



**Stenner Creek Erosion Control and  
Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California**

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## COVER PHOTO

Left photo is a view of Stenner Creek Road looking northeast towards Los Padres National Forest. Right photo is a view of an undersized culverted stream crossing along Peterson Ranch Road and its associated fill.

## 1 PROJECT SUMMARY

In 2022, Coastal San Luis Resource Conservation District (CSLRCD) received a grant from the California Department of Conservation (DOC) for restoration and enhancement of riparian corridor along approximately 16 miles of stream channel, and the surrounding 2,000 acres of actively grazed ranchland commonly known as the headwater's region of the Stenner Creek Watershed area, near San Luis Obispo, California (agreement/grant #3022-100). This report, entitled *Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California*, completes Task 2.1.1 of the grant work plan for an upslope road and trail assessment on two ranches owned and managed by California Polytechnic State University (Cal Poly), Serrano Ranch and Peterson Ranch located in the Stenner Creek watershed, and development of a prioritized erosion control plan.

In 2005, Pacific Watershed Associates (PWA) received a grant from the California Department of Fish and Wildlife (CDFW) to conduct an assessment of erosion and sediment delivery to streams within the Chorro Creek and Stenner Creek watersheds, near San Luis Obispo, California. Under that contract, PWA assessed 36.7 mi of road and 2.14 mi of trail in the Chorro and Stenner Creeks watersheds, developed estimates of future erosion risk, and developed detailed, site-specific prescriptions, prioritized treatment plans, and cost estimates for upland road erosion control treatments to prevent and control sediment impacts to the streams supporting threatened South-Central California coast steelhead.

The 2022 *Stenner Creek Erosion Control and Sediment Reduction Plan* project involved re-assessing existing roads and trails that were inventoried in the 2005 assessment, as well as assessing additional roads and trails developed since the 2005 assessment and reporting were completed. In total, 8.6 mi of roads and 2.7 mi of trail were inventoried as part of this assessment within the landholdings of Cal Poly. According to Task 2.1.1 of the grant work plan, work tasks included: (1) compiling existing data of the upslope Stenner Creek watershed conditions, (2) conducting a field-based re-assessment of road and trail of existing and potential erosion and sediment delivery to Stenner and Brizziolari Creeks and their tributaries, (3) analyzing the field assessment data, and (4) developing a final Erosion Control and Sediment Reduction Plan including a map of all identified sites and treatment plans for each site.

PWA identified a total of 55 sites of ongoing and/or potential erosion and sediment delivery to streams along the 8.6 mi of road and 11 problematic sites along the 2.7 mi of trail. We recommend erosion control and erosion prevention treatments for 50 of the road related sites and 8 of the trail sites, which if left untreated, could deliver approximately 2,230 yd<sup>3</sup> of sediment to the mainstems and tributaries of Stenner and Brizziolari Creeks. In addition, field crews measured approximately 6.11 mi of road/ditch/cutbank surfaces and approximately 0.70 mi of trail/cutbank surfaces that are currently draining to stream channels, either directly or via gullies. We recommend treating approximately 5.91 mi of the road reaches and 0.63 mi of the trail segments to reduce surface erosion and sediment delivery to the stream system. If no efforts are made to change drainage patterns on these hydrologically connected stretches of roads and trails, we estimate that approximately 3,945 yd<sup>3</sup> of fine sediment (3,765 yd<sup>3</sup> from roads and 180 yd<sup>3</sup> from trails) could be delivered to the local stream system during the next 10 years. A prioritized, cost-effective treatment plan was developed to curtail both site-specific and road/trail surface erosion and sediment delivery using field data collected during the assessment. The estimated total cost to implement this plan is \$1,016,661, which includes expenses for labor, supplies, and use of heavy equipment.

The expected benefit of completing the erosion control and prevention planning work outlined in this report lies in a long-term reduction of road related sediment delivery to Stenner Creek, Brizziolari Creek, and ultimately to San Luis Bay. With this prioritized plan of action, cooperative watershed stakeholders can advance efforts to obtain funding to implement the recommended erosion remediation treatments for

the Cal Poly assessment area. We assert that the erosion control and erosion prevention treatments recommended in this assessment, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in these watersheds and in downstream areas.

## 2 CERTIFICATION AND LIMITATIONS

This report, entitled *Stenner Creek Erosion Control and Sediment Reduction Plan California Polytechnic State University, San Luis Obispo, California*, 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 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.

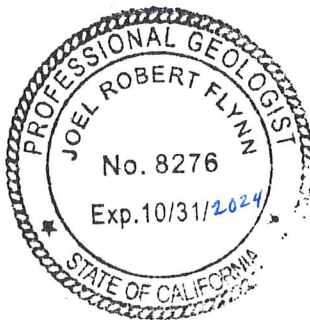
The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations are qualitative, or semi-quantitative, and confined to surface expressions of limited extent and artificial exposures of subsurface materials. Interpretations of problematic geologic 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 conclusions and recommendations contained 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 be consistent with existing conditions, information contained in the report should be reevaluated after a period of no more than three years, and it is the responsibility of the landowner to ensure that all recommendations in the report are reviewed and implemented according to the conditions existing at the time of construction. 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:

  
Joel Flynn, PG #8276

Pacific Watershed Associates Inc.



### 3 INTRODUCTION

One of the most important 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 (Harr and Nichols, 1993; Flosi et al., 1998). Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of rural, ranch, and forest road systems has an immediate benefit to the streams and aquatic habitat of a watershed (Weaver and Hagans, 1999; Weaver et al., 2006, 2015). It helps ensure that the biological productivity of the watershed's streams is minimally impacted by future road-related erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas.

Stenner Creek and its main tributary Brizziolari Creek are important streams for populations of threatened South-Central California coast steelhead, whose spawning and rearing habitat continues to be impacted by excessive fine sediment input. Stenner Creek drains a watershed covering about 10 mi<sup>2</sup> and flows through the city of San Luis Obispo. It is one of the 11 tributaries of San Luis Obispo Creek, which flows into the Pacific Ocean approximately 30 mi south of Morro Bay at San Luis Bay (Map 1). The lower Stenner Creek and Brizziolari Creek watersheds, along the mainstems of both streams, are primarily managed for agriculture and cattle ranching, whereas the upper watersheds are managed for various other purposes by San Luis Obispo County, the State, and the U.S. Forest Service (Map 1).

In 2005, Pacific Watershed Associates Inc. (PWA) was funded by CDFW to assess road and trail related erosion and sediment delivery to streams along maintained and abandoned roads and trails in the Chorro Creek and Stenner Creek watersheds<sup>1</sup> (Contract #P0430434) (Map 1). The purpose of that assessment project was twofold: (1) to identify and quantify road and trail related erosion and sediment delivery to streams in the watersheds and (2) to develop a prioritized plan of action for cost-effective erosion prevention and erosion control for problematic sites and sections of the road and trail systems. However, no road/trail treatment implementation work was ultimately performed as a result of PWA's 2009 report.

In 2022, Coastal San Luis Resource Conservation District (CSLRCD) received a grant from the DOC for restoration and enhancement of riparian corridors along approximately 16 miles of creek channel, and the surrounding 2,000 acres of actively grazed ranchland commonly known as the upper Stenner Creek Watershed area, near San Luis Obispo, California (Map 1). Subsequently, PWA was retained by CSLRCD as an independent contractor to reassess up to 19 miles of roads and trails within the original project area. The purpose of the reassessment was to investigate existing conditions and to assess current permitting needs.

This report presents the reassessment results for the area owned by Cal Poly which includes 2 separate ranches managed by the Cal Poly College of Agriculture. The *Stenner Creek Erosion Control and Sediment Reduction Plan* area (referred to as the "Stenner Creek project area" for this report) includes approximately 8.6 mi of the previously assessed 10 mi of road, and 2.7 mi of trails including the 2.4 miles of trails originally assessed within the Stenner Creek watershed (Map 2).

PWA conducted our initial road and trail assessment for this report during the summer and fall of 2022. According to the nearest rain gauge located in the hills above Serrano Ranch near the headwaters of Stenner Creek, from January 7-11, 2023, the Stenner Creek watershed received approximately 8.75 inches

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<sup>1</sup> Results for the entire Chorro/Stenner assessment area are provided in PWA Report No. 09071502 (Pacific Watershed Associates, 2009).

of rain<sup>2</sup>. Extensive damage to existing stream crossings, roads, and trails on the Serrano Ranch and Peterson Ranch occurred as a result of that and other high intensity rainstorms throughout the winter 2023 months. The damage included two culvert washouts at two stream crossing sites along mainstem Brizziolari Creek, one moderate size landslide along Poly Canyon Road (Map 2).

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 erosion originating from roads and trails in the Stenner Creek project area. All treatment prescriptions follow guidelines described in the *Handbook for Forest, Ranch and Rural Roads* (Weaver et al., 2015), 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). Discussions between PWA and CSLRCD personnel and Cal Poly staff were conducted throughout the assessment process in order to better understand the future infrastructure needs of the University and to make sure our recommendations would best fit these needs as well as Cal Poly's management practices. The overall treatment plan and site-specific prescriptions recommended in this report are intended to reflect Cal Poly's ranching and agricultural requirements for the transportation network. Although PWA's standard approach is to present the most cost-effective treatment prescription for erosion sites and road/trail reaches, variations to these plans are possible. With this in mind, Cal Poly road maintenance staff, with input from PWA, can adjust as needed the recommended site-specific treatments to accommodate the transportation needs of the road and trail system while still protecting streams and water quality.

Assessment data are summarized in Tables 1-8, Maps 1 and 2, and Appendixes B and C. Projected requirements for heavy equipment and estimated project costs are provided in Tables 9-10. A general overview of stormproofing rural and ranch road concepts is provided in Appendix A. Construction and installation instructions for the recommended erosion control and erosion prevention treatments are provided in Appendix D. Additionally, Appendix E provides a photo document of existing site conditions as of 2022.

## **4 FIELD DESCRIPTION OF THE ASSESSMENT AREA**

### **4.1 Climate, Terrain, and Geology**

The climate of central-coastal California in the Stenner Creek watershed is typically characterized by dry, warm-to-hot summers and cool winters with relatively mild storm events. This region has a mean annual precipitation of approximately 25 in., with most of the rainfall occurring in the winter months between November and March.

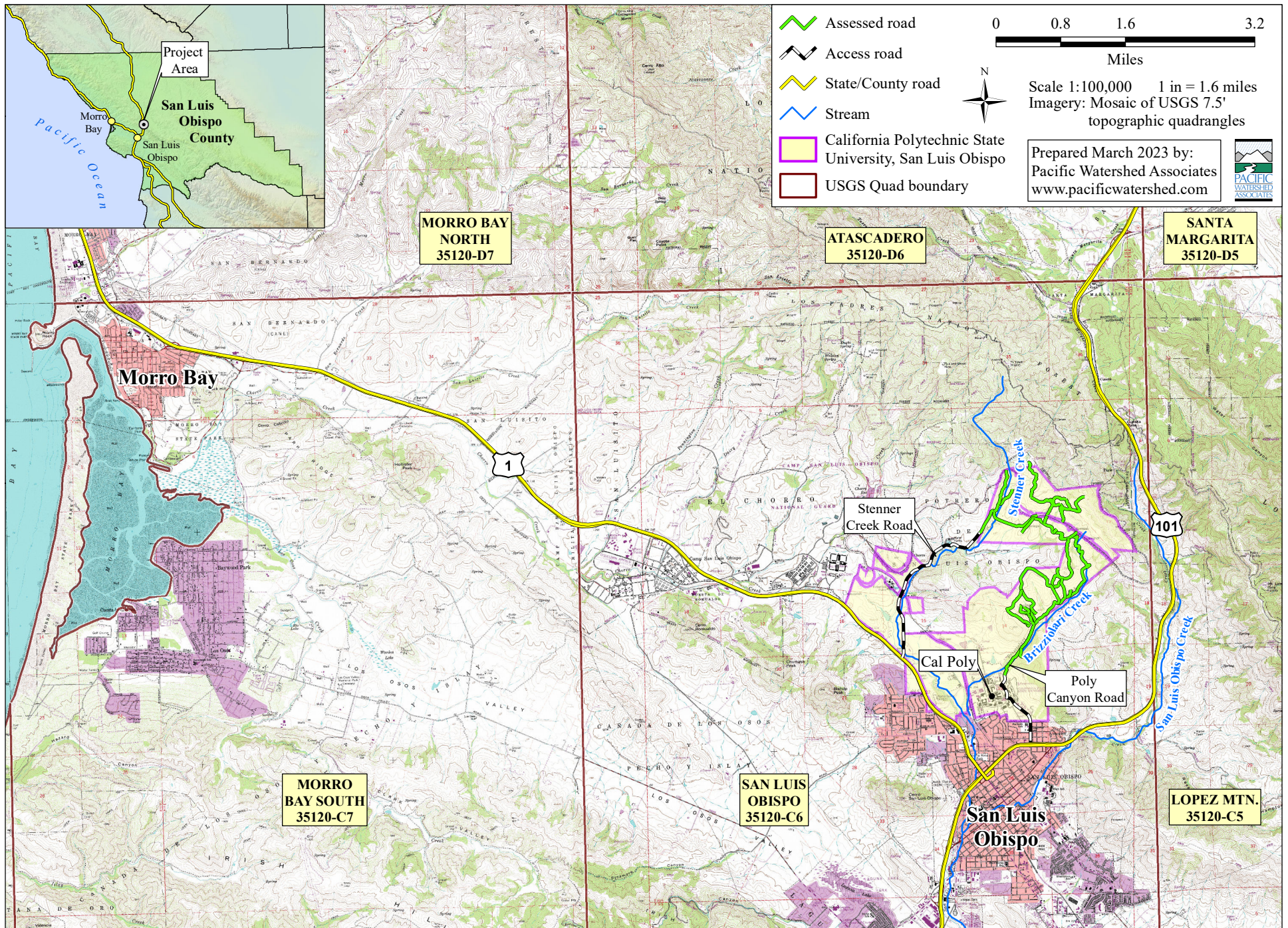
Elevations in the Stenner Creek project area range from approximately 400 ft in the southwest corner near the Cal Poly campus to 1,600 ft in the northeast edge of Serrano Ranch property boundary (Map 1). The southern portion of the assessment area is located along Brizziolari Creek within the narrow and steep Poly Canyon walls (Map 2). The northern portion of the area extends into the precipitous, mountainous terrain of the Los Padres National Forest, with hillslope gradients frequently exceeding 70% along inner gorges of steep, lower order tributary stream channels.

The vegetation of the property attests to the mild, short winters, hot summers, and history of frequent fires in the area. The vegetation is predominantly grassland and chaparral, with widely scattered oak and bay

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<sup>2</sup> [https://wr.slocountywater.org/sensor/?time\\_zone=US%2FPacific&site\\_id=31&site=03b43847-9ed0-4d76-9583-e](https://wr.slocountywater.org/sensor/?time_zone=US%2FPacific&site_id=31&site=03b43847-9ed0-4d76-9583-e)





Map 1. Location of the Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California



trees growing on the northern slopes and in the lower hillslope position of deeply incised and steep stream canyons.

The geology of the Stenner Creek project area is controlled by active compressional tectonics and strike-slip faulting resulting in distinct north-northwest trends in bedrock units. Most of the property is underlain by highly sheared Late Cretaceous and Paleogene Franciscan subduction Complex characterized by graywacke, shale, greenstone, and chert interspersed with serpentine and ophiolitic rocks commonly associated with the Jurassic Period (Page et al., 1998). Most of the grassland slopes are underlain by *mélange* and, in general, the steeper chaparral hillslopes are underlain by more massive serpentinite rock types. Along the highest elevation northeastern area, a narrow belt of Miocene marine sandstones, shales, and cherts are exposed (Wieggers, M.O., 2010).

Elsewhere throughout the property, several narrow north-northwest trending serpentinized ultramafic zones crop out within and adjacent to Franciscan Complex lithologies. The *mélange* and sedimentary rock units are highly weathered and fractured making them very erodible during the infrequent winter storm events characteristic of the region. There appears to be a widespread occurrence of expansive soils in the project area likely associated with swelling clay minerals formed by alteration of mafic and ultramafic rock units. While the expansive properties of these soils are of greatest concern when designing and constructing building foundations, pipelines, and other structures, rural and ranch land roads can also be adversely affected. Because of the soil's properties, unsurfaced roads cannot be safely used when they are wet, and even minor amounts of vehicle traffic can severely damage the road surface and defeat proper road surface drainage. Even on fairly gentle slopes, bare cutbanks in expansive soils are often characterized by shallow slope failures and soil flowage during periods of saturation. These processes increase sediment delivery to the road surface and streams and result in increased grading and road maintenance requirements.

Continuous shrinking and swelling of the fine-grained soils, in combination with vehicle and other traffic during dry periods, produces erodible materials on native surface roads and this material is easily eroded and transported to nearby streams. Because of their properties, expansive clay soils should be disturbed as little as possible when wet or moist. The overall combination of unstable and erodible geologic substrates, sensitive soils, cattle movement, recreational activity, ranch and farm vehicle traffic, and poor road drainage has led to relatively high rates of erosion and sediment delivery from road and trail networks to stream channels in the project area.

## **4.2 Assessed Roads on Cal Poly Property**

The Stenner Creek project area includes 8.6 mi of roads, primarily consisting of low-use ranch access and fire roads (Map 2). The majority of the roads within the Cal Poly assessment area were originally constructed to access pasture lands or used as firebreaks. Undersized drainage structures, stream diversions, occasional fill failures, and uncontrolled road surface runoff are typical along many of these low-use roads.

The Stenner Creek project area lies entirely within the greater Stenner Creek watershed (Map 2). It includes Serrano Ranch (754 acres), which is within the watershed of mainstem Stenner Creek, and Peterson Ranch (650 acres), which mainly encompasses the Brizziolari Creek sub-watershed, a tributary to Stenner Creek (Map 2). The Stenner Creek project area is bounded to the north by the Los Padres National Forest, to the south by the Cal Poly San Luis Obispo (SLO) campus, to the west by private property, and to the east by the Southern Pacific Railroad. The northern section of the project area can be reached via Stenner Creek Road, which enters the area along the mainstem of Stenner Creek. The best

access for the southern part of the area is via Poly Canyon Road, which runs from the north end of the Cal Poly campus along Brizziolari Creek before it turns west to connect with the northern end of Stenner Creek Road. Stenner Creek and Poly Canyon Roads basically form a loop through the area, and several small spur roads branch off of this loop to access water troughs, barns, and other structures (Map 2).

Approximately 8.6 mi of roads were assessed in the hilly, grassland environment of the project area. Vehicle traffic on these roads is light, but because of the proximity to the Cal Poly SLO campus, they are actively used by hikers and cyclists. In general, the roads are narrow with shallow road fills. The exception is the southern portion of Poly Canyon Road, which traverses Poly Canyon along Brizziolari Creek to provide access to campus facilities. Constructing the broad bed for this road required significant cutting into the steep bedrock walls of Poly Canyon.

In general, stream crossings in the Stenner Creek project area have small fill volumes, appear to receive minimal maintenance, and exhibit high levels of cattle impacts, with fences installed around many of the small perennial streams to keep cattle out. Several of the stream crossings are fitted with poorly functioning and undersized culverts that are old, rusting, short or poorly aligned. Long stretches of road have no road surface drainage structures installed, and a very high percentage of the road lengths are concentrating road surface runoff and erosional products which is then being delivered to the stream system in the watershed.

#### **4.3 Assessed Trails on Cal Poly Property**

Hiking and cycling are very popular pastimes in the Cal Poly SLO assessment area. Serrano and Peterson Ranches, north of the Cal Poly SLO campus, are open to the public and receive high levels of recreational use. In addition to the road system, there is also a network of approximately 2.7 mi of single-track trails available for use by hikers and cyclists (Map 2). This network in the Stenner Creek watershed is connected to trails on neighboring publicly-owned properties, creating a total trail network more than 5 mi long for the Chorro Creek and Stenner Creek watersheds. Although the average width of the trails assessed for the project (in the Stenner Creek watershed) is only 3 to 4 ft, the trails are still capable of disrupting the local hydrology by diverting streams and channeling hillslope drainage and trail derived sediment into local waterways.

### **5 SEDIMENT SOURCES**

Sources for erosion and sediment delivery in the assessment area are divided into two categories: (1) sediment derived from specific treatment sites, and (2) sediment derived from the surfaces of road and trail segments of varying lengths—and their associated cutbanks and inboard ditches—that are hydrologically connected<sup>3</sup> to streams.

Site-specific erosion is termed *episodic* because it is projected to occur at some indeterminate time in the future, usually in response to an event such as a high intensity and/or long duration storm or flood. Some sites, such as unstable fillslope landslides on steep hillslopes, may show evidence for imminent failure, erosion, and sediment delivery. Other sites may show a more subtle potential for erosion and sediment delivery, but these sites might not erode and deliver sediment to the stream until a threshold event occurs and a combination of site factors lead to failure (for example, peak flood flow events occurring at a stream crossing with diversion potential and/or an undersized culvert with a high plug potential).

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<sup>3</sup> *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

In contrast to site-specific episodic erosion, erosion from road surfaces is termed *chronic* because it occurs on an on-going basis, during every rainfall event that results in surface runoff. Chronic road surface erosion is primarily dependent on the level of road usage, the erodibility of the road surface, the steepness of the road, and the amount or length of surface runoff that is collected, concentrated, and discharged from the road. Chronic sediment delivery for rocked or native surface roads and cutbanks is calculated for a 10-yr period. It is based on field-measured road, ditch, and cutbank contributing areas and empirical values (rates) of (1) surface lowering on rocked roads, (2) surface lowering on native roads, and (3) cutbank retreat. The empirical values for surface lowering are based on field observations and analyses in peer-reviewed publications and by PWA geologic staff and ranked as high, high-moderate, moderate, moderate-low, or low. The amount of fine sediment delivered to stream channels from these chronically eroding road surfaces can be substantial when evaluated on timescales similar to those applied to episodic erosion sites (multi-decades), and in many watersheds may represent the greater detriment to water quality, fish habitat and the aquatic ecosystem, primarily because the sediments being delivered to the stream network is generally sand-sized particles and finer.

## 5.1 Site-Specific Episodic Erosion Sources

### 5.1.1 Stream crossings

A stream crossing is the location where a road crosses a stream channel (Weaver et al. 2015). Drainage structures used in stream crossings include bridges, fords, armored fills, culverts, and a variety of temporary crossing structures. When they erode, sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded from the crossing site is delivered directly to the stream (Furniss et al., 1997; Weaver et al., 2006). The size of the stream affects the size, rate, and volume of sediment mobilization and movement, but any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels. Because of this, it is important to identify all stream crossings and evaluate the potential for erosion and sediment delivery from each stream crossing site.

Features of stream crossings that could lead to erosion problems in the Cal Poly SLO assessment area include (1) fill crossings without drainage structures like culverts, (2) crossings with undersized culverts, (3) crossings with culverts susceptible to being plugged, (4) crossings with a potential for stream diversion, (5) crossings that have currently diverted streams, and (6) crossings with culvert outlet erosion.

A *fill crossing* is a stream crossing without a culvert or other drainage structure to carry the flow through the road prism. At such sites, stream flows either cross the road and flow over the fillslope or are diverted down the road via the inboard ditch. Most fill crossings are located at small Class II or III streams<sup>4</sup> that only have flow during larger runoff events. *Armored fill crossings* and *ford crossings* are 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 protected road prism (Weaver et al., 2006, 2015). 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.

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

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<sup>4</sup> In general, Class I streams are waterways containing viable fish habitat; Class II streams are perennial or intermittent waterways capable of supporting non-fish aquatic vertebrate habitat; Class III streams are defined but ephemeral channels not capable of supporting vertebrate aquatic habitat; Class IV streams are man-made watercourses.

these instances, flood runoff will either divert down the road, or spill across the road, allowing erosion of the stream crossing fill and development of a *washout crossing*. Washout crossings may cut off vehicular access as the stream continues to erode to a natural grade.

Serious erosion problems may also occur as a result of a stream crossing that has a *diversion potential*. Stream diversions occur at stream crossings that are unculverted, or have culverts that plug during a flood event, which allows water to spill out onto the road surface or into the inboard ditch, and flow down the road and onto adjacent hillslopes or into nearby stream channels. When this occurs, the roadbed, hillslope, and/or stream channel that receives the diverted flow may become deeply gullied or destabilized. Road and hillslope gullies can develop and enlarge quickly leading to the delivery of large quantities of sediment to stream channels (Hagans et al., 1986; Furniss et al., 1997). Streamflow that is diverted onto steep or unstable slopes may also trigger hillslope landslides and large debris flows.

To be considered adequately sized, culverts at stream crossings must have the capacity to convey a 100-year peak storm flow<sup>5</sup> with associated sediment and organic debris in transport (Weaver et al., 2006, 2015). In areas where large woody debris may lodge against the culvert, 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 and/or are installed at too low of a gradient through the stream crossing fill. Installing a culvert at a shallower grade than the natural upstream channel will cause sediment and debris to be deposited at and immediately upstream of the culvert inlet, which promotes plugging and decreases the culvert's capacity to carry streamflow. 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 efforts because the culvert discharges water onto unconsolidated road fill, rather than into the preexisting stable natural stream channel, which can result in pronounced erosion of the outboard, downstream fill face.

#### 5.1.2 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 on the native hillslopes below the road while 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.

#### 5.1.3 Discharge points for road or trail surface erosion

Unpaved road surfaces, and their associated cutbanks and inboard ditches, are major sources for erosion and delivery of fine sediment to stream channels. For paved roads, ditches, cutbanks, and unpaved turnouts may still represent active sediment sources. Surface erosion from trails, although minor compared to erosion from heavily traveled unsurfaced roads, is still an important consideration for reducing fine sediment pollution and improving/protecting water quality. Erosion from road or trail surfaces, cutbanks, and ditches 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/trail surfaces by frequent traffic (e.g., autos/trucks, bikes, horses, foot traffic); (2) erosion of unpaved surfaces by rainsplash and runoff during periods of wet weather; (3) erosion of inboard ditches by runoff

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<sup>5</sup> 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.

during wet weather; and (4) erosion of cutbanks by dry ravel, rainfall, slope failures, and brushing/grading practices. Discharge points for road or trail surface, cutbank, and ditch erosion are locations where sediment-laden flow from poorly drained road, trail, cutbank, or ditch segments exit the road or trail to be delivered into the stream system. Discharge points are often in the form of gullies or water bars but may simply be low spots on some low gradient or streamside roads or trails where concentrated flow is delivered directly into a stream without gully formation.

#### *5.1.4 Hillslope and Fillslope Failures*

For this assessment, PWA mapped all relevant hillslope and fillslope failures observed in the field. For the inventory, the presence of features such as tension cracks, scarps showing vertical displacement, corrective re-growth on trees (i.e., leaning or pistol butt conifer trees) and perched, hummocky fill indicative of shallow instability were required for a site to be documented as a potential road-related slope failure.

The section of Cal Poly Road traversing the Brizziolari Creek canyon holds potential for the development of future slope failures from unstable fill and sidecast material from earlier road construction and maintenance activities. Scars from several historic fillslope failures were observed and this section of road could experience instability in the future. Brizziolari Creek locally impinges against the base of the road fillslope in this canyon section and peak stream flows can erode and undermine the road fill. Road maintenance staff should monitor these slopes for signs of instability during and following flood events and take corrective action if road fillslope failures begin to develop.

### **5.2 Evaluation of Chronic Hydrologically Connected Road and Trail Segments**

PWA measures the lengths of hydrologically connected road or trail 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 and trail surfaces in the project area (Tables 1, 2). In addition, because the adjacent hydrologically connected road or trail segments contribute to the overall erosion and sediment delivery problem at a site, PWA considers the treatment site and adjacent road or trail segments as a unit when developing treatment prescriptions for that specific location (Tables 7, 8).

## **6 FIELD TECHNIQUES AND DATA COLLECTION**

The Stenner Creek Erosion Control and Sediment Reduction Plan consists of three distinct elements: (1) an analysis of Google Earth and LiDAR imagery to document road and trail networks; (2) a complete field inventory of all current and potential road related erosion sources along 8.56 mi of roads and 2.72 mi of trails; and (3) the development of a prioritized plan of action for cost-effective erosion control and erosion prevention treatments in the watershed.

For the first phase of the Cal Poly assessment, PWA analyzed Google Earth and LiDAR imagery to document all roads within the project area. To define a road, we looked for a terminal turnaround, and took apparent road grade and width into consideration. Data and GIS base maps produced by PWA staff were used to develop composite maps that accurately depict the location and morphology of road networks in the project area. These served as our reference maps for documenting the locations of inventoried sites and road segments in the field. Following field investigations, we made any necessary modifications to the road layer for the development of the final maps.

For the second phase of the project, PWA completed a field inventory of road segments and individual road related sites showing evidence for both erosion and 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 strong evidence for current or potential sediment delivery to a stream (Weaver et al., 2006).

Inventoried sites for this assessment area primarily consist of stream crossings, gullies below ditch relief culverts, isolated fillslope failures, and various discharge points (e.g., roadside gullies, berm breaks, waterbars) for uncontrolled road surface and/or inboard ditch runoff. For each site identified as a potential sediment delivery source, PWA staff plotted its location on the GIS-generated base map, and recorded a series of field observations on a data form 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 stream channels in the watershed, and the level of urgency, i.e. priority, 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 (with the exception of stream crossings), PWA staff evaluated the potential for erosion and sediment delivery, and collected field measurements (length, width, and depth of the potential erosion area) to derive sediment delivery volumes. For most stream crossings, PWA field crews used tape and clinometer surveying techniques to develop longitudinal profiles and cross sections and compile the data necessary 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 washouts; (2) excavation volumes associated with culvert installation, culvert replacement, or complete decommissioning of a stream crossing; and (3) backfill volumes associated with proposed culvert installation or replacement. Furthermore, field crews measured the lengths of hydrologically connected road and trail segments to derive estimates for chronic sediment delivery as described in text section 6.

Stream crossing culverts are sized to convey the 100-year peak storm flow as well as sediment and organic debris in transport. Where new or replacement stream crossing culverts are recommended for installation, PWA staff calculate the necessary culvert sizes using peak flow estimates generated by either (1) the Rational Method (Dunne and Leopold, 1978) for drainage areas less than 80 acres or (2) the USGS Magnitude and Frequency Method for drainage areas equal to or larger than 80 acres (Gotvald et al., 2012). These culvert sizing calculations are used for stream crossings where the field-estimated channel dimensions are greater than approximately 3 ft by 1 ft in cross-sectional area.<sup>6</sup>

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 from the landowner about realistic needs for future road usage, PWA staff assigned a treatment designation of either “upgrade” or “decommission” for each treatment site<sup>7</sup>. These designations are intended to provide the landowner with prescriptions and

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<sup>6</sup>For stream channels with cross sectional areas of 3 ft<sup>2</sup> 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.

<sup>7</sup> Road upgrading and decommissioning is discussed in further detail in Section 7 and Appendix A.



estimated costs for storm-proofing treatment sites and hydrologically connected road segments and are our best recommendations for the cost-effective methods to accomplish this goal.

## **7 GENERAL CONSIDERATIONS FOR STORM-PROOFING ROADS**

Forest, ranch and rural roads, as well as trails, may be storm-proofed by one of two methods: upgrading or decommissioning (Weaver and Hagans, 1999; Weaver et al., 2006, 2015). 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. 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 the hydrologic impact of the road and to reduce or prevent future sediment delivery from the road to the local stream system. Heavy equipment techniques for storm-proofing roads, as well as the characteristics and benefits of a properly designed storm-proofed road, are described in Appendix A. Similar techniques are applied when upgrading and decommissioning trails, but constraints on operating space usually limit their application to the use of small trail-sized equipment and/or hand labor.

### **7.1 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, and insloping or outsloping the road) to improve dispersion of surface runoff (Appendix A). Road upgrading often includes adding road rock or riprap as needed to fortify road surfaces and crossings.

### **7.2 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. 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 (Appendix A) have been extensively field tested, and are widely accepted (Weaver and Sonnevil, 1984; Weaver et al., 1987, 2006, 2015; Harr and Nichols, 1993).

### **7.3 Maintenance Considerations**

Good maintenance techniques and road drainage design are important to the longevity and stability of ranch and agricultural road systems. During the field assessment of the Cal Poly ranches, PWA staff observed elements of current maintenance practices and drainage design that may be increasing the level of sedimentation of the stream system, inhibiting effective road drainage, and likely increasing the amount of maintenance work that is required to keep the road system in peak condition.

For example, at several locations along Poly Canyon Road and at other sites on the ranch property, PWA staff observed piles of spoil material that had been graded off the road surface during routine maintenance and stored in potentially unstable settings or in locations where subsequent erosion could deliver sediment to a stream. At these locations uncompacted road spoil has been pushed to the outside of the road and stored on the steep fillslope above Brizziolari Creek and immediately adjacent other smaller streams. In some cases, these spoil storage sites show signs of cracking and slumping and could eventually contribute sediment to the streams below. These spoils can easily be stored on the inside edge of the road or simply pushed or hauled to a stable disposal site where eroded sediment cannot enter the stream system.

At some stream crossings the existing culverts are so short that the road narrows significantly at the crossing site and road grading directly sidecasts soil materials into the stream at the inlet and/or outlet of the culvert. This can be solved by installing culverts of sufficient length such that a stable fillslope can be constructed on both the upstream and downstream side of the new stream crossing. In several other areas along the road network, especially in cattle grazing regions, fence lines have been constructed immediately alongside the roads or on the road shoulder to contain cattle on the grazing lot. For fences built directly alongside the roadbed, their proximity to the road inhibits maintenance crews from effectively shaping the road surface and constructing road drainage structures for better and more effective drainage design. For example, outslipping of the road surface requires the excavating or reshaping of the outboard road fill where the fences now exist. The installation of rolling dips and critical dips also require excavation or grading of road fill material from the outside edge to create a low spot for the dip to drain onto the hillslope below the road. In addition, during routine grading of the road, the grader cannot cut soil materials along the fence line. Because of this, road grading eventually develops a berm on the outboard edge of the road and road drainage can no longer be dispersed or discharged onto the adjacent vegetated hillslopes. Instead, road runoff now collects and flows down the road often discharging runoff and fine sediment to a stream. A simple way to solve this drainage problem is to construct fences with a 10-15 ft buffer from the road. This will give the maintenance personnel room to grade and shape the road surface to achieve effective drainage design.

## **8 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,” “high-moderate,” “moderate,” “moderate-low,” 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 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 \$5,000, and the treatment will potentially prevent 500 yd<sup>3</sup> of sediment from reaching the stream channel, the predicted cost-effectiveness for that site would be \$5,000/500yd<sup>3</sup>, or \$10/yd<sup>3</sup> prevented from entering the stream system.

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.

## 9 SUMMARY OF FIELD DATA AND ANALYSIS

The purpose of the field assessment was to identify and quantify all locations that either are currently eroding and delivering sediment to streams in the project area or show a strong 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 or trail maintenance, they do not represent a threat to water quality or fish habitat, and therefore were not applicable to this project.

### 9.1 Road Related Sediment Sources

PWA inventoried 8.56 mi of road and identified a total of 55 sites and 6.11 mi of hydrologically connected road surfaces with the potential to deliver sediment to streams in the Cal Poly project area (Table 1). We recommend that 50 sites and 5.91 mi of road be treated for erosion control and erosion prevention (Map 2; Table 1; Appendix B).

PWA recommends treatment for 32 stream crossings on roads in the Cal Poly assessment area, which account for 64% of all treatment sites (Map 2; Table 1). Stream crossings recommended for treatment include 29 crossings with culverts, 1 ford crossing, 1 fill crossing, and 1 diverted stream (Appendix B). We project that approximately 1,995 yd<sup>3</sup> of future road related sediment delivery will originate from stream crossings if they are left untreated, which is approximately 90% of total future sediment delivery from episodic erosion sources for the Cal Poly assessment area (Table 2). Furthermore, of the 32 stream crossings, 12 have the potential to divert in the future and 2 streams are currently diverted (Table 3). Of the 29 existing culverts at stream crossings, PWA estimates that 16 are undersized for their drainage areas and 20 have a moderate or high potential to become plugged by sediment and debris (Table 3).

**Table 1.** Inventory results for sediment delivery sites and hydrologically connected road segments, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo 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	36	32	4.40	4.21	-
Ditch relief culverts	11	11	1.07	1.07	-
Road drainage discharge points	5	5	0.51	0.51	-
Hillslope debris slide	1	1	0.11	0.11	-
Fill failure	2	1	0.02	0.01	-
<b>Total</b>	<b>55</b>	<b>50</b>	<b>6.11</b>	<b>5.91</b>	<b>8.56</b>

**Table 2.** Estimated future sediment delivery for sites and road surfaces recommended for treatment, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Sources of sediment delivery	Estimated future sediment delivery (yd <sup>3</sup> )	Percent of total
1. Episodic sediment delivery from road related erosion sites (indeterminate time period)		
Stream crossings	1,995	90%
Fill failure	85	4%
Ditch relief culverts	65	3%
Hillslope debris slide	55	2%
Road drainage discharge points	30	1%
<b>Total episodic sediment delivery</b>	<b>2,230</b>	<b>100%</b>
2. Chronic sediment delivery from road surface erosion (estimated for a 10 yr period) <sup>a</sup>		
<b>Total chronic sediment delivery</b>	<b>3,765</b>	
<b>Total estimated future sediment delivery for the project area</b>	<b>5,995</b>	

<sup>a</sup>Chronic sediment delivery for rocked and native surface roads and cutbanks is calculated for a 10-yr period. It is based on field-measured road, ditch, and cutbank contributing areas and empirical values (rates) of 1) surface lowering on rocked roads, 2) surface lowering on native roads, and 3) cutbank retreat. The empirical values for surface lowering are based on field observations and analyses by PWA staff and ranked as high, high-moderate, moderate, moderate-low, or low.

**Table 3.** Erosion problems at stream crossings on roads, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Stream crossing problem	# Inventoried	Percent of total <sup>a</sup>
Stream crossings with diversion potential	12	33%
Stream crossings currently diverted	2	6%
Crossings with culverts likely to plug <sup>b</sup>	20	56%
Crossings with culverts that are currently undersized <sup>c</sup>	16	44%

<sup>a</sup>From Table 1a, total stream crossings recommended for treatment = 32.

<sup>b</sup>Culvert plug potential is moderate to high.

<sup>c</sup>Culverts in stream channels larger than 3 ft x 1 ft that are too small to convey the calculated 100-year peak storm flow.

We recommend treating erosion and sediment delivery problems associated with 11 ditch relief culverts in the Cal Poly assessment area (Table 1). We estimate that 65 yd<sup>3</sup> of future site-specific sediment delivery could originate from ditch relief culvert sites, which is roughly 3% of the estimated future episodic sediment delivery from road related sites in the project area (Table 2).

Two unstable slope failures are recommended for treatment, including one potential hillslope failure causing the road fill to become unstable and one potentially unstable road fillslope. We estimate that 115 yd<sup>3</sup> of site-specific sediment delivery will occur if these sites are not treated in the future, which represents approximately 6% of the estimated future episodic sediment delivery from road related sites in project area (Table 2).

PWA recommends treating five road drainage discharge points (Table 1), which are locations where concentrated road surface runoff is exiting the road and reaching the stream system. A discharge point may simply be a low spot in the road, and therefore have no site-specific sediment delivery, or involve gully formation, in which the projected amount of sediment delivered from the site will be based on estimated amounts of gully enlargement. Estimated potential sediment delivery for road drainage discharge points is approximately 30 yd<sup>3</sup>, which is about 1% of the total estimated future episodic erosion for the project area (Table 2).

PWA recommends treating 5.91 mi of road surfaces and/or ditches (representing roughly 97% of the total inventoried road mileage) currently draining to stream channels, either directly from the adjacent road approaches or via hillslope gullies (Table 1). If no efforts are made to change road drainage patterns, we estimate that approximately 3,765 yd<sup>3</sup> of sediment from these hydrologically connected road segments could be delivered to stream channels in the Cal Poly assessment area during the next decade (Table 2).

Of the 50 inventoried sites that we recommend for treatment, we designate 17 with priority ratings of high or high-moderate (Map 2; Table 4). The potential episodic sediment delivery (over an indeterminate time period) for the 17 sites is approximately 1,115 yd<sup>3</sup>, which is about 50% of the projected episodic sediment delivery for the project area. There is a total of 2.65 mi of hydrologically connected road segments associated with these sites, which, we project, could deliver an additional 1,830 yd<sup>3</sup> of sediment to streams in the project area during the next decade. We assign moderate or moderate-low priorities to 25 sites, which include a total of 2.79 mi of associated hydrologically connected road reaches. Estimated

future sediment delivery for the 25 sites is approximately 1,100 yd<sup>3</sup>. We project that the hydrologically connected road segments adjacent to these sites could deliver approximately 1,775 yd<sup>3</sup> of sediment to the stream system during the next 10 years. Finally, we assign a low priority to 8 sites, which have a total of 0.47 mi of associated hydrologically connected road segments. Estimated potential sediment delivery for these sites is approximately 10 yd<sup>3</sup>, with an additional 180 yd<sup>3</sup> of sediment projected to be delivered from the road reaches during the coming decade.

## **9.2 Trail Related Sediment Sources**

PWA inventoried a total of 2.7 mi of trail in the Cal Poly assessment area and identified 11 sites and approximately 0.70 mi of hydrologically connected trail surfaces with the potential to deliver sediment to streams in the assessment area (Map 2; Table 5; Appendix C). Of the 11 identified sites, 10 are stream crossings and 1 is a hillslope debris slide. PWA recommends erosion control and erosion prevention treatments for 8 of the crossings and approximately 0.63 mi of hydrologically connected trail segments.

Stream crossings recommended for treatment include 3 fill crossings, 4 ford crossings, and 1 bridge. The total estimated episodic (site-specific) future sediment delivery for these sites is nearly 10 yd<sup>3</sup>, with an additional 180 yd<sup>3</sup> of sediment projected to be delivered from adjacent segments of hydrologically connected trail and cutbank surfaces during the next 10 years (Table 6). Treatment immediacy ratings are moderate or moderate-low for 5 of the 8 sites, and low for 3 sites.

As with many other public and private properties throughout California where PWA has conducted sediment source property-wide assessments that contain both a road and trail system, the road system has always produced orders of magnitude higher potential for future sediment delivery than the trail system per unit area of disturbed ground. As can be seen in a comparison between the future erosion sites and hydrologically connected roads verses trails metric volumes per site or road mile as shown in Tables 1 and 2 verses 5 and 6 for the Cal Poly assessment area, the significant difference in road verses trail widths and cut areas, as well as width and depth of stream crossing fill volumes explains the observed differences in future erosion and sediment delivery volume estimates.

## **10 RECOMMENDED TREATMENTS**

The following is a summary of recommended treatments for the Cal Poly assessment area (Table 7). Complete details for treatment prescriptions are provided in the electronic project database, and a summary of site priorities and treatments is provided in Appendix B.

### **10.1 Road Treatments**

PWA recommends 15 different types of erosion control and erosion prevention treatments for inventoried road sites and hydrologically connected road segments in the Cal Poly assessment area, which we generally subdivide into 2 categories: site-specific treatments and road surface treatments (Table 7, Appendix B). These prescriptions include both upgrading and decommissioning measures. Typical drawings (schematic diagrams) showing techniques for constructing or installing treatments are provided in Appendix D.



**Table 4.** Evaluation of treatment immediacy for road-related sediment delivery sites in the Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Treatment immediacy	Number of treatment sites by type	Hydrologically connected road length (mi) <sup>a</sup>	Estimated future sediment delivery from inventoried erosion sites <sup>b</sup>		Estimated future sediment delivery from road, ditch, and cutbank surfaces <sup>c</sup>	
			(yd <sup>3</sup> )	%	(yd <sup>3</sup> )	%
High	7 Stream crossings [#206, 213, 214, 216, 218, 222, 230]	1.12	825	37%	785	21%
High-moderate	8 Stream crossings [#195, 209, 210, 211, 212, 220, 224, 228] 2 Road surface discharge points [#215, 238.1]	1.53	290	13%	1,045	28%
<i>Subtotal</i>	<i>17 sites</i>	<i>2.65</i>	<i>1,115</i>	<i>50%</i>	<i>1,830</i>	<i>49%</i>
Moderate	8 Stream crossings [#193, 205, 208, 217, 227, 229, 234, 236] 2 Road surface discharge Points [#207, 217.1] 4 Ditch relief culverts [#201, 225, 232, 238] 1 Fill failure [#232.1]	2.00	790	35%	1,275	33%
Moderate-low	5 Stream crossings [# 195.1, 199, 219, 221, 233] 4 Ditch relief culverts [#198, 227.1, 231, 237] 1 Hillslope debris slide [#226]	0.79	310	14%	480	13%
<i>Subtotal</i>	<i>25 sites</i>	<i>2.79</i>	<i>1,100</i>	<i>49%</i>	<i>1,755</i>	<i>46%</i>
Low	4 Stream crossings [#196, 197.1, 223, 230.1] 1 Road surface discharge point [#195.3] 3 Ditch relief culverts [#197, 198.1, 200]	0.47	10	1%	180	5%
<i>Subtotal</i>	<i>8 sites</i>	<i>0.47</i>	<i>10</i>	<i>1%</i>	<i>180</i>	<i>5%</i>
<b>Total</b>	<b>50 sites</b>	<b>5.91</b>	<b>2,230</b>	<b>100%</b>	<b>3,765</b>	<b>100%</b>

<sup>a</sup>Road length refers to hydrologically connected road reaches adjacent to recommended treatment sites.

<sup>b</sup>Episodic sediment delivery for road related sites (indeterminate time period).

<sup>c</sup>Chronic sediment delivery from adjacent hydrologically connected roads and cutbanks (estimated for a 10 yr period).

**Table 5.** Inventory results for sediment delivery sites and hydrologically connected trail segments, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Sources of sediment delivery	Sediment delivery sites		Hydrologically connected trails adjacent to sites		Total length of trails surveyed for project (mi)
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)	
Stream crossings	10	8	0.67	0.63	-
Hillslope debris slide	1	0	0.03	0.00	-
<b>Total</b>	<b>11</b>	<b>8</b>	<b>0.70</b>	<b>0.63</b>	<b>2.72</b>

**Table 6.** Evaluation of treatment immediacy for trail-related sediment delivery sites in the Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Treatment immediacy	Number of treatment sites by type	Trail length (mi) <sup>a</sup>	Estimated future sediment delivery from inventoried erosion sites <sup>b</sup>		Estimated future sediment delivery from trail, ditch, and cutbank surfaces <sup>c</sup>	
			(yd <sup>3</sup> )	%	(yd <sup>3</sup> )	%
Moderate	1 Stream crossing [#415]	0.12	2	22%	35	21%
Moderate-low	4 Stream crossings [#194, 410, 411, 417]	0.34	2	22%	100	54%
<i>Subtotal</i>	<i>5 sites</i>	<i>0.46</i>	<i>4</i>	<i>44%</i>	<i>135</i>	<i>75%</i>
Low	3 Stream crossings [#412, 413, 416]	0.17	5	56%	45	25%
<i>Subtotal</i>	<i>3 sites</i>	<i>0.17</i>	<i>5</i>	<i>56%</i>	<i>45</i>	<i>25%</i>
<b>Total</b>	<b>8 sites</b>	<b>0.63</b>	<b>9</b>	<b>100%</b>	<b>180</b>	<b>100%</b>

<sup>a</sup>Trail *length* refers to hydrologically connected trail reaches adjacent to recommended treatment sites.

<sup>b</sup>Episodic sediment delivery for trail related sites (indeterminate time period).

<sup>c</sup>Chronic sediment delivery from adjacent hydrologically connected trail and cutbanks (estimated for a 10 yr period).

**Table 7.** Recommended road erosion control and erosion prevention treatments, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Treatment type			No.	Comments
Site specific stream crossing treatments	Stream crossing treatments	Culvert (replace)	18	Replace an undersized, poorly installed, or worn-out culvert (Site #193, 195, 205, 206, 209, 210, 211, 212, 214, 218, 222, 223, 224, 227, 229, 230, 233, 234).
		Culvert (clean/clear)	3	Remove sediment or debris from the culvert (Site #201, 208, 225).
		Trash rack	18	Install at culvert inlets to prevent plugging (Site #193, 195, 205, 206, 208, 209, 210, 212, 214, 218, 222, 223, 224, 227, 229, 230, 233, 234).
		Wet crossing (armored fill or rocked ford)	10	Install 1 rocked ford crossing (Site #221) and 9 armored fill crossings (Site #195.1, 196, 197.1, 213, 216, 217, 219, 220, 228) using 200 yd <sup>3</sup> of rock armor.
		Critical dip	10	Install to prevent stream diversions (Site #195, 199, 210, 212, 218, 222, 229, 230, 230.1, 234).
	Other	Rock (armor)	16	At 16 sites, add a total of 420 yd <sup>3</sup> of rock armor on inboard and outboard stream crossing fillslopes, ditches, and headcuts (Site #197, 206, 207, 208, 215, 218, 222, 223, 224, 227, 228, 229, 230, 232, 232.1, 234).
		Soil excavation	23	At 23 sites, excavate and remove a total of 735 yd <sup>3</sup> of sediment, primarily at fillslopes and stream crossings (Site #195.1, 196, 197.1, 205, 206, 208, 209, 210, 213, 215, 216, 217, 218, 219, 220, 221, 222, 224, 228, 230, 232.1, 233, 234).
Road surface treatments	Road drainage structures	Ditch relief culvert (install or replace)	10	Install or replace ditch relief culverts to improve road surface drainage.
		Ditch relief culvert downspout	3	Install to prevent erosion at ditch relief culvert outlets.
		Rolling dip	149	Install to improve road drainage.
	Road shaping treatments	Outslope road and remove ditch	18,725 ft	At 31 locations, outslope road and remove ditch for a total of 18,725 ft of road to improve road surface drainage.
		Outslope road and retain ditch	4,195 ft	At 13 locations, outslope road and retain ditch for a total of 4,195 ft of road to improve road surface drainage.
		Inslope road	85 ft	At 1 location, inslope road for a total of 85 ft to improve road surface drainage.
		Clean or cut ditch	2,775 ft	At 12 locations, clean or cut ditch for a total of 2,775 ft.
		Road rock (for road surfaces)	4,745 ft/ 650 yd <sup>3</sup>	Use a total of 650 yd <sup>3</sup> of road rock to rock the road surface along 4,745 ft (0.9 mi) of year-round use road.

Site-specific treatments include the following stream crossing treatments: (1) constructing a total of 10 critical dips to prevent diversions at streams with diversion potential; (2) replacing 18 culverts at currently undersized, poorly installed, or worn-out culverted stream crossings; (3) constructing 10 wet crossings, which includes 1 ford crossing, and 9 armored fill crossings using 200 yd<sup>3</sup> of mixed rip-rap sized rock. We recommend installing a trash rack at the inlet of 18 stream crossing culverts (Table 7). PWA estimates that site-specific erosion prevention and erosion control work in the assessment area will require excavation and disposal of a total of 735 yd<sup>3</sup> of sediment from 23 different sites. Most of this material can be used to shape the adjacent roads reaches and improve road drainage. As an erosion prevention measure, we recommend adding a total of approximately 420 yd<sup>3</sup> of mixed and clean riprap to armor

stream crossing fillslopes, ditch headcuts, and stream banks at 16 sites. Any potential local quarry locations should be studied for potential utilization in this restoration work.

To curtail road surface erosion and sediment delivery, we recommend: (1) cleaning or cutting a ditch to capture water runoff along approximately 2,775 ft of road; (2) constructing 149 rolling dips; (3) insloping road for 85 ft; and (4) installing or replacing 10 ditch relief culverts at selected sites and at intervals appropriate for the steepness of the road; (5) outsloping the road surface and removing the inside ditch along approximately 18,725 ft of road; and (6) outsloping the road surface and retaining the ditch for 4,195 ft. In addition, we recommend using approximately 650 yd<sup>3</sup> of road rock to fortify road surfaces and prevent surface erosion following treatment, by replacing material on currently rocked roads.

## 10.2 Trail Treatments

PWA recommends constructing armored fill crossings at two trail stream crossing sites (Table 8). Each crossing treatment will require excavating approximately 5 yd<sup>3</sup> of fill material and adding approximately 5 yd<sup>3</sup> of locally available riprap to protect the remaining trail prism. To improve the drainage of trail surfaces that are hydrologically connected to the stream crossings, we recommend installing 35 rolling dips and outsloping trail segments for a total of 810 ft.

**Table 8.** Recommended trail erosion control and erosion prevention treatments, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Treatment type	No.	Comments
<b>Site specific stream crossing treatments</b>		
Wet crossing (armored fill)	2	Install armored fill crossings (Site #412, 413) using 10 yd <sup>3</sup> of rock armor.
<b>Road surface treatments</b>		
Rolling dip	35	Install to improve road drainage.
Outslope road and retain ditch	810 ft	At 2 locations, outslope road and retain ditch for a total of 810 ft of road to improve road surface drainage.

## 11 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 priority level, in Table 9. Most road upgrade 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, culvert repairs, or for applying seed and mulch to ground disturbed during construction. Most trail upgrade treatments will require the use of hand labor exclusively, although equipment access is possible on a limited number of sites and the use of trail-size equipment has been prescribed for treatment construction at those locations.

Equipment needs are reported as equipment times, in hours, to treat all sites and road and trail segments. These estimates only include the time needed for the actual site-specific treatments, and do not include other activities categorized as logistics, such as travel time between work sites, or the time needed for work conferences at each site. Work hours tallied under logistics are added to the hours needed for site specific treatment work to determine total equipment costs (Table 10).

**Table 9.** Estimated heavy equipment and labor requirements based on treatment immediacy, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.<sup>a</sup>

<b>Treatment immediacy</b>	<b># of sites</b>	<b>Excavated volume<sup>a</sup> (yd<sup>3</sup>)</b>	<b>Excavator (hr)</b>	<b>Bulldozer (hr)</b>	<b>Dump truck (hr)</b>	<b>Water truck (hr)</b>	<b>Labor (hr)</b>
High or high-moderate	17	2,000	153	264	3	108	73
Moderate or moderate-low	25	1,175	106	240	10	111	62
Low	8	80	13	39	3	18	5
<b>Total</b>	<b>50</b>	<b>3,255</b>	<b>272</b>	<b>542</b>	<b>32</b>	<b>237</b>	<b>140</b>

<sup>a</sup>Equipment and labor times do not include hours necessary for opening roads, traveling between sites, delivering culverts and straw, spreading straw and mulch, and to finalize road treatments.

<sup>b</sup>Excavated volume includes material permanently removed and stored as well as material excavated and reused for backfilling upgraded stream crossings.

### 11.1 Requirements for Road Treatments

PWA estimates that erosion control and erosion prevention remediation for road sites and hydrologically connected road segments in the Cal Poly assessment area will require 272 hr of excavator time and 542 hr of bulldozer time (Table 9). 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 32 hr to transport rock armor and fill at stream crossing sites. These sites will need to be designated. Approximately 310 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 140 hr of labor time will be required for various tasks, including culvert installation or replacement. Construction activities such as opening roads, staging materials at work sites, traveling between sites, final grading, and spreading road rock, straw, and mulch require equipment and labor hours are in addition to those direct treatment times listed above. These additional needs are described in detail in Table 10 (text Section 12). In addition, because we do not break down hours for roller/compactor by treatment immediacy, these times were not included in Table 9 but are included in the cost summary table (Table 10).

### 11.2 Requirements for Trail Treatments

Due to the narrow width of most of the trails in the Cal Poly assessment area, it would be difficult to use heavy equipment to construct most of the recommended trail upgrade treatments. For the most part, heavy equipment is also not necessary for most of the trail work, but a trail-sized mini bulldozer and excavator is recommended in many instances. A trail bulldozer is recommended for installation of the 2 armored fill crossings, as well as for the 35 recommended rolling dips. We estimate that this will require approximately 14 hrs of trail sized excavator time, 13 hrs of bulldozer time, and 33 hrs of labor time to complete.

## **12 ESTIMATED TOTAL COSTS**

Costs to implement erosion control work will vary over time as heavy equipment rates, labor rates, and materials costs change. At the present time, the estimated total cost to implement the recommended erosion control and erosion prevention treatments for the road system of the Stenner Creek project area is \$1,016,661 (Table 10). Approximately \$553,890 or 54% of the total budget is for heavy equipment and labor to implement road erosion control and erosion prevention treatments on both roads and trails, as well as for the use of lowboy trucks to haul construction equipment to and from the work area. Approximately \$296,604 (30% of the total) is for the purchase of rock and culvert materials. A total of \$166,167 (16% of the total) is projected for detailed project planning, on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project analysis and reporting.

The costs in Table 10 are based on several assumptions and estimates, and many of these are included as footnotes in the table. The costs provided are assumed reasonable if work is performed by outside contractors, and there is no added overhead for contract administration and pre- and post-project surveying.

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 ranch or forestlands. 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 ensure the success of the project, it is imperative that the project coordinator be on-site full-time at the beginning of the project and intermittently after equipment operations have begun.

## **13 CONCLUSIONS**

This assessment is a comprehensive inventory of road-related erosion and sediment delivery to streams along a total of 8.6 mi of roads and 2.7 mi of trails in the Stenner Creek watershed, San Luis Obispo County, California. It provides field data to identify and quantify currently observable and possible future sources of sediment and erosion along roads and selected trails on property owned and managed by Cal Poly.

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 Stenner Creek watershed.



**Table 10.** Estimated equipment times and costs to implement erosion control and erosion prevention treatments, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California.

Cost category <sup>a</sup>		Cost rate <sup>b</sup> (\$/hr)	Estimated Project Times			Total estimated costs <sup>e</sup> (\$)
			Treatment <sup>c</sup> (hr)	Logistics <sup>d</sup> (hr)	Total (hr)	
Move in, move out <sup>f</sup>	Lowboy	210	42	--	42	\$8,820
	Dump Truck	280	6	--	6	\$1,680
	Water Truck	227	6	--	6	\$1,362
	Truck/trailer	137	6	--	6	\$822
Heavy equipment for site-specific treatments <sup>g</sup>	Excavator (road)	272	236	71	307	\$83,504
	Excavator (trail)	185	12	2	14	\$2,960
	Bulldozer (road)	245	164	49	213	\$52,185
	Bulldozer (trail)	250	12	1	13	\$4,000
	Loader	263	36	11	47	\$12,361
	Dump Truck	280	12	4	16	\$4,480
	Roller	250	22	7	29	\$7,250
	Water Truck	227	110	11	121	\$32,461
	Truck/trailer	137	38	11	49	\$6,713
Heavy equipment for road drainage treatments <sup>h</sup>	Excavator (road)	272	44	13	57	\$15,504
	Bulldozer (road)	245	379	114	493	\$120,785
	Bulldozer (trail)	250	73	22	95	\$23,750
	Roller	250	219	66	285	\$71,250
	Water Truck	227	230	69	299	\$67,873
	Grader	212	58	17	75	\$15,900
Laborers <sup>i</sup>		85	183	55	238	\$20,230
Rock costs (includes trucking for 650 yd <sup>3</sup> of road rock and 611 yd <sup>3</sup> of riprap)						\$150,265
Culvert materials costs (240' of 15", 160' of 18", 80' of 24", 50' of 30", 90 of 36", 260' of 42", 130 of 60", 150' of 72", and 70' of 96" round culvert, and 70' of 87" x 63" plate arch culvert; includes costs for couplers, downspouts, elbows, and trash racks)						\$144,454
Mulch, seed, and planting materials for 0.67 acres of disturbed ground <sup>j</sup>						\$1,885
Supervision, coordination, layout, and reporting <sup>k</sup>						\$166,167
<b>Estimated sediment savings: 5,995 yd<sup>3</sup></b>					<b>Total Estimated Costs: \$1,016,661</b>	

(Continued on next page.)

**Table 10—continued.**

<sup>a</sup> Costs excluded from the list are for (1) tools and miscellaneous materials, (2) variable administration and contracting expenses, (3) pilot car, (4) permitting.
<sup>b</sup> Heavy equipment costs include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.
<sup>c</sup> Treatment times refer to equipment hours expended explicitly for erosion control and erosion prevention work at all project sites and roads.
<sup>d</sup> 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.
<sup>e</sup> Total estimated project costs for equipment rental and labor are based on private sector rates at prevailing wage. Materials costs are subject to change.
<sup>f</sup> Lowboy hauling costs are based on 2 hauls each (1 to move in and 1 to move out) at 3 hr/ trip for excavator (road), excavator (trail) bulldozer (road), bulldozer (trail), grader, roller, and loader.
<sup>g</sup> An additional 10 hrs of truck & trailer time are added for delivering straw to sites. A total of 4 hrs of excavator, 28 hrs of loader and truck & trailer time are added for delivering culverts, and an additional 72 hrs of water truck time for soil compaction.
<sup>h</sup> An additional 23 hrs of grader, roller, and water truck time are added for final grading; and 8 hrs of water truck and 33 hrs of grader and roller are added for spreading road rock.
<sup>i</sup> An additional 21 hrs of labor time are added for spreading straw mulch and seeding. This includes 10 hrs of labor for initial delivery of straw to sites. Labor times includes for work on roads and trails.
<sup>j</sup> Seed costs are based on 35 lbs of erosion control seed per acre at \$25/lb. Straw needs are 50 bales per acre at \$25/bale. Labor time for straw mulching and seeding is 85/hr.
<sup>k</sup> 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.

In 2023, CSLRCD received an award notification from the DOC Prop 68 Working Lands and Riparian Corridors Program to implement storm-proofing designs from this Stenner Creek Erosion Control and Sediment Reduction Plan for 21 of the 50 stream crossing sites recommended for treatment and to improve road surface drainage features along 3.9 miles of the 5.9 miles of hydrologically connected roads recommended for treatment. Construction for that portion of the project is slated to be completed in summer/fall 2024.

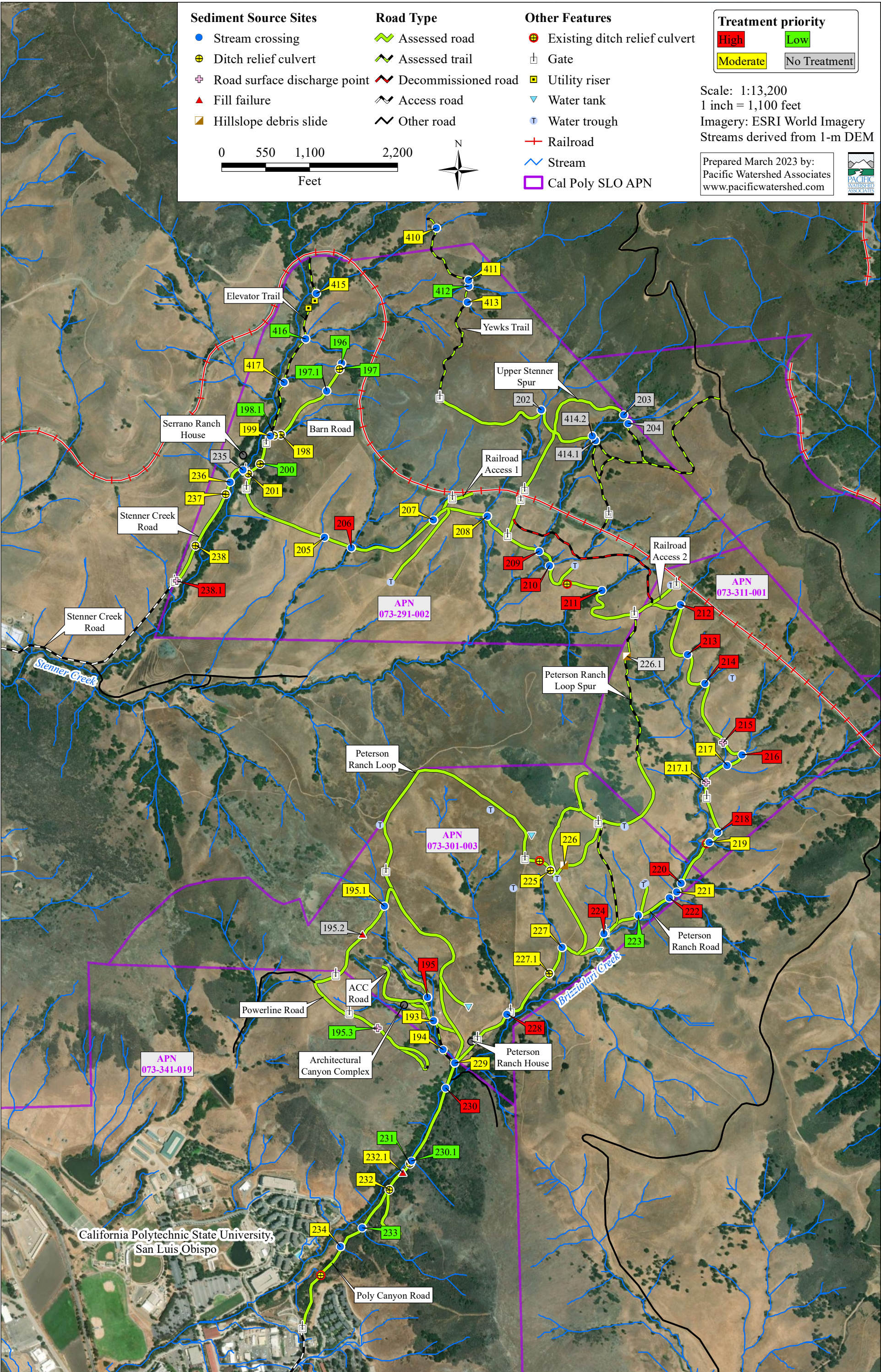
## 14 REFERENCES

- Dunne, T. and Leopold, L.B., 1978, Water in Environmental Planning: New York, W.H. Freeman, 818p.
- Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., and Collins, B., eds., 1998, California salmonid stream habitat restoration manual, 3d. ed.: Sacramento, CA, California Department of Fish and Game, 497 p. Available from: <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=22653>
- Furniss, M.J., Love, M.A., and Flanagan, S.A., 1997, Diversion potential at road-stream crossings: USDA Forest Service Water-Road Interaction Technology Series Publication 9777-1814, 14 p.

- Furniss, M., Flanagan, S., and McFadin, B., 2000, Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology and exposure to toxic chemicals: Fort Collins, CO, USDA Forest Service, Rocky Mountain Research Station, Stream Systems Technology Center, Stream Notes, July, 2000, p. 5-7. Available from: [https://www.fs.usda.gov/biology/nsaec/assets/sn\\_07\\_00.pdf](https://www.fs.usda.gov/biology/nsaec/assets/sn_07_00.pdf)
- Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, C., 2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl., available online only at <http://pubs.usgs.gov/sir/2012/5113/>.
- Hagans, D.K., Weaver, W.E., and Madej, M.A., 1986, Long-term on-site and off-site effects of logging and erosion in the Redwood Creek Basin, Northern California, *in* Papers presented at the American Geophysical Union meeting on cumulative effects (December 1985): New York, NY, National Council for Air and Stream Improvement Technical Bulletin, no. 490, p. 38-66. Available from: [http://www.pacificwatershed.com/sites/default/files/Hagans\\_Madej\\_Weaver\\_1986.pdf](http://www.pacificwatershed.com/sites/default/files/Hagans_Madej_Weaver_1986.pdf)
- Harr, R.D. and Nichols, R.A. 1993, Stabilizing forest roads to help restore fish habitats: A northwest Washington example: *Fisheries*, v. 18, no. 4, p. 18-22.
- Pacific Watershed Associates, 2009, 2009 Road and trail erosion assessment for the Chorro Creek and Stenner Creek watersheds, San Luis Obispo County, California [unpublished]: Arcata, CA, Pacific Watershed Associates Report No. 09071502 (prepared for the California Department of Fish and Game, California Polytechnic State University, Morro Bay National Estuary Program, and California Army National Guard).
- Page, B.M., Coleman R.G., Thompson, G.A., 1998, Late Cenozoic tectonics of the central and southern Coast Ranges of California. *Geological Society of America Bulletin*, v. 110, no. 7 p. 846–876.
- Taylor, R.N. and Love, M., 2003, Part IX, Fish Passage Evaluation at Stream Crossings, *in* Flosi, G., Downie, S., et al., eds., California salmonid stream habitat restoration manual, 3d. ed.: Sacramento, CA, California Department of Fish and Game, 177 p. Available from: <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=105810>
- Weaver, W.E. and Hagans, D.K., 1999, Storm-proofing forest roads, *in* Sessions, J., and Chung, W., eds., Proceedings of the International Mountain Logging and 10<sup>th</sup> Pacific Northwest Skyline Symposium, Corvallis, Oregon, April 1999: Oregon State University, Forest Engineering Department, p 230-245.
- Weaver, W.E., Hagans, D.K., Weppner, E., 2006, Part X: Upslope erosion inventory and sediment control guidance, *in* Flosi, G., Downie, S., et al., eds., California salmonid stream habitat restoration manual, 3d. ed.: Sacramento, CA, California Department of Fish and Game, 207 p. Available from: [http://www.pacificwatershed.com/sites/default/files/Weaver\\_et\\_al\\_2006\\_Upslope\\_erosion\\_inventory\\_and\\_sediment\\_control\\_guidance.PDF](http://www.pacificwatershed.com/sites/default/files/Weaver_et_al_2006_Upslope_erosion_inventory_and_sediment_control_guidance.PDF)
- Weaver, W.E., and Sonnevill, R.A., 1984, Relative cost-effectiveness of erosion control for forest land rehabilitation, Redwood National Park, *in* Conference on Erosion Control, Man and Nature, XV, Denver, CO., February 23-24, 1984, Proceedings: Denver, CO., International Erosion Control Association, p. 83-115.
- Weaver, W.E., Sonnevill, R.A., and Klein, R.D., 1987, Field methods used for monitoring erosion and sedimentation processes in steeplands of northwestern California, *in* Beschta, R.L., Blinn, T., Grant, G.E., Swanson, F.J., and Ice, G.G., eds., Erosion and sedimentation in the Pacific Rim: Washington, D.C., International Association of Hydrological Sciences Publication No. 165, p. 509-510.

- Weaver, W.E., Weppner, E.M., and Hagans, D.K., 2015, Handbook for Forest, Ranch and Rural Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Upgrading, Maintaining and Closing Wildland Roads, Mendocino County Resource Conservation District, Ukiah, California, 416 p. Available from: <https://www.pacificwatershed.com/roadshandbook>
- Wieggers, M.O., 2010, [Geologic map of the San Luis Obispo 7.5' quadrangle, San Luis Obispo County, California: A digital database](#): California Geological Survey, Preliminary Geologic Maps PGM-10-04, scale 1:24,000





Map 2. Sediment Delivery Sites and Assessed Roads with Prioritization, Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo, California



## **Appendix A**

### **Overview of storm-proofing roads (Road upgrading and decommissioning)**

Stenner Creek Erosion Control and Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California

## 1 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 (Weaver and Hagans, 1994, 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. 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 minimize the hydrologic effects of the road and to reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (Table A1), all proven to contribute to long-term improvement and protection of watershed hydrology and aquatic habitat.

### 1.1 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 treatments to 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 often also includes adding road rock or riprap as needed to fortify roads and crossings. The treatments are fully described by Weaver et al. (2006).

#### 1.1.1 *Installing rolling dips*

Rolling dips are installed on low- to moderate-gradient, hydrologically connected roads to disperse surface runoff and discharge it onto the native hillslope below the road. Rolling dips may extend from the inboard edge to the outboard edge of a road prism, or just on the roadbed, 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.

#### 1.1.2 *Road shaping*

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 near the center axis of the road so that it slopes both 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. Road shaping is almost always used in concert with rolling dips to disperse surface runoff.

**Table A1.** Characteristics of storm-proofed roads (*from* Weaver et al., 2006).

<p><b>Storm-proofed stream crossings</b></p> <ul style="list-style-type: none"> <li>• All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris).</li> <li>• Stream crossings have no diversion potential (functional critical dips are in place).</li> <li>• Stream crossing inlets have low plug potential (trash barriers installed).</li> <li>• Stream crossing outlets are protected from erosion (extended beyond the base of fill; dissipated with rock armor).</li> <li>• Culvert inlet, outlet, and bottom are open and in sound condition.</li> <li>• Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert.</li> <li>• Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.</li> <li>• Fills are stable (unstable fills are removed or stabilized).</li> <li>• Road surfaces and ditches are “hydrologically disconnected” from streams and stream crossing culverts.</li> <li>• Class I stream crossings meet CDFG and NMFS fish passage criteria (Taylor and Love, 2003).</li> </ul>
<p><b>Storm-proofed fills</b></p> <ul style="list-style-type: none"> <li>• Unstable and potentially unstable road and landing fills are excavated or structurally stabilized.</li> <li>• Excavated spoil is placed in locations where it will not enter a stream.</li> <li>• Excavated spoil is placed where it will not cause a slope failure or landslide.</li> </ul>
<p><b>Road surface drainage</b></p> <ul style="list-style-type: none"> <li>• Road surfaces and ditches are “hydrologically disconnected” from streams and stream crossing culverts.</li> <li>• Ditches are drained frequently by functional rolling dips or ditch relief culverts.</li> <li>• Outflow from ditch relief culverts does not discharge to streams.</li> <li>• Gullies (including those below ditch relief culverts) are dewatered to the extent possible.</li> <li>• Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides.</li> <li>• Decommissioned roads have permanent drainage and do not rely on ditches.</li> <li>• 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.</li> </ul>

### *1.1.3 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 downslope from 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.

### *1.1.4 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 (endhauled or pushed) to a permanent, stable spoil disposal site.



### 1.1.5 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 crossings of Class II and III streams is to construct a culverted fill crossing capable of withstanding the 100-year flood flow. Techniques for upgrading small and moderate-size stream crossings include:

Installing or replacing culverts. A culvert capable of withstanding the 100-year peak storm flow 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 or unlikely to occur. The roadbed is heavily rocked and a keyway at the base of 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 plugging, 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 on the down-road hingeline of the fill) 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.

## 1.2 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 cross-road drains, and/or partial outslipping. As with road upgrading, the heavy equipment techniques used in road decommissioning have been extensively field tested and are widely accepted (Weaver and Sonnevill, 1984; Weaver et al., 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994).

### *1.2.1 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.

### *1.2.2 Installing cross-road drains*

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.

### *1.2.3 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, or more, 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.

### *1.2.4 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.

### *1.2.5 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 vehicular access to the road.

### *1.2.6 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.

## **References for Appendix A**

- Furniss, M., Flanagan, S., and McFadin, B., 2000, Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology and exposure to toxic chemicals: Fort Collins, CO, USDA Forest Service, Rocky Mountain Research Station, Stream Systems Technology Center, Stream Notes, July, 2000, p. 5-7
- Harr, R.D., and Nichols, R.A. 1993, Stabilizing forest roads to help restore fish habitats: A northwest Washington example: Fisheries, v. 18, no. 4, p. 18-22. Weaver, W.E. and Hagans, D.K., 1999, Storm-proofing forest roads, *in* Sessions, J., and Chung, W., eds., Proceedings of the International Mountain Logging and 10<sup>th</sup> Pacific Northwest Skyline Symposium, Corvallis, Oregon, April 1999: Oregon State University, Forest Engineering Department, p 230-245.
- Weaver, W.E., and Hagans, D.K., 1994, Handbook for forest and ranch roads: a guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads: Ukiah, CA, Mendocino County Resource Conservation District, 198 p. Available from: <http://www.mcrcd.org/publications/>
- Weaver, W.E., and Sonnevill, R.A., 1984, Relative cost-effectiveness of erosion control for forest land rehabilitation, Redwood National Park, *in* Conference on Erosion Control, Man and Nature, XV, Denver, CO., February 23-24, 1984, Proceedings: Denver, CO, International Erosion Control Association, p. 83-115.
- Weaver, W.E., Hagans, D.K., and Madej, M.A., 1987, Managing forest roads to control cumulative erosion and sedimentation effects, *in* Callahan, R.Z., and DeVries, J.J., eds., California Watershed Management Conference, November 18-20, 1986, Proceedings: Berkeley, CA, University of California, Wildland Resources Center, Report 11, p. 119-124.
- Weaver, W.E., Hagans, D.K., Weppner, E., 2006, Part X: Upslope erosion inventory and sediment control guidance, *in* Flosi, G., Downie, S., et al., eds., California salmonid stream habitat restoration manual, 3d. ed.: Sacramento, CA, California Department of Fish and Game, 207 p.
- Weaver, W.E., Weppner, E.M., and Hagans, D.K., 2015, Handbook for forest, ranch and rural roads: a guide for planning, designing, constructing, reconstructing, upgrading, maintaining and closing wildland roads: Ukiah, CA, Mendocino County Resource Conservation District, 406 p. Available from: <http://www.mcrcd.org/publications/>

## **Appendix B**

### **Field observations and treatment recommendations for road related sediment delivery sites**

Stenner Creek Erosion Control and Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
193	Architectural Canyon Complex Road	M	Stream crossing	2046	1380	35	110	The right road approach is a chronic delivery source. The road is steep with enlarged ditches and many rills torn in road surface. The left approach is not as steep but delivers to stream 30' to the left of the crossing near a footbridge. The culvert is plugged. The outlet is placed too short and erodes the outboard fill. The outlet is steep. 1731' of left approach is a seasonal, native drive road. The road has enlarged gullies and is a rough driving surface. Several contributing roads on both sides rocked with gravel.	1. Excavate TOP to BOT for 40' to remove old culvert. 2. Replace with a 48" x 40' culvert with both fillslopes at 2:1. 3. Outslope and remove ditch for 1300' of right approach. 4. Construct five rolling dips to the right. 5. Outslope the first 315' of left road. 6. Construct 13 rolling dips on left road. 7. Decommission east road upslope on the right. 8. Install 7' galvanized T-post trash rack above new inlet.
195	Architectural Canyon Complex Road	HM	Stream crossing	475	40	57	51	A 3' x 1' Class III stream flows through a rusted 24" pipe. High flows have rafted organic materials above the inlet. The inboard fill is armored with 1'-2' riprap. 475' of steep left road contributes to this site. 100% plugged culvert with organic detritus. Road realignment possible for better drainage.	1. Excavate from TOP to BOT for 50'. 2. Replace with a 30" x 50' culvert at channel grade with both fillslopes at 2:1. 3. Outslope road and fill ditch for 475' of left road. 4. Install 3 type III rolling dips to along the left road. 5. Install 6-foot t-post above new inlet. 6. Install critical dip on the right hingeline.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
195.1	Powerline Road	ML	Stream crossing	230	30	13	35	Small stream crosses a low-use road used for access to the powerline towers. Less than 5 cy of 6" rock was placed in the stream where the gully was migrating through outboard fillslope. The stream now flanks on either side of the rock gully plug and is causing erosion on both sides leaving bare vertical slopes. Sloughing and sediment delivery will continue if left untreated. The right road approach has a layer of 2" drain rock on the surface.	1. Excavate from TOP to BOT for 20'. 2. Improve existing armored fill: a) create a broad dip to center flowline. b) excavate a keyway 15' wide tapering to 3' wide x 20' long. c) install 15 cy of 0.5' to 1.5' riprap. 3. Install 1 rolling dip along the left road.
195.2	Powerline Road	-	Fill failure	15	60	0	12	This is a road cut at the headwaters of a class III stream. The area has erodible soils and emergent springs just below the fillslope. No cracks are observed but the steep fillslope and saturated fillslope look like they have the potential to fail and deliver to the stream below although a small future sediment yield is likely.	No treat, monitor for now.
195.3	Powerline Road	L	Road surface	450	0	0	72	Nearly 450' of road and hillslope runoff exit the road at this location. A 5' x 2' deep gully has developed below the road and will continue to migrate into the road over time. The gully size decreases downslope but continues down to a Class III stream.	1. install 3 rolling dips along the left road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
196	Barn Road	L	Stream crossing	20	10	0	1	A Class III stream on low use road. Road surface has a paved dip and outboard fill is buttressed with a vertical wall of concrete bags. During peak events, the stream fans out and flows to right or left of pavement/concrete and is eroding exposed fill or native ground. Below the concrete wall the left bank is bare and eroding for 20' long. This bank will continue to sluff and erode over time as no vegetation can grow on its steep slope.	1. Excavate from TOP to BOT for 13'. 2. Remove concrete and pavement. 3. Install an armored fill crossing. a) improve u-shape to improve drivability and capture of stream flow to keep centered. b) excavate a keyway 1/3 into road and 10' wide at outboard road tapering to 3' wide x 13' long c) Install 10 cy of 0.5'-1.5' riprap in keyway
197	Barn Road	L	Ditch relief culvert	363	40	0	8	A 12" plugged and rusty ditch relief culvert that conveys a small amount of runoff from the hillslope, ditch, and road approaches for 40' right road and 300' left road.	1. Remove ditch relief culvert and replace with a rolling dip and add 5 cy of 0.5'-1.5' riprap to outboard fillslope.
197.1	Barn Road	L	Stream crossing	0	0	0	0	There is currently a high spot in the road above the culvert. There is 0' left road length and 0' right road length.	1. Excavate from TOP to BOT for 50' to remove old culvert. 2. Install an armored fill crossing. a) excavate keyway 1/3 into the road 10' wide at outboard edge of road tapering to 2' wide at the base for 30' long. b) install 15 cy of 0.5' to 1.5' riprap into keyway. 4. Outslope road for 50' along the left road. 5. Spoil soil locally on the road.
198	Barn Road	ML	Ditch relief culvert	753	0	0	89	The 718' of insloped road drains to a culvert. The culvert outlets onto floodplain of Class II stream and should be disconnected from long road approach.	1. Outslope road and remove ditch for 700' along left road. 2. Install 5 rolling dips along left road. 3. Remove existing ditch relief culvert and dispose. 4. Backfill with soil generated locally.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
198.1	Barn Road	L	Ditch relief culvert	130	0	0	20	Aluminum 12' ditch relief culvert drains just above inlet to the corrugated metal pipe at site 199. The road is Perpendicular to Stenner Creek, which is approximately 50 yards downslope. Road is currently insloped but should be outsloped. Inlet is about 30-40% plugged, outlet is more than 20% plugged. No rust line visible.	1. Transition to insloped road and cut clean ditch for 85' along the left road and connect ditch to ditch relief culvert at this site. 2. Construct 1 rolling ditch along the left road.
199	Barn Road	ML	Stream crossing	0	190	137	10	A 36" aluminum culvert drains a 5' x 1' Class II stream. The pipe appears to accommodate flows well. 190' of right road delivers to the site. A ditch relief culvert drains to the culvert inlet but is not a major contributor. Road treatments will treat ditch relief culvert contribution. There is diversion potential to the left.	1. Outslope road and fill the ditch for 190' of right road. 2. Install 1 rolling dip to the right. 3. Install critical dip on the left hingeline.
200	Barn Road	L	Ditch relief culvert	0	330	0	7	Culvert drains a long wide grassy swale. The road segment is parallel to Stenner Creek 100' away and is very flat. The culvert is 30% plugged at the inlet and outlet due to flat topography.	1. Excavate for 20' to remove existing culvert. 2. Create deep broad dip. 3. Place 300 sq.ft. of road rock in dip. 4. Place 2 rolling dips along right approach.



**Table B1.** Field observations and treatment recommendations for road related sediment delivery sites. *Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California*

**Abbreviations:** H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.

PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
201	Barn Road	M	Ditch relief culvert	930	185	0	152	An 18" ditch relief culvert with outlet delivering directly to mainstem Stenner Creek. The culvert itself is in okay condition but the low gradient location creates high plug potential. There is significant road runoff contribution from the highly erodible left road approach. Left road is low gradient at first as inboard ditch wraps around barn site and then climbs steeply beyond barn. Much of the 930' of left road is insloped with inadequate ditch capacity and has a series of gullies developed on the road surface.	1. Outslope road and keep ditch for 930' along left road. 2. Clean and cut ditch for 930' with a minimum of 2' wide x 1' deep along left road to drain road only. 3. Install 4 rolling dips on left approach. 4. Install an 18" x 30' long ditch relief culvert above gate. 5. Rock road for 930' using 124 cy of 1.5" minus road rock. 6. Clean culvert inlet to regain function.
202	Upper Stenner Spur	-	Stream crossing	300	387	5	32	Riprap has dislodged from outboard fill and gulley is migrating into the road crossing. The crossing is dry as of 8/3/22.	No treat.
203	Upper Stenner Spur	-	Stream crossing	50	55	9	1	Less than 10 cy of potential future erosion for this site, but there is a greater impact to the site by trying to access it. Additionally, there is a washed out crossing.	No treat.
204	Upper Stenner Spur	-	Stream crossing	60	40	5	1	Class III stream on abandoned road with minimal future erosion potential. Both road approaches are outsloped and vegetated. The crossings are best left as is. There is some rock that is presently stabilizing the site.	No treat.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
205	Peterson Ranch Road	M	Stream crossing	180	250	402	19	Existing 12" diameter x 40' long culvert at 8' x 1' stream crossing is 90% plugged with fine sediment and will eventually plug completely. Extremely broad and grassy channel above and below the crossing. This crossing has a lot of fill and fillslopes are long but vegetated.	1. Excavate from TOP to BOT for 80'. 2. Replace current culvert with a 42" x 80' corrugated metal pipe at channel grade. 3. Rebuild both fillslopes at 2:1 slope. 4. Install 7' tall, galvanized trash rack above new inlet. 5. Install 1 rolling dip along the right road. 6. Install 1 rolling dip along the left road. 6. Outslope road and fill any ditch for 430' along left and right road. 7. Rock road for 430' using 57 cy of 1.5" minus road rock.
206	Peterson Ranch Road	H	Stream crossing	1220	180	407	238	A 9' x 1' Class II stream flows through a 54" diameter x 18' long steel pipe. The pipe is an old truck or train car tank. The pipe is very short and set high in fill. A 10' drop exists below the pipe outlet. The entire outboard fill is vertical and collapsing. An old wooden buttress is rotting away. Concrete slabs have been stacked on the outboard fillslope and tossed below the culvert spillway. The fill alongside the pipe has eroded out. This crossing is failing. Left road drainage is very active and is contributing to the erosion of the fill face. Two gullies related to road surface drainage exit the fill here. The culvert is out of natural alignment of the stream and is eroding 25' of the left bank of the stream below the road. A 7' x 1' and 3' x 1' stream also contribute to this site.	1. Excavate from TOP to BOT for 80'. 2. Remove existing culvert and install a 72" x 80' long corrugated metal pipe. 3. Get culvert to the bottom of fill and move pipe outlet ~25' to the right of the current alignment to better align with stream flow. 4. Armor outboard fillslope for 0.25 of face with 10 cy of 1'-2' riprap. 5. Build inboard fillslope at 2:1. 6. Install 10' tall, galvanized post trash rack above new inlet. 7. Outslope road and fill ditch for 1,220' along left road. 8. Install 8 rolling dips along the left road. 9. Outslope road and keep ditch for 180' along right road. 10. Install 1 rolling dip 70' up right road. 11. Rock road for 1,400' using 187 cy of 1.5" minus road rock.

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Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
207	Peterson Ranch Road	M	Road surface	0	475	7	93	Road surface discharge point with a large gully that terminates in a Class II stream. The gully at outboard fill is currently 15' wide x3' deep x 25' long and will continue to enlarge. Right approach has a surface that is partially bedrock.	1. Outslope and fill any ditch for 475' along right road approach. 2. Install 3 rolling dips on right approach. 3. Install 40 cy of 0.5'-1.5' riprap to plug road surface gully exit point. 4. Rock road for 475' using 63 cy of 1.5" minus road rock.
208	Peterson Ranch Road	M	Stream crossing	200	445	23	145	A 5' x 2' Class II stream flows through a 54" diameter x 20' long steel pipe. The pipe may have been a tank from train or truck. The pipe is sized adequately. Vegetation growing at the inlet is increasing plug potential and bare vertical fillslopes are eroding into nearby stream. Road approaches are rilling and delivering directly to stream.	1. Excavate from TOP to BOT for 20'. 2. Clean stream crossing culvert inlet area of aggraded sediment and willows by defining a 5' wide channel with 2:1 slopes for 20 linear feet from inlet and up. 3. Armor both inboard and outboard fillslopes using a total of 10 cy of 1'-2' riprap. 4. Install 10' tall, galvanized post trash rack above inlet. 5. Outslope road and fill the ditch for 445' along right road. 6. Outslope road and fill the ditch for 100' along left road. 7. Install 3 rolling dips along the right road. 8. Install 3 rolling dips along the left road. 9. Stock spoil locally on road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
209	Peterson Ranch Road	HM	Stream crossing	90	130	68	18	An active Class II stream is pinched for 20' above a 24" diameter x 18' long culvert. Organic material obstructs 16% of the inlet. The inboard fillslope is steep and sloughing into the stream, which has overtopped the crossing at two different locations in the past. The crossing is at a low point in the road and both road approaches drain directly instream down the inboard and outboard fillslopes.	1. Excavate from TOP to BOT for 90’ long. 2. Transition above TOP by excavating a 5’ channel width 20’ above the road. 3. Layback left bank below new outlet for 12’ long with 2:1 slope (do not disturb oak tree on upper left bank, closer to 30 degrees here). 4. Replace current culvert with a 72" x 70' long corrugated metal pipe. 5. Import 35 cy of clean fill in order to raise road to accommodate larger diameter culvert (can be generated locally). 5. Install 10' tall, galvanized post trash rack above new inlet. 6. Outslope and remove ditch for 90' along left road. 7. Remove 3 - 3'-5' diameter willow clusters and 1 - 5" diameter oak from discharge area.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
210	Peterson Ranch Road	HM	Stream crossing	0	155	40	23	A 2' x 1' Class III stream is diverted by the road to a 3' x 1' Class II stream. These enter an undersized 24" pipe right below the confluence. There is diversion potential to the left. The upslope diversion is OK if the pipe is sized correctly and there is no alternative place for this stream to cross the road. The pipe inlet has plugged in the past. The outboard fill is steep and failing concrete slabs have been stacked at the outboard fill. Material has been placed below the outlet that pushed flow to the left and into the stream bank. This material (concrete fill and rocks) should be removed.	<ol style="list-style-type: none"><li>1. Excavate from TOP to BOT for 110'.</li><li>2. Replace current culvert with a 42" x 40' long corrugated metal pipe with outlet moved to right to better align stream.</li><li>3. Raise the roadbed up by 1' to accommodate larger culvert and rebuild both fillslopes at 2:1 slope.</li><li>4. Define stream channel on right 3' wide x 50' long with a steeper grade into new inlet to ensure stream does not aggrade in ditch and overtop onto the road.</li><li>5. Below new culvert outlet layback left bank for 20' to a 2:1 slope by moving existing break in slope ~9' out/away from stream and use material for crossing rebuild.</li><li>6. Install critical dip on the left hingeline.</li><li>7. Install 7' tall, galvanized post trash rack above new inlet.</li><li>8. Install 1 rolling dip along the right road.</li></ol>

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
211	Peterson Ranch Road	HM	Stream crossing	1850	500	28	259	A 5' x 1' Class II stream has plugged this 24" culvert before. A large sediment wedge has developed above the plugged inlet. Stream flow eroded 4 cy from the outboard fill where the road overtopped. A 1 cy hole was dug at the inlet to unplug the pipe. Flow is now headcutting through the sediment wedge. A 3' x 3' x 20' gully runs down the outboard fill about 100' to the right (will treat with road shaping). A wet swale 50' to the right of the crossing saturates the road at the crossing and exits the outboard fill over the culvert.	1. Excavate from TOP to BOT for 50' to remove existing culvert. 2. Install 54" diameter x 50' culvert. 3. Raise road by 4' to accommodate larger pipe diameter by importing 20 cy of clean fill (can be generated locally). 4. Rebuild fillslope angles at 2:1. 5. Install 4 rolling dips along the right road. 6. Install 8 rolling dips along the left road. 7. Outslope the road and fill ditch for 530' along the right road. 8. Outslope the road and fill ditch for 1,050' along the left road. 9. Clean and cut ditch on the right road for 50' to capture swale and drain to stream above road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
212	Peterson Ranch Road	HM	Stream crossing	0	25	24	4	<p>This Class III stream crossing has been trampled by cattle and has overtopped in the past. Existing 24" diameter x 20' long culvert inlet has brush acting as trash rack. Outlet is 50% plugged with sediment. Outboard fill is actively calving into stream. If the road was a lower use, seasonal road, then a ford crossing upgrade would be acceptable.</p>	<ol style="list-style-type: none"><li>1. Excavate from TOP to BOT for 70'.</li><li>2. Move centerline of road 25' upstream in order to move road away from stream and broaden turn and reduce road grades into new crossing.</li><li>3. Install 48" x 50' long corrugated metal pipe on new upstream alignment.</li><li>4. Raise road by 2' by importing 10 cy of clean fill to accommodate larger pipe diameter (can be generated locally).</li><li>5. Layback both fillslopes at 2:1 slope.</li><li>6. Decommission existing crossing by defining a 4' wide channel for 20' long with 2:1 side slope.</li><li>7. Preserve large trees but remove 6" willow clusters in channel.</li><li>8. Install 7' tall, galvanized post trash rack above new inlet.</li><li>9. Install critical dip on the left hingeline.</li></ol>



Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
213	Peterson Ranch Road	H	Stream crossing	60	775	54	124	Ephemeral stream crossing with 100% plugged 24" diameter x 20' long culvert. Inlet area is choked with fine sediment for nearly 30' and both fillslopes are bare and eroding from stream overtopping. Crossing is at a low point in the road so both road approaches discharge directly into the stream.	1. Excavate from TOP to BOT for 54' to remove existing culvert and replace with an armored fill crossing: a) create a broad dip by lowering centerline 2' deep, b) excavate a keyway 1/3 into road 15' wide and taper to 3' at base of fill for 25' long, c) Place 15 cy of 0.5'-1.5' riprap. 2. Armor inboard edge of road with 10 cy of 0.5'-1.5' riprap to prevent washout. 3. Remove 1.5' diameter multi-trunk willow from outboard fill. 4. Outslope road and fill ditch for 775' along the right road. 5. Install 5 rolling dips along the right road.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
214	Peterson Ranch Road	H	Stream crossing	75	550	88	109	Undersized 30" diameter x 20' long metal culvert installed at a lesser gradient than the natural channel grade that has caused outlet scour and undercutting of the steep fill. Additional erosion has occurred from the descending road approach from both sides. Both the outboard fill and inboard fill are bare, nearly vertical, and have generations of gullies down them. Some concrete has been placed on the fillslopes to help stabilize but the effort is futile at this problematic site. A 4' x 2' and 2' x 1' stream contribute to this site.	1. Excavate from TOP to BOT for 100' and remove existing culvert. 2. Replace current culvert with a 36" x 60' corrugated metal pipe. 3. Define channel 6' wide x 40' long with 2:1 fillslope above current inlet (do not remove oak tree on the left bank but it is ok to trim branches). 4. Outslope and keep ditch for 75' along left road approach. 5. Outslope and keep ditch for 550' along right road approach. 6. Install 3 rolling dips along right approach. 7. Remove 3.5' oak next to the bottom of fill for new pipe. 8. Clean and cut a 2' wide x 1' deep ditch for 70' on the left road to capture emergent spring/springy hillside to the new inlet. 9. Install 6' tall, galvanized post trash rack above new inlet. 10. Dig out contributing stream channels to 2:1 so that they flow into center channel.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
215	Peterson Ranch Road	HM	Road surface	0	825	17	134	A ditch relief culvert and 825' of very erodible road surface drains to this site. The last 400' of road is thru cut. Within the thru-cut section two swales drain onto the road surface. The discharge point delivers into the headwaters of the Brizziolari Creek. A bedrock knickpoint exists near an exit gulley and would make a good target for controlling future gulley expansion. A 12' ditch relief culvert contributes to this site as well.	1. Install a rocked grade control structure to stabilize the gully: a) lower the centerline by 1' and move 5' towards the hillslope/to right to move the centerline away from the road, b) excavate a keyway 20' wide at the top and taper to 5' wide at the base for 20' long, c) place 20 cy of 0.5'-2' riprap in keyway. 2. Outslope road and fill ditch for 825' along right road. 3. Install 5 rolling dips along the right road and 1 robust dip above contributing ditch relief culvert that leads to the site. 4. Cut and clean ditch for 80' in order to extend channel definition to ditch relief culvert to center flow towards grade control structure. 5. Stock spoil locally on road.
216	Peterson Ranch Road	H	Stream crossing	0	300	32	38	Existing 24" diameter x 20' long culvert is too short and not at base of fill or channel grade. Currently the stream meanders through fine sediment disturbed by cattle, through a 30% plugged inlet, and then through a rust hole in the interior of the pipe. Once below the pipe, water flows through to the base of fill and natural channel grade. This Class II stream likely overtops and diverts during average winter storms.	1. Excavate from TOP to BOT for 25' to remove existing culvert and replace with an armored fill crossing: a) create a broad dip by lowering centerline 3' deep, b) excavate a keyway 1/3 into road 25' wide and taper to 5' at base of fill for 18' long, c) Place 30 cy of 0.5'-3' riprap. 2. Install 1 rolling dip on right approach. 3. Outslope road and fill ditch for 300' along right road.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
217	Peterson Ranch Road	M	Stream crossing	0	270	6	49	An 18" diameter x 20' corrugated metal pipe drains a wet swale and 270' of right road. Right road is actively rilling from past diversion of Site 216. Culvert is in good condition but outlets directly into Class II stream. The road is too close to the larger stream below, and bank erosion is occurring at the outlet. There is room to move the road upslope and away from the stream.	1. Excavate from TOP to BOT for 20'. 2. Move centerline of road 5' upslope for 25' to move road away from stream that travels parallel to the road. 3. Excavate to remove existing culvert and replace with an armored fill crossing 5' upslope: a) create a broad dip by lowering centerline 3' deep, b) excavate a keyway 1/2 into road 15' wide and taper to 3' at base of fill for 13' long, c) Place 10 cy of 0.5'-3' riprap. 4. Spoil locally along the road approaches. 5.Outslope road and fill ditch for 270' along the right road. 6.Install 1 rolling dip along the right road.
217.1	Peterson Ranch Road	M	Road surface	145	335	5	81	A road surface discharge point is at a low point in the road. A 5' wide x 2' deep x 30' long gully has developed from the outboard ditch down to mainstem Brizziolari. Initial erosion could have been from a stream diversion in the past from one of the undersized culverts up the road. It is now a direct funnel for road surface discharge.	1. Outslope the road and the fill ditch for 145' along the left road. 2. Outslope the road and fill the gulley for 335' along the right road. 3. Install 2 rolling dips along right road. 4. Install 1 rolling dip along the left road.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
218	Peterson Ranch Road	H	Stream crossing	0	465	52	76	Undersized 24" diameter x 20' rusty metal culvert drains ephemeral stream and 300' of steep right road. The inlet is currently 50% plugged and there is evidence of overtopping. Roads or free discharges runoff at the centerline and a gully is migrating into the road. A new bike trail was recently built just left of the crossing and the intersection needs to be incorporated into the design considerations.	1. Excavate from TOP to BOT for 75'. 2. Remove perched material to right of BOT. 3. Replace current culvert with a 48" x 40' long corrugated metal pipe with outlet moved 7' to the right. 4. Armor entire outboard fillslope with 10 cy of 1'-2' riprap. 5. Outslope road and fill ditch for 465' along the right road. 6. Install 2 rolling dips along the right road. 7. Layback eroding edge of left bank below the outlet for 20' at 2:1 slope. 8. Armor the left side of the channel below the BOT for 15' at the bend with 7 cy of 2' minus rock. 9. Install 7' tall, galvanized trash rack above new inlet. 10. Install critical dip on left hingeline. 11. Armor the left bank directly above the inlet with 3 cy of 2' minus riprap.

**Table B1.** Field observations and treatment recommendations for road related sediment delivery sites. *Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California*

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
219	Peterson Ranch Road	ML	Stream crossing	100	150	2	31	A springy swale oozes water along 60' of shallow grassed inboard ditch. One 12" diameter x 20' steel pipe drains the road at the stream and another one drains the springy hillslope 50' further down road. A 1' x 0.5' x 80' gully runs from outlet to upper mainstem Brizziolari.	<ol style="list-style-type: none"> <li>1. Excavate from TOP to BOT for 45' and replace existing culvert with armored fill. a) create a broad dip. b) excavate keyway 1/3 into the road 12' wide at the top tapering to 3' wide at the base for 25' long.</li> <li>2. Create a broad u-shape to center the flow and layback the road approaches.</li> <li>3. Armor with 15 cy of 0.5' to 1.5' riprap.</li> <li>4. Clean or cut ditch for 100' on the left road.</li> <li>5. Install 1 Type II rolling dip with a 10' long outlet along the right road 15' above contributing ditch relief culvert.</li> <li>6. Outslope road and fill ditch for 150' along the right road.</li> <li>7. Spoil stockpile locally on road.</li> </ol>
220	Peterson Ranch Road	HM	Stream crossing	0	550	22	114	A 24" diameter x 20' long plastic culvert drains a 4' x 1' Class II stream that outlets into Brizziolari Creek. The streamside road is very close to mainstem Brizziolari Creek and constricts flow. Moving the road upslope will allow for better road drainage and increase capacity of Brizziolari Creek once the outlet and edge of the road is laid back.	<ol style="list-style-type: none"> <li>1. Excavate from TOP to BOT for 35'.</li> <li>2. Move crossing 15' upslope and decommission 20' of road with in-place out sloping.</li> <li>3. Decommission existing crossing by excavating a 5' wide channel and laying back side slopes 2:1 for 25' (spoil locally on road).</li> <li>4. Install an armored fill crossing 20' upslope on new alignment: a) create a broad dip 20' wide tapering to 5' wide at base for 20' long, and b) install 25 cy of 0.5'-3' rock.</li> <li>5. Outslope road and fill ditch for 550' along the right road.</li> <li>6. Install 4 rolling dips along the right road.</li> </ol>

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
221	Peterson Ranch Road	ML	Stream crossing	0	170	2	25	Stream channel is low gradient, grassy, and filled with leaf litter. The existing 18" diameter x 20' long culvert is placed to right of the channel axis and appears to plug often.	1. Excavate from TOP to BOT for 35'. 2. Move crossing and road approach approximately 30' upslope and decommission existing streamside alignment by in-place out sloping for 170' (work around trees). 3. Decommission existing crossing by excavating a 4' wide channel and laying back side slopes 2:1 for 15' (spoil locally on road). 4. Install an armored ford crossing on new alignment: a) create a broad dip, b) smooth whole channel alignment above new crossing for 35', c) excavate 5' wide x 30' long x 1' deep channel at new stream crossing, d) install 10 cy of 3"-9" cobbles within in new channel 5. Outslope road and fill ditch for 170' along the new right road alignment. 6. Install 1 rolling dip along new right road alignment.



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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
222	Peterson Ranch Road	H	Stream crossing	120	320	35	37	An 8' x 1.5' Class II Brizziolari Creek flows through a very undersized 24" diameter x 20' long culvert. The pipe is set at a right angle to the creek. Concrete has been poured at the inlet to divert flow into the pipe. Concrete wing-walls protect the road fill. Ample signs show that the pipe has overtopped in the past with the stream flowing across the road. Our drainage area calculations show that a 72" diameter culvert would be appropriate for this site. The shallow road fill here, however, would need to be raise 6' to accommodate this pipe and is simply not feasible for this location. A ford crossing would suffice but would be difficult to cross during high flows. A bridge will likely be necessary.	1. Excavate from TOP to BOT for 90'. 2. Replace with a plate arch culvert 95" x 67" x 70' long oblique to the road (move inlet upstream to achieve a natural stream alignment). 3. Raise the road 5' to accommodate the large culvert (import 30 cy of clean fill to site). 4. Rebuild the inboard fillslope at 30 degrees and armor the lower 1/2 with 10 cy of 1'-3' riprap. 5. Rebuild the outboard fillslope at 2:1 slope. 6. Define a 10' wide channel with 2:1 side slopes for 20' above new inlet. 7. Install critical dip on the right hingeline. 8. Install 12' tall, galvanized post trash rack 6' above the new inlet. 9. Reroute 120' of left approach approximately 10' upslope and away from mainstem Brizziolari Creek. 10. Decommission 120' of stream side road with inplace outslipping. 11. Outslope road and fill ditch for 320' along the right approach. 12. Outslope road and fill ditch for 120' along the new left approach alignment. 13. Install 2 rolling dip along the right road.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
223	Peterson Ranch Road	L	Stream crossing	100	215	10	47	Undersized 18" diameter x 20' long culverted stream crossing with broad grassy channel above inlet with some livestock disturbance. The road is 50' from Brizziolari Creek and has gentle fillslopes. The culvert is very short and high in the fill. Bedrock may make placing the new pipe at channel grade difficult.	1. Excavate crossing from TOP to BOT for 40'. 2. Replace current culvert with a 42" x 40' long culvert at channel grade and at base of fill. 3. Build inboard fillslope at 2:1. 4. Build outboard fillslope at 1.5:1 and armor 0.25 up using 15 cy of 1'-2' riprap. 5. Place culvert outlet at the top of the head cut that is present 20' down slope from the stream crossing. 6. Install 7' tall, galvanized post trash rack above new inlet. 7. Outslope road and fill ditch for 100' along the left road. 8. Outslope road and fill ditch for 200' along the right road. 9. Install 1 rolling dip along the right road. 10. Import 25 cy of clean fill to raise the road (can be generated locally). 11. Raise the road by 4' at the centerline to accommodate a larger pipe.

**Table B1.** Field observations and treatment recommendations for road related sediment delivery sites. *Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California*

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
224	Peterson Ranch Road	HM	Stream crossing	270	1750	19	342	Stream flows along road for 80' before entering an undersized 18" diameter x 20' long culvert. Culvert is set at a right angle to flow. A fence and gate prevent much deviation from this situation. The current culvert is short. Road drainage has begun to erode fill over culvert at outboard fill. Roughly 1,300' of upper road (Peterson Ranch Loop) contributes to this site and should be treated soon. The culvert is placed at a low point in the road so the long length of hydrologically connected road is discharging sediment-laden runoff with every storm. This excessive runoff is eroding the outboard fill edge and the road is calving off reducing road width and creating a hazard.	<ol style="list-style-type: none"> <li>1. Excavate crossing from TOP to BOT for 51'.</li> <li>2. Replace current culvert with a 36" by 30' long corrugated metal pipe set in at channel grade and at base of fill 5' right of current location.</li> <li>3. Define a 13' long x 3' wide channel from the new outlet to mainstem Brizziolari Creek.</li> <li>4. Outslope road and fill ditch for 270' along the left road.</li> <li>5. Outslope road and fill ditch for 1,750' along the right road (1,300' up connecting Peterson Ranch Loop).</li> <li>6. Install 1 rolling dip along left road.</li> <li>7. Install 10 rolling dips along right road (9 on upper road).</li> <li>8. Rebuild the road at 12' wide.</li> <li>9. Rebuild the inboard fillslope at 36 degrees and armor for 0.75 the way up inboard fillslope face with 5 cy of 2' minus riprap.</li> <li>10. Rebuild the outboard fillslope at 42 degrees and armor the entire face with 5 cy of 0.5'-2.0' riprap.</li> <li>11. Install an 3' wide x 2' deep x 8' long grade control structure 8' above the road using 4 cy of 0.5'-2.0' minus riprap.</li> <li>12. Armor the right bank from the grade control structure to the new inlet using 2 cy of 0.5'-2.0' riprap.</li> <li>13. Install 6' tall, galvanized trash rack above new inlet.</li> </ol>

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
225	Peterson Ranch Road	M	Ditch relief culvert	0	800	60	149	This road segment is near the ridge and traverses around the headwall of a Class II stream. The road surface is native and disturbed by cattle. 800' of road and ditch drains to ditch relief culvert. A large gully has formed from outlet to stream. The ditch flow at one point goes subsurface at outlet and a subsurface tunnel has formed. Over time the tunnel has collapsed, and gully enlargement started and will continue. There is an existing ditch relief culvert 170' up right road that should be lumped in with the treatment of this site.	1. Outslope road and remove ditch for 800' along the right road. 2. Install 5 rolling dips along the right road reach. 3. Clean ditch relief culvert.
226	Peterson Ranch Loop Spur	ML	Hillslope debris slide	400	160	57	53	Both left and right road lengths contribute to this gully/fill failure. A 50' wide area of outboard fill is collapsing into headwall swale. Site also gets contribution from slope above. Upper slope is moist and hummocky. It is likely that subsurface flows are a factor here. Treating road surface drainage will help but the big fix would be an engineered fill, which is way too expensive for such a low use road.	1. Outslope road and fill ditch for 400' along left road. 2. Outslope road and fill ditch for 160' along right road. 3. Install 1 rolling dip along right road. 4. Install 3 rolling dips along left road.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
227	Peterson Ranch Road	M	Stream crossing	100	75	46	28	The stream has a flat, broad, grassy channel above and below the crossing. 2' minus rock armor lines a break in slope/head cut above the TOP and inboard fill. Culvert is undersized and not aligned on center to reduce culvert length. The outboard fill is vertical and shifting off directly into the stream. The outlet is 60% plugged. This crossing is a low point in the road and both bare and native surfaced roads discharge at this point with every runoff. There is a social bike trail entering near the inlet and should be decommissioned before the erosion worsens.	1. Excavate from TOP to BOT for 50'. 2. Set aside 5 cy of 2' minus riprap to be used for grade control structure. 4. Install a grade control structure 10' wide at the top from each valley wall and taper to 6' wide at the base for 10' long using 10 cy of 1'-2' riprap. 5. Replace current culvert with a 42" x 40' corrugated metal pipe with outlet 10' to the left of centerline. 6. Rebuild both fillslopes at 2:1 slope. 7. Install 10' tall, galvanized post trash rack above new inlet. 8. Outslope road and fill ditch for 125' along the left road. 9. Outslope road and fill ditch for 50' along the right road. 10. Install 1 rolling dip on the left approach. 11. Armor from left edge of grade control structure to the inlet on the left side with 5 cy of 1'-2' riprap.

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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
227.1	Peterson Ranch Road	ML	Ditch relief culvert	300	215	2	81	A plugged 12" ditch relief culvert drains a broad swale above the road and a total of 50' bare roads. The current ditch relief culvert is draining a low point in the road. The inlet is 75% plugged, outlet is 100% plugged, runoff appears to overtop the road and come down the fillslope. A 1' wide gulley from the ditch relief culvert outlets to an ephemeral stream below (100' downslope).	1. Replace ditch relief culvert with a 24" x 30' corrugated metal culvert. 2. Outslope road and keep ditch for 100' on the right road. 3. Clean and cut ditch for 100' along right road and connect ditch to ditch relief culvert. 4. Outslope road and fill ditch for 115' along the right road. 5. Outslope road and keep ditch for 100' along the left road. 6. Clean and cut ditch for 100' along left road and connect ditch to ditch relief culvert. 7. Outslope road and fill ditch for 185' along the left road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
228	Peterson Ranch Road	HM	Stream crossing	550	450	16	59	A 10' x 1' Class II stream has been pushed or diverted to the right valley wall for some time and crosses the road via two 12" steel pipes are set side-by-side. The culverts appear to regularly plug, and streamflow passes over the culverts and across the road in the wet season. The outboard fill has been eroded over the top and under the culverts. The fill is too shallow for a big culvert, so this is a candidate for a shallow armored fill crossing. Restoring the channel alignment above the road will help long-term success of this crossing.	1. Excavate from TOP to BOT for 186'. 2. Excavate and replace dual culverts at the diverted stream crossing site with a rocked rolling dip using 5 cy of 0.5'-1.5' rock. 3. Excavate rolling dip 15' wide at top tapering to 3' wide at bottom for 6' long. 4. Restore channel alignment by defining a 10' wide channel above the road for 135' above the inboard edge of road (existing gate and fence will need to be removed and replaced). 5. Move centerline of crossing 45' left of the existing crossing at the low point in the road. 6. Install an armored fill by creating a broad dip, a) excavate a keyway 1/3 of the way into the road 30' wide at top tapering to 9' wide at bottom for 16' long, b) install 45 cy of 0.5'-3' riprap at 1.75:1. 7. Define a channel that is 5' wide from the base of armored fill for 35' to the base of existing gully. 8. Remove tree limbs as necessary but large trees should remain post construction. 9. Spoil excess soil on right hillslope to bury old, diverted channel and endhaul remaining spoil as needed. 10. Outslope road and fill ditch for 300' along the right road. 11. Outslope road and fill ditch for 550' along the left road. 12. Install 3 rolling dips along the left road. 13. Install 2 rolling dips along the right road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
229	Peterson Ranch Road	M	Stream crossing	1065	0	93	213	The stream crossing has two culverts, a 30" and a 24". Both are very rusty and the 30" has no bottom. The inboard fill is steep but armored with a cement wall. Three separate roads deliver to this site and can easily be disconnected. Right road that runs parallel to the creek channel has a rock wall on both sides preventing any sediment discharge. Only two roads deliver to this site (new Powerline Road is potentially hydrologically disconnected to Shellhouse Road).	1. Excavate TOP to BOT for 60'. 2. Replace with a 54" x 60' culvert. 3. Construct one rolling dip and outslope where possible on Poly Canyon Rd. 4. Construct two rolling dips and outslope Shell House Rd. 5. Install critical dip on the right hingeline. 6. Import 15 cy of clean fill. 7. Build inboard fillslope at 40 degrees and armor with 1'-2' riprap for 100% of the fill face. 8. Build outboard fill at 2:1. 9. Outslope Shell House Road and Poly Canyon Road. 10. Improve rolling dips on Shell House Road. 11. Install 7' t-post trash rack above inlet.



Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
230	Poly Canyon Road	H	Stream crossing	160	1670	156	163	The 15' x 2' class 1 Brizziolari Creek flows through an undersized 60" pipe. Bottom of the pipe is rusted through. The inboard and outboard fill faces are heavily reinforced with masoned rock walls and formed concrete. This reinforcement is all that has saved this crossing. Flow has overtopped the road many times in the past. There are signs that flow has crossed the road at the site and diverted to the left across a small rest area. Large concrete slabs have been placed in this area to buttress the fill.	1. Excavate existing culvert(s) and concrete and backfill and compact existing crossing. 2. Excavate from TOP to BOT for 70' long to establish a 12' wide channel bottom along the natural channel alignment) oblique to the road). 3. Install a 96" x 70' long culvert. 4. Rebuild the road with both fillslopes at 30 degrees. 5. Add 20 cy of 1'-3' riprap on each fillslope halfway up (40 cy total). 6. Install 12' tall, galvanized post trash rack 8' above new inlet. 7. Install critical dip on the left hingeline. 8. Outslope and retain ditch for 200' along the left road and drain the ditch to the new inlet. Note: Site will need to be dewatered and a biologist present at this Cass I stream.
230.1	Poly Canyon Road	L	Stream crossing	0	820	2	27	Steep bed rock channel that diverts to site 231 via ditch causing 15' headcut in ditch adjacent to ditch relief culvert at site 231.	1. Outslope road for 820' along the left road and install 6 rolling dips. 2. Install critical dip along on left hingeline.
231	Poly Canyon Road	ML	Ditch relief culvert	80	40	0	154	Long insloped road drains thru this ditch relief culvert. The culvert is new and has a welded bent ring on outlet. 450' to the right there is an ephemeral spring in a bedrock swale that discharges on to road surface and enlarges gully on surface. The road segment is wide and well-traveled and traverses the inner gorge of Brizziolari Creek.	1. Place 20' long downspout to outlet of culvert. 2. Cut clean 3 sq.ft. ditch for 40' from site 230.1 to existing ditch relief culvert at this site. 3. Outslope road for 40' of right road. 4. Outslope 80' of left road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
232	Poly Canyon Road	M	Ditch relief culvert	400	340	1	157	Newly installed ditch relief culvert. Road is behind a locked gate and may be quarry access. A concrete wing wall is installed at inboard road. Slope below outlet is heavily armored with 0.5'-1' riprap. A 1' x 0'x 5' x 40' gulley is connected to creek. Additionally, there is a log crib-wall buttressing the fillslope.	1. Outslope road and fill ditch for 340' along right road. 2. Install 1 rolling dip up right road. 3. Clean/cut ditch for 100' up left access road. 4. Remove log stringers and replace with 1'-2' riprap, 15' wide x 15' long using 17 cy. 5. Add an 18" x 40' ditch relief culvert with an elbow and 10' downspout 100' from existing 24" plastic ditch relief culvert on right road.
232.1	Poly Canyon Road	M	Fill failure	0	45	83	12	Incipient landslide on outboard road 240' up right road from site #232. Landslide location is approximately 50' above mainstem Brizziolari Creek along a year-round used road. There is a potential to lose access at this point if it is not treated.	1. Excavate 50' wide x 4' deep (average) x 25' long. 2. Refill void with 185 cy of 1'-2' riprap. 3. Build berm 2' wide x 2' tall 75' long around the top of the riprap to prevent further erosion. 4. Stock spoil locally on road.
233	Poly Canyon Road	ML	Stream crossing	365	580	98	82	Newly installed culvert, not at channel grade. Culvert currently shot gunned onto a of large riprap. Hillslopes of both sides of crossing are springy and hummocky.	1. Excavate crossing from TOP to BOT for 60'. 2. Replace existing culvert with a 42" x 60' long culvert set in at channel grade and at base of fill. 3. Outslope road and keep ditch for 100' up right road and 50' up left road. 4. Outslope road and remove ditch for 450' along right road. 5. Install 3 rolling dips along right road. 6. Outslope road and remove ditch for 315' along left road. 7. Install 2 rolling dips along left road. 8. Remove 4" oak tree at inboard fill edge. 9. Install 7' t-post trash rack above new inlet. 10. Stock spoils locally on road.

Table B1. Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
234	Poly Canyon Road	M	Stream crossing	200	0	0	7	A 24" concrete pipe drains a Class III stream and 200' of left road. The culvert inlet is concrete, and the outlet is steel. The culvert inlet is located at the base of a landslide deposit and the outlet is eroding the outboard fill. The culvert is installed at a low gradient causing potential plugging. Stream has diversion potential as well.	1. Excavate from to TOP to BOT for 50' to replace existing culvert. 2. Replace existing culvert with a 24" x 50' long culvert set at channel grade. 3. Rebuild inboard fillslope at 26.5 degrees and outboard fillslope at 35 degrees. 4. Armor outboard fillslope 3/4 of the slope with 10 cy of 0.5'-1.0' riprap. 5. Install critical dip on right hingeline. 6. Install 6' t-post trash rack above new inlet. 7. Outslope road and keep ditch for 200' along the left road. 8. Install 1 rolling dips along the left road. 9. Stock spoil locally along road approaches.
235	Stenner Creek Road	-	Stream crossing	50	0	0	1	Heavy duty steel and concrete bridge spans Stenner Creek. Top of the 40' long bridge is wood planked. Concrete abutments look stable and may constrict flow slightly, but there is no evidence of problems.	No treat.
236	Stenner Creek Road	M	Stream crossing	200	190	28	38	Newly installed culvert installed at base of fill with concrete slab wall at inboard fill. Installation looks good, treat road approach only to reduce runoff to the Class III stream crossing culvert inlet. Ephemeral stream crossing on streamside road to Stenner Creek. The insloped road drains hillslope and road surface.	1. Outslope road and remove ditch for 200' along the left road. 2. Outslope road and remove ditch for 190' along the right road. 3. Install 1 rolling dip on the left road. 4. Install 1 rolling dip on the right road. 5. Rock road surface for 390' using 52 cy of 1.5" minus road rock.

<b>Table B1.</b> Field observations and treatment recommendations for road related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
<b>Abbreviations:</b> H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
237	Stenner Creek Road	ML	Ditch relief culvert	0	420	0	39	Newly installed 12" ditch relief culvert drains 440' of right road. Hillslopes are grassy and likely flashy. Inboard fill has a new concrete wing wall.	1. Install a 15" x 40' long ditch relief culvert along the right road (approximately 150' up right road). 2. Install 2 rolling dips along the right road. 3. Rock road for 420' long using 56 cy of 1.5" minus road rock. 4. Cut ditch for 420' along the left road to capture springy hillside.
238	Stenner Creek Road	M	Ditch relief culvert	300	0	0	23	The 9" ditch relief culvert is 80% plugged from accumulated road surface and hillslope material. The contributing road surface is insloped and rocked with fine-grained loose material on an 8% grade road. The ditch relief culvert outlet is placed in the middle of the outboard fill causing erosion. Evidence of the ditch relief culvert over pipping is present within the gully starting at the outboard road and down the fillslope. The incised gully from outlet down native hillslope suggests too much water is being conveyed to this area.	1. Replace the existing ditch relief culvert with a 15" x 40' ditch relief culvert (move inlet up road to achieve 30% angle to the road). 2. Add new 15" x 40' long ditch relief culvert 100' feet up road from existing ditch relief culvert. 3. Install 2 rolling dips along the left road to drain the road only (do not connect to ditch). 4. Cut ditch for 300 feet along the left road to capture springy hillside. 5. Rock the road surface for 300' using 40 cy of 1.5" minus road rock.
238.1	Stenner Creek Road	HM	Road surface	450	0	0	39	The 450' of insloped road drains off Cal Poly property and delivers sediment laden runoff to stream crossing located 50' beyond property boundary. During wet periods, the road is soft, muddy, and highly erodible and becomes greatly disturbed with daily residential and farm access needs.	1. Outslope road and keep ditch for 400' along the left road. 2. Clean or cut ditch for 400' along the left road. 3. Replace 1 ditch relief culvert with a 15" x 40' corrugated metal culvert. 4. Install 2 ditch relief culverts with 15" x 40' corrugated metal culverts. 5. Rock road for 400' using 53 cy of 1.5" minus road rock.

## **Appendix C**

### **Field observations and treatment recommendations for trail related sediment delivery sites.**

Stenner Creek Erosion Control and Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California

Table C1. Field observations and treatment recommendations for trail related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
194	Architect ural Canyon Complex Road	ML	Stream crossing	302	30	2	22	A well-constructed concrete foot bridge spans a 9' x 2' Class II stream. Bridge and abutments look stable, and stream is not constricted. The left road approach is actively rilling. Future erosion is from gully expansion on the left road.	1. Outslope left road approach for 300'. 2. Install 3 small rolling dips along left road.
226.1	Peterson Ranch Loop Spur	-	Hillslope debris slide	75	90	14	3	The trail traverses through a steep and rocky unstable hillslope area. This is a larger feature, and the trail bisects. Over the years, many fixes have been tried but have not been successful. This is a single-track trail used by bikers and hikers. There are no cost-effective solutions at this location and safety is a concern as well as sediment delivery.	No treat.
410	Yewks	ML	Stream crossing	279	0	0	9	A 3' wide bike trail crosses Class III stream. A headcut is migrating into the trail crossing and is threatening the ongoing use of the trail. The stream has the potential to divert down the left trail.	1. Install 2 rolling dips along the right trail. 2. Install 1 rolling dip along the left trail.
411	Yewks	ML	Stream crossing	15	682	0	45	A 2' x 1' Class II flows across a small ford crossing. Channel is low gradient and grassed over. There is no fill in crossing. Right trail contributes drainage. The right road approach is long, steep, through cut, and has multiple alignments.	1. Install 9 rolling dips along the right trail.
412	Yewks	L	Stream crossing	167	0	5	7	A low gradient, low power stream with a semi-saturated fill prism. Channel is well grassed over and impacted by cattle. Erosion is low from trail, and armored fill installation is likely above and beyond what is necessary here.	1. Excavate a keyway 10' wide at the top tapering to 3' wide at the bottom for 9' long. 2. Install an armored fill crossing using ~5 cy of 0.5' - 1.5' rock armor. 3. Install 2 rolling dips along the left trail. 4. Stock spoil locally on trail.

Table C1. Field observations and treatment recommendations for trail related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
Abbreviations: H = high; L = low; M = moderate; TI = Treatment immediacy (priority); TOP = Top limit of excavation; BOT = Bottom limit of excavation.									
PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
413	Yewks	L	Stream crossing	346	65	0	11	A small 2' x 0.5' Class III stream flows across a small 2' wide trail here. There is currently armored fill in the crossing. The stream channel is grassy, and approaches show signs of wear from usage when wet. They will contribute drainage to the crossing. There is currently a 2' wide x 2' long gulley migrating into the trail.	1. Excavate a keyway 10' wide at the top tapering to 3' wide at the bottom for 6' long. 2. Install an armored fill crossing using ~5 cy of 0.5' - 1.5' rock armor. 3. Install 4 rolling dips along the left trail. 4. Install 1 rolling dip along the right trail. 5. Stock spoil locally on trail.
414.1	Upper Stenner Spur	-	Stream crossing	75	45	0	5	Hardened ford crossing on a Class II stream. Concrete/cinder block apron placed thru crossing 15' wide x 10' long with flow centered through the crossing. This is a high use area for cattle. This trail crossing appears to be stable as is (low use trail).	No treat.
414.2	Upper Stenner Spur	-	Stream crossing	60	0	0	3	A Class II ford crossing with abundant juncus and sycamores. The crossing is wet with multiple trail alignments as users navigate and renavigate the wet crossing. In peak events the stream may divert down the right trail, but low gradient and the adjacent grassy area can handle the diversion. There is no gulley present adjacent to the current stream channel.	No treat.

Table C1. Field observations and treatment recommendations for trail related sediment delivery sites. <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>									
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PWA Site #	Road name	TI	Problem	Hydrologically connected road length (ft)		Estimated future sediment delivery <sup>c</sup> (yd <sup>3</sup> )		Site Description	Recommended Treatment
				Left	Right	Episodic	Chronic		
415	Elevator	M	Stream crossing	45	616	2	37	A ford crossing on Stenner Creek. The crossing itself looks stable, upslope a 10' board has been placed at the narrowest gap in the near-vertical banks, though despite their steep angle, these banks appear natural. Significant right approach could benefit from drainage treatments, though water bars currently in place are helpful. As with many streams in this watershed, most impact comes from the cattle grazing. Future erosion is based on possible (though unlikely) calving of the bank material.	1. outslope 510' of right approach. 2. Install 5 rolling dips along the right trail.
416	Elevator	L	Stream crossing	33	280	0	27	A 2' x 1' Class II flows across a small but heavily used mountain bike trail. There is no fill in the crossing and no eroding banks. The crossing is a perfect ford. The right approach is connected.	1. Install 3 rolling dips along the right trail.
417	Elevator	ML	Stream crossing	40	295	0	16	This is a well-designed ford crossing on a bike trail. Banks are pulled back and stable. There is no fill left in the crossing. Right approach shows wear from bike traffic and is getting rutted. Multiple trail alignments have been developed along the right approach with up to three parallel alignments.	1. Install 5 rolling dips to right.



## Appendix D

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

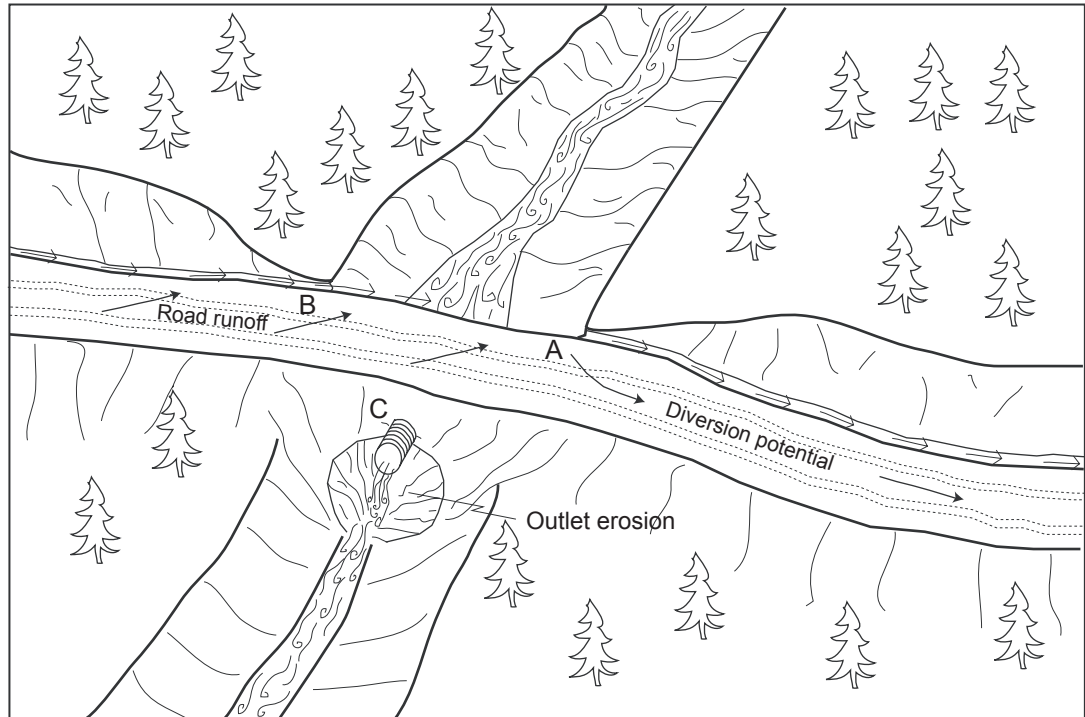
Stenner Creek Erosion Control and Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California

<b>No.</b>	<b>Drawing title</b>
1a	Typical problems and applied treatments for a non-fish bearing upgraded stream crossing
1b	Armoring fill faces to upgrade stream crossings
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
17	Typical construction of road decompaction and cross road drain installation
18	Typical rock grade control structure installation
19a	Standard (Type 1) rolling dip construction
19c	Type 3 rolling dip construction for steep slope road reaches
19d	Typical design for resurfacing after dip construction
20	Typical ford crossing installation
21	Typical design for de-watering streams

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

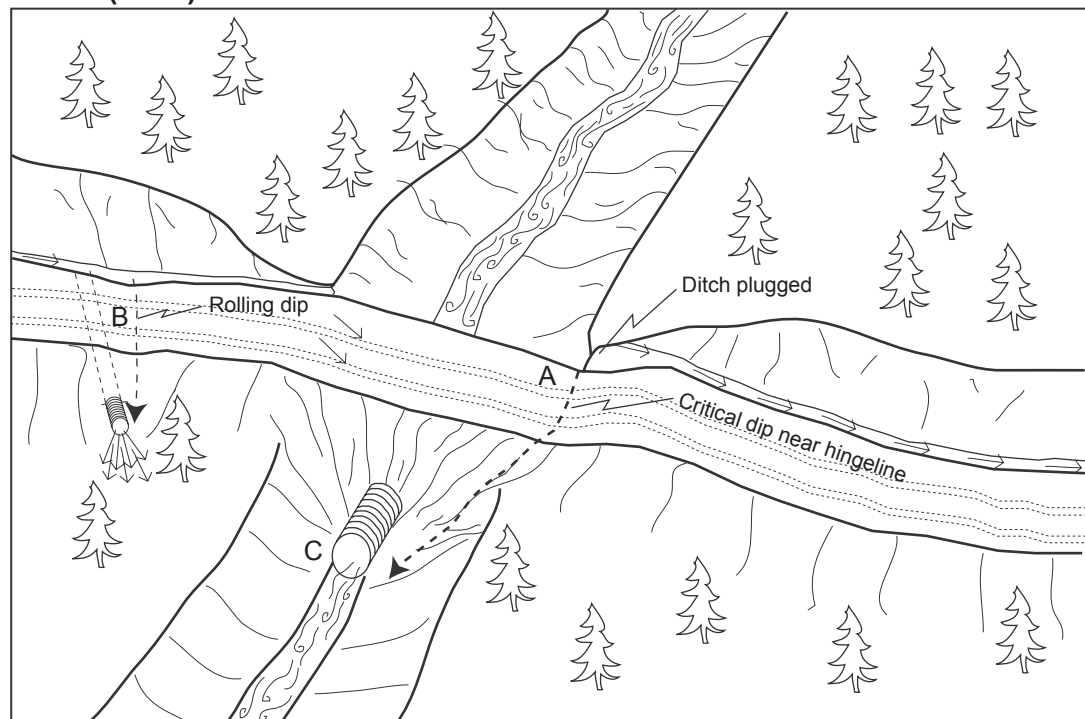
## Problem condition (before)

- 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

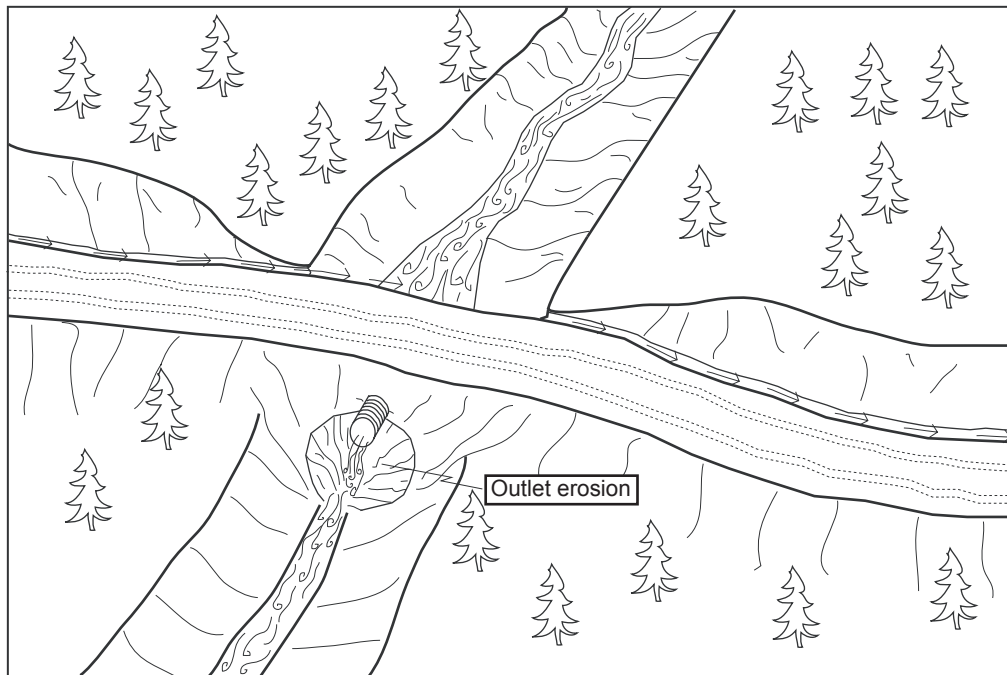


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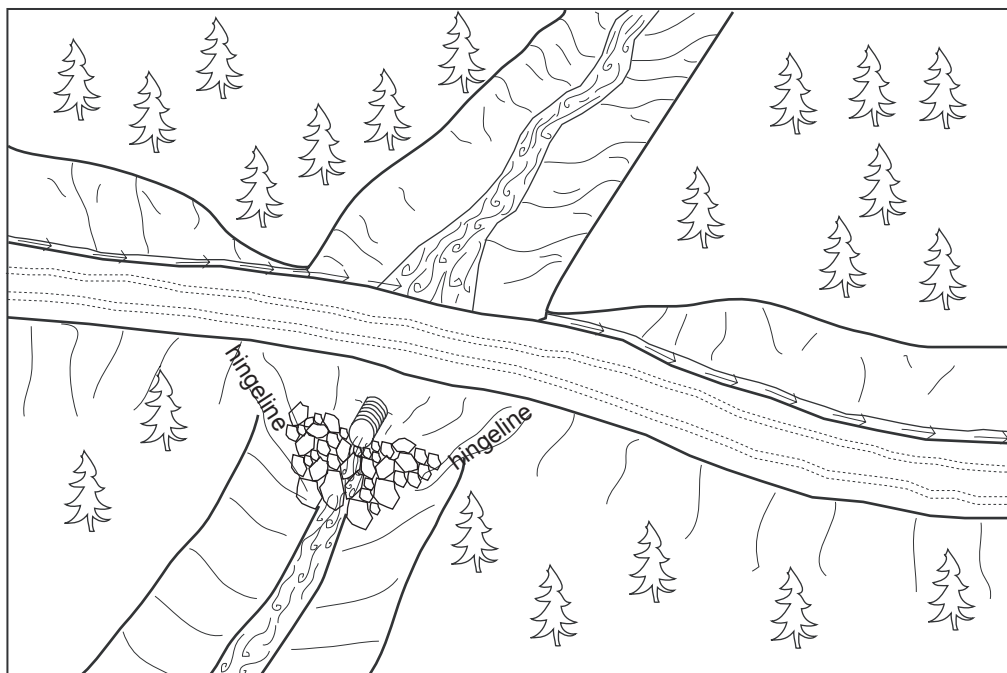
PWA Typical Drawing #1a

## Armoring Fill Faces to Upgrade Stream Crossings



**Problem:** Culvert set high in outboard fill has resulted in scour of the outboard fill face and natural channel.

**Conditions:** The existing stream crossing has a culvert sufficient in diameter to manage design stream flows and has a functional life.



**Action:** The area of scour is backfilled with rip-rap to provide protection in the form of energy dissipation for the remaining fill face and channel.

**Treatment Specifications:**

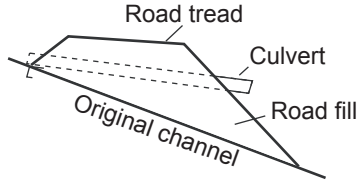
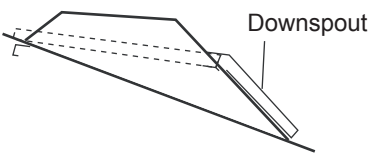
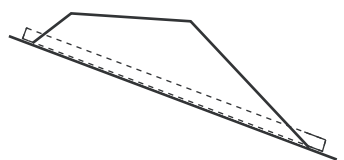
- 1) Placement of rip-rap should be between the left and right hingelines and extend from a keyway excavated below the existing channel base level at the base of the fill slope up and under the existing culvert.
- 2) Rock size and volume is determined on a site basis based on estimated discharge and existing stream bed particle size range (See accompanying road log).

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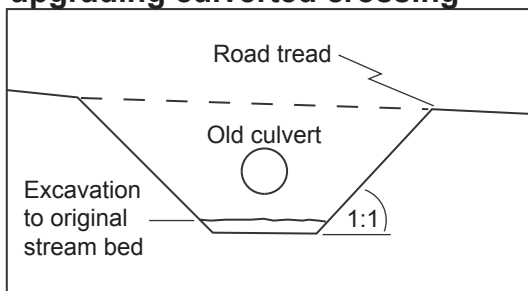
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PWA Typical Drawing #1b

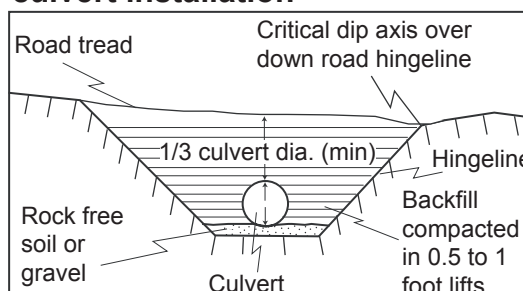
# Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing	Upgraded	Upgraded (preferred)
 <ol style="list-style-type: none"> <li>1. Culvert not placed at channel grade.</li> <li>2. culvert does not extend past base of fill.</li> </ol>	 <ol style="list-style-type: none"> <li>1. Culvert not placed at channel grade.</li> <li>2. Downspout added to extend outlet past road fill.</li> </ol>	 <ol style="list-style-type: none"> <li>1. Culvert placed at channel grade.</li> <li>2. Culvert inlet and outlet rest on, or partially in, the original streambed.</li> </ol>

## 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 calculations 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 inches 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:

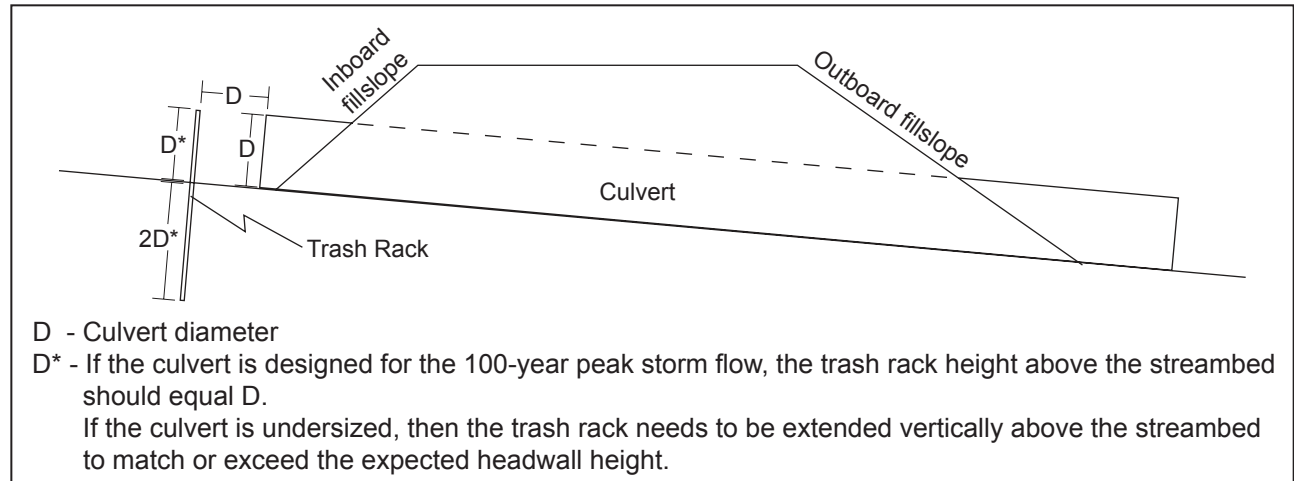
1. Minimizing soil exposure by limiting excavation areas and heavy equipment disturbance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as "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

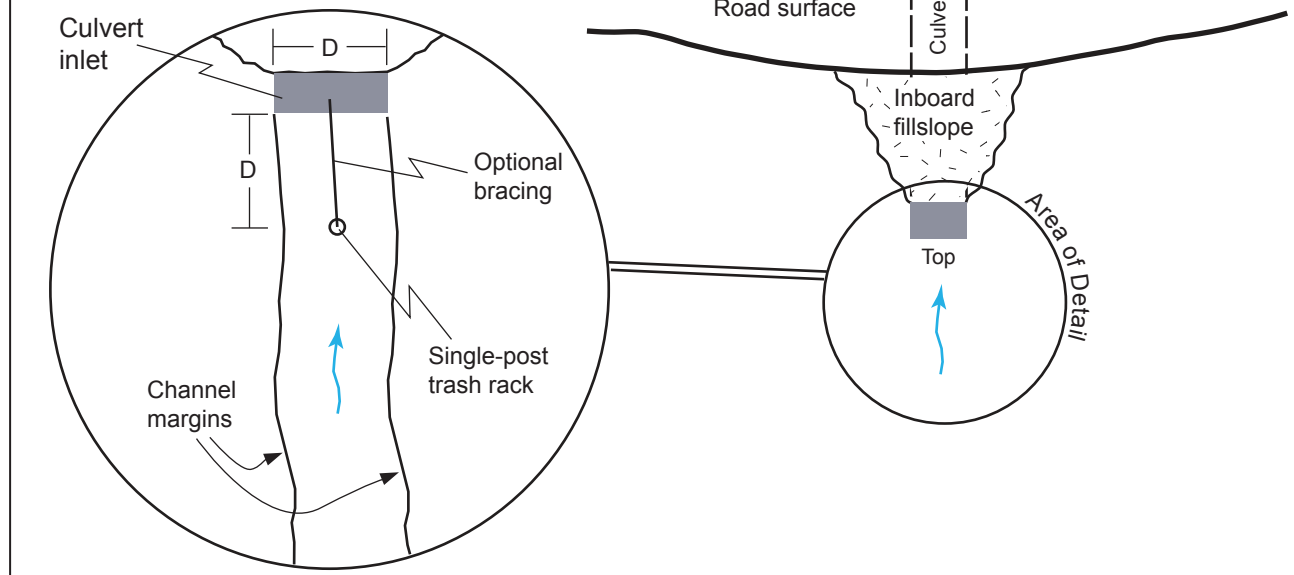
## Cross section view



## 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.

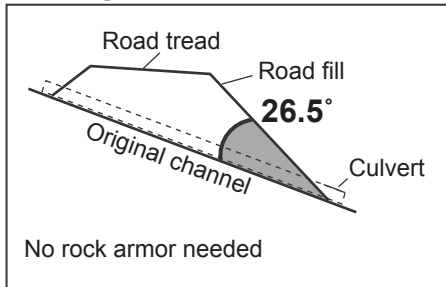


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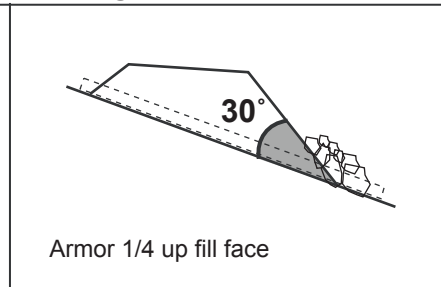
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# Typical Design of Stream Crossing Fill Armor

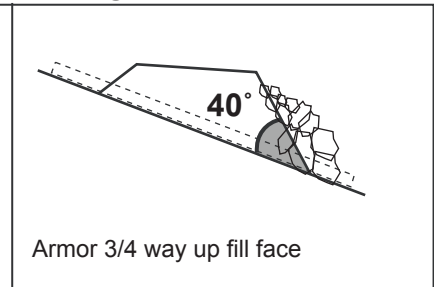
**Fill angles  $\leq 26.5^\circ$  (2:1)**



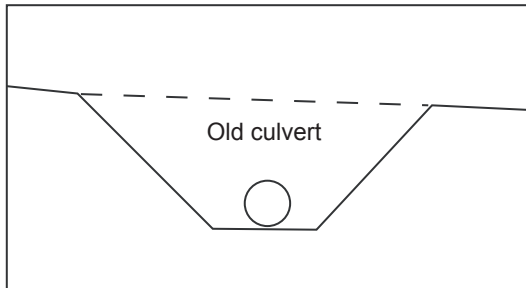
**Fill angles  $26.5^\circ - 35^\circ$  (1.5:1)**



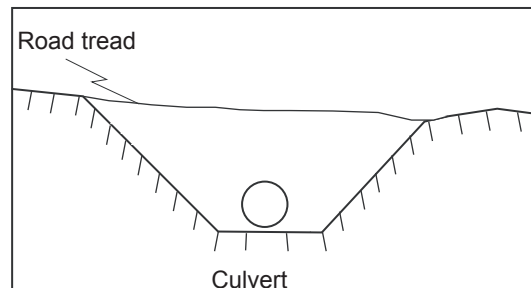
**Fill angles  $35^\circ - 45^\circ$  (1:1)**



**Fill angles  $26.5^\circ - 35^\circ$  (1.5:1)**



**Fill angles  $35^\circ - 45^\circ$  (1:1)**



**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.

## Stream crossing culvert Installation

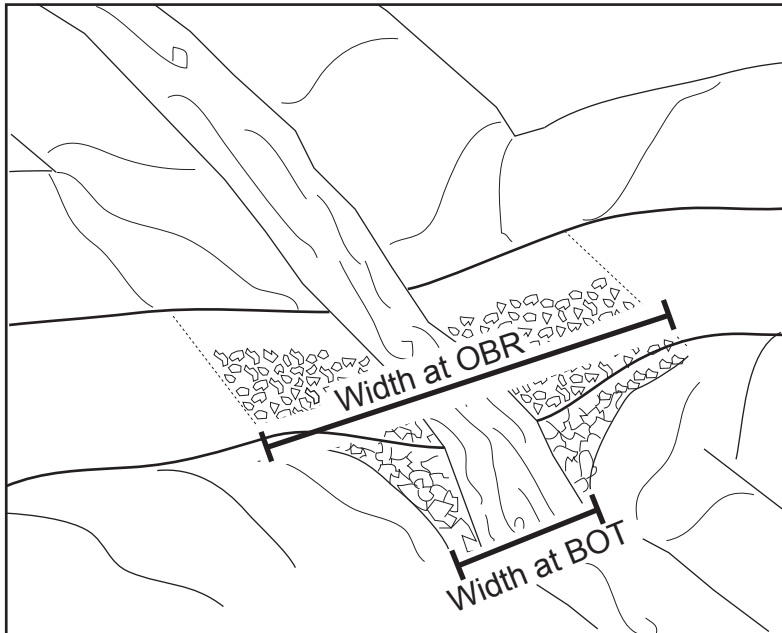
1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed or downspouted past the base of the fill.
3. Culverts shall be set slightly 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 inches 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.

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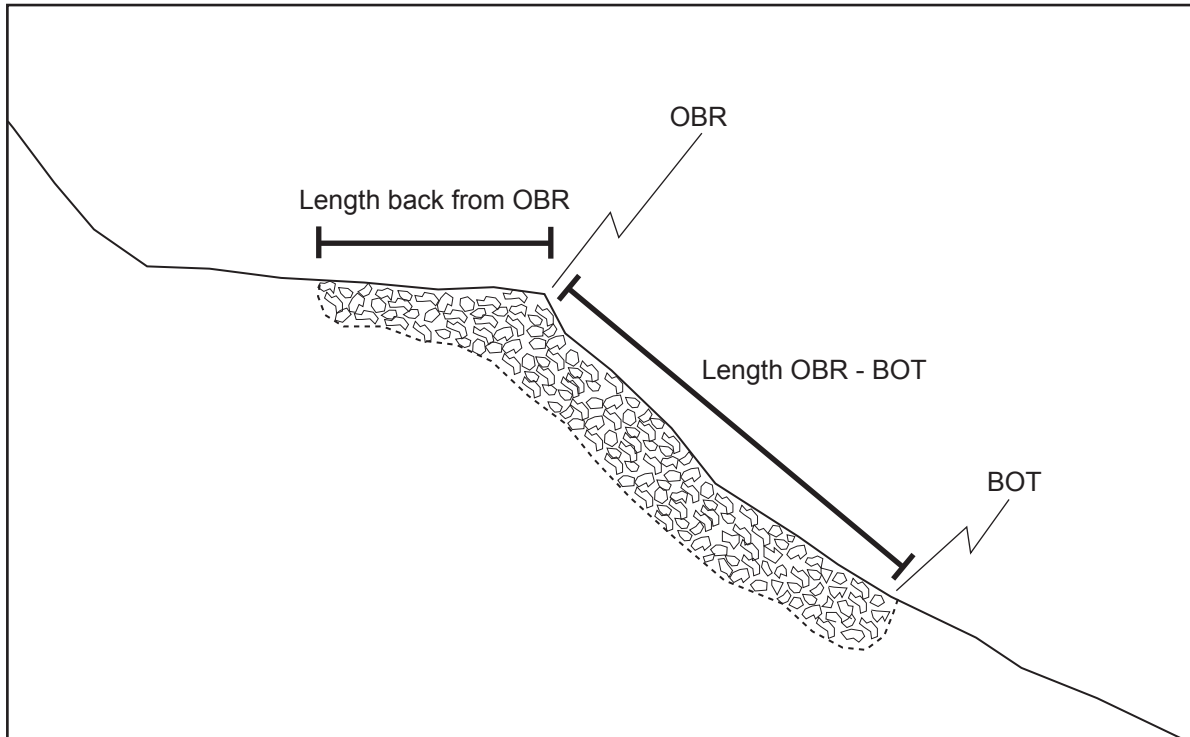
# Typical Dimensions Referred to for Armored Fill Crossings

## Widths in oblique view



OBR - Outboard edge of road  
BOT - Bottom of excavation

## Lengths in profile view

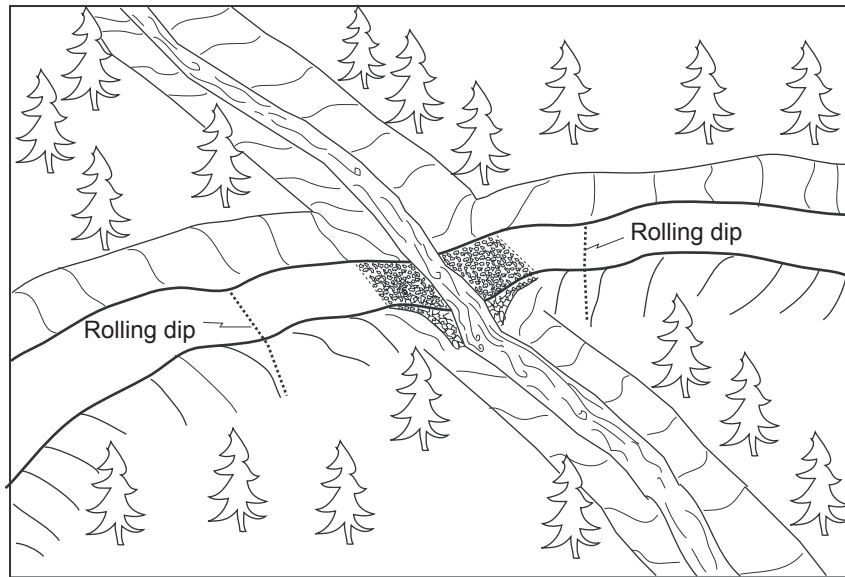


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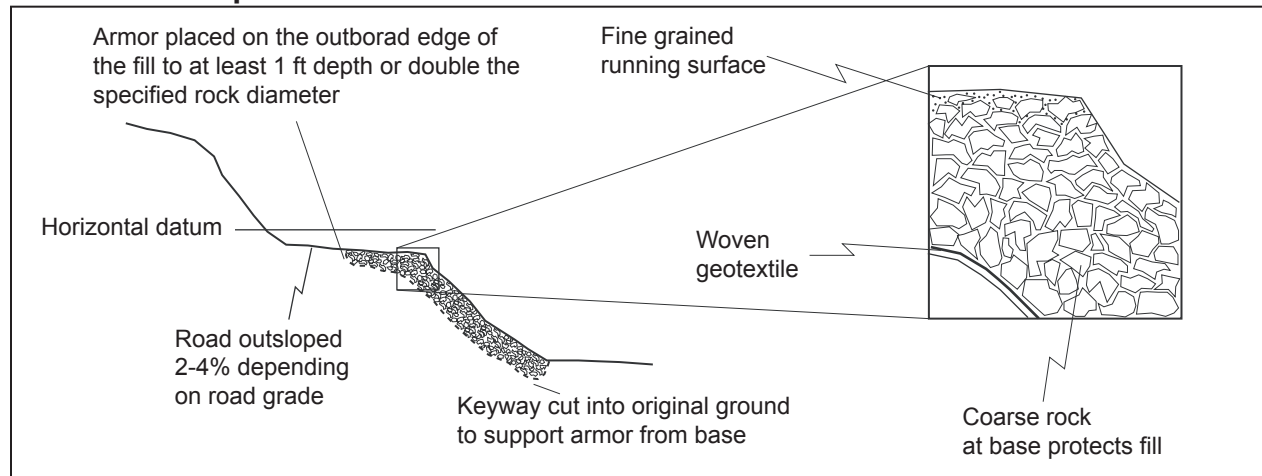
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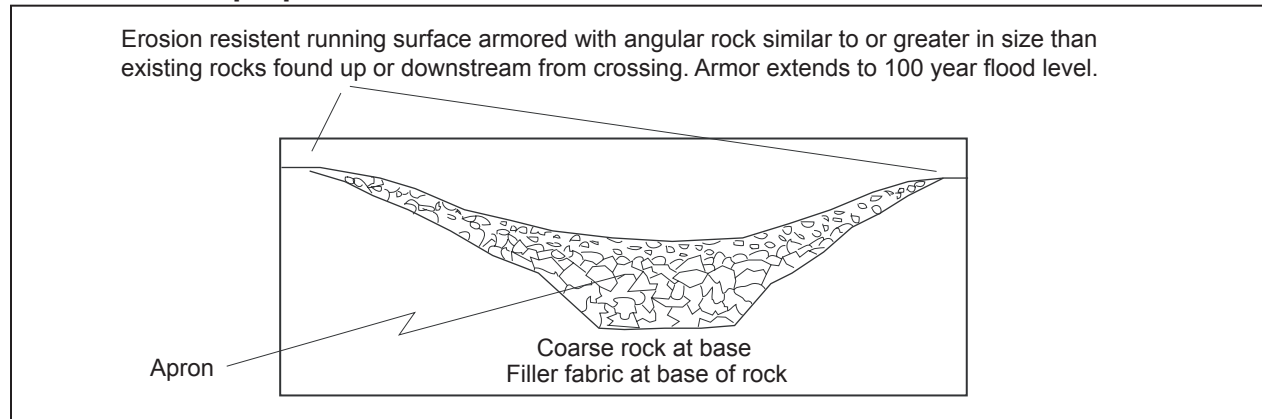
# Typical Armored Fill Crossing Installation



## Cross section parallel to watercourse



## Cross section perpendicular to watercourse

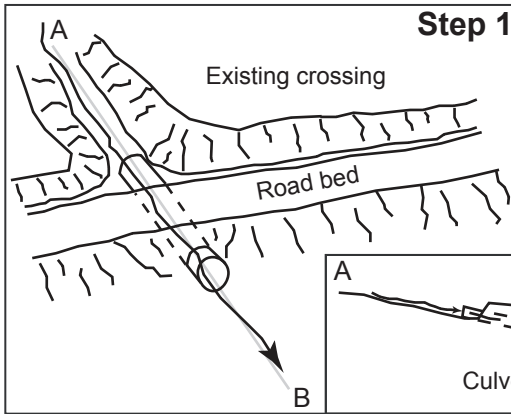


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# Ten Steps for Constructing a Typical Armored Fill Stream Crossing

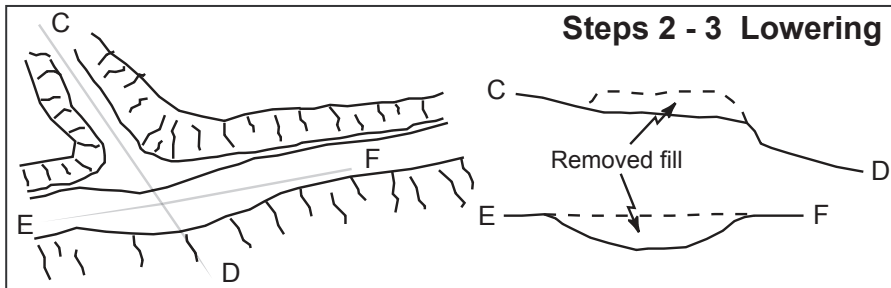


## Step 1

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).

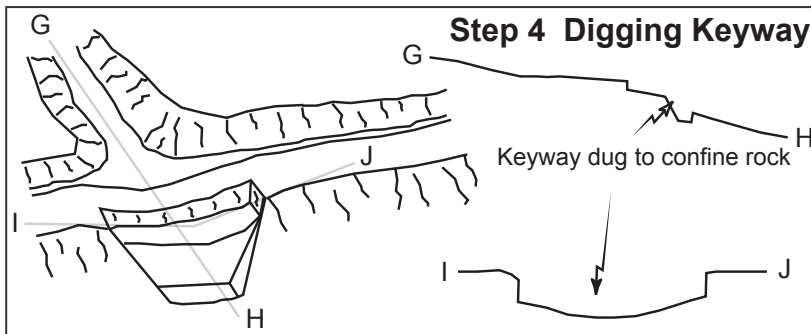
B) **The largest rocks must be used to buttress the rest of the armor in two locations:** i) The base of the armored fill where the fill meets natural channel. (This will buttress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). ii) The break in slope from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



## Steps 2 - 3 Lowering

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

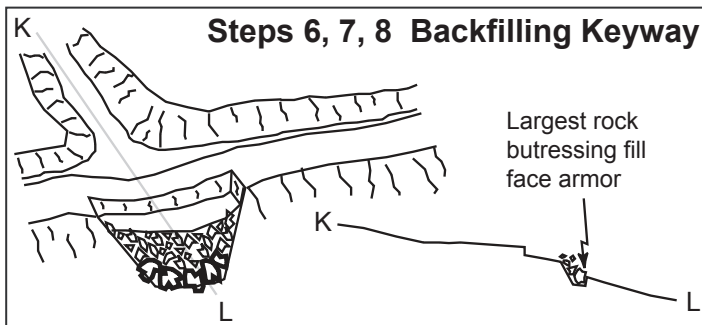
3. **Construct a dip** centered at the crossing that is large enough to accommodate the 100-year flow event and prevent diversion (C-D, E-F).



## Step 4 Digging Keyway

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 outboard 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.

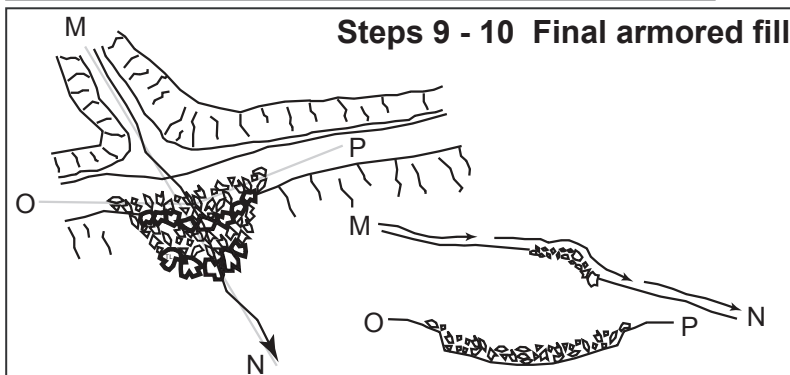


## Steps 6, 7, 8 Backfilling Keyway

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 accommodate the largest expected flow (K-L).



## Steps 9 - 10 Final armored fill

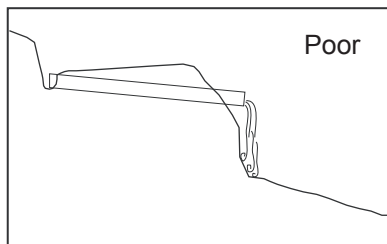
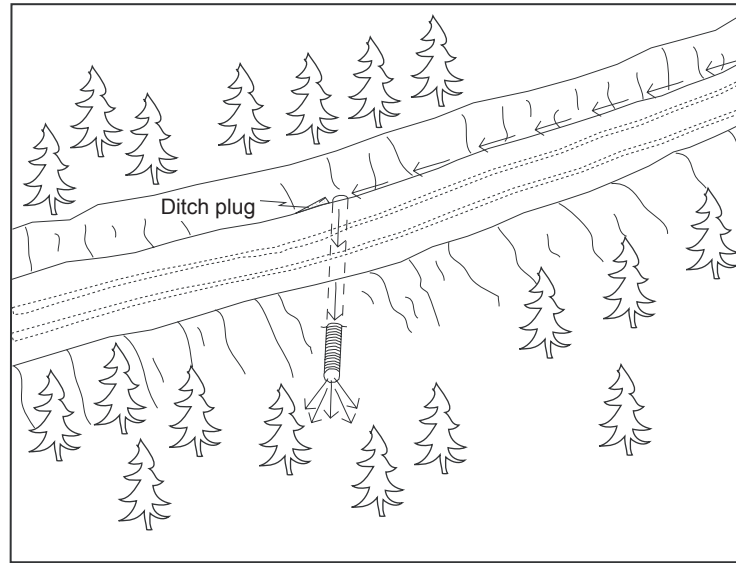
9. **Install a second buttress** at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction) (M-N).

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).

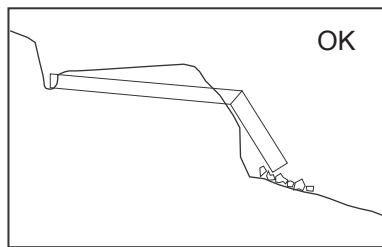
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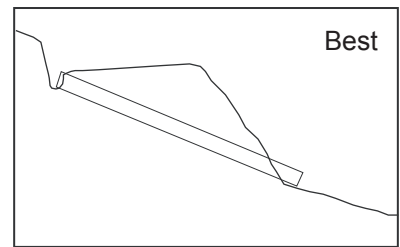
## Typical Ditch Relief Culvert Installation



Poor



OK



Best

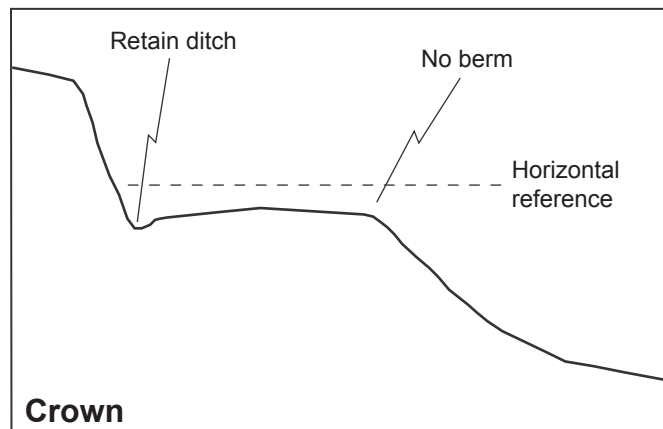
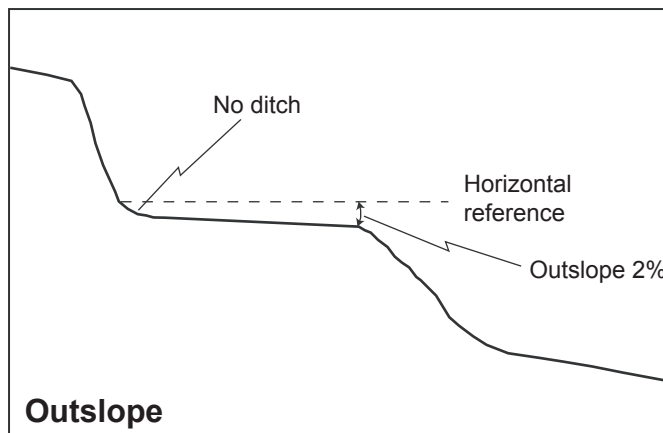
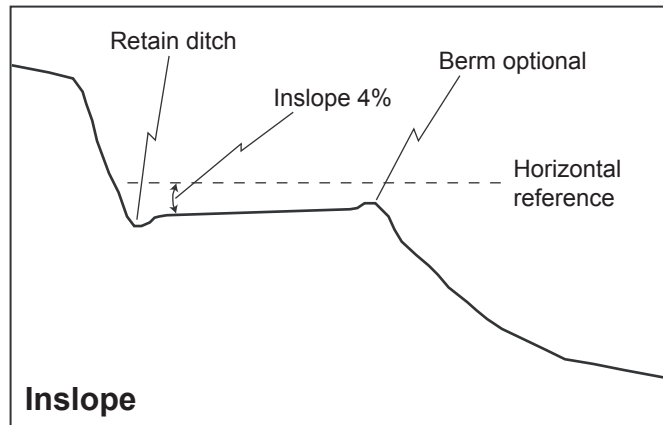
### Ditch relief culvert installation

- 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).  
Culverts 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



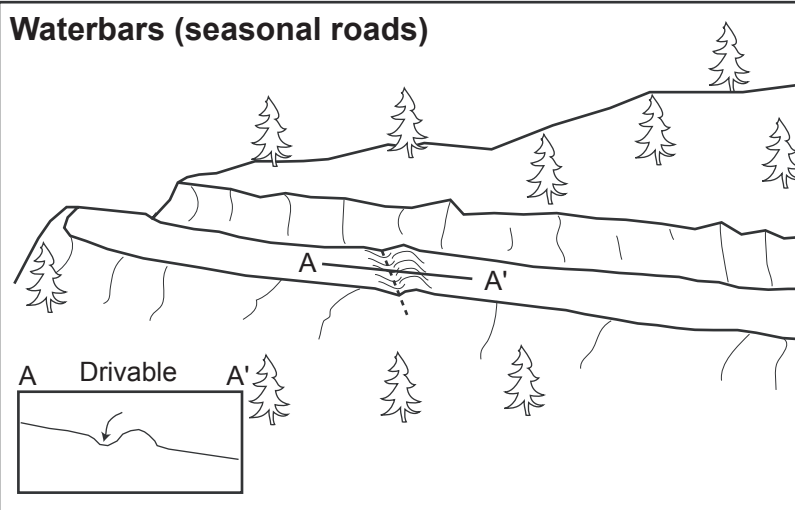
Outsloping Pitch for Roads Up to 8% Grade		
Road grade	Unsurfaced roads	Surfaced roads
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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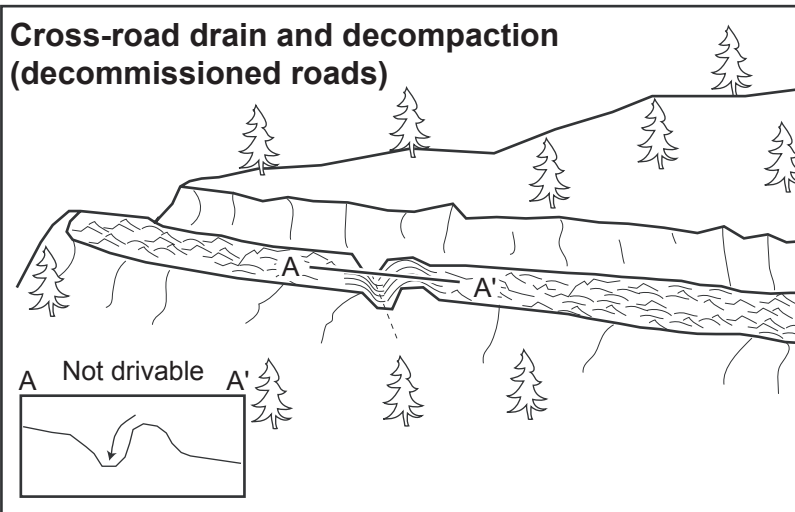
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## Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

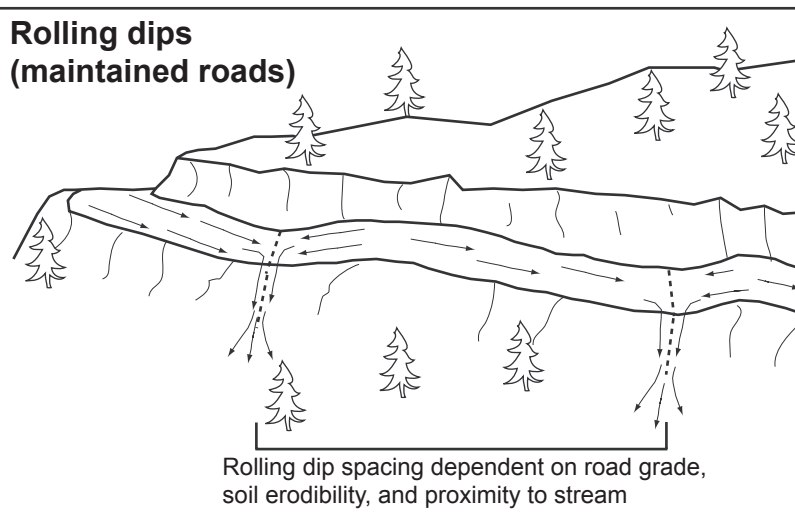
**Waterbars (seasonal roads)**



**Cross-road drain and decompaction (decommissioned roads)**



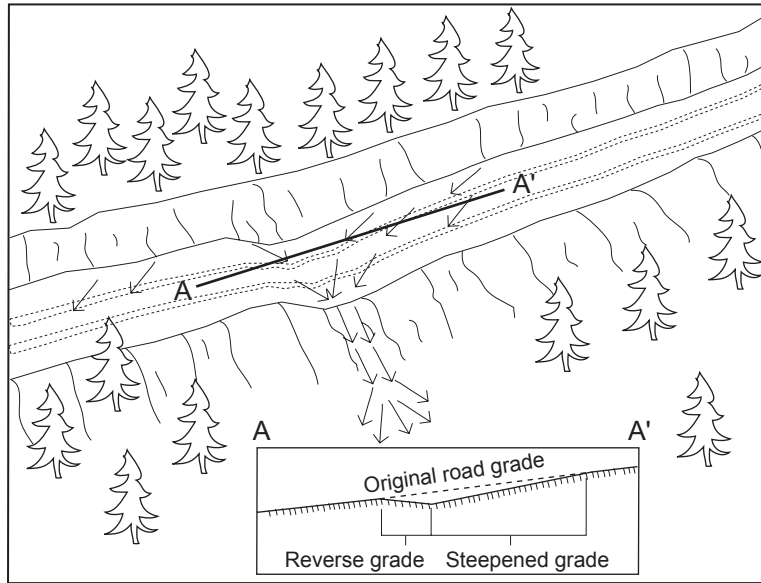
**Rolling dips (maintained roads)**



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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 until 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**

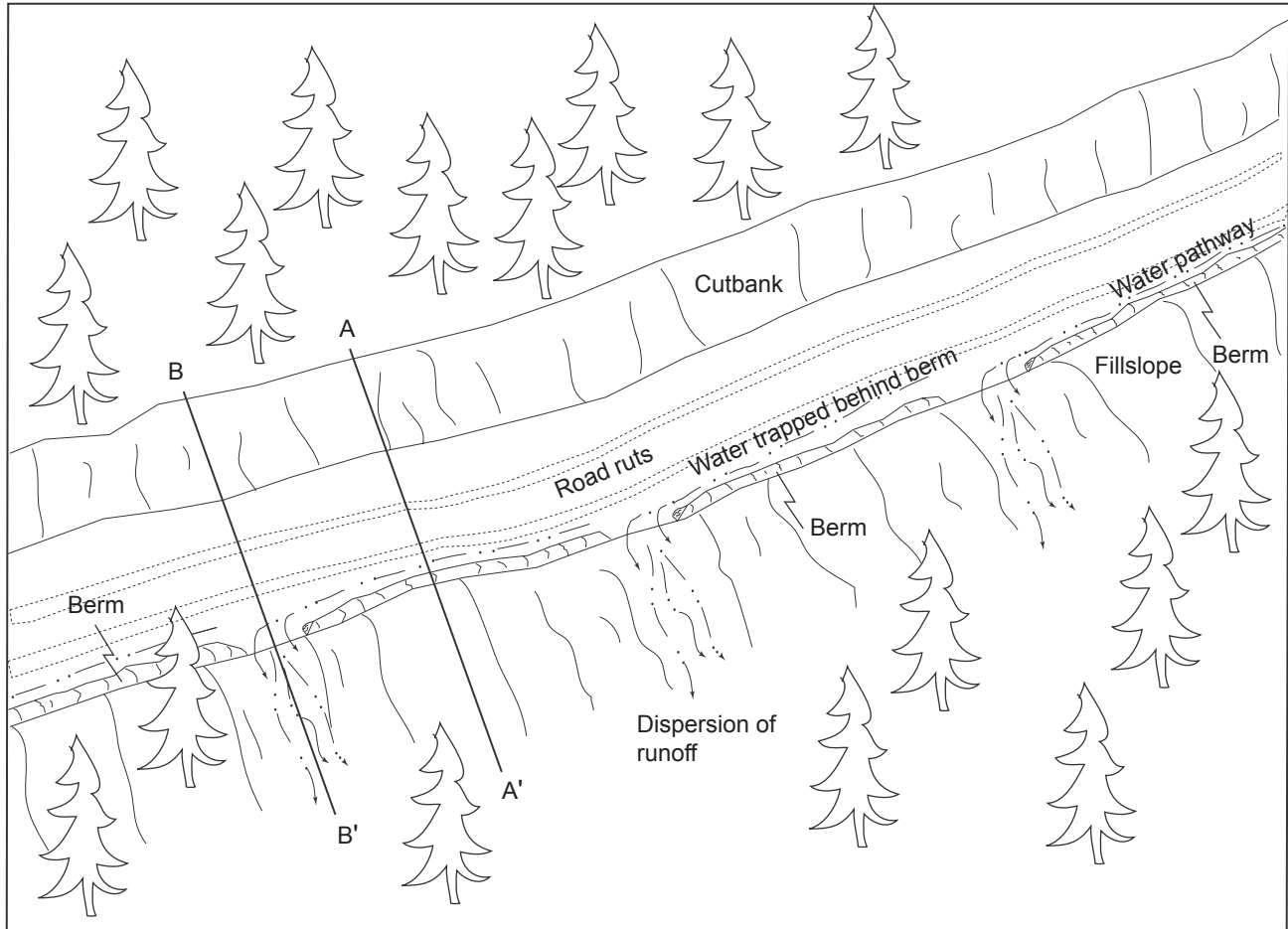
Road grade %	Upslope approach distance (from up road start to trough) ft	Reverse grade distance (from trough to crest) ft	Depth at trough outlet (below average road grade) ft	Depth at trough inlet (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20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

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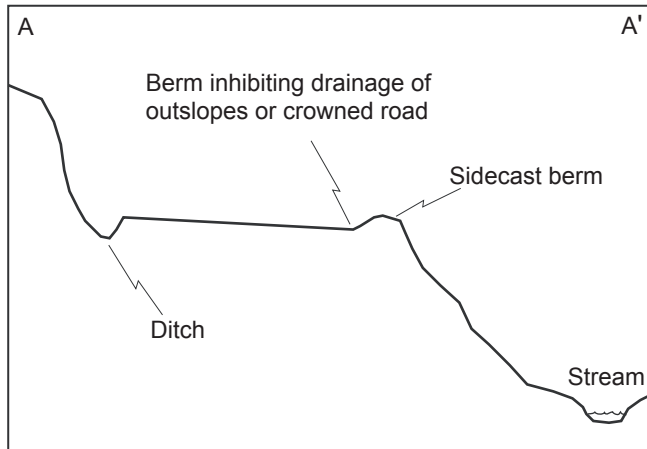
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## Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

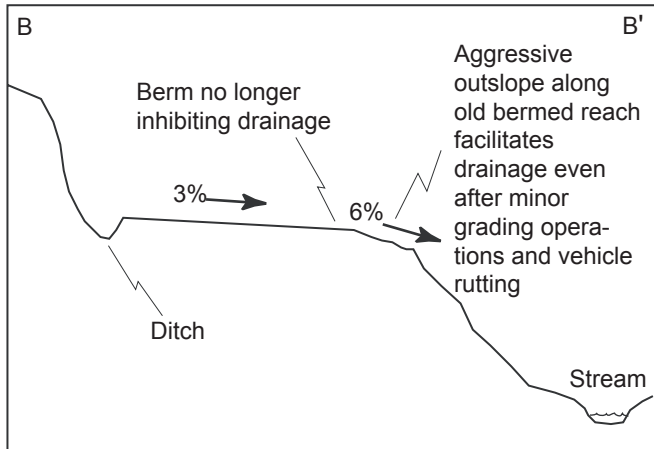
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B').  
Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining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



Road cross section between berm breaches



Road cross section at berm breaches

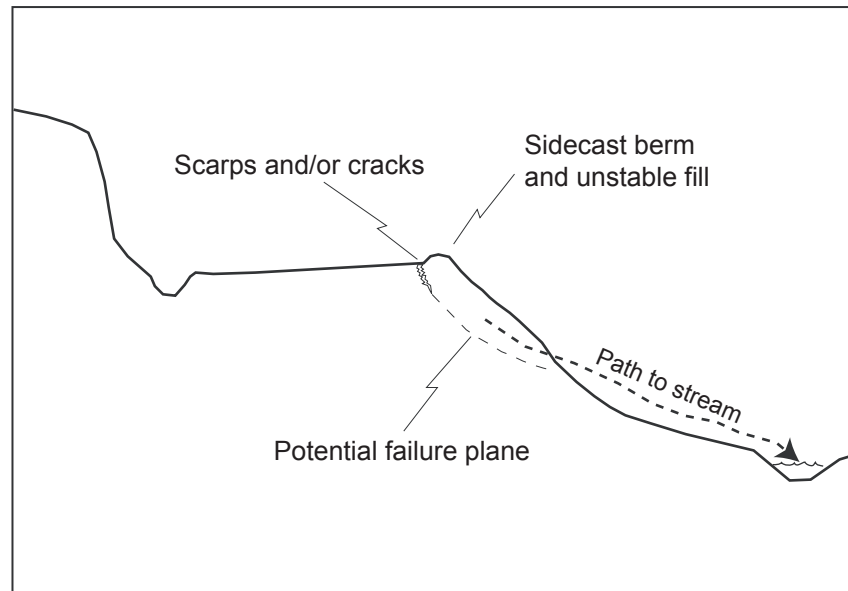


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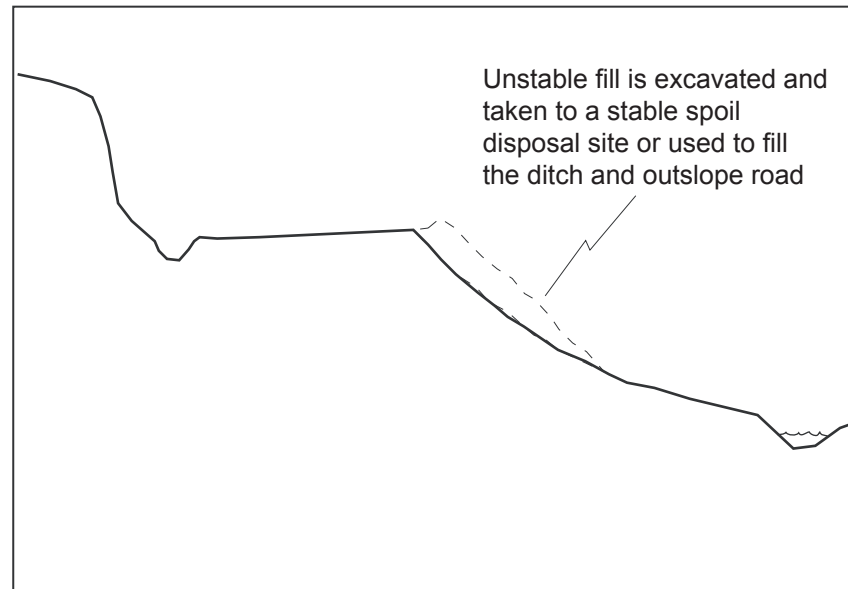
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# Typical Excavation of Unstable Fillslope on an Upgraded Road

**Before**



**After**



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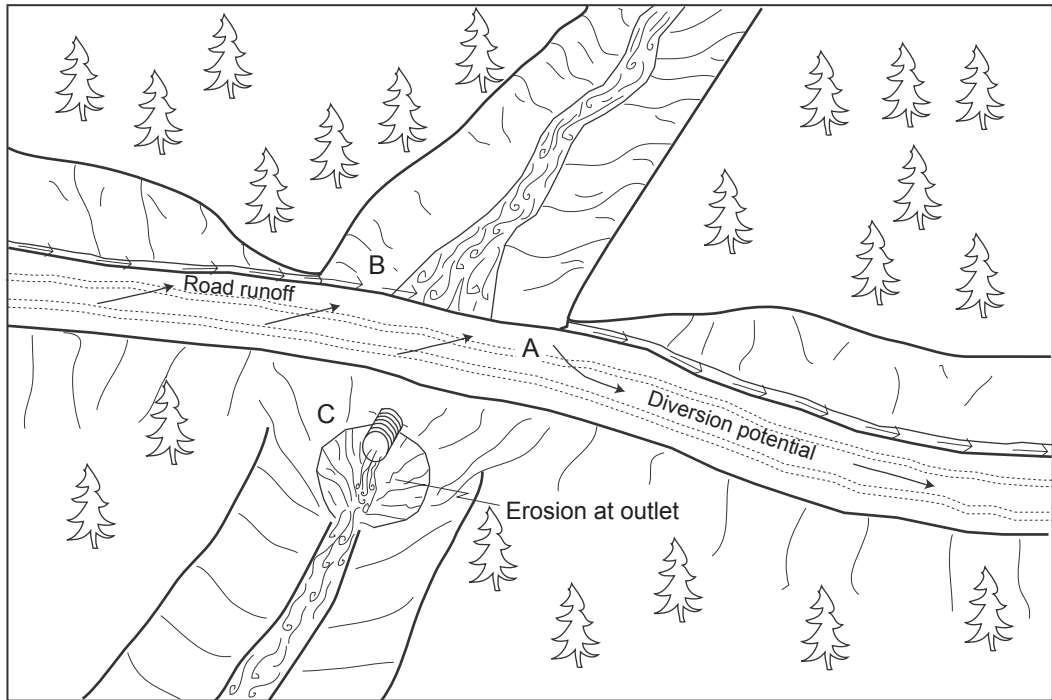
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# Typical Problems and Applied Treatments for a Decommissioned Stream Crossing

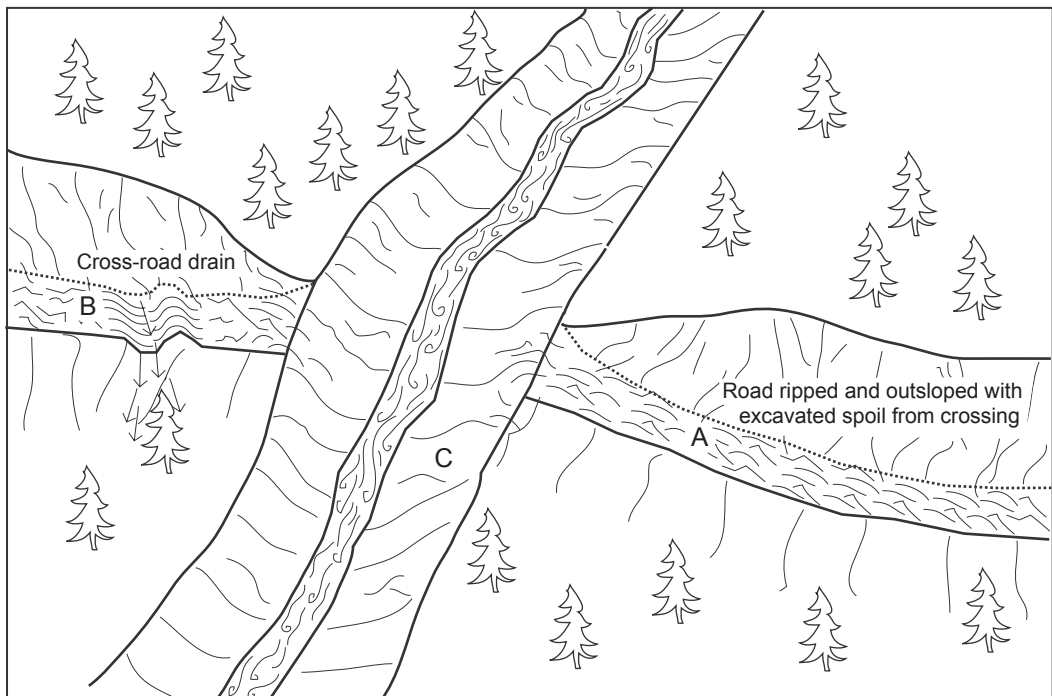
## Problem condition (before)

- 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 excavated spoils
- B - Road surface and ditch disconnected from stream by road surface decompaction and cross-road drains
- C - Stream crossing fill completely excavated



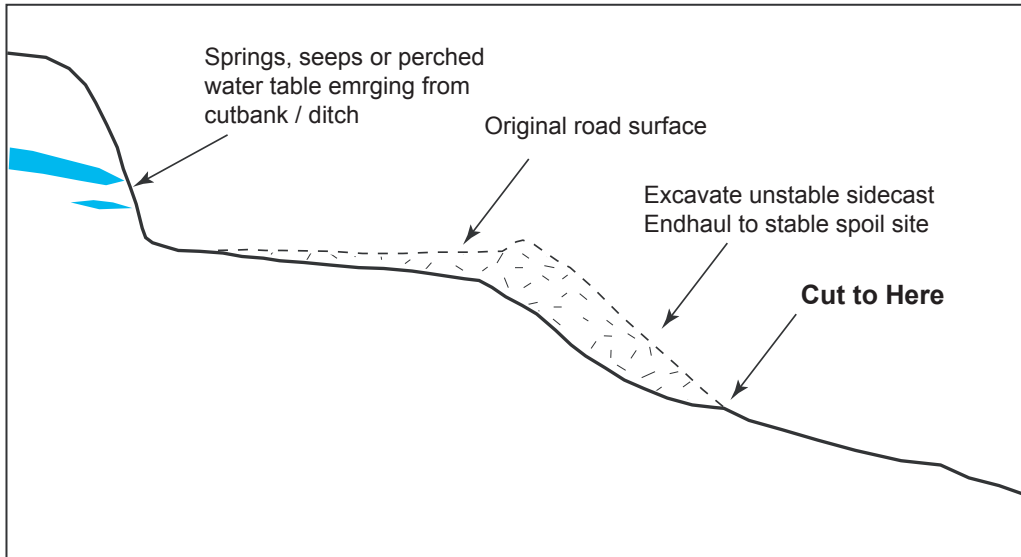
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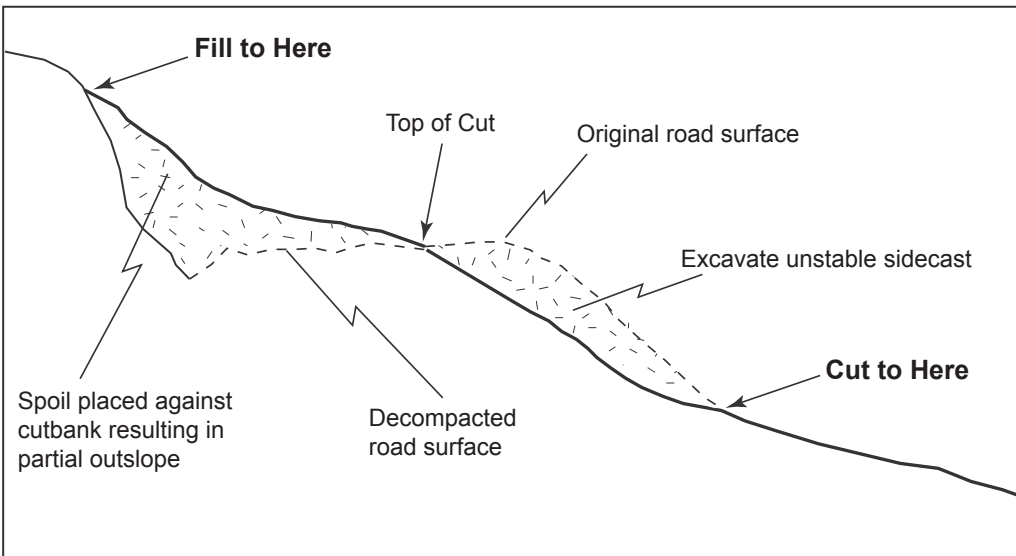


# Typical Design for Road Decommissioning Treatments Employing Export and In-Place Outsloping Techniques

## Export outslope (EPOS)



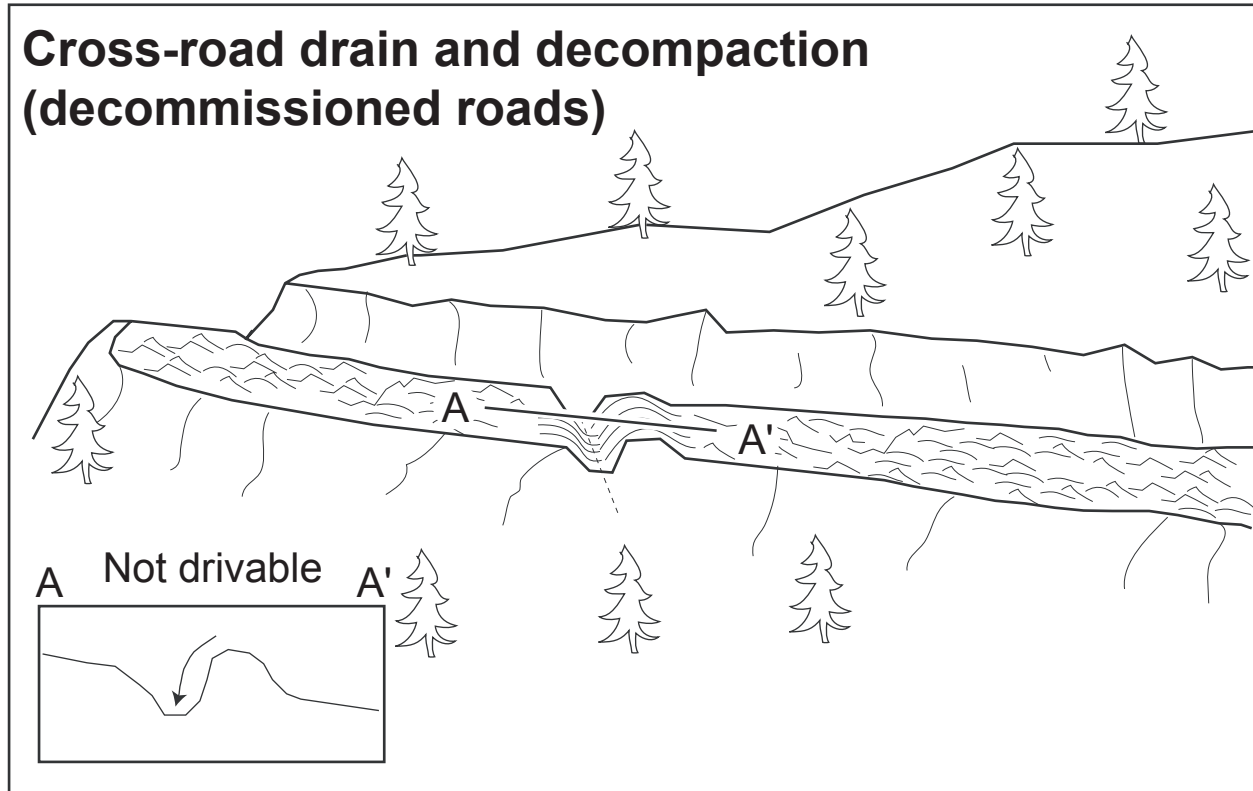
## In-place outslope (IPOS)



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## Cross-road drain and decompaction (decommissioned roads)



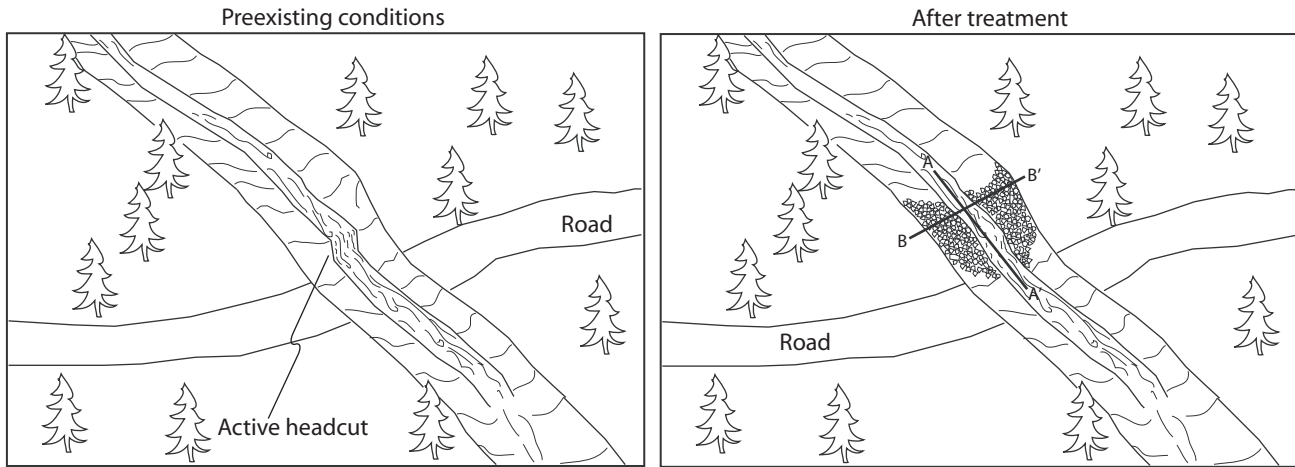
*Cross road drain* construction will ensure gullies, springs, road runoff and other concentrated flow will no longer collect over long lengths of road causing gully erosion and sediment delivery to streams. Cross road drains will be constructed at approximately 75 ft spacing intervals and these cross road drains will direct road surface runoff off the road onto stable hillslope locations.

*Ripping* the road surface 16 to 24 inches deep will increase road surface infiltration rates, decompact the road surface, and prevent concentrated runoff. Road ripping will also pulverize the compacted road surface or hardpan and allow for vegetation to establish and recover naturally.

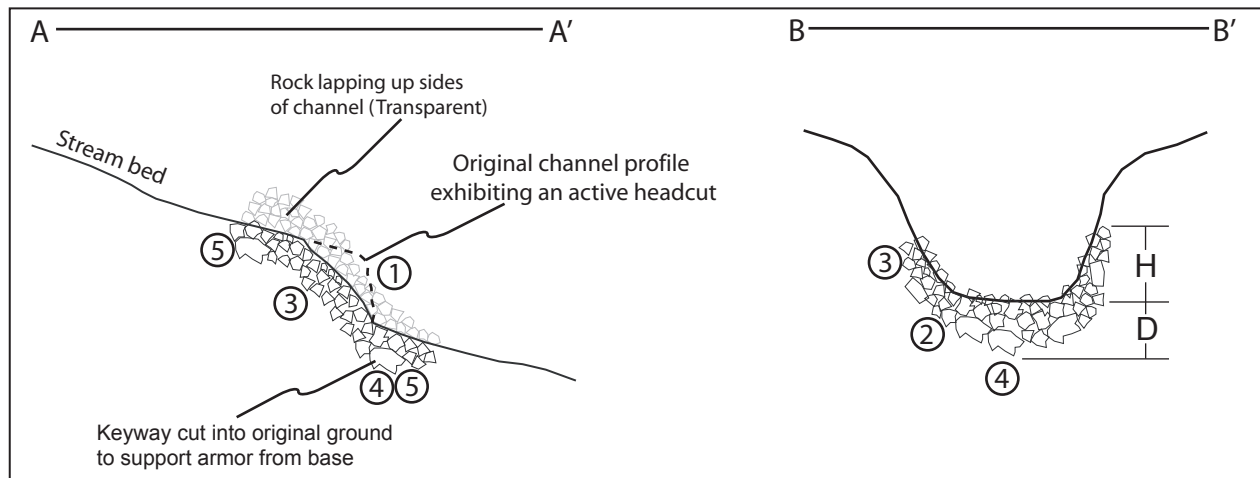
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# Typical Rock Grade Control Structure Installation at man-made headcuts/knickpoints in a non-fish bearing stream channel



## Cross section parallel and perpendicular to watercourse



## Notes

The main objective is to create a structure that will not be flanked, undercut, or eroded by the stream.

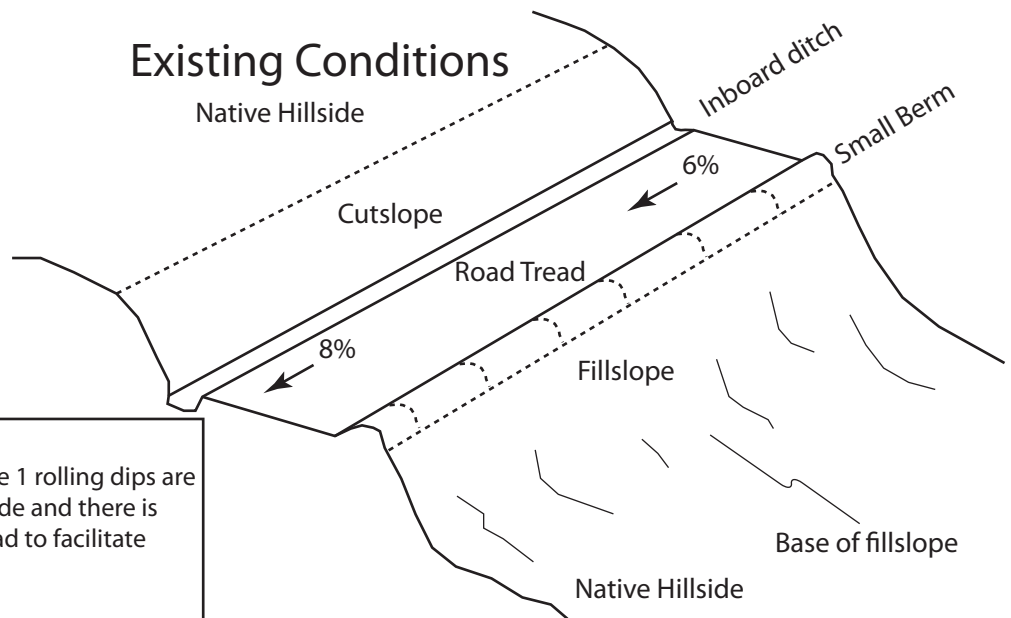
The critical elements of a successful grade control structure are:

- 1) Excavating the headcut to a gentler channel gradient over a distance of stream  
(See road log for details)
- 2) rock selection- rock should be selected that is resistant to transport during design flows, and has a bell shaped distribution of sizes with the median diameter equivalent to the D50 particle size of the stream at the site of installation (See road log for range of rock diameters).
- 3) The rock must be placed in a "U" shape that will contain the 100 yr. return interval stream flow, won't constrict the channel cross sectional area, and be flush with the streambed and not deflect flow.
- 4) The rock must be imbedded into the channel at least two rock diameters in thickness.
- 5) The largest rock should be used at the base and top of the grade control structure to buttress the other rock

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# Standard (Type 1) Rolling Dip Construction



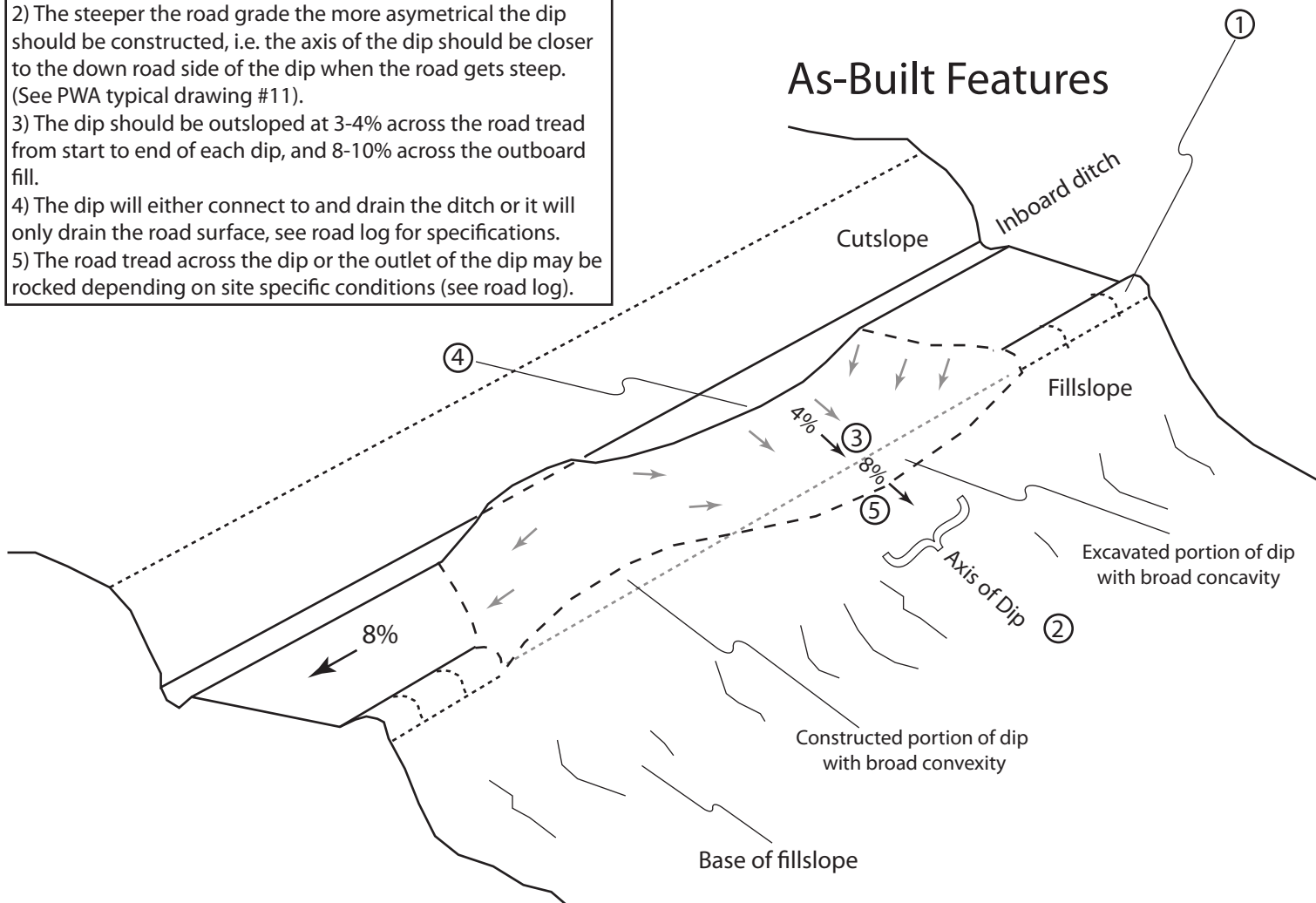
## Notes

**Rolling dip type 1 existing conditions:** Type 1 rolling dips are utilized when roads are less than 12-14% grade and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

### Design Notes:

- 1) The berm should be removed for the entire length of the dip.
- 2) The steeper the road grade the more asymmetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
- 3) The dip should be outsloped at 3-4% across the road tread from start to end of each dip, and 8-10% across the outboard fill.
- 4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
- 5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

## As-Built Features



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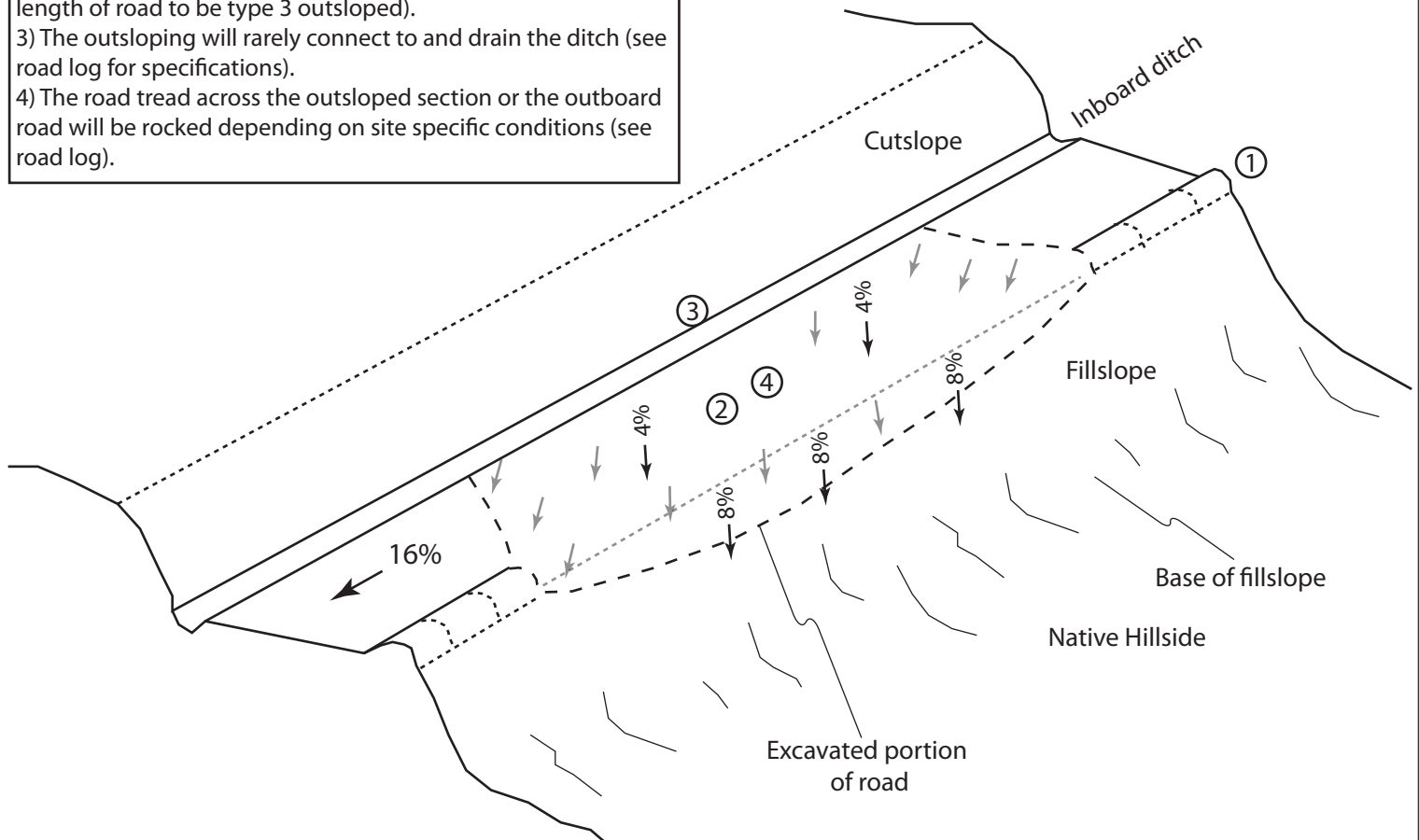
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**Existing Conditions**

The diagram illustrates the existing conditions of a road cross-section. It shows a road with a 16% grade, indicated by an arrow and the text "16%". The road structure includes a "Road Tread" and a "Cutslope" on the left side. On the right side, there is a "Fillslope" and a "Small Berm". The road is situated between two "Native Hillside" areas. An "Inboard ditch" is shown on the right side of the road. The "Base of fillslope" is also indicated.

- 1) The berm should be removed for the entire length of the outsloped section.
- 2) The dip should be outsloped at 2-4% across the road tread and 4-8% across the outboard fill. (The road log will specify the length of road to be type 3 outsloped).
- 3) The outsloping will rarely connect to and drain the ditch (see road log for specifications).
- 4) The road tread across the outsloped section or the outboard road will be rocked depending on site specific conditions (see road log).



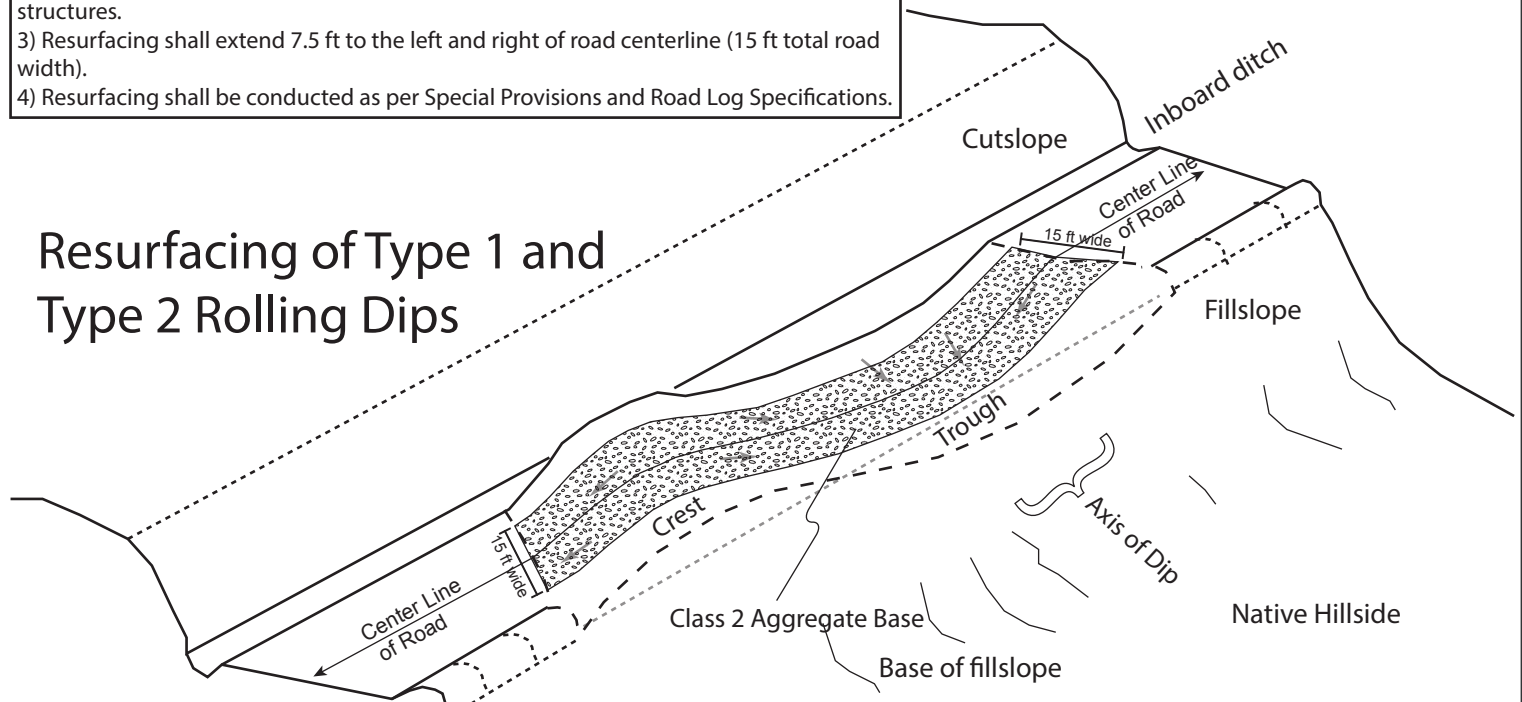
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# Resurfacing after Dip Construction

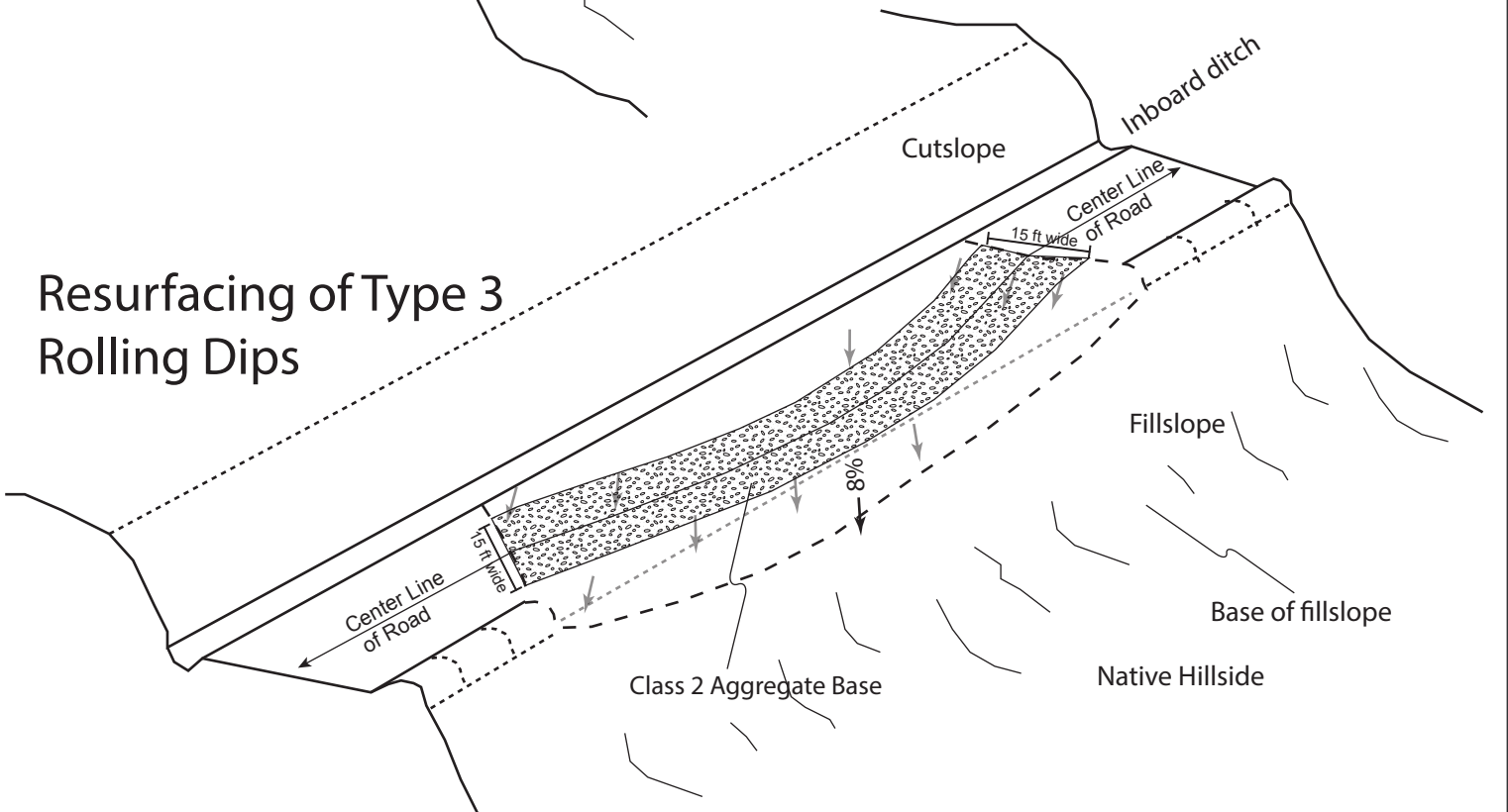
## Notes

- 1) Road travelway areas disturbed by rolling dip construction shall be resurfaced with Class 2 Aggregate Base, as per Special Provisions.
- 2) Resurfacing shall extend through rolling dip excavated trough and constructed crest structures.
- 3) Resurfacing shall extend 7.5 ft to the left and right of road centerline (15 ft total road width).
- 4) Resurfacing shall be conducted as per Special Provisions and Road Log Specifications.

## Resurfacing of Type 1 and Type 2 Rolling Dips



## Resurfacing of Type 3 Rolling Dips

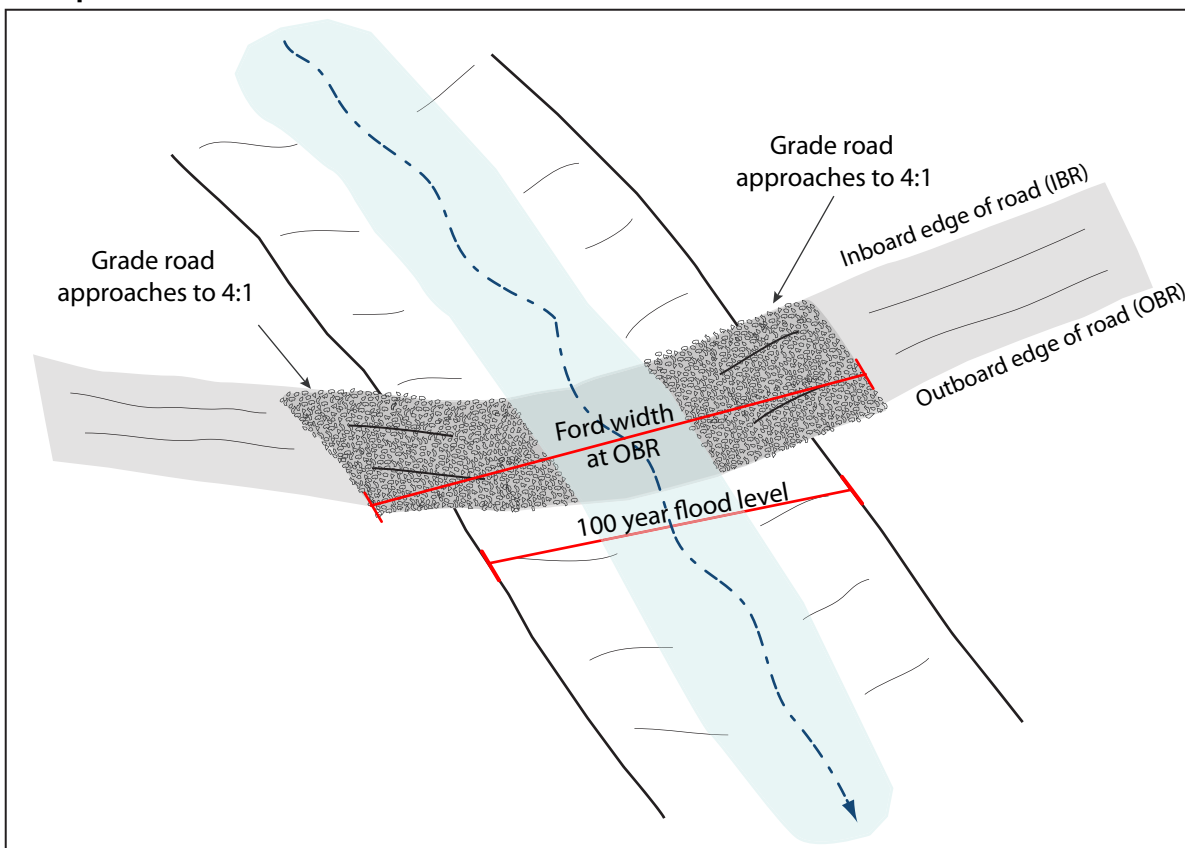


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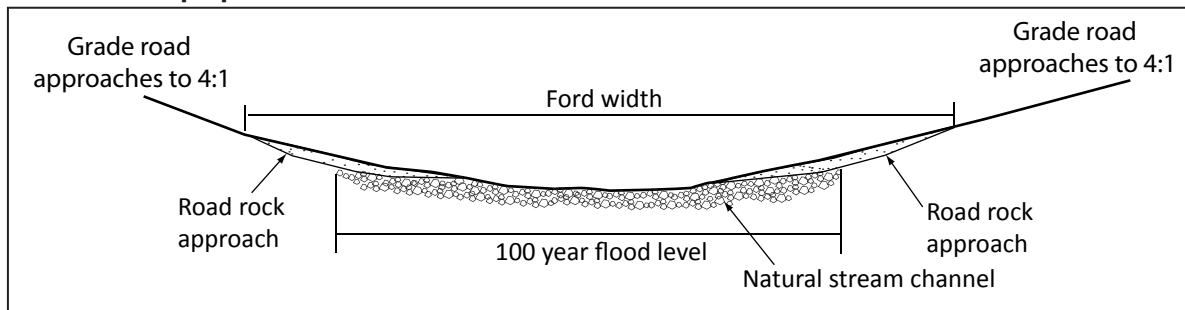
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# Typical Ford Crossing Installation

**Oblique view**



**Cross-section perpendicular to watercourse**



## **Steps for ford crossing construction:**

1. Remove any existing structures (culverts, logs, large boulders, etc.)
2. Remove all road fill as you dip through the crossing to reach natural stream channel.
3. Establish a "U" shape across the channel at the width specified in the road logs.
4. Grade road approaches to specified slope angle (e.g., 4:1). Approaches may or may not be rocked; follow specifications in the road logs.

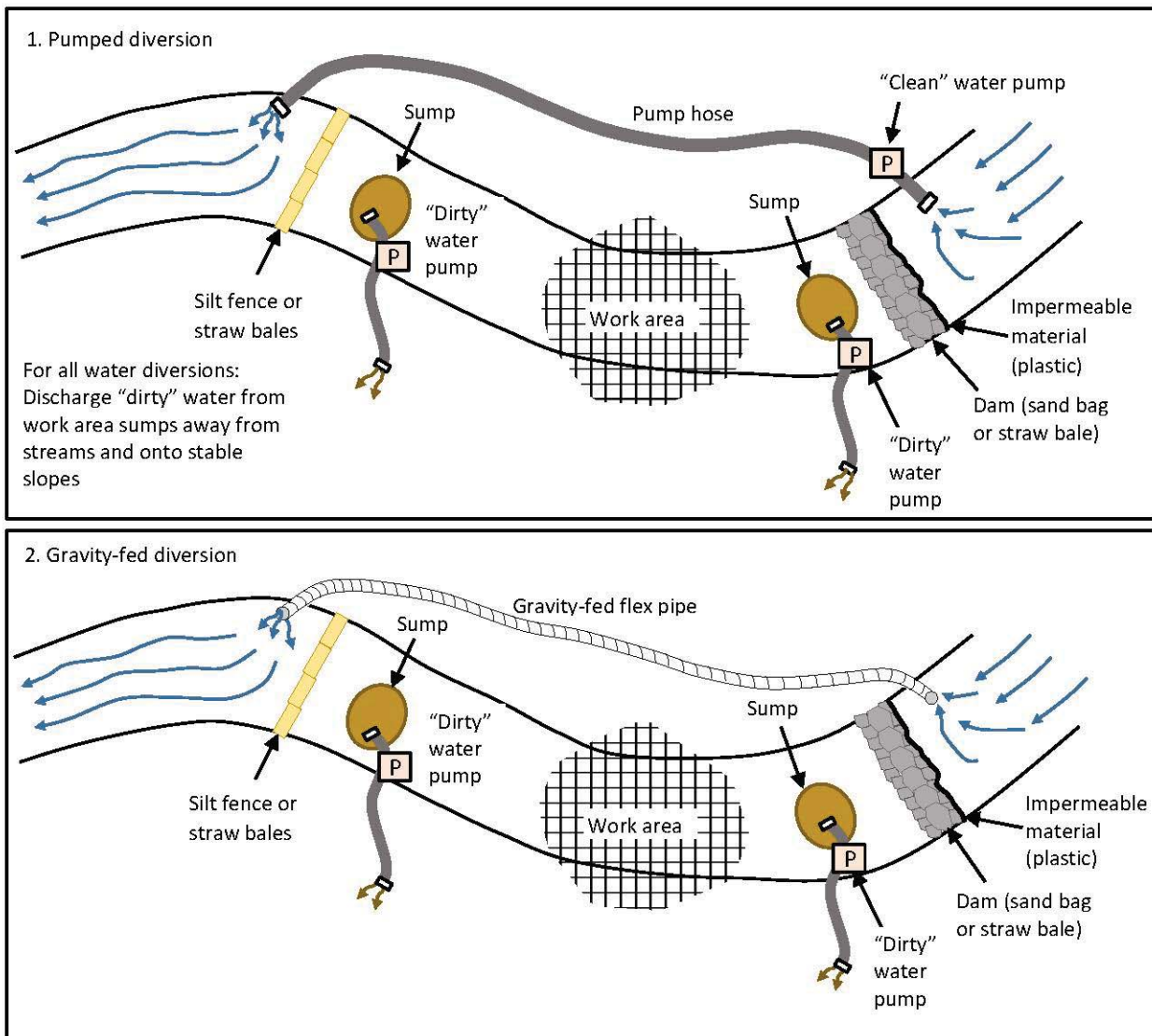
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**Typical Drawing #20**



## Typical Design for De-watering Streams



### Stream crossing de-watering

Prior to working in and around the active stream channel, proper stream dewatering and avoidance of increasing downstream turbidity should be employed. Stream flows will be isolated upstream of the work area using cofferdams and transported downstream / around the work site through either a pumped diversion (Type 1) or by gravity diversion (Type 2) to keep the stream "live" (flowing) below the work area. An additional dam will be installed downstream of the work areas to capture any subsurface flow that might travel through the construction area. Any "dirty" water will be collected at this location and pumped away from the site where it can infiltrate into the ground without the potential of delivery to the stream and/or be used to wet fill being deposited in the spoil disposal areas.

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## **Appendix E**

### **Representative photographs of existing conditions**

Stenner Creek Erosion Control and Sediment Reduction Plan,  
California Polytechnic State University,  
San Luis Obispo County, California

Table E1. Representative photos of existing site conditions, <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>			
Photo #	Site #	Site Type	Road/Trail Name
1	193	Stream crossing	Architectural Canyon Complex Road
2	193		
3	194	Stream crossing	
4	194		
5	195	Stream crossing	
6	195		
7	195.1	Stream crossing	Powerline Road
8	195.1		
9	195.2	Landslide	
10	195.2		
11	195.3	Road surface discharge point	
12	195.3		
13	196	Stream crossing	Barn Road
14	196		
15	197	Ditch relief culvert	
16	197		
17	197.1	Stream crossing	
18	197.1		
19	198	Ditch relief culvert	
20	198		
21	198.1	Ditch relief culvert	
22	198.1		
23	199	Stream crossing	
24	199		
25	200	Ditch relief culvert	
26	200		
27	201	Ditch relief culvert	Peterson Ranch Road
28	201		
29	202	Stream crossing	Upper Stenner Spur
30	202		
31	203	Stream crossing	
32	203		
33	204	Stream crossing	
34	204		
35	205	Stream crossing	Peterson Ranch Road
36	205		
37	206	Stream crossing	
38	206		
39	207	Road surface discharge point	
40	207		
41	208	Stream crossing	
42	208		

Table E1. Representative photos of existing site conditions, <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>			
Photo #	Site #	Site Type	Road/Trail Name
43	209	Stream crossing	Peterson Ranch Road
44	209		
45	210	Stream crossing	
46	210		
47	211	Stream crossing	
48	211		
49	212	Stream crossing	
50	212		
51	213	Stream crossing	
52	213		
53	214	Stream crossing	
54	214		
55	215	Road surface discharge point	
56	215		
57	216	Stream crossing	
58	216		
59	217	Stream crossing	
60	217		
61	217.1	Road surface discharge point	
62	217.1		
63	218	Stream crossing	
64	218		
65	219	Ditch relief culvert	
66	219		
67	220	Stream crossing	
68	220		
69	221	Stream crossing	
70	221		
71	222	Stream crossing	
72	222		
73	223	Stream crossing	
74	223		
75	224	Stream crossing	
76	224		
77	225	Ditch relief culvert	Peterson Ranch Loop
78	225		
79	226	Road surface discharge point	Peterson Loop Spur
80	226		
81	227	Stream crossing	Peterson Ranch Road
82	227		
83	227.1	Ditch relief culvert	Peterson Ranch Road
84	227.1		

Table E1. Representative photos of existing site conditions, <i>Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California</i>			
Photo #	Site #	Site Type	Road/Trail Name
85	228	Stream crossing	
86	228		
87	229	Stream crossing	
88	229		
89	230	Stream crossing	Poly Canyon Road
90	230		
91	230		
92	230		
93	231	Ditch relief culvert	
94	232	Ditch relief culvert	
95	232.1	Landslide	
96	232.1		
97	234	Ditch relief culvert	
98	234		
99	235	Road surface discharge point	Stenner Creek Road
100	235		
101	236	Stream crossing	
102	236		
103	237	Ditch relief culvert	
104	237		
105	238	Ditch relief culvert	
106	238		
107	238.1	Ditch relief culvert	
108	238.1		
109	410	Stream crossing	Yewks Trail
110	410		
111	411	Stream crossing	
112	411		
113	412	Stream crossing	
114	412		
115	413	Stream crossing	
116	413		
117	414.1	Stream crossing	
118	414.1		
119	414.2	Stream crossing	
120	414.2		
121	415	Stream crossing	Elevator Trail
122	415		Elevator Trail
123	416		
124	416		
125	417		
126	417		



**Photo 1.** Site 193 (Architectural Canyon Complex Rd.): View of Site 193 looking downstream. This plugged and undersized culvert inlet is visible in the center and the road crossing is in the top of the frame.



**Photo 2.** Site 193 (Architectural Canyon Complex Rd.): View of Site 193 looking upstream. The plugged culvert outlet is visible in the center, the road crossing, and road gravel discharge load are in top of the frame.





**Photo 3.** Site 194 (Architectural Canyon Complex Rd.): Looking up the left trail at road surface discharge point adjacent to stream crossing Site 194. Concrete bridge is visible in the right edge of the frame. No proposed work at the bridge, trail only.



**Photo 4.** Site 194 Architectural Canyon Complex Rd.): View of Site 194 looking upstream where road surface drainage delivers directly to this location. No proposed work at bridge, trail only.





**Photo 5.** Site 195 (Architectural Canyon Complex Rd.): View of Site 195 looking obliquely at the stream crossing. The undersized culvert inlet is plugged with organic matter at the center of the frame (see arrow). Partial view of right approach.



**Photo 6.** Site 195 (Architectural Canyon Complex Rd.): View of Site 195 looking downstream. The culvert is plugged with detritus at the center of the frame (see arrow). The road crossing is visible at the top of the frame. The stream flows from right to left.





**Photo 7.** Site 195.1 (Powerline Rd.): View of Site 195.1 looking upstream at the armored fill crossing. Visible in the center of the frame is a headcut that is migrating up towards the outboard road edge.



**Photo 8.** Site 195.1 (Powerline Rd.): View of Site 195.1 looking down the right road approach towards the stream crossing. The proximity of the headcut to the road is visible in the upper right frame. The left road approach is visible in the upper left corner of the photo.





**Photo 9.** Site 195.2 (Powerline Rd.): View of Site 195.2 looking up the road at an unstable road fillslope. This section of road is located at the headwaters of a Class III stream. The steep fillslope is saturated and has the potential for failure.



**Photo 10.** Site 195.2 (Powerline Rd.): View of Site 195.2 looking at the outboard edge of the fillslope. This area has erodible soils and is saturated from emergent springs. The steep fillslope should be monitored for potential failure.





**Photo 11.** Site 195.3 (Powerline Rd.): View of Site 195.3 looking up at the road surface discharge point and subsequent gully (see arrow). Nearly 450' of road and hillslope runoff exit the road at this location.



**Photo 12.** Site 195.3 (Powerline Rd.): View of Site 195.3 looking down the left road towards the road surface discharge point. The discharge point and subsequent gully are visible in the upper left corner of the frame (see arrow).





**Photo 13.** Site 196 (Barn Rd.): View of Site 196 looking upstream. The outboard fill of this ford crossing is buttressed with solidified sacks of concrete. An erosional gully has formed below the outboard edge.



**Photo 14.** Site 196 (Barn Rd.): View of Site 196 looking downstream at the ford crossing. The right and left road approach are visible in the center of the frame.





**Photo 15.** Site 197 (Barn Rd.): View of Site 197 looking obliquely at ditch relief culvert outlet. The culvert outlet is at the center of the frame and is approximately 90% plugged with organic matter (see arrow). The stream flows from right to left.



**Photo 16.** Site 197 (Barn Rd.): View of Site 197 standing upslope of the ditch relief culvert inlet area. The culvert inlet is visible to the right of the worker's feet and is approximately 25% plugged (see arrow).





**Photo 17.** Site 197.1 (Barn Rd.): View of Site 197.1 looking downstream. The culvert inlet is plugged in this location and not easily discernible (see arrow). The road crossing is visible in the top of the frame.



**Photo 18.** Site 197.1 (Barn Rd.): View of Site 197.1 looking upslope towards culvert outlet. The road crossing is visible in the upper frame and the culvert outlet is protruding from the riprap in the center of the frame.





**Photo 19.** Site 198 (Barn Rd.): View of the ditch relief culvert inlet area at Site 198. A short rock wall encases the culvert in this location. The culvert inlet is mostly plugged with sediment.



**Photo 20.** Site 198 (Barn Rd.): View of the ditch relief culvert outlet area at Site 198. The culvert outlet is approximately 50% plugged with sediment.





**Photo 21.** Site 198.1 (Barn Rd.): View of Site 198.1 looking downslope at the ditch relief culvert inlet area. The culvert inlet is approximately 50% plugged with sediment.



**Photo 22.** Site 198.1 (Barn Rd.): View of Site 198.1 looking obliquely/upslope at the ditch relief culvert outlet. The culvert outlet is visible in the middle of the frame and the road is above. Site 199 culvert inlet is located on the left.





**Photo 23.** Site 199 (Barn Rd.): View of the Site 199 Looking downstream towards the culvert inlet area. The crossing is present in the top of the frame. This culvert flows to mainstem Stenner Creek. Site 198.1 is in the right of the frame.



**Photo 24.** Site 199 (Barn Rd.): View of the Site 199 looking upstream at the culvert outlet area. The culvert outlet is visible in the center of the photo.





**Photo 25.** Site 200 (Barn Rd.): View of Site 200 ditch relief culvert inlet area. This culvert inlet is approximately 30% plugged due to the long, wide, and grassy swale that feeds this location.



**Photo 26.** Site 200 (Barn Rd.): View of Site 200 ditch relief culvert outlet area. Looking upslope, the outlet is present in the center of the photo and is approximately 30% plugged.





**Photo 27.** Site 201 (Peterson Ranch Rd.): View of Site 201 looking down left road towards mainstem Stenner Creek. This road approach leads to Site 201 which outlets directly into Stenner Creek. Road erosion is visible in the bottom of the frame.



**Photo 28.** Site 201 (Peterson Ranch Rd.): View of Site 201 looking towards mainstem Stenner Creek. The plugged and undersized ditch relief culvert inlet is in the upper center frame.





**Photo 29.** Site 202 (Upper Stenner Spur): View of Site 202 looking obliquely at the stream crossing. The outboard fill riprap has dislodged in this location and a gully is migrating into the trail.



**Photo 30.** Site 202 (Upper Stenner Spur): View of Site 202 looking down the left trail. Erosion is visible in the center of the frame. The stream flows from left to right.





**Photo 31.** Site 203 (Upper Stenner Spur): View of Site 203 looking downstream. This crossing is mostly washed out and would need major improvements to be made usable again.



**Photo 32.** Site 203 (Upper Stenner Spur): View of Site 203 looking obliquely at stream crossing. This portion of the trail is heavily overgrown and not currently usable.





**Photo 33.** Site 204 (Upper Stenner Spur): View of Site 204 looking obliquely at stream crossing. This portion of the trail is heavily overgrown and not currently usable.



**Photo 34.** Site 204 (Upper Stenner Spur): View of Site 203 looking downstream. This area has been neglected for some time and needs major improvements to be made usable.





**Photo 35.** Site 205 (Peterson Ranch Rd.): View of Site 205 looking downstream. The undersized culvert inlet is 90% plugged at the center of the frame. The inboard fillslope is visible beginning at the fence line.



**Photo 36.** Site 205 (Peterson Ranch Rd.): View of Site 205 looking upstream. The culvert outlet is plugged with silt and is overgrown with vegetation. The outboard edge of the road fill is visible in center of the frame.





**Photo 37.** Site 206 (Peterson Ranch Rd.): View of Site 206 looking downstream at the culvert inlet area. The inboard fill area has been shored up by old railroad ties and concrete.



**Photo 38.** Site 206 (Peterson Ranch Rd.): View of Site 206 looking up left road and obliquely at stream crossing. Evidence of sediment discharge from road erosion is visible along the outboard edge of the road in the center of the frame.





**Photo 39.** Site 207 (Peterson Ranch Rd.): View of Site 207 looking up at the road surface discharge point from the Class II stream. The discharge point is in the upper right corner of the frame and has created the 15' wide x 25' long erosional gully.



**Photo 40.** Site 207 (Peterson Ranch Rd.): View of Site 207 looking down the right road towards the road surface discharge point and subsequent gully. Note that fine sediment generated from road surface erosion is being transported down road via a gully in the roadbed.





**Photo 41.** Site 208 (Peterson Ranch Rd.): View of Site 208 looking upstream at the culvert outlet area. Fine sediment generated from road surface erosion is visible below and to the left of the culvert outlet. The culvert is adequately sized but vertical fillslopes are eroding and unstable.



**Photo 42.** Site 208 (Peterson Ranch Rd.): View of Site 208 road approach looking down the right road approach with stream crossing located in the upper frame. Two gullies have formed on the road surface from excessive road drainage, which funnel sediment to the stream.





**Photo 43.** Site 209 (Peterson Ranch Rd.): View of Site 209 looking obliquely at the undersized stream crossing (see arrow). The right road is visible in the uppermost right frame. The stream flows from right to left.



**Photo 44.** Site 209 (Peterson Ranch Rd.): View of Site 209 looking obliquely/upstream. The culvert outlet area is visible in the center of the frame (see arrow) and the inlet area is visible in the upper left corner. The stream flows from left to right.





**Photo 45.** Site 210 (Peterson Ranch Rd.): View of Site 210 looking upstream at the undersized culvert outlet. Concrete blocks and eroding fill are visible in the center of the frame. Upper channel area is visible in the top of frame.



**Photo 46.** Site 210 (Peterson Ranch Rd.): View of Site 210 looking downstream at the undersized culvert inlet. The stream overtops the road crossing, visible in the top frame, during peak events.





**Photo 47.** Site 211 (Peterson Ranch Rd.): View of Site 211 looking up the right road and obliquely at the stream crossing. The culvert inlet area is visible in the right frame (see arrow).



**Photo 48.** Site 211 (Peterson Ranch Rd.): View of Site 211 looking up the left road and obliquely at the stream crossing. The culvert inlet area is visible in the upper left frame (see arrow) and the culvert outlet area is visible in the upper right frame.





**Photo 49.** Site 212 (Peterson Ranch Rd.): View of Site 212 looking down/obliquely at the stream crossing. The road crossing is visible in the top frame (see arrow) as is the left road.



**Photo 50.** Site 212 (Peterson Ranch Rd.): View of Site 212 looking up/obliquely at the stream crossing. The road crossing is visible in the center of the frame. The upper stream channel is visible in the upper frame.





**Photo 51.** Site 213 (Peterson Ranch Rd.): View of Site 213 looking obliquely at the undersized stream crossing. The culvert outlet area is visible in the right frame located to the right of the ATV. The stream flows from left to right.



**Photo 52.** Site 213 (Peterson Ranch Rd.): View of Site 213 looking downstream. The culvert inlet area and aggraded sediment is visible in the middle frame. Both road approaches contribute fine sediment runoff directly to site.





**Photo 53.** Site 214 (Peterson Ranch Rd.): View of Site 214 looking downstream. The undersized culvert inlet area is visible in the top center of the frame. The Right and left road approaches funnel fine sediment to the site each winter.



**Photo 54.** Site 214 (Peterson Ranch Rd.): View of Site 214 looking upstream. The culvert outlet is visible in the center of the frame.





**Photo 55.** Site 215 (Peterson Ranch Rd.): View of Site 215 looking towards the discharge point and the headwaters area of a Class III stream (see arrow). Concentrated road and hillslope runoff exits the road at this location.



**Photo 56.** Site 215 (Peterson Ranch Rd.): View of Site 215 looking upslope at the road surface discharge point. The contributing swale is visible in the top of the frame (see arrow).





**Photo 57.** Site 216 (Peterson Ranch Rd.): View of Site 216 looking upstream at the culvert outlet. Erosion is visible on the outboard fillslope and at the base of the culvert due to culvert being installed high in the fill.



**Photo 58.** Site 216 (Peterson Ranch Rd.): View of Site 216 looking downstream at the culvert inlet area. The right road is funneling fine sediment directly to stream crossing each winter and the left road carries diverted stream when culvert plugs.





**Photo 59.** Site 217 (Peterson Ranch Rd.): View of Site 217 looking upstream at the culvert outlet. The upper stream channel is visible in the top of the frame.



**Photo 60.** Site 217 (Peterson Ranch Rd.): View of Site 217 looking downstream at the culvert inlet. A secondary stream running parallel to the road crossing is visible in the uppermost portion of the frame as well (see arrow).





**Photo 61.** Site 217.1 (Peterson Ranch Rd.): View of Site 217.1 looking down towards the discharge point. The discharge point area is visible in the upper middle portion of the frame (see arrow).



**Photo 62.** Site 217.1 (Peterson Ranch Rd.): View of Site 217.1 looking up at the discharge point (see arrow). The road discharge point is visible in the center of the frame and the road is visible in the center top portion of the frame.





**Photo 63.** Site 218 (Peterson Ranch Rd.): View of Site 218 looking downstream at the culvert inlet. The road crossing is visible in the top of the frame.



**Photo 64.** Site 218 (Peterson Ranch Rd.): View of Site 218 looking upstream at the culvert outlet. Some concrete block fill is visible in the center of the frame.





**Photo 65.** Site 219 (Peterson Ranch Rd.): View of Site 219 looking upstream at culvert outlet area. The plugged culvert is visible in the center of the frame.



**Photo 66.** Site 219 (Peterson Ranch Rd.): View of Site 219 looking downstream at the culvert inlet. The road crossing and mainstem Brizzolari Creek are visible at the top of the frame (see arrow).





**Photo 67.** Site 220 (Peterson Ranch Rd.): View of Site 220 looking downstream towards culvert inlet. This undersized culvert is prone to plugging during storm events and discharges directly in Brizziolari Creek.



**Photo 68.** Site 220 (Peterson Ranch Rd.): View of Site 220 looking upstream at the culvert outlet area. Fine sediment from a recent storm is visible on the bottom of the corrugated plastic pipe.





**Photo 69.** Site 221 (Peterson Ranch Rd.): View of Site 221 looking downstream towards the culvert inlet (see arrow). This undersized culvert is prone to plugging during wet weather events. This culvert discharges directly into Brizziolari Creek.



**Photo 70.** Site 221 (Peterson Ranch Rd.): View of Site 221 looking upstream at the culvert outlet area. This section of road runs adjacent to mainstem Brizziolari Creek and frequently becomes inundated during wet weather events.





**Photo 71.** Site 222 (Peterson Ranch Rd.): View of Site 222 looking downstream. Mainstem Brizzolari Creek makes a 90 degree turn at this location, and concrete has been poured on the right bank in an attempt to buttress the slope from erosion.



**Photo 72.** Site 222 (Peterson Ranch Rd.): View of Site 222 looking upstream at the drastically undersized culvert outlet. The road crossing is visible in the top of the frame. Gravel washed into stream can be seen in the center of the frame.





**Photo 73.** Site 223 (Peterson Ranch Rd.): View of Site 223 looking downstream at the culvert inlet. Mainstem Brizziolari Creek is located parallel to the road crossing at the top of the frame.



**Photo 74.** Site 223 (Peterson Ranch Rd.): View of Site 223 looking upstream at the culvert outlet. The outlet and the road crossing are visible in the top of the frame (see arrow) while erosion is visible in the center of the frame.





**Photo 75.** Site 224 (Peterson Ranch Rd.): View of Site 224 looking downstream at the culvert inlet. This culvert is undersized and visible in the center of the frame.



**Photo 76.** Site 224 (Peterson Ranch Rd.): View of Site 224 looking upstream at the culvert outlet area. This 18" culvert is undersized for this location and is recommended to be upgraded to a 36" culvert.





**Photo 77.** Site 225 (Peterson Ranch Rd.): View of Site 225 looking down road towards mainstem Brizziolari Creek. A plugged ditch relief culvert inlet is visible in the upper lefthand side of the frame (see arrow).



**Photo 78.** Site 225 (Peterson Ranch Rd.): View of Site 225 looking upslope towards the culvert outlet area (see arrow). The gully that has formed as a result of the culvert discharge is visible in the center left of the frame.





**Photo 79.** Site 226 (Peterson loop Spur) View of Site 226 looking towards outboard edge of fill. The fill in this location is failing and collapsing into the headwall of the succeeding swale.



**Photo 80.** Site 226 (Peterson Loop Spur): View of Site 226 looking up the right road and outboard fill edge. The failing fill edge is visible in the upper half of the frame.





**Photo 81.** Site 227 (Peterson Ranch Rd.): View of Site 227 looking upstream at the culvert outlet. The outboard fill area is visible at the top of the frame and the upper stream channel is visible in the uppermost portion of the frame.



**Photo 82.** Site 227 (Peterson Ranch Rd.): View of Site 227 looking downstream at the culvert inlet area (see arrow). This 30" culvert is undersized and is recommended to be upgraded to a 36" corrugated metal culvert.





**Photo 83.** Site 227.1 (Peterson Ranch Rd.): View of Site 227.1 plugged ditch relief culvert inlet (see arrow) looking towards mainstem Brizziolari Creek. The road crossing is also visible in the top of the frame.



**Photo 84.** Site 227.1 (Peterson Ranch Rd.): View of Site 227.1 looking at the plugged ditch relief culvert outlet (see outlet). The road crossing is visible at the center of the frame and the swale leading to the culvert is present at the top of the frame.





**Photo 85.** Site 228 (Peterson Ranch Rd.): View of Site 228 looking downstream towards mainstem Brizziolari Creek. The current alignment is visible on the right while the proposed stream channel restoration is in the left frame (see arrows).



**Photo 86.** Site 228 (Peterson Ranch Rd.): View of Site 228 looking obliquely at the current stream channel. The double culvert inlet is visible in the lower right frame. The proposed stream channel is visible in the upper left frame (see arrow).





**Photo 87.** Site 229 (Peterson Ranch Rd.): View of Site 229 looking downstream towards the double culvert inlets that are plugged with detritus. The road crossing is visible at the top of the frame.



**Photo 88.** Site 229 (Peterson Ranch Rd.): View of Site 229 culvert outlet area looking upstream. The culverts are not plugged at the outlets but there is evident erosion at the base of the culverts from undercutting.





**Photo 89.** Site 230 (Poly Canyon Rd.): View of Site 230 culvert inlet and road crossing. Looking downstream at mainstem Brizziolari Creek. This culvert is not aligned properly with the stream channel.



**Photo 90.** Site 230 (Poly Canyon Rd.): View of Site 230 culvert inlet. Looking downstream, notice the rusted-out bottom of the culvert and the washed-out trash rack.





**Photo 91.** Site 230 (Poly Canyon Rd.): View of Site 230 culvert outlet and road crossing. Looking upstream at mainstem Brizziolari Creek, notice the pool of water at culvert outlet and the erosion on the left side of the frame.



**Photo 92.** Site 230 (Poly Canyon Rd.): View of Site 230 culvert outlet, road crossing, and downstream channel of mainstem Brizziolari Creek.





**Photo 93.** Site 231 (Poly Canyon Rd.): View of Site 231 ditch relief culvert inlet area. The inlet of the culvert has been embedded in a short concrete wall. Site 230.1 diverts to this location along the right road (upper frame).



**Photo 94.** Site 232 (Poly Canyon Rd.): View of site 232 ditch relief culvert outlet area. Looking upslope, the culvert outlet is protruding from a crib wall built of eucalyptus branches at the top-center of the frame.





**Photo 95.** Site 232.1 (Poly Canyon Rd.): View of Site 232.1 looking southwest. Site 232.1 is located above mainstem Brizziolari Creek. Tension cracks in the road indicate a potential road fill failure.



**Photo 96.** Site 232.1 (Poly Canyon Rd.): View of Site 232.1 looking northeast at tension cracks in road.





**Photo 97.** Site 234 (Poly Canyon Rd.): View of Site 234 ditch relief culvert outlet area. A gully extends from the culvert outlet towards the left side of the frame.

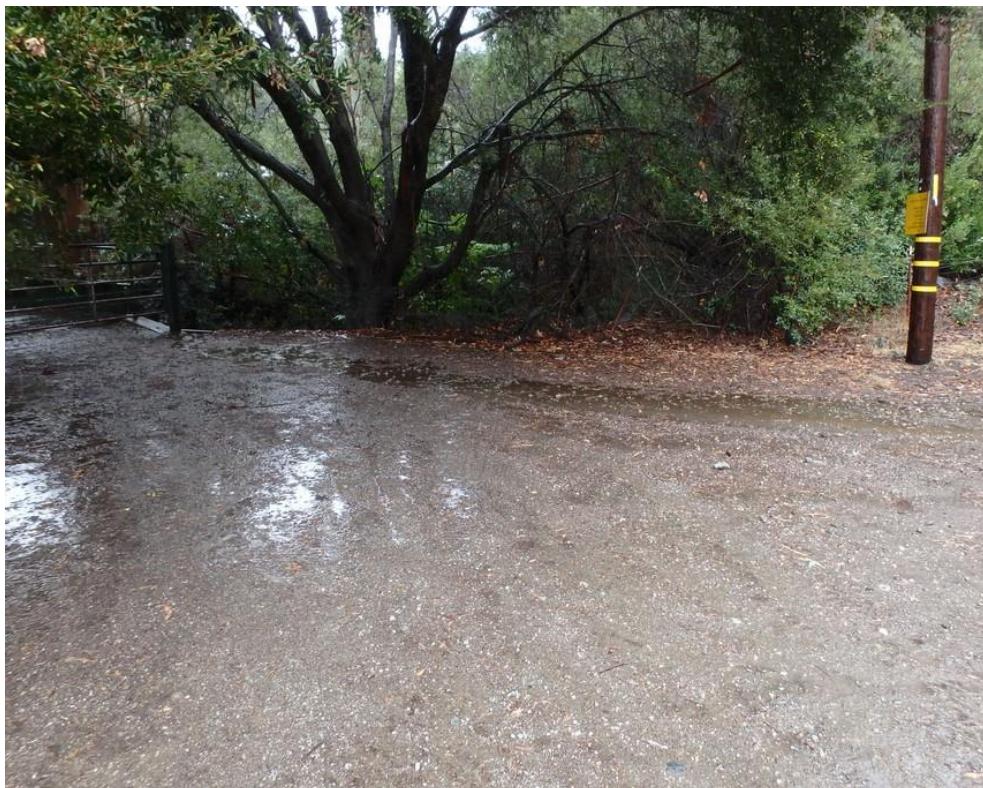


**Photo 98.** Site 234: View of Site 234 ditch relief culvert inlet area (see arrow).





**Photo 99.** Site 235 (Stenner Creek Rd.): View of Site 235 looking obliquely at the stream crossing. This heavy-duty steel and concrete bridge spans mainstem Stenner Creek. Fifty feet of left road approach discharges to this location.



**Photo 100.** Site 235 (Stenner Creek Rd.): View of Site 235 looking upstream of mainstem Stenner Creek. The bridge is visible in the left frame.





**Photo 101.** Site 236 (Stenner Creek Rd.): View of Site 236 looking upstream at culvert outlet. Road crossing visible in upper frame.



**Photo 102.** Site 236 (Stenner Creek Rd.): View of Site 236 looking downstream at the culvert inlet. Mainstem Stenner Creek is located in the upper frame.





**Photo 103.** Site 237 (Stenner Creek Rd.): View of Site 237 looking down the right road. Muddy water is visibly ponding and draining into the inlet with concrete headwall in the center of the frame. Mainstem Stenner Creek is located to the left and runs parallel to the road.



**Photo 104.** Site 237 (Stenner Creek Rd.): View of Site 237 looking obliquely at the culvert inlet with concrete headwall. The culvert discharges approximately 15' above mainstem Stenner Creek, which is in the upper frame.





**Photo 105.** Site 238 (Stenner Creek Rd.): View of Site 238 gully erosion from concentrated road runoff from the ditch relief culvert outlet. Fine sediment and muddy water deliver to mainstem Stenner Creek at this location.



**Photo 106.** Site 238 (Stenner Creek Rd.): View of Site 238 looking at the ditch relief culvert inlet (see arrow). Muddy water is visibly running down the road and into the culvert. Mainstem Stenner Creek runs parallel to this road on the right side of the frame.





**Photo 107.** Site 238.1 (Stenner Creek Rd.): View of Site 238.1 looking towards Site 238 (see arrow). Evidence of poor road drainage is visible to the evidenced by presence of rilling from concentrated road runoff. Mainstem Stenner Creek runs parallel to this road on the right side of the frame.



**Photo 108.** Site 238.1 (Stenner Creek Rd.): View of Site 238.1 road approach, looking up road. The insloped road concentrates road and hillslope runoff to a stream crossing located just outside of Cal Poly property.





**Photo 109.** Site 410 (Yewks Trail): View of Site 410 looking obliquely at the stream crossing. The stream flows from right to left (see arrow).



**Photo 110.** Site 410 (Yewks Trail): View of Site 410 stream crossing looking obliquely at the stream crossing. The downstream gully can be seen in this photo migrating into the outboard edge of the trail.





**Photo 111.** Site 411(Yewks Trail): View of Site 411 ford crossing. Looking obliquely at the stream crossing.



**Photo 112.** Site 411 (Yewks Trail): View of Site 411 ford crossing. This stream channel is low in gradient and grassed over. Both right and left trail approaches contribute to this site.





**Photo 113.** Site 412 (Yewks Trail): View of Site 412 looking upstream towards the stream crossing. The stream channel is grassed over, and the outboard fillslope is armored with riprap.



**Photo 114.** Site 412 (Yewks Trail): View of Site 412 looking obliquely at the stream crossing. The stream flows from right to left. The upper channel is armored with riprap.





**Photo 115.** Site 413 (Yewks Trail): View of Site 413 stream crossing looking obliquely at the stream crossing. This stream crossing shows signs of wear from bicycle traffic.



**Photo 116.** Site 413 (Yewks Trail): View of Site 413 stream crossing looking obliquely at the stream crossing. The stream flows from right to left.





**Photo 117.** Site 414.1 (Yewks Trail): View of Site 414.1 ford crossing looking upstream. This Class III stream ford crossing has been reinforced with concrete blocks that are visible in the right of the frame.



**Photo 118.** Site 414.1 (Yewks Trail): View of Site 414.1 ford crossing looking downstream. This Class III stream ford crossing has been reinforced with concrete blocks.





**Photo 119.** Site 414.2 (Yewks Trail): View of Site 414.2 ford crossing looking obliquely at the crossing. Bicyclists and hikers have been navigating this Class II stream by lying down sticks to get across.



**Photo 120.** Site 414.2 (Yewks Trail): View of Site 414.2 ford crossing. Looking obliquely at the crossing the stream flows left to right. Site 414.1 is visible in the background (see arrow).





**Photo 121.** Site 415 (Elevator Trail): View of Site 415 ford crossing. Looking obliquely at the stream crossing the right road is visible in the upper right frame. 616' of right and 45' of left trail contribute to this site.



**Photo 122.** Site 415 (Elevator Trail): View of Site 415 ford crossing looking downstream.





**Photo 123.** Site 416 (Elevator Trail): View of Site 416 ford crossing looking downstream. The stream crossing is visible in the center of the frame.



**Photo 124.** Site 416 (Elevator Trail): View of Site 416 ford crossing. Looking upstream the stream crossing is visible in the center of the frame. 210' of right and 15' of left trail contribute to this site.





**Photo 125.** Site 417 (Elevator Trail): View of Site 417 ford crossing looking obliquely at the crossing. Multiple trail alignments have been developed along the right approach with up to 3 parallel alignments.



**Photo 126.** Site 417 (Elevator Trail): View of Site 417 ford crossing looking upstream. The stream crossing is visible in the center of the frame. 295' of right and 40' of left trail contribute to this site.