Summary Report

1999 S. B. 271 Watershed Assessment for a portion of Mill Creek, Tributary to the Navarro River

prepared for

Daniel T. Sicular, and the
Mendocino County Resource Conservation District,
and the California Department of Fish and Game

by

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Background

Mill Creek is an important anadromous fish bearing third order tributary to the Navarro River basin in Mendocino County. The basin is approximately 12 mi^2 with the confluence of Mill Creek and the Navarro River located approximately 4 miles downstream from the town of Philo (Figure 1). Three tributaries, Hungry Hollow Creek, Little Mill Creek, and Meyer Gulch within the Mill Creek watershed are known to have or be capable of sustaining populations of anadromous salmonids including coho salmon and steelhead trout. There is a high abundance of steelhead trout in Mill Creek, but lack of pool habitat and large amounts of fine sediment have limited the presence of and rearing habitat for coho salmon (ENTRIX, Inc, et al., 1998).

Initial timber harvesting in the lowland areas of the Mill Creek watershed occurred early in this century with the construction of a rail line along the mainstem of Mill Creek to above Hungry Hollow Creek and up Little Mill Creek. Timber harvesting and livestock grazing (first by sheep and then by cattle) were the predominant land uses during the recent historical period from the 1940's to the 1970's. There are approximately 130 landowners in the Mill Creek watershed. Currently, the dominant land uses in the watershed are rural residential, small orchards or vineyards, and limited grazing (primarily sheep). A few landowners have continued some timber harvesting activities that involve selective thinning (Pacific Watershed Associates, 1998).

The Mill Creek Watershed Restoration Project was conducted in two phases (phase I -1998, phase II -1999) utilizing funding secured through the California Department of Fish and Game Senate Bill 271 Proposal process (PWA, 1998). The project was contracted through the Mendocino County Resource Conservation District and Daniel T. Sicular to develop an erosion control and prevention plan of action for a portion of the Mill Creek watershed. The two S.B. 271 grants were administered by the Mendocino County Resource Conservation District (MCRCD), with Daniel Sicular serving as the Contractor's Representative. Pacific Watershed Associates (PWA) was retained as a subcontractor by Daniel Sicular to conduct the upland sediment source assessments and develop implementation plans for controlling erosion and sediment yield to Mill Creek and its tributaries. The goal of the assessments was to lessen road related impacts on Mill Creek and ultimately improve the habitat for coho salmon re-population.

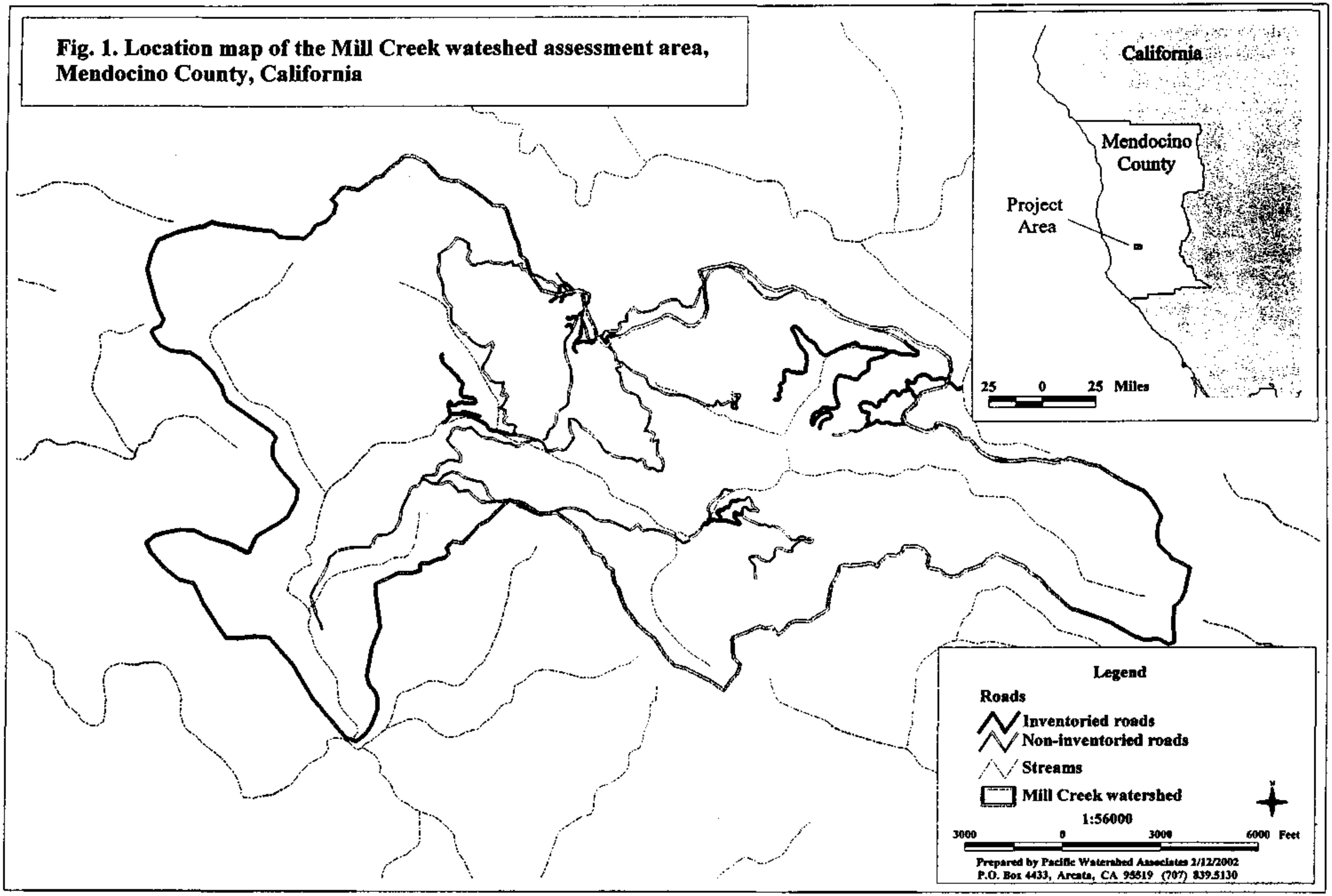

Fig. 1. Location map of the Mill Creek wateshed assessment area, Mendocino County, California

Phase I of the Mill Creek Watershed Restoration Project was initiated in the summer of 1998 to inventory approximately 29 miles of roads managed and maintained by 4 separate landowner/road association groups for sites with potential future erosion and sediment delivery to Mill Creek and its tributaries. The landowners include the Bates ownership, the Hungry Hollow Road Association, the Holmes Ranch Road Association, and the Nash-Mill Road Association A final summary report and erosion control and erosion prevention plan was submitted to the California Department of Fish and Game, the Mendocino County Resource Conservation District and Daniel T. Sicular in July, 1999. In the conclusion of the final report, it was suggested that watershed assessment inventories should be conducted on the remaining upland roads, both driveable and abandoned, in the Mill Creek watershed.

In 1999, S.B. 271 funding was secured to conduct Phase II of the Mill Creek Watershed Restoration Project. The goal of the project was to inventory approximately 18 miles of additional roads for sediment sources with potential future delivery to Mill Creek and its tributaries, and produce a prioritized erosion control and erosion prevention plan. Due to the difficulty in acquiring landowner access for the entire 18 miles of road within the Mill Creek watershed, only 15 miles were inventoried utilizing the available S.B. 271 grant monies.

Project Description

In the first stage of the project, digital orthoquads were analyzed to determine the location of roads within the Mill Creek assessment area. Each road identified was mapped on a mylar overlay over a GIS generated USGS topographic base map. The base map was used in the field to locate sites with future erosion and sediment delivery. The second stage of the project involved a complete inventory of the road system. The inventory identified sites where there was a potential for future sediment delivery to the stream system that could impact fish bearing streams in the watershed. Sites of future erosion that were not expected to deliver sediment to a stream were identified, but not included in the assessment. Sites of past erosion were not inventoried, unless there was a potential for future sediment delivery. All roads, including both maintained and abandoned routes, were walked and inspected by trained personnel and all existing and potential erosion sites were identified and mapped.

Inventoried sites generally consisted of stream crossings, gullies below ditch relief culverts and long sections of uncontrolled road and ditch surface runoff. For each identified existing or potential sediment source, a database form was filled out and the site was mapped on a Mylar overlay over an orthoquad or topographic map. The database form (Figure 2) contains 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. The volume of potential future sediment erosion and the percentage delivered to the stream system was estimated for each site. This estimate provides quantitative volumes of how much sediment 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 stream diversion sites, actual sediment loss could easily exceed field predictions.

In addition to the database information, tape and clinometer surveys were completed on virtually all

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

*ASAP*___ **PWA ROAD INVENTORY DATA FORM** (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:							
EXCAVATION VOLUME Total excavated (yds^3) ______			Vol put back in (yds^3) ______		Volume removed (yds^3) ______		
	Vol stockpiled (yds^3) ____	Vol endhauled (yds^3) ____	Dist endhauled (ft) ____	Excav prod rate (yds^3/hr) ______			
EQUIPMENT HOURS	Excavator (hrs) ______	Dozer (hrs) ______	Dump truck (hrs) _____	Grader (hrs) ______			
	Loader (hrs) ____	Backhoe (hrs) _____	Labor (hrs) _____	Other (hrs) ____			
COMMENT ON TREATMENT:							

stream crossings. These surveys included a longitudinal profile of the stream crossing through the road prism, as well as one or more cross sections. The survey data was entered into a computer program that calculates the volume of fill in the crossing. The survey allows for accurate and repeatable quantification of future erosion volumes (assuming the road 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.)

Inventory Results

Approximately 15 miles of roads were inventoried for future sediment sources within the Mill Creek watershed. Inventoried road-related erosion sites fit into one of two treatment categories: 1) upgrade sites - defined as sites on maintained open roads that are to be retained for access and management and 2) decommission sites - defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure.

A total of 46 road-related sites were identified with the potential to deliver sediment to streams. Of these, 42 were recommended for erosion control and erosion prevention treatment. Approximately 35 (76%) of the sites are classified as stream crossings and 1 as a potential landslide (Table 1 and Figure 3). The remaining 10 (22%) of the inventoried sites consist of "other" sites which include ditch relief culverts, gullies, stream bank erosion and springs.

Landslides - Only road-related landslide sites with a potential for sediment delivery to a stream channel were inventoried. One potential landslide was inventoried in the Mill Creek assessment area (Table 1). This site was found along a road where material was sidecast during earlier construction and now shows signs of instability. The potential landslide is expected to deliver approximately 13 yds^3 of sediment to Mill Creek and its tributaries in the future. Correcting or preventing potential landslides associated with the road is relatively straightforward, and involves the physical excavation of potentially unstable road fill and sidecast materials.

There are a small number of potential landslide sites located in the Mill Creek assessment area that did not, or will not deliver sediment to streams. The location of these sites was mapped on the field base map, but they were not inventoried due to the lack of expected delivery to a stream channel. They are generally shallow, or located far enough away from an active stream such that delivery is unlikely to occur.

Stream crossings - Thirty-five (35) stream crossings were inventoried in the Mill Creek assessment area including 14 culverted crossings, 2 bridges, 1 ford, 9 unculverted fill crossings, and 10 pulled or excavated crossings. 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, over the fillslope, or it is diverted down the road surface or the inboard ditch. Most of the unculverted fill crossings are located at small Class III streams that exhibit flow only in larger runoff events.

Approximately 3,112 yds^3 of future road-related sediment delivery in the Mill Creek assessment area is expected to originate from stream crossings if not treated (Table 1). This amounts to

Table 1. Site classification and sediment yield from all inventoried sites with future sediment deliver}' in the Phase II Mill Creek watershed assessment area, Mendocino County, California.

			Sites recommended for treatment			
Site Type	**Number of sites (#)**	**Number of sites or road miles to treat (#)**	**Future yield (yds^3)**	**Stream crossings w/ a diversion potential (#)**	**Streams currently diverted (#)**	**Stream culverts likely to plug (plug potential rating = high or moderate) (#)**
Landslides	1	1	13	--	--	--
Stream crossings	35	32	3,112	10	5	5
Other	10	9	1,579	--	--	--
Total (all sites)	46	42	4,704	--	--	--
Persistent surface erosion[1]	3.06	3.03	5,933	--	--	--
Totals	**46**	**42**	**10,637**	**10**	**5**	**5**

[1] Assumes 25' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over a two decade period.

about 29% of the total sediment yield from the road system. The most common problems that cause erosion at stream 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, 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. Even sediment delivered to small ephemeral streams will eventually deliver to downstream fish-bearing stream channels.

At stream crossings, the largest volumes of future erosion can occur when culverts plug or when potential storm flows exceed culvert capacity (i.e., the culvert is too small for the drainage area) 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

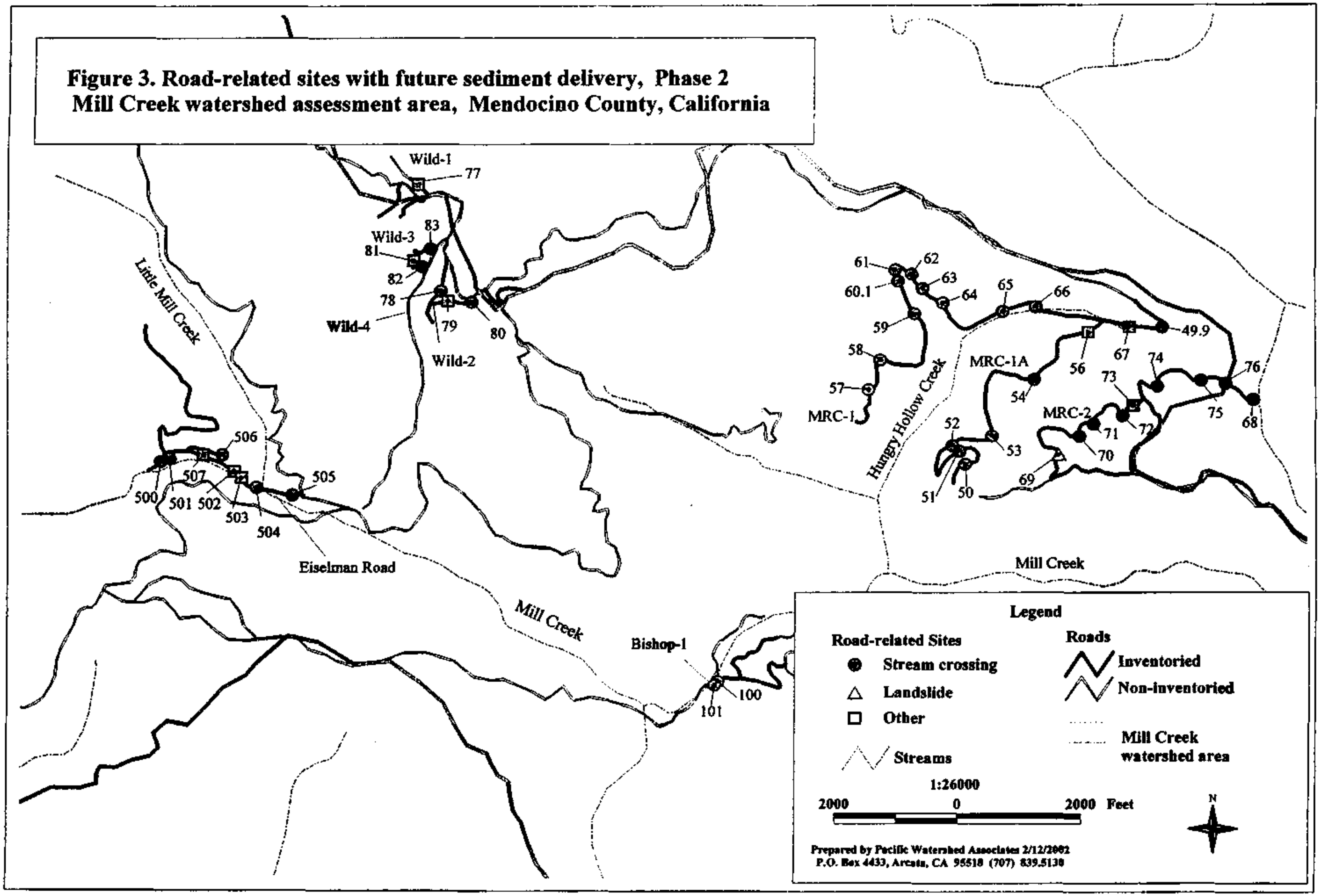

Figure 3. Road-related sites with future sediment delivery, Phase 2 Mill Creek watershed assessment area, Mendocino County, California

quite large and can deliver significant quantities of sediment to stream channels. Diverted stream flows discharged onto steep, potentially unstable slopes can also trigger large hillslope landslides.

Of the 32 stream crossings recommended for treatment, 10 (31 %) have the potential to divert in the future and 5 (16%) streams are currently diverted (Table 1). Five of the fourteen existing culverts have a moderate to high plugging potential. Because the roads were constructed many years ago, many culverted stream crossings are under designed for the 100 year storm flow. At stream crossings with no or undersized culverts, or where there is a diversion potential, corrective prescriptions have been outlined on the data sheets and in the following tables. Preventative treatments include such measures as constructing critical dips (rolling dips) at stream crossings to prevent stream diversions, installing larger culverts wherever current pipes are under designed for the 100 year storm flow (or where they are prone to plugging), installing culverts at the natural channel gradient to maximize the sediment transport efficiency of the pipe and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill, and installing debris barriers and/or downspouts to prevent culvert plugging and outlet erosion, respectively, and armoring the downstream fill face of the crossing to minimize or prevent future erosion, or properly excavating the stream crossing of all fill material.

"Other" sites - A total of 10 "other" sites were also identified in the Mill Creek assessment area. '"Other" sites include ditch relief culverts, major springs, gullies and bank erosion sites which exhibited the potential to deliver sediment to Mill Creek and/or its tributaries. 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 gully erosion on the hillslopes below the outlet of ditch relief culverts. Of the 10 "other" sites identified, 9 have been recommended for erosion control and erosion prevention treatment. We estimate 1,579 yds^3 of sediment will be delivered to streams if they are left untreated (Table 1). Sediment delivery from these sites represents nearly 15% 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 3.06 miles of road surface and/or road ditch (representing 24% 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 Mill Creek assessment area (Table 1). These roads are said to be "hydrologically connected" to the stream channel network. All 3 miles of "hydrologically connected" roads have been recommended for erosion control and erosion prevention treatment.

Of the 3.06 miles of road surface/and or road ditch contribution, 3.03 miles have been recommended for treatment. From the 3.03 miles, we calculated approximately 5,933 yds^3 of sediment could be delivered to stream channels in the Mill 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 (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.

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:

1) the expected volume of sediment to be delivered to streams (yds^3),
2) the potential or "likelihood" for future erosion (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 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. It 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 the cost-effectiveness of the 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. If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy might be considered "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.

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

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$ ($2000/500$yds^3$).

To be considered for a priority treatment a site should typically exhibit: 1) potential for significant (>25 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 averaging in the general range of approximately $5 to $15/$yds^3$, or less. 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. During road decommissioning, groups of sites are usually considered together since there will only be one opportunity to treat potential sediment sources along the road. In this case, cost-effectiveness may be calculated for entire roads or road reaches that fall into logical treatment units.

Cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and Sonnevil, 1984; Weaver, *et al.,* 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 (>$15/$yds^3$), 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 (when access is reopened into areas for future management activities), or when heavy equipment is performing routine maintenance or restoration at nearby, higher priority sites.

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). 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, 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. The characteristics of storm-proofed roads, including those which are either upgraded or decommissioned, are depicted in Figure 4.

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FIGURE 4. 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

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

ROAD AND LANDING FILLS

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

ROAD SURFACE DRAINAGE

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

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, 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 berm removal, road outsloping, rolling dip construction, and/or the installation of additional ditch relief culverts.

Road decommissioning basically involves "reverse road construction," except that full topographic obliteration of the road bed is not normally required to accomplish sediment prevention goals. Generic treatments for decommissioning roads and landings range from outsloping or simple crossroad drain construction to full road decommissioning (closure), including the excavation of unstable and potentially unstable sidecast materials road fills, and all stream crossing fills.

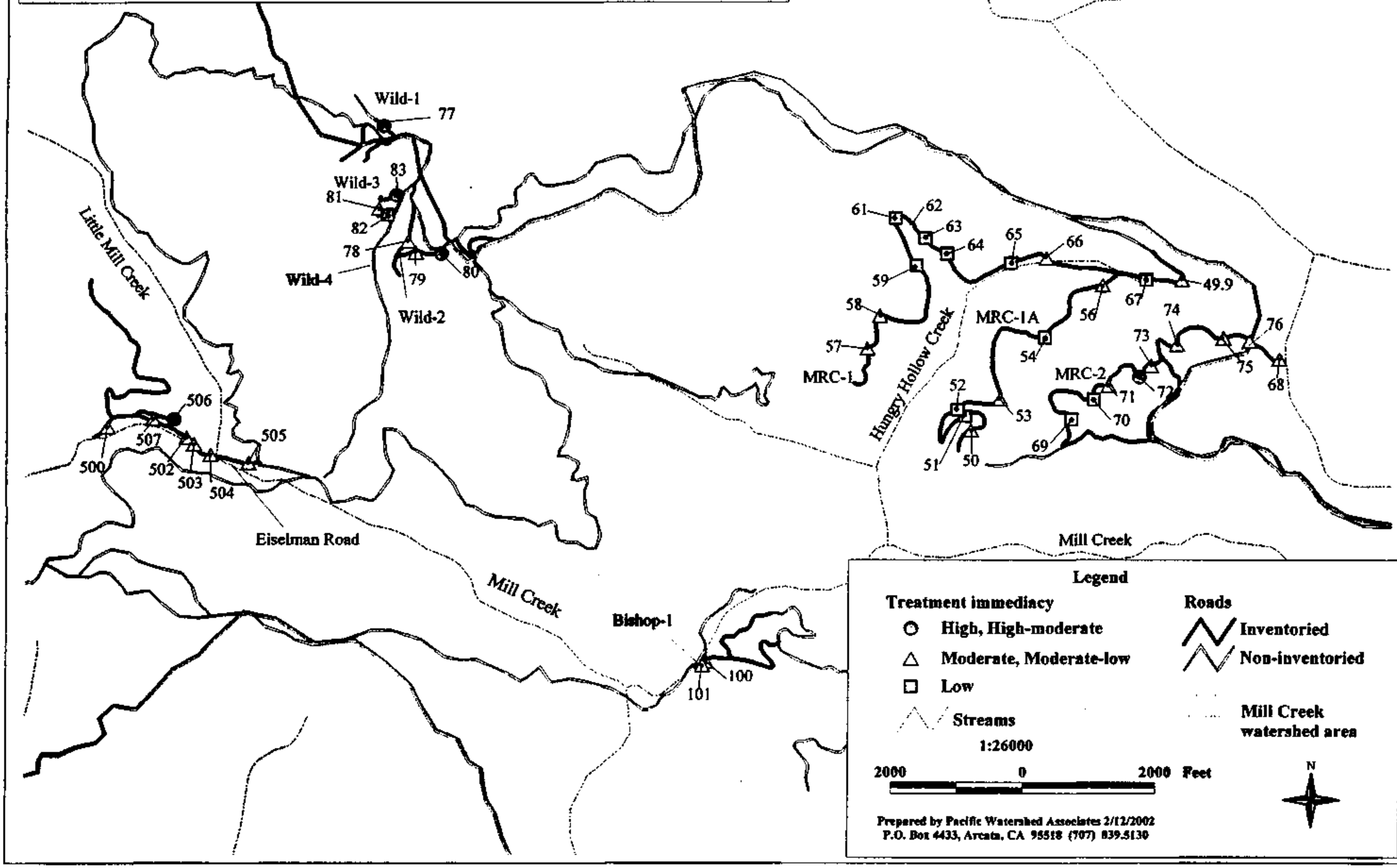
Treatments

Basic treatment priorities and prescriptions were formulated concurrently with the identification, description and mapping of potential sources of road-related sediment delivery sites. Table 2 and Figure 5 outline the treatment priorities for all 42 sites with future sediment delivery that have been recommended for treatment in the Mill Creek assessment area. Of the 42 sites with future sediment

Table 2. Treatment priorities for inventoried sediment sources in the Phase II Mill Creek watershed assessment area, Mendocino County, California

Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High Moderate	4 (site #: 72, 77, 80, 83)	1 (site #: 506)	4 stream crossings, 1 other	1,078
Moderate	5 (site #: 49.9, 71, 100, 101,505)	6 (site #: 55, 57, 58, 78, 79,81)	9 stream crossings, 2 other	5,616
Moderate Low	11 (site #: 66, 68, 73, 74, 75, 76, 500, 502, 503, 504, 507)	3 (site #: 50, 53,56)	9 stream crossings, 5 other	2,971
Low	6 (site #: 59, 65, 67, 69, 70, 82)	6 (site #: 51, 52, 54,61, 63, 64)	10 stream crossings, 1 landslides, 1 other	972
Total	**26**	**16**	**32 stream crossings, 1 landslide, 9 other**	**10,637**

Figure 5. Treatment immediacy for road-related sites, Phase 2 Mill Creek watershed assessment area, Mendocino County, California



delivery, 5 sites were identified as having a high-moderate treatment immediacy with a potential sediment delivery of approximately 1,078 yds^3. Twenty-five (25) sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 8,587 yds^3. Finally, 12 sites were listed as having a low treatment immediacy with approximately 972 yds^3 of future sediment delivery.

Table 3 summarizes the proposed treatments for sites on inventoried roads in the Mill Creek assessment area. These prescriptions include both upgrading and road closure measures. The database, as well as the field inventory sheets, provide details of the treatment prescriptions for each site. Most treatments require the use of heavy equipment, including any one or a combination of the following: excavator, tractor and/or dump truck. Some hand labor is required at sites needing new culverts, downspouts, flared inlets, culvert repairs or for applying seed, plants and mulch following ground disturbance activities.

Table 3. Recommended treatments along all inventoried roads in the Mill Creek watershed assessment area, Mendocino, California.

Treatment	No.	Comment II	Treatment	No.	Comment
Critical dip	4	To prevent stream diversions	Armor fill face	2	Rock armor to protect outboard fillslope from erosion using 15 yds^3 of rock
Install CMP	2	Install a CMP at an unculverted fill	In stream armor	1	Rock armor to protect stream channel from head cut erosion using 20 yds^3 of rip rap
Replace CMP	8	Upgrade an undersized CMP	Install rolling dips	79	Install rolling dips to improve road drainage
Excavate soil	30	Typically fillslope & crossing excavations; permanent excavation of 5732 yds^3	Cross-road drains	85	Install permanent road drainage for decom-missioned roads
Down spouts	1	Installed to protect the outlet fillslope from erosion	Rock road surface	27	Rock road surface using 270 yds^3 road rock.
Wet crossing	7	Install rocked ford and armored fill crossing using 35 yds^3 rip-rap	Clean/cut ditch	1	Clean/cut 40 feet of ditch
Clean culvert	1	Clean culvert inlet to prevent plugging	No treatment recommended	4	

A total of 4 critical rolling dips have been recommended to prevent future diversions at streams that currently have a diversion potential. A total of 10 culverts are recommended to upgrade existing culverts or install culverts at unculverted streams. It is estimated that erosion prevention work will require the removal of approximately 5,732 yds^3 at 30 sites. Approximately 44% of the total volume excavated is associated with upgrading or excavating stream crossings, 3% is proposed for excavating potentially unstable road fills (landslide) and the remaining 53% is associated with excavation at "other" sites. We have recommended 79 rolling dips be constructed at selected locations, at spacings dictated by the steepness of the road. A total of 70 yds^3 of 0.25 to 1 foot diameter mixed and clean rip-rap sized rock is proposed to construct 7 armored wet crossings, armor 2 outboard fill faces, and armor 1 stream channel site. Approximately 270 yds^3 of road rock is required to rock the road surface at 18 rolling dips, 7 stream crossing culvert installations, and 2 other site specific locations. All recommended treatments conform to 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.

Equipment Needs and Costs

Treatments for the 42 sites identified with future sediment delivery in the Mill Creek assessment area will require approximately 182 hours of excavator time and 289 hours of tractor time to complete all prescribed upgrading, road closure, erosion control and erosion prevention work (Table 4). Excavator and tractor work is not needed at all the sites that have been recommended for treatment and, likewise, not all the sites will require both a tractor and an excavator. Approximately 32 hours of dump truck time has been listed for work in the basin for end-hauling excavated spoil from stream crossings. In addition, approximately 45 hours of labor time is needed for a variety of tasks including installation or replacement of culverts, installation of downspouts, and 44 additional labor hours are needed for seeding, mulching and planting activities.

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment deliver)', Mill Creek assessment area, Mendocino County, California.

Treatment Immediacy	Site (#)	Total Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Labor (hrs)
High, High/Moderate	5	762	30	42	30	13
Moderate, Low/Moderate	25	6,028	132	220	2	27
Low	12	565	20	27	0	5
Total	**42**	**7,355**	**182**	**289**	**32**	**45**

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

Estimated costs for erosion prevention treatments - Prescribed treatments were divided into two categories: 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 delivery to streams. The total costs for road related erosion control at sites with sediment delivery is estimated at approximately $111,420 for an average cost-effectiveness value of approximately $ 10.47 per cubic yard of sediment prevented from entering Mill Creek and its tributaries (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 and road decommissioning operations on forest lands. The use of inexperienced operators or the wrong combination of heavy equipment would require additional technical oversight and supervision in the field, as well as an escalation of the costs to implement the work.

Table 5 lists a total of 174 hours for "supervision" time for detailed pre-work layout, project planning (coordinating and securing equipment and obtaining plant and mulch materials), on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project cost effectiveness analysis and reporting. It is expected that the project coordinator will be on-site full time at the beginning of the project and intermittently after equipment operations have begun.

Conclusion

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

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

The proper word for pro-active road closure is "decommissioning". Decommissioning may be either permanent or temporary, but the treatments are largely the same. Properly decommissioned roads no longer require maintenance and are no longer sources of accelerated erosion and sediment delivery to a watershed's streams. The impacts of reopening old, abandoned roads so that they can be correctly decommissioned has been evaluated on a case-by-case basis, but the benefits (large reductions in long term erosion) almost always far outweigh the negative effects (small, short-term increases in erosion from bare soil areas).

Decommissioning does not necessarily suggest permanent closure. Most decommissioned roads, if they are in stable locations, can be rebuilt and reopened at a future date, if they are needed, by simply reinstalling the stream crossings and regrading the former road bed. Some roads are to be permanently closed, and they will be ripped (decompacted) and replanted.

Road upgrading consists of a variety of techniques employed to "erosion-proof and to "storm-proof" a road and prevent unnecessary future erosion and sedimentation. Erosion-proofing and storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road is capable of withstanding both annual winter rainfall and runoff as well as a large storm event without failing or delivering excessive sediment to the stream system. The goal of road upgrading is to strictly minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment yield when large magnitude, infrequent storms and floods occur.

All currently open and maintained roads within the Mill Creek assessment area were recommended for upgrade treatments. Unmaintained and/or abandoned roads were evaluated on a road by road basis to determine whether roads should be upgraded and maintained, or temporarily or permanently decommissioned. With this prioritized plan of action, the landowners can work with the Mendocino County RCD or other entities to obtain potential funding to implement the proposed projects.

The goal of completing the recommended erosion control and storm-proofing is to minimize sediment pollution to Mill Creek watershed and ultimately the Navarro River watershed. The integrity and driveability of the roads will also be improved with storm proofing because they will be capable of withstanding both annual rainfall and runoff, as well as withstanding larger magnitude storms and floods.

All currently maintained roads in the Mill Creek assessment area were recommended for upgrading. Unused, unmaintained and/or abandoned roads were individually evaluated for either upgrading or temporary or permanent decommissioning. A variety of techniques were recommended to "erosion-proof and to "storm-proof roads to prevent unnecessary future erosion and sedimentation. Erosion- and storm-proofing for upgrading roads typically consists of stabilizing slopes and upgrading drainage structures so the road is capable of handling large storms without failing or delivering excessive sediment to the stream system. Treatments recommended for decommissioning roads typically include removing unstable road fill, decompaction of the road surface, and removing fill from the stream crossings. All of the recommendations in this report are intended to be used as a tool to help with the long term planning and prioritization of erosion control and road decommissioning activities in the watershed.

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 Mill Creek watershed assessment area, Mendocino County, California

Cost Category'		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	95	6	-	6	570
	D-5 tractor	70	6	--	6	420
Road opening costs[7]	Excavator	125	75	-	75	9,375
Heavy Equipment requirements for site specific treatments	Excavator	125	182	55	237	29,625
	D-5 tractor	90	167	50	217	19,530
	Dump Truck	65	32	10	42	2,730
Heavy Equipment requirements for road drainage treatments			0	0	0	0
	D-5 tractor	90	122	37	159	14,310
	Grader	85	0	0	0	0
Laborers[8]		20	89	27	116	2,320
Rock Costs: (includes trucking for 270 yds[3] of road rock and 70 yds[3] of rip-rap sized rock)						10,320
Culvert materials costs (280[1] of 24", 120' of 30", 150' of 36", 70' of 48. Costs included for couplers)						12,008
Mulch, seed and planting materials for 3 acres of disturbed ground*						1,512
Layout, Coordination, Supervision, and Reporting[10]		50	-	~	174	8,700
Total Estimated Costs				$111 ,420		
Potential sediment savings: 10,637 yds[3]						
Overall project cost-effectiveness: $10.47 spent per cubic yard saved						

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

[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 limes include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at alt the sites.

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

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

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

[7] Road opening costs are applied to roads that are currently abandoned and not driveablc.

[8]An additional 44 hours of labor lime is added for straw mulch and seeding activities.

[9.]Seed costs equal $6 pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching. Does not include additional seed and mulch required on decommissioned road surfaces within the Water/Lake Protection Zones.

[10] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 30% of the total excavator time plus 1 week prior and 1 week post project implementation.

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