *Salmonid Stream Habitat Restoration Manual* (Taylor and Love, 2003; Weaver et al., 2006). Assessment data are summarized in Tables 1-5, Maps 1-4, and Appendix A. Projected requirements for heavy equipment and estimated project costs are provided in Tables 6 and 7. Construction and installation instructions for the recommended erosion control and erosion prevention treatments are provided in Appendixes B. For an overview of terminology and techniques used in road related erosion assessments, see

4 FIELD DESCRIPTION OF THE ASSESSMENT AREA

4.1 Location and Travel Directions to the Field Area

The project area is located in the central coast region of Mendocino County, California, south of the town of Mendocino and between the Albion River and Navarro River watersheds (Map 1).[1] The maintained roads within the project area are accessed by taking Albion Ridge Road (off US Highway 1 near the town of Albion) approximately 4.6 mi to The Conservation Fund property access road at the Iron Gate on the right. The central and western areas of the property can easily be accessed from Albion Ridge Road by taking the private Elliot Road, located approximately 6.5 miles from US Highway 1, to The Conservation Fund gate on Road 29000 (Maps 1, 2). The seasonal and abandoned roads located in the southern portion of the watershed and in the headwaters of Hazel Gulch are accessed from multiple points along the Navarro Ridge Road, which begins at US Highway 1 near the mouth of the Navarro River (Map 2).

4.2 Climate and Terrain

The climate of north-coastal California in the area of the Salmon Creek watershed is characterized by cool, dry summers, and cool winters with periods of low intensity rainfall and rare instances of snow accumulation during cold storms. Mean annual precipitation is approximately 43-49 in., based on California Department of Water Resources rain gauges in Point Arena and the surrounding area.[2] Most rainfall occurs between November and April. As snowfall in the watershed is rare, large flood events are associated with intense periods of rainfall and not rain-on-snow events.

The Mediterranean climatic conditions and relatively high rainfall amounts in the watershed support expansive forests of redwood and Douglas fir, with varying amounts of Tanoak and Mendocino Cypress. Some of the larger marine terraces with low gradient surfaces support areas of stunted trees and shrubs (“pygmy forests”), the result of nutrient-poor and highly acidic surface soils, and an iron hardpan horizon in the shallow subsurface (Westman, 1975).

The steep terrain of the 8,600-acre Salmon Creek watershed is an effect of coastal tectonic uplift, with prominent, emergent coastal marine terraces deeply incised by stream channels. Elevations in the watershed range from sea level to approximately 1,200 ft; elevations in the project area range from approximately 130 ft to 1,200 ft (USGS, 1960). Unsurfaced roads in the project area traverse a range of elevations from ridgetops to the inner gorges of streams, including the mainstem of Big Salmon Creek, Hazel Gulch, Donnelly Gulch, Pullen Gulch, Hardel Gulch, Boyd Gulch, and several small unnamed tributaries (Maps 2-4). Of significance for salmonid habitat, the extensive construction of roads for timber harvesting in this area of steep terrain, erodible geologic substrate, and high rainfall (including occasional intense winter storms) has

[1] The pertinent USGS 7.5-minute quadrangle map showing the location of the project area is *Elk* (39123B6; USGS, 1960).
[2] Rainfall data acquired from: http://www.krisweb.com/krisgarcia/krisdb/webbuilder/selecttopic_climate.htm

resulted in high rates of erosion and sediment delivery from road networks to stream channels. The lower tributaries within the basin alternately traverse gorges with steep, unstable slopes and high rates of erosion, and low gradient areas that facilitate sediment deposition and accumulation. Whereas salmonid populations have evolved and flourished with the natural processes of rainfall and erosion in the area, the impact of anthropogenically induced erosion from resource management and road construction has resulted in accelerated sediment delivery to streams and a degradation of salmonid habitat in this important watershed.

4.3 Geology

4.3.1 Regional geology

The project area is located along the middle-west portion of the Coast Range Geomorphic Province (CGS, 2002). The Coast Ranges lie between the Pacific Ocean and the California Central Valley, extending from the Transverse Ranges in the vicinity of Point Conception to the California-Oregon border. The San Andreas Fault, a major strike-slip plate boundary fault, is a dominant structural feature of the Coast Ranges, extending along the western part of the province as far north as Cape Mendocino (CGS, 1977; Page et al., 1979). The ranges and valleys of the province trend northwest, subparallel to the San Andreas fault.

4.3.2 Regional seismicity

Based on data from the U.S. Geological Survey (USGS) and the California Geological Survey (CGS), no active (<11,000 yr) or potentially active faults are located in the Salmon Creek Watershed. However, the historically active San Andreas fault is located less than 15 mi west of the project area. According to CGS, there is a 10% probability that the project area will experience ground acceleration of 0.30-0.40 g between the calendar years 2002-2052 (CGS, 2002)

4.3.3 Local geology

The geology of the Salmon Creek watershed is primarily composed of sheared and potentially unstable rocks of the Tertiary-Cretaceous Coastal Belt Franciscan Complex, Quaternary marine terrace deposits, and Quaternary stream channel deposits (Manson, 1984). The Coastal Belt Franciscan Complex consists of light-colored, well-cemented to deeply weathered and sheared clastic sedimentary rocks that are particularly susceptible to erosion and mass wasting during periods of sustained or heavy rainfall. Quaternary marine terrace deposits, consisting of well-sorted sand with minor gravel, are located on the relatively flat ridges at the highest watershed elevations and at drainage basin divides. Quaternary stream channel deposits are found in the lowland settings of the wide valley floors of mainstem Big Salmon Creek, Hazel Gulch, and Donnelly Gulch.

4.3.4 Geologic hazards

Geologic hazards that impact road treatment activities in the project area include: erodible geologic units, mass wasting, and seismic hazards. A professional geologist should be consulted on a site-by-site basis to address any geologic hazard that may be relevant at the time a specific work site is treated.

Erodible geologic units

The erosion potential of a geologic unit will vary based on local conditions, including hillslope gradients, depth to bedrock, degree of fracturing, presence and orientation of slip planes, soil erodibility, and volume of surface runoff or groundwater throughflow. Erosion and mass wasting is prevalent in the project area because of the sheared and incompetent bedrock materials of the Coastal Belt Franciscan Complex, as well as the poorly cemented and weakly cohesive sands comprising the more sparsely vegetated Quaternary marine terraces. In general, the erodibility of geologic units in the project area greatly increases when vegetation is removed, either through natural processes like landsliding, or anthropogenic processes like logging or road construction. Road treatment strategies when dealing with erosion prone zones include minimizing excavation cuts, using additional rock armor, minimizing concentration of hillslope runoff or spring flow, and dispersing road surface runoff as frequently as possible.

Mass wasting (landsliding)

Large-scale mass wasting is evident in the watershed, characterized by debris sliding, debris flows, and earthflows (Manson, 1984). The largest mass wasting features are located in areas of the steepest hillslope gradient, i.e., inner gorge and headwall areas. Road treatment strategies in areas of large-scale mass wasting include diligent identification and characterization of mass wasting features; minimizing or avoiding additional surface disturbance, including disturbance to vegetation; restricting the volume of placed fill to what is absolutely necessary; mulching and seeding bare soil areas where sediment delivery is likely. Sometimes a road must be maintained across a low-activity mass wasting feature when detour around it is logistically impossible. In this case, minimal treatments to minimize road related sediment delivery may be prescribed with the expectation that occasional repairs will be required. Rather than installing costly culverts that can be compromised by even moderate translation, hillslope movement, etc., fords or armored fills are installed at crossings, and the on-site rock materials (riprap, road rock) can be gathered and reassembled as necessary for road upkeep. Consultation with a professional and/or engineering geologist is recommended when developing or implementing any remedial road related treatment prescriptions associated with mass wasting features.

Other mass wasting features evident throughout the Salmon Creek watershed include relatively small hillslope debris slides, debris slide slopes, small debris flows, slumps, cutbank slides, and road fill failures. Natural deposits of colluvium or man-made fill perched on steep slopes (i.e. logging landings) within the project area are also susceptible to failure as debris slides or flows. Smaller road related fillslope instabilities can usually be treated by excavation of perched, unstable material.

Seismic hazards

Potential seismic hazards in the project area include strong ground shaking, slope instability, and liquefaction. There are no documented surface fault ruptures in the project area, but given the proximity (~15 mi) of the historically active San Andreas fault, there is a high likelihood that the project area will be subjected to strong ground shaking and associated slope failures. Geologic units susceptible to failure through liquefaction include sandy marine terrace deposits with relatively uniform particle sizes, alluvial sediments within stream valleys, and road fills. No previous studies have accurately delineated liquefaction hazard zones in the project area, and it was beyond the scope of this project. In some locations, failures and liquefaction associated with strong ground shaking may be unavoidable because of the previous techniques used in designing and constructing the road infrastructure. Future road treatments would incorporate strategies to help minimize road related failures due to ground shaking, such as ensuring adequate compaction of newly placed fills; constructing cut and fill slopes to 50% grade or less; using rock armor for slope buttressing; and excavating and removing unstable fill or large amounts of man-made fill perched on steep slopes.

Geologic Summary
In regards to implementing the recommended treatments outlined in the BSCA project, the most significant, potential geologic constraints are highly erodible surficial deposits and areas susceptible to mass wasting. These are common constraints for road upgrading or road decommissioning projects throughout northwest California. The longevity and maintenance of treated sites in the BSCA area could also be affected by ground shaking resulting from regional seismicity. In order to minimize unanticipated failures and resulting deleterious affects to water quality and salmonid habitat, it is imperative that the recommendations outlined in this report be implemented under the direction of a licensed professional geologist experienced in the techniques required to address the geologic constraints pertinent to this project area.

4.4 The Big Salmon Creek Road Network

The BSCA project area consists of a moderately sized road network (~67 mi) to support land use, transportation, and resource management activities (Maps 1-4). Roads in the BSCA area were constructed over many decades in order to access timber harvest units and for hauling timber to mill sites. The 26000, 27000, 27200, and 29000 Roads are well maintained and provide access to the mainstem Big Salmon Creek valley and multiple smaller road network systems. Year-round access is also possible along the east and west sides of the valley of Hazel Gulch via the 29000 and 29100 Roads (Map 2).

Roads inventoried in the BSCA project area are categorized as maintained, abandoned, or decommissioned. Maintained roads show some evidence for recent maintenance (e.g. brushing, culvert cleaning, recent rocking, etc). Abandoned roads show no evidence of recent maintenance and are usually overgrown to varying degrees. Along many of these abandoned road segments, PWA observed problems typical of outdated land use management practices, including Humboldt crossings, fill crossings, severely undersized culverts, diverted or potentially diverted streams, and excessive hydrologic connectivity of road reaches adjacent to stream crossings. Decommissioned roads are roads that have been determined by the landowner to be unnecessary for future use in land management activities and have been treated to eliminate the adverse effects of the road on hydrology and hillslope stability. Decommissioned roads generally have had the fill completely excavated from stream crossings, all potentially unstable fills excavated and placed in a stable hillslope location, and the road surface decompacted, obliterated, or otherwise hydrologically disconnected[3] from the stream system.

Maintained year-round haul roads in the BSCA area are surfaced with coarse aggregate base and surface rock, and have culverted drainage structures at most stream crossings. Although road drainage has been improved along previously upgraded reaches, many untreated permanent

[3] Hydrologically connected describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000). See also Section 12 (Supplementary Information)

roads are insufficiently drained, with infrequent ditch relief culverts and minimal road shaping to improve drainage. In addition, along many of these maintained road segments, PWA observed that excessively long inboard ditches are currently draining directly into stream crossings and hydrologically connected ditch relief culverts, resulting in delivery of fine sediment from road runoff, ditch incision, and cutbank ravel directly into the stream system.

Prior to the summer of 2008, roads 29121.1 and 29070 were significant lengths of abandoned road in the valley of upper Hazel Gulch. These roads were abandoned, with mostly washed out crossings and significant vegetative regrowth. During the summer fires of 2008, both roads were reopened to facilitate fire access and suppression. Stream crossings along 2.25 mi of road were filled in to permit truck and bulldozer access. After fire containment, an effort was undertaken to decommission the recently opened roads. PWA observed that while the majority of the hydrologically connected road lengths were adequately disconnected with cross road drains, some of the stream crossings were underexcavated, with measurable volumes of erodible fill remaining in the crossings.

5 FIELD TECHNIQUES AND DATA COLLECTION

The BSCA project consists of three distinct elements: (1) an analysis of historical aerial photographs to document road networks and large landslides; (2) a complete field inventory of all current and potential road related erosion sources along 67.1 mi of road; and (3) the development of a prioritized plan of action for cost-effective erosion control and erosion prevention treatments in the watershed. All project elements were completed under the direction of a PWA licensed professional geologist.

For the first phase of the BSCA project, PWA staff analyzed sequential historical aerial photographs and a set of digital imagery to document the history of road construction and the development of large landslides within The Conservation Fund ownership within the Big Salmon Creek watershed. The road and landslide history was determined by identifying the first occurrence of each road or landslide on aerial photographs for the years 1965 (1:15,000), 1975 (1:15,000), 1987 (1:12,000), 1999 (1:12,000), and 2004 (1:12,000), or on 2005 National Agricultural Imagery Program (NAIP) digital imagery (CaSIL, 2005). Mylar overlays were used to trace the image of roads and landslides observed on the photographs and imagery, and the information was then transferred to a base map (1:13,000) and spatially digitized into ArcMap.

To facilitate the field inventory, roads identified on the historical aerial photos were digitized and combined with data layers provided by TCF to produce rectified composite base maps. These maps were used to document the locations of inventoried sites, and to ground truth the location and configuration of mapped road segments in the field. Roads that were not identified on the aerial photos but were located in the field were also mapped, and were included in the field inventory. The GIS roads layer was then modified based on ground truthing, and used in the development of the final project maps.

For the second phase of the project, PWA conducted a field inventory of all identified road segments, and assessed all road related erosion sites showing evidence of sediment delivery to the stream system. Because the purpose of the inventory was to quantify the potential magnitude of impacts of road related erosion on fish-bearing streams, we excluded any site or road reach showing evidence for erosion (past, current, or potential) that did not also show evidence for current or potential sediment delivery to a stream.

Inventoried sites for this assessment primarily consist of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts, and various discharge points (e.g., roadside gullies, low spots in the road without gully formation) for uncontrolled road surface and/or inboard ditch runoff.[4] For each site identified as a potential sediment source, PWA staff plotted its location on a GIS-generated map with a 1:6,000 scale aerial photograph base, recorded a GPS waypoint using a GPSmap 60Cx handheld GPS unit, and recorded a series of field observations including: (1) detailed site description; (2) nature and magnitude of existing and potential erosion problems; (3) likelihood of erosion or slope failure; (4) length of hydrologically connected road surface associated with the site; and (5) treatments needed for prevention or elimination of future sediment delivery. The data collected for each site also includes an evaluation of *treatment immediacy* based on the potential or likelihood of sediment delivery from the site to a stream channel, and the level of urgency for addressing erosion problems at that location. Stream crossing sites were additionally evaluated for potential fish barrier problems.

For each existing or possible problem site in the project area, PWA field staff evaluated the potential for erosion and sediment delivery, and collected field measurements (width, depth, and length of the potential erosion area) to derive sediment volume. For most stream crossings, PWA field crews used tape and clinometer surveys to develop longitudinal profiles and cross sections of the site. These data were used to calculate road fill and potential sediment delivery volumes with the STREAM computer program. This proprietary software, developed by PWA, provides accurate and reproducible estimates of: (1) the potential volume of erosion at a stream crossing, whether over time or during any possible catastrophic, storm-generated washout; (2) excavation volumes associated with culvert installation, culvert replacement, or complete decommissioning of a stream crossing; and (3) backfill volumes associated with culvert installation or replacement. In addition, field crews measured the lengths of hydrologically connected road to derive estimates for chronic sediment delivery. The roadbed, ditch, and cutbank of hydrologically connected road reaches were inspected and each road reach assigned to 1 of 5 rates of chronic road surface lowering/cutbank retreat based on the level of road usage; types of surfacing materials; soil competency; vegetative cover; and observed evidence of surface erosion in progress. Chronic sediment production from hydrologically connected road reaches was calculated on a decadal basis, using the empirical formula: (measured length) x (25 ft average width, including cutbanks and ditches) x (0.1-0.25 ft average lowering of the road per decade).

Where new or replacement stream crossing culverts are recommended for installation, culverts are sized to convey the 100-year peak storm flow[5] including expected sediment and organic debris in transport. PWA staff calculated the necessary culvert sizes using either (1) the Rational Method (Dunne and Leopold, 1978), for drainage areas less than 80 acres; or (2) the empirical

[4] Detailed definitions of sediment delivery sites are provided in Section 12.
[5] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

equations of the USGS Magnitude and Frequency Method (Wannanan and Crippen, 1977) for drainage areas equal to or larger than 80 acres. These culvert sizing calculations were used for stream crossings where the field-estimated bankfull channel dimensions were greater than approximately 3 ft by 1 ft in cross sectional area[6].

In the final phase of the project, PWA personnel analyzed the inventory results to develop cost-effective erosion control and erosion prevention prescriptions, as well as a prioritized plan of action for the project area. Using field observations, data analyses, and information about realistic needs for future road use from The Conservation Fund and Registered Professional Forester Christopher Blencowe, PWA staff assigned a treatment designation of either "upgrade" or "decommission" for each treatment site[7]. These designations are intended to provide the landowner with prescriptions and estimated costs for storm-proofing treatment sites and hydrologically connected road segments, and are PWA's best recommendations for the most efficient and cost-effective methods to accomplish this goal.

6 RESULTS

The purpose of the field assessment was to identify and quantify all locations that are currently eroding and delivering sediment to streams in the project area or show a potential to do so in the future. We did not inventory any on-going or potential erosion sites identified in the field that did not also show evidence for sediment delivery to a stream. Although such sites may impact road maintenance, they do not represent a threat to water quality or fish habitat, and therefore were not applicable to this project. Should TCF wish to address these sites of non-sediment delivery on their properties, we recommend applying the same corrective measures described in this erosion control plan to the non-delivery erosion sites.

6.1 Road Construction History Based on Aerial Photographic Analysis

Using aerial photographs and NAIP digital imagery, PWA developed a history of road construction in the project area for 5 time periods: pre-1965, 1966-1975, 1976-1987, 1988-1999, 2000-2004, and 2005 (Figure 1, Map 2). Our measurements show that a total of approximately 67.1 mi of roads were constructed within the project area by 2004 (Figure 1). PWA inventoried all 67.1 mi of road in the project area. It should be noted that the road construction history reflects second growth logging throughout the Big Salmon Creek watershed. The entire area was previously logged around the turn of the 20th century utilizing railroads and steam donkey yarding methods.

[6]For stream channels with cross sectional areas of 3 ft^2 or smaller, PWA follows the recommendations outlined in the California Department Fish and Game *Salmonid Stream Habitat Restoration Manual* and defaults to a minimum culvert size of 24 in.

[7] An overview of road upgrading and decommissioning is provided in Section 12.

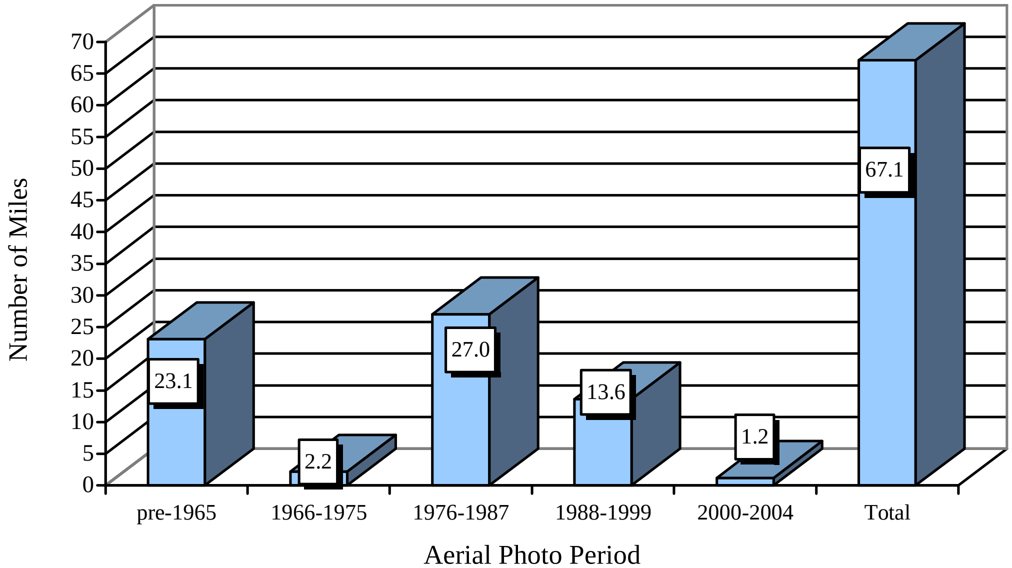

Figure 1. Road construction history for the The Conservation Fund ownership in the Big Salmon Creek watershed (Mendocino County, California) based on analysis of historical aerial photographs and NAIP digital imagery.

By 1965 a total of 23.1 mi of road had been constructed in the project area, which is 34% of the total road mileage (Figure 1). This includes the roads and/or railroads constructed along the length of the low gradient mainstem Big Salmon Creek, Hazel Gulch, the Elliot and Iron Gate Roads, and the ridgetop roads between Hazel Gulch and the Albion River watershed (Roads 27000, 26000, 26020, 27000, 27200, 29000, 29100, and 29121) (Map 2).

Between 1965 and 1975, an additional 2.2 mi of roads were built in the project area, which is approximately 3% of the total road mileage (Figure 1). Roads constructed between 1965 and 1975 include short spur roads used for timber harvesting in various channel valley locations in the headwaters of Hazel Gulch and the reentry to Pullen Gulch (Map 2).

Approximately 40% of the roads identified in the project area (27 mi) were constructed between 1976 and 1987 to access logging operations in Donnelly Gulch, northwest Hazel Gulch, and the northern slopes of mainstem Big Salmon Creek (Figure 1, Map 2). In addition to the extensive mainline logging roads located in subwatershed valleys, networks of midslope spurs extending from ridgetop mainline access roads were also constructed at this time.

Approximately 13.6 mi of road were constructed between 1988 and 1999, which is approximately 20% of the total road mileage identified in the project area. Roads and landings constructed during this time period are generally upslope extensions of previously constructed road networks and are primarily associated with cable logging practices (Figure 1, Map 2).

Finally, approximately 1.2 mi of roads were constructed between 1999 and 2004, which accounts for approximately 1.7% of the total road mileage identified in the project area. Roads constructed during this time period are small extensions of existing road networks (Figure 1, Map 2). There were no additional roads identified on the 2005 NAIP imagery.

6.2 Landslide History Based on Aerial Photographic Analysis

PWA used the same aerial photo sets and digital imagery as in the road construction study to document the development of large mass wasting features (landslides). During the total time period evaluated (1955-2005), we found evidence for 15 large landslides within the BSCA project area. One of the 15 landslides is evident on the 1965 photo set (Map 2). This landslide occurred upslope of Road 26020, located on inner gorge slopes of the mainstem Big Salmon Creek (Map 2). The hillslope gradient of the inner gorge in this area is one of the steepest in the Big Salmon Creek watershed. Although the inner gorge roadcut of Road 26020 crosses the toe of this large landslide, both hillslope and field evidence suggest that the initiation of this landslide is related to the geomorphology of the location and is unlikely to have be related to the construction of Road 26020.

Five additional large landslides had developed in the project area by 1975 (Map 2). One of these landslides appears to be a large non-road related debris slide located above Road 29100 on the inner gorge of the mainstem Hazel Creek. The other 4 landslides observed on the 1975 aerial photographs include 2 inner gorge debris slides in small tributaries to Hazel Creek, and 2 road or skid road related debris slides located on the steep streamside slopes of the headwaters of Hazel Gulch.

The aerial photo analysis revealed the development of a large landslide on a steep hillslope above mainstem Big Salmon Creek between 1975 and 1987 (Map 2). The evidence suggests that the formation of this landslide is related to the construction of Road 26000.

One large landslide was observed on the 1999 aerial photographs within the BSCA project area (Map 2). This landslide is a debris flow related to the construction of Road 26000 across the headwall slopes of Ketty Gulch. The photos show that debris flow runout extended from the inception point of the feature down to the mainstem channel of Ketty Gulch.

Finally, 7 additional large landslides were observed on the 2004 aerial photos in the Big Salmon Creek Assessment project area (Map 2). Four of the landslides that developed during this period are located on streamside or headwall slopes, and were likely triggered by timber harvesting activities. The other 3 large landslides that originated during this time include: (1) 1 non-road related debris slide located below Road 26000 in the inner gorge of mainstem Big Salmon Creek; (2) 1 large active debris slide slope beneath Road 26100 on the inner gorge of mainstem Big Salmon Creek; and (3) 1 debris slide located on a steep midslope hillside beneath Road 27020 in Ketty Gulch (Map 2). The NAIP imagery revealed no additional landslide formation between 2004 and 2005.

6.3 Summary of Field Data and Analyses

PWA field crews identified a total of 187 sites and 13.37 mi of hydrologically connected road surfaces with the potential to deliver sediment to streams in the Big Salmon Creek assessment area (Maps 3, 4; Table 1; Appendix A). We recommend that 154 of these sites and 12.67 mi of the connected road segments be treated for erosion control and erosion prevention (Table 1).

Field data show that treating the 154 sites will prevent the future episodic delivery of approximately 8,700 yd^3 of sediment to streams in the Big Salmon Creek watershed, and that treating the 12.67 mi of connected road segments could prevent delivery of approximately 9,400 yd^3 of fine sediment during the next decade alone (Table 2). The total estimated sediment delivery for the sites and road reaches recommended for treatment account for 96% of the total identified volume of potential sediment delivery from all identified sites and connected road surfaces within the project area.

Table 1. Inventory results for sediment delivery sites and hydrologically connected road segments, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Sources of sediment delivery	Sediment delivery sites		Hydrologically connected roads adjacent to sites		Total length of roads surveyed for project (mi)
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)	
Stream crossings	149	119	10.41	9.77	-
Ditch relief culverts	16	15	1.74	1.71	-
Landslides	7	7	0.26	0.26	-
Springs	3	2	0.07	0.04	
Bank erosion	3	3	0.21	0.21	-
Road drainage discharge points	8	8	0.68	0.68	-
Filled channel[a]	1	0	0	0	-
Total	**187**	**154**	**13.37**	**12.67**	**67.1**

[a]Erosion of railroad grade fill along an approximately 700 ft length of Class 1 stream channel.

Table 2. Estimated future sediment delivery for sites and road surfaces recommended for treatment, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Sources of sediment delivery	Estimated future sediment delivery (yd^3)	Percent of total
1. Episodic sediment delivery from road related erosion sites (indeterminate time period)		
Stream crossings	8,234	94%
Landslides	343	4%
Ditch relief culverts	14	<1%
Springs	4	<1%
Bank erosion	106	1%
Discharge points for road surface drainage	7	<1%
Total episodic sediment delivery	**8,708**	**100%**
2. Chronic sediment delivery from road surface erosion (estimated for a 10 yr period)[a]		
Total chronic sediment delivery	**9,382**	

[a]Sediment delivery for rocked and native surface roads is calculated for a 10 yr period. It assumes a combined width of 25 ft for the road, ditch, and cutbank contributing area, and 1 of 5 empirical values for road surface lowering and cutbank retreat based on field analyses by PWA staff: (1) 0.1 ft/10 yr (low rating); (2) 0.15 ft/10 yr (moderate-low rating); (3) 0.2 ft/10 yr (moderate rating); (4) 0.25 ft/10yr (high-moderate rating); and (5) 0.3 ft/10yr (high rating).

PWA recommends treatment for 119 stream crossings in the Big Salmon Creek assessment area, which account for 77% of all treatment sites (Table 1). Inventoried stream crossing sites include 51 crossings with culverts, 39 fill (unculverted) crossings, 22 pulled or decommissioned crossings, 3 Humboldt crossings, 2 bridges, 1 armored fill, and 1 ford. We project that approximately 8,234 yd^3 of future road related sediment delivery will originate from the 119 stream crossings if they are left untreated, which is approximately 94% of total future episodic sediment delivery from sites recommended for treatment in the BSCA project area (Table 2).

PWA identified 6 stream crossings on maintained and unmaintained roads that have drainage structures not sufficiently designed for the 100-year peak storm discharge (Table 3). Furthermore, of the 149 stream crossings, 43 have the potential to divert in the future and 16 streams are currently diverted. Of the 51 existing culverts at stream crossings, 30 have a moderate or high potential to become plugged by sediment and debris (Table 3).

Table 3. Erosion problems at stream crossings, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Stream crossing problem	# Inventoried	Percent of total[a]
Stream crossings with diversion potential	43	29%
Stream crossings currently diverted	16	11%
Crossings with culverts likely to plug[b]	30	20%
Crossings with culverts that are currently undersized[c]	6	4%

[a]From Table 1, total stream crossings inventoried = 149.
[b]Culvert plug potential is moderate to high.
[c]Culverts in stream channels larger than 3 ft x 1 ft that are too small to convey the calculated 100-year peak storm flow.

Ditch relief culverts were inventoried if they showed the potential to deliver future, site-specific erosion, or were currently functioning as conduits for delivery of road surface sediment. PWA inventoried a total of 16 ditch relief culverts, 15 of which are recommended for treatment (Maps 3, 4; Table 1). Ditch relief culverts represent 10% of all treatment sites, with a projected potential sediment delivery of 14 yd^3 (Table 2). This implies that most of the gullies below ditch relief culverts are mature and stable, yet they still serve as efficient conducts for road sediment delivery.

Field crews identified a total of 7 road related landslides that require treatment: 5 potential road fill landslides (sites #16, 17, 116, 162, and 169), 1 potential landing fill failure (site #42), and 1 hillslope debris slide (site #69; Maps 3, 4; Table 1). The total estimated sediment delivery from landslides is 343 yd^3 (Table 2). We project that approximately 181 yd^3 of future site-specific sediment delivery will originate from road fill landslides if they are left untreated, which is approximately 2% of the total future episodic sediment delivery from recommended treatment sites in the BSCA project area (Table 2). An estimated 162 yd^3 of future site-specific sediment delivery will originate from the landing fill failure if left untreated, also approximately 2% of total future episodic sediment delivery. Field data show that the hillslope debris flow is not a problem for site-specific sediment delivery, but the debris flow channel will serve as a conduit for future sediment delivery from hydrologically connected road reaches to the stream channel below.

A bank erosion site is the result of stream erosion at the base of road fill, as compared to a landslide site that includes other kinds of hillslope mechanisms. PWA recommends treatment for all 3 inventoried bank erosion sites in the BSCA area (Maps 3, 4; Table 1). Estimated future sediment delivery for these sites is 106 yd^3 (Table 2).

PWA inventoried 3 springs that exhibit the potential for sediment delivery, two of which are recommended for treatment. Springs account for less than 2% of all treatment sites. Total estimated future sediment delivery from the 2 springs recommended for treatment is 4 yd^3.

Eight discharge points for road surface drainage were identified in the assessment. These are locations along poorly drained road segments where accumulated concentrated flow from road surface/ditch/cutbank erosion exits the road to be delivered to a stream. The accumulation and subsequent discharge of large quantities of road surface runoff frequently results in the erosion of a length of native hillside or fillslope between the road and the receiving stream channel. In addition, these sites are also commonly found along streamside roads in close proximity to a stream channel. All 8 discharge points identified in the Big Salmon Creek assessment area were recommended for treatment. Estimated site-specific future sediment delivery from these sites totals 8 yd^3.

In total, PWA field crews measured approximately 12.7 mi of road surfaces and/or ditches (representing 19% of the total inventoried road mileage) currently draining to stream channels, either directly or via gullies (Table 1). Based on assessments PWA has conducted over the last 2 decades in many similar forested watersheds, this represents a low connectivity value. However, from the hydrologically connected road segments recommended for treatment, we estimate that approximately 9,380 yd^3 of sediment (52% of total) could be delivered to stream channels within the Big Salmon Creek assessment area over the next decade if no efforts are made to change road drainage patterns (Table 2). By aggressively reshaping road beds and installing additional road drainage structures such as rolling dips, TCF should be able to easily meet TMDL standards for road bed connectivity as defined by the US Environmental Protection Agency and the North Coast Regional Water Quality Control Board (USEPA 2000, 2001).

Of the 154 inventoried sites that we recommend for treatment, we designate 11 with priority ratings of high or high-moderate: 9 upgrade sites and 2 decommission sites (Map 4, Tables 4a, 4b). We project that, if left untreated, these 11 sites and their hydrologically connected road reaches could deliver approximately 2,020 yd^3 of sediment to streams in the Big Salmon Creek watershed. This is approximately 11% of projected sediment delivery from the sites recommended for treatment in the Big Salmon Creek assessment area. We assign moderate or moderate-low priorities to 108 sites: 73 upgrade sites and 35 decommission sites. This represents approximately 12,680 yd^3, or 70% of the potential sediment delivery from the sites recommended for treatment in the Big Salmon Creek assessment area. Finally, we assign a low priority to 35 sites: 21 upgrade sites and 14 decommission sites. We estimate that implementing erosion control and erosion prevention for these sites and hydrologically connected road reaches could prevent approximately 3,385 yd^3 of sediment delivery to area streams, which is about 19% of the total for all recommended treatments.

The 33 inventoried sites that do not require treatment include: (1) well installed bridge and armored fill crossings where the adjacent lengths of hydrologically connected road surface have been minimized; (2) well installed culverted stream crossings with capacity to pass 100-year storm flow where the adjacent lengths of hydrologically connected road surface have been minimized; (3) appropriately decommissioned stream crossings; (4) necessary road drainage structures such as ditch relief culverts and rolling dips where the lengths of hydrologically connected road surfaces have been minimized as well as feasible; (5) and sites where disturbance associated with treatment was determined to be more detrimental to water quality and fish habitat than leaving the site untreated. Although these 33 sites have the potential to deliver a total of approximately 790 yd^3 of sediment to stream channels through both episodic and chronic road surface erosion, field data show that the risk of sediment delivery from these sites is extremely low.

Table 4a. Treatment immediacy ratings for sediment delivery sites and associated lengths of hydrologically connected road, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Treatment immediacy	Treatment sites				Estimated future sediment delivery from inventoried erosion sites[b]		Estimated future sediment delivery from road, ditch, and cutbank surfaces[c]	
	Upgrade sites	Road length (mi)[a]	Decommission sites	Road length (mi)[a]	Volume (yd^3)	Relative percentage	Volume (yd^3)	Relative percentage
High-moderate	8 Stream crossings 1 Ditch relief culvert	0.91	2 Stream crossings	0.12	1,232	14%	791	8%
Subtotal	*9 sites*	*0.91*	*2 sites*	*0.12*	*1,232*	*14%*	*791*	*8%*
Moderate	29 Stream crossings 2 Landslides 2 Ditch relief culverts 4 Road drainage discharge points	3.56	13 Stream crossings 1 Ditch relief culvert	0.95	2,612	30%	3,044	33%
Moderate-Low	26 Stream crossings 9 Ditch relief culverts 1 Road drainage discharge point	3.93	14 Stream crossings 3 Landslides 3 Bank erosion 1 Road drainage discharge point	1.23	2,770	32%	4,255	45%
Subtotal	*73 sites*	*7.49*	*35 sites*	*2.18*	*5,382*	*62%*	*7,299*	*78%*
Low	15 Stream crossings 1 Landslide 2 Ditch relief culverts 2 Springs 1 Road drainage discharge point	1.46	12 Stream crossings 1 Landslide 1 Road drainage discharge point	0.51	2,094	24%	1,292	14%
Subtotal	*21 sites*	*1.46*	*14 sites*	*0.51*	*2,094*	*24%*	*1,292*	*14%*
Total	**103 upgrade sites[d]**	**9.86**	**51 decommission sites[e]**	**2.81**	**8,708**	**100%**	**9,382**	**100%**

[a]*Road length* refers to hydrologically connected road reaches adjacent to recommended treatment sites.
[b]Episodic sediment delivery for road related sites (indeterminate time period).
[c]Chronic sediment delivery from adjacent hydrologically connected roads and cutbanks (estimated for a 10 yr period).
[d]Upgrade sites (103 total): 78 stream crossings, 3 landslides, 14 ditch relief culverts, 2 springs, and 6 road drainage discharge points.
[e]Decommission sites (51 total): 41 stream crossings, 4 landslides, 1 ditch relief culvert, 3 bank erosion, and 2 road drainage discharge points.

Table 4b. Individual upgrade and decommission sites listed by treatment immediacy, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Site type	Upgrade site ID #	Decommission site ID #
High-moderate treatment immediacy		
Stream crossing	#34, 43, 52, 91, 97, 112, 146, 147	#83, 107
Ditch relief culvert	#10	
Moderate treatment immediacy		
Stream crossing	#5, 12, 18, 27, 28, 30, 41, 45, 51, 53, 54, 76, 77, 81, 87, 95, 98, 99, 101, 108, 113, 128, 131, 142, 148, 149, 150, 170, 172	#19, 49, 61, 62, 73, 74, 121, 122, 145, 154, 165, 167, 177
Landslide	#42, 69	
Ditch relief culvert	#14, 15	#59
Road drainage discharge point	#6, 22, 35, 96	
Moderate-low treatment immediacy		
Stream crossing	#2, 3, 4, 7, 8, 13, 20, 21, 24, 29, 31, 38, 46, 47, 82, 84, 86, 94, 102, 109, 111, 123, 124, 129, 171, 175	#8.5, 48, 55, 63, 67, 68, 72, 75, 126, 135, 155, 157, 159, 163
Landslide		#16, 17, 162
Ditch relief culvert	#23, 26, 33, 37, 79, 80, 88, 92, 130	
Bank erosion		#60, 118, 166
Road drainage discharge point	#57	#65
Low treatment immediacy		
Stream crossing	#1, 39, 40, 56, 58, 78, 93, 106, 110, 125, 127, 141, 173, 176, 186	#64, 104, 105, 114, 115, 137, 139, 140, 158, 160, 164, 168
Landslide	#116	#169
Ditch relief culvert	#32, 85	
Spring	#25, 174	
Road drainage discharge point	#44	#117

6.4 Problematic or Complex Sites

Of the 187 inventoried sites in the project area, 18 sites are particularly noteworthy for their complexity or limited accessibility. Sites deserving specific mention include 10 sites with access problems; 6 that would benefit more from abandonment than attempted treatments using heavy equipment; and 2 where treatment is significantly complex.

6.4.1 Sites with restricted access (#76, 77, 96, 150, 154, 155, 157-160, 162-168, and 177)

Sites 76 and 77, located on the south side of Donnelly Gulch on Road 29310, are accessed by crossing Donnelly Gulch at site 78, a pulled crossing (Map 3). Site 78 will need to be rebuilt to permit heavy equipment access to sites 76 and 77.

Site 96, located near the end of Road 29130 in the Hazel Gulch subwatershed, is accessed by crossing site 95. Site 95 is a pulled crossing that is also recommended for upgrading, and will need to be rebuilt to access site 96 with heavy equipment.

Access to site 157 can most easily be obtained by crossing Hazel Gulch at site 156 (Map 3). Site 156 is an entirely washed out Humboldt crossing. Installation of a temporary bridge will be necessary to access site 157 for treatment.

Access to sites 165 through 168 from Road 29070 is complicated because a non-sediment delivering landslide has obliterated the unnamed road on which sites 165 through 168 are located (Maps 3, 4). The landslide is approximately 150 feet from the intersection with Road 29070, and approximately 125 ft of the unnamed road will have to be rebuilt to allow heavy equipment access to sites 165 through 168. We recommend constructing a minimum standard road across the failed road section in order to properly treat the 295 yd^3 of projected sediment delivery from the 4 sites.

Site 177 is located on the inner gorge of mainstem Big Salmon Creek at the west end of the abandoned Road 26300 (Maps 3, 4). A fill failure approximately 800 ft to the east of site 177, near the intersection of Road 26300 and the unnamed inner gorge road, currently prohibits heavy equipment access to this location. Access to this site could quickly be established with minimal effort with a bulldozer and excavator.

Road 29070 was recently decommissioned after being reopened for fire management access in the summer of 2008. The recent decommissioning treatments included installing cross-road drains, and partially or fully excavating crossing fills. Treating sites 155, 158, 159, 160, 162, 163, and 164 will require temporarily installing new stream crossing fills and filling cross-road drains to gain heavy equipment access for proper road closure. Due to the low fill volumes and relatively low erosion potentials, treatment immediacies given to sites on Road 29070 range from no recommended treatment to moderate-low.

Sites 154, 157, 165, 166, 167, and 168 are located on abandoned road spurs stemming from decommissioned Road 29070. Accessing these sites for treatment will require the temporary installation of crossing fills and filling of cross-road drains on Road 29070, as well as opening of the abandoned road spurs. Treatment of site 157 would require the installation of a temporary bridge at site 156.

6.4.2 Sites determined to be infeasible to treat (#50, 178-182)

Our field data show that 6 sites are either infeasible or not cost-effective to treat. Site 50 is a 700 ft long, > 60 yr old railroad grade constructed in the center of the stream valley of the Class I Ketty Gulch, near the confluence with mainstem Big Salmon Creek (Map 3). Construction of the railroad on top of the existing channel resulted in the burial of the channel bed and banks along with a large volume of large woody debris. Subsequent to railroad grade construction, the stream channel has reestablished itself, incising through the railroad grade fill and exposing the buried large woody debris and roots of the second growth redwood trees. The present channel is now relatively stable with multiple large woody debris and live redwood root grade controls. The woody debris functioning as grade control throughout the site will gradually decay due to rot and abrasion from bedload transport, and allow fill and aggraded bedload materials stored behind the grade controls to slowly mobilize downstream. Treatment of this site would involve extensive channel disturbance along nearly 700 linear feet of a Class I stream, and extensive removal of riparian vegetation, canopy, and advanced-second growth redwood trees. It is our conclusion that disturbance of this magnitude in a currently stable Class I stream would be more detrimental than leaving the remaining railroad grade in place.

Sites 178-182 are located on a very old abandoned railroad grade running along the inner gorge and intermittent flood plain of mainstem Big Salmon Creek (Map 3). The road, no more than 15 ft above the Class I channel, has a 20 to 40 ft wide road bed and was likely developed on the first entry into the watershed for timber harvest operations well before the turn of the 20^{th} Century. Sites 178-182 are fill crossings located in the low gradient depositional zone, where steep tributary streams abruptly lose gradient as they approach their confluence with the mainstem channel of Big Salmon Creek. Streams draining to this geomorphic setting form alluvial fans composed of poorly sorted bedload deposits dropped from transport as the stream gradient and flow velocities decrease. As these stream crossings are located in a depositional area, the erosion potential of the remaining crossing fill is very low. Access to these sites for treatment is also severely limited by dense stands of advanced second growth redwood trees growing in the road prism and on the developing fans. Given the geomorphic setting, low erosion potential, and disturbance required to effectively treat these sites, treatment of sites 178-182 is not recommended.

6.4.3 Sites with high treatment complexity (#140, 146, 157)

Site 140 is a railroad crossing of a Class III stream at its confluence with Hazel Creek (Map 3). The fill remaining in the crossing is located on the left bank of Hazel Creek. Site 157 is an abandoned fill crossing, with vertical banks of fill, located at the confluence of a Class II stream with Hazel Creek. Treating these sites will be more complicated than usual because of their close proximity to the Class I Hazel Creek. Extreme care should be taken when accessing and implementing erosion control measures at these sites to avoid accidental sediment delivery to the Class I stream: best management practices for erosion control and prevention must be in place prior to treatment with heavy equipment.

Treating site 146, a culverted Class III stream crossing, will require excavating more than 350 yd^3 of crossing fill. A large quantity of large woody debris was incorporated into the crossing fill during the initial culvert installation. An active spring to the left of the crossing axis will likely keep the crossing fill wet during summer treatment implementation. Removing the excavated woody debris and wet fill by dump truck will be necessary, and clean, dry fill will need to be imported to rebuild the crossing after culvert replacement.

6.4.4 Sites to treat as part of ongoing THPs

Site #21 is a culverted stream crossing of Kitchen Gulch near its confluence with mainstem Big Salmon Creek. Outflow from the existing 48” diameter culvert at this site falls 2 feet to a plunge pool below the crossing, creating a barrier to coho passage. CDFG has examined the fish barrier and determined that a bridge should be installed at this site to facilitate fish passage. Treatment of the stream crossing structure at this site will take place as part of an existing THP, and is not included in this treatment plan. Treatments for site #21 included in this plan address associated connected road surface lengths, fill material in the stream above the crossing, unstable road fill associated with the crossing, and correction of the existing diversion potential..

7 RECOMMENDED TREATMENTS

PWA recommends 19 different types of erosion control and erosion prevention treatments for the BSCA project area. The treatments are organized into 2 categories (site-specific treatments and road surface treatments), and include both upgrading and decommissioning measures (Table 5). In addition to the treatment summaries in Table 5, detailed treatment information for each site is also provided on the site dataforms (Appendix A) and in the assessment database. Overviews of construction and installation techniques for the recommended treatments are provided in Appendix B.

Stream crossing treatments are primarily implemented to reduce the risk of catastrophic failure and sediment delivery resulting from road fill erosion or stream diversion along road surfaces. Recommended treatments for stream crossings include: (1) constructing a total of 27 critical dips to prevent diversions at streams with diversion potential; (2) installing 12 culverts at currently unculverted stream crossings; (3) replacing 19 undersized or damaged culverts; (4) constructing 20 armored fill or ford crossings; (5) excavating approximately 7,800 yd^3 of fill material, primarily at stream crossings and fillslopes; (6) installing approximately 320 yd^3 of rock armor to stabilize stream crossing fillslopes, ditches, and headcuts; (7) implementing 6 miscellaneous site-specific treatments such as correcting upstream flow diversion, plugging inboard ditches, installing slotted risers to ditch relief culvert inlets, and removing woody debris from non-fish bearing stream channels above culvert crossings. In addition, installing a trash rack is required for 5 stream crossing culverts, and 2 culverts require cleaning to fix a blocked inlet.

Road treatments are designed to control road drainage by reshaping the roadbed, dispersing road surface runoff onto stable slopes and preventing delivery of concentrated runoff to streams. Upgrading treatments to redirect flow include outsloping the road, insloping the road, installing rolling dips, installing ditch relief culverts, cutting ditches, and removing berms. Road surface erosion is curtailed by adding road rock, which fortifies the surface and reduces production of fine sediment. For road decommissioning, frequent cross-road drains and in-place outsloping are proposed to direct water off road and skid trail surfaces.

Road treatments in the project area include: (1) removing a total of approximately 1,880 ft of outboard road berm; (2) cleaning/cutting 400 ft of ditch; (3) outsloping a total of 12,300 ft of road (outsloping and retaining ditch for 3,750 ft; outsloping and removing ditch for 8,550 ft); (4) installing 261 rolling dips; (5) installing 132 cross road drains; (6) installing 3 ditch relief culverts; (7) replacing 1 ditch relief culvert; and (9) adding a total of approximately 2,750 yd^3 of road rock at 141 locations.

Once the road shaping and road drainage structures have been constructed, moderate to high use sections of the road will need to be watered and recompacted as a final road treatment. Following the completion of all construction and road rocking, bare soil areas should be seeded with native grasses appropriate for the area. In addition, bare soil areas should be mulched with weed-free straw where necessary to prevent sediment delivery to nearby gullies or streams.

Table 5. Recommended erosion control and erosion prevention treatments, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Treatment type			No.	Comments
Site specific treatments	Stream crossing treatments	Culvert (install)	12	Install a culvert at an unculverted fill (Site #12, 20, 30, 31, 53, 76, 86, 149, 172, 173, 176, 186).
		Culvert (replace)	19	Replace an undersized, poorly installed, or worn out culvert (Site #18, 28, 29, 34, 43, 54, 81, 87, 91, 98, 99, 102, 106, 123, 128, 141, 146, 147, 171).
		Culvert (clean/clear)	2	Remove sediment or debris from the culvert (Site #10, 129).
		Trash rack	5	Install at culvert inlets to prevent plugging (Site #86, 150, 173, 176, 186).
		Armored fill or rocked ford (wet) crossing	20	Install armored fill crossings (Site #3, 4, 5, 27, 51, 52, 82, 95, 97, 101, 108, 109, 110, 111, 112, 113, 131, 148, 170, 175) using 411 yd^3 of rock armor.
		Critical dip	27	Install to prevent stream diversions (Site #7, 12, 13, 18, 20, 21, 24, 28, 29, 30, 31, 34, 38, 40, 41, 53, 77, 86, 124, 125, 129, 146, 147, 149, 150, 172, 176).
	Other	Rock (armor)	31	At 31 sites, add a total of 323 yd^3 of rock armor on inboard and outboard stream crossing fillslopes, ditches, and headcuts (Site #2, 8.5, 14, 18, 20, 21, 28, 34, 39, 41, 43, 53, 54, 58, 62, 81, 82, 86, 87, 91, 94, 96, 99, 102, 109, 146, 147, 171, 173, 177, 186).
		Soil excavation	86	At 86 sites, excavate and remove a total of 7,820 yd^3 of sediment, primarily at fillslopes and stream crossings (Site #2, 3, 5, 8.5, 16, 17, 18, 19, 20, 21, 27, 28, 29, 30, 31, 34, 42, 43, 46, 48, 49, 51, 52, 53, 54, 55, 60, 61, 62, 63, 64, 67, 68, 72, 73, 74, 75, 77, 82, 83, 87, 97, 98, 99, 101, 104, 105, 107, 108, 109, 111, 112, 113, 114, 115, 116, 118, 121, 122, 123, 126, 135, 137, 139, 140, 142, 145, 149, 154, 155, 157, 158, 159, 160, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 177, 186).
		Miscellaneous treatments	6	Miscellaneous treatments at 6 site-specific locations (Site #13, 14, 15, 31, 86, 111).
Road surface treatments	Road drainage structures	Ditch relief culvert (install)	3	Install new ditch relief culverts to improve road surface drainage.
		Ditch relief culvert (replace)	1	Replace existing ditch relief culverts to improve road surface drainage.
		Ditch relief culvert downspout	1	Install to prevent erosion at ditch relief culvert outlets.
		Rolling dip	261	Install to improve road drainage.
		Cross-road drain	132	Install to improve drainage on decommission roads.
	Road shaping treatments	Outslope road and remove ditch	16	At 16 locations, outslope road and remove ditch for a total of 8,545 ft of road to improve road surface drainage.
		Outslope road and retain ditch	12	At 12 locations, outslope road and retain ditch for a total of 3,747 ft of road to improve road surface drainage.
		Inslope road	2	At 2 locations, inslope road for a total of 400 ft to improve road surface drainage.
		Berm (remove)	10	At 10 locations, remove a total of 1,877 ft of berm to improve road surface drainage.
		Clean or cut ditch	4	At 4 locations, clean or cut ditch for a total of 400 ft.
	Other	Road rock (for road surfaces)	141	At 141 locations, use a total of 2,739 yd^3 of road rock to rock the road surface at 13 stream culvert installations; 6 critical dip locations; 1 DRC installation; 66 rolling dips; 2,815 ft of outslope and remove ditch; 3,360 ft of outslope and retain ditch; 400 ft of inslope road; 20 armored fills and 16 other site-specific locations.

8 HEAVY EQUIPMENT AND LABOR REQUIREMENTS

Equipment needs for erosion control treatments in the assessment area are detailed in the project database and summarized, based on immediacy, in Table 6. Most treatments require the use of heavy equipment, e.g., excavator, bulldozer, grader, and water truck. Some hand labor is required at sites needing downspouts, new culverts or culvert repairs, or for applying seed and mulch to ground disturbed during construction. Equipment needs are reported as equipment times, in hours, to treat all sites and road segments. These estimates only include the time needed for the actual treatment work, and do not include additional construction activities such as opening roads, staging materials at work sites, traveling between sites, final grading, or spreading road rock, straw, and mulch. Equipment and labor hours in addition to those listed in Table 6 are further explained in Section 9.

Table 6. Estimated heavy equipment and labor requirements based on treatment immediacy, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Treatment immediacy	# of sites	Excavated volume[a] (yd^3)	Excavator (hr)	Bulldozer (hr)	Dump truck (hr)	Water truck (hr)	Grader (hr)	Labor (hr)
High-moderate	11	1,741	82	108	19	22	1	28
Moderate or moderate-low	108	8,433	391	664	71	120	9	127
Low	35	1,828	80	114	12	21	4	29
Total	**154**	**12,002**	**553**	**886**	**102**	**163**	**14**	**184**

Note: Equipment and labor times do not include hours necessary for opening roads, traveling between sites, transporting culverts, spreading road rock, and spreading straw and mulch.

[a]Excavated volume includes material permanently removed and stored as well as material excavated and reused for backfilling upgraded stream crossings.

PWA estimates that erosion control and erosion prevention remediation in the BSCA project area will require 553 hr of excavator time and 886 hr of bulldozer time (Table 6). An excavator and bulldozer will not be needed at all treatment sites, and some treatment sites will require one but not the other. Dump truck operators will require 102 hr to transport excavated spoil material to disposal sites and to import clean backfill. Approximately 163 hr of water truck time will be needed for applying water to dry soils during road-drainage treatment implementation, and for backfilling excavations at stream crossings and ditch relief culverts. Finally, approximately 184 hours of labor time will be required for various tasks, including culvert installation or replacement.

9 ESTIMATED COSTS

The estimated total cost to implement the recommended erosion control and erosion prevention treatments for the BSCA project is $736,337 (Table 7). Approximately $189,927, or 26% of the total, is for the purchase of rock and culvert materials. A total of $138,560, or 19% of the total project cost, is projected for detailed project planning, on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project analysis and reporting. Costs detailed in Table 7 also include expenses for the use of lowboy trucks to haul construction equipment to and from the work area (footnote "f"); truck/trailer time for delivering straw mulch and culverts to work sites (footnote “g”); time required by a motor grader and water truck to create a “finished” grade to banks, ditches, and road surfaces following rough construction by other equipment (footnote “h”); and labor time for spreading straw mulch and seed (footnote “i”).

Most of the treatments listed in this plan are not complex or difficult for equipment operators with experience in road upgrading and decommissioning operations on forestlands. The costs in Table 7 are assumed reasonable if work is performed by experienced outside contractors, and there is no added overhead for contract administration and pre- and post-project surveying. The use of inexperienced operators or the wrong combination of heavy equipment would require additional technical oversight and supervision in the field, as well as an escalation of the costs to implement the work. To help insure success of the project, it is imperative that only the most experienced and reliable heavy equipment operators be employed under the supervision of a professional geologist, and that the project coordinator is on-site full time at the beginning of the project and intermittently after equipment operations have begun.

10 CONCLUSIONS

This assessment is a comprehensive evaluation of road related erosion and sediment delivery to streams along a total of 67.1 mi of maintained, seasonal, and abandoned, roads in Big Salmon Creek subwatershed of Salmon Creek, Mendocino County, California. It provides field data and historical aerial photographic analyses to identify and quantify currently observable and possible future sources of sediment and erosion along roads on property owned and managed by The Conservation Fund.

An integral part of this assessment is a prioritized plan of action for cost-effective erosion control and erosion prevention for the assessment area. When implemented and employed in combination with protective land use practices, the treatment prescriptions outlined in this report may be expected to significantly contribute to the long-term protection and improvement of water quality and salmonid habitat in the Salmon Creek watershed.

Table 7. Estimated equipment times and costs to implement erosion control and erosion prevention treatments, Big Salmon Creek Sediment Source Assessment Project, Mendocino County, California.

Cost category[a]		Cost rate[b] ($/hr)	Estimated Project Times			Total estimated costs[e] ($)
			Treatment[c] (hr)	Logistics[d] (hr)	Total (hr)	
Move in, move out[f]	Excavator	115	12	--	12	1,380
	Bulldozer	115	12	--	12	1,380
	Grader	115	12	--	12	1,380
	Dump Truck	100	4	--	4	400
	Water Truck	100	4	--	4	400
	Roller	115	12	--	12	1,380
	Truck/trailer	59	10	--	10	590
Road opening	Excavator	150	70	--	70	10,500
	Bulldozer	153	76	--	76	11,628
Heavy equipment for site-specific treatments[g]	Excavator	150	534	160	694	104,100
	Bulldozer	153	430	129	559	85,527
	Dump truck	100	102	31	133	13,300
	Roller	90	40	12	52	4,680
	Water truck	100	69	21	90	9,000
	Truck / trailer	59	70	21	91	5,369
Heavy equipment for road drainage treatments[h]	Excavator	150	19	6	25	3,750
	Bulldozer	153	485	146	631	96,543
	Roller	90	40	12	52	4,680
	Water truck	100	134	41	175	17,500
	Grader	109	54	17	71	7,739
Laborers[i]		54	281	84	365	19,710
Rock costs (includes trucking for 2,739 yd^3 of road rock and 734 yd^3 of riprap)						121,564
Culvert materials costs (20' of 12", 160' of 18", 890' of 24", 70' of 30", 160' of 36", 100' of 42", 150' of 48", 40' of 54", 50' of 60", and 120' of 72", including costs for couplers, elbows, and trash racks)						68,363
Mulch, seed, and planting materials for 6.05 acres of disturbed ground[j]						4,164
Permitting						2,250
Miscellaneous costs						500
Supervision, coordination, layout, and reporting[k]						138,560
Estimated sediment savings: 18,090 yd^3				**Total Estimated Costs: $736,337**		

(Continued on next page.)

Table 7—continued.

[a]Costs excluded from the list are for (1) tools and miscellaneous materials, (2) variable administration and contracting expenses, and (3) repaving upgraded roads.

[b]Heavy equipment costs include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[c]Treatment times refer to equipment hours expended explicitly for erosion control and erosion prevention work at all project sites and roads.

[d]Logistics times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from site to site, and conference times with equipment operators to convey treatment prescriptions and strategies. Logistic times for laborers (30%) include estimated daily travel time to project area.

[e]Total estimated project costs for equipment rental and labor are based on private sector rates at prevailing wage. Materials costs are subject to change.

[f]Lowboy hauling costs area based on 2 hauls each (1 to move in and 1 to move out) at 6 hr/ trip for excavator, bulldozer, roller, and grader.

[g]An additional 35 hr of truck/trailer time are added for delivering straw to sites, and an additional 35 hr of truck and trailer time are added for delivering culverts.

[h]An additional 40 hr of water truck time and 40 hr of grader time and 40 hr of roller time are added for final grading and spreading road rock.

[i]An additional 123 hr of labor time are added for spreading straw mulch and seeding. This includes 26 hr of labor for initial delivery of straw to sites.

[j]Seed costs are based on 35 lb of native seed per acre at $9.75/lb. Straw needs are 50 bales per acre at $6.95/bale. Labor time for straw mulching and seeding is 97 hr.

[k]Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work, and post-project documentation and reporting.

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12 SUPPLEMENTARY INFORMATION: TERMINOLOGY AND TECHNIQUES USED IN ROAD RELATED EROSION ASSESSMENTS

12.1 Sources of Road Related Erosion

Sources for erosion and sediment delivery in the assessment area are divided into two categories: (1) sediment from specific treatment sites, and (2) sediment from the surfaces of road segments of varying lengths—and their associated cutbanks and inboard ditches—that are hydrologically connected[8] to streams.

Site-specific erosion is termed *episodic*, as it is projected to occur over an indeterminate time frame, usually from months to decades. Some sites may show evidence for imminent failure, erosion, and sediment delivery, such as unstable landslides on steep hillslopes. Other sites may show the potential for erosion and sediment delivery, but will not activate until a threshold is reached based on a combination of factors at the site (for example, type of geologic substrate, type and density of vegetative cover; size of channel, steepness of terrain, and intensity and duration of rainfall).

In contrast to site-specific episodic erosion, erosion from road surfaces is termed *chronic* because it occurs on an on-going basis, and is primarily dependent on the level of road usage, the erodibility of the road surface, and the steepness of the road. PWA estimates chronic erosion for a 10-year period, based on empirical calculations for fine sediment generation from hydrologically connected road surfaces and associated cutbanks and ditches. The amount of fine sediment delivered to stream channels from eroding road surfaces can be substantial when evaluated on timescales similar to those applied to episodic erosion sites (mulit-decades), and in some watersheds may represent the greater detriment to water quality and fish habitat.

12.1.1 Site-specific erosion sources

Stream crossings

A *stream crossing* is a ford or structure on a road (such as a culvert or bridge) installed across a stream or watercourse (USDA Forest Service, 2000). When they erode, sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded is delivered directly to the stream. The size of the stream affects the rate of sediment movement, but any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels.

Common features of stream crossings that lead to erosion problems include (1) fill crossings without culverts, (2) crossings with undersized culverts, (3) crossings with culverts susceptible to being plugged, (4) crossings with logs or debris buried in the fill intended to convey streamflow (i.e., *Humboldt crossings*), (5) crossings with a potential for stream diversion, and (6)

[8] *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

crossings that have currently diverted streams.

A *fill crossing* is a stream crossing without a culvert to carry the flow through the road prism. At such sites, stream flow either crosses the road and flows over the fillslope, or is diverted down the road via the inboard ditch. Most fill crossings are located at small Class II or III streams that only have flow during larger runoff events. *Armored fill crossings* and *ford crossings* are similarly designed to be functional, unculverted stream crossings. A properly constructed armored fill crossing is based on a site-specific design, using a mix of riprap-sized rock to minimize erosion while allowing the stream to flow across the road prism. A ford crossing may use rock armor to stabilize the roadway, but the road is built essentially on the natural stream channel, and fill is not used.

Humboldt crossings are constructed from logs or woody debris, usually laid parallel to flow, which are then covered with fill. Humboldt crossings are susceptible to plugging, gullying, and washout during storm flows (Weaver et al., 2006). Older Humboldt log crossing structures beneath more recently installed culverts are often found in rural northern California road networks.

Large volumes of erosion may occur at stream crossings when culverts are too small for the drainage area and storm flows exceed culvert capacity, or when culverts become plugged by sediment and debris. In these instances, flood runoff will spill across the road, allowing erosion of the stream crossing fill and development of a *washout crossing*. Washout crossings will remain highly problematic as the stream banks continue to erode to a natural grade.

Serious erosion problems may occur at a stream crossing that has a high *diversion potential*, which means that flow is diverted down the road, either on the roadbed or in the ditch, instead of spilling over the fill and back into the same stream channel. In this case, the roadbed, hillslope, and/or stream channel that receive the diverted flow may become deeply gullied or destabilized. As road and hillslope gullies enlarge over time, they will deliver increasingly greater quantities of sediment to stream channels (Hagans et al., 1986), and streamflow diverted onto steep, unstable slopes may trigger hillslope landslides.

To be considered adequately sized, culverts at stream crossings must have the capacity to convey a 100-year peak storm flow[9] with sediment and organic debris in transport (Weaver et al., 2006). In areas where large woody debris may also be a problem, trash racks should be installed slightly upstream from culvert inlets as an additional precaution against plugging. Substandard stream crossing culverts include those that are not large enough to convey a 100-year flow, or are installed at too low of a gradient through the stream crossing fill to prevent plugging. Improper, low-gradient culvert installations were once common because they required shorter lengths of pipe to convey flow through the road, and were therefore used to minimize construction costs. However, in the long run these cost-cutting measures prove detrimental to erosion control and maintenance costs because the culvert discharges water onto unconsolidated road fill, rather than

[9] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

into the pre-existing stream channel, which results in pronounced erosion of the outboard, downstream fill face.

Ditch relief culverts

A *ditch relief culvert* (DRC) is a plastic, metal, or concrete pipe installed beneath the road surface to convey flow from an inside road ditch to an area beyond the outer edge of the road fill. When properly spaced, DRCs limit the quantity of water available to cause erosion at any single location, allowing flow to disperse and reducing the likelihood of gullies forming at their outlets. It is sometimes necessary to install downspouts or rock armor at DRC outlets to further disperse energy and prevent erosion.

Landslides

Landslides with the potential to fail during periods of high and prolonged rainfall events are identified in the field by tension cracks, scarps showing vertical displacement, corrective regrowth on trees (i.e., pistol butt trees) and perched, hummocky fill indicating surface instability. As a standard practice, PWA maps all landslides observed in the field, but only Inventories those that are associated with roads and show a potential to deliver sediment to a watercourse. Types of landslides in a road related erosion assessment typically include (1) road fill failures, (2) landing fill failures, (3) hillslope debris slides, and (4) deep-seated, slow landslides. The majority of treatable landslides in an assessment area are often the result of failure of unstable fill and sidecast material from earlier road construction. Preemptive excavation of small, current or potential landslides is an effective technique for erosion control, achieved by removing the eroding material and redepositing it in a stable, designated location either at or near the treatment site. Conversely, large, deep-seated landslides are usually technically infeasible to treat.

Additional site-specific sediment sources

Additional, typically less frequent sources of sediment delivery include: (1) discharge points for road surface, cutbank, and ditch erosion; (2) point source springs; (3) sites of bank erosion; (4) swales; (5) channel scour; and (6) non-road related upslope gullies.

Unpaved road surfaces, and their associated cutbanks and inboard ditches, are major sources for erosion and delivery of fine sediment to stream channels. Road surface, cutbank, and ditch erosion is termed “chronic” because it occurs throughout the year, and may include one or more of the following processes: (1) mechanical pulverizing and wearing down of road surfaces by vehicular traffic; (2) erosion of unpaved road surfaces by rainsplash and runoff during periods of wet weather; (3) erosion of inboard ditches by runoff during wet weather; and (4) erosion of cutbanks by dry ravel, rainfall, slope failures, and brushing/grading practices. *Discharge points for road surface, cutbank, and ditch erosion* are locations where sediment-laden flow from poorly drained road/cutbank/ditch segments exits the roadway to be delivered into the stream system. Discharge points are often in the form of roadside gullies or water bars, but on some low gradient or streamside roads may simply be low spots where concentrated flow exits the road and is delivered directly into a stream without gully formation.

Point source springs refer to sites where spring flow is entering the roadbed and causing erosion. Flow from multiple springs may become concentrated along a road with inadequate drainage structures, creating roadside gullies or fillslope failures. *Swales* are channel-like depressions that only carry minor flow during periods of extreme rainfall. *Bank erosion* sites refer to locations of streambank erosion caused or exacerbated by emplacement of a nearby road. *Non-road related upslope gullies* are sites of focused runoff channeled from upslope areas during high discharge.

12.1.2 Evaluation of hydrologically connected road segments

PWA measures the lengths of hydrologically connected road segments adjacent to sediment delivery sites, such as on either side of a stream crossing, ditch relief culvert, or discharge point, to derive an estimate for total potential sediment delivery from connected road surfaces in the project area. In addition, because the adjacent hydrologically connected road segments contribute to the overall erosion and sediment delivery problem at a site, PWA considers the treatment site and adjacent road segments as a unit when estimating future sediment delivery and developing treatment prescriptions for that location.

12.2 Overview of Storm-Proofing Roads (Road Upgrading and Decommissioning)

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Pacific Watershed Associates, 1994; Weaver and Hagans, 1999; Weaver et al., 2006). Upgraded roads are kept open, and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate the 100-year peak storm flow[10]. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as "hydrologically invisible" as possible, that is, to reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (see table, next page), all proven to contribute to long-term improvement and preservation of watershed hydrology and aquatic habitat.

12.2.1 Road upgrading

Road upgrading involves a variety of treatments used to make a road more resilient to large storms and flood flows. The most important of these include upgrading stream crossings (especially culvert upsizing to accommodate the 100-year peak storm flow and debris in transport, and correct or prevent stream diversion); removing unstable sidecast and fill materials from steep slopes; and applying road drainage techniques (e.g., installing ditch relief culverts, removing berms, constructing rolling dips, insloping or outsloping the road) to improve dispersion of surface runoff. Road upgrading usually also includes adding road rock or riprap as needed to fortify roads and crossings.

<u>Installing rolling dips</u>

Rolling dips are installed on low- to moderate-gradient hydrologically connected[11] roads to disperse surface runoff and discharge it onto native hillslope below the road. Rolling dips extend from the inboard edge to the outboard edge of a road, and are constructed at intervals as needed to control erosion (typically 100, 150, or 200 ft). They are effective in reducing year-round ("chronic") sediment delivery from road surfaces, and are designed to be easily drivable and not impede vehicular traffic.

<u>Road shaping</u>

Road shaping changes the existing geometry or orientation of the road surface, and is accomplished through insloping (sloping the road toward the cutbank), outsloping (sloping the road toward the outside edge), or crowning (creating a high point down the center axis of the road so that it slopes equally inward and outward). Like rolling dips, road shaping is used to prevent uncontrolled delivery of road surface runoff by dispersing it into the inside ditch or onto the hillslope below the road. This is also effective in preventing the formation of gullies at the edge of the road, and localized slope instability below the road.

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[10] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.
[11] *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

Characteristics of storm-proofed roads (*from* Weaver et al., 2006).

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers installed).
- Stream crossing outlets are protected from erosion (extended beyond the base of fill; dissipated with rock armor).
- Culvert inlet, outlet, and bottom are open and in sound condition.
- Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert.
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Fills are stable (unstable fills are removed or stabilized).
- Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts.
- Class I stream crossings meet CDFG and NMFS fish passage criteria (Taylor and Love, 2003).

Storm-proofed fills

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

Road surface drainage

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

Installing ditch relief culverts

A ditch relief culvert is a drainage structure (usually an 18 in. pipe) installed across a road prism to move water and sediment from the inboard ditch so that it can be dispersed on native hillslope beneath the road. Ditch relief culverts are used to drain ditch flow on roads that are too steep for rolling dips or outsloping, as well as at sites with excessive flow from springs or seepage from cutbanks.

Excavating unstable fillslope

The fillslope, the sloping part of the road between its outboard edge and the natural ground surface below, may fail or show signs of potential failure. As a preventative measure, unstable fillslope sediment is excavated and relocated to a permanent, stable spoil depository site.

Upgrading stream crossings

Techniques used to remediate road related erosion at a stream crossing are dependent on the size of the stream channel, and specific physical characteristics at the crossing site. Class I and large stream crossings may require a bridge, or, if their banks are small or low gradient, a ford crossing may be suitable, particularly if seasonal use is anticipated. A common approach to upgrading moderate sized Class II and III crossings is to construct a culverted fill crossing capable of withstanding the 100-year flood flow. Techniques for upgrading small stream crossings include:

Installing or replacing culverts. A culvert capable of withstanding the 100-year storm flow, including expected sediment and debris, is installed or replaced in the fill crossing. Culverts on non fish-bearing streams are placed at the base of fill, in line and on grade with the natural stream channel upstream and downstream of the crossing site. Backfill material, free of woody debris, is compacted in 0.5-1.0 ft thick lifts until 1/3 of the diameter of the culvert has been covered. At sites where fillslopes are steeper than 2:1, or where eddying currents might erode fill on either side of the inlet, rock armor is applied as needed.

Installing an armored fill. Armored fills are installed on smaller stream crossings with relatively small fill volume, but where debris torrents are common, channel gradients are steep, or inspection and maintenance of a culverted crossing is impossible. The roadbed is heavily rocked, and a keyway in the outboard fillslope is excavated and backfilled with interlocking rock armor of sufficient size to resist transport by stream flow. Armored fill crossings are constructed with a dip in the axis of the crossing to prevent diversion of the stream flow, and focus the flow over the part of the fill that is most densely armored.

Installing secondary structures. A variety of secondary structures may be used to increase the function of small stream crossings by allowing uninterrupted stream flow, decreasing flooding, and controlling erosion. Where a culvert has been improperly installed too high in the fill, a *downspout* may be added to its outlet to release the flow close to the ground surface, rather than letting it cascade from the height of the culvert. *Rock armor* may be used to buttress steep fillslopes, as well as to prevent erosion of inboard or outboard fillslopes by eddying currents. A *trash rack* placed in the channel above a culvert inlet will trap debris and reduce plugging. To prevent stream diversion should the culvert become plugged or its capacity exceeded, a *critical dip* (essentially a rolling dip constructed in line with the stream channel) may be installed to ensure that stream flow will be directed across the road and back into the natural channel. Finally, an *overflow culvert* may be a necessary addition at a culverted crossing where, because of site conditions, plugging or capacity exceedence of the primary culvert is anticipated.

12.2.2 Road decommissioning

In essence, decommissioning is “reverse road construction”, although complete topographic obliteration of the roadbed is not usually required to achieve cost-effective erosion prevention. In most cases, serious erosion problems are confined to a few, isolated locations along a road (perhaps 10% to 20% of the full road network to be decommissioned) where stream crossings need to be excavated, unstable sidecast on the downslope side of a road or landing needs to be removed before failure, or the road crosses unstable terrain and the entire road prism must be removed. But typically, lengths of road beyond the extent of individual treatment sites usually require simpler, permanent improvements to surface drainage, such as surface decompaction, additional road drains, and/or partial outsloping. As with road upgrading, the heavy equipment techniques used in road decommissioning have been extensively field tested, and are widely accepted (Weaver and Sonnevil, 1984; Weaver and others, 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994).

Road ripping or decompaction

Road ripping is a technique in which the surface of a road or landing is disaggregated or "decompacted" to a depth of at least 18 in.using mechanical rippers. This action reduces or eliminates surface runoff and usually enhances revegetation.

Installing cross-road drain

Cross-road drains (also called “deep waterbars”) are large ditches or trenches excavated across a road or landing surface to provide drainage and prevent runoff from traveling along, or pooling on, the former road bed. They are typically installed at 50, 75, 100 or 200 ft intervals, or as necessary at springs and seeps. In some locations (e.g., streamside zones), partial outsloping may be used instead of cross-road drain construction.

In-place stream crossing excavation (IPRX)

IPRX is a decommissioning treatment used for roads or landings that are built across stream channels. The fill (including the culvert or Humboldt log crossing) is completely excavated and the original streambed and side slopes are exhumed. Excavated spoil is stored at nearby, stable locations where it will not erode. In some cases, this may necessarily be as far as several hundred feet from the crossing. An IPRX typically involves more than simply removing a culvert, as the underlying and adjacent fill material must also be removed and stabilized. As a final measure, the sides of the channel may be cut back to slopes of 2:1, and mulched and seeded for erosion control.

Exported stream crossing excavation (ERX)

ERX is a decommissioning treatment in which stream crossing fill material is excavated and the spoil is hauled off-site for storage (the act of moving spoil material off-site is called “endhauling”). This procedure is necessary when large, stable storage areas are not available at or near the excavation site. It is most efficient to use dump trucks to endhaul the spoil material.

In-place outsloping (IPOS)

IPOS (also called "pulling the sidecast") calls for excavation of unstable or potentially unstable sidecast material along the outside edge of a road prism or landing, and placement of the spoil on the roadbed against the corresponding, adjacent cutbank or within several hundred feet of the site. As a further decommissioning measure, the spoil material is placed against the cutbank to block access to the road.

Export outsloping (EOS)

EOS is a technique comparable to IPOS, except that spoil material is moved off-site to a permanent, stable storage location. EOS is required when it is not possible to place spoil material against the cutbank, e.g., where the road prism is narrow or where there are springs along the cutbank. EOS usually requires dump trucks to endhaul the spoil material. This technique is used for both decommissioning and upgrading roads, but as the roadbed is partially or completely removed, EOS is more commonly used for decommissioning.

12.3 Determining Treatment Immediacy and Cost-Effectiveness

Identifying *treatment immediacy* is an integral part of an assessment used to prioritize sites prior to implementation. Treatment immediacy is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work. It is defined as “high,” “moderate,” or “low,” and represents the urgency of treating the site before it erodes or fails. An evaluation of treatment immediacy is based on the following criteria: (1) *erosion potential*, or whether there is a low, moderate, or high likelihood for future erosion at a site; (2) *sediment delivery*, which is an estimate of the sediment volume projected to be eroded from a site and delivered to a nearby stream; and (3) the value or sensitivity of downstream resources being protected. Generally, sites that are likely to erode or fail in a normal winter, and are expected to deliver significant quantities of sediment to a stream channel, are rated as having high treatment immediacy.

The *erosion potential* of a site is a professional evaluation of the likelihood that erosion will occur during a future storm, based on local site conditions and field observations. It is a subjective probability estimate, expressed as “low,” “moderate,” or “high,” and not an estimate of how much erosion is likely to occur. The volume of sediment projected to erode and reach stream channels is described by *sediment delivery*, which plays a significant role in determining the treatment immediacy for a site. The larger the volume of potential future sediment delivery to a stream, the more important it becomes to closely evaluate the need for treatment.

From this assessment, treatment immediacy and *cost-effectiveness* may be analyzed, along with the client’s transportation needs, to prioritize treatment sites or locations for implementation. *Cost-effectiveness* is not only a necessary consideration for environmental protection and restoration projects for which funding may be limited, but is also an accepted and well-documented tool for prioritizing potential treatment sites in an area (Weaver and Sonnevil, 1984; Weaver and Hagans, 1999). A quantitative estimate for cost-effectiveness is determined by dividing the cost of accessing and treating a site by the volume of sediment prevented from being delivered to local stream channels. The resulting value, or *sediment savings*, provides a comparison of cost-effectiveness among sites, and an average for the entire project area. For example, if the cost to develop access and treat an eroding stream crossing is projected to be \$5000, and the treatment will potentially prevent 500 yd^3 of sediment from reaching the stream channel, the predicted cost-effectiveness for that site would be \$5000/500yd^3, or \$10/yd^3.

PWA further evaluates cost-effectiveness for an entire assessment area by organizing sites into logistical groups based on similar requirements for heavy equipment and materials, and addressing these as a unit to minimize expenses. Furthermore, although sites and road segments with the lowest immediacy ratings are placed last on the list for treatment, it is sometimes possible to treat these sites once the project is underway, as opportunities to cost-effectively treat low-immediacy sites often arise when heavy equipment is already located nearby to perform maintenance or restoration at higher-immediacy sites.

12.4 References for Supplementary Information

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Appendix A

Field observations and treatment recommendations for road related sites

2009 Big Salmon Creek Sediment Source Assessment Project
Mendocino County, California

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
1	26100	L	Stream crossing	454	352	623	Adequately sized plastic culvert was installed in 2007. Inboard and outboard fillslopes were armored with 3/4' and smaller rock. Culvert outlet is ~4' high in fill but fillslope is adequately armored at culvert outflow.	1) Install 1 rolling dip to the left road reach and 2 to the right road reach 2) Outslope 500' of right road reach
2	26100	ML	Stream crossing	178	110	185	Culvert has been recently installed in 2007. Outlet of culvert is ~5' high in the fill. A small headcut exists ~8' below the outlet. This will continue to migrate and develop into a splash zone below the outlet and deliver ~4yd.	1) Excavate headcut area below outlet in a 6'wide x 8' long keyway. 2) Install 5yd of 1' diameter armor to harden knickpoint 3) Install 2 rolling dips, one to the left of the crossing at the current waterbar location and one to the right road reach.
3	26100	ML	Stream crossing	113	10	273	Small class III stream with little channel morphology. Crossing is grassed over and sediment transport is not present. Any future erosion will be from saturated outboard fill slope failure.	1) Construct armored fill. Keyway construction 30' long by 6' wide at base, 12' wide at top, and 2' deep. 2) Armor keyway with 27yd of 1.5' diameter and smaller rock armor 3) Outslope right road reach for 250' 4) Refine armored fill dip

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
4	26100	ML	Stream crossing	36	10	537	This is a very low power stream with little channel morphology above the road. The crossing has been recently dipped to prevent diversion.	1) Redefine dip to accommodate truck traffic 2) Install an armored fill crossing with keyway 10' wide at the top, 4' wide at the base, 26' long and 2' deep. 3) Armor keyway with 18yd of 1' diameter rock 4) Outslope 500' of right road 5) Install 2 rolling dips to the right road reach 6) Rock 1,200 square feet of right road reach and armored fill dip
5	26100	M	Stream crossing	67	0	185	Channel above crossing is crossed by a recently opened skid ~70' above road 26100. Channel between skid and 26100 road is filled with logging debris and flow is piping under wood and soil. A 2' deep collapse hole is developing at the IBR. Flow emerges from LWD on outboard fillslope. Stream flow is piping entirely beneath road.	1) Lower crossing at location of channel to create an armored fill dip and daylight channel. 2) Construct armored fill, excavating keyway 12' wide at the top, 7' wide at base, 31' long, and 2' deep. 3) Armor keyway with 22yd of 1.5' diameter rip-rap 4) Excavate/clean channel above IBR for 20', removing 10+ yards of soil. 5) Geofabric should be used at this site in conjunction with rocks placed in road surface portion of keyway 6) Install 1 rolling dip to right road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
6	26200	M	Road surface	0	778	0	Left road reach on streamside road in pygmy forest shows signs of high/moderate surface erosion delivering to a near origin marshy class II stream. Road is moderately through-cut. A 24" DRC is located ~ 30' to the left of the site. The DRC carries flow and is currently functioning with some minor aggradation at DRC outlet.	1) Install two rolling dips to the left road reach, placing the nearest dip 120' to the left of the current delivery point. Punch dips through the through-cut berm to allow adequate sediment storage/diffusion. Pull berm for 60' left of delivery point. 2) Rock road surface between first dip and delivery point.
7	26200	ML	Stream crossing	22	306	0	Class II crossing with well installed plastic 24" culvert. Spring contribution along 75' of IBD and 40' of springy channel above pipe. Excessive left road reach can be broken up by installation of two rolling dips. Stream diversion potential up to 150' down right road. No critical dip is present.	1) Install critical dip at crossing 2) Install two rolling dips on road reach 3) Rock road reach between closest dip and crossing/critical dip
8	26200	ML	Stream crossing	55	141	405	This stream crossing has a well installed culvert. Both fillslopes are short and steep but adequately buttressed with rock. Right road reach is through-cut. The water bar to the right of the culvert is directing road surface runoff over the OBF and may be delivering a small amount of sediment to the stream.	1) Install 2 rolling dips to the right road reach. 2) Rock road at class II stream crossing with road rock, 12'w x 80'long.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
8.5	26200	ML	Stream crossing	34	125	0	A collapse hole has developed at the head of a buried stream channel. No holes are visible above the hole in the roadbed. Channel depth appears to be below depth of fill. Channel below site is filled with LWD and logging related sediments. Collapse hole is approximately 8'w x 15'L. There is no diversion potential at this site.	1) Excavate road fill and establish a channel from cutbank to natural channel location ~20' below OBR 2) Armor head of excavation with 5yd of 1' diameter rocks. 3) Install 1 cross-road drain to left road reach
9	26000	-	Stream crossing	0	30	227	This bridge has just enough capacity to pass 100-year flow and debris. The abutments are made of cement filled loader tires. The abutments are protected and further supported by 5' diameter rip-rap. Bridge is an old flat car, 12'w x 30'L. Bridge and abutments appear to have little influence on channel morphology. Right road reach is drained with DRCs and rolling dips. This crossing is known as "First Crossing".	No treatment.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
10	27000	HM	Ditch relief culvert	2	2700	75	This DRC outlets 20' from Big Salmon Creek mainstem and delivers via 20’ long 1'w gully. Ditch to left of DRC is filled with sediment and ditch flow crosses road next to bridge (site 9) and delivers to Big Salmon Creek via a 30' long gully. Many waterbars drain the IBD of the left road reach. Left road surface is still hydrologically connected for ~2,700'. Left road reach is native surfaced. Three plugged DRCs and 1 open DRC have been installed on left road. A historic non-delivering landslide is present ~1,800' up left road.	1) Install 18 rolling dips to left road reach. Retain DRCs and construct dips between DRCs. Connect dips to IBD to drain IBD. Rock dips in steep section of road (~10 dips). 2) Inslope road to ditch at landslide location. Do not outlet dips or DRCs onto landslide feature. 3) Clean DRC inlets 4) Outslope upper section of low gradient left road and lower section of low gradient left road. Totals 1000'. Retain ditch where present. 5) Clean 165' of IBD left of delivering DRC

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
11	27000	-	Stream crossing	27	50	0	This is known as "Second Crossing". This bridge is similar in construction to the bridge at site 9, "First Crossing". The abutments are loader tires filled with cement and the abutments have been laterally supported by 4' diameter rip rap. The bridge appears to almost have enough capacity to pass 100-year flow. Bridge dimensions ~30' x 12'. Bridge is located where the stream makes a tight left turn and is not perpendicular to flow. This somewhat compromises the capacity of the crossing. Due to orientation and height, it is possible that this bridge is washed out in a 100-year flow event. Future erosion comes from left abutment. Bridge is cabled to a redwood tree.	No treatment.
12	27000	M	Stream crossing	9	500	0	This is the crossing of a developing class III channel. Upslope harvest and skid and road development have likely led to the development of this channel. Many collapse holes are present upslope of road revealing the subsurface channel. Channel emerges from cutbank ~50' to left of culvert location. Culvert is ~20% plugged with sediment and perpendicular to the road.	1) Install a 24" x 40' culvert at flagged location, left of current culvert (install IBD block). 2) Clean ditch for 40' left of inlet 3) Install a critical dip 4) Install 2 rolling dips to left road, draining IBD.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
13	27000	ML	Stream crossing	20	0	85	Class III crossing with recently installed plastic 24" culvert. Channel morphology is minimal below crossing and allows for adequate sediment filtering on wide terrace. However, culvert was installed with inlet above or equal to left IBD elevation. Flow can divert down left IBD. Skid trail 90' upslope of crossing has recently been treated restore flow path to native channel. Future erosion will likely come from migration of knickpoint at the top of inlet excavation.	1) Plug left IBD to prevent diversion down ditch. 2) Install critical dip along right hinge of crossing.
14	27000	M	Ditch relief culvert	2	18	132	This site (and site 15) is at a low point in the road. The cutbank here is very erosive and has failed, plugging the culvert historically. An old road prism is ~12' below the road. Outlet flow gullies the base of the outboard fillslope and then delivers to Big Salmon Creek at site 16.	1) Outslope right road reach 130' to the right of DRC. 2) Install a slotted riser on DRC inlet 3) Install an energy dissipater at DRC outlet (5yd of 1' diameter rocks) 4) Clean ditch and cutbank 80' right of DRC and 15' to the left
15	27000	M	Ditch relief culvert	0	210	157	Recently installed 18" plastic DRC drains 210' of left road surface. Outlet is very close to class I stream. There is a nice root wad dissipater on outlet. Also cutbank shows signs of small failures and slumping which could block inlet.	1) Install one rolling dip approximately 120' up left road to drain the road and IBD. 2) Install a slotted riser on the inlet to prevent inlet from plugging if there is a bank failure. Connect slotted riser to inlet.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
16	-	ML	Landslide	6	0	0	Historic railroad/legacy road grade has partially failed directly into Big Salmon Creek. Flow from sites #14 and #15 deliver water to feature. Most erosion has already occurred but left lateral scarp and headscarp may have additional failures.	1) Excavate approximately 18' x 6' x 2' material from headscarp and left lateral scarp of slide. Lay back bank to accommodate flow from sites # 14 and 15. Access may be difficult and excavator may have to ramp down and move material twice.
17	-	ML	Landslide	38	0	0	The road at this location is directly on a floodplain/terrace of Big Salmon Creek mainstem. A tree and OBF cribbing log have failed into Big Salmon Creek along with soil/fill from the outboard fillslope. Access should be relatively easy. FE= Root wad + deposit - 8yd Bank layback - 30yd	1) Excavate steep bank/road fill, 75'w x 2'd x 6'high = 23yds. Excavated material will have to be moved twice to reach dump truck on road 27000.
18	27000	M	Stream crossing	68	75	0	This crossing is located in the toe of a dormant debris landslide feature mapped by CGS and PWA (landslide history). The channel is subsurface above the road and is exposed just above the cutbank. The cutbank is gullied by the incising channel to a depth of ~3'. The culvert is set too shallow in the fill and some sediment remains in the culvert. The cutbank is likely to fail above the inlet when saturated and plug the pipe.	1) Replace culvert with a 24" culvert. 2) Install a critical dip 3) Lay back cutbank at TOP and armor to stabilize with 5yd of 1' diameter rock, (10yd excavation).

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
19	-	M	Stream crossing	8	400	70	This stream crossing lies about 60' below site #18 on abandoned road (railroad grade). Small sediment fan on IBR of road. Small 3 yd failure along OBR. Outboard fill face is directly on top of right stream bank at Big Salmon Creek. Access for treatment from left road reach. This feature located on toe of dormant debris slide identified by CGS.	1) Decommission crossing laying back slopes 2:1. Place BOT at fill/native stream bank interface. 2) Material will need to be endhauled out left road reach, approximately 400'. Road is covered with small trees and brush that will need to be reopened. 3) Install 5 cross-road drains should be installed to left road reach. All bare soils should be mulched at this site due to its proximity to Class I.
20	2700	ML	Stream crossing	69	0	369	This channel is entrenched with 6-7' vertical banks. The culvert is well placed in the fill, but high flows in the mainstem of Big Salmon Creek may backwater up the culvert. The right ditch has been cleaned recently and an inboard berm has been created, functionally ponding water on the right road. Large woody debris is present in the upstream channel. If culvert capacity was exceeded, flow would divert to left and exit road through a berm break ~50' left of the crossing. Stream is named "Stone Gulch".	1) Install a critical dip 2) Pull berm on right road for 60'. 3) Outslope 60' of right road 4) Install one rolling dip to the right road reach above the intersection with road 27000 RR 5) Excavate crossing from TOP to BOT. 6) Replace culvert with a 54"x40' culvert 7) Armor base of outboard fillslope with 8yd of 1.5' diameter riprap

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
21	27000	ML	Stream crossing	339	1000	120	Active channel width is 7.5'. This fish crossing can potentially pass steelhead but not coho salmon. The upstream channel reach flows across a heavily tractored fan, created by the BIS of Kitchen Gulch as it reaches the low gradient Big Salmon Creek stream valley. Some fill and large woody debris should be removed between TOP and IBR if a new crossing structure is installed. The pool below is deep enough to facilitate some fish passage.	1) Between TOP and inlet, establish an 8'wide channel with 2:1 sideslopes 2) Armor base of outboard and inboard fillslopes with 24yd of 2' diameter rip rap 3) Outslope 700' of left road reaches 4) Install 4 rolling dips to left road reaches 5) Install a critical dip
22	27000	M	Road surface	1	0	200	Road is located high on an inner gorge slope above Big Salmon Creek. Multiple waterbars currently drain road surface. A gully has been formed at one waterbar and extends to Big Salmon Creek.	1) Outslope 250' of road, 200' up right road and 50' down left road reach.
23	27000	ML	Ditch relief culvert	0	100	250	18" culvert with downspout that releases water immediately above Class I Big Salmon Creek. Cutbank is wet and there is evidence of a spring and possibly year-round water. There is no gully below downspout but suspend material will deliver. There is evidence of some water pooling on left road. The ditch is heavily vegetated with fern and grass.	1) Pull berm and outslope road, retaining inboard ditch for 50' of the right road 2) Rock and inslope left road 100' through the through-cut

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
24	27000	ML	Stream crossing	102	58	0	Class II crossing that is well installed, minus the lack of a critical dip. Crossing is only 125' above Class I Big Salmon Creek. Inboard and outboard fillslopes are rock armored with 2.5' diameter rock. Channel is on bedrock above the crossing. A notched weir log serves as a gradient control ~10' below the outlet. All features are functioning properly. There is a 3" pvc bypass culvert diverting water around stream to the water tank on the nearby landing to the right. Inlet of pvc culvert is well upstream of the crossing. Tank outlet is located at culvert outlet.	1) Install critical dip. ** Be careful of the buried 3" PVC pipe
25	27000	L	Spring	0	110	0	The spring flow at this site is conveyed over the road surface by a rocked waterbar. Road surface runoff in storms, combined with spring flow, delivers directly to Big Salmon Creek mainstem. Delivery % is very low.	1) Install a rolling dip to convey spring flow across road.
26	27000	ML	Ditch relief culvert	0	219	25	12" DRC delivers to Big Salmon Creek. Currently, left road reach drains back into inboard ditch. The ditch is wet from a cutbank spring. Above here, ditch shows signs of being wet seasonally. Ditch is well vegetated and stable. Berm present on OBR of left road.	1) Replace DRC with an 18" x 40' DRC. 2) Outslope and remove berm above existing waterbar, approximately 200' of outsloping and 100' of berm removal 3) Do not clean IBD.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
27	27000	M	Stream crossing	43	4	85	This stream crossing has been recently upgraded to an armored fill and has no diversion potential. The stream is well defined ~100' upslope, the stream fans at a disturbed, more gently graded slope (35%) and diverges into 3 separate channels. These channels gully down the cutbank and have eroded the outboard fillslope. Below road 27000 stream flows onto an old road/railroad grade. An alluvial fan has developed on the lower road and stream flow travels down the road to the right ~50' before delivering to Big Salmon Creek. An old fillslope failure exists on the lower road at the delivery point. Additional future erosion from cutbank layback (3'd x 20'L x 3'w) x 2 = 14yd.	1) Install/improve the armored fill at crossing. 2) Excavate keyway through both fillslopes, 12'w at base, 10'w at top, 36' long, and 3' deep. 3) Armor keyway with 45yd of 1.5' diameter rocks (5yd of rock is already onsite) 4) Construct armored fill dip to collect/convey flow from all channels. 5) Outslope 60' of right road above large redwoods on OBF to drainage divide. 6) Install 1 road to left road reach
28	27000	M	Stream crossing	95	20	100	Class II crossing with what appears to be a rusty undersized pipe. Everything functions properly as is. Diversion potential exists to the right. There is a splash zone gully (11yd) at outlet which connects directly to Class I Big Salmon Creek. Bedrock channel exists approximately 25' above inlet.	1) Replace culvert with a 36" x 50' 2) Armor culvert outfall channel with ~5yd of rip rap. 3) Install critical dip 4) Buttress base of outboard fillslope with 5yd of 1.5' diameter rock
29	27000	ML	Stream crossing	9	100	60	Very small spring fed Class III stream crossing. Culvert is rusted and only 12". There is a spring that looks to be wet most of the year just upslope from the inlet. This crossing has a High plug potential.	1) Excavate crossing from TOP to BOT and replace culvert with an 18"x40' culvert. 2) Install a critical dip

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
30	27000	M	Stream crossing	3	140	0	This stream is spring fed. Flow is diverted down right inboard ditch at a low gradient. Sediment has filled up the inboard ditch historically and the ditch has been recently cleaned out at confluence with the stream channel. No historic channel is visible below the road. Big Salmon Creek mainstem is ~30' below road 27000. **A small hole exists on the IBR ~12' left of the stream crossing axis. Stream/spring flow does not appear to emanate, but this hole should be examined at time of implementation.	1) Install a 24" culvert at stream crossing, leaving existing culvert in place. Extend outlet to BOT. 2) Install a critical dip 3) Examine hole in IBR~12' left of the stream crossing axis.
31	27000	ML	Stream crossing	40	0	30	This stream has been heavily tractored. The reach of channel immediately above the road has many sinkholes and subsurface reaches. Flow is diverted down the left IBD to site #32. Ditch is vegetated and aggrading.	1) Install a 24" x 40' culvert with inlet at stream channel and road confluence. Outlet culvert left of the stump and redwoods at the base of fill. 2) Install a critical dip 3) Plug the inboard ditch upon rebuild

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
32	27000	L	Ditch relief culvert	0	258	106	18" DRC that drains a wet inboard ditch and small cutbank spring. There is a downspout on the outlet that discharges directly into the active channel zone of Big Salmon Creek. There is an old 12" DRC set higher in the fill that doesn't appear to ever carry water. Road is relatively flat in this area but does drain down to culvert. Currently DRC carries flow from site #31 Class III which travels down right side IBD.	1) Outslope and remove ditch for 250' left road. 2) Remove berm along left road reach for 200' around big trees 3) Install 1 rolling dip to the left road reach
33	27000	ML	Ditch relief culvert	0	125	65	This DRC has a 1/2 round downspout that extends to Big Salmon Creek mainstem. The left road ditch is springy but waterbars divert flow from ditch across road.	1) Install 1 rolling dip, draining the inboard ditch
34	27000	HM	Stream crossing	92	148	0	Small 12" culvert draining wet class II crossing. Channel upslope is steep and on bedrock. Culvert inlet is partially crushed and plugged ~50%. There is some stored sediment around the inlet area. Outlet is partially plugged as well. Outlet discharges and runs for approximately 20' before it spills over the old railroad grade below. A 30yd actively eroding headcut has formed in the railroad grade. An old fallen Douglas fir temporarily constrains knickpoint migration.	1) Excavate crossing from TOP to BOT 2) Install a 24" x 50' long culvert in the axis of the stream channel at the approximate stream channel grade 3) Lay back banks below the outlet to 2:1 or native stable material. 4) Armor culvert outfall and transition to natural channel below with 10yd of 1.5'-riprap. 5) Install critical dip 6) Install one rolling dip along the left road reach

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
35	27000	M	Road surface	1	250	135	Concentrated road surface runoff is directed over OBF and delivers directly to Big Salmon Creek mainstem. A small rill, 12"w x 4"d extends from the waterbar. Future erosion comes from enlargement of rill and chronic road surface contribution.	1) Outslope 135' of right road reach and 250' of left road reach 2) Install a rolling dip immediately after intersection with seasonal road ~240' left of delivering waterbar
36	27000	-	Stream crossing	119	116	158	Well installed, embedded 6' culvert on a class I, Russell Gulch. Culvert is embedded 2'. Inboard and outboard fillslopes are well armored and vegetated and appear to be stable. Road surface is well rocked with minimal evidence of surface erosion. Stream is low gradient with a bedrock channel above the culvert. Old weir log below outlet has stored sediment below it.	No treatment.
37	27000	ML	Ditch relief culvert	0	90	0	This DRC drains a springy cutbank in a section of road immediately adjacent to Big Salmon Creek. The ditch is highly vegetated and there is no sediment production from the IBD.	1) Outslope road while retaining ditch for 90' left of the DRC.
38	27000	ML	Stream crossing	42	548	0	This 18" plastic culvert services a small Class III with a very small drainage area. Culvert inlet is ~8' to the right of the location that the stream intersects the road. Road surface runoff from the left road reach has over 500' to accumulate and delivers to this site.	1) Outlsope and retain ditch for the 120' immediately adjacent left road reach 2) Install 2 rolling dips to left road reach beyond outsloping. Connect dips to the IBD. 3) Install a critical dip

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
39	26040	L	Stream crossing	508	700	80	This road has been abandoned for >10 years. 2 culverts have been placed in the crossing fill. A plastic 12" culvert was probably the original culvert but has had the inlet plug. A 24" steel culvert looks to have been subsequently placed. A cutbank spring to the right of the culver by ~50' is very active and delivers to the inlet via a 2-3' deep IBD. A 6' deep scour hole has developed beneath the outlet. A gully in the outboard fillface is probably from past over topping of the crossing when the plastic CMP was initially plugged.	1) Rock CMP outflow area/splash zone to dissipate energy from outlet flow and stabilize banks 2) Rock crossing with road rock. 3) Install 4 rolling dips to the left road reach
40	26040	L	Stream crossing	219	120	50	This crossing has 2 culverts (18" + partially plugged 12"). There is a small 1/4 yd past erosion splash zone at outlet. Culverts are somewhat curved and light cannot be seen through the pipes. The outboard fillslope fillface has several small rills and scarps from superficial failures. These features are old and indicate no recent instability or erosion. This stream has so little flow that the erosion potential here is low.	1) Install a critical dip

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
41	26040	M	Stream crossing	148	210	0	Relatively well installed 24" culvert on a class III. A root wad is jammed into the channel ~4' below the outlet. A splash zone gully has formed in the channel between the outlet and root wad. High velocity flow from outlet will deflect off of root wad and erode the left bank of the stream (up to 10yds FE). This crossing also has a diversion potential to the right. A small exists spring just above culvert inlet to the left of the crossing.	1) Install a critical dip 2) Remove stump/root wad from channel below the outlet 3) Armor splash zone at outlet with 10yd of 1.5' diameter rock armor for the purpose of energy dissipation and bank erosion control 4) Install 2 rolling dips to the left road
42	26000	M	Landslide	162	0	0	This large slide probably evacuated 1,200 yd of landing fill and native hillslope. The slide deposit now sits partially in the lower portion of the feature and partially in the headwaters of a class II headwall channel. There is the potential for more landing fill to fail from the headscarp and for the stream to erode through the deposit at the toe. The deposit/toe material is nearly inaccessible by heavy equipment and is located in a steep headwall area. Disturbance/treatment at the deposit is not recommended.	1) Lay back scarp between Start and End flags, ~65'w x 4'd x 16' back from current scarp location, i.e. 2:1. 2) Stockpile material locally.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
43	26000	HM	Stream crossing	306	190	60	This is a crossing of an at origin headwall stream with tractored swale above. Flow is subsurface above with sinkholes. The outboard road fill is held in place with log cribbing. This fill is saturated during wet winters and small failures and fill and native ground are creeping below the outlet. Outlet is plugged, likely from fill failure. Left road has historic delivering gullies from laundry runoff.	1) Excavate fill from TOP to BOT flags. 2) Install a 24" culvert at base of fill 3) Excavate deep enough to daylight subsurface channel 4) Armor outboard fill face upon rebuild, 25'h x 17'w x 1.5'd = 24yd with 1.5' diameter rock 5) Armor transition at TOP with 10yd of 1' diameter rock
44	29200	L	Road surface	0	413	0	A waterbar directs road surface runoff into the headwaters of a class III stream. Stream has very little channel definition here and is filled with redwood duff. Average road width is ~19'.	1) Install 2 rolling dips to left road
45	29200	M	Stream crossing	3	1141	218	This crossing has been pulled ~2-3 years ago. A small rill has been formed by stream flow through the crossing, 3/4'w x 1/4' deep. A waterbar, placed ~25' to the right of the crossing, delivers sediment to this site.	1) Outslope 1,000' of left road and 200' of right road 2) Install 6 rolling dips to the left road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
46	29200	ML	Stream crossing	60	12	1225	Class III temporary crossing has been removed. Stream power is low. The majority of crossing sideslopes have been adequately laid back, except the left OBR, which is at 35°.The channel excavation should have been straighter and at a more consistent grade. Road surface treatments have a moderate immediacy. Crossing treatment immediacy is moderate-low.	1) Outslope right road for 1,000' 2) Install 6 rolling dips to the right road reach 3) Excavate from TOP to BOT. Establish a 4' channel width. Lay back banks to 2:1. Spoil locally.
47	27000	ML	Stream crossing	3	2869	372	The bridge used at this site has been removed. Stream banks within the crossing are similar to the native banks adjacent to the crossing. Quads, dirt bikes, and horses use this crossing and a small amount of bank disturbance is the only quantifiable future erosion at this site.	1) Outslope 237' of road 27000 to right of crossing 2) Install 14 rolling dips to the left road reach
48	-	ML	Stream crossing	12	48	80	This site is an old bridge crossing of Big Salmon Creek located ~35' downstream of the Ketty Gulch confluence. The bridge was pulled or blown out many years ago, (60s-80s). Only a portion of the left abutment remains. Future erosion is from potential erosion of left abutment made of fill on top of a 2.5' diameter log. Channel is bedrock through the crossing.	1) Excavate abutment fill from left bank. Leave bank at 2:1 or to competent native material

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
49	-	M	Stream crossing	25	45	124	This crossing is ~150' from Ketty Gulch and Big Salmon Creek confluence. One large log still remains in fill. Right bank is undercut by stream flow and has cracks. Future erosion from right bank is more likely to occur than erosion of left bank as left bank is protected by log. Channel grade is controlled by bedrock.	This crossing will likely have to be temporarily rebuilt to treat site #48. 1) Excavate remaining fill and LWD from crossing, laying banks back to 2:1. 2) Install 1 cross-road drain to right road reach
50	-	-	Other	67			This section of stream has been filled in with logs and sediment, (both fill and aggraded bed load) from railroad era construction. Several sections of stream have bifurcated channel with new channels eroding through both fill and native materials. Many sections of old channelization are now relatively stabilized with LWD grade controls. Treatment of this site would involve major tree removal in the class I stream and extensive channel disturbance for ~700', and is not recommended.	No treatment.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
51	27030	M	Stream crossing	51	700	0	Class III headwall (near origin) area that has channel filled in by road. Fill is saturated in wet season. Outboard edge of road is showing signs of failures. Several significant cracks are present along OBR. Gully through fill has 5' knickpoint, 3' into the road from the outboard edge of fill. Two 10' dbh Doug Firs growing in the CLP. A small channel has formed across the road prism surface.	1) Construct armored fill crossing: a) Construct armored fill dip, lowering road 3' at OBF and 1' at IBF. b) excavate keyway 40' long, 12'w at the top, 6'w at the bottom c) armor keyway with 27yds of 1' and smaller diameter 2) Install 7 rolling dips to left road reach 3) Install road rock to armored fill dip, 12'w x 60' long
52	27030	HM	Stream crossing	152	40	60	This Class III channel has had slash and woody debris stuffed into it. A skid has been built on both banks and there is no canopy cover over the channel. A small fan of aggraded material and brush has formed above the IBR. 2 gullies have formed from scour on OBF. OBF is wet during winters and many large cracks (1') are evidence of OBF instability. 1' dbh trees are present in the road bed and a 2' dbh redwood is growing on the failing outboard fillslope.	1) Install an armored fill at crossing a) Install armored fill dip (lowering OBF 3' and IBF1') b) Excavate keyway in OBF, 42' long x 2'd x 12w at top and 6'w at base c) Armor keyway with 28yd of 1' and smaller rock 2) Rock armored fill dip 3) Excavate debris in channel above road from TOP to IBR, establishing a 2' wide channel
53	27030	M	Stream crossing	67	800	0	This stream is near origin and has little channel expression above the crossing but has a well defined valley. There was no drainage structure at this site and the crossing has nearly completely blown out.	1) Excavate crossing from TOP to BOT 2) Install a 24"x50' culvert and rebuild the road prism 3) Install a critical dip 4) Armor TOP transition with 10yd of 1' diameter rip-rap 5) Install 7 rolling dips to left road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
54	26042	M	Stream crossing	203	310	450	This road is heavily vegetated with ceonothus. Culvert is ~35% plugged. Channel morphology is subtle upstream, but small bed and banks are present just above TOP (10') with a 2.5' knickpoint at TOP. Outlet is placed on an old stump and outlet flow has diverted left with a minor (<1yd) amount of scour. Crossing appears to have over-topped historically and a gully has formed on OBF and extends to channel below outlet. Gully is ~1.5' deep and 2' wide average. A 1' dbh Doug Fir and 10" dbh redwoods will need to be removed for implementation.	1) Excavate from TOP to BOT 2) Install a 24" x 60' culvert in axis of crossing. 3) Lower crossing 2' upon rebuild 4) Stockpile locally 5) Install 2 rolling dips to the right road reach and 1 to the left. 6) Buttress outboard fillslope with 20yds of 1' diameter rock
55	27050	ML	Stream crossing	92	120	730	This landing was constructed with its lateral edge on top of a Class III. A skid intersects at the site and a portion of the site is similar to a typical skid crossing. The landing looks very wet and is covered with juncus. A waterbar near site 55 conveys landing runoff to the site forming a small 1'w x 2'd gully through LWD. This landing will be opened very soon as part of a THP.	1) Excavate crossing from TOP to BOT, laying back landing fill to 2:1 and establishing a 4' wide channel 2) Install 4 rolling dips to right road reach 3) Install 1 cross-road drain to left road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds^3)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
56	29000	L	Stream crossing	6	348	177	This bridge has recently been redecked. There is a good rolling dip to the right. The bridge has adequate capacity for very large flow, maybe even 100 year event. 2 logs remain in right abutment from previous bridge installation. Flat car bridge is 10'w x 56' long. Some fill at base of left abutment has potential to erode during storm events (FE= 10'l x 4'w x 4'h).	1) Install 1 rolling dip to the left road reach
57	29000	ML	Road surface	0	230	900	This site is located just above the right bank of Donnelly Creek. Road surface runoff collects forming moderately defined rills and ponds at the intersection of 29300 and 29000. Some of this ponded sediment laden water delivers to Donnelly after flowing through a 20' vegetative buffer. A DRC up right road carries cutbank seepage and has plugged in the past. Installation of dips will alleviate flow to DRC.	1) Install 4 rolling dips to the right road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
58	29300	L	Stream crossing	108	317	30	This culvert is at channel grade and has bed load accumulated shallowly within the culvert over 80% of its length. This culvert is not a fish barrier. Inlet is placed ~5' out of the center line of the crossing. Inboard and outboard fillslopes are steep, ~45°, and armored with 2' diameter rocks. On the right side of the outlet, a small fillslope failure occurred just after installation. A large woody debris project was implemented ~30' downstream of the crossing.	1) Install 2 yards of 2' rip rap to outboard fillslope to right of culvert to buttress slope. 2) Install 1 rolling dip to left road reach
59	29300	M	Ditch relief culvert	2	821	0	This DRC drains a springy Cutbank and runoff from 2 skid trails. A 12' downspout is attached to the outlet and outlets flow 9' away from Donnelly Creek (across a 70% bank).	1) Excavate and remove DRC, creating a large cross-road drain at DRC location. 2) In-place outslope 820' of left road reach 3) Install 10 cross-road drains to left road reach
60	29300	ML	Bank erosion	12	0	0	Bedrock in channel of Donnelly Creek deflects flow into outboard fillslope of road 29300. Fillslope has already eroded somewhat but erosion will continue in high flows.	1) Excavate outboard fillslope, laying it back to 2:1, (16'w x 4'd x 16'L). 2) Spoil locally on skid

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
61	29330	M	Stream crossing	100	45	0	This crossing has a squashed culvert placed on bedrocks. Diversion potential is to the right and prior diversion may have caused erosion at site 60. This culvert is not a fish barrier.	1) Excavate crossing fill, removing the culvert from TOP to BOT flag, establishing an 8' wide channel and sideslopes at 2:1 grade 2) Endhaul spoil to 29320 road ~700' to the right 3) Remove log weir
62	29300	M	Stream crossing	13	900	0	The stream has eroded the cutbank in 2 locations. The culvert has been installed ~45' to the right (down road) of where the stream flow spills over the cutbank. Culvert outlet has a small downspout (6') attached and outlets directly in Donnely Creek. The area upslope of the road has been skid tractor logged and the stream channel morphology is completely altered destroyed.	1) Reestablish channel on skid/landing above cutbank for approximately 60' 2) Lay back cutbank at location of crossing fill removal, ~56' left of existing culvert 3) Excavate crossing from TOP to BOT, establishing a 4' wide channel and sideslopes at 2:1 grade. Spoil on skid up right road. 4) Armor break-in-slope at cutbank with 10yd of 3/4' diameter rip rap 5) Install 9 cross-road drains to the left road reach
63	29300	ML	Stream crossing	25	130	0	This culvert is probably sufficiently sized for the stream size. The inlet is placed ~10' down the road to the right of where the channel intersects the road. The outlet is set at the base of fill. There is no structure present to prevent diversion if culvert capacity is exceeded.	1) Excavate crossing from TOP to BOT, establishing a 4' wide channel and side slopes 2:1 2) Install 2 cross-road drain to the left road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
64	29300	L	Stream crossing	16	299	0	This stream has very little power and almost no bed/bank morphology. The stream flows to a waterbar ~15' down right road and over the OBF with no evidence of road erosion.	1) Excavate crossing fill from TOP to BOT, establishing a 4' wide channel with 2:1 banks for decommission 2) Install 3 cross-road drains to left road reach. 3) Pull berm intermittently for 150 to left road.
65	29300	ML	Road surface	2	270	0	477' of left road drainage contributes to this site. A small waterbar has been cut into road and active ditch to drain flow down fillslope and into Donnelly creek. A duffy 2'x1'x50' fully reaches stream below. Waterbar also gets contribution from old, densely vegetated skid road which intersects main road directly above it (see sketch). Cutting off left approach will cease gully enlargement. Future erosion is from 50% gully enlargement. Site likely received flow in past from diversion at site #67.	1) In-place outslope road filling the ditch for 270' on left road approach 2) Install 4 cross-road drains to the left road reach
66	29301	-	Stream crossing	5	275	100	This road is beneath the grade of 29300 and crosses Donnelly Creek at this location. This is a small volume fill crossing with the channel having already eroded through the fill. Banks are mossy and adjacent road lengths contribute no sediment to site.	No treatment.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
67	29300	ML	Stream crossing	64	807	0	Culvert is at base of fill at the outlet but is a bit high in the fill at the inlet (~1.5'). Diversion potential is down the IBD to the right. Channel bed and banks are obscured with duff and vegetation. Low stream power.	1) Excavate crossing from TOP to BOT, establishing a 4' wide channel with banks 2:1 for decommission. 2) Install 10 cross-road drains to left road reach
68	29300	ML	Stream crossing	163	1352	50	A low gradient and broad alluvial valley has a 9' x 1.5' class 2 stream (Donnelly Cr) running through it. Stream is braided above crossing. Flow passes through a 60" x 48" oval culvert. Culvert is set flat with 60" across the bottom. One small braid reaches the road ~40' to the left and then flows down stable inboard ditch to culvert inlet. This scenario appears to be ok. OBF is well armored with 3'-5' diameter boulders.	1) Excavate crossing from TOP to BOT, establishing a 9' wide channel width and banks at 2:1 slope. 2) Outslope road, filling the ditch, for 1350' to the left 3) Install 8 rolling dips to the left road 4) Install 2 cross-road drains to the left road reach immediately adjacent to the site and one to the right. 5) Endhaul excess spoil to the left to a safe location, or well beyond large debris flow Drainage area/discharge at this crossing was checked and CMP size is ok
69	29300	M	Landslide	0	1350	0	This slide is a debris flow on relatively low gradient hillslope. This slide may have been influenced by the road but is probably more related to the underlying geology. Left road reach delivers to a landslide scarp gully via a waterbar.	1) Install 8 rolling dips to the left road reach 2) Pull berm for 500' of left road, intermittently

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
70	-	-	Stream crossing	17	0	100	This site is located in an aggraded section of stream valley once used as a landing. Road/landing fill is thin, ~1' deep. Stream cut its course through landing fill and diverted down the left road. Channel has eroded its natural channel dimensions out of road and landing fill and is now stable, with gentle rounded banks. The road leading to this landing is skid-like.	No treatment.
71	-	-	Stream crossing	0	40	6	This small 2x1' class 3 flows through a highly disturbed environment. Flow is braided through dense slash and logging debris. The entire area is tractored. At this site, the stream has eroded a 3' x 3' x 80' channel through old road bed. Channel is stable and overgrown. Coming in here with heavy equipment to pull back small banks would create more problems than we would solve. No treatment.	No treatment.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
72	-	ML	Stream crossing	18	0	360	A small near-source 1'x1' class 3 flows onto an abandoned road bed here. Flow then diverts ~70' to the left down the IBD. The ditch drains into Donnelly Creek at the culvert outlet of site #61. Ditch is vegetated, low gradient, and stable. OBF of site #1 is well armored so no headcutting is occurring at outlet. Upper 200' of right approach is through-cut.	1) Excavate crossing fill from TOP to BOT, establishing a 4' wide channel and 2:1 sideslopes. 2) Grade channel from base of fill to native Donnelly Creek channel to avoid headcutting (20yd) 3) In-place outslope right road reach for 360' 4) Install 4 cross-road drains to right road reach 5) Spoil on road reach to right
73	29330.05	M	Stream crossing	93	0	550	This stream is partially diverted down the left road. A lot of fill and large woody debris is stored in the OBF.	1) Excavate a 4' wide channel from TOP to BOT, laying back banks 2:1 2) In-place outslope 550' of right road reach 3) Install 7 cross-road drains to right road reach
74	29330	M	Stream crossing	96	935	0	A small 2'x1' class 3 flows through a very disturbed canyon. The tractored and slashed area above the road has become more of a wetland than a stream valley. The flow channelizes ~20' above road and 24" culvert. A 10' half-round downspout has been attached to the outlet. Situation looks stable but there is diversion potential to the right. Site also receives contribution from a large spring at cutbank ~150' to the left.	1) Excavate crossing fill from TOP to BOT, establishing a 4' wide channel and laying the sideslopes of excavation back to 2:1 2) Install an 18" x 40' DRC at the right hinge of the large spring. 4) Install 2 cross-road drains to left road reach between DRC and stream crossing

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
75	29330.05	ML	Stream crossing	162	75	0	This crossing is a landing built on a very low power spring fed Class II. The stream that this confluences with is in a wide stream valley that has been heavily tractored. The road beyond this site is actually a steep skid. Flow ponds on this landing and then diverts down the right road reach. The diversion gully is shallow and mossy. If this site was upgraded, a 24" culvert would be appropriated.	1) Excavate crossing from TOP to BOT with banks 2:1 2) Spoil locally to left, on landing 3) Install 8 cross-road drains to right road reach
76	29310	M	Stream crossing	86	475	244	A 3' x 1' class 3 stream flows through a partially pulled crossing. The crossing has been excavated likely to remove old culvert, but they did not reach the natural channel. Now stream flow is cutting through the bottom of the excavation which will destabilize banks. A 4' knickpoint has developed at OBF, which will advance through the crossing.	1) Excavate from TOP to BOT to get down to natural stream grade. 2) Install a 48' x 50' culvert in the CLP 3) Install 1 rolling dip to left and 3 to right
77	29310	M	Stream crossing	56	0	295	A relatively recent installation of a plastic culvert. Outboard fillslopes are not laid back enough below culvert outlet and should be laid back 2:1. The drainage area upslope is heavily tractored and springy.	1) Lay back OBF fill to 2:1 below the culvert outlet (40yd) 2) Install a critical dip 3) Install 1 rolling dip to right road

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
78	29310	L	Stream crossing	0	360	80	This is a very stable ford crossing on Donnelly Creek. Road banks area laid back well enough to quad across. No future erosion, only on approaches which look ok, too. If this road is to be reopened for logging, a new culvert will need to be installed to make it drivable.	1) Install 2 rolling dips to left approach.
79	29400	ML	Ditch relief culvert	2	250	0	This DRC directly delivers to Pullen Gulch. DRC drains a small spring and left road reach has freshly installed waterbars.	1) Remove 1/2 round downspout and install a 12" x 20' downspout 2) Outslope and pull berm for 250' to left
80	29400	ML	Ditch relief culvert	0	545	50	A 15" plastic culvert has been installed to drain a wet swale and 545' of left road. Pipe install looks ok. Outlet drains directly into Pullen Creek. Left approach has small impermanent waterbars.	1) Install 4 rolling dips to left
81	29400	M	Stream crossing	82	590	30	This stream crossing is located in an alluvial stream valley. Culvert is undersized and inlet has a grade control structure made of 3' diameter rock. Channel below outlet is not the native channel location but is now the best location for culvert outflow.	1) Excavate crossing from Top to BOT. 2) Replace culvert with a 72" x 60 culvert 3) Replace grade control structure ~15' above the inlet, adding 5yd additional rock 4) Lay back banks of channel below outlet 30yd 5) Install 4 rolling dips to left road reach

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
82	29400	ML	Stream crossing	2	1400	12	A small 2' x0.5' class 3 crosses a broad road bed here. A large dip has been created to right to prevent diversion. Flow enters old skid road which it exits ~50' below. A small 2' x 1' x 10' gully runs down from the skid road.	1) Install an armored fill at site. Excavate keyway, 10'w at top x 4'w at base x 18'l by 3'd. Armor keyway with 10yd of 0.5-1.5' diameter rock armor 2) Place 2yd rock at the top of knickpoint on skid to prevent gully enlargement and to act as grade control 3) Install 9 rolling dips to left approach
83	-	HM	Stream crossing	58	350	80	This spur road is probably 1960's era in origin. The road intersects with 29410 and runs up the south bank of Pullen Gulch. Flow from Pullen Creek diverts down road for 220', gullying through road fill, down to bedrock at point. Stream valley is flat and was heavily tractored during first cycle logging. A small class III confluences with diversion ~70' to left of crossing axis. FE= crossing (28yd) + class 3 (5yds) + gully (25yd)= 58yd	1) Excavate crossing from TOP-BOT for decommission with banks at 2:1 and a 6'w channel. 2) Correct diversion at point of diversion by re-establishing channel and excavation of 12'long x 16'w x 5'deep= 36yd 3) Excavate class 3 crossing through road with a 4' channel width and banks at 2:1 for decommission, 40yd 4) Endhaul spoil out of WLPZ to small landing at road intersection with 29400 5) Install 4 cross-road drains to left road reach

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length: Left ditch/road length (ft)	Hydrologically connected road length: Right ditch/road length (ft)	Comment on problem	Comment on treatment
84	29400	ML	Stream crossing	0	2000	80	A 9' x 1' class 2 has ford crossing installed here. Road is well dipped and rocked with no fill left in stream axis. Stream valley is broad and low gradient and heavily disturbed. Stream flow is braided through duff and logging debris. No future erosion from crossing only approaches structure on it; a rolling dip ~150' to the left. The rest of the approach is drained by crumbling waterbars. This dip is already beginning to fail and is not enough to drain entire road.	1) Install 14 rolling dips to left road
85	29100	L	Ditch relief culvert	0	841	80	An 18" ditch relief culvert drains 840' of left road and 80' from right. Virtually the entire left road reach is through-cut. Pipe has a functioning 10 long downspout attached to the outlet. Flow enters a small depression below downspout before entering Hazel Creek. IBD is grassed and stable.	1) Install 1 rolling dip ~30' to left of site
86	29100	ML	Stream crossing	18	70	100	Small class II is filled with logging slash. Spring fed channel is incising with small buried knickpoints. Flow is diverted ~20' right of crossing axis and carried across road via a DRC type culvert with a 1/2-round downspout. Excavator cut a breach through the through-cut for downspout placement. Downspout outflow gullies for 10' directly into Hazel Creek.	1) Excavate crossing from Top to BOT 2) Install a 24"x40' culvert 3) Clean woody debris from channel for ~30' upstream of inlet. 4) Leave existing culvert in place 5) Install a trash rack on new culvert 6) Armor base of outboard fillflace with 10yd of 1' diameter rock armor

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
87	29100	M	Stream crossing	21	620	40	A small 2' x 0.5' class 3 flows through an undersized 12" culvert. Pipe also receives flow from springy area to left. Culvert outlet shotguns out over Hazel Creek. Small pipe will plug easily.	1) Replace existing culvert with a 24"x30' culvert 2) Clean/cut ditch for 100' to the left 3) Armor steep OBF with 7 yd of 1'-2' rip-rap 4) Outslope and keep ditch for 620' left
88	29100	ML	Ditch relief culvert	4	635	345	This delivering DRC drains a springy IBD from both sides. Gully erosion is minor until flow reaches the break-in-slope at the stream bank.	1) Install 3 rolling dips to the left road reach and 1 rolling dip to the right
89	29100	-	Stream crossing	13	140	195	Small class III stream with very little channel morphology upstream. Well established channel is present downstream.	No treatment.
90	29100	-	Ditch relief culvert	0	65	70	An 18" culvert drains roughly 130' of ditch and a wet orchard above road. A 10' 1/2 round downspout is attached to outlet. A 2' x 1' x 20' stable gully runs to Hazel Creek below. There is nothing to be done at this site that will be effective.	No treatment.
91	29100	HM	Stream crossing	108	60	40	This stream takes a rather extreme meander before confluencing the road. Culvert is set at a ~45° angle to the road. Large redwoods on the right bank deflect flow into the outboard fillslope, eroding the fill and destabilizing the OBF. The current culvert location is the most appropriate location for it at this crossing.	1) Excavate unstable fill at OBF, 20'w x 1'd x 14'Long and store on nearby skid 2) Armor outboard fillslope with 16yd of 2'-3' diameter rip-rap, to prevent erosion from flow deflection 3) Install rolling dip to left road reach 4) Excavate crossing from TOP to BOT and replace culvert with a 60" x 50' culvert.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
92	29100	ML	Ditch relief culvert	0	100	290	N.F. Hazel is <30' from the OBR. IBD is very well vegetated and no future erosion exists from either IBD or downspout outflow. DRC has ~10' of 1/2 road downspout. DRC is partially plugged with road rock.	1) Outslope right road reach for 290'. 2) Outslope left road reach for 100'. 3) Install 1 rolling dip to the right road reach.
93	29100	L	Stream crossing	48	580	30	Class III channel above road has been completely tractored. Last entry resulted in re-channelization of flow. Excavation at inlet is down to bedrock. Class III stream has very little power and doesn't gully 3' cut bank.	1) Outslope 550' of left road (road 29120) 2) Install 3 rolling dips to the left road reach
94	29130	ML	Stream crossing	78	475	230	The culvert at this site is installed at the base of fill, but outlet is ~7' to the right of the channel axis. Inboard fillslope has failed around the culvert inlet (<1yd). Outboard fillslope is 33° and unarmored/buttressed. No past failures of outboard fillslope are evident.	1) Install 3 rolling dips to the left road reach and 2 dips to the right. 2) Armor base of outboard fillslope and right stream bank at the culvert outlet area with 5yd of 1' diameter rip-rap.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
95	29130	M	Stream crossing	8	7	510	Class III crossing that was pulled inadequately. The upper half of the crossing is on bedrock; however the lower 1/2 of road and channel down to the BOT needs further excavation. The slopes are too steep as well. This appears to be a temporary pulled c crossing as future timber operations will necessitate continued use of the road. Road will need to be built out along the OBR to allow log truck use. There is some minor right road surface erosion as well.	1) Clear channel of fill and root wads below OBR of road, defining a 4' wide channel 2) Need to import 40 yds of fill to straighten and rebuild road through crossing approximately 10' out. 3) Install an armored fill: - Create a keyway 15'w at top, 6'w at base, 22' long, and 3' deep. 4) Armor keyway with 30yd of 1.5' diameter rip rap 5) Install 3 rolling dips to right road reach (place one ~70' to the right of the crossing
96	29130	M	Road surface	3	0	150	Small swale crosses road with waterbar that is showing signs of downcutting along outer 1/4 edge of road (~15'). There is another waterbar above on right road that is showing some downcut, but much less. Swale continues below road. Large collection area for waterbars with landing and skid trails nearby.	1) Armor OBF with 6 yds of 1' diameter rip rap, (15' long x 10'wide x 1' deep) 2) Rebuild dip to proper specifications and rock with road rock

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
97	29100	HM	Stream crossing	101	300	125	A tractored class 3 channel upslope still generates overland flow. A 3' knickpoint has head cut most of the way through the road prism. Pushed fill from the large landing from the left lies in the channel and stream flow has gullied a 3' deep average channel through the fill.	1) Excavate crossing from TOP to BOT, leaving some road prism intact between IBR and OBR. Lay back banks below OBR to 2:1. 2) Install an armored fill crossing with keyway dimensions 18'long, 15' wide at top, 6' at base, 2' deep 3) Armor keyway with 20yds of 1' diameter rip rap 4) Rock armored fill dip with 10yds of road rock 5) Install 1 rolling dip to the left road reach
98	29100	M	Stream crossing	195	200	125	This culvert is in good condition but is low gradient (3%). The stream channel in this area is also low gradient. Outlet is shotgunned and eroding a hole ~6' deep. Flow goes subsurface at this point and flows under fill and a large redwood stump, emerging at the BOT. CulvQ = 36"	1) Excavate crossing from TOP to BOT. 2) Replace culvert with a 36" x 60' culvert set at the base of fill in the axis of the stream crossing. 3) Endhaul spoil to the landing approximately 225' to the left. 4) Install 1 rolling dip to the left road reach
99	29100	M	Stream crossing	48	225	180	This CMP crossing is located in a low-gradient wide valley. The stream upslope has been tractored and the channel is visible through a number of collapse holes. The last 10' of the culvert has separated, coming unscrewed like a ribbon.	1) Excavate crossing from Top to BOT 2) Install a 36" x 50' culvert at base of fill 3) Clean/channelize channel above TOP for ~20' 4) Armor TOP transition with 10yd of 1' diameter rock 5) Install 1 rolling dip to the right road reach and 1 rolling dip to the left road reach.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
100	29120	-	Stream crossing	0	220	0	This bridge crossing Hazel Creek is made of a 25' flatcar with wood and sheet metal decking. Hazel Creek makes a gentle curve in this location such that upstream flow is not quite perpendicular to the bridge. The right bank has been armored to protect it from scour with 3'- diameter rocks. 2 Logs, ~2' diameter, form the abutments. Banks beneath bridge are 2:1 or less. Capacity beneath bridge is ~18' wide by 5' deep.	No treatment.
101	29100	M	Stream crossing	37	40	325	Class 3 crossing on road with no maintenance. Crossing was not pulled properly. Existing structure more closely resembles a big waterbar. Outboard edge of fill is eroding, with a gully extending 30' below OBF through fill pushed into channel from adjacent landing.	1) Excavate material below road out of channel with a 4' wide channel with 2:1 banks 2) Install armored fill. -Excavate a 25 long keyway, extending ~10' into the roadway, 10' wide at the top and 6'w at the base, 2' deep. -Armor keyway with 15yd of 1' diameter rip-rap 3) Push spoils on adjacent landing to left of crossing 4) Several 6"-14" dbh redwood trees will need to be removed to implement treatment 5) Install 2 rolling dips to the right road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
102	29100	ML	Stream crossing	145	375	75	Culvert is ~80' in length and near the base of the fill. A 10', 1/2 round, metal downspout is affixed to stakes at the outlet. Culvert install is good and there is no diversion potential at this site. No erosion at the BOT. A large willow tree is rooted in the channel at the inlet and has fallen over. Willow does not appear to present a future problem.	1) Excavate crossing from Top to Bot 2) Replace culvert with a 30" x 70' culvert at the base of fill 3) Buttress base of outboard fillslope with 15yd of 1' diameter rock armor 4) Install 3 rolling dips to the left road reach
103	29120.02	-	Stream crossing	2	35	30	Old road that appears to have been decommissioned long ago. The crossing has been bladed out with a dozer wide enough to allow channel migration. There is some minor incision/gullying around the OBR/OBF, however, it appears to now have stabilized. Both road reaches are well vegetated and do not appear to be contributing any flows and there are berms adjacent to the crossing that disconnect the road reach. If upgrading was desired, an armored fill would be appropriate.	No treatment.
104	29120.02	L	Stream crossing	97	90	0	The small class 2 (spring fed) stream of site 102 has been diverted by this landing. Spring flow from cutbank on right side of the landing is also diverted down the right IBD. Diverted flow has little erosive power and is only problematic in that it doesn't flow into its native location and connect with a wetland.	1) Excavate fill from TOP to BOT, laying back banks to 2:1 and connecting stream with wetland.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
105	29120.02	L	Stream crossing	6	800	0	This crossing has been pulled with a dozer. Some fill is left at the OBR. A berm is built upon the right side of the crossing to prevent diversion.	1) Excavate from TOP to BOT with a 4' wide channel. 2) Lay bank back to 2:1 3) Install 10 cross-road drains to the left road reach.
106	29122	L	Stream crossing	38	80	150	This CMP is an oval shaped "squashed" pipe (3' tall x 4' wide).	1) Excavate crossing from Top to Bot 2) Replace culvert with a 48" x 40' culvert at the base of fill 3) Install 1 rolling dip to the right road reach
107	-	HM	Stream crossing	16	100	90	This old crossing has a 10' long section of filled channel remaining. A hewn log has been placed across the banks as a foot bridge. The remaining crossing fill is easy to access and easy to remove.	1) Excavate crossing fill from TOP to BOT, establishing a 4' channel. Lay back banks to 2:1 or to native material.
108	29122.2	M	Stream crossing	29	84	180	This crossing has been partially pulled with a dozer. Most of the fill (80%) remains. Stream has low power and a small gully is headcutting through the outboard fill (2' knickpoint). A skid trail below road prism contains an n early equal volume of erodible fill and is included in the erosion and excavation profile.	1) Excavate skid crossing fill from the base of the road fill to BOT, laying back banks 2:1. Leave large trees undamaged/intact. 2) Excavate keyway dimensions for armored fill: 12'wide at top, 6'wide at base, 25' long, and 2' deep. 3) Lower approaches to build armored fill at the current dip height. 4) Install 17yd3 of 1' diameter rip rap to armored fill keyway 5) Install 1 rolling dip to right road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
109	-	ML	Stream crossing	4	9	50	This stream has a small overland flow channel and subsurface piping. A 3' knickpoint has developed at the TOP,~ 20' above the IBR.	1) Install an armored fill a) Excavated keyway 12' wide at TOP, 5' wide at base, + 16' long x 2' deep. b) Armor keyway with 15yd 1' diameter rock armor 2) Stabilize knickpoint by laying it back 2:1 and armoring with 2yd of 1' diameter
110	-	L	Stream crossing	1	185	50	This crossing contains almost no fill (<1yd). Equisetum covers the road prism throughout the crossing. The last entry into this area must have been from the north (right).	1) Install an armored fill crossing a) Enhance/improve existing dip for armored fill installation b) Excavate keyway, 10'w at top, 6'w at base, 12' long, and 2' deep. c) Armor keyway with 1' diameter rock d) Rock armored fill dip with road rock 2) Install 1 rolling dip to the left road reach
111	-	ML	Stream crossing	5	240	0	This stream emerges from a wide stream channel valley of ~12% grade. The valley ~ 65' wide has been heavily tractored. The stream upslope is prone to diversion and therefore periodically enters the stream crossing at different locations and angles.	1) Install 2 cross-road drains on skids upstream of crossing to prevent diversion 2) Install an armored fill crossing a) Dip crossing with dozer b) Excavate keyway: 12' wide at top, 6' wide at base, 25' long and 2' deep c) Armor keyway with 17'yd of 1' diameter rip-rap d) Rock armored fill dip with 20yd of road rock 3) Install 2 rolling dips to left road reach.

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
112	-	HM	Stream crossing	57	5	155	This site is located ~100' downstream of site #113. A 2'wide x 3' deep x 33' long gully has been rocked through the outboard fillslope. Crossing has been bermed on the left side to prevent diversion. Site # 113 is ~ 100' upstream.	1) Install armored fill at crossing: a) Reduce outboard fill length by excavation of ~50yd of fill and woody debris b) Dip crossing for armored fill installation c) Excavate keyway: 12' wide at top x 6' wide at base x 28' long x 3' deep d) Armor keyway with 28yd of 1.5' diameter rip-rap Stockpile excavated spoils on landing to the right.
113	-	M	Stream crossing	24	180	0	The road has been dipped at this crossing to prevent diversion. A gully, ~2' deep is incising through the outboard edge of fill. This site is perfect for an armored fill.	1) Install an armored fill crossing: a) Broaden dip to increase drivability and outslope dip, lowing the outboard edge of fill by ~1'. B) Excavate keyway in outboard fillslope: 12' wide at top x 5' wide at base x 20' long x 3' deep. C) Armor keyway with 19yd of 1.5' diameter rock 2) Install 1 rolling dip to the left road reach.

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
114	-	L	Stream crossing	12	0	30	The stream channel above this site is heavily tractored and filled with logging debris. Stream flow intersects road and flows down left road for ~30' before leaving the road prism. A lot of the flow appears to be piping beneath logging debris and disturbed ground. Flow gullies through road prism and a 2.5' head cut is actively migrating through native sediments at IBR. Future erosion is from knickpoint migration and gully bank retreat. This site is in a WLPZ zone. Historic channel is unrecognizable.	1) Lay back gully banks to 2:1 2) Excavate 30' long x 4' wide x 3' deep channel through logging debris above the knickpoint and transition to native ground/grade. 3) Spoil locally.
115	29120	L	Stream crossing	13	25	35	This crossing is at the end of an abandoned road at the boundary of the property. The road is heavily vegetated and a large mound effectively hydrologically disconnects the right road reach. The hillslope upstream and left of the site is slightly unstable and evidence of past movement is observed (hummocky topography, pistol butted trees, exhumed small boulders). A gully has been incising through the road fill and is almost stable with banks 1:1.	1) Excavate crossing from TOP to BOT with 2:1 banks and 4' channel width. 2) Spoil locally

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
116	29120.1	L	Landslide	4	0	0	A headwall landslide has failed ~20 years ago and delivered to a steep, at origin, stream channel. Most of the road fill has eroded in the original failure. It is unlikely that the remaining fill could fail when saturated, but a low degree of potential exists. The slide face has revegetated ~80% with 8' high brush.	1) Excavate remaining outboard edge of fill from road: 75' wide x 10' long x 1.5' deep = 42yd 2) Move road in 3', laying back cutbank to a stable angle 3) Endhaul spoil back to either landing ~1,200'
117	29121	L	Road surface	0	220	32	A relatively low gradient segment of road is immediately adjacent to Hazel Creek. A 4.-5' berm on the outboard edge of the road makes it function hydrologically as a through-cut road. The berm has been breached in this location with an excavator and the road surface runoff delivers to the flood plain and channel of Hazel Cr.	1) Install 2 XRDs to left road reach.
118	29121	ML	Bank erosion	27	400	200	Hazel Cr. is pushed to the right bank by a large bedrock outcrop. The outboard fillslope has been eroded at the toe and a slump has occurred. Feature is now difficult to identify due to revegetation. There is a low likely hood that this feature continues to erode but this site should definitely be addressed if road is decommissioned.	1) Excavate outboard fill of road 50'w x 10'l x 3'd = 56yd, leaving as many trees for stability and riparian canopy as possible 2) Install 2 cross-road drains to the right road reach and 5 cross-road drains to the left road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
119	29121	-	Stream crossing	0	17	20	This crossing has been completely pulled. The banks are laid back enough to permit quad passage. Drivable banks are the only future erosion here and are covered with dirty mulch.	No treatment.
120	29121.1	-	Stream crossing	4	8	80	This crossing has been excavated with a little fill remaining on the left bank. The channel upslope is gully-like with many 3' knickpoints. The drainage area upslope has been harvested within the last 10 years. The disturbance involved with excavating the remaining fill is probably more destructive than not treating this site. A small rill (adjustment) is working its way through the crossing.	No treatment.
121	29121.1	M	Stream crossing	43	0	100	This small channel emanates from the hillside ~15' above the TOP. The flow is conveyed across the road prism by a small trench/waterbar (No diversion potential). The historic channel is set at ~45° to the general downslope direction. The stream power here is low.	1) Excavate crossing from TOP to BOT with a <4' channel. Lay back banks to 2:1 or native material 2) Spoil locally

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
122	29121	M	Stream crossing	23	190	0	This crossing has a partially effective waterbar ~20' to the right of its intersection with the road which directs the water out of its native channel below the road. Channel upstream has vertical banks (3' high).	1) Excavate crossing fill from Top to Bot for decommission. Lay back banks 2:1 or native material and establish a 4' wide channel 2) Spoil locally to the left 3) Install 2 cross-road drains to the left road reach
123	29000	ML	Stream crossing	89	125	98	The inlet of this culvert is well placed but the outlet is ~2' high in the fill. The stream channel above shows minor bank erosion and ~1' of incision. The stream channel was live at the time of assessment. Inboard ditches both have 1.5yd retention basins excavated in them.	1) Check discharge of drainage area and determine correct culvert size. (CulvQ= 48") 2) Replace culverts with a 48" x 60' culvert in the axis of the channel 3) Retain sediment basins in inboard ditches
124	29000	ML	Stream crossing	97	0	400	This crossing of Hardell Gulch has bedrock in the channel ~20' above the inlet. Channel above is entrenched ~2-3'. Fill is well rocked on inboard and outboard slopes. Culvert is at base of fill. See site #125 for treatment of diversion potential.	1) Check 100year flow discharge and determine if culvert is adequately sized. (CulvQ = 72"x60') 2) Install 3 rolling dips to the right road reach
125	29000	L	Stream crossing	16	0	35	This crossing drains a wetland area that is probably infrequently occupied by high flows of Hardell Gulch ~125' above site #124. There is very little evidence of past flow through this culvert.	1) Install a critical dip to the right of existing culvert. This will function as the critical dip for site # 124 as well.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
126	29121	ML	Stream crossing	36	970	0	This culvert is installed at the base of fill. This road will likely never be reopened for timber harvest. The area was yarded in 2004. A large berm has been built to prevent diversion. Left road reach has cross-road-drain-like structures that are more berm like than desired. CulvQ= 42"	1) Check discharge to determine proper culvert size. 2) Decommission crossing by excavating road fill from the stream crossing between Top and Bot. Establish a 3' wide channel. 3) Lay back banks to 2:1 or native material 4) Decommission with quad access 5) Install 12 cross-road drains to left road reach
127	29121	L	Stream crossing	57	228	163	The stream above is a little wet from some spring flow. Culvert is steep and an 18" is probably adequate in this location. Road reaches are relatively highly eroded.	1) Install 1 rolling dip to left road and 1 rolling dip to the right road reach.
128	29121	M	Stream crossing	95	70	240	The left portion of the fillslope has failed into the stream channel. A small deposit of failed fill remains in the channel below the culvert outlet. Culvert is rusted through at inlet. Fill failure is ~30yd. Campbell declared this an ECP site.	1) Excavate crossing from TOP to BOT 2) Replace culvert with a 24" x 50' culvert at the base of fill in the axis of the stream crossing 3) Rebuild OBF fillslope 4) Install 1 rolling dip to the right road reach
129	29121	ML	Stream crossing	42	0	130	This stream channel sees little flow. The culvert is set steep in the fill but is shotgunned ~5' at the outlet into the side of a tree stump. Inboard ditch to the left looks like it is frequently wet from cutbank spring flow.	1) Install a critical dip on the left hinge of the crossing 2) Clean inlet of dirt and vegetation.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
130	29121	ML	Ditch relief culvert	2	147	415	This DRC drains into the headwaters of a Class III stream. No channel is present upslope. DRC is totally rusted through. A very small channel/gully links DRC outflow with stream.	1) Replace DRC with an 18" x 40' DRC. 2) Outslope 150' of right road reach, keeping the inboard ditch 3) Install 1 rolling dip to the right of the road outsloping
131	29121	M	Stream crossing	17	0	460	Headwall swale with multiple small channels coming together just below the road. Large waterbar is currently draining all of road surface runoff onto the fillslope (No diversion potential). There is evidence of past fillslope erosion. The channel below this site drains immediately into a swale.	1) Install an armored fill. Keyway dimensions: 10' wide at the top x 5' wide at the base x 25' long x 2' deep Armor keyway with 14yd of 1' diameter rock armor 2) Install 2 rolling dips to the right road reach.
132	29121.2	-	Stream crossing	2	20	20	This crossing was filled with fill by CDF during the fires of 2008 and recently decommissioned. Nearly all the fill was removed from the crossing. A small amount of fill remains on the right approach (3'l x 3'd x 10'w)*1/2 = 2yd of future. Approaches are now well mulched and left road is well disconnected. 3 fish were observed at this site during the assessment.	No treatment.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
133	29121.1	-	Stream crossing	144	13	80	Class III crosses recently redecommissioned road. The running road surface is very gently sloped and the stream power is low, however, the old OBF is directly adjacent to Hazel and has failed in the past in failures up to 15yds. There is a knickpoint which shows evidence of activity which will migrate back through the road prism. Road is built on an old alluvial fan deposit. Channel above road is meandering on bedload/fan deposits.	No treatment.
134	29121.1	-	Stream crossing	0	35	50	This stream crossing has had its fill removed since being filled in for fire use in 2008. Banks have been laid back beyond natural banks. Banks have been adequately mulched. Fish are present.	No treatment.
135	29121.1	ML	Stream crossing	10	24	30	This crossing has been recently pulled and some fill and large woody debris (cribbing) remains on the left road. There are fish present at this crossing. Future erosion at this site is 35w x 4'high x 2' average. Stream takes a tight left turn through crossing and grade level is slightly high above. Some aggraded bedload is still visible in the channel upstream of the crossing.	1) Lay back left bank of crossing and remove wood. (~15yd of soil)

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
136	29121.1	-	Stream crossing	7	33	45	The majority of the fill has been pulled here. A large amount of LWD is present above and below the crossing. Future erosion comes from erosion of left bank.	No treatment.
137	29510	-L	Stream crossing	3	150	30	The vast majority of fill has been pulled from this crossing. Only some small OBF wings of fill remain. A small 1.5' knickpoint is migrating through the crossing. 2 yd of 6" diameter rock has been placed in the channel of the crossing.	1) Excavate crossing from TOP to BOT, establishing a 4' wide channel and laying banks back to 2:1 or native material. Remove fill from OBF area.
138	29510		Stream crossing	2	175	35	This crossing has had the fill removed with the dozer. Approximately 1'-2' of fill thickness remains at the OBF. The stream power at this site is extremely low and a small 1' high knickpoint at the outboard edge of the road is the only evidence of channel morphology (bed/banks) identifiable.	No treatment.
139	-	L	Stream crossing	5	420	0	This crossing has been partially pulled. A lot of small woody debris is packed in the fill. A 2' knickpoint is located at the outboard edge of the road. Road is on a flat terrace and really has no fill except in the crossing.	1) Excavate crossing from TOP to BOT, taking care to not damage the tagged wildlife tree Lay back banks to 2:1, spoiling locally 3) Install 2 cross-road drains to the left road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
140	-	L	Stream crossing	120	145	0	This site is located next to Hazel Creek. This is a railroad crossing. Trees in this area are very mature. The railroad crossed Hazel creek immediately to the right of this site. Erosion rate here is very low and treatment immediacy is amongst the lowest of low.	1) Excavate crossing from Top to Bot for decommission. Lay back banks to 2:1 or stable native material 2) Install 1 cross-road drain to left road reach
141	29020	L	Stream crossing	25	40	166	This stream crossing has a good critical dip. Culvert should be a 24" to accommodate flashy flows. Channel ~25' upstream of inlet has a steep left bank encroaching on channel width as a result of timber harvest tractor work. CulvQ = 42"	1) Excavate crossing from Top to Bot 2) Install a 42" x 40' culvert 3) Layback left bank above inlet for 25" to a 2:1. 4) Install 1 rolling dip to the right road reach
142	29020	M	Stream crossing	17	190	125	This stream is channelized intermittently upstream. The culvert is slightly out of alignment (to the left) with the stream channel at the inlet. The ground at the outlet is nearly flat and bedload aggrades at the outlet. Outlet of culvert is currently 35-40% plugged.	1) Define channel below outlet for 30" to allow sediment to clear from the culvert. 4'w x 30'l x 2'd. 2) Install 1 rolling dip to left road.
143	29025	-	Stream crossing	2	125	0	This is a low power stream at the location of the site. Crossing has been broadly excavated and channel is now thickly vegetated through crossing. Stream is subsurface upslope.	No treatment.

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
144	29025	-	Stream crossing	3	40	25	This crossing has had most of the fill pulled by a dozer. The excavated valley through the crossing is wide and the channel meanders from the center to the left bank. A 2' high knickpoint has migrated through outboard fill to the OBF. This road will not be used for future timber harvest activity. Erosion rate here is low.	No treatment.
145	-	M	Stream crossing	18	25	45	This crossing has no drainage structure and the stream gullies through the road fill 3' deep x 2.5' wide. The entire drainage area upslope was clear-cut and increased runoff due to canopy loss has caused the stream to incise ~2'.	1) Excavate crossing fill from TOP to BOT. Establish a 4' wide channel. Lay back banks to 2:1 or stable native material. 2) Install 1 cross-road drain to the right road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
146	29600	HM	Stream crossing	219	250	420	This crossing has several logs and root wads in the fill (culvert placed over a humboldt). A large sediment fan has built up between IBF and TOP and culvert is ~35' to the left of the crossing axis at the inlet. An active spring in cutbank and road bed drains partially to inlet and partially over road at the critical dip. Two gullies are present where spring flow and probably piping through the road bed exit the outboard edge of fill. Road bed is wet even in summer and abundant equisetum grows throughout site. CulvQ = 24".	1) Check drainage area/discharge for proper culvert size (CulvQ = 24") 2) Excavate crossing from TOP to BOT with banks 1:1, removing the existing culvert 3) Replace culvert with a 24" x 70' culvert at base of fill 4) Fillslope will be steeper than 2:1 upon rebuild. Armor/buttress the outboard fillslope with ~30yd of 1.5' diameter rip-rap 5) Drain spring with installation of critical dip to the left 6) Rock critical dip 7) Install 4 rolling dips, one to the left road reach and one to the right
147	29600	HM	Stream crossing	121	180	0	This is a relatively steep stream and the culvert has a 20" 1/2 round downspout attached to the outlet. The 30' culvert appears to be separated ~2/3 of the way down its length and the last 10" section has a tear/rusted through section causing the erosion of the outboard fill. Cracks exist in the outboard fillslope is continuing to fail.	1) Excavate crossing from TOP to BOT, removing the culvert 2) Replace culvert with a 24" x 60' culvert that the base of fill 3) Install a critical dip 4) Buttress base of fill with 12 yd of 1.5' diameter rock armor 5) Install 1 rolling dip to the left road reach

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
148	29050.05	M	Stream crossing	46	753	0	This crossing has been dipped out, reducing the fill volume. The channel above is steep and thickly vegetated with second growth. A gully is migrating back through the crossing fill (24'l x 3'd x 2.5'w). Left road reach has ineffective waterbars.	1) Install an armored fill with keyway dimensions: 12' wide at top x 6' wide at base x 2' deep x 3' total length. - Armor keyway with 25yd of 1' diameter rip rap 2) Install 6 rolling dips to the left road.
149	29060	M	Stream crossing	93	0	80	This road is abandoned and has a springy cutbank to the right of the crossing, causing numerous non delivery failures. The crossing outboard fillslope has 2 large gullies from flow over the road prism. Multiple 4"-12" dbh trees will need to be removed to install a new culvert. A cutbank slide to the left of the crossing prevents diversion and is non delivering.	1) Excavate crossing from Top to Bot 2) Install a 24" x 60' culvert at the base of fill in the axis of the stream crossing 3) Install a critical dip 4) Install 2 rolling dips to the right road reach
150	29800	M	Stream crossing	121	920	50	Culverted stream crossing on an unused spur road. Crossing is in headwall swale with minimal channel development above. Culvert is set shallow, relative to the channel grade, but little sign of incision is present below the outlet. Critical dip is very small and built along the right hinge line.	1) Install single post trash rack 18" above the inlet 2) Install a critical dip along the right hinge line 3) Install 6 rolling dips up the left road

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
151	29070	-	Stream crossing	0	15	10	100% decommissioned crossing. Older (stable) landslide has pushed current stream channel along the right hinge line of the stream valley. Fillslopes through the crossing have been laid back to an angle less steep than 2:1 and straw mulched. Channel width looks sufficient to carry storm flow.	No treatment.
152	29070	-	Stream crossing	10	150	0	This crossing has been pulled down to the base of large trees. The stream above the crossing is gully-like and runs down a yarding corridor. Overland flow likely only occurs on the heaviest of storms. The remaining road bed shows no signs of erosion from stream flow. Effective cross-road drain is 150' to the left but road bed is heavily duffed.	No treatment.
153	29070	-	Stream crossing	0	15	30	Deeply incised channel above and below crossing. Stream valley may have been skidded and affected by a hillslope debris slide. Spur road/skid exists along the right bank above the crossing. Fills are oversteepened through his section of the crossing but is consistent with the channel condition above.	No treatment.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
154	-	M	Stream crossing	27	100	0	This road has not been opened since the 60s or 70s. Stream above road has a recently cut/burned drainage area. Stream flow is diverted down right road and has caused numerous gullies and fillslope failure. Road is thickly vegetated with fir trees. Future erosion comes from crossing and future diversion erosion.	1) Excavate crossing fill from Top to Bot establishing a 4'w channel and 2:1 banks for decommission. 2) Excavate slumping fill failure ~120' down right road from crossing and endhaul spoil. Lay back unstable road fill to 2:1, 50'w x 15' long x 2' deep.
155	29070	ML	Stream crossing	4	10	15	Majority of fill has been pulled through crossing excavation of material stopped at OBR, leaving a wedge of fill from OBR down to the BOT (at the base of the outboard fillslope).	1) Excavate crossing from TOP to BOT with a 4' wide channel and 2:1 banks for decommission. 2) Spoil locally
156	-	-	Stream crossing	17	27	0	This old crossing still has a few logs and a small culvert in place. Culvert is entirely rusted and is now just a piece of rusty scrap metal. Wood in crossing is in a pool and deflects some flow into right bank. Crossing is approximately 98% blown out, and the banks have laid back to old growth stumps. Future erosion from aggraded bedload above logs.	No treatment.

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
157	-	ML	Stream crossing	120	60	0	Abandoned fill crossing near confluence with Hazel Creek. Fillslopes are near vertical and an average of 9' high. Road/skid on left bank has recently been straw mulched due to fire access. Class 2 stream continues to be incised upstream, through old skid/road fill.	1) Pull back oversteepened fillslope (on both sides of the channel) from confluence with Hazel Creek, 40' up channel. Laying slopes back 2:1 where possible for decommission. 2) Install 2 cross-road drains up left road
158	29070	L	Stream crossing	9	9	11	This crossing has had approximately 50% of the fill pulled. A hay bale has been placed at the OBR. Stream above is steep and channel is actively transporting sediment. Some of the drainage area upslope has been burned.	1) Excavate crossing from Top to Bot for decommission. Establish a 2'-4' wide channel with 2:1 banks.
159	29070	ML	Stream crossing	25	15	10	Partially pulled stream crossing. About an 8' headcut occurs on OBF from OBR to BOT. This fill material will most likely fail and migrate its way back to IBR.	1) Excavate crossing from TOP to BOT with a 4' channel width, down to natural channel grade. Lay back fillslopes to 2:1 for decommission. 2) Spoil locally
160	29070	L	Stream crossing	16	9	10	Steep stream channel upstream of crossing. This crossing has been partially pulled after being opened for fire related purposes. Two large pieces of wood have been placed in the channel at the outboard edge of the road.	1) Excavate crossing from TOP to BOT, establishing a 2'-4' wide channel. Lay back banks to 2:1.

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
161	29070	-	Stream crossing	6	100	0	Ford crossing where 29070 road crosses Hazel Creek. Road contains no fill at the site. A 1' high head cut exists at the outboard edge of the road that is migrating with fractured bedrock exposed. Channel is braided and aggraded above and below road. Looks to be natural depositional area that has been heavily skidded. Left road reach has very large waterbars effectively disconnecting the road surface from the stream crossing.	No treatment. If this road were upgraded, this site would be a ford crossing.
162	29070	ML	Landslide	7	0	0	This site is located on the left hinge of a headwall swale. The road fill through the axis of the swale has been excavated ~65%. The road fill on the left hinge of the excavation has failed, ~10'l x 2'd x 5'w and the Class III channel is directly below. The outboard edge of fill may fail in the future when saturated and deliver to the Class III stream below.	1) Excavate fill from the outboard edge of the road (~15'w x 12'l x 3'd average) 2) spoil locally
163	29070	ML	Stream crossing	19	100	5	Springy wet swale with minimal channel morphology. Crossing as well as hillslope above and below are densely covered with equisetum. Road fill remains in crossing and will erode if left untreated.	1) Excavate crossing from TOP to BOT with a 4' channel width and banks 2:1 for decommission 2) Spoil locally

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					Left ditch/road length (ft)	Right ditch/road length (ft)		
164	29070	L	Stream crossing	20	45	0	This stream has almost no discernable bed and banks above the crossing. The crossing has been dipped out but most of the fill remains. 6 hay bales have been placed at the OBF to prevent sediment transport from the site. Evidence of flow is observable below the OBF as channelization begins on outboard fillslope. The headwall swale above has been recently harvested and then burned.	1) Excavate crossing from Top to Bot Lay back banks to 2:1 or native stable slopes
165	-	M	Stream crossing	70	80	80	This road has been abandoned since the late 1960's. At least 1 large log (2.5' diameter) has been laid in the Class III channel. A massive quantity of large woody debris is present at the OBF. The Class III channel has been skidded up the right bank and bedload has formed a large fan behind the large woody debris at the crossing. 3 large gullies have developed in the outboard fill. Erosion rate is moderately low due to duff and canopy cover upstream, reducing the erosion potential during small events. However, these headcuts will migrate extensively in large storm events.	1) Excavate crossing from TOP to BOT, establishing a 4' wide channel. Lay back banks to 2:1 or stable native material. Mulch banks with large woody debris. Spoil as much material locally as possible and endhaul remaining fill.

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
166	-	ML	Bank erosion	67	500	0	Landing/road fill has filled in valley bottom and pushed stream against the left valley wall. Road fill is now right bank of the stream Fill area is densely overgrown with 6" diameter fir and redwood trees. Sloughing areas are mossed over. Area will continue to fail during large storm events.	1) Excavate from START to END flags, laying fillslope back to 2:1 - 100'w x 6'd x 12' long 2) Endhaul spoil up left road 3) Install 7 cross-road drains up left road reach.
167	-	M	Stream crossing	27	220	0	This fill crossing is similar to site #165. However, no logs are in the fill and the stream flow/gully flows down the right road before confluencing the mainstem channel. A 9'dbh, burned redwood stump is located near the BOT.	1) Excavate crossing from TOP to BOT, establishing a 4'w channel. Lay back banks 2:1. 2) Install 3 cross-road drains to left road
168	-	L	Stream crossing	21	300	0	About 90% washed out stream crossing. Stream looks to be at grade through road fill. Fillslopes are laid back to almost 1:1. Roadbed and entire area are dense with 6" fir and redwood trees.	1) Excavate crossing from TOP to BOT with 5' channel width and lay slopes back to 2:1 for decommission. 2) Spoil locally 3) Install 4 cross-road drains up left road
169	-	L	Landslide	126	0	40	Road passes (midslope) through a swale that looks to develop into a Class III stream below the outboard edge of fill. Entire outboard edge of road has continuous cracks with ~1' vertical displacement and cracks extend about 3' back into the roadbed. Roadbed and fillslope are grown over with 6"-1' diameter fir trees.	1) Excavate slumping fill from START to END flags through the axis of the swale. 100' x 3' x 20'x 1.2 = 266yd 2) Spoil locally

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
170	-	M	Stream crossing	27	60	1500	This stream is near origin at the location of the site. A 6' deep sinkhole has developed ~15' above the IBR and flow must be subsurface beneath the crossing fill.	1) Excavate fill between IBR and hole to TOP, daylighting subsurface channel 2) Install an armored fill with keyway dimensions: 10'w at top x 5'w at base x 24' long x 2' deep. Armor keyway with 14yd of 1' diameter rip-rap 3) Install 9 rolling dips to the right road reach
171	-	ML	Stream crossing	173	550	338	This plastic culvert is not at the base of fill. A sinkhole carries stream flow from ~8' upstream of inlet. Only high flows and spring flow from left IBD enter culvert. Stream flows likely pipe through the entire length of crossing fill and emerges at the BOT.	1) Excavate crossing from TOP to BOT, removing existing culvert. (expose subsurface piping) 2) Install a 24" x 60' culvert at the base of the fill. 3) Buttress outboard fillslope with 10yd of 1.5' diameter rip-rap 4) Install 3 rolling dips to the right road and 4 rolling dips to the left road
172	26000	M	Stream crossing	35	1700	0	This crossing has been partially pulled by dozer and excavator. Bermed spoils are located on either side of the crossing. A large hole is present at OBF (3'w x 6'd). Stream below crossing is mostly subsurface and holes are present in natural channel ~50' below crossing. Stream above crossing is hummocky and channel looks youthful. Subsurface flow and size of fill make this site less than appropriate for an armored fill.	1) Excavate crossing from TOP to BOT 2) Install a 24" x 60' culvert at the base of the fill 3) Lay back unstable material above the TOP (~20yd) 4) Install a critical dip 5) Install 11 rolling dips to left road

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Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
173	26000	L	Stream crossing	7	200	80	Currently flowing Class II stream crossing has mostly been pulled. Stream looks to be at natural bottom and natural grade. Banks are well laid back and densely vegetated. Crossing could be left untreated if road were not upgraded. CulvQ = 72"	1) Excavate crossing from TOP to BOT to install a 72" x 60' long culvert at channel grade 2) Will need to import fill to rebuild crossing 3) Install 1 rolling dip up left road 4) Install a single post trash rack above inlet (2hours labor, 1 hr excavator) 5) Armor around culvert inlet and outlet with 2' diameter rip-rap up to culvert height (15yd)
174	26000	L	Spring	4	0	120	This spring flow is emanating from the cutbank and is captured by the IBR. Flow is concentrated for ~65' before being carried across the road prism by a waterbar and gullying to the stream of site #173. Future erosion is 50'long x 2'w x 1'deep enlargement and chronic erosion.	1) Install a well rocked rolling dip at site.
175	26000	ML	Stream crossing	78	400	0	This small stream crossing is gullying through the road prism (3' knickpoint at OBF). A skid prism below also shows moderate erosion through its fill prism. Flow disappears beneath redwood stump below BOT.	1) Excavate fill from skid below crossing ~20yd, laying banks back 2:1 and establishing a 4'w channel (1hr excavator) 2) Install an armored fill. Keyway dimensions: 10' wide at top x 6'wide at base x 25' long x 2' deep (3 hours excavator) 3) Rock armored fill dip 4) Install 2 rolling dips to the left road reach

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
176	26000	L	Stream crossing	49	300	40	Partially pulled stream crossing. Stream channel stair-steps down the hillside through old (stabilized) debris torrent deposits in the valley bottom. Stream is bifurcated through crossing. Fillslopes and channel banks are densely vegetated. If road is not upgraded, this site doesn't need to be treated.	1) Excavate crossing to install a 42" x 60' long culvert at the base of the fill at channel grade. 2) Install a single post trash rack above the inlet 3) Rebuild crossing with critical dip on right hingeline 4) Install 2 rolling dips up left road.
177	26020	M	Stream crossing	104	250	55	This road has been abandoned since ~1960's. The stream has steeply incised through the crossing fill and banks are 6' vertical through the crossing. A 6' knickpoint exists at the IBR. Channel above the crossing has been tractored and the stream valley is hummocky and filled with large woody debris.	1) Excavate crossing from TOP to BOT, laying back banks 2:1 for decommission 2) Provide grade control by installation of 10yd of 2' diameter rip-rap at the TOP of the excavation 3) Install 3 cross-road drains to the left road reach.
178	26020	-	Stream crossing	18	0	0	Class II that had experienced a debris slide in the past. Slide deposit has developed an alluvial fan on an old railroad bed along the right bank of Big Salmon Creek. Fan deposit is entirely vegetated with alders and redwood. Fan is saturated with multiple channels.	No treatment.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
179	26020	-	Stream crossing	15	25	80	This site is on the old railroad grade. Stream of site #174. A large fan has developed at the confluence of this stream and BSC. Many ASG or old growth trees are within the fan. Stream flows down left side of fan and has a 6' knickpoint near the TOP. Future erosion is from erosion of banks through the fan. Stream channel above the site is tractored.	This site is relatively inaccessible.
180	26020	-	Stream crossing	3	0	0	Class II stream with evidence of debris slide deposits in the channel. Toe of slide has deposited onto road/railroad bed and continued to Big Salmon Creek. Slide deposit is densely vegetated with redwoods maples and alders. Minimal channel development across deposit.	No treatment.
181	26020	-	Stream crossing	42	0	45	Site is located on an old railroad grade. This stream is very low power. Small pebbles have been deposited on the road surface. Stream is likely to never erode through the fill. Some holes in the fill are visible at the OBF (2'd x 3'w). Equipment access to this site is a major issue/problem.	None

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
182	26020	-	Stream crossing	6	130	0	Railroad fill crossing crosses Class II stream channel about 40' upslope from mainstem Big Salmon Creek. Stream has diverted down the right road reach for about 40' from center line of profile before leaving the road surface. Area looks very stable and densely vegetated with alders and redwoods.	No treatment.
183	26020	-	Spring	3	130	0	A spring saturates road surface. The majority of the road fill has already failed into the Class 1 mainstem of Big Salmon Creek. FE= 6'h x 4'd x 28'w (*1/2) = 15	No treatment.
184	26020	-	Stream crossing	0	0	50	Minimal channel development above road. Stream flows onto road prism and dissipates into fill. Most likely only connected to Big Salmon Creek during the largest storm events. There is no left road contribution but no diversion potential either.	No treatment.
185	26020	-	Stream crossing	7	70	120	This small stream is on the left (east) side of a landslide identified on the 1960's photos. Most of the fill has been eroded and the channel is down to roots and large rocks and is relatively stable.	No treatment.

Table A1. Field observations and treatment recommendations for road related sites, Big Salmon Creek Sediment Source Assessment, Mendocino County, California.

Site #	Road	Treatment immediacy	Problem	Estimated future sediment delivery (yds³)	Hydrologically connected road length		Comment on problem	Comment on treatment
					Left ditch/road length (ft)	Right ditch/road length (ft)		
186	-	L	Stream crossing	86	140	65	This crossing may be difficult to access due to private property to the right. Small wood is present in the fill. Wood is acting as temporary grade control. Several 2-3' knickpoints exist in channel through the profile.	1) Excavate crossing from TOP to BOT. Install a 24" x 50' culvert at the base of fill. 2) Buttress the base of the outboard fillslope with 5yd of 1.5 diameter rip rap. 3) Install 1 rolling dip to the left road reach (or a cross-road drain if site is decommissioned).

Appendix B

Typical drawings (schematic diagrams) showing components of erosion control and erosion prevention treatments, and techniques for construction.

2009 Big Salmon Creek Sediment Source Assessment Project
Mendocino County, California

No.	Drawing title
1	Typical problems and applied treatments for a non-fish bearing upgraded stream crossing
2	Typical design of a non-fish bearing culverted stream crossing
3	Typical design of a single-post culvert inlet trash rack
4	Typical design for armoring fillslopes
5	General armored fill dimensions
6	Typical armored fill crossing installation
7	Ten steps for constructing a typical armored fill crossing
8	Typical ditch relief culvert installation
9	Typical designs for using road shape to control road runoff (using insloping, outsloping, and crowning)
10	Typical methods for dispersing road surface runoff with waterbars, cross-road drains, and rolling dips
11	Typical road surface drainage by rolling dips
12	Typical sidecast or excavation methods for removing outboard berms on a maintained road
13	Typical excavation of unstable fillslope on an upgraded road
14	Typical problems and applied treatments for a decommissioned stream crossing
15	Typical design for road decommissioning treatments employing export and in-place outsloping techniques
16	Typical excavation of unstable fillslope on a decommissioned road

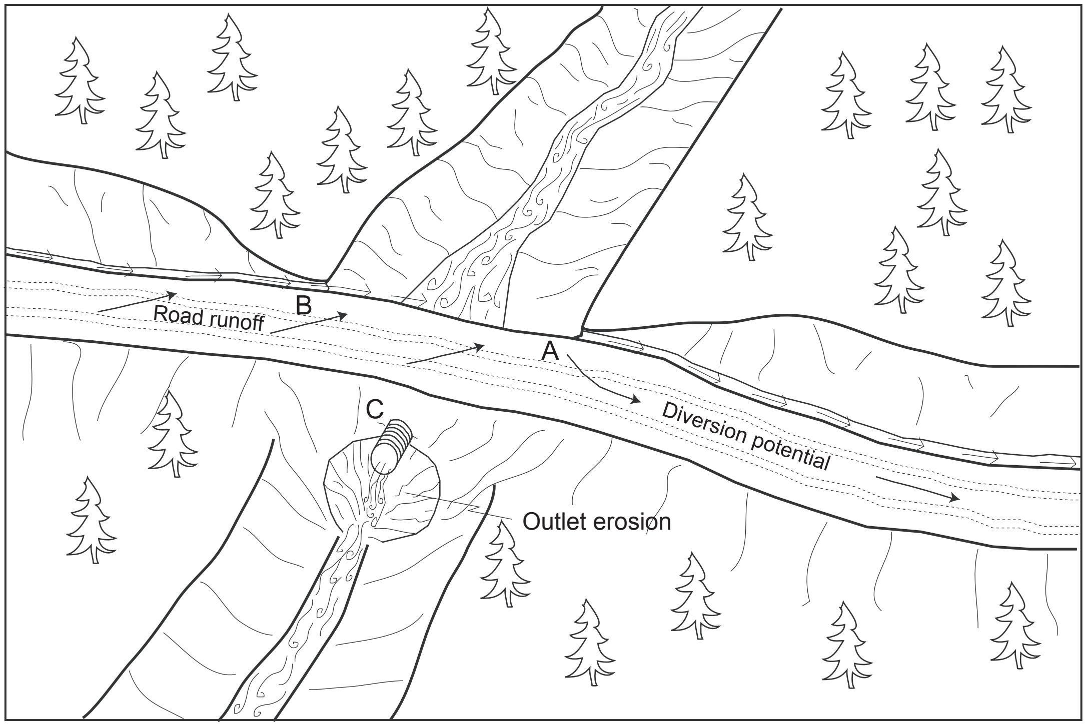
Typical Problems and Applied Treatments for a Non-fish Bearing Upgraded Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

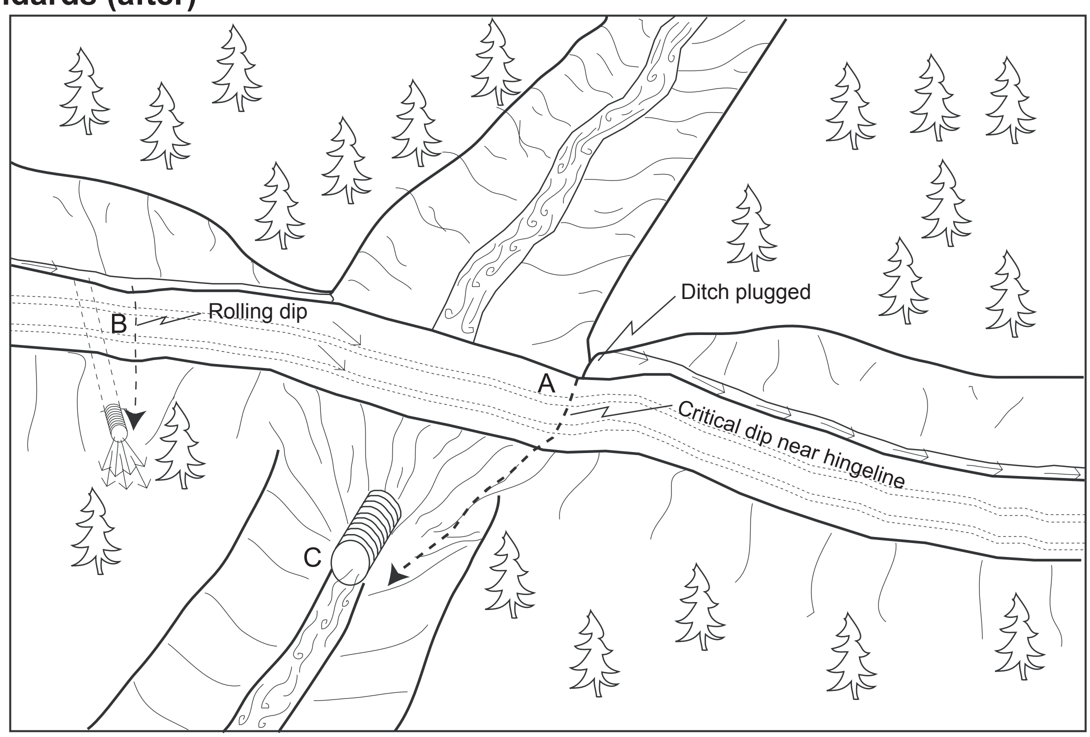


Treatment standards (after)

A - No diversion potential with critical dip installed near hingeline

B - Road surface and ditch disconnected from stream by rolling dip and ditch relief culvert

C - 100-year culvert set at base of fill



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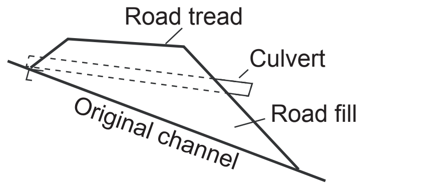
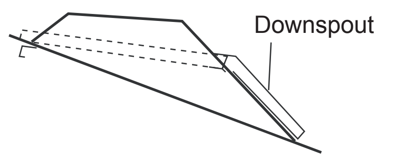
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing



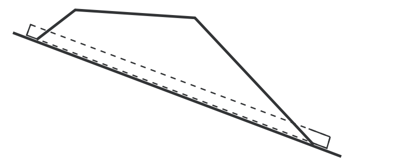
1. Culvert not placed at channel grade.
2. culvert does not extend past base of fill.

Upgraded



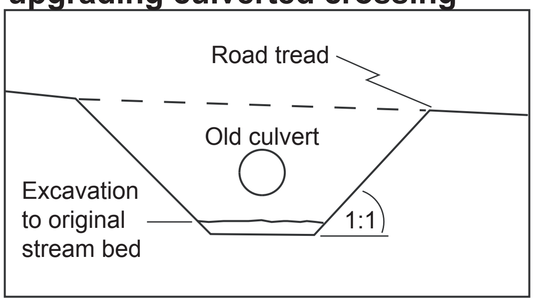
1. Culvert not placed at channel grade.
2. Downspout added to extend outlet past road fill.

Upgraded (preferred)

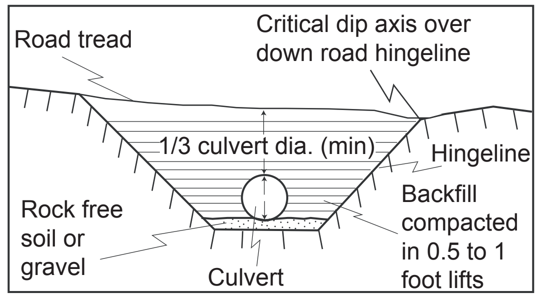


1. Culvert placed at channel grade.
2. Culvert inlet and outlet rest on, or partially in, the originial streambed.

Excavation in preparation for upgrading culverted crossing



Upgraded stream crossing culvert installation



Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calulations using a procedure such as the Rational Formula.

Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed, or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - Backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures implemented will be evaluated on a site by site basis. Erosion control measures include but are not limited to:

1. Minimizing soil exposure by limiting excavation areas and heavy equipment distrubance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as “anchor” for the fill and filter windrows.
4. Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first rains.
5. Excess or unusable soil will be stored in long term spoil disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential, or proximity to a watercourse.
6. On running streams, water will be pumped or diverted past the crossing and into the downstream channel during the construction process.
7. Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.

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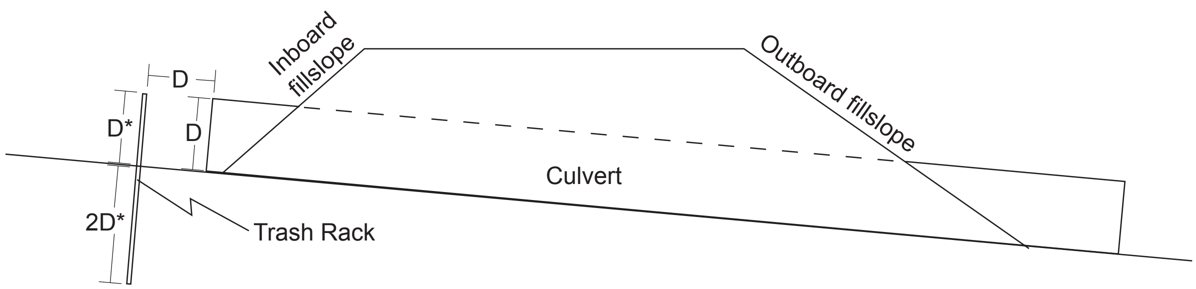
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



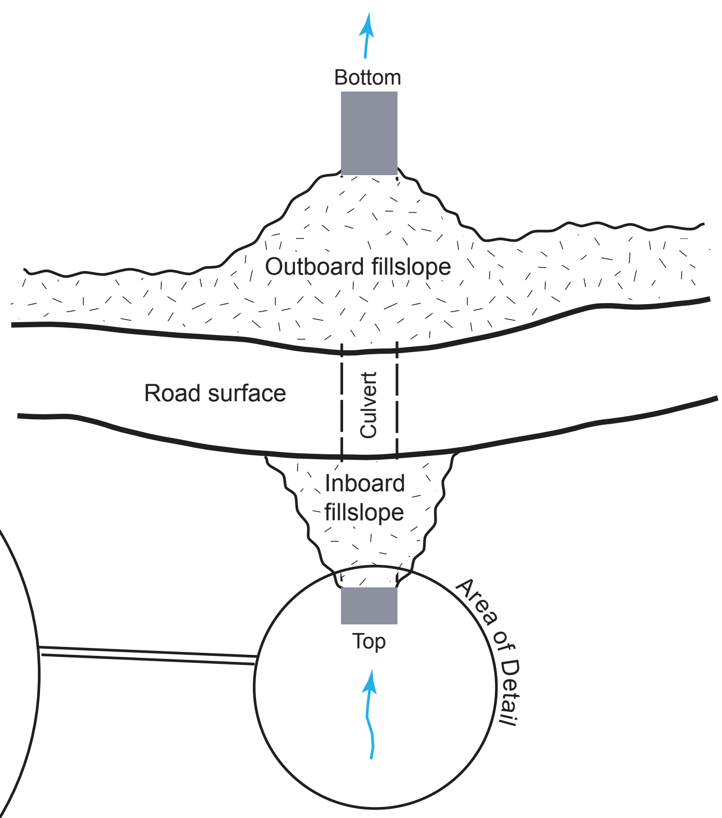
D - Culvert diameter

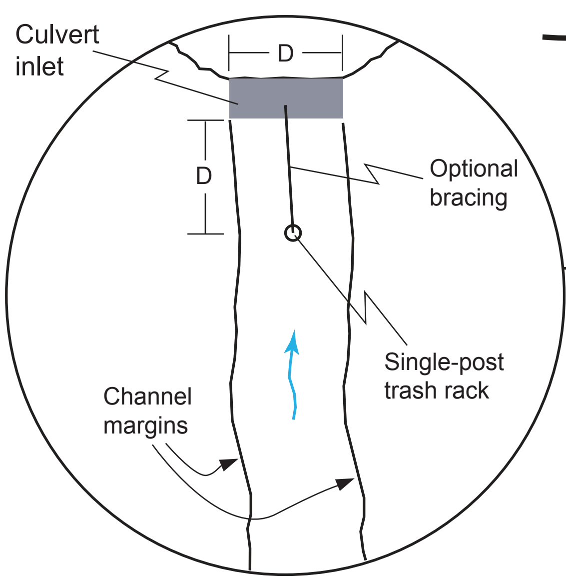
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

Plan view

Notes:

1. Many materials can be used for a single-post trash rack including old railroad track, galvanized pipe, and fence posts.
2. The diameter of single-post trash racks should be sized based on the size of expected woody debris. As a basic rule of thumb, the diameter of the trash rack should be equal to the diameter of the expected woody debris up to 4 inches.





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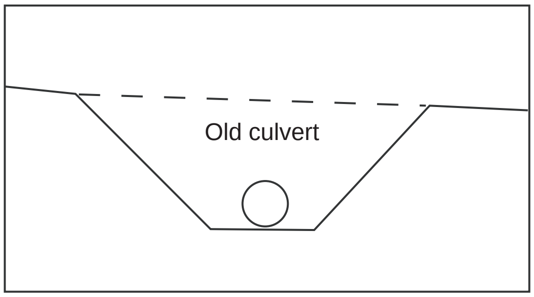
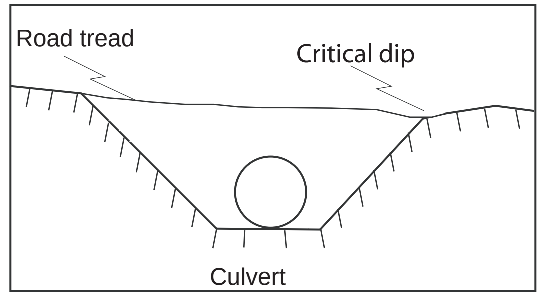
Typical Design of Upgraded Stream Crossings





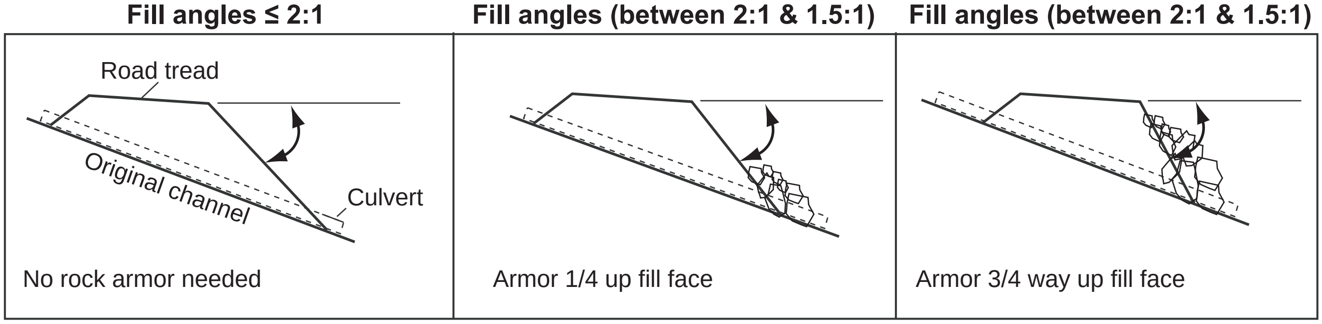
Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end and then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

Armoring fill faces

Fill angles ≤ 2:1 | **Fill angles (between 2:1 & 1.5:1)** | **Fill angles (between 2:1 & 1.5:1)**



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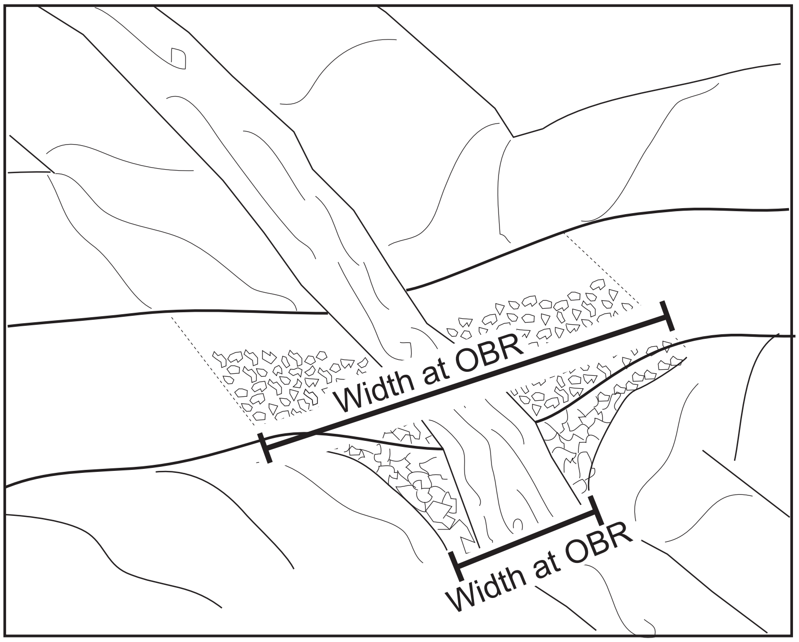
PWA Typical Drawing #4

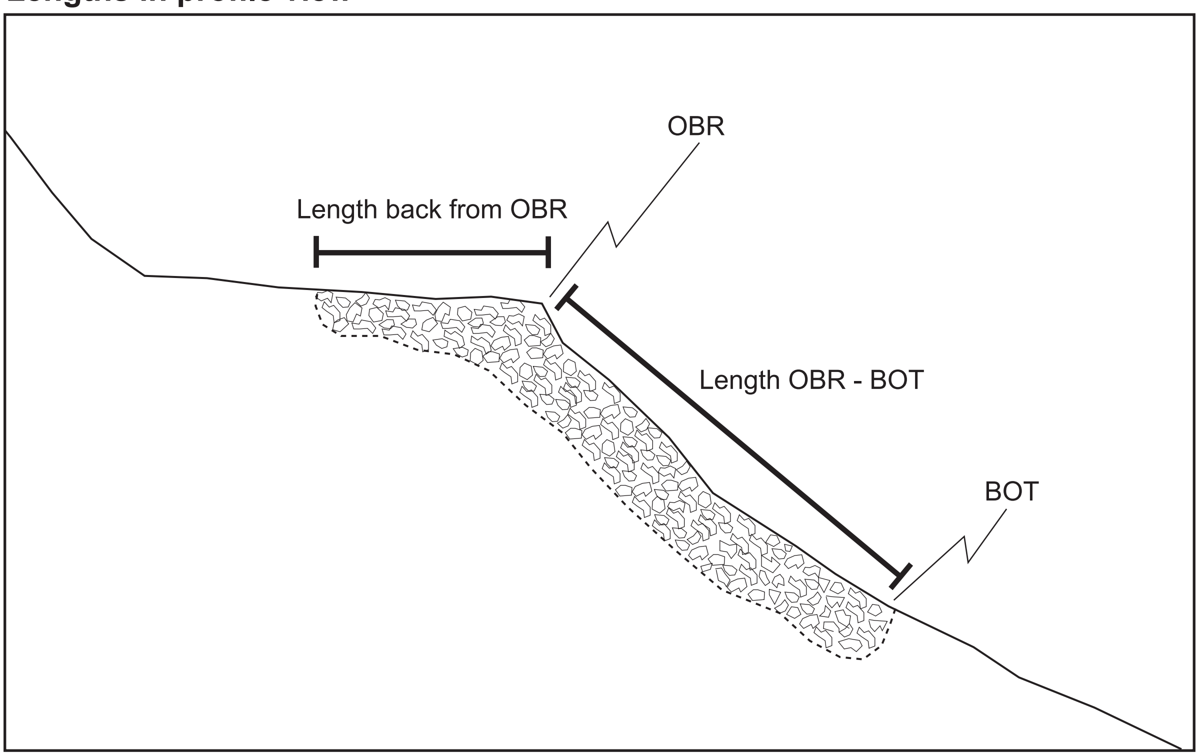
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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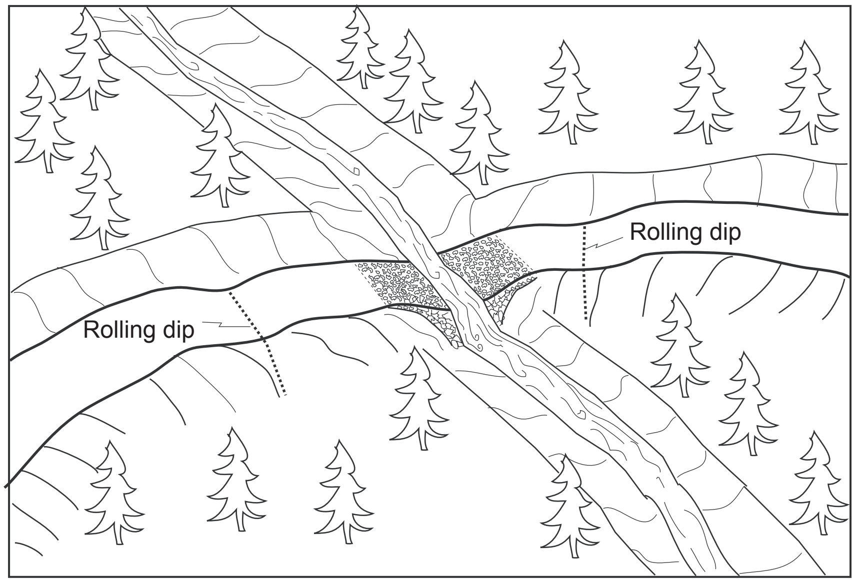
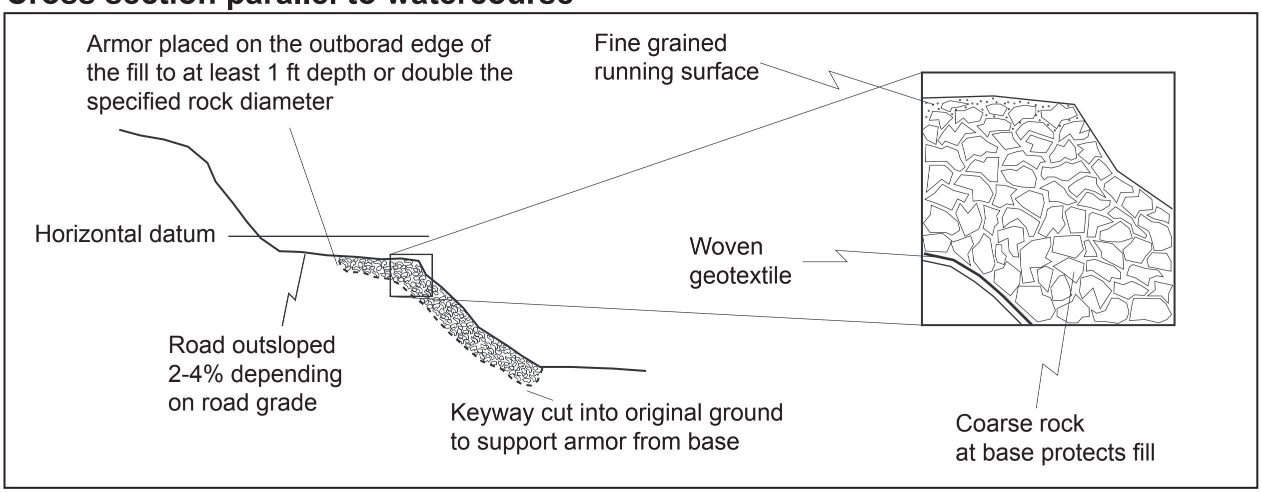
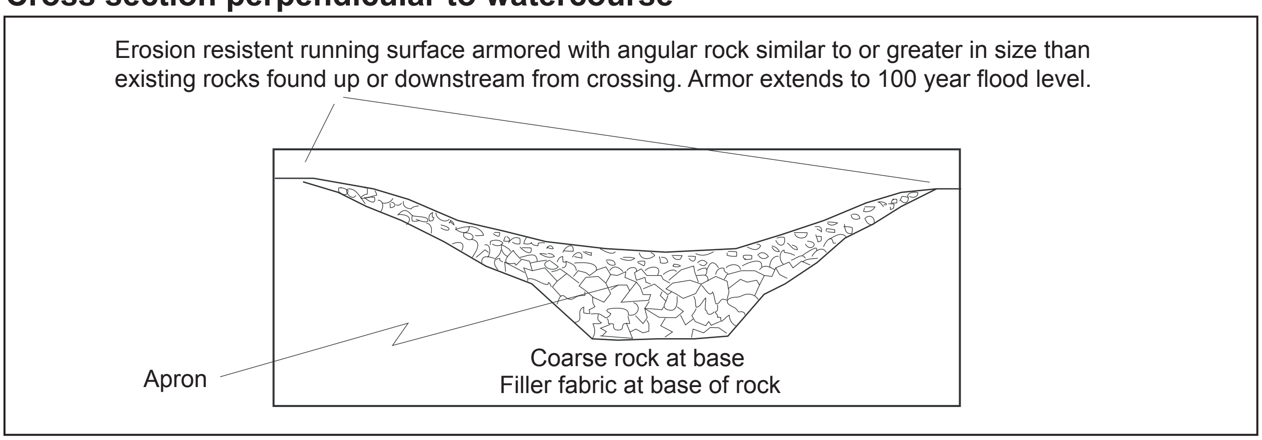
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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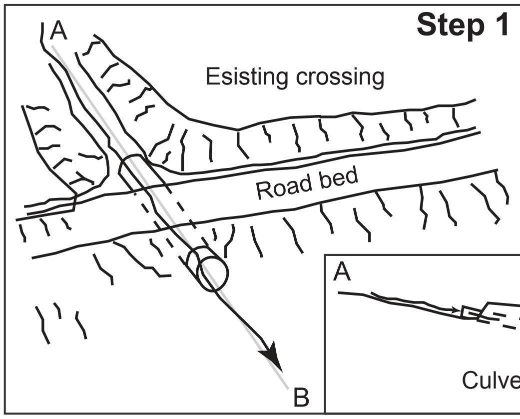
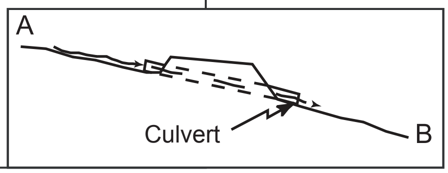
Ten Steps for Constructing a Typical Armored Fill Stream Crossing

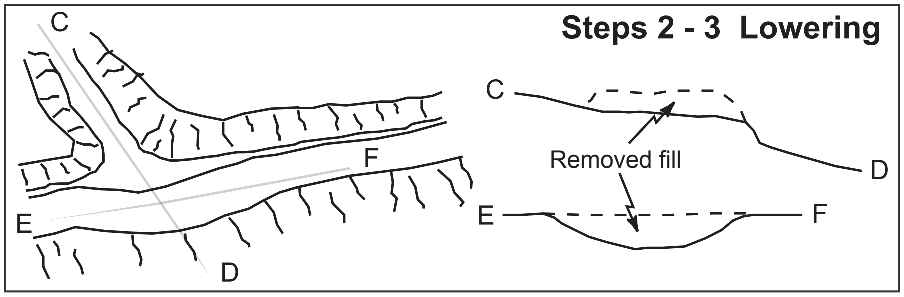


1. The two most important points are:

A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

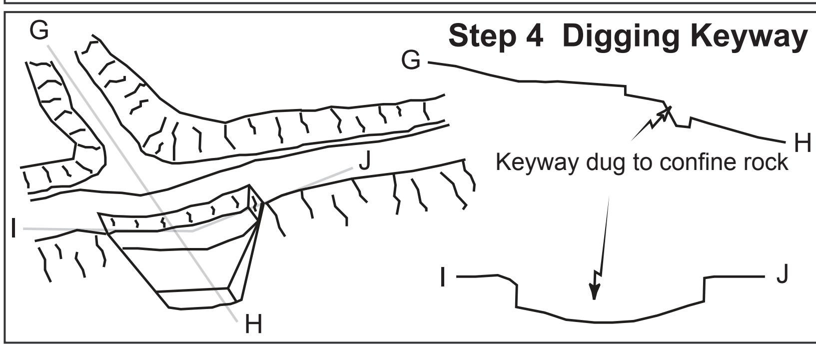
B) **The largest rocks must be used to buttress the rest of the armor in two locations:** (i) The base of the armored fill where the fill meets natural channel. (This will butress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). (ii) The break in slope from the road tread to the outer fill face. (This will butress the fill placed on the outer road tread and will determine the "base level" of the creek as it crosses the road surface).





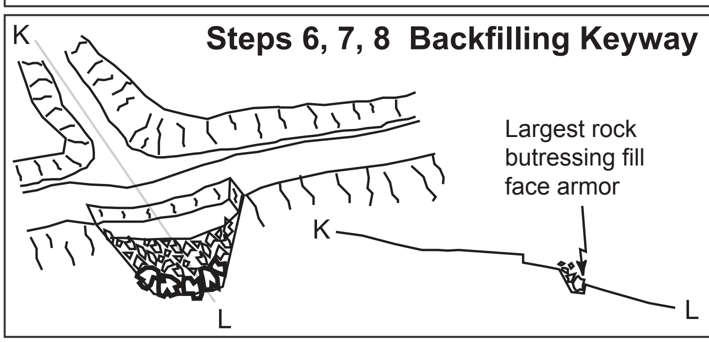
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year peak storm flow and prevent diversion (C-D, E-F).



4. Dig a keyway (to place rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to the point where outbaord fill meets natural channel (up to 3 feet into the channel bed depending on site specifics) (G-H, I-J).

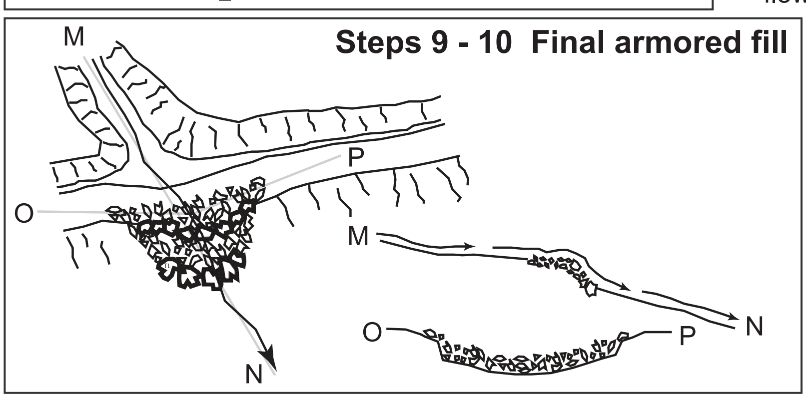
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



6. Put aside the largest rock armoring to create 2 buttresses in the next step.

7. Create a buttress using the largest rock (as described in the site treatments specifications) at the base of fill. (This should have a "U" shape to it and will define the outlet of the armored fill.)

8. Backfill the fill face with remaining rock armor making sure the final armored area has "U" shape that will accomodate the largest expected flow (K-L).



9. Install a second buttress at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction). (M-N)

10. Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a "U" shape that will accommodate the largest expected flow (O-P).

Typical Drawing #7

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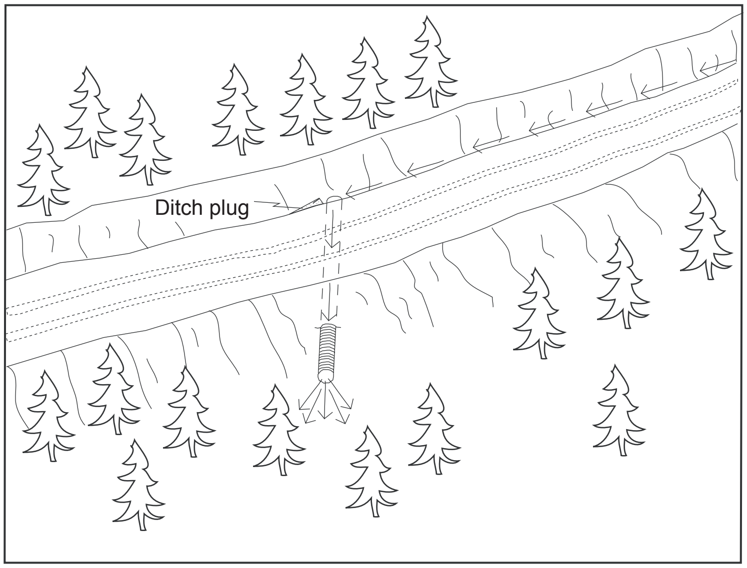
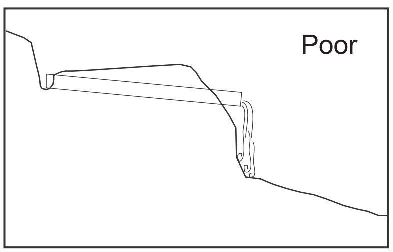
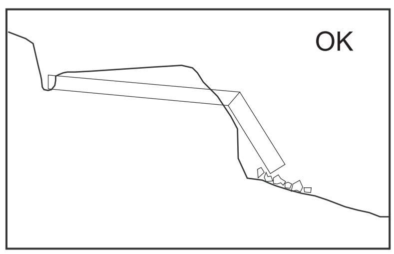
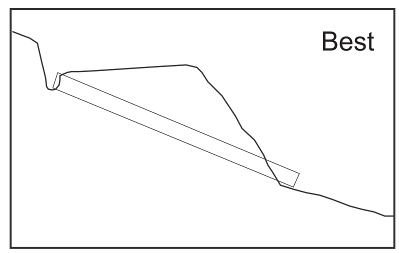
Typical Ditch Relief Culvert Installation









Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum, culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, which ever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used). 7Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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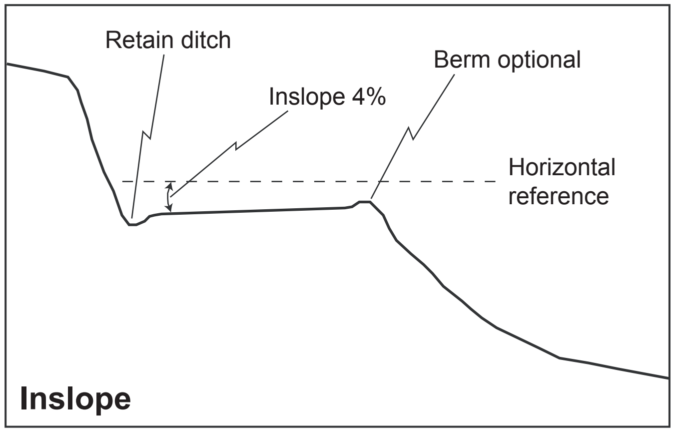
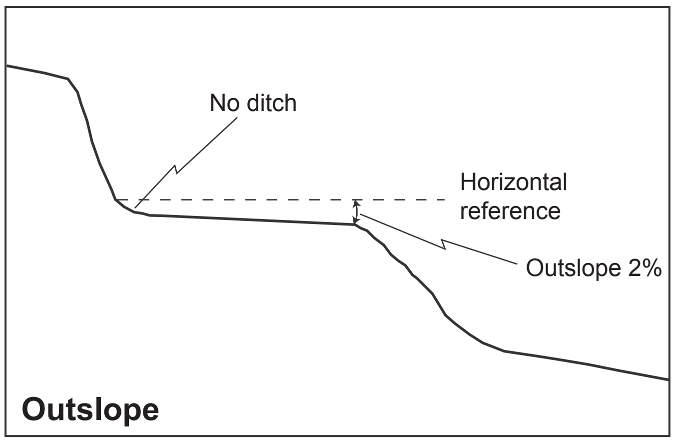
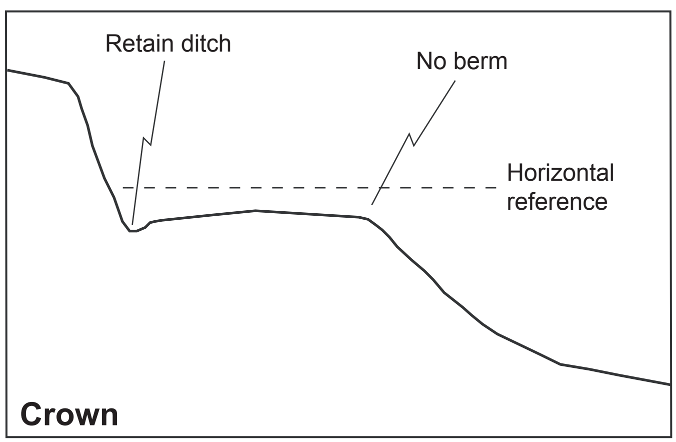
Typical Designs for Using Road Shape to Control Road Runoff







Outsloping Pitch for Roads Up to 8% Grade		
Road grade	**Unsurfaced roads**	**Surfaced roads**
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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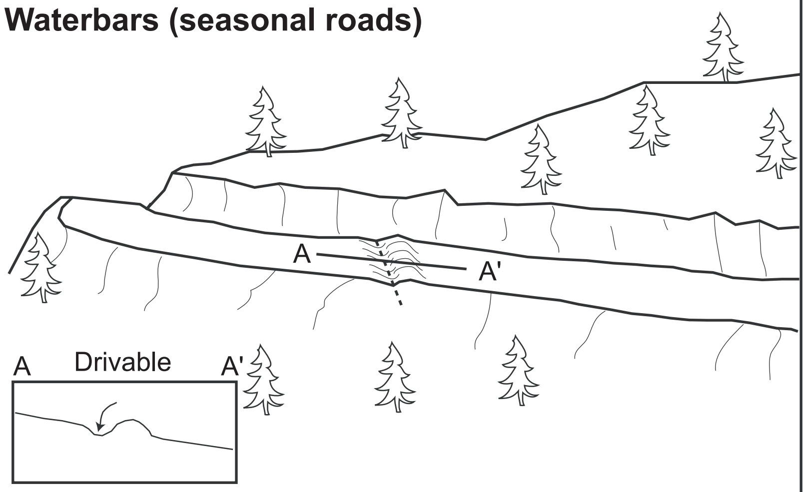
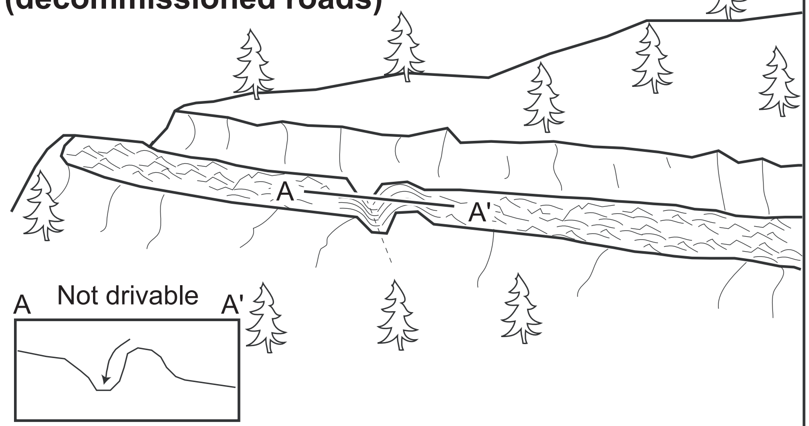
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

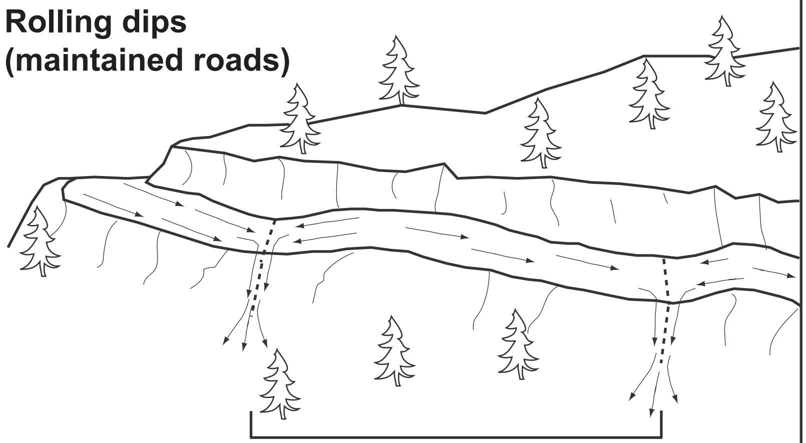
Waterbars (seasonal roads)



Cross-road drain and decompaction (decommissioned roads)



Rolling dips (maintained roads)



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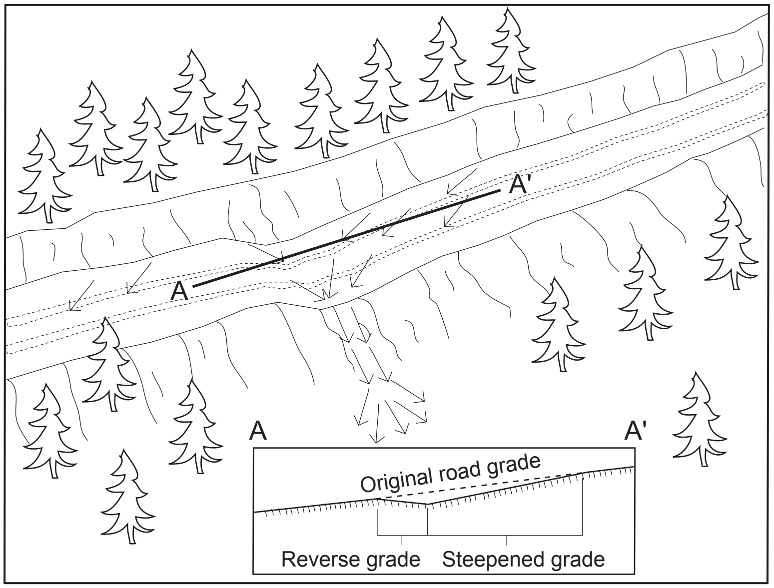
Typical Road Surface Drainage by Rolling Dips



Rolling dip installation:

1. Rolling dips will be installed in the roadbed as needed to drain the road surface.
2. Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3. Rolling dips are usually built at 30 to 45 degree angles to the road alignment with cross road grade of at least 1% greater than the grade of the road.
4. Excavation for the dips will be done with a medium-size bulldozer or similar equipment.
5. Excavation of the dips will begin 50 to 100 feet up road from where the axis of the dip is planned as per guidelines established in the rolling dip dimensions table.
6. Material will be progressively excavated from the roadbed, steepening the grade unitl the axis is reached.
7. The depth of the dip will be determined by the grade of the road (see table below).
8. On the down road side of the rolling dip axis, a grade change will be installed to prevent the runoff from continuing down the road (see figure above).
9. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to the original slope.
10. The transition from axis to bottom, through rising grade to falling grade, will be in a road distance of at least 15 to 30 feet.

Table of rolling dip dimensions by road grade

Road grade %	**Upslope approach distance** (from up road start to trough) ft	**Reverse grade distance** (from trough to crest) ft	**Depth at trough outlet** (below average road grade) ft	**Depth at trough inlet** (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20 - 25	1.2	0.01
>12	100	20 - 25	1.3	0.01

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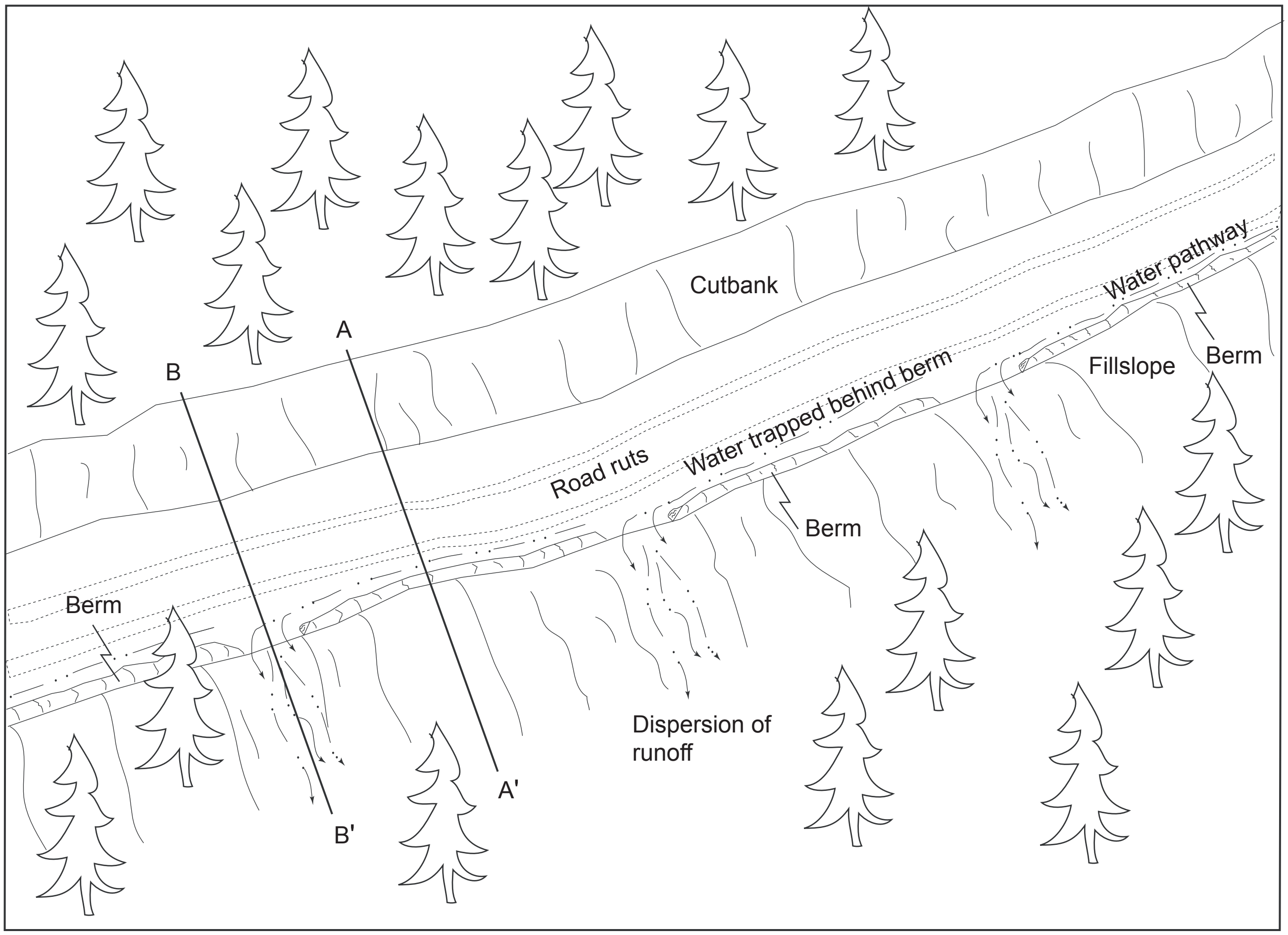
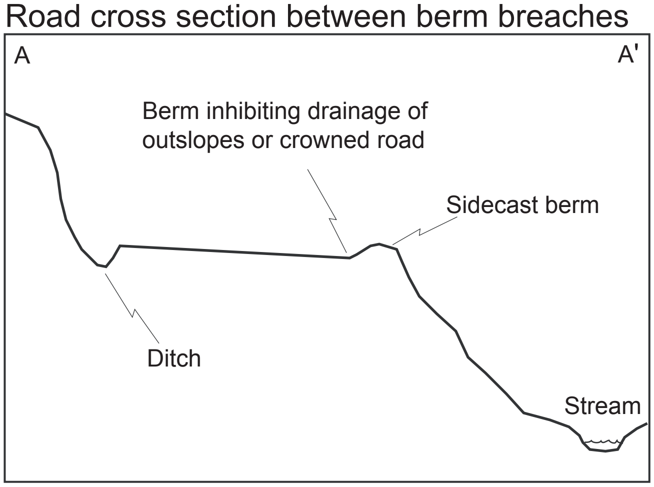
Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

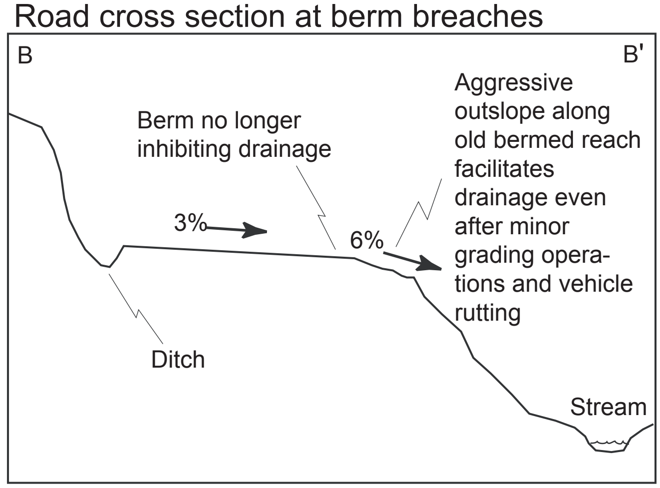
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B') Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a semi-continuous berm for vehicle safety.



Road cross section between berm breaches



Road cross section at berm breaches



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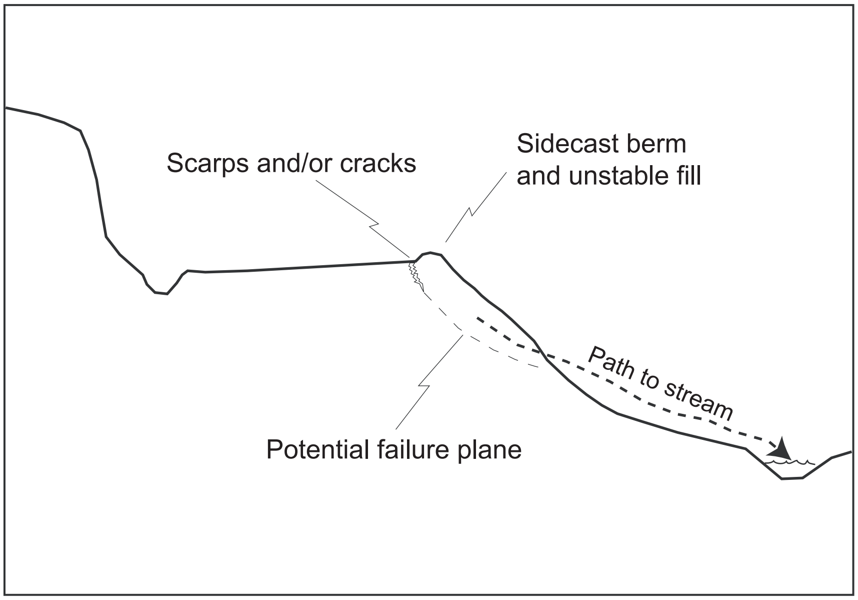
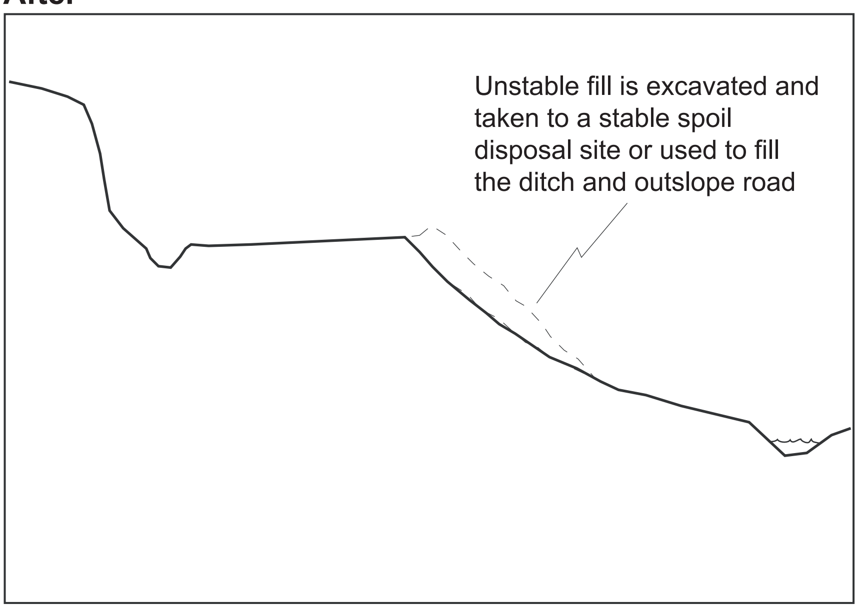
Typical Excavation of Unstable Fillslope on an Upgraded Road

Before



After



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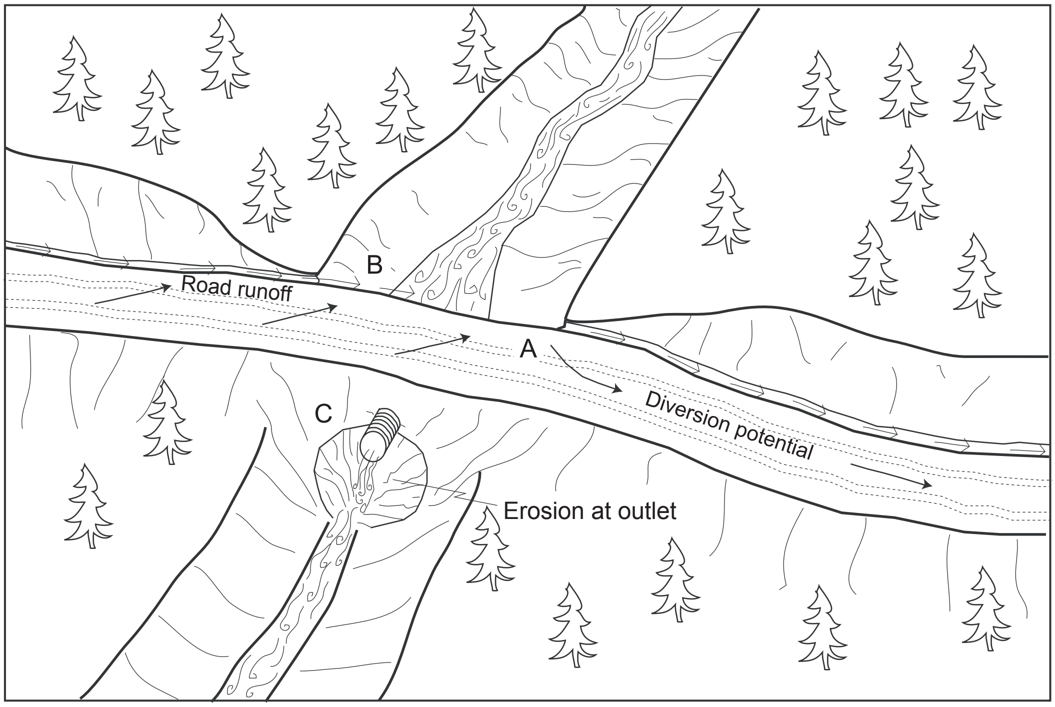
Typical Problems and Applied Treatments for a Decommissioned Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

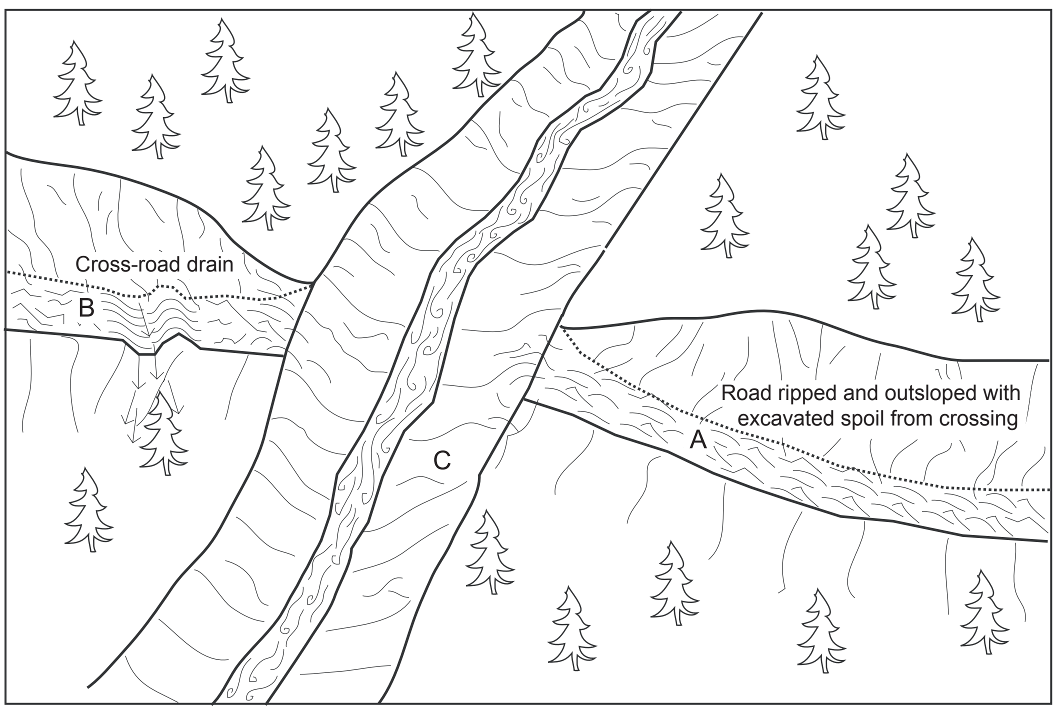


Treatment standards (after)

A - Diversion prevented by road surface ripping and outsloping using exca-vated spoils

B - Road surface and ditch disconnected from stream by road surface decompaction and cross-road drains

C - Stream crossing fill completely excavated



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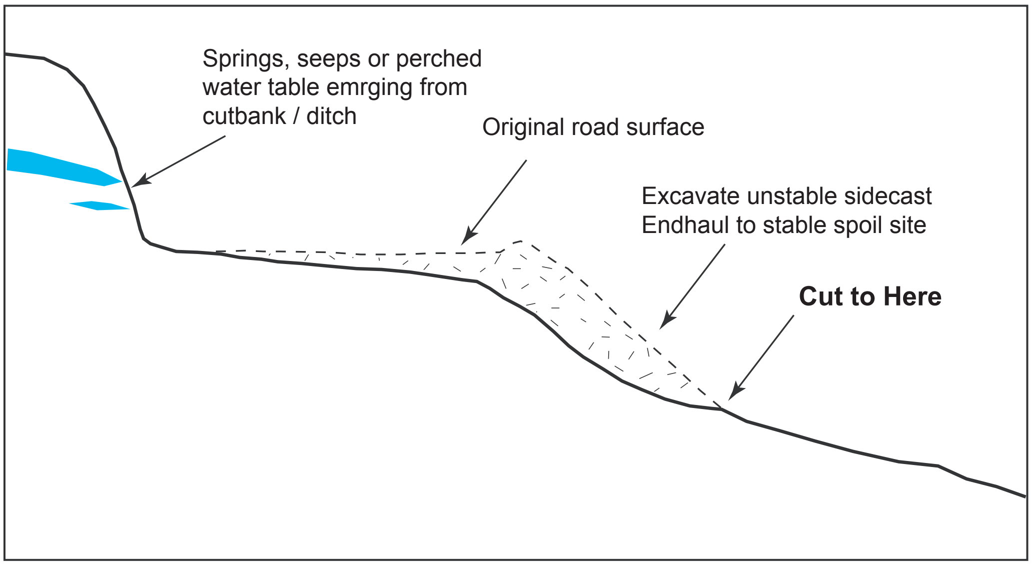
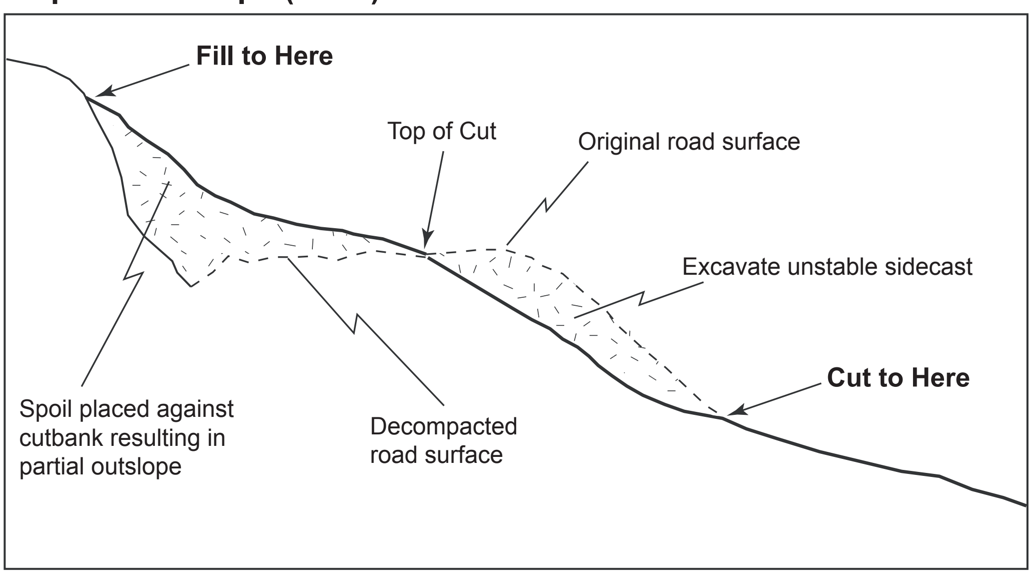
Typical Design for Road Decommisioning Treatments Employing Export and In-Place Outsloping Techniques

Export outslope (EPOS)



In-place outslope (IPOS)



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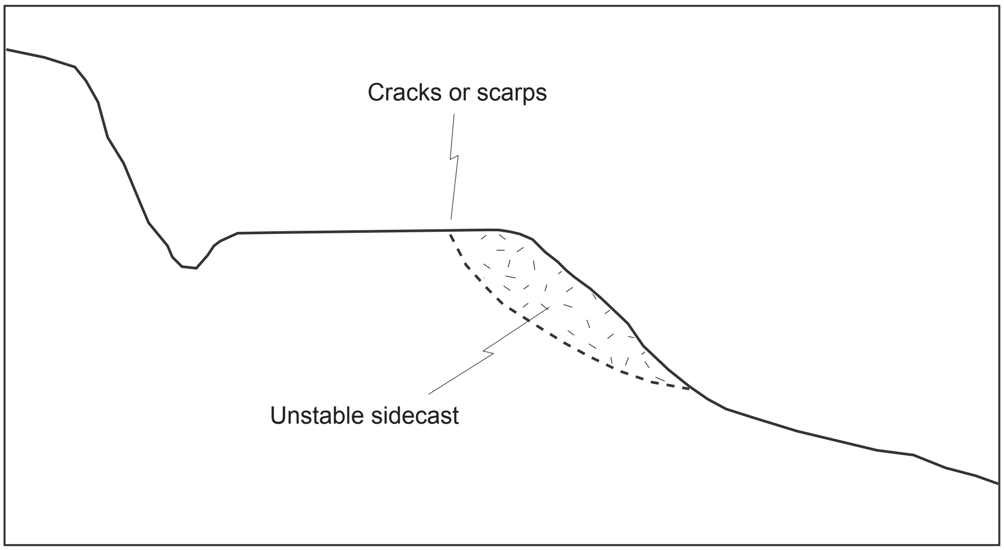
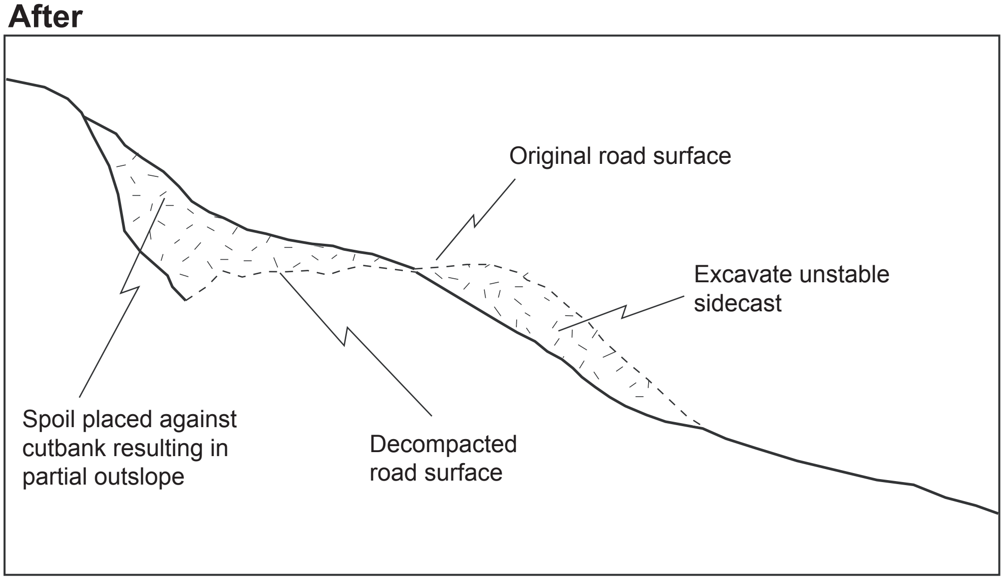
Typical Excavation of Unstable Fillslope on a Decommissioned Road

Before



After



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