Draft Summary Report
1998 S. B. 271 Watershed Assessment within Mill Creek, Tributary to the Navarro River

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

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 (NWRP, 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 Hungry Hollow 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.

In the summer of 1998, funding was secured through the California Department of Fish and Game Senate Bill 271 Proposal process for 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 grant is 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 sub-contractor by Daniel Sicular to conduct the upland sediment source assessment and develop an implementation plan for controlling erosion and sediment yield to Mill Creek and its tributaries. The assessment area included all the primary routes maintained by 4 separate landowner/road association groups. These are the 1) Bates ownership, 2) Hungry Hollow road association, 3) Holmes Ranch road

Figure 1. Location map of Mill Creek watershed, Navarro River basin identifying portions of the watershed inventoried for future sediment sources in 1998.

association, and 4) Nash-Mill road association). The goal of the assessment is to lessen road related impacts on Mill Creek and ultimately improve the habitat for coho populations.

This summary report describes the watershed assessment and inventory process, as well as serves as a plan-of-action for erosion control and erosion prevention treatments for the entire assessment area in the Mill Creek watershed. Separate assessments and implementation plans are also provided in Appendix A through D for each of the 4 landowners/road associations. Based on the leadership provided by the three road associations and Mr. Bates to permit this assessment, additions areas of the Mill Creek have also received watershed assessment funding from the California Department of Fish and Game and will be inventoried this fall and winter.

Project Description

In the first phase of the Mill Creek inventory project all roads within the study area were identified and age dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. Each road identified was mapped on mylar overlays on the most recent aerial photos. A composite map of the road system in Mill Creek was drafted and served as the base map for locating sites. The base map, used in combination with the aerial photos, shows the primary road network managed by the 4 landowners/road associations in the watershed and shows 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 the road systems, as well as selected hillslope areas. Each road was walked by experienced PWA staff and all existing and potential erosion sites were classified as either sediment delivery sites or as maintenance sites (where there is no future sediment yield to streams but if left untreated the sites could affect the road integrity). 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. 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 aerial photograph. 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 sediment yield site. All sites were assigned a treatment priority, based on either their potential to deliver sediment to stream channels in the watershed or their potential to affect the road integrity.

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 one or more cross sections. The survey data was entered into a computer program that computed the volume of fill contained in each stream crossing and allowed for accurate and repeatable volume estimates to be made for a variety of possible erosion prevention treatments (culvert installation, culvert replacement, complete excavation, etc.).

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*ASAP*____ *PWA* ROAD INVENTORY DATA FORM (3/98 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 (mi²) _______					
EROSION	E.P. (H, M, L)	Potential for extreme erosion? (Y, N)		Volume of extreme erosion (yds³): 100-500, 500-1000, 1K-2K, >2K			
Past erosion...	Rd&ditch vol (yds³) (yds³)________	Gully fillslope/hillslope (yds³)________	Fill failure volume (yds³) ________	Cutbank erosion (yds³)________	Hillslope slide vol. (yds³) ________	Stream bank erosion (yds³) ________	xing failure vol (yds³) ________
	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 (ft²)				
	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 (ft²) ______	*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 - ft²* ________	
	Install DR-CMP	*DR-CMP (#)* ______	Check CMP size? (Y)	Other tmt? (Y)	No tmt. (Y)		
COMMENT ON PROBLEM:							

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Inventory Results
Approximately 29 miles of road were inventoried within the 12 mi^2 assessment area in the Mill Creek watershed. Only roads managed and maintained by the Holmes Ranch road association, Nash-Mill road association, Hungry Hollow road association and the Bates land ownership were inventoried in this assessment.

Most of the roads in this assessment were built between the 1930's and 1960's for timber and grazing activities. Most of the road routes inventoried have been constructed on weak and low strength marine sandstones and shales of the Coastal Belt of the Franciscan Complex bedrock. The road beds are very prone to mechanical breakdown, rutting, rilling and gullying in the presence of the very high year around use levels. At the time of the inventory, the majority of roads assessed were open and maintained routes with few abandoned sections. Virtually all the routes have the same road drainage approach (i.e., crowned, flat or mostly insloped road bed with inboard ditches and grader berms). In the majority of these cases, the prescribed treatments have focused on road upgrading to provide low maintenance and long term life of the road network. There are a few short routes managed by the Nash-Mill road association that have been recommended for temporary or permanent closure.

Inventoried sites fell into one of three types: 1) ***upgrade*** - defined as sites on maintained open roads with future sediment delivery to a stream channel, 2) ***decomission*** - defined as sites with future sediment delivery that are recommended for permanent hydrological closure and 3) ***maintenance*** - defined as sites that do not have future sediment delivery but if left untreated will affect the road integrity. Past and potential erosion sites that did not deliver, or would not deliver eroded sediment to a stream channel or seriously affect the condition of the road were not inventoried as sites for this assessment. They may represent potential sources of erosion, but they do not represent a threat to water quality, fisheries resources or the road integrity.

Virtually all future erosion and road-related sediment yield in the Mill Creek watershed is expected to come from four sources: 1) the failure of road and landing fills (landsliding), 2) large deep seated landslides, 3) erosion at (or associated with) stream crossings (from several possible causes) and 4) road surface and ditch erosion. The latter source of sediment (road and ditch erosion and subsequent sediment delivery) is defined by the length of road and ditch currently contributing runoff and fine sediment to stream channels.

The erosion potential (and potential for sediment delivery) was estimated for each major problem site or potential problem site. Estimates of future expected volume of sediment to be eroded and the volume delivered to streams was 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 stream diversion sites, actual sediment loss could easily exceed field predictions.

A total of 124 sites were identified with potential to deliver sediment to streams. Of these, 121 sites were recommended for erosion control and erosion prevention treatment. Approximately 60% (n=75) of the sites are classified as stream crossings, 7% (n=9) as road surface problems and 6% (n=8) as potential landslides (Table 1 and Map 1). The remaining 27% of the inventoried sites consist of ditch relief culverts and gullies. An additional 38 sites were identified as maintenance sites where there was no sediment delivery but chronic road surface drainage problems will affect the long term condition of the road.

Landslides - Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. Potential landslides account for approximately 6% of the inventoried sites in the Mill Creek assessment area (Table 1). The majority of the potential landslide sites (75%) were found along roads and landings where material has been sidecast during earlier construction and now shows signs of instability. Potential landslides currently do not appear to be a large sediment contributor to the Mill Creek watershed. This may be due to the generally old age of most of the roads in the watershed, where past large storms have triggered failures at most of the locations where the road was poorly located or where spoil had been placed in inappropriate places. 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 number of potential landslide sites located in the Mill 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 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. For reference, the sites were mapped on the mylar overlays of the aerial photographs.

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

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 (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Landslides	8	7	3,908	NA	NA	NA
Stream crossings	75	75	28,255	49	14	28
Road surface	10	10	292	NA	NA	NA
Other	31	29	729	NA	NA	NA
Total (all sites)	124	121	33,184	49	14	28
Persistent surface erosion[1]	18.07	18.07	17,668	NA	NA	NA
Totals	124	121	50,852	49	14	28

[1] Assumes 25' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade.

Stream crossings - Seventy-five stream crossings were inventoried in the Mill Creek assessment area including 52 culverted crossings, 19 unculverted fill crossings, 3 fords and 1 Humboldt log crossing. 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 fillslope, or it is diverted down the road to the inboard ditch. Most unculverted fill crossings are located at small Class III streams that exhibit flow only in the larger runoff events. If logs were intentionally placed in the axis of the channel at or near the base of the fill to convey flow beneath the road, then these crossings are commonly known as "Humboldt" or log crossings.

Approximately 28,255 yds^3 of future road-related sediment yield in the Mill Creek assessment area is expected to originate from stream crossings (Table 1). This amounts to nearly 56% of the total sediment yield from the road system. The most common mechanisms of erosion at stream crossings include crossings with undersized culverts, culverts that are likely to plug frequently, stream crossings with a diversion potential and collapsing Humboldt crossings. The sediment delivery from stream crossing sites is always classified as 100% because any sediment introduced to even small ephemeral streams will eventually be delivered to 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. These hillslope gullies can be quite large and can deliver significant quantities of sediment to stream channels. Of the 75 stream crossings inventoried, 49 have the potential to divert in the future and 14 stream crossings 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 50 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.

The majority of the stream crossings on the roads inventoried in the Mill Creek assessment area will need to be upgraded. For example, 37% of the existing culverts had a moderate to high plugging potential and nearly 65% of the stream crossings exhibit a diversion potential (Table 1). Because the roads were constructed many years ago, many culverted stream crossings are under designed for the 50 year storm flow. At stream crossings with undersized culverts or where there was 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 50 year storm flow, 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.

Road Surface and "Other"sites - A total of 10 road surface and 31 "other" sites were identified in the Mill Creek assessment area. The main cause of existing or future erosion at these sites is long sections of uncontrolled flow along the road surface and ditch . Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause gully erosion on the hillslopes below ditch relief culverts. It is also a major source of fine sediment input to nearby stream channels. In general, 18.1 miles of roads in the assessment area (62% of the total mileage of roads inventoried) deliver ditch and road sediment and runoff to stream channels in Mill Creek. Although fine sediment may seem an unimportant sediment source relative to stream crossings and landslides, it can affect the recovery of fish-bearing streams.

We estimate 1,021 yds^3 of sediment will be delivered to streams from the 41 "road surface" and "other" specific sites inventoried (Table 1). From the 18.1 miles of road, we calculated nearly 17,700 yds^3 of sediment will be delivered to stream channels in the Mill Creek watershed over the next 10 years if no efforts are made to change road drainage practices. This will occur through a combination of 1) cutbank erosion delivering sediment to the ditch triggered by dry ravel, rainfall, freeze-thaw processes, cutbank slides and brushing practices, 2) inboard ditch erosion and sediment transport, 3) mechanically pulverizing and wearing down the road surface during dry periods due to high amounts of vehicular use, and 4) erosion of the road surface during wet weather periods where every vehicle pass entrains sediment which is transported to nearby streams.

Relatively easy treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff and hydrologically disconnect the roads from the stream network.

Treatment Priority

An erosion inventory is intended to provide information which can guide long range transportation planning, as well as identify and prioritize erosion prevention, erosion control and road decomissioning activities in the watershed. As a result, not all of the sites that have been recommended for treatment have the same priority, and some are more cost effective than others to treat. 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,
2) the potential for future erosion (high, moderate, low),
3) the "urgency" of treating the site (treatment immediacy),
4) the ease and cost of accessing the site for treatments, and
5) recommended treatments, logistics and costs.

The likelihood of erosion (erosion potential) and the volume of sediment expected to enter stream channels from future erosion (sediment delivery) at each site play a significant roles in determining its treatment priority. 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. The ***erosion potential*** of a site is a professional evaluation of the likelihood that future erosion will occur during a storm with a greater than 25 year peak flow return interval. Erosion potential was evaluated for each site, and expressed as "High", "Moderate" or "Low". Erosion potential is an estimate of the potential for additional erosion, based on local site conditions and field observations. Thus, it is employed as a subjective probability estimate, and not an estimate of how much erosion is likely to occur.

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 the severity or urgency of the threat 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.

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 (>25-50 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 averaging in the general range of approximately $5 to $15/$yds^3$, or less. Treatment cost-

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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 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.

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 receive 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 rates, 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 erosion-proofed by one of two methods: upgrading or decommissioning. Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 50-year storm. In contrast, properly decommissioned roads are closed and no longer require maintenance. 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, road fills, and all stream crossing fills.

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 50-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. The road drainage techniques include berm removal, road outsloping, rolling dip construction, and/or the installation of ditch relief culverts. The goal of all treatments is to make the road as "hydrologically invisible" as is possible. The majority of roads in the Mill Creek assessment area are recommended for upgrading.

Along some low strength road routes, such as those in the Mill Creek watershed, re-rocking the road following rolling dip construction and road outsloping or insloping efforts will often be necessary. These activities will incorporate pre-existing road rock into the new road shape design, thereby providing some road bed strength and stability. However, this often may not be enough material to provide safe passage in the winter months. Predicting the total amount of new road rock required can be difficult, but at a minimum rock should be applied at all newly constructed rolling dips.

General heavy equipment treatments for ***road decommissioning*** or closure are newer and less well published, but the basic techniques have been tested, described and evaluated. Decommissioning essentially involves "reverse road construction," except that full topographic obliteration of the road bed is not normally required to accomplish sediment prevention goals. In order to protect the aquatic ecosystem, the goal is to "hydrologically" close the road; that is, to minimize the adverse effect of the road on natural hillslope processes and watershed hydrology.

Treatments

Basic treatments priorities and prescriptions were formulated concurrent with the identification, description and mapping of potential sources of road-related sediment yield and road maintenance sites with no potential sediment delivery. Table 2 and Map 2 outline the treatment priorities for all 121 inventoried sites with future sediment delivery and the 38 maintenance sites with no future sediment delivery in the Mill Creek assessment area. Of the 121 sites with future sediment delivery, 39 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 20,200 yds^3. Sixty sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 8,660 yds^3. Finally, 22 sites were listed as having a low treatment immediacy and approximately 3,530 yds^3 of future sediment delivery. The 38 inventoried maintenance sites with no future sediment delivery were assigned the following treatment immediacies: 1 high-moderate, 8 moderate or moderate- low and 29 low.

Table 3 summarizes the proposed treatments for sites inventoried on all roads in the Mill Creek assessment area. These prescriptions include both upgrading, road closure and maintenance 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 an excavator, tractor, dump truck, grader and/or backhoe. Some hand labor is required at sites needing new culverts, downspouts, flaired inlets or culvert repairs, trash racks or for applying seed, plants and mulch following ground disturbance activities. It is estimated that erosion prevention work will require the excavation of approximately 11,545 yds^3 at 45 sites. Approximately 70% of the volume excavated is associated with upgrading stream crossings and nearly 25% of the volume is proposed for excavating potentially unstable road fills (landslides).

Finally, long lengths of road are proposed to be converted from insloped, flat or crowned shapes to outsloped road routes, along some of which we will retain the ditch (Table 3). We have recommended 419 rolling dips be constructed at selected locations along the road, at different spacing, depending on the steepness of the road. Re-rocking of the rolling dips post construction will require 2,750 yd^3 of rock. A minimum of 49 new ditch relief culverts are recommended to be installed along the road routes inventoried. Some proposed rolling dips can be replaced with additional ditch relief culverts, but this will increase costs at each dip by 125%.

Equipment needs and costs

Treatments for the 121 sites identified with future sediment delivery in the Mill Creek assessment area will require approximately 309 hours of excavator time and 395 hours of tractor time to complete all prescribed upgrading, road closure, erosion control and erosion prevention work (Table 4 and Map 2). 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 192 hours of dump truck time has been listed for work in the basin for endhauling excavated spoil from stream crossings and unstable road and landing fill where local obliteration of the road bed is not normally required to accomplish sediment prevention goals. In order to protect the aquatic ecosystem, the goal is to "hydrologically" close the road; that is, to minimize the adverse effect of the road on natural hillslope processes and watershed hydrology.

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

Treatment Priority	Upgrade sites (#)	Decommission sites (#)	Upgrade/ Decom. Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance problems
High	**16** (site #: 2, 4, 28, 33, 37, 44, 46, 49, 62, 65, 76, 80.1, 87, 103, 121, 134)	**0**	2 landslides, 2 ditch relief culverts, 12 stream crossings	14,989	**0**	
Moderate High	**23** (site #:10, 16, 17, 25, 26, 35, 39, 42, 47, 48, 58, 59, 60, 80, 81, 85, 99, 100, 102, 117, 142, 145, 151)	**1** (site #:100)	2 landslides, 1 gully, 2 road surface, 2 ditch relief culverts, 16 stream crossings	5,208	**1** (site #: 114)	1 other misc. site
Moderate	**39** (site #:1, 3, 6, 9, 11, 15, 27, 36, 38, 43, 45, 53, 54, 56, 61, 64, 67, 68, 72, 73, 74, 75, 77, 78, 90, 101, 119, 128, 134.1, 126, 135, 136, 138, 139, 140, 149, 150, 152, 153)	**0**	1 landslide, 6 gullies, 5 ditch relief culverts, 2 road surface, 25 stream crossings	7,060	**4** (site #: 8, 18, 20, 122)	2 ditch relief culvert, 1 gully, 1 road surface
Moderate Low	**21** (site #: 29, 30, 34, 38.1, 50, 51, 57, 70, 81.1, 84, 86, 89, 97, 118, 123, 127, 132, 137, 141, 148, 161)	**0**	4 road surface, 7 ditch relief culverts, 10 stream crossings	1,598	**4** (site#: 23, 32, 66, 104)	3 ditch relief culvert, 1 road surface
Low	**22** (site #:29.1, 40, 41, 82, 96, 106, 107, 108, 109, 110, 111, 112, 113, 116, 120, 125, 129, 143, 144, 146, 156, 157)	**0**	2 landslides, 1 gully, 2 road surface, 5 ditch relief culverts, 12 stream crossings	3,527	**29** (site #: 7, 12, 13, 14, 19, 21, 22, 24, 31, 52, 55, 71, 88, 91, 92, 93, 94, 95, 98, 105, 124, 130, 131, 133, 146.1, 147, 155, 158, 160)	10 ditch relief culvert, 19 road surface
Total	**120**	**1**		**32,382**	**38**	

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

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	38	To prevent stream diversions	Outslope road & fill ditch	103	Outslope 76,653 feet of road to improve road surface drainage (19 maintenance sites for 18, 087')
Install CMP	17	Install a CMP at an unculverted fill	Outslope road & retain ditch	10	Outslope 6,419 feet of road & retain ditch to improve road surface drainage (6 maintenance sites for 3, 234')
Replace CMP	32	Upgrade an undersized CMP	Inslope road	7	Inslope 1,855 feet of road to improve road surface drainage (1 maintenance site for 100')
Excavate soil	45	Typically fillslope & crossing excavations; excavate a total of 11,545 yds^3	Install rolling dips	419	Install rolling dips to improve road drainage (156 rolling dips for maintenance sites)
Down spouts	13	Installed to protect the outlet fillslope from erosion (1 maintenance site)	Remove ditch	2	Remove 550 feet of inboard ditch (1 maintenance site for 300')
Wet crossing	13	Install 1 rocked ford and 12 armored fill crossings	Clean ditch	5	Clean 930 feet of ditch (1 maintenance site for 100')
Install bridge	1	Install bridge where stream is large and culvert or wet crossing is not feasible	Remove berm	26	Remove 20,564 feet of berm to improve road surface drainage (9 maintenance sites for 10,117')
Install trash rack	3	Installed to prevent culvert from plugging	Install ditch relief CMP	49	Install ditch relief culverts to improve road surface drainage (2 maintenance sites)
Clean CMP	8	Remove debris and/or sediment from CMP inlet (3 maintenance sites)	Rock road surface	280	Rock road surface using 371,340 ft^2 of rock (2,750 yd^3)
Armor fill face	3	Rock armor to protect outboard fillslope from erosion using 1,080 ft^2 of rock	Other	1	Miscellaneous treatments
Install flared inlet	6	Installed to increase CMP capacity	No treatment recommended	8	

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment delivery, Mill Creek watershed assessment area, Mendocino County, California.								
Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	39	10,116	309	395	93	47.75	5	120
Moderate, Low/Moderate	60	1,074	224	399	73	81.25	6	146
Low	22	355	14	45	26	17	3	10
Total	**121**	**11,545**	**547**	**839**	**192**	**146**	**14**	**276**

disposal sites are not available. Nearly 146 hours of grader time is necessary to apply road surface treatments including outsloping and insloping. Finally, approximately 276 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts.

Table 5 summarizes the equipment hours necessary to treat the 38 maintenance sites with no future sediment delivery in the Mill Creek assessment area. It is expected that approximately 6 hours of excavator will be required for installation of ditch relief culverts and 156 hours of tractor time to install rolling dips (tractor time can be switched to backhoe/excavator time if additional ditch relief culverts are preferable to rolling dips). Nearly 65 hours of grader time is necessary to apply various road surface treatments such as outsloping, insloping, removing the berm, cleaning the ditch, etc. Approximately 5 hours of backhoe time is necessary to clean ditch relief culvert inlets. In addition, 8 hours of labor time is necessary to aid with installation of ditch relief culverts.

Estimated costs for erosion prevention treatments - Prescribed treatments were divided into two categories: a) site specific erosion prevention work identified during the watershed inventories at sites with future sediment delivery, and b) site specific erosion prevention maintenance work at sites with no future sediment delivery to control road surface, ditch and cutbank erosion and its impact on the road network. The total costs for road related erosion control at sites with sediment delivery is estimated at approximately $ 434,124 for an average cost-effectiveness value of approximately $ 8.54 per cubic yard of sediment prevented from entering Mill Creek and its tributaries (Table 6). **(Note: costs to re-rock the whole road system following implementing the proposed storm proofing activities are not included in this table. Costs are not included for purchasing/constructing the 1 proposed bridge)**. The total costs for treating maintenance sites with no future delivery is figured at nearly $ 32,104 (Table 7).

Overall site specific erosion prevention work: Equipment needs for site specific erosion prevention work at both sites with future sediment delivery and maintenance sites are expressed in the database, and summarized in Tables 4 and 5, as direct excavation times, in hours, to treat all

Table 5. Estimated heavy equipment and labor requirements for treatment of all inventoried maintenance sites, Mill Creek watershed, Mendocino County, California.								
Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	1	0	0	3	0	3	0	0
Moderate, Low/Moderate	8	0	6	22	0	15	0	8
Low	29	0	0	131	0	46.5	5	0
Total	**38**	**0**	**6**	**156**	**0**	**64.5**	**5**	**8**

sites in the basin which have 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, the time needed to reconstruct or clear roads which have been abandoned, 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 Tables 6 and 7. Costs in Tables 6 and 7 assume that the work in this watershed is accomplished during one summer work period employing two equipment teams. This minimizes moving and transport costs for equipment and personnel.

The costs in Tables 6 and 7 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 maintenance and road building operations on forest lands.

Table 6 and 7 list a total of 760 and 100 hours, respectively 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, 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. An important first phase of inventory work has been completed in the lower Mill Creek watershed. While the extent of potential future sediment yield is moderately high within the subdivisions which have been inventoried, we have no idea of what potential risks exist in the remainder of the Mill Creek watershed.

With this prioritized plan of action, the various road associations and landowners can work with the Mendocino 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 Mill 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.

Table 6. 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, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	40	--	40	2,800
Heavy Equipment	D-5 size tractor	85	839	252	1,091	92,735
	Excavator	115	547	165	712	81,880
	Dump Truck	60	192	58	250	15,000
	Grader	85	146	44	190	16,150
	Backhoe	65	14	5	19	1,235
Laborers		20	455	137	592	11,840
Rock Costs						55,100
Culvert materials costs						79,384
Mulch, seed and planting materials						40,000
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	760	38,000
Total Estimated Costs						**$ 434,124**
Cost-effectiveness: $8.54 spent per cubic yard saved						

[1]Costs for tools andmiscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface at sites where upgraded roads are outsloped.

[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 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, five hours round trip for each ownership or road association area. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

[7] 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).

Table 7. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried maintenance sites in the Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	--
Heavy Equipment	D-5 size tractor	85	156	47	203	17,255
	Excavator	115	6	2	8	920
	Grader	85	64.5	20	84.5	7,183
	Backhoe	65	5	2	7	455
Laborers		20	8	3	11	220
Culvert materials costs						1,071
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	100	5,000
Total Estimated Costs						**$ 32,104**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface at sites where upgraded roads are outsloped, where rolling dips are constructed and where stream crossing culverts are replaced or upgraded have not been estimated.

[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 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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

[7] 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).