Final Summary Report

2001 S. B. 271 Road Assessment and Erosion Prevention Planning Project for the Dry Creek Watershed, Napa County, California

prepared for

Napa County Resource Conservation District
and
California Department of Fish and Game

by

***P**acific **W**atershed **A**ssociates*
Arcata, California
(707) 839-5130

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I. Background

Dry Creek is a 20 mi^2 third-order tributary to the Napa River located in the Mayacamas Range in Napa County (Figure 1). According to the USGS Napa, Yountville, and Rutherford 7.5' minute topographic quadrangle maps, the Dry Creek watershed contains approximately 50 miles of blue-line streams and tributaries, including 13 miles of the mainstem. Elevations in the watershed range between 60 feet at the confluence with the Napa River to 2,275 feet at the headwaters on Bald Mountain.

The majority of the Dry Creek watershed is privately owned and is composed of rural subdivision residences, vineyards and cattle ranches. A small proportion of the watershed consists of public open lands managed by the Bureau of Land Management, the Napa County Land Trust and the Napa Valley College. Vegetation in the Dry Creek watershed is dominated by annual grasses and oak woodlands in the headwaters and by Douglas Fir, redwoods and other hardwood species in the remaining portions of the watershed. The Dry Creek watershed has experienced several cycles of timber harvesting since the turn of 20^{th} century, with much of the timberlands being presently converted to residential property and vineyards (Napa RCD). This timberland conversion is expected to increase in the future.

The watershed contains a historic and existing network of unpaved logging roads, as well as an extensive county road network along the mainstem of Dry Creek, Campbell Creek and Montgomery Creek. Many of the maintained and abandoned roads are currently causing erosion and sedimentation to Dry Creek.

Dry Creek has value as a historic coho salmon and steelhead trout stream, although only steelhead trout have recently been found. In 1997, the National Marine Fisheries Service listed steelhead as a threatened species in Napa County. The California Department of Fish & Game.

Figure 1. Location map of the Dry Creek study area

(CDFG) identified Dry Creek as the primary steelhead spawning tributary in the Napa River watershed. In 1997, CDFG conducted a stream inventory on Dry Creek during the summer to document the current habitat conditions and recommend options for the potential enhancement of habitat for steelhead trout. Based on the results of the habitat inventory, Bob Coey (CDFG) made the preliminary recommendation that all sources of sediment to the stream channels be mapped and rated according to their sediment yields, and adequate erosion control measures taken.

Pacific Watershed Associates (PWA) was contracted by the Napa County Resource Conservation District (Napa RCD) to complete a sediment source assessment and prepare a prioritized erosion prevention plan for selected county roads and private subdivision roads as part of a comprehensive preliminary watershed assessment of the Dry Creek watershed. This project was funded by an S.B. 271 restoration grant administered by the California Department of Fish and Game (CDFG). The PWA sediment source assessment is specifically aimed at identifying future erosion sources that are impacting, or could impact, fish bearing streams and to develop prescriptions aimed at reducing sediment input to the watershed.

II. Dry Creek Watershed Assessment

Perhaps the most important elements needed for long term restoration of salmon habitat, and the eventual recovery of salmonid populations is the reduction of accelerated erosion and sediment delivery to the stream channel system.. The latter is a very complex problem influenced by tectonic activity, geology, watershed erosion rates and land management activities in the watershed, among other factors. The geology of the Dry Creek watershed is composed primarily of Jurassic and Cretaceous sedimentary rocks of the Great Valley sequence. The underlying geology in combination with numerous faults within the Dry Creek watershed, including the St. John thrust fault, result in a tectonically unstable environment that is prone to erosion. There are few large Quaternary deep-seated landslides located in the upper portion of the Dry Creek and Montgomery Creek.

Erosion and sediment delivery can have both natural and anthropogenic causes. In the absence of human activity, watersheds and streams have a natural background rate of erosion and sediment delivery. Dominant natural erosion processes include geologically and/or tectonically controlled mass wasting (landsliding), gully erosion and bank erosion. Anthropogenic erosion and sediment delivery is caused by a variety of land management activities including road construction, road maintenance, agriculture (vineyards), rural residential development and grazing. As a result, land use activities can result in accelerated fine sediment inputs to the stream system.

In Dry Creek, as in many other coastal watersheds, the disturbance caused by excess sediment input to stream channels during large rainfall events is perhaps one of the most significant factors affecting salmonid populations. Negative effects from excess sediment inputs include, 1) increased water temperatures, 2) lowered dissolved oxygen, and 3) the loss of adequate salmon spawning habitat.

This summary report describes the erosion assessment and inventory process that was employed in the Dry Creek watershed. The key to the assessment process was not to control or prevent natural erosion and sediment delivery, but to bring the levels of anthropogenic erosion and sediment delivery closer to the natural background rates by reducing the effects of past and current land management practices on sediment production. The summary report also serves as a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments for selected county public roads and private rural subdivision roads within the watershed. When implemented and employed in combination with protective land use practices, the proposed projects are expected to significantly contribute to the long term protection and improvement of salmonid habitat in the basin. The implementation of erosion control and erosion prevention work is an important step toward protecting and restoring watersheds and their anadromous fisheries (especially where sediment input is a limiting factor to fisheries production, as is the case for Dry Creek).

Road systems are perhaps the most significant and most easily controlled sources of sediment production and delivery to stream channels. The Dry Creek watershed is underlain by erodible and potentially unstable geologic substrate, and field observations indicate that roads have been, and continue to be, a significant source of accelerated sediment production and delivery in the watershed. Chronic sediment inputs to the channel system, from roads, driveways and other bare soil areas, are also thought to be important contributors to impaired habitat and reduced salmonid populations.

Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of road systems has an immediate benefit to the streams and aquatic habitat of the basin. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion (or that such impacts are minimized), and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas. Sites targeted as high or moderate treatment immediacy in the Dry Creek watershed have been identified as priority sites for implementation so that fill failures, undersized stream crossing culverts, washouts, ditch relief gully erosion, stream diversions and chronic sediment delivery do not degrade the stream system.

The assessment conducted between September, 2002 and January, 2003 identified all recognizable current and future sediment sources on selected roads that were granted access within the Dry Creek watershed. The field inventory identified future sediment sources from approximately of 18 miles of road within the Dry Creek watershed including 14.7 miles of county maintained roads and 3.3 miles of private rural subdivision roads. The primary objective of these road storm-proofing projects is to implement cost-effective erosion control and erosion prevention work on prioritized sites that were identified as a part of this comprehensive watershed assessment and inventory. This assessment is also intended to be used as a tool for basin wide planning in which the ecological impacts of specific roads can be balanced against the needs for private and public use.

III. Project Description

In the first phase of the Dry Creek inventory project all roads within the watershed were identified and age dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. A composite map of the road systems in Dry Creek was developed from GIS layers provided by the Napa County RCD and updated through analysis of aerial photos. GIS base maps used in the field inventory were generated using the air photo identified roads, and depict the primary road network in the watershed and show the location of sites with future erosion and sediment delivery to the stream system.

The second phase of the project involved a complete inventory of 18 miles of county maintained roads and rural subdivision roads, selected hillslope areas and major stream channels within the Dry Creek assessment area. The assessment process used in this project was developed by Pacific Watershed Associates and is one of the preferred methods outlined in the Stream Habitat Restoration Manual prepared by the California Department of Fish and Game. Technically, this assessment was neither an erosion inventory nor a road maintenance inventory. Rather, it was an inventory of sites where there is a potential for future sediment delivery to the stream system that could impact fish bearing streams. All roads, including both maintained and abandoned routes, were walked and inspected by trained personnel from Pacific Watershed Associates with the assistance of Napa County RCD staff. All existing and potential erosion sites were identified and described. Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to a stream channel. Sites of past erosion were not inventoried unless there was a potential for additional future sediment delivery. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were not included in the inventory. Non-delivery sites include small shallow fillslope failures and gullies that are located far enough from a stream that they do not have the potential to deliver to a stream.

Inventoried sites generally consisted of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts and long sections of uncontrolled road and ditch surface runoff which currently discharge to the stream system. For each identified existing or potential erosion source, a database form was filled out and the site was mapped on a mylar overlay over a 1:12,000 scale topographic map. The database form (Figure 2) contained questions regarding the site location, the nature and magnitude of existing and potential erosion problems, the likelihood of erosion or slope failure and recommended treatments to eliminate the site as a future source of sediment delivery.

Stream class was identified at each stream according to the *California Forest Practice Rules* outlined by the California Department of Forestry. Generally, a class I stream is defined as a fish-bearing stream or a domestic water source, a class II stream is defined as non-fish bearing stream that supports other types of aquatic life, a class III stream is defined as not supporting any aquatic life, and a class IV stream is defined as a man-made watercourse.

The erosion potential (and potential for sediment delivery) was estimated for each major problem site or potential problem site. The expected volume of sediment to be eroded and the volume to be delivered to streams were estimated for each site. The data provides quantitative estimates of how much material could be eroded and delivered in the future, if no erosion control or erosion prevention work is performed. In a number of locations, especially at potential stream diversion sites, actual sediment loss could easily exceed field predictions. All sites were assigned a treatment priority, based on their potential to deliver deleterious quantities of sediment to stream channels in the watershed and the cost-effectiveness of the proposed treatment.

In addition to the database information, tape and clinometer surveys were completed on virtually all stream crossings. These surveys included a longitudinal profile of the stream crossing through the road prism, as well as two or more cross sections. The survey data was entered into

Figure 2. Road erosion inventory data form used in the Dry Creek watershed assessment

ASAP____		**P W A R O A D I N V E N T O R Y D A T A F O R M** (3/99 version)				*Check_____*	
GENERAL	**Site No:** ________	GPS:	Watershed:		CALWAA:		
Treat (Y,N):	Photo: ______	T/R/S:	Road #:		Mileage: ___________		
	Inspectors:_______	Date: ________	Year built:______	Sketch (Y):			
	Maintained	Abandoned	Driveable	Upgrade	Decommission	Maintenance	
PROBLEM	Stream xing	Landslide (fill, cut, hill)	Roadbed (bed, ditch, cut)	DR-CMP	Gully	Other	
	Location of problem (U, M, L, S)	Road related? (Y)	Harvest history: (1=<15 yrs old; 2=>15 yrs old) TC1, TC2, CC1, CC2, PT1, PT2, ASG, No		Geomorphic association*:* Streamside, I.G., Stream Channel, Swale, Headwall, B.I.S.		
LANDSLIDE	Road fill	Landing fill	Deep-seated	Cutbank	Already failed	Pot. failure	
	Slope shape: (convergent, divergent, planar, hummocky)			Slope (%) ______	Distance to stream (ft) __________		
STREAM	CMP	Bridge	Humboldt	Fill	Ford	Armored fill	
	Pulled xing: (Y)	% pulled ______	Left ditch length (ft) ___________		Right ditch length (ft) ___________		
	cmp dia (in) ______	inlet (O, C, P, R)	outlet (O, C, P, R)	bottom (O, C,P, R)	Separated?		
	Headwall (in) ____	CMP slope (%) _____	Stream class (1, 2, 3)	Rustline (in)			
	% washed out ____	D.P.? (Y)	Currently dvted? (Y)	Past dvted? (Y)	Rd grade (%) ________		
	Plug pot: (H, M, L)	Ch grade (%) _____	Ch width (ft) _____	Ch depth (ft) ____			
	Sed trans (H, M, L)	Drainage area (mi^2) _________					
EROSION	E.P. (H, M, L)	Potential for extreme erosion? (Y, N)		Volume of extreme erosion (yds^3): 100-500, 500-1000, 1K-2K, >2K			
Past erosion...	Rd&ditch vol (yds^3) (yds^3)___________	Gully fillslope/hillslope (yds^3)__________	Fill failure volume (yds^3) _________	Cutbank erosion (yds^3)__________	Hillslope slide vol. (yds^3) ____________	Stream bank erosion (yds^3) __________	xing failure vol (yds^3) _________
	Total past erosion (yds) __________	Past delivery (%) __________	Total past yield (yds) _________	Age of past erosion (decade)_______			
Future erosion...	Total future erosion (yds) __________	Future delivery (%) __________	Total future yield (yds) _________	Future width (ft) _________	Future depth (ft) ________	Future length (ft) _______	
TREATMENT	Immed (H,M,L)	Complex (H,M,L)	Mulch (ft^2)				
	Excavate soil	Critical dip	Wet crossing (ford or armored fill) (circle)		sill hgt (ft) ___	sill width (ft) _______	
	Trash Rack	Downspout	D.S. length (ft) ________	Repair CMP	Clean CMP		
	Install culvert	Replace culvert	CMP diameter (in) _____	CMP length (ft) _______			
	Reconstruct fill	Armor fill face (up, dn)	Armor area (ft^2) _______	*Clean or cut ditch*	*Ditch length (ft)* _________		
	Outslope road (Y)	*OS and Retain ditch (Y)*	*O.S. (ft)* ____________	*Inslope road*	*I.S. (ft)* _____	*Rolling dip*	*R.D. (#)* __
	Remove berm	*Remove berm (ft)* _____	*Remove ditch*	*Remove ditch (ft)* __________		*Rock road - ft^2* ________	
	Install DR-CMP	*DR-CMP (#)* ________	Check CMP size? (Y)	Other tmt? (Y)	No tmt. (Y)		
COMMENT ON PROBLEM:							
EQUIPMENT HOURS	Excavator (hrs) ________	Dozer (hrs) ________	Dump truck (hrs) ______	Grader (hrs) ________			
	Loader (hrs) _____	Backhoe (hrs) ______	Labor (hrs) _______	Other (hrs) ______			
COMMENT ON TREATMENT:							

a computer program that calculates the volume of fill in the crossing. The survey allows for an accurate and repeatable quantification of future erosion volumes (assuming the stream crossing was to washout during a future storm), decommissioning volumes (assuming the road was to be closed) and/or excavation volumes that would be required to complete a variety of road upgrading and erosion prevention treatments (culvert installation, culvert replacement, complete excavation, etc.).

IV. Dry Creek Road Assessment and Sediment Reduction Plan

A. Inventory Results

Approximately 82 miles of road were identified in the sequential air photo analysis of the 1940, 1985 and 2002 air photo set years (Map 1). Of the 82 miles in the Dry Creek watershed assessment area, approximately 50 miles were constructed as of 1940, 23 miles were constructed between 1940 and 1985, and 9 miles were constructed between 1985 and 2002. Of the 82 miles of road in the Dry Creek watershed assessment area, 18 miles were granted access for the sediment source assessment including 14.7 miles of county road and 3.3 miles of private residential subdivision roads.

Approximately 18 miles of roads were inventoried for future sediment sources within the Dry Creek watershed. Inventoried road-related erosion sites fit into one of two treatment categories: 1) upgrade sites - defined as sites on maintained county roads and open private roads that are to be retained for access and management and 2) decommission sites - defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure. Virtually all future road-related erosion and sediment yield in the Dry Creek watershed assessment area is expected to come from three sources: 1) erosion at or associated with stream crossings (from several possible causes), 2) failure of road fills (landsliding), and 3) road surface and ditch erosion.

A total of 176 sites were identified with the potential to deliver sediment to streams. Of these, 146 were recommended for erosion control and erosion prevention treatment. Approximately 71% (n=103) of the sites recommended for treatment are classified as stream crossings, 8% (n=11) as existing or potential landslides, and 18% (n=27) as ditch relief culverts (Table 1 and Map 2). The remaining 3% (n=5) of the inventoried sites consist of other sites which include road surface, gullies, stream bank erosion and springs.

Stream crossings - One hundred and thirteen (113) stream crossings were inventoried in the Dry Creek assessment area including 98 culverted crossings, 11 unculverted fill crossings and 4 bridges. An unculverted fill crossing refers to a stream crossing with no drainage structure to carry the flow through the road prism. Flow is either carried beneath or through the fill, or it flows over the road surface, or it is diverted down the road surface to the inboard ditch. The majority of the unculverted fill crossings are located at small Class III streams that exhibit flow only in larger runoff events.

Of the 113 stream crossings identified in the assessment, 103 have been recommended for erosion control and erosion prevention treatment. Approximately 10,928 yds^3 of future road-related sediment delivery in the Dry Creek watershed assessment area could originate from stream crossings if they are not treated (Table 1). This amounts to about 52% of the total sediment yield from the road system. The most common problems that cause erosion at stream

Table 1. Site classification and sediment yield from all inventoried sites with future sediment delivery, Dry Creek watershed assessment area, Napa County, California.						
			Sites recommended for treatment			
Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Stream crossings currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate) (#)
Stream crossings	113	103	10,928	71	12	60
Landslides	21	11	549	--	--	--
Ditch relief culverts	37	27	748	--	--	--
Other	5	5	50	--	--	--
Total (all sites)	176	146	12,275	71	12	60
Persistent surface erosion[1]	12.11	10.84	8,635	--	--	--
Totals	**176**	**146**	**20,910**	**71**	**12**	**60**

[1] Unpaved roads assume 25' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over two decades. Paved roads assume 8' average cutbank and ditch contributing area, and 0.4' surface lowering rate over two decades.

crossings include: 1) crossings with no or undersized culverts, 2) crossings with culverts that are likely to plug, 3) stream crossings with a diversion potential and 4) crossings with gully erosion at the culvert outlet. The sediment delivery from stream crossing sites is always classified as 100% because any sediment eroded is delivered to the channel. Any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels.

At stream crossings, the largest volumes of future erosion can occur when culverts plug or when potential storm flow exceeds the culvert capacity (i.e., the culvert is undersized or prone to plugging) and flood runoff spills onto or across the road. When stream flow goes over the fill, part or all of the stream crossing fill may be eroded. Alternately, when flow is diverted down the road, either on the road bed or in the ditch (instead of spilling over the fill and back into the same stream channel), the crossing is said to have a diversion potential and the road bed, hillslope and/or stream channel that receives the diverted flow can become deeply gullied or destabilized. These hillslope gullies can be quite large and can deliver significant quantities of sediment to stream channels. Alternately, diverted stream flow which is discharged onto steep, potentially unstable slopes can also trigger large hillslope landslides. Of the 94 stream crossings inventoried and recommended for erosion control and erosion prevention treatment in the Dry Creek watershed, 71 have the potential to divert in the future and 12 streams are currently diverted (Table 1).

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

Approximately 91% (n=103) of the stream crossings inventoried in the Dry Creek assessment area will need to be upgraded for the roads to be considered storm-proofed. For example, 61% (n=60) of the existing culverts have a moderate to high plugging potential and nearly 63% of the stream crossings exhibit a diversion potential (Table 1). Because most of the roads were constructed many years ago, culverted stream crossings are typically under-designed for the 100 year storm flow. At stream crossings with undersized culverts or where there is a diversion potential, corrective prescriptions have been outlined on the data sheets and in the following tables.

Preventative treatments include such measures as constructing critical dips (rolling dips) at stream crossings to prevent stream diversions on rocked and native private roads, installing larger culverts wherever current pipes are under-designed for the 100 year storm flow (or where they are prone to plugging), installing culverts at the natural channel gradient to maximize the sediment transport efficiency of the pipe and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill, installing debris barriers and/or downspouts to prevent culvert plugging and outlet erosion, respectively, installing flared inlets to increase the culvert capacity, and armoring the downstream fill face of the crossing to minimize or prevent future erosion.

Landslides - Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. Twenty-one (21) potential landslides were identified and these account for approximately 12% of the inventoried sites in the Dry Creek assessment area (Table 1). Eleven (11) of the 21 potential landslide sites were found along roads where material had been side cast during earlier construction and now shows signs of instability, where roads were built directly in the channel and are being undercut by high flows, where roads are built along the stream inner gorge and/or where roads were built along the steep headwall areas of Class 3 streams. The remaining 10 potential landslide sites consist of unstable, over steepened road cutbanks.

Of the 21 landslides identified in the Dry Creek watershed assessment area, 11 have been recommended for erosion control and erosion prevention treatment. Potential landslides recommended for treatment are expected to deliver up to 549 yds^3 of sediment to Dry Creek and its tributaries in the future. Correcting or preventing potential landslides associated with the road is relatively straightforward, and involves the physical excavation of potentially unstable road fill and side cast materials. The majority of the potential landslides were identified along public highway routes. Currently, road widths are insufficient at these sites to allow unstable road fill to be excavated without compromising driver safety. Therefore, these sites may need to have a engineered fills or retaining walls constructed in order to prevent road slip outs and sediment delivery to the stream network while maintaining sufficient road width. Although we have identified a number of these potential sites, we have not included engineering designs for these structures.

The majority of inventoried potential landslide sites that were not recommended for treatment were identified as cutbank landslides. Typically, cutbank landslides have low sediment delivery since the majority of failed materials are captured on the road bed. Cutbank landslide sites become more of a maintenance issue with regards to keeping the ditch and road surface free of failed cutbank materials. Direct excavation of unstable cutbanks is not recommended because it can result in further destabilization of the cutbank.

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

Ditch relief culverts -Thirty-seven (37) ditch relief culvert sites were identified to have future sediment yield to stream channels. Of the 37 ditch relief culverts, 27 were recommended for erosion control and erosion prevention treatment. These sites are attributed to excessive ditch length contribution that causes a gully below the outlet that delivers sediment to a stream channel. Approximately 748 yds^3 of future sediment yield is expected to occur associated with these ditch relief culvert sites. These sites represent approximately 4% of the total predicted sediment yield from road related erosion.

Other sites - A total of 5 other sites were also identified in the Dry Creek watershed assessment area. Other sites include road surface, ditch, major springs and bank erosion sites which exhibited the potential to deliver sediment to streams. One of the main causes of existing or future erosion at these sites is surface runoff and uncontrolled flow from long sections of undrained road surface and/or inboard ditch. Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause hillslope gully erosion.

All 5 of the other sites have been recommended for erosion control and erosion prevention treatment. We estimate 50 yds^3 of sediment will be delivered to streams if they are left untreated (Table 1). Sediment delivery from these sites represents less than 1% of the total potential sediment yield from sites recommended for erosion control and erosion prevention treatment.

Chronic erosion - Road runoff is also a major source of fine sediment input to nearby stream channels. We measured approximately 12.11 miles of road surface and/or road ditch (representing 67% of the total inventoried road mileage) which currently drain directly to stream channels and deliver ditch flow, road runoff and fine sediment to stream channels in the Dry Creek watershed assessment area (Table 1). These roads are said to be hydrologically connected to the stream channel network. This does not include inaccessible spur roads and driveways that also contribute runoff and sediment to the county roads and their drainage structures. When these roads are being actively maintained and used for access, they represent a potentially important source of chronic fine sediment delivery to the stream system.

Of the 12.11 miles of road surface and/or road ditch contribution, 10.84 miles have been recommended for treatment. From the 10.84 miles, we calculated approximately 8,635 yds^3 (41%) of sediment could be delivered to stream channels within the Dry Creek watershed over the next two decades, depending on road use, if no efforts are made to change road drainage patterns. This will occur through a combination of 1) cutbank erosion (ie., dry ravel, rainfall, freeze-thaw processes, cutbank failures and brushing/grading practices) delivering sediment to the ditch, 2) inboard ditch erosion and sediment transport, 3) mechanical pulverizing and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods.

Relatively straight-forward erosion prevention treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing road runoff and disconnecting road surface and ditch drainage from the natural stream channel network. Road surface treatments include the additional ditch relief culverts on paved county roads and adding frequent ditch relief culverts and/or adding rolling dips on rocked and native private roads.

B. Treatment Priority

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

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

The ***erosion potential*** of a site is a professional evaluation of the likelihood that future erosion will occur during a future storm event. Erosion potential is an estimate of the potential for additional erosion, based on field observations of a number of local site conditions. Erosion potential was evaluated for each site, and expressed as High, Moderate or Low. The evaluation of erosion potential is a subjective estimate of the probability of erosion, and not an estimate of how much erosion is likely to occur. It is based on the age and nature of direct physical indicators and evidence of pending instability or erosion. The likelihood of erosion (erosion potential) and the volume of sediment expected to enter a stream channel from future erosion (sediment delivery) play significant roles in determining the treatment priority of each inventoried site (see treatment immediacy, below). Field indicators that are evaluated in determining the potential for sediment delivery include such factors as slope steepness, slope shape, distance to the stream channel, soil moisture and evaluation of erosion process. The larger the potential future contribution of sediment to a stream, the more important it becomes to closely evaluate its potential for cost-effective treatment.

Treatment immediacy (treatment priority) is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work. It is also defined as High, Moderate and Low and represents both the severity and urgency of addressing the threat of sediment delivery to downstream areas. An evaluation of treatment immediacy considers erosion potential, future erosion and delivery volumes, the value or sensitivity of downstream resources being protected, and treatability, as well as, in some cases, whether or not there is a potential for an extremely large erosion event occurring at the site (larger than field evidence might at first suggest). If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy might be judged High. *Treatment immediacy is a summary, professional assessment of a site=s need for immediate treatment.* Generally, sites that are likely to erode or fail in a normal winter, and that are expected to deliver significant quantities of sediment to a stream channel, are rated as having a high treatment immediacy or priority.

C. Evaluating Treatment Cost-Effectiveness

Treatment priorities are developed from the above factors, as well as from the estimated cost-effectiveness of the proposed erosion control or erosion prevention treatment. 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. For example, if it would cost $2000 to develop access and treat an eroding stream crossing that would have delivered 500 yds^3 (had it been left to erode), the predicted cost-effectiveness would be $4/yds^3 ($2000/500yds^3).

To be considered for priority treatment a site should typically exhibit: 1) potential for significant (>25-50 yds^3) sediment delivery to a stream channel (with the potential for transport to a fish-bearing stream), 2) a high or moderate treatment immediacy and 3) a predicted cost-effectiveness value. Treatment cost-effectiveness analysis is often applied to a group of sites (rather than on a single site-by-site basis) so that only the most cost-effective groups of sites or projects are undertaken. Typical measures of treatment cost-effectiveness for forest, ranch and rural subdivision roads are not directly comparable to values which might be developed for the treatment of county public roads, such as 14.7 miles of county public roads in the Dry Creek watershed. Here, the costs for treatments are typically much higher, and the resulting cost-effectiveness values will be less favorable.

Regardless of the absolute values, cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and Sonnevil, 1984; Weaver and others, 1987). It assures that the greatest benefit is received for the limited funding that is typically available for protection and restoration projects. Sites, or groups of sites, that have a predicted marginal cost-effectiveness value, or are judged to have a lower erosion potential or treatment immediacy, or low sediment delivery volumes, are less likely to be treated as part of the primary watershed protection and erosion-proofing program. However, these sites should be addressed during future road reconstruction or when heavy equipment is performing routine maintenance or restoration at nearby, higher priority sites.

D. Types of Prescribed Heavy Equipment Erosion Prevention Treatments

Forest roads can be storm-proofed by one of two methods: upgrading or decommissioning (Weaver and Hagans, 1994). The characteristics of storm-proofed roads, including those which are either upgraded or decommissioned, are depicted in Figure 3.

Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 100-year storm. In contrast,

FIGURE 3. CHARACTERISTICS OF STORM-PROOFED ROADS

The following abbreviated criteria identify common characteristics of storm-proofed roads. Roads are storm-proofed when sediment delivery to streams is strictly minimized. This is accomplished by dispersing road surface drainage, preventing road erosion from entering streams, protecting stream crossings from failure or diversion, and preventing failure of unstable fills which would otherwise deliver sediment to a stream. Minor exceptions to these guidelines can occur at specific sites within a forest or ranch road system.

STREAM CROSSINGS

Y all stream crossings have a drainage structure designed for the 100-year flow
Y stream crossings have no diversion potential (functional critical dips are in place)
Y stream crossing inlets have low plug potential (trash barriers & graded drainage)
Y stream crossing outlets are protected from erosion (extended, transported or dissipated)
Y culvert inlet, outlet and bottom are open and in sound condition
Y undersized culverts in deep fills (> backhoe reach) have emergency overflow culvert
Y bridges have stable, non-eroding abutments & do not significantly restrict design flood
Y fills are stable (unstable fills are removed or stabilized)
Y road surfaces and ditches are disconnected from streams and stream crossing culverts
Y decommissioned roads have all stream crossings completely excavated to original grade
Y Class 1 (fish) streams accommodate fish passage

ROAD AND LANDING FILLS

Y unstable and potentially unstable road and landing fills are excavated (removed)
Y excavated spoil is placed in locations where eroded material will not enter a stream
Y excavated spoil is placed where it will not cause a slope failure or landslide

ROAD SURFACE DRAINAGE

Y road surfaces and ditches are disconnected from streams and stream crossing culverts
Y ditches are drained frequently by functional rolling dips or ditch relief culverts
Y outflow from ditch relief culverts does not discharge to streams
Y gullies (including those below ditch relief culverts) are dewatered to the extent possible
Y ditches do not discharge (through culverts or rolling dips) onto active or potential landslides
Y decommissioned roads have permanent road surface drainage and do not rely on ditches

properly decommissioned roads are closed and no longer require maintenance. The goal of storm-proofing is to make the road as hydrologically invisible as is possible, that is to disconnect the road from the stream system and thereby preserve aquatic habitat.

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 stream crossing upgrading (especially culvert up-sizing to accommodate the 100-year storm flow and debris in transport, and to eliminate stream diversion potential), removal of unstable sidecast and fill materials from steep slopes, and the application of drainage techniques to improve dispersion of road surface runoff. Road drainage techniques include rolling dips and/or the installation of ditch relief culverts. The goal of all treatments is to make the road as hydrologically invisible as is possible.

Heavy equipment conducting stream crossing culvert upgrades on county roads will utilize two different methods to install new pipes. Methods are dependent on the depth of road fill at the stream crossing site. For a stream crossing that has a <8' deep road fill, a trench will be excavated. The new pipe will be installed and the crossing excavation will be back filled with an aggregate concrete slurry. All of the road fill that is excavated for the new culvert installation will be endhauled away from the site. Estimated excavator and backhoe times are based on a excavation production rate that is determined by the complexity of the work site. Dump trucks will endhaul spoil to a temporary storage area located by Napa County Department of Public Works (Napa DPW). A loader or dozer will be located at the temporary storage area to work the spoils.

Once the new pipe is set at or close to the natural channel gradient a cement truck will haul slurry material to backfill the excavated crossing. Each trench crossing will be backfilled with a slurry to ensure a hardened surface that will not settle after the new pipe installation is completed. Cement trucks can haul 10 yds^3 of slurry and are able to backfill at a rapid 10 yds^3 in 10 minutes. Costs for the cement truck are based on the cost of the material delivered to the average work site. Several cement trucks will be utilized at once and may be required to deliver up to 150 cubic yards of slurry to backfill a larger trench crossing. The crossing then will be capped with new pavement whose surface area is based on the width and length of the excavation. Then the crossing then will be swept with a mechanical broom.

For crossings >8' deep and fill depths beyond the reach of an excavated trench, a non-trenched excavation will be applied. To install a new pipe at the natural channel gradient, a deep crossing will require the excavator to open up a crossing completely to safely allow room for laborers to replace or install the pipe deep in the fill. The excavation will require sideslopes be excavated back at a 1:1 slope (at least), which differs significantly from a typical trenched excavation. Approximately 100 yds^3 of material will be stockpiled on-site and the remaining road fill will need to be endhauled to a temporary storage location. The new pipe will be installed using the locally stockpiled spoils for a compacted bed. The remaining excavation will then be backfilled with clean quarry fill.

Road decommissioning basically involves reverse road construction, except that full topographic obliteration of the road bed is <u>not</u> normally required to accomplish sediment prevention goals. Generic treatments for decommissioning roads and landings range from outsloping or simple cross-road drain construction to full road decommissioning (closure), including the excavation of unstable and potentially unstable sidecast materials and road fills, and all stream crossing fills. Four (4) sites located on private subdivision roads have been recommended for temporary or permanent closure.

E. Treatments

Basic treatment priorities and prescriptions for inventoried roads in Dry Creek were formulated concurrent with the identification, description and mapping of potential sources of road-related sediment yield. Table 2 and Map 3 outline the treatment priorities for all 146 inventoried sites with future sediment delivery that have been recommended for treatment in the Dry Creek

Table 2. Treatment priorities for all inventoried sediment sources in the Dry Creek watershed assessment area, Napa County, California				
Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**20** (site #: 10, 12, 28, 59, 60, 61, 77, 82, 88, 89, 92, 108, 117, 119, 135, 148, 150, 151, 152, 308)	**1** (site #: 304)	17 stream crossings, 1 landslide, 3 ditch relief culverts	3,530
High Moderate	**33** (site #: 9, 13, 14, 16, 17, 20, 21, 25, 34, 37, 46, 56, 62, 67, 70, 71, 75, 85, 102, 104, 109, 112, 120, 123, 126, 130, 134, 137, 306, 307, 406, 407, 408)	**0**	26 stream crossings, 3 landslides, 4 ditch relief culverts	8,677
Moderate	**47** (site #: 2, 4, 6, 7, 24, 38, 41, 42, 44, 48, 49, 51, 52, 53, 57.1, 63, 66, 68, 72, 73, 76, 78, 80, 81, 83, 87, 91, 93, 101, 103, 103.1, 105, 106, 107, 110, 114, 115, 122, 137, 138, 139, 143, 309, 401, 403, 412, 414)	**1** (site #: 305)	39 stream crossings, 4 landslides, 4 ditch relief culverts, 1 other	4,874
Moderate Low	**36** (site #: 11, 19, 22, 29, 31, 33, 36, 39, 43, 54, 55, 58, 74, 79, 86, 94, 113, 118, 121, 124, 128, 129, 131, 132, 133, 141, 144, 145, 310, 311, 312, 402, 409, 410, 411, 413)	**0**	17 stream crossings, 3 landslide, 12 ditch relief culverts 4 other	3,580
Low	**6** (site #: 23, 30, 57, 65, 90, 142)	**2** (site #: 303, 400)	4 stream crossings, 4 ditch relief culverts	249
Total	**142**	**4**	**103 stream crossings, 11 landslides, 27 ditch relief culverts 5 other**	**20,910**

watershed assessment area. Of the 146 sites with future sediment delivery, fifty-four (54) sites were identified as having a high-moderate treatment immediacy with a potential sediment delivery of approximately 12,207 yds^3. Eighty-four (84) sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 8,454 yds^3 of future sediment delivery. Finally, eight (8) sites were listed as having a low treatment immediacy with approximately 249 yds^3 of future sediment delivery.

Table 3 summarizes the proposed treatments for sites inventoried on inventoried roads in the Dry Creek watershed assessment area. The database, as well as the field inventory sheets, provide details of the treatment prescriptions for each site. Most treatments require the use of heavy equipment, including an excavator, loader, tractor, dump truck and backhoe. Some hand labor is required at sites needing new culverts, downspouts, culvert repairs, trash racks and/or for applying seed, plants and mulch following ground disturbance activities. Additional labor will be required to conduct traffic control at all work sites. Labor necessary to allow vehicles to pass through the work site with minimal delay will require a single flagman on both sides of the work site. The flaggers will be equipped with radios and stop signs and direct traffic to a single lane. Stop signs will replace flaggers during nights or hours when work will not be conducted. Longer or blind reaches may require the use of a pilot car.

Table 3. Recommended treatments along inventoried roads in the Dry Creek watershed assessment area, Napa County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	3	To prevent stream diversions	Reconstruct fill	1	Engineered fill design to reconstruct fill at 1 landslide site
Install CMP	6	Install a CMP at an unculverted fill	Back fill at culvert trench installations with 2 sack slurry mix	184	Backfill with 4,151 yds^3 slurry mix at stream crossing and ditch relief culvert trench installations
Replace CMP	84	Upgrade an undersized CMP	Back fill at culvert non-trench installations with clean rock	6	Backfill at non-trench culvert installations with 2,583 yds^3 of clean rock
Replace bridge	1	Upgrade an old, unstable bridge (cost not included in this estimate)	Install rolling dips	15	Install rolling dips to improve road drainage
Excavate and remove soil	91	Typically consisting of fillslope & stream crossing excavations; permanent excavation of 9,118 yds^3	Add asphalt berm	3	Add 279' of asphalt berm to improve road surface drainage
Clean culvert	5	Clean culvert inlet to prevent plugging	Clean/cut ditch	11	Clean/cut 1,565' of ditch to improve road surface drainage
Install flared inlet	36	Install to increase the pipe capacity	Install ditch relief CMP	94	Install ditch relief culverts to improve road surface drainage
Downspouts	30	Installed on stream crossing and ditch relief pipes to protect fillslope erosion	Replace ditch relief CMP	16	Replace ditch relief culverts to improve road surface drainage

Table 3. Recommended treatments along inventoried roads in the Dry Creek watershed assessment area, Napa County, California.					
Treatment	**No.**	**Comment**	**Treatment**	**No.**	**Comment**
Rebar or fence post trash rack	13	Installed to prevent culvert from plugging	Rock road surface	14	Rock or re-rock road surface using 215 yds^3 road rock at 8 stream crossing culvert replacements, 2 ditch relief culvert installations, 3 rolling dip installations, and 1 other site
Armor inboard/ outboard fill face or ditch	25	Rock armor to protect inboard and outboard fillslopes, and ditches from erosion using 688 yds^3 of rock	Other	7	Miscellaneous treatments
Install wet crossing	1	Install 1 armored ford using 27 yds^3 of rip rap	No treatment recommended	30	

It is estimated that erosion prevention work will require the excavation of approximately 9,118 yds^3 at 91 sites. Approximately 99% of the volume excavated is associated with upgrading and decommissioning stream crossings. A total of 715 yds^3 of 1.0 to 3.0 foot diameter mixed and clean rip-rap sized rock will be needed to armor twenty-five (25) inboard/outboard fill faces and inboard ditches, and 27 yds^3 is required to construct 1 armored ford. Rock armor has been prescribed on steep stream crossing outboard fillslopes to buttress the lower portion of the excavation in order to prevent the newly replaced fill from slumping and/or delivering to the stream network. A total of 90 culverts are recommended to upgrade existing stream crossing culverts or install culverts at unculverted streams.

For some deep stream crossings where an excavator cannot reach the natural stream bottom and install a culvert at the natural channel gradient, downspouts have been prescribed to transport the stream flow beyond the road fill to the natural stream bottom. To prevent potential stream diversions, each site with a high diversion potential has been prescribed to either have an oversized pipe or to have a flared inlet to increase pipe inlet capacity. Thirty-six (36) flared inlets have been prescribed for installation to increase the inlet capacity at certain stream crossings. A minimum of 110 new ditch relief culverts are recommended for installation or replacement along the inventoried road routes to disconnect connected ditches from natural stream channels (Table 3).

F. Equipment Needs and Costs

Treatments for the 146 sites identified with future sediment delivery in the Dry Creek assessment area will require approximately 562 hours of excavator time and 430 hours of backhoe time to complete all prescribed upgrading and erosion control and erosion prevention work (Table 4). Backhoe time has been listed to conduct shallow excavations, install ditch relief

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment delivery, Dry Creek watershed assessment area, Napa County, California. [1]

Treatment Immediacy	High, High/Moderate	Moderate, Low/Moderate	Low	**Total**
Site (#)	54	84	8	**146**
Total Excavated Volume (yds^3)[2]	6,357	3,161	16	**9,534**
Excavator (hrs)	313	246	3	**562**
Dozer (hrs)	32	31	0	**63**
Loader (hrs)	22	5	0	**27**
Dump Trucks (hrs)	608	349	3	**960**
Labor (hrs)	480	637	15	**1,132**
Traffic Control (hrs)	978	1,170	30	**2,178**
Roller (hrs)	140	220	6	**366**
Broom (hrs)	140	220	6	**366**
Pavement cutter (hrs)	69	110	3	**182**
Backhoe (hrs)	129	286	15	**430**

[1] Estimated equipment times do not include daily lowboy or travel costs to treatment sites.
[2] Total excavated volume includes permanently excavated material and a percentage of temporarily excavated materials used in backfilling upgraded stream crossings at non-trench installations.

culverts, and clean ditches. A loader has been listed for 27 hours of work to backfill large stream crossings, and keep the road swept of any obstacles that might stop traffic.

Approximately 960 hours of dump truck time has been listed for work in the basin for end-hauling excavated spoil from stream crossings and at unstable road and landing fills where local disposal sites are not available. Approximately 1,132 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts, and an additional 32 hours of labor are for seeding, mulching and planting activities. Approximately 2,178 hours have been for traffic control and includes a crew of two flagmen during heavy equipment work hours. Approximately 366 hours for a roller and 366 hours for a mechanical broom have been listed to finish each site.

Estimated costs for erosion prevention treatments - Prescribed treatments are divided into two components: a) site specific erosion prevention work identified during the watershed inventories, and b) control of persistent sources of road surface, ditch and cutbank erosion and associated sediment delivery to streams. The total costs for road-related erosion control at all the inventoried sites with future sediment delivery to the Dry Creek watershed is estimated at approximately $1,294,026 for an average cost-effectiveness value of approximately $61.89 per cubic yard of sediment prevented from entering Dry Creek and its tributaries (Table 5).

Costs are not included for the materials needed to install one flat car bridge on a private road. In addition, total estimated costs include lowboy costs for one round trip to transport an excavator and a dozer to the Dry Creek assessment area. Total estimated costs do not include the daily travel costs to transport equipment and labor to the treatment sites.

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

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

Treatments prescribed on county maintained roads were modified from these general standards to more closely meet current county procedures and acceptable standards for paved public roads. The specific treatments for the 14.7 miles of county roads outlined in this report will need to be reviewed by County DPW staff on a site-by-site basis to ensure they meet current operating practices that are in place for similar treatments. It should also be noted that approximately 82% of the road length inventoried was on paved county maintained roads where engineers will likely need to be involved in the design of specific upgrade work. Extra costs could include safety flagging, painting, guard rails, etc. This could add a significant cost to completing the proposed work.

Table 5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery in the Dry Creek watershed assessment area, Napa County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times: Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	Total Estimated Costs[5] ($)
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	3	--	3	300
	Dozer	100	3	--	3	300
Heavy Equipment requirements for site specific treatments	Excavator	165	544	163	707	116,655
	Dozer	140	48	14	62	8,680
	Dump truck	75	856	257	1,113	83,475
	Backhoe	85	14	4	18	1,530
	Loader	140	27	8	35	4,900
	Pavement cutter	140	78	23	101	14,140
	Broom	55	158	47	205	11,275
	Roller	50	158	47	205	10,250
Heavy Equipment requirements for road drainage treatments	Excavator	165	18	5	23	3,795
	Dozer	85	15	5	20	1,700
	Backhoe	85	416	125	541	45,985
	Dump truck	75	104	31	135	10,125
	Pavement cutter	140	104	31	135	18,900
	Broom	55	208	62	270	14,850
	Roller	50	208	62	270	13,500
Laborers[7]		40	1,164	349	1,513	60,520
Traffic control laborers		30	2,178	653	2,831	84,930
Grader[8]		120	35	11	46	5,520
Water truck[9]		90	39	12	51	4,590
Rock Costs: (includes trucking for 215 yds^3 of road rock, 715 yds^3 of rip-rap sized rock and 2,583 yds^3 of clean backfill)						105,390
Backfill Slurry Costs: (includes trucking and pouring for 4,151 yds^3 of backfill slurry)						394,345
Culvert materials costs (5,230' of 18', 1,730' of 24", 1,835' of 30", 680' of 36", 280' of 42", 710' of 48", 140' of 54", 400' of 60", 60' of 66", 70' of 72" and 110' of 96". Costs included for couplers, flared inlets and elbows)						206,154
Paving for 35,080 ft^2 @ $ 0.63/ft^2						22,100
Asphalt beam installation ($23/ft. @ 279')						6,417
Mulch, seed and planting materials for approximately 2 acres of disturbed ground[10]						1,100
Layout, Coordination, Supervision, and		45 60	--	--	560 240	25,200 14,400

Table 5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery in the Dry Creek watershed assessment area, Napa County, California

Cost Category[1]	Cost Rate[2] ($/hr)	Estimated Project Times: Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	Total Estimated Costs[5] ($)
Reporting[11]	75			40	3,000
Total Estimated Costs[12]					**$ 1,294,026**
Potential sediment savings: 20,910 yds^3					
Overall project cost-effectiveness: $61.89 spent per cubic yard saved[9]					

[1] Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs for replacing excavated striping and reflectors not included.

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

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

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

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for one crew to areas within the Dry Creek watershed. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] An additional 32 hours of labor time is added for straw mulch and seeding on non-trench stream crossing culvert installations and stream crossing decommission excavations.

[8] Thirty-five (35) hours of grader time is added to re-grade non-paved roads post treatment.

[9] Thirty-nine (39) hours of water truck time is added to at stream crossing backfills and rolling dip installations on private roads.

[10] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50 lbs. of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching.

[11] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 50% of the total excavator time for sit specific treatments and 50% of the backhoe time for road drainage treatments plus 1 week prior and 1 week post project implementation.

[12] Total estimated costs do not include costs for engineered upgrades (i.e. engineered fills).

Table 5 lists a total of 840 hours for supervision time for detailed pre-work layout, project planning (coordinating and securing equipment, materials and obtaining plant and mulch materials), on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project cost effectiveness analysis and reporting. It is expected that the project coordinator and/or Contracting Officer=s Representative (COR) will be on-site full time at the beginning of the project and intermittently after equipment operations have begun.

G. Conclusion

The expected benefit of completing the erosion control and prevention planning work lies in the reduction of long term sediment delivery to Dry Creek, an important salmonid stream. A first-step in the overall risk-reduction process is the development of a proactive plan for erosion prevention and erosion control on public roads. In developing this plan, selected roads in the watershed are considered for either decommissioning or upgrading, depending upon the risk of erosion and sediment delivery to streams. Not all roads are high risk and those that pose a low risk of degrading aquatic habitat in the watershed may not need immediate attention. It is therefore important to rank and prioritize roads in each sub-watershed, and within each ownership, based on their potential to impact downstream resources, as well as, their importance to the overall transportation system and to management needs. PWA can work with road managers to make recommendations that achieve both long term sediment delivery reduction as well as retaining the road shapes and locations.

Good land stewardship requires that roads either be upgraded or maintained, or intentionally closed (put-to-bed). The old practice of crisis management and treating roads only when a flooding disaster happens, is no longer considered acceptable. Road upgrading consists of a variety of techniques employed to erosion-proof and to storm-proof a road and prevent unnecessary future erosion and sediment delivery. This requires a proactive investment in the basic infrastructure of the transportation network. Erosion-proofing and storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road is capable of withstanding both annual winter rainfall and runoff as well as a large storm event without failing or delivering excessive sediment to the stream system. In fact, many of the drainage structures (culverts) at inventoried stream crossings are nearing the end of their useful life. They are rusted out and beginning to fail through erosion and collapse of the fill. These will need to be replaced, and this presents an opportunity to upgrade the drainage structure with one that better meets today=s higher standards. Finding adequate funding to accomplish this upgrading of the road network will be a challenging task, but one that has rewards in terms of lowered maintenance and storm damage costs, and increased protection to fish habitat and water quality throughout the watershed.

In identifying potential sediment sources along the county road system, PWA employed a standardized and accepted protocol for identifying, describing and quantifying erosion problems. However, in developing recommended treatments to address the various sediment sources, we employed a modified set of prescriptions that were formulated to be consistent with paved public roads standards. These can be changed globally in the database to provide a revised treatment prescription and/or cost estimate.

With this prioritized plan of action, various landowners and Napa County Public Work staff can work with the Napa County RCD to obtain potential funding to implement the proposed projects. However, watershed assessment inventories should be conducted on upland roads, both driveable and abandoned, in the remainder of the Dry Creek watershed. This will permit us to continue to refine the prioritization of which sites throughout the watershed pose the most critical threats to salmonid recovery, as well as allow us to know we are spending the limited available funds on the highest priority work sites in the watershed.

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APPENDIX A
Inventory results, erosion control and erosion prevention plan for private roads within the Dry Creek watershed, Napa County, California

Approximately 3.3 miles of private roads within the Dry Creek watershed assessment were granted access for the field inventory. Inventoried private roads are located on the south facing slopes of the watershed within the mainstem of Dry Creek, Montgomery Creek, Segassia Canyon, and Wing Canyon. PWA personnel with the assistance of Napa RCD staff inventoried these roads for sites of potential sediment delivery to Dry Creek and its tributaries.

Sites with future sediment delivery were inventoried using a PWA data form (Figure 2 and Map 2). Table 6 displays the distribution of site types mapped during the sediment source investigation. Any potential landslides which posed a risk of delivering sediment to streams were identified along all the inventoried private roads. Every stream crossing was identified according to stream class (I, II, II), inventoried and described in detail. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

Ditch relief culverts were also identified where long stretches of road surface and/or ditch runoff deliver fine sediment to stream channels via gullies extending from ditch relief culvert outlets.. The other category of sites includes miscellaneous erosional features such as bank erosion, road surface and ditch drainage problems, or springs that have the potential to deliver sediment to a stream channel. All sites were mapped on 1:12,000 USGS topographic maps with mylar overlays.

A total of 26 sites were identified with a risk of future sediment delivery along private roads within the Dry Creek assessment area (Table 6). Sites include 17 stream crossings, 1 potential landslide, 5 ditch relief culverts and 3 miscellaneous other sites. Of the 26 inventoried sites, 23 have been recommended for erosion prevention treatment. In addition, 1.88 miles (56%) of the 3.33 miles of inventoried private roads currently deliver sediment and runoff to streams.

Stream crossings - Seventeen (17) stream crossings were identified in the field including 14 culverted fill crossings, 2 unculverted fill crossings, and 1 bridge. Of the 17 stream crossings inventoried, 15 have been recommended for erosion control and erosion prevention treatments. Total future erosion and sediment yield from stream crossing sites recommended for treatment is approximately 353 yds^3 if erosion prevention measures are not undertaken.

A significant problem from stream crossings inventoried on private roads within the Dry Creek assessment area arise from stream crossings with a diversion potential. Of the 15 crossings recommended for erosion control and erosion prevention treatment, 6 have a diversion potential and 1 is currently diverted. Treatment for stream diversions is easy and requires installation of a critical dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 14 culverted stream crossings, 8 have a moderate to high plug potential. Erosion can also occur as a

Table 6. Site classification and sediment yield from inventoried sites with future sediment delivery along private roads, Dry Creek watershed assessment area, Napa County, California.						
			Sites recommended for treatment			
Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Stream crossings currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate) (#)
Stream crossings	17	15	353	6	1	8
Landslides	1	1	26	--	--	--
Ditch relief culverts	5	4	525	--	--	--
Other	3	3	30	--	--	--
Total (all sites)	26	23	934	6	1	8
Persistent surface erosion[1]	1.88	1.64	2,788	--	--	--
Totals	**26**	**23**	**3,722**	**6**	**1**	**8**

[1] Unpaved roads assume 25' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over two decades. Paved roads assume 8' average cutbank and ditch contributing area, and 0.4' surface lowering rate over two decades.

result of poorly installed culverts causing major gully erosion below the outlet. Approximately 9% of the total future sediment yield would result from erosion associated with stream crossing failures.

Landslides - Potential road-related landslides identified during the road inventory were divided into cutbank failures, landing fill failures, road fill failures, deep seated failures and others. The 1 identified site of future road-related mass wasting was classified as a road fill failure. Left untreated, this road-related landslide is expected to deliver approximately 26 yds^3 to the stream system.

There are a number of potential landslide sites located in the Dry Creek assessment area that did not, or will not deliver sediment to streams. These sites were not inventoried using data sheets (Figure 2) due to the lack of expected sediment delivery to a stream channel, but they were mapped on the mylar overlays of the 1:12000 scale field maps. They are generally shallow and of small volume, or located far enough away from an active stream such that delivery is unlikely to occur.

Ditch relief culverts - Five (5) ditch relief culvert sites were identified to have future sediment yield to stream channels. Of the 5 ditch relief culverts, 4 were recommended for erosion control and erosion prevention treatment. These sites are attributed to excessive ditch length contribution that causes a gully below the outlet which delivers sediment to a stream channel. Approximately 525 yds^3 of future sediment yield is expected to occur associated with these ditch relief culvert sites. These sites represent approximately 14% of the total predicted sediment yield from road related erosion.

Other sites - Three (3) other sites were identified for future sediment yield to stream channels. Other sites include springs, road surface drainage problems, and bank erosion. Approximately 30 yds^3 of future sediment yield is expected to occur associated with these miscellaneous sites. The other sites represent less than 1% of the total predicted sediment yield from road-related erosion.

Chronic erosion - Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 1.88 miles of the roadbed, ditch and cutbank along private roads currently deliver fine sediment and runoff to stream channels. Cutbank, road bed and ditch erosional processes are predicted to yield nearly 2,788 yds^3 (75%) of sediment to nearby streams over the next two decades, if road drainage practices remain the same. Relatively easy treatments can be applied to upgrade road systems to prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips and/or additional ditch relief culverts to disperse runoff.

Treatment Priority

Table 7 and Map 3 outline the treatment immediacy for all 23 inventoried sites with future sediment delivery recommended for erosion control and erosion prevention treatment along private roads in the Dry Creek watershed assessment area. Altogether, 7 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 2,224 yds^3. Fourteen (14) sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 1,463 yds^3. Finally, 2 sites were listed as having a low treatment immediacy which could yield approximately 35 yds^3 of future sediment delivery.

Treatments

Table 8 lists the site specific treatments for inventoried sites along private roads recommended for erosion prevention work in the Dry Creek watershed assessment area. Recommended erosion prevention work includes upgrading existing roads located in stable locations and temporarily or permanently decommissioning roads that are no longer necessary or located in unstable areas.

Upgrading typically consists of properly installing new culverts designed to accommodate the 100 - year return interval peak storm flow and debris which will be in transport. Upgrading also includes improving the road drainage by utilizing different road surface treatments such as installing frequent rolling dips or additional ditch relief culverts. When rolling dips are constructed on rocked roads, itemized costs include 10 yd^3 of road rock per rolling dip.

It is estimated that erosion prevention work will require the excavation of just over 287 yds^3 at 6 sites. Approximately 97% of the volume excavated is associated with upgrading or decommissioning stream crossings. Other miscellaneous treatments for inventoried sites on private roads in the Dry Creek watershed assessment area will include culvert replacements, installation of downspouts to prevent culvert outlet erosion, installation of rolling dips and ditch

Table 7. Treatment priorities for inventoried sediment sources on private roads in the Dry Creek watershed assessment area, Napa County, California				
Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**1** (site #: 308)	**1** (site #: 304)	2 stream crossings	152
High Moderate	**5** (site #: 306, 307, 406, 407, 408)	**0**	2 stream crossings, 1 landslide, 2 ditch relief culverts	2,072
Moderate	**5** (site #: 309, 401, 403, 412, 414)	**1** (site #: 305)	5 stream crossings, 1 other	538
Moderate Low	**8** (site #: 310, 311, 312, 402, 409, 410, 411, 413)	**0**	4 stream crossings, 2 ditch relief culverts 2 other	925
Low	**0**	**2** (site #: 303, 400)	2 stream crossings	35
Total	**19**	**4**	**15 stream crossings, 1 landslide, 4 ditch relief culverts 3 other**	**3,722**

Table 8. Recommended treatments along inventoried private roads in the Dry Creek watershed assessment area, Napa County, California.					
Treatment	**No.**	**Comment**	**Treatment**	**No.**	**Comment**
Critical dip	3	To prevent stream diversions	Armor inboard/ outboard fill face or ditch	2	Rock armor to protect outboard fillslope from erosion using 13 yds^3 of rock
Replace CMP	9	Upgrade an undersized CMP	Install rolling dips	15	Install rolling dips to improve road drainage
Replace bridge	1	Upgrade an old, unstable bridge (cost not included in this estimate)	Install ditch relief CMP	4	Install ditch relief culverts to improve road surface drainage
Excavate soil	6	Typically consisting of fillslope & stream crossing excavations; permanent excavation of 287 yds^3	Replace ditch relief CMP	2	Replace ditch relief culverts to improve road surface drainage
Install flared inlet	1	Install to increase the pipe capacity	Rock road surface	14	Rock or re-rock road surface using 215 yds^3 road rock at 8 stream crossing culvert replacements, 2 ditch relief culvert installations, 3 rolling dip installations, and 1 other site
Downspouts	2	Installed on stream crossing and ditch relief pipes to protect fillslope erosion	No treatment recommended	3	

relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Re-rocking the road prism has been prescribed on rocked roads at rolling dip installations, ditch relief culvert installations and stream crossing culvert upgrade locations. Each site has an individual data form which outlines the problem and describes in detail the recommended treatment and the estimated heavy equipment and labor requirements necessary at each site.

Equipment needs
Table 9 lists the expected heavy equipment and labor requirements by treatment immediacy to treat inventoried sites with future sediment delivery. Treatments for the 23 sites with potential sediment delivery along the 3.33 miles of the private road in the Dry Creek watershed assessment area will require approximately 78 hours of excavator and 56 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 9) . Approximately 4

Table 9. Estimated heavy equipment and labor requirements for treatment of inventoried sites on private roads with future sediment delivery, Dry Creek assessment area, Napa County, California.							
Treatment Immediacy	Site (#)	Total Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	7	192	38	32	3	1	38
Moderate, Low/Moderate	14	345	38	24	1	0	35
Low	2	16	2	0	0	0	0
Total	**23**	**553**	**78**	**56**	**4**	**1**	**73**

[1] Total excavated volume includes permanently excavated material and temporarily excavated materials used in backfilling upgraded stream crossings.

dump truck hours are needed for endhauling excess spoil. Dump truck times for road rocking are included with rock costs. Seventy-three (73) hours of labor is necessary for installing new culverts and other miscellaneous tasks, and 18 hours are for seeding, mulching and planting activities. The remaining equipment hours apply to prescribed road surfacing treatments.

Labor intensive needs

Many potential work sites will need mulching, seeding and/or tree planting following re-construction activities. These include fillslopes at stream crossings where new culverts are to be installed, at fillslope excavations to prevent future landsliding, as well as at all areas where excess spoil material derived from excavations is disposed of. Costs have been included for laborers to seed and mulch approximately 1.1 acres of ground following heavy equipment work along the private roads in the Dry Creek watershed assessment area. Weed free straw mulch will be applied at 50 bales/acre and erosion control seed will be applied at 50 pounds/acre.

Cost estimate for inventoried sites along 3.33 miles of private roads in the Dry Creek watershed assessment area

Table 10 summarizes the necessary costs by equipment types for the 23 sites with future sediment delivery. The estimate includes costs for seed and mulch, new culverts, downspouts, flared inlets, as well as rock necessary for rip rap and road surfacing at rolling dip and other specific locations. Hours represent direct equipment times and do not include travel time between work sites, additional costs for unseen complications or the time needed for conferences with equipment operators. These additional times are accounted for as logistics and are added to the total equipment hours to determine the total project cost (Table 10).

Table 10. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites with future sediment delivery on private roads in the Dry Creek watershed assessment area, Napa County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times: Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	Total Estimated Costs[5] ($)
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	3	--	3	300
	Dozer	100	3	--	3	300
Heavy Equipment requirements for site specific treatments	Excavator	165	60	18	78	12,870
	Dozer	140	41	12	53	7,420
	Dump truck	75	4	1	5	375
	Backhoe	85	1	0	1	85
Heavy Equipment requirements for road drainage treatments	Excavator	165	18	5	23	3,795
	Dozer	85	15	5	20	1,700
Laborers[7]		40	91	27	118	4,720
Grader[8]		120	35	11	46	5,520
Water truck[9]		90	39	12	51	4,590
Rock Costs: (includes trucking for 215 yds^3 of road rock and 13 yds^3 of rip-rap sized rock)						6,840
Culvert materials costs (240' of 18', 120' of 24", 50' of 30", 80' of 36" and 110' of 60". Costs included for couplers, flared inlets and elbows)						11,519
Paving for 200 ft^2 @ $ 0.63/ft^2						126
Bridge costs (1 bridge replacement)						20,000
Mulch, seed and planting materials for approximately 1.1 acres of disturbed ground[10]						606
Layout, Coordination, Supervision, and Reporting[11]		65	--	--	119	7,735
Total Estimated Costs[12]						**$ 68,501**
Potential sediment savings: 3,722 yds^3						
Overall project cost-effectiveness: $ 18.40 spent per cubic yard saved[9]						

[1] Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs for replacing excavated striping and reflectors not included.

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

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

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

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for one crew to areas within the Dry Creek watershed. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] An additional 18 hours of labor time is added for straw mulch and seeding on non-trench stream crossing culvert installations and stream crossing

decommission excavations.

[8] Thirty-five (35) hours of grader time is added to re-grade non-paved roads post treatment.

[9] Thirty-nine (39) hours of water truck time is added to at stream crossing backfills and rolling dip installations on private roads.

[10] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50 lbs. of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching.

[11] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 50% of the total excavator time for sit specific treatments and 50% of the excavator time for road drainage treatments plus 1 week prior and 1 week post project implementation.

[12] Total estimated costs do not include costs for engineered upgrades (i.e. engineered fills).

Total costs for the project are estimated at approximately $ 68,501 to treat the 23 sites inventoried with future sediment delivery along private roads and to significantly reduce sediment yield from the 1.88 miles of private road feeding sediment annual to streams. The average cost effectiveness value of the project is $ 18.40 per cubic yard of sediment prevented from entering Dry Creek and its tributaries. Cost effectiveness is slightly low to treat the private roads in the Dry Creek watershed. Many of the sites inventoried along private roads consisted of small volume stream crossings and the resulting sediment impacts would be less as compared to the remaining county maintained roads.

Costs are not included for the materials needed to install one flat car bridge on a private road. Costs in Table 10 assume that the work along the private roads will be accomplished during a single summer work period using one equipment team **(Note: Costs to re-rock the whole road system following implementing the proposed storm-proofing activities are not included in this table**.) The cost estimate includes layout, coordination, monitoring and reporting hours for a project coordinator to work with equipment operators to insure the plan is cost effectively implemented, as proposed, and treatments are installed or constructed properly and according to specifications.

Finally, the costs in Table 10 are based on a number of assumptions and estimates. The costs provided are reasonable if work is performed by outside contractors, with no added overhead for contract administration, and pre- and post-project surveying. Movement of equipment to and from the site will require the use of low-boy trucks. The majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road upgrading. The use of inexperienced operators would require additional technical oversight and supervision in the field. All recommended treatments conform to the general guidelines described in The Handbook for Forest and Ranch Roads prepared by PWA (1994) for the California Department of Forestry, Natural Resources Conservation Service and the Mendocino County Resource Conservation District.

APPENDIX B
Inventory results, erosion control and erosion prevention plan for county maintained roads within the Dry Creek watershed, Napa County, California

Approximately 14.7 miles of county maintained roads within the Dry Creek were inventoried in the assessment. Inventoried county roads include Dry Creek Road and Mount Veeder Road. Dry Creek Road is located along the mainstem of Dry Creek and on the south facing slopes of the watershed. Mount Veeder Road extends from the mainstem of Dry Creek into Montgomery Creek and along the south slopes encompassing Wing Canyon and Segassia Canyon. PWA personnel with the assistance of Napa RCD staff inventoried these roads for sites of potential sediment delivery to Dry Creek and its tributaries.

Sites with future sediment delivery were inventoried using a PWA data form (Figure 2 and Map 2). Table 11 displays the distribution of site types mapped during the sediment source investigation. Any potential landslides which posed a risk of delivering sediment to streams were identified along all the inventoried private roads. Every stream crossing was identified according to stream class (I, II, II), inventoried and described in detail. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

Ditch relief culverts were also identified where long stretches of road surface or ditch runoff deliver fine sediment to stream channels via gullies extending from ditch relief culvert outlets. The other category of sites includes miscellaneous erosional features such as road surface and ditch drainage problems that have the potential to deliver sediment to a stream channel. All sites were mapped on 1:12,000 USGS topographic maps with mylar overlays.

A total of 150 sites were identified with a risk of future sediment delivery along county maintained roads within the Dry Creek assessment area (Table 11). Sites include 96 stream crossings, 20 potential landslides, 32 ditch relief culverts and 2 miscellaneous other sites. Of the 150 inventoried sites, 123 have been recommended for erosion prevention treatment. In addition, 10.23 miles (70%) of the 14.7 miles of inventoried county maintained roads currently deliver sediment and runoff to streams.

Stream crossings - Ninety-six (96) stream crossings were identified in the field including 84 culverted fill crossings, 9 unculverted fill crossings, and 3 bridges. Of the 96 stream crossings inventoried, 88 have been recommended for erosion control and erosion prevention treatments. Total future erosion and sediment yield from stream crossing sites recommended for treatment is approximately 10,575 yds^3 if erosion prevention measures are not undertaken.

A significant problem from stream crossings inventoried on county maintained roads within the Dry Creek assessment area arise from stream crossings with a diversion potential. Of the 88 crossings recommended for erosion control and erosion prevention treatment, 65 have a diversion potential and 11 are currently diverted. Typically, treatments for stream diversions is easy and requires installation of a critical dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage. This can become an expensive treatment on paved county roads, because approximately 100 feet of the road would need to be resurfaced after each critical dip installation. A variety of alternate treatments can be used to treat diversion

Table 11. Site classification and sediment yield from all inventoried sites with future sediment delivery along county maintained roads, Dry Creek watershed assessment area, Napa County, California.

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Sites recommended for treatment			
			Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Stream crossings currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate) (#)
Stream crossings	96	88	10,575	65	11	52
Landslides	20	10	523	--	--	--
Ditch relief culverts	32	23	223	--	--	--
Other	2	2	20	--	--	--
Total (all sites)	150	123	11,341	65	11	52
Persistent surface erosion[1]	10.23	9.20	5,847	--	--	--
Totals	**150**	**123**	**17,188**	**65**	**11**	**52**

[1] Paved roads assume 8' average cutbank and ditch contributing area, and 0.4' surface lowering rate over two decades.

potentials other than critical dips. Although these treatments do not eliminate a diversion potential, they can reduce the likelihood of one occurring. Alternate treatments include over sizing the stream crossing pipe one size larger than required to pass the 100 - year storm flow, installing flared inlets to increase culvert capacity, and installing overflow pipes at the down road stream crossing hinge line.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 84 culverted stream crossings, 52 (62%) have a moderate to high plug potential. Erosion can also occur as a result of poorly installed culverts causing major gully erosion below the outlet. Approximately 62% of the total future sediment yield would result from erosion associated with stream crossing failures.

Landslides - Potential road-related landslides identified during the road inventory were divided into cutbank failures, landing fill failures, road fill failures, deep seated failures and others. Of the 20 identified sites of future road-related mass wasting, 11 were classified as a road fill failures and 9 were classified as cutbank failures. Ten (10) of the 20 potential landslides were recommended for erosion control and erosion prevention treatment. It is estimated that approximately 523 yds^3 could deliver to streams in the future is left untreated (Table 11). Correcting or preventing potential landslides associated with the road is typically straightforward, and involves the physical excavation of potentially unstable road fill and sidecast materials. These potential landslides were identified along public highway routes where road widths are insufficient to allow unstable road fill to be excavated without compromising driver safety. Therefore, these sites may need to have a engineered fills or retaining walls constructed in order to prevent road slip outs and sediment delivery to the stream network while maintaining sufficient road width. Although we have identified a number of these potential sites, we have not included engineering designs for these structures.

The majority of inventoried potential landslide sites that were not recommended for treatment were identified as cutbank landslides. Typically, cutbank landslides have low sediment delivery since the majority of failed materials are captured on the road bed. Cutbank landslide sites become more of a maintenance issue with regards to keeping the ditch and road surface free of failed cutbank materials. Direct excavation of unstable cutbanks is not recommended because it can result in further destabilization of the cutbank.

There are a number of potential landslide sites located in the Dry Creek assessment area that did not, or will not deliver sediment to streams. These sites were not inventoried using data sheets (Figure 2) due to the lack of expected sediment delivery to a stream channel, but they were mapped on the mylar overlays of the 1:12000 scale field maps. They are generally shallow and of small volume, or located far enough away from an active stream such that delivery is unlikely to occur.

Ditch relief culverts - Thirty-two (32) ditch relief culvert sites were identified to have future sediment yield to stream channels. Of the 32 ditch relief culvert, 23 have been recommended for erosion control and erosion prevention treatment. These sites are attributed to excessive ditch length contribution that causes a gully below the outlet which delivers sediment to a stream channel. Approximately 223 yds^3 of future sediment yield is expected to occur associated with these ditch relief culvert sites. These sites represent approximately 13% of the total predicted sediment yield from road related erosion.

Other sites - A total of 2 other sites were also identified in the Dry Creek watershed assessment area. Other sites include road surface and ditch problems which exhibited the potential to deliver sediment to streams. Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause hillslope gully erosion.

All 2 of the other sites have been recommended for erosion control and erosion prevention treatment. We estimate 20 yds^3 of sediment will be delivered to streams if they are left untreated (Table 11). Sediment delivery from these sites represents less than 1% of the total potential sediment yield from sites recommended for erosion control and erosion prevention treatment.

Chronic erosion - Road runoff is also a major source of fine sediment input to nearby stream channels. We measured approximately 10.23 miles of road surface and/or road ditch (representing 70% of the total inventoried county road mileage) which currently drain directly to stream channels and deliver ditch flow, road runoff and fine sediment to stream channels in the Dry Creek watershed assessment area (Table 11). These roads are said to be hydrologically connected to the stream channel network. This does not include inaccessible spur roads and driveways that also contribute runoff and sediment to the county roads and their drainage structures. When these roads are being actively maintained and used for access, they represent a potentially important source of chronic fine sediment delivery to the stream system.

Of the 10.23 miles of road surface and/or road ditch contribution, 9.2 miles have been recommended for treatment. From the 9.2 miles, we calculated approximately 5,847 yds^3 (34%) of sediment could be delivered to stream channels within the Dry Creek watershed over the next two decades, depending on road use, if no efforts are made to change road drainage patterns. This will occur through a combination of 1) cutbank erosion (ie., dry ravel, rainfall, freeze-thaw processes, cutbank failures and brushing/grading practices) delivering sediment to the ditch, 2) inboard ditch erosion and sediment transport, 3) mechanical pulverizing and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods.

Relatively straight-forward erosion prevention treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing road runoff and disconnecting road surface and ditch drainage from the natural stream channel network. Road surface treatments include the additional ditch relief culverts on paved county roads.

Treatment Priority

Table 12 and Map 3 outline the treatment immediacy for all 123 inventoried sites with future sediment delivery recommended for erosion control and erosion prevention treatment along county roads in the Dry Creek watershed assessment area. Altogether, 47 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 9,983 yds^3. Seventy (70) sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 6,991 yds^3. Finally, 6 sites were listed as having a low treatment immediacy which could yield approximately 214 yds^3 of future sediment delivery.

Treatments

Table 13 summarizes the proposed treatments for sites inventoried on inventoried county maintained roads in the Dry Creek watershed assessment area. The database, as well as the field inventory sheets, provides details of the treatment prescriptions for each site. Most treatments require the use of heavy equipment, including an excavator, loader, tractor, dump truck and backhoe. Some hand labor is required at sites needing new culverts, downspouts, culvert repairs, trash racks and/or for applying seed, plants and mulch following ground disturbance activities. Additional labor will be required to conduct traffic control at all work sites. Labor necessary to allow vehicles to pass through the work site with minimal delay will require a single flagman on both sides of the work site. The flaggers will be equipped with radios and stop signs and direct traffic to a single lane. Stop signs will replace flaggers during nights or hours when work will not be conducted. Longer or blind reaches may require the use of a pilot car.

It is estimated that erosion prevention work will require the excavation of approximately 8,831 yds^3 at 85 sites. Approximately 99% of the volume excavated is associated with upgrading and decommissioning stream crossings. A total of 702 yds^3 of 1.0 to 3.0 foot diameter mixed and clean rip-rap sized rock will be needed to armor twenty-three (23) inboard/outboard fill faces and inboard ditches, and 27 yds^3 is required to construct 1 armored ford. Rock armor has been

Table 12. Treatment priorities for inventoried sediment sources on county maintained roads in the Dry Creek watershed assessment area, Napa County, California

Treatment Priority	Upgrade sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**19** (site #: 10, 12, 28, 59, 60, 61, 77, 82, 88, 89, 92, 108, 117, 119, 135, 148, 150, 151, 152)	15 stream crossings, 1 landslide, 3 ditch relief culverts	3,378
High Moderate	**28** (site #: 9, 13, 14, 16, 17, 20, 21, 25, 34, 37, 46, 56, 62, 67, 70, 71, 75, 85, 102, 104, 109, 112, 120, 123, 126, 130, 134, 137)	24 stream crossings, 2 landslides, 2 ditch relief culverts	6,605
Moderate	**42** (site #: 2, 4, 6, 7, 24, 38, 41, 42, 44, 48, 49, 51, 52, 53, 57.1, 63, 66, 68, 72, 73, 76, 78, 80, 81, 83, 87, 91, 93, 101, 103, 103.1, 105, 106, 107, 110, 114, 115, 122, 137, 138, 139, 143)	34 stream crossings, 4 landslides, 4 ditch relief culverts	4,337
Moderate Low	**28** (site #: 11, 19, 22, 29, 31, 33, 36, 39, 43, 54, 55, 58, 74, 79, 86, 94, 113, 118, 121, 124, 128, 129, 131, 132, 133, 141, 144, 145)	13 stream crossings, 3 landslide, 10 ditch relief culverts 2 other	2,654
Low	**6** (site #: 23, 30, 57, 65, 90, 142)	2 stream crossings, 4 ditch relief culverts	214
Total	**123**	**88 stream crossings, 10 landslides, 23 ditch relief culverts 2 other**	**17,188**

prescribed on steep stream crossing outboard fillslopes to buttress the lower portion of the excavation in order to prevent the newly replaced fill from slumping and/or delivering to the stream network.

A total of 81 culverts are recommended to upgrade existing stream crossing culverts or install culverts at unculverted streams. Heavy equipment conducting stream crossing culvert upgrades on county roads will utilize two different methods to install new pipes. Methods are dependent on the depth of road fill at the stream crossing site. For a stream crossing that has a <8' deep road fill, a trench will be excavated. The new pipe will be installed and the crossing excavation will be back filled with an aggregate concrete slurry. All of the road fill that is excavated for the new culvert installation will be endhauled away from the site. Estimated excavator and backhoe times are based on a excavation production rate that is determined by the complexity of the work site. Dump trucks will endhaul spoil to a temporary storage area located by Napa County Department of Public Works (Napa DPW). A loader or dozer will be located at the temporary storage area to work the spoils.

Once the new pipe is set at or close to the natural channel gradient a cement truck will haul slurry material to backfill the excavated crossing. Each trench crossing will be backfilled with a

Table 13. Recommended treatments along inventoried county maintained roads in the Dry Creek watershed assessment area, Napa County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Excavate and remove soil	85	Typically consisting of fillslope & stream crossing excavations; permanent excavation of 8,831 yds^3	Reconstruct fill	1	Engineered fill design to reconstruct fill at 1 landslide site
Install CMP	6	Install a CMP at an unculverted fill	Back fill at culvert trench installations with 2 sack slurry mix	184	Backfill with 4,151 yds^3 slurry mix at stream crossing and ditch relief culvert trench installations
Replace CMP	75	Upgrade an undersized CMP	Back fill at culvert non-trench installations with clean rock	6	Backfill at non-trench culvert installations with 2,583 yds^3 of clean rock
Clean culvert	5	Clean culvert inlet to prevent plugging	Add asphalt berm	3	Add 279' of asphalt berm to improve road surface drainage
Install wet crossing	1	Install 1 armored ford using 27 yds^3 of rip rap	Clean/cut ditch	11	Clean/cut 1,565' of ditch to improve road surface drainage
Armor inboard/ outboard fill face or ditch	23	Rock armor to protect inboard and outboard fillslopes, and ditches from erosion using 675 yds^3 of rock	Install ditch relief CMP	90	Install ditch relief culverts to improve road surface drainage
Install flared inlet	35	Install to increase the pipe capacity	Replace ditch relief CMP	14	Replace ditch relief culverts to improve road surface drainage
Downspouts	28	Installed on stream crossing and ditch relief pipes to protect fillslope erosion	Other	7	Miscellaneous treatments
Rebar or fence post trash rack	13	Installed to prevent culvert from plugging	No treatment recommended	27	

slurry to ensure a hardened surface that will not settle after the new pipe installation is completed. Cement trucks can haul 10 yds^3 of slurry and are able to backfill at a rapid 10 yds^3 in 10 minutes. Costs for the cement truck are based on the cost of the material delivered to the average work site. Several cement trucks will be utilized at once and may be required to deliver up to 150 cubic yards of slurry to backfill a larger trench crossing. The crossing then will be capped with new pavement whose surface area is based on the width and length of the excavation. Then the crossing then will be swept with a mechanical broom.

For crossings >8' deep and fill depths beyond the reach of an excavated trench, a non-trenched excavation will be applied. To install a new pipe at the natural channel gradient, a deep crossing will require the excavator to open up a crossing completely to safely allow room for laborers to replace or install the pipe deep in the fill. The excavation will require sideslopes be excavated back at a 1:1 slope (at least), which differs significantly from a typical trenched excavation. Approximately 100 yds^3 of material will be stockpiled on-site and the remaining road fill will need to be endhauled to a temporary storage location. The new pipe will be installed using the locally stockpiled spoils for a compacted bed. The remaining excavation will then be backfilled with clean quarry fill.

For some deep stream crossings where an excavator cannot reach the natural stream bottom and install a culvert at the natural channel gradient, downspouts have been prescribed to transport the stream flow beyond the road fill to the natural stream bottom. To prevent potential stream diversions, each site with a high diversion potential has been prescribed to either have an oversized pipe or to have a flared inlet to increase pipe inlet capacity. Thirty-five (35) flared inlets have been prescribed for installation to increase the inlet capacity at certain stream crossings. A minimum of 104 new ditch relief culverts are recommended for installation or replacement along the inventoried road routes to disconnect connected ditches from natural stream channels (Table 13).

Equipment Needs and Costs

Treatments for the 123 sites identified with future sediment delivery along county maintained roads in the Dry Creek assessment area will require approximately 484 hours of excavator time and 429 hours of backhoe time to complete all prescribed upgrading and erosion control and erosion prevention work (Table 14).

Backhoe time has been listed to conduct shallow excavations, install ditch relief culverts, and clean ditches. A loader has been listed for 27 hours of work to backfill large stream crossings, and keep the road swept of any obstacles that might stop traffic. Approximately 956 hours of dump truck time has been listed for work in the basin for end-hauling excavated spoil from stream crossings and at unstable road and landing fills where local disposal sites are not available. Approximately 1,059 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts, and an additional 14 hours of labor are for seeding, mulching and planting activities.

Approximately 2,178 hours have been for traffic control and includes a crew of two flagmen during heavy equipment work hours. Approximately 366 hours for a roller and 366 hours for a mechanical broom have been listed to finish each site.

Table 14. Estimated heavy equipment and labor requirements for treatment of inventoried sites with future sediment delivery on county maintained roads, Dry Creek watershed assessment area, Napa County, California. [1]

Treatment Immediacy	High, High/Moderate	Moderate, Low/Moderate	Low	**Total**
Site (#)	47	70	6	**123**
Total Excavated Volume (yds^3)[2]	6,165	2,816	0	**8,981**
Excavator (hrs)	275	208	1	**484**
Dozer (hrs)	0	7	0	**7**
Loader (hrs)	22	5	0	**27**
Dump Trucks (hrs)	605	348	3	**956**
Labor (hrs)	442	602	15	**1,059**
Traffic Control (hrs)	978	1,170	30	**2,178**
Roller (hrs)	140	220	6	**366**
Broom (hrs)	140	220	6	**366**
Pavement cutter (hrs)	69	110	3	**182**
Backhoe (hrs)	128	286	15	**429**

[1] Estimated equipment times do not include daily lowboy or travel costs to treatment sites.
[2] Total excavated volume includes permanently excavated material and a percentage of temporarily excavated materials used in backfilling upgraded stream crossings at non-trench installations.

Estimated costs for erosion prevention treatments - Prescribed treatments are divided into two components: a) site specific erosion prevention work identified during the watershed inventories, and b) control of persistent sources of road surface, ditch and cutbank erosion and associated sediment delivery to streams. The total costs for road-related erosion control at all the inventoried sites with future sediment delivery to the Dry Creek watershed is estimated at approximately $1,231,101 for an average cost-effectiveness value of approximately $71.62 per cubic yard of sediment prevented from entering Dry Creek and its tributaries (Table 15). As

Table 15. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites on county maintained roads with future sediment delivery in the Dry Creek watershed assessment area, Napa County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	3	--	3	300
	Dozer	100	3	--	3	300
Heavy Equipment requirements for site specific treatments	Excavator	165	484	145	629	103,785
	Dozer	140	7	2	9	1,260
	Dump truck	75	852	256	1,108	83,100
	Backhoe	85	13	4	17	1,445
	Loader	140	27	8	35	4,900
	Pavement cutter	140	78	23	101	14,140
	Broom	55	158	47	205	11,275
	Roller	50	158	47	205	10,250
Heavy Equipment requirements for road drainage treatments	Backhoe	85	416	125	541	45,985
	Dump truck	75	104	31	135	10,125
	Pavement cutter	140	104	31	135	18,900
	Broom	55	206	62	268	14,740
	Roller	50	206	62	268	13,400
Laborers[7]		40	1,073	322	1,395	55,800
Traffic control laborers		30	2,178	653	2,831	84,930
Rock Costs: (includes trucking for 702 yds^3 of rip-rap sized rock and 2,583 yds^3 of clean backfill)						98,550
Backfill Slurry Costs: (includes trucking and pouring for 4,151 yds^3 of backfill slurry)						394,345
Culvert materials costs (4,990' of 18', 1,610' of 24", 1,785' of 30", 600' of 36", 280' of 42", 710' of 48", 140' of 54", 290' of 60", 60' of 66", 70' of 72" and 110' of 96". Costs included for couplers, flared inlets and elbows)						194,635
Paving for 34,880 ft^2 @ $ 0.63/ft^2						21,974
Asphalt berm installation ($23/ft. @ 279')						6,417
Mulch, seed and planting materials for approximately 0.9 acres of disturbed ground[8]						495
Layout, Coordination, Supervision, and Reporting[9]		45 60 75	--	--		23,850 13,200 3,000
Total Estimated Costs[12]						**$ 1,231,101**

Table 15. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites on county maintained roads with future sediment delivery in the Dry Creek watershed assessment area, Napa County, California

Cost Category[1]	Cost Rate[2] ($/hr)	Estimated Project Times: Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	Total Estimated Costs[5] ($)
Potential sediment savings: 17,188 yds³					
Overall project cost-effectiveness: $71.62 spent per cubic yard saved[10]					

[1] Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs for replacing excavated striping and reflectors not included.

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

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

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

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for one crew to areas within the Dry Creek watershed. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] An additional 14 hours of labor time is added for straw mulch and seeding post excavation at selected sites.

[8] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50 lbs. of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching.

[9] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 50% of the total excavator time for sit specific treatments and 50% of the backhoe time for road drainage treatments plus 1 week prior and 1 week post project implementation.

[10] Total estimated costs do not include costs for engineered upgrades (i.e. engineered fills).

stated earlier, treatment cost-effectiveness for forest, ranch and rural subdivision roads is not directly comparable to values which might be developed for the treatment of county public roads. Costs for treatments on county public roads are typically much higher, and the resulting cost-effectiveness values will be less favorable.

Total estimated costs include lowboy costs for one round trip to transport an excavator and a dozer to the Dry Creek assessment area. Total estimated costs do not include the daily travel costs to transport equipment and labor to the treatment sites.

Overall site specific erosion prevention work: Equipment needs for site specific erosion prevention work at sites with future sediment delivery are expressed in the database, and summarized in Table 14, as direct excavation times, in hours, to treat all sites having a high, moderate, or low treatment immediacy. These hourly estimates include only the time needed to treat each of the sites, and do not include travel time between work sites, times for basic road surface treatments that are not associated with a specific site, or the time needed for work conferences at each site. These additional times are accumulated as "logistics" and must be added to the work times to determine total equipment costs as shown in Table 15.

The costs in Table 15 are based on a number of assumptions and estimates, and many of these are included as footnotes to the table. The costs provided are assumed reasonable if work is performed by outside contractors, with no added overhead for contract administration and preand post-project surveying. Movement of equipment to and from the site will require the use of low-boy trucks. The majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road upgrading. The use of inexperienced operators would require additional technical oversight and supervision in the field. All recommended treatments conform to the general guidelines described in The Handbook for Forest and Ranch Roads prepared by PWA (1994) for the California Department of Forestry, Natural Resources \ Conservation Service and the Mendocino County Resource Conservation District.

PHOTOGRAPHS OF HIGH PRIORITY ROAD TREATMENT SITES AFTER DECEMBER, 2002 STORMS

Photograph 1: Culvert plugged from heavy December 2002 rainfall. (Mt. Veeder Road within the upper Montgomery Creek watershed.)

Photograph 2: Eroding road fillslope delivering sediment to Dry Creek. (Dry Creek Rd. in the middle canyon region of the watershed)

Photograph 3: Crushed culvert plugged with sediment (Mt. Veeder Road).

Photograph 4: Inadequately armored outlet of plugged culvert with newly deposited sediment from failing road cutbank and overland flow erosion. (Dry Creek Road).

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Photograph 5: Deeply cut erosional gully with undersized ditch relief culvert (Mt. Veeder Road, upper Wing Canyon watershed).

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Photograph 6: Road failure from delivering landslide. (Mt. Veeder Road, upper Segassia Creek watershed).